Section Semiconductor Physics
Fachverband Halbleiterphysik (HL)

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Overview of Invited Talks and Sessions

(lecture rooms H1, H13, H14, H15, and H17; Poster A)

Invited Talks

HL 2.1	Mon	9:15–10:00	H15	**Metamaterials: Magnetism enters photonics** — •Martin Wegener
HL 3.1	Mon	10:00–10:45	H15	**Wide-bandgap quantum dot based microcavity VCSEL structures** — •K. Sebald, H. Lohmeyer, J. Gutowski, C. Kruse, R. Kröger, T. Yamaguchi, A. Gust, D. Hommel, J. Wiersig, F. Jahnke
HL 8.1	Mon	14:00–14:45	H15	**Coupling phenomena in dual electron waveguide structures** — •Saskia Fischer, Sven Bucholz, Gabriela Aptetrii, Ulrich Kunze, Dieter Schuh, Gerhard Abstreiter
HL 16.1	Tue	9:15–10:00	H15	**Why has doping been difficult in colloidal semiconductor quantum dots?** — •David J. Norris
HL 17.1	Tue	10:00–10:45	H15	**Magnetic anisotropy and magnetization switching in ferromagnetic GaMnAs** — •Wolfgang Limmer
HL 34.1	Thu	9:15–10:00	H15	**Momentum space wave functions in InAs quantum dots mapped by capacitance voltage spectroscopy** — •Dirk Reuter
HL 50.1	Fri	10:15–11:00	H15	**Quantum Transport in High Mobility GaN/AlGaN 2DEGs and Nanostructures** — •Stefan Schmult, Alexander Punnoose, Michael J. Manfra, Hungtao Chou, David Goldhaber-Gordon, Richard J. Molnar

Internal symposia within HL

Internal Symposium: THz interactions

Organisation: D. Hägele (Ruhr-Universität Bochum)

HL 29.1	Wed	14:15–14:45	H15	**Interaction of semiconductor laser dynamics with THz radiation** — •Martin Hofmann
HL 29.2	Wed	14:45–15:15	H15	**Ultrafast THz Spectroscopy of Carrier Correlations in Complex Materials** — •Robert A. Kaindl
HL 29.3	Wed	15:15–15:45	H15	**Interaction of THz Radiation with Semiconductor Nanostructures: Microscopic Theory** — •Stephan Koch, Mackillo Kira
HL 29.4	Wed	15:45–16:15	H15	**Nonlinear terahertz and midinfrared response of n-type GaAs** — •Michael Woerner, Peter Gaal, Wilhelm Kühn, Klaus Reimann, Thomas Elsaesser, Rudolph Hey, Klaus Ploog
HL 29.5	Wed	16:15–16:45	H15	**Terahertz near-field microscopy** — •Roland Kersting, Federico Buersgens, Gyu Cheon Cho

Internal Symposium: Bose-Einstein Kondensation in Halbleitern

Organisation: G. Bauer (Universität Linz)

HL 20.1	Tue	10:45–11:15	H15	**Polariton Condensation in CdTe Microcavities: interaction and coherence** — J. Kasprzak, M. Richard, S. Kundermann, A. Baas, P. Jeambrun, J. Keeling, F. M. Marchetti, M. H. Szymanska, R. André, J. L. Staehli, P. B. Littlewood, B. Deveaud, •Daniel Le Si Dang
HL 20.2	Tue	11:15–11:45	H15	**On the way to an excitonic Bose-Einstein condensate: New experiments in Cuprous Oxide.** — •Heinrich Stolz, Dietmar Fröhlich
HL 20.3	Tue	11:45–12:15	H15	**Challenges on the way towards Bose-Einstein condensation of excitons** — •Roland Zimmermann
HL 20.4	Tue	12:15–12:45	H15	**Signatures of excitonic condensates in quantum Hall bilayers** — •Lars Tiemann, Rodney Wiersma, Sjoerd Lok, Werner Dietsche, Klaus v. Klitzing, Koji Muraki

Internal Symposium: Graphene

Organisation: T. Seyller (Universität Erlangen-Nürnberg)

HL 37.1	Thu	10:00–10:30	H15	**Photoelectron spectroscopy of graphene on SiC: growth, interface, and electronic structure** — A. Bostwick, K.V. Emtsev, K. Horn, E. Huwald, L. Ley, J.L. McChesney, T. Ohta, J. Riley, E. Rotenberg, •Th. Seyller, F. Speck
HL 37.2	Thu	10:30–11:00	H15	**Raman Imaging of Graphene** — Davy Graf, Francoise Molitor, •Klaus Ensslin, Christoph Stampfer, Alain Jungen, Christopher Hierold
HL 37.3	Thu	11:00–11:30	H15	**Electronic confinement and coherence in high mobility epitaxial graphene** — •Claire Berger
HL 37.4	Thu	11:30–12:00	H15	**News from the quantum Hall effects in graphene** — •Uli Zeitler
HL 37.5	Thu	12:00–12:30	H15	**The structure of suspended graphene membranes** — •J. C. Meyer, A. K. Geim, M. I. Katsnelson, K. S. Novoselov, T. Booth, D. Obergfell, S. Roth, C. Girit, A. Kis, A. Zettl

Internal Symposium: Semiconductor Microcavities and Entangled States in Quantum Dots

Organisation: D. Heitmann (Universität Hamburg)

HL 44.1	Thu	14:00–14:30	H15	**Electron spin dynamics in quantum dots** — •Manfred Bayer
HL 44.2	Thu	14:30–15:00	H15	**Electrical control of entangled excitons in self-assembled quantum dot molecules** — •Hubert J. Krenner
HL 44.3	Thu	15:00–15:30	H15	**Quantum optical studies on laterally coupled quantum dots and pillar microcavities** — •P. Michler, Gareth Beirne, C. Hermannstädter, S. M. Ulrich, Serkan Ates, L. Wang, A. Rastelli, O. G. Schmidt, C. Gies, J. Wiersing, F. Jahnke, S. Reitzenstein, C. Hoffmann, A. Löffler, A. Forchel
HL 44.4	Thu	15:30–16:00	H15	**Exciton qubits: From Rabi oscillations towards optoelectronic quantum gates** — •Artur Zrenner, Stefan Stufler, Patrik Ester, Steffen Michaelis de Vasconcellos, Marc C. Hübner, Max Bichler, Pawel Machnikowski, Vollrath M. Axt, Tilmann Kuhn
HL 44.5	Thu	16:15–16:45	H15	**Optical Semiconductor Microtube Ring Cavities** — •Tobias Kipp, Christian Strelow, Holger Welsch, Hagen Rehberg, Christoph M. Schultz, Christian Heyn, Detlef Heitmann
HL 44.6	Thu	16:45–17:15	H15	**Semiconductor quantum dots as entangled light sources** — •David Gershoni
HL 44.7	Thu	17:15–17:45	H15	**Configuration mixing of electronic states in quantum dots** — Kroner M., Govorov S., Remi S., Seidl S., Badoleto A., Petroff P., Warburton R., •Kahled Karrai
HL 44.8	Thu	17:45–18:15	H15	**Coupled Quantum Dots for Quantum Information** — •Tom Reinecke

Invited talks of the joint symposium SYSS

See SYSS for the full program of the Symposium.
(arranged by the divisions HL, MA, O,TT)

Organization: G. Bayreuther, J. Fabian, Universität Regensburg

SYSS 1.1	Mon	9:30–10:00	H1	**Generating and manipulating spins in semiconductors** — •David Awschalom
SYSS 1.2	Mon	10:00–10:20	H1	**Spin noise spectroscopy and spin dynamics in semiconductors** — •Michael Oestreich, Michael Römer, Stefanie Döhrmann, Stefan Oertel, Daniel Hägele, Jens Hübner
SYSS 1.3	Mon	10:20–10:40	H1	**Spin-orbit interaction in Si quantum wells** — •Wolfgang Jantsch, Hans Malissa, Zbyslaw Wilamowski
SYSS 1.4	Mon	10:40–11:00	H1	**Driven coherent oscillations of a single electron spin in a quantum dot** — •Frank Koppens, Christo Buizert, Klaas-Jan Tielrooij, Ivo Vink, Katja Nowack, Tristan Meunier, Leo Kouwenhoven, Lieven Vandersypen
SYSS 1.5	Mon	11:00–11:20	H1	**Electrical spin injection and detection in semiconductors** — •Paul Crowell
SYSS 1.6	Mon	11:20–11:40	H1	**A microscopic view of the magnetism in magnetic semiconductors** *(replaces the contribution by N. Samarth)* — •Michael Flatté
SYSS 1.7	Mon	11:40–12:00	H1	**Tailoring ferromagnetism in bulk semiconductors and quantum dots** — •Igor Zutic
SYSS 1.8	Mon	12:00–12:20	H1	**Tunnel Anisotropic Magneto Resistance - TAMR** — •Laurens Molenkamp
SYSS 1.9	Mon	12:20–12:40	H1	**Electric field controlled spintronic effects based on spin-orbit coupling** — •Tomas Jungwirth
SYSS 1.10	Mon	12:40–13:00	H1	**Zero-bias spin separation in semiconductor heterostructures** — •Sergey Ganichev

Invited talks of the joint symposium SYSE

See SYSE for the full program of the Symposium.
(arranged by the divisions DF, DS, HL, MM)
Organization: O. G. Schmidt, Max-Planck-Institut für Festkörperforschung, Stuttgart, D. Hesse, Max-Planck-Institut für Mikrostrukturphysik, Halle

SYSE 1.1	Mon	14:30–15:00	H1	**Wavy and Buckled Nanoribbons and Nanotubes: Mechanics and Applications** — •John Rogers
SYSE 2.1	Mon	16:15–16:45	H1	**Enhancing Ferroelectrics and Multiferroics using Strain** — •D.G. Schlom, M.D. Biegalski, A. Soukiassian, J.H. Haeni, J.H. Lee, R.W. Ulbricht, C.M. Brooks, Y. Jia, V. Vaithyanathan, W. Tian, X. Ke, D.A. Tenne, A.V. Rao, A. Kumar, L. Tian, A. Sharan, S. Choudhury, Y.L. Li, P. Schiffer, S. Trolier-McKinstry, X.X. Xi, V. Gopalan, L.Q. Chen, K.J. Choi, D.M. Kim, C.B. Eom, Y.B. Chen, H.P. Sun, X.Q. Pan, D.D. Fong, M.A. Zurbuchen, J.A. Eastman, P.H. Fuoss, S.K. Streiffer, P. Irvin, J. Levy, W. Chang, S.W. Kirchoefer, T. Heeg, J. Schubert, A. Bruchhausen, N.D. Lanzillotti-Kimura, A. Fainstein, R.S. Katiyar, A. Cantarero, M.E. Hawley, Q.X. Jia, C.J. Fennie, S.M. Nakhmanson, K.M. Rabe, A.K. Tagantsev, B. Velickov, R. Uecker, P. Reiche
SYSE 2.3	Mon	17:00–17:30	H1	**Patterning ferroelectric nanostructures by epitaxial strain** — •Ho Nyung Lee, Matthew Chisholm
SYSE 2.4	Mon	17:30–18:00	H1	**Curl in Photonic Crystals Induced by Drying Stresses upon Sol-Gel Infiltration** — •Vladimir Kitaev, Evangellos Vekris, Geoffrey Ozin

Invited talks of the joint symposium SYOE

See SYOE for the full program of the Symposium.
(arranged by the divisions CPP, DS, HL, O)
Organization: V. Wagner, International University Bremen, C. Wöll, Ruhr-Universität-Bochum

SYOE 4.1	Tue	9:30–10:15	H1	**Vapor and Solution Deposited Small Molecule Organic Thin Film Transistors** — •Thomas Jackson
SYOE 5.1	Tue	11:15–12:00	H1	**Organic electronic devices and their applications** — •Paul Heremans

SYOE 6.1	Tue	14:30–15:15	H32	**Theory of polymer devices: OFETs and OLEDs** — •Reinder Coehoorn
SYOE 7.1	Tue	16:30–17:15	H32	**Electronic spectrum and spin states of a single organic molecule** — •Herre van der Zant
SYOE 10.1	Wed	16:45–17:30	H32	**Single grain contacts** — •Gregor Witte

Invited talks of the joint symposium SYEN

See SYEN for the full program of the Symposium.
(arranged by the divisions DY, HL, TT)
Organization: J. Siewert, Universität Catania Italien

SYEN 1.1	Thu	14:00–14:30	H1	**Probabilities (and more) from entanglement** — •Wojciech Zurek
SYEN 1.2	Thu	14:30–15:00	H1	**Entanglement and the Foundations of Statistical Mechanics** — •Sandu Popescu
SYEN 1.3	Thu	15:00–15:30	H1	**Universality and classical simulation of quantum computation** — Maarten van den Nest, Wolfgang Dür, Akimasa Miyake, Guifre Vidal, •Hans Briegel
SYEN 1.4	Thu	15:30–16:00	H1	**Towards the convex roof of multipartite entanglement measures** — •Andreas Osterloh, Jens Siewert, Robert Lohmayer, Armin Uhlmann
SYEN 1.5	Thu	16:00–16:30	H1	**Decoherence induced by interacting quantum spin baths** — •Rosario Fazio
SYEN 1.6	Thu	16:30–17:00	H1	**Sweep a qubit to learn about its environment** — •Peter Hänggi, Martijn Wubs, Keiji Saito, Roland Doll, Sigmund Kohler, Yosuke Kayanuma

Gaede Prize

(arranged by the divisions O, VA, HL)

O 37.1	Wed	14:00–14:45	H36	**Gallium-Nitride-on-Silicon: Mission possible!** — •Armin Dadgar

Sessions

HL 1.1–1.3	Sun	14:00–17:00	H1	**Tutorial on Semiconductor Spintronics**
HL 2.1–2.1	Mon	9:15–10:00	H15	**Invited Talk Wegener**
HL 3.1–3.1	Mon	10:00–10:45	H15	**Invited Talk Sebald**
HL 4.1–4.9	Mon	10:45–13:00	H13	**Semiconductor Laser I**
HL 5.1–5.9	Mon	11:00–13:15	H14	**Photovoltaic**
HL 6.1–6.8	Mon	11:00–13:00	H15	**Quantum dots and wires: preparation and characterization I**
HL 7.1–7.8	Mon	11:00–13:00	H17	**III-V semiconductors I**
HL 8.1–8.1	Mon	14:00–14:45	H15	**Invited Talk Fischer**
HL 9.1–9.10	Mon	14:45–17:15	H13	**Semiconductor Laser II**
HL 10.1–10.5	Mon	14:45–16:00	H14	**Organic semiconductors**
HL 11.1–11.10	Mon	14:45–17:30	H15	**Quantum dots and wires: Transport properties I**
HL 12.1–12.12	Mon	14:45–18:00	H17	**Quantum dots and wires: Optical properties I**
HL 13.1–13.80	Mon	15:00–17:30	Poster A	**Poster 1**
HL 14.1–14.6	Mon	16:00–17:30	H14	**Si/Ge**
HL 15.1–15.3	Mon	17:15–18:00	H13	**Preparation and characterization**
HL 16.1–16.1	Tue	9:15–10:00	H15	**Invited Talk Norris**
HL 17.1–17.1	Tue	10:00–10:45	H15	**Invited Talk Limmer**
HL 18.1–18.8	Tue	10:45–12:45	H13	**Photonic crystals I**
HL 19.1–19.9	Tue	10:45–13:00	H14	**Spin controlled transport I**
HL 20.1–20.4	Tue	10:45–12:45	H15	**Symposium Bose-Einstein Kondensation in Halbleitern**
HL 21.1–21.8	Tue	11:00–13:00	H17	**III-V semiconductors II**
HL 22.1–22.10	Tue	14:00–16:45	H13	**Photonic crystals II**
HL 23.1–23.8	Tue	14:00–16:00	H14	**Spin controlled transport II**
HL 24.1–24.11	Tue	14:00–17:00	H15	**Quantum dots and wires: Transport properties II**
HL 25.1–25.11	Tue	14:00–17:00	H17	**Quantum dots and wires: Optical properties II**
HL 26.1–26.4	Tue	16:00–17:00	H14	**Interfaces/surfaces**

HL 27.1–27.12	Wed	14:15–17:30	H13	**II-VI semiconductors**
HL 28.1–28.9	Wed	14:15–16:30	H14	**Optical properties**
HL 29.1–29.5	Wed	14:15–16:45	H15	**Symposium THZ interactions**
HL 30.1–30.2	Wed	14:15–14:45	H17	**Hybrid systems**
HL 31.1–31.12	Wed	14:45–18:00	H17	**Quantum dots and wires: Optical properties III**
HL 32.1–32.6	Wed	16:30–18:00	H14	**C/diamond**
HL 33.1–33.4	Wed	16:45–17:45	H15	**New materials**
HL 34.1–34.1	Thu	9:15–10:00	H15	**Invited Talk Reuter**
HL 35.1–35.10	Thu	10:00–12:45	H13	**Devices**
HL 36.1–36.9	Thu	10:00–12:15	H14	**Heterostructures**
HL 37.1–37.5	Thu	10:00–12:30	H15	**Symposium Graphene**
HL 38.1–38.11	Thu	10:00–13:00	H17	**ZnO I**
HL 39.1–39.3	Thu	12:15–13:00	H14	**Impurities/amorphous semiconductors**
HL 40.1–40.2	Thu	12:30–13:00	H15	**SiC**
HL 41.1–41.1	Thu	12:45–13:00	H13	**Metal-insulator transitions**
HL 42.1–42.9	Thu	14:00–16:15	H13	**GaN: devices**
HL 43.1–43.7	Thu	14:00–15:45	H14	**Theory of electronic structure**
HL 44.1–44.8	Thu	14:00–18:15	H15	**Semiconductor Microcavities and Entangled States in Quantum Dots**
HL 45.1–45.13	Thu	14:00–17:30	H17	**ZnO II**
HL 46.1–46.79	Thu	15:00–17:30	Poster A	**Poster 2**
HL 47.1–47.10	Thu	15:45–18:15	H14	**Transport in high magnetic field/quantum-Hall-effect**
HL 48.1–48.7	Thu	16:15–18:00	H13	**Quantum dots and wires: preparation and characterization II**
HL 49.1–49.3	Thu	17:30–18:15	H17	**Graphene**
HL 50.1–50.1	Fri	10:15–11:00	H15	**Invited Talk Schmult**
HL 51.1–51.10	Fri	11:00–13:30	H13	**GaN: preparation and characterization**
HL 52.1–52.10	Fri	11:00–13:30	H14	**Transport properties**
HL 53.1–53.11	Fri	11:00–13:45	H15	**Ultra fast phenomena**

Annual General Meeting of the Section Semiconductor Physics

Donnerstag 19:00–21:00 Teppichraum Mensa

- Begrüßung und Bericht
- Stichwortkatalog
- Wahl des Fachverbandsvorsitzenden und dessen Stellvertreter
- Verschiedenes

HL 1: Tutorial on Semiconductor Spintronics

Time: Sunday 14:00–17:00 Location: H1

Tutorial HL 1.1 Sun 14:00 H1
Theory of semiconductor spintronics — •J. König — Ruhr-Universität Bochum, D-44780 Bochum

Spintronic devices rely on exploiting the spin degree of freedom of charge carriers. Spintronics in semiconductors seems particularly attractive since the charge-carrier properties can be controlled by doping and/or electric fields. In this lecture, we will give an introduction to basic concepts of semiconductor spintronics, with a special emphasis on the theory of spin dynamics in semiconductors.

Tutorial HL 1.2 Sun 15:00 H1
Spin dynamics and coherence in semiconductors — •David Awschalom — University of California, Santa Barbara, CA

The ability to optically measure coherent ensembles of spin polarized car-riers in semiconductors has enabled numerous advances in spintronics and quantum information processing. Optoelectronic experiments reveal new capa-bilities of generating spin polarization through all-electrical means with-out magnetic materials or external magnetic fields. We will provide an overview of optical studies exploring spin dynamics and coherence in con-ventional and magnetically-doped semiconductors, followed by recent meas-urements probing the all-electrical generation, transport, and manipulation of spins. These include current-induced spin polarization, the spin Hall effect, and gigahertz control of single spins.

Tutorial HL 1.3 Sun 16:00 H1
Spin + Electronics = Spintronics — •Dieter Weiss — Universität Regensburg

In electronics all information is carried by the elementary charge of electrons. To use in addition the electrons' spin degree of freedom is at the very heart of spintronics. In my presentation I will review some of the ba-sic concepts to achieve spin dependent electrical transport. Special focus will be on spin dependent transport in or through semiconductors.

HL 2: Invited Talk Wegener

Time: Monday 9:15–10:00 Location: H15

Invited Talk HL 2.1 Mon 9:15 H15
Metamaterials: Magnetism enters photonics — •Martin Wegener — DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH),

Light is an electromagnetic wave. Nevertheless, for centuries, the field of optics & photonics has been determined exclusively by the electric-field component of light - magnetism at optical frequencies does not occur in natural materials. However, artificial high-frequency magnetism can be accomplished in metamaterials composed of nanoscale sub-wavelength metallic building blocks that are densely packed into an effective material. After an introduction into this emerging field, we focus on recent experimental progress.

HL 3: Invited Talk Sebald

Time: Monday 10:00–10:45 Location: H15

Invited Talk HL 3.1 Mon 10:00 H15
Wide-bandgap quantum dot based microcavity VCSEL structures — •K. Sebald[1], H. Lohmeyer[1], J. Gutowski[1], C. Kruse[1], R. Kröger[1], T. Yamaguchi[1], A. Gust[1], D. Hommel[1], J. Wiersig[2], and F. Jahnke[2] — [1]Institute of Solid State Physics — [2]Institute of Theoretical Physics, University of Bremen, P. O. Box 330440, Germany

Embedding semiconductor quantum dots (QDs) in solid state microcavities is promising for a variety of classical and quantum-optical devices leading to improved properties and new applications. By utilization of the selenide and nitride wide-bandgap system devices for the UV to green spectral region can be realized. Furthermore, QDs being formed on base of these material systems are characterised by a high temperature stability of their emission making them good candidates for operation at elevated temperatures. In this contribution we report on the optical properties of planar and pillar structured GaN- and ZnSe-based monolithic microcavities [1]. The latter reveal three-dimensional confined optical modes with high quality factors and potentially small mode volumes. The measured data are discussed with regard to theoretical calculations. Furthermore, the optical emission properties of CdSe QDs embedded into microcavities have been studied [2]. The Purcell effect is indicated to occur by the pronounced enhancement of the spontaneous emission rate of QDs coupling to the discrete optical modes of the cavities. This enhancement depends systematically on the pillar diameter and thus on the Purcell factor of the individual pillars. [1] H. Lohmeyer et al., Appl. Phys. Lett. 88, 051101 (2006). [2] H. Lohmeyer et al., Appl. Phys. Lett. 89, 091107 (2006).

HL 4: Semiconductor Laser I

Time: Monday 10:45–13:00 Location: H13

HL 4.1 Mon 10:45 H13
High-temperature measurements and reliability of red 660 nm AlGaInP-VCSEL — •Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Heinz Schweizer[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In this paper we discuss the potential and the possible limitations of the AlGaInP material system and its consequences for the application as vertical-cavity surface-emitting lasers (VCSEL). Epitaxial and technological solutions were presented to overcome some parts of the inherent problems. Measurements of internal heating of oxide-confined 660 nm AlGaInP-VCSEL are compared with calculated data by a cylindrical heat dissipation model to improve the heat removal out of the device. Pulsed lasing operation of a 660 nm VCSEL at +140°C heatsink temperature is demonstrated, where we exceeded more than 0.5 mW and at 170°C more than 0.1 mW output power was achieved. Continuous-wave measurements of our 660 nm devices show laser emission at 60°C with an optical output power over 0.1 mW and operating times of more than 3700 hours without spontaneous failure.

HL 4.2 Mon 11:00 H13

Micro-Raman investigation of facet temperatures during catastrophic optical damage in AlGaInP laser diodes — •Marwan Bou Sanayeh[1], Peter Brick[1], Bernt Mayer[1], Martin Müller[1], Martin Reufer[1], Wolfgang Schmid[1], Klaus Streubel[1], Sandy Schwirzke-Schaaf[2], and Jens Tomm[2] — [1]OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, 12489 Berlin

Red-emitting AlGaInP lasers have found commercial applications in optical discs, barcode readers, and color printers. Moreover, high-power AlGaInP broad-area lasers are being developed for laser displays, as direct pump sources for Cr:LiSAF fs-lasers, and for the medical field, e.g. in photodynamic therapy. However, high-power applications are still limited by major degradation effects, especially catastrophic optical damage (COD). Facet temperature changes during COD of high-power red-emitting broad-area AlGaInP lasers are analysed by means of micro-Raman spectroscopy. Although no visible damage at the coated output facet can be observed, extreme temperature increase in the immediate vicinity of the COD starting point is detected. Moreover, differences between fresh and >1000h aged lasers are analyzed.

HL 4.3 Mon 11:15 H13

Measurement of the linewidth enhancement factor of semiconductor lasers — •Wolfgang Rick[1], Jens von Staden[1], Tobias Gensty[1], Guido Guiliani[2], and Wolfgang Elsässer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, D-64289 Darmstadt — [2]Dipartimento di Elettronica, Università di Pavia, Via Ferrata 1, I-27100 Italy

We present measurements of the linewidth enhancement factor of different semiconductor laser structures using the interferometric self-mixing technique [1]. In our experiments the laser is simultaniously used as emitter and detector, i.e. the self-mixing signal can be obtained by measuring the voltage variations across the laserchip. An alternative possibility is to measure the selfmixing-waveform with a classical setup using a monitor photodiode. In this work both methods are compared with respect to their potential to measure the alpha-factor. We find the electrical signal to be the first choice because of its better signal-to-noise-ratio. Also we present a statistical analysis of the alpha-measurement that allows to determine alpha and its FWHM and gives an overview of its temporal development. Finally we report on our results measuring the alpha-factor of a Quantum Dot laser.
[1] Y. Yu, G. Giuliani and S. Donati, IEEE Photon. Technol. Lett., vol. 16, pp. 990-992, April 2004.

HL 4.4 Mon 11:30 H13

Measurements of the Linewidth Enhancement Factor of Distributed Feedback Quantum Cascade Lasers by the Self-Mixing Technique — •Jens von Staden[1], Tobias Gensty[1], Wolfgang Elsässer[1], Guido Giuliani[2], and Christian Mann[3] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, 64289 Darmstadt, Germany — [2]Dipartimento di Elettronica, Laboratorio Elettroottica, Università di Pavia, Via Ferrata 1, Pavia I-27100, Italy — [3]Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Tullastrasse 72, 79108 Freiburg, Germany

We present measurements of the linewidth enhancement (α) factor of a distributed feedback (DFB) quantum cascade laser (QCL), using the interferometric self-mixing technique. The vality of this method has been shown for interband semiconductor lasers and is now transferred to the mid infrared wavelength range. In our experiments we use the QCL also to detect the self-mixing waveform by measuring the voltage drop variations across the device. The obtained self-mixing signal can then be used to evaluate both, the linewidth as well as the α-factor. Theoretical considerations predict the linewidth of QCLs to be extremly small. Limited by the resolution of the improved experimental setup, a reduced upper limit for the linewidth can be given. Our investigations of the α-factor have revealed a strong dependence on the injection current. Therefore the underlying mechanisms are further investigated. Thus we present measurements of the influence of the temperature dependent misalignment of the DFB grating on the value of the α-factor.

HL 4.5 Mon 11:45 H13

Tunable two color semiconductor lasers — •Carsten Brenner, Claus-Stefan Friedrich, Michael Breede, Stefan Hoffmann, and Martin Hofmann — AG Optoelectronic devices and materials, Ruhr-University Bochum, IC 2/133, Universitätsstr. 150, 44780 Bochum, Germany

We present different concepts for tunable two color and multimode emission by semiconductor lasers. These systems are particularly interesting for terahertz generation, telecommunications and spectroscopy. Simultaneous lasing on different frequencies is achieved using three different external cavity setups:

The first design is based on a structured end mirror in an external cavity. The emitted frequencies are selected by the geometry of the mirror. For the second configuration the end mirror of the external cavity is replaced by a digital micromirror device, hence the tuning can be achieved all electrically without any moving mechanical parts. To improve the spectral purity of the two colors we introduce a final setup incorporating a prism to achieve a double Littman geometry. In this layout both frequencies can be tuned separately.

HL 4.6 Mon 12:00 H13

Low threshold 1260nm (GaIn)(NAs) semiconductor disk laser — •Wolfgang Diehl[1,2], Bernadette Kunert[2], Stefan Reinhard[2], Peter Brick[1], and Wolfgang Stolz[2] — [1]OSRAM Opto Semiconductors, Leibnizstr. 4, D-93055 Regensburg, Germany — [2]Philipps-University Marburg, Hans Meerwein Str., D-35032 Marburg, Germany

We demonstrate low threshold lasing in semiconductor disk lasers emitting at 1260nm. Threshold densities as low as 1,1kW/cm^2 and slope efficiencies of 12,9% were achieved at 20°C while barrier pumping in pulsed operation. No intracavity heatsink was used so in cw-operation the bottomemitter reached 75°C while emitting more than 120mW. Thermal resistance of our chips was determined to be 50K/W. Nevertheless threshold densities in cw-operation were around 1,3kW/cm^2 with slope efficiencies of 11,4%. The performance of barrier pumping compared to direct well pumping showed only little difference in pulsed mode, reaching 1,4kW/cm^2 with slope efficiencies of 10,7%.

HL 4.7 Mon 12:15 H13

Tuneable Turnkey THz Sources Based on Diode Lasers — •Sebastian Berning, Icksoon Park, Tobias Gensty, and Wolfgang Elsässer — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, D-64289 Darmstadt

The continuous-wave generation of Terahertz (THz) radiation by means of diode laser devices has experienced extensive research in the past decade. A promising approach in this field of research is based on laser diodes in an external double-cavity setup simultaneously operating at two wavelengths (2λ-ECDL) to drive non-linear photomixers emitting cw radiation at the difference frequency in the THz regime. In the present work, we address the long-term stability of the laser setup combined with fast, repeatable scanning throughout the entire frequency range, as desirable for spectroscopic applications. For this purpose, we realize a two-colour ECDL device with a new low-loss cavity design allowing simple control of all relevant beam parameters, as the total and relative intensities, the beat frequency and the absolute wavelengths of the two laser modes. Furthermore, we present how modern microprocessor control is introduced to the miniaturized setup in order to enable active stabilization of the above discussed beam properties, allowing for extensive parameter studies and systematic optimizations for this class of THz sources.

HL 4.8 Mon 12:30 H13

Amplified hybrid-mode-locked semiconductor laser in an external cavity with intracavity dispersion control — •Tobias Schlauch[1], Tuyen Le[1], Stefan Hoffmann[1], Martin Hofmann[1], Andreas Klehr[2], and Götz Erbert[2] — [1]AG Optoelektrische Bauelemente und Werstoffe, Ruhr Universität Bochum, D-44780 — [2]Ferdinand Braun Institut für Höchstfrequenztechnik, D-12489 Berlin, Germany

Laser diodes are attractive sources for short pulse generation. Due to their compactness and cost effectiveness, they could be a very promising alternative to the conventional complex and expensive optically pumped short pulse lasers. However, though the gain bandwidth of laser diodes is sufficient for the generation of sub – 100fs pulses, pulses below 1ps are rather difficult to achieve in practice. Critical for shorter pulses is the significant chirp caused by the strong coupling of real and imaginary part of the susceptibility in the semiconductor. While optically pumped solid state femtosecond lasers contain elements for intracavity dispersion control, this concept is rarely used in short pulse diode lasers. We present an approach of an amplified hybrid-mode-locked two-section laser diode in an external cavity. The

cavity contains elements which enable spatial separation of the spectral components. A spatial light modulator is used to control phases and amplitudes of the individual spectral components.

HL 4.9 Mon 12:45 H13

Beitrag abgesagt — •XXX XXX —

HL 5: Photovoltaic

Time: Monday 11:00–13:15 Location: H14

HL 5.1 Mon 11:00 H14

Electrochemically prepared schottky-type nanoemitter solar cells — •Thomas Stempel Pereira, Katarzyna Skorupska, Michael Kanis, Michael Lublow, Mohammed Aggour, and Hans-Joachim Lewerenz — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

We produced a schottky-type nanoemitter solar cell with photoelectrochemical methods. It is known, that anodic current-oscillations in fluoride-containing solutions built up porous SiO_2 with an average thickness of 10 nm. The pores, some of which maintain contact to the Si-surface, have a diameter of several ten nm. Their distribution depends on the process-parameters and the chosen emersion current phase. These oxides can be used as a mask for selective alkaline Si-etching and subsequent electrodeposition of metals into the pores. Used in electrochemical solar-cells with Pt-nanoemitters and I^-/I_3^--redox-electrolyte we achieved efficiencies better than 5 %. AFM and HRSEM-images of the preparation steps and the complete device are presented, as well as a model for the bandstructure based on the determination of the flatband-potential by electrochemical impedance-spectroscopy.

HL 5.2 Mon 11:15 H14

Spectrally Selective Photonic Structures for Photovoltaic Applications — •Andreas Bielawny[1], Andreas von Rhein[2], Ralf Boris Wehrspohn[1], Rheinhard Carius[3], Carsten Rockstuhl[4], Marian Lisca[4], and Falk Lederer[4] — [1]Institute of Physics, AG Wehrspohn, MLU Halle-Wittenberg, Heinrich-Damerow-Str. 4, D-06120 Halle, Germany — [2]Dept. Physics, University of Paderborn, D-33095 Paderborn, Germany — [3]Institute for Photovoltaics, Research Center Juelich, D-52425 Juelich, Germany — [4]Dept. Physics, University of Jena, D-07743 Jena, Germany

One of the most appealing and lasting applications for photonics is photovoltaic (PV) energy conversion. While significant successes in material research and cell design were reported, photon management basically relies thus far on empirically obtained random rough surfaces.

We present a novel concept to incorporate a photonic crystal material with tailored properties into a photovoltaic tandem solar cell, causing two desirable effects. Firstly, our structure acts as a spectrally selective filter (according to the designed photonic stop-gaps) between PV-junctions of different electronic bandgaps: this increases multi-gap efficiency. Secondly, the periodicity of the photonic crystal provides diffraction of light into higher orders, which results in an enlargement of the optical path inside a PV-cell. This increases absorption and allows to improve current output or for the employment of even thinner cells. We present our work on photon management in a silicon-tandem cell with simulations based on experimental data, showing significant increase of the tandem cell's efficiency.

HL 5.3 Mon 11:30 H14

Growth and band gap characterizations of single crystals in the series ZrS_2Se_{2-x} — •Mohamed Moustafa, Thorsten Zandt, Christoph Janowitz, and Recardo Manzke — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Single crystals of layered transition metal dichalcogenides with composition ZrS_2Se_{2-x}, where x varies within the range 0-2, were grown by the chemical vapour transport technique using iodine as a transporting agent. Growth conditions are reported and the characterizations of the grown crystals were carried out with the help of LEED and EDX techniques. In addition, the absorption coefficient α was determined from transmission measurements at room temperature and approximate values of the band gaps were determined from the intercepts of the linear plots of the absorption coefficient on the energy axis [1]. The determined band gaps show good correspondence for the photovoltaic applications which is for a single junction cell about 1.45 eV and for two junctions about 1.1 eV and 1.8 eV. The observed exponential behaviour part in the absorption curve in the gap is also interpreted [2].

[1] P.A. Lee et al., J.Phys. Chem. Solids 30, 2719 (1969)
[2] F. Urbach, Phys. Rev. 92, 1324 (1953)

HL 5.4 Mon 11:45 H14

Interface Condition during Oscillatory Behavior of Silicon Photoelectrodes Investigated by Brewster Angle Reflectometry — •Michael Lublow and Hans Joachim Lewerenz — Hahn-Meitner-Institut Berlin, Abt. SE5, Glienicker Str. 100, 14109 Berlin

In-situ Brewster angle reflectometry was employed during anodic current oscillations of silicon electrodes in HF containing solutions. At selected points of the oscillation cycles, surface and interface topographies were investigated by Atomic Force Microscopy. The morphology of the anodic oxide was found to be built of regular cone shaped rods with uniform lateral diameter (80-120 nm) depending upon the oscillation state. In order to uncover the silicon oxide / silicon interface carefully, Brewster angle analysis was used during successive etch steps of the sample in 40% NH_4F. Thus, the change in film thickness of the anodic oxide as well as the variation of the roughened interfaces could be accurately quantified. It can be shown that the silicon interface is characterized by a transitory behavior from statistically rough to self-organized topographies.

HL 5.5 Mon 12:00 H14

Tuning the photovoltage of dye-sensitized solar cells based on electrodeposited ZnO — •Torsten Oekermann[1], Laurence Peter[2], and Tsukasa Yoshida[3] — [1]Institute of Physical Chemistry and Electrochemistry, Leibniz Universität Hannover, Callinstrasse 3-3A, 30167 Hannover, Germany — [2]Department of Chemistry, University of Bath, Bath BA2 7AY, United Kingdom — [3]Graduate School of Engineering, Gifu University, Yanagido 1-1, Gifu 501-1193, Japan

Nanoporous, fully crystalline ZnO films can be prepared by cathodic electrodeposition from aqueous solutions of Zn salts under the influence of structure-directing agents such as surfactants. Dye-sensitized solar cells (DSSC) based on such films have emerged as a possible alternative for nanocrystalline TiO2-based DSSC due to the very high porosity and good electron transport properties of the films.[1] In this study, we have investigated the influence of the sensitizer dye molecules on the photovoltage of the ZnO-based DSSC. Impedance measurements show that the adsorbed dye molecules lead to a shift of the flatband potential of the ZnO. Electron pushing or withdrawing effects of the dye molecules and protonation or deprotonation of the ZnO surface are discussed as possible explanations. The shifts in the flatband potential partly explain the differences in the photovoltages caused by different dyes, however, differences in the electron injection efficiency and the blocking of electron back reaction by the dye molecules have to be taken into account, too, for a complete description.

[1] Oekermann, T.; Yoshida, T.; Minoura, H.; Wijayantha, K. G. U.; Peter, L.M. J. Phys. Chem. B 2004, 108, 8364.

HL 5.6 Mon 12:15 H14

Deposition and characterization of (Zn,Mg)O buffer layers on CIGSSe thin film solar cells — •Felix Erfurth[1], Thomas Niesen[2], Jörg Palm[2], and Eberhard Umbach[1] — [1]University of Würzburg, Experimental Physics II, Am Hubland, 97070 Würzburg, Germany — [2]Avancis GmbH, München, Germany

The replacement of the CdS buffer layer in thin film solar cells based on $Cu(In,Ga)(S,Se)_2$ (CIGSSe), and the use of dry physical deposition methods, would be beneficial for high volume mass production. (Zn,Mg)O buffer layers deposited by radio frequency magnetron sputtering can result in efficiencies comparable to those of CdS containing solar cells. Using two separated ZnO and MgO sputter targets we are able to control the Zn/Mg – ratio of the buffer layer. A higher Mg content enhances the optical band–gap of (Zn,Mg)O, which is expected to have a great influence on the solar cell parameters by changing the electronic band alignment, too. In our experimental setup the sputter preparation chamber is connected with a UHV analysis system which

allows in–situ characterization even during the layer deposition by interrupting the sputter process.

To understand the impact of sputter parameters, such as Mg content, on the cell efficiency, we investigated the buffer layer and the absorber–buffer interface by photoelectron spectroscopy (XPS, UPS) and inverse photoelectron spectroscopy (IPES). The combination of both techniques allows determining the buffer layer stoichiometry as well as the alignment of the conduction and valence band at the heterojunction interface.

HL 5.7 Mon 12:30 H14

InP(100)-based low band gap tandem solar cell with an InGaAs/GaAsSb tunnel junction — •Ulf Seidel, Erol Sagol, Ulrike Bloeck, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institute, Glienicker Str. 100, 14109 Berlin, Germany

Triple junction III-V solar cells lattice-matched to GaAs(100) and grown on a Germanium bottom cell have recently shown world record conversion efficiencies of 39% under concentrated sunlight. Even higher efficiencies can be expected when employing more than 3 junctions with optimized band gaps. However, to realize high-efficiency multijunction solar cells with more than 3 junctions an appropriate absorber material with a band gap around 1eV is needed. Therefore, a monolithic low band gap tandem solar cell on the lattice constant of InP(100) was designed with optimized band gaps. It is thought to be combined with a GaAs-based high band gap tandem or triple cell via different techniques.

Here, we report on our results obtained when realizing an InP(100)-based low band gap tandem structure. The cell was grown monolithically on p-doped InP(100) via MOVPE in an AIX-200 reactor. The bottom cell (InGaAs E_g = 0.73eV) and the top cell (InGaAsP E_g = 1.03eV) of the low band gap tandem solar cell are connected via an Esaki-diode-like tunnel junction that includes n-InGaAs and p-GaAsSb. The influence of different preparation procedures on the critical InGaAs-GaAsSb hetero-interface and on the cell performance was investigated in detail.

HL 5.8 Mon 12:45 H14

Electrical Detection of Spin Coherence in Microcrystalline pin Solar Cells — •Jan Behrends[1], Christoph Boehme[1,2], Stefan Haas[3], Bernd Rech[1,3], and Klaus Lips[1] — [1]Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Berlin, Germany — [2]Department of Physics, University of Utah, Salt Lake City, UT, USA — [3]Institute of Photovoltaics, Forschungszentrum Jülich, Jülich, Germany

Defects in the band gap of hydrogenated microcrystalline silicon (μc-Si:H) pin solar cells, even at low concentrations, can act as recombination centres and thus, they can influence the electronic properties of the device significantly. A powerful technique to investigate these recombination processes is pulsed electrically detected magnetic resonance (pEDMR). This method is based on transient photocurrent measurements after varying specific recombination or transport rates and reveals information about the microscopic mechanisms of recombination and transport that involve paramagnetic states. In this study we report on the application of pEDMR on state-of-the-art μc-Si:H pin solar cells prepared on ZnO coated glass. An adapted contact structure allows the observation of Rabi oscillations in the photocurrent at low temperatures (T=10K) reflecting coherent spin motion. The coherence time is found to be on the order of several hundred nanoseconds and is determined by recombination. A Fourier analysis of the observed Rabi oscillations allows a distinction between the involved recombination processes. A discussion on the different recombination mechanisms in μc-Si:H cells will be given.

HL 5.9 Mon 13:00 H14

A Systematic Study on the Deposition of μm Thick $CuInS_2$ Spray ILGAR Layers — •Christian Camus, Daniel Abou-Ras, Nicholas Allsop, Wolfgang Bohne, Sophie Gledhill, Iver Lauermann, Martha Christina Lux-Steiner, Jörg Röhrich, and Christian-Herbert Fischer — Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin

The Spray Ion Layer Gas Reaction (ILGAR) is a new non-vacuum process, well suited for roll-to-roll production. In the first step of the process a metal salt solution is sprayed onto a heated substrate. The resulting solid layer is converted to the metal sulfide by H_2S. Both steps are repeated until the desired thickness is achieved. Recently In_2S_3 buffer layers for highly efficient $Cu(In,Ga)(S,Se)_2$ solar cells have been deposited by this method. Now we have significantly extended the process and enabled the deposition of copper containing compounds, such as $CuInS_2$. By aerosol preheating, temperature optimization and the use of appropriate precursor-salts, the deposition rate has been increased from 3nm/cycle up to 35nm/cycle in order to achieve μm thick films needed for solar cells. However, in addition to $CuInS_2$, In_2O_3 was also detected, which was strongly reduced by H_2S-postanealing. Nevertheless, XPS-, ERDA-, SEM- and EDX-measurements still revealed some structural and chemical inhomogeneities. Thus several approaches like a reducing atmosphere were tested to further improve the layer quality. Working solar cells have been produced with these $CuInS_2$ absorber layers. Their optimization with respect to photovoltaic performance is in progress.

HL 6: Quantum dots and wires: preparation and characterization I

Time: Monday 11:00–13:00 Location: H15

HL 6.1 Mon 11:00 H15

Morphology and properties of silicon nanowires grown by thermal evaporation — •Wilma Dewald[1], Daniel Stichtenoth[1], Sven Müller[1], Tore Niermann[2], Sebastian Geburt[1], and Carsten Ronning[1] — [1]II. Institute of Physics, University of Göttingen, Germany — [2]IV. Institute of Physics, University of Göttingen, Germany

Silicon nanowires of different morphology were grown by thermal evaporation. SiO was placed into the centre of a horizontal tube furnace, which was heated up to 1200°C. The vapour was transported to colder regions by a regulated Argon/Hydrogen gas flow, where it could condense onto Si substrates coated with a thin Au layer. Here, Au acts as a catalyst in the so called vapour-liquid-solid (VLS) growth process. In general, the obtained nanowires show a Si-SiO core-shell structure. Different morphologies occurred due to changed parameters including pressure, temperature, gas flow etc. The correlation between these parameters and the observed morphologies (SEM/TEM) has been studied. Long and straight nanowires grown under optimised parameters were dispersed on a second substrate and contacted by a FIB-system or e-beam lithography. First results on the electrical properties will be presented.

HL 6.2 Mon 11:15 H15

Templated Selforganization of SiGe Quantumdots — •Christian Dais, Harun Solak, Hans Sigg, Elisabeth Müller, and Detlev Grützmacher — Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, Villigen-PSI, Switzerland

Templated self-organization has been used to prepare samples with regimented arrays of Ge quantum dots. For prepatterning of Si (001) substrates we used extreme ultra-violet interference lithography (EUV-IL) which was performed at the Swiss Light Source (SLS) at the PSI. The EUV-IL technique is based on multiple beam interference to form an interference pattern which is projected onto PMMA resist. EUV-IL allows the definition of patterns of various symmetries with a periodicity smaller than 30 nm over areas as large as 2x2 mm. After the pattern had been transferred into the Si (100) substrate by reactive ion etching, molecular beam epitaxy was employed to grow Si/Ge quantum dot layers on the prepatterned substrates. By choosing appropriate growth conditions, dense packed 2D dot arrays, quantum dot molecule arrays, as well as 3D quantum dot crystals have been realized. AFM surface scans as well as cross-sectional TEM micrographs exhibit a remarkably narrow size distribution of the dots. This is confirmed by X-ray diffraction experiments at symmetric and asymmetric diffraction peaks. Moreover, photoluminescence measurements have been performed giving insights into the bandstructure of the 2-d and 3-d quantum dot crystals. Our results on the fabrication and properties of 2- and 3-dimensional Ge quantum dot crystals may open new routes towards the realization of nanoelectronic and spintronic devices.

HL 6.3 Mon 11:30 H15

Transferring achievements of quantum dot test structures to laser devices — •Tim David Germann, André Strittmatter, Thorsten Kettler, Kristijan Posilovic, Udo W. Pohl, and Dieter Bimberg — Institute of Solid State Physics, Sekr. PN 5-2, Hardenbergstr. 36, Technical University of Berlin, D-10623 Berlin, Germany

Fabrication of quantum dot (QD) based lasers for 1.3 μm emission and beyond requires a better understanding of epitaxial processes of the active QD region. The lasing wavelength of QD layers grown by MOCVD is typically blue shifted with respect to the ground state photoluminescence of test structures. We identified mechanisms driving the blue shift and developed techniques to reduce or even suppress this shift. A crucial parameter is the V/III ratio during the process of overgrowing the QDs with GaAs. High V/III ratios promote the blue shift due to a preferential formation of group-III vacancies at the surface. This increases group-III diffusion, leading to smaller QDs with less In content. In contrast, by using low V/III ratios, negligible blue shift of the photoluminescence is observed for laser structures.

However, laser diodes grown with low V/III ratios showing QD ground state emission at 1270-1280 nm still exhibit lasing at only 1220-1240 nm. This shift is shown to originate from gain saturation of the ground state emission and contributions of excited states emission. The growth of the p-doped AlGaAs cladding layer and the highly p-doped GaAs contact layer may affect the luminescence properties of the active region and induce fast saturation. Strategies and achievements to overcome this limit are discussed.

HL 6.4 Mon 11:45 H15

positioning of self-assembled InAs quantum dots by focused ion beam implantation — •minisha mehta, dirk reuter, alexander melnikov, and andreas d. wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätstraße 150, D-44780, Bochum

We present results on the positioning of InAs quantum dots (QDs) by a combined focused ion beam (FIB) and molecular beam epitaxy (MBE) process. First, a layer of GaAs was grown by MBE before a square lattice of holes was fabricated by FIB implantation. Thereafter, before overgrowth with InAs an in-situ annealing step was performed. The QDs were preferentially formed in the holes generated by FIB implantation. We have studied the influence of ion dose, the annealing parameters and the In amount. With an optimized process one can achieve one QD per hole without QDs between the holes. Photoluminescence studies on GaAs-capped QDs confirmed the optical quality of the QDs.

Financial support by GRK384 and the BMBF via the NanoQuit program is gratefully acknowledged.

HL 6.5 Mon 12:00 H15

Horizontal arrangement of alumina nanopores on a silicon chip — •Ying Xiang[1], Woo Lee[2], Kornelius Nielsch[2], Gerhard Abstreiter[1], and Anna Fontcuberta i Morral[1] — [1]Walter Schottky Institut, TU München, Am Coulombwall 3, 85748 Garching, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Template growth of nanowires has been extensively studied over the past few years, since it provides compactness and uniformity which are necessary for reproducible device fabrication based on arrays of individual nanoobjects. Especially porous anodic alumina (PAA) film has attracted much interest due to the high aspect ratio, high level of ordering, high pore density, and uniformity. PAA templates are commonly obtained with the pores oriented perpendicular to the substrate plane[MAS,LEE]. Unfortunately this method is not compatible with mainstream Si planar processing technology. Here, we present horizontally aligned, well-defined nanopores fabricated by two-step anodic oxidation of aluminum. To characterize different pore diameters obtained by different electrolytes and different anodization voltages, SEM measurements were performed. We obtained pore diameters between 15 nm and 110 nm, and interpore distances between 45 nm and 250 nm. The pore diameter is linearly dependent on the anodization voltage, but slightly different from that of typical vertical anodization. As a result of horizontal alignment, our approach is promising for nanoelectronic applications. Reference: [LEE] W. Lee et al., Nature Materials 5, 741-747 [MAS] H. Masuda et al., Science 268, 1466 (1995)

HL 6.6 Mon 12:15 H15

Self-organised growth of InN-nanocolumns by MBE — •Christian Denker[1], Joerg Malindretos[1], Henning Schuhmann[1], Michael Seibt[1], Angela Rizzi[1], Núria Garro[2], and Andrés Cantarero[2] — [1]IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August Universität Göttingen, 37077 Göttingen, Germany — [2]Material Science Institute, University of Valencia, PO Box 22085, 46071 Valencia, Spain

InN nanocolumns (NCs) are an attractive system for light harvesting applications. Our aim is to investigate the optical and electrical properties of nanorod ensembles and of single objects. An electron accumulation layer is known to be formed at the surface of epitaxial thin layers due to Fermi level pinning and should therefore facilitate the electrical contacting of the nanorods. InN-NCs were grown on p-Si(111) by plasma assisted MBE. In dependence on the growth parameters four different growth regimes were identified, according to the final shape of the NCs: broadened, tapered, uniform, tapered as well as long uniform rods. The early stages of nucleation have been analysed and correlated to the final shape distribution of the NCs. Nanorods with diameters of 20-250 nm and lengths up to 1.75 μm have been grown. The aspect ratio (length-to-diameter) reaches values of 45. HR-TEM images show a perfect crystal quality. Additionally we will present I-U-characteristics of a single NC contacted by Focused Ion Beam and e-beam lithography. First results show a resistance of a single object in the order of $k\Omega$. Micro-Raman and micro-PL measurements will provide an insight into the optical properties of InN-NC-ensembles and single objects.

HL 6.7 Mon 12:30 H15

Guided self assembly of mono- and bi- chain of InAs quantum dots on a cleaved facet — •Emanuele Uccelli[1], Dieter Schuh[2], Jochen Bauer[1], Max Bichler[1], Gerhard Abstreiter[1], and Anna Fontcuberta i Morral[1] — [1]Walter Schottky Institute, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Institut für Angewandte und Experimentelle Physik II, Universität Regensburg, 93040 Regensburg, Germany

Recently, we were able to fabricate long range ordered chains of InAs QDs by combining selective growth with self-assembly (APL 85, 4750 (2004)). InAs growth was realized on a (110) facet consisting of AlAs nanostripes embedded in GaAs, that was obtained by *in situ* cleaving of a previuosly MBE grown AlAs/GaAs (001) heterostructure. Here, we present an extended phase diagram for the fabrication of QDs arrays, showing under which conditions preferential growth of QDs on the AlAs stripes occurs. We found that the lateral dimensions of the QDs directly reflect the thickness of the underlying AlAs layer, with an onset for the QDs nucleation at AlAs stripe thickness of about 14 nm. The volume and the height of the QDs increases linearly with the stripe thickness. For AlAs stripes thicker than 40 nm, we also observed the formation of double QDs chain on the same stripe depending by the amount of the InAs deposited material. Finally, a comprehensive model is presented, for the understanding of the mechanism of selective nucleation of the single and double QDs chain on the AlAs stripes as a function of the growth conditions. The model gives insight for the mastering of the density and uniformity of the dots arrays.

HL 6.8 Mon 12:45 H15

Herstellung von InAs/GaAs-Quantenpunktstrukturen zur Ladungsträgerspeicherung — David Feise, •Konstantin Pötschke, Andreas Marent, Martin Geller, Udo Pohl und Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Aufgrund der steigenden Verbreitung portabler IT-Geräte sind insbesondere nicht-flüchtige Festkörperspeicher hoher Kapazität stark nachgefragt. Diese Flash-Speicher benötigen zur Ladungsträgerspeicherung allerdings ein Barrierenmaterial, dessen Haltbarkeit durch den Betrieb des Bauelements limitiert ist.

Quantenpunkte sind ideal als Speicherort für Ladungsträger, da sie ausschließlich diskrete Energiezustände enthalten und sich gezielt mit einzelnen Ladungsträgern beladen lassen. Theoretisch ist für Quantenpunkt-Speicher eine Schreibzeit von unter einer Nanosekunde möglich, so daß ein solches Speicherbauelement auch als Arbeitsspeicher verwendbar wäre.

In diesem Vortrag wird das Konzept und die Herstellung einer InAs/GaAs-Quantenpunktstruktur zur Ladungsträgerspeicherung mittels metallorganischer Gasphasenepitaxie vorgestellt. Der Speicherszustand der Quantenpunkte kann mit Hilfe eines 2D-Elektronengases (2DEG) ausgelesen werden. Zur Verlängerung der Speicherzeit wird eine AlGaAs-Barriere eingesetzt. Die Wachstumsbedingungen für das 2DEG und der Einfluß des InGaAs-Quantenfilms auf die optimalen Wachstumsbedingungen der Quantenpunkte werden diskutiert.

HL 7: III-V semiconductors I

Time: Monday 11:00–13:00 Location: H17

HL 7.1 Mon 11:00 H17

Strain properties of AlN layers grown on different substrates — •Ronny Kirste[1], Ute Haboeck[1], Axel Hoffmann[1], Christian Thomsen[1], Barbara Bastek[2], Frank Bertram[2], Jürgen Christen[2], Armin Dadgar[2], and Alois Krost[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

We present results of micro-Raman investigations on AlN samples grown by MOCVD on silicon and sapphire substrates. Thermal and lattice mismatch lead to a strong tensile strain in case of growth on silicon. Thus, already thin layers tend to relax by cracking. In the vicinity of such cracks we observed a strong shift of the nonpolar E_2(high) line. This mode is suitable to probe the strain properties because it is not affected by free carriers or internal electric fields. Converting this shift we found strain gradients of about 1 GPa in 300 nm thick layers and less than 0.5 GPa in thicker films of 1 or 2 μm. Even, at the center of the cracks the AlN layers are not fully relaxed. We will discuss the reasons, therefore, in comparison to AlN samples grown on sapphire. AlN on sapphire is, contrarily to growth on silicon, almost relaxed or slightly and uniformly compressive strained. Apart from cracking good crystal quality is achieved in both cases.

HL 7.2 Mon 11:15 H17

Optical Spectroscopy of doped and undoped Aluminium Nitride Layers on Sapphire Substrates — •Günther M. Prinz[1], Martin Schirra[1], Martin Feneberg[1], Sarad B. Thapa[2], Matthias Bickermann[3], Boris Epelbaum[3], Ferdinand Scholz[2], Rolf Sauer[1], and Klaus Thonke[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, D-89069 Ulm — [3]Institut für Werkstoffwissenschaften 6, Universität Erlangen, D-91058

Doped and undoped aluminium nitride layers were grown by MOVPE on sapphire substrates. We investigate these layers by photoluminescence, cathodoluminescence, and reflectance spectroscopy, and determine the fundamental band gap energy and the crystal field splitting of aluminium nitride. The temperature dependence of the near-band edge luminescence is investigated from 10K to 300K.

Doped and undoped samples are differently strained. Strain is tensile as measured by red-shifts of the near-band edge luminescence. Tensile strain is also observed by Raman measurements which show a shift of the E2 mode to lower wave numbers. Based on these measurements we use appropriate deformation potentials to quantitatively calculate the strain in the aluminium nitride layers.

HL 7.3 Mon 11:30 H17

Spinoidal decomposition in GaN:Mn grown by MBE — •Dong-Du Mai, Tore Niermann, Martin Roever, Jan Zenneck, Henning Schuhmann, Amilcar Bedoya Pinto, Joerg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut and Virtual Institute for Spin Electronics (VISel), Georg-August Universität Göttingen, D-37077 Göttingen, Germany

GaN:Mn is grown by plasma assisted Molecular Beam Epitaxy (MBE) on $GaN/Al_2O_3(0001)$. Samples were grown at various substrate temperatures, from T_S=775°C down to T_S=575°C and at various metal-to-nitrogen fluxes. It was possible to define parameter regions in which wurtzite GaMnN grows without second phases. For growth at high T_S and close to stoichiometry GaN:Mn exhibits good crystallinity (TEM, XRD). However only a maximum of $\sim$ 1% incorporation of diluted Mn can be achieved. At lower T_S and nitrogen-rich growth regime higher manganese incorporation (up to $\sim$ 5%) is possible without second phase formation. However the crystal quality worsens. EDX maps measured both in cross-section and plane-view through a scanning TEM analysis reveal an inhomogeneous distribution of the Mn in the layers (spinoidal decomposition). SQUID measurements are discussed in correlation with the structural and compositional analysis.

At regular T_S PL measurements near the band edge show strong bound and free excitonic luminescence (3 meV FWHM). Also a characteristic intra-3d luminescence for substitutional Mn at 1.42 eV (ZPL) could be detected. The latter is quenched at increasing Mn incorporation and its intensity correlates with the near band edge PL.

HL 7.4 Mon 11:45 H17

In-N anti-correlation in InGaAsN alloys: the delicate interplay between adatom thermodynamics and kinetics — •Hazem Abu-Farsakh[1,2] and Jörg Neugebauer[1,2] — [1]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [2]Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

Quaternary InGaAsN alloys have sparked a lot of interest in making infrared laser diodes for optical data transmission. Recent growth experiments showed a complex behavior for this quaternary system, such as In-N anti-correlation and a tendency to 3D growth with increasing growth temperature. The underlying mechanisms, however, could not be identified so far. We have therefore performed an extensive theoretical study to identify and quantify the fundamental growth mechanisms. Specifically, we computed the incorporation/solubility of N at GaAs and InGaAs surfaces employing density functional theory within the PAW approach. Based on theses results, we (i) derive the thermodynamics phase diagram for N incorporation into the experimentally relevant surface reconstructions, and (ii) identify the kinetic processes for N incorporation at different surface and subsurface sites. Based on these results we have been able to interpret recent experiments and to identify suitable growth conditions.

HL 7.5 Mon 12:00 H17

MOCVD Prozessentwicklung und Charakterisierung von AlIn/GaN-HEMT-Strukturen — Steffen Weller[1], Christoph Giesen[1], Lars Rahimzadeh-Khoshroo[2], Michael Fieger[2], Martin Eichelkamp[2], Holger Kalisch[2], Andrei Vescan[2], Rolf Jansen[2] und •Michael Heuken[1,2] — [1]AIXTRON AG, Kackertstr. 15-17, 52072 Aachen — [2]Institut für Theoretische Elektrotechnik, RWTH Aachen, Kopernikusstr. 16, 52074 Aachen

Im Rahmen der vorliegenden Arbeit wurden MOCVD-Prozesse für die Herstellung von AlInN/GaN-Heterostrukturen für HEMTs (High Electron Mobility Transistors) entwickelt. Zunächst wurden Basisprozesse für die Abscheidung von AlInN auf Saphir untersucht. Es wurde der jeweilige Einfluss der wichtigsten Prozessparameter auf die strukturellen, morphologischen und elektrischen Schichteigenschaften untersucht. Anschließend wurde die komplette AlInN/GaN-Heterostruktur hinsichtlich ihrer elektrischen Eigenschaften optimiert. Der Schwerpunkt der Optimierung lag auf dem In-Gehalt in der AlInN-Barriere und den Wachstumsparametern an der AlInN-GaN-Grenzfläche. Es hat sich gezeigt, dass sich eine ca. 1 nm dicke AlN Zwischenschicht positiv auf die elektrischen Eigenschaften der Heterostruktur auswirkt. An optimierten Strukturen wurden $n_S = 2,3 \cdot 10^{13}$ cm^{-2} und μ = 700 cm^2/Vs gemessen. Neben der detaillierten Darstellung der Wachstumsexperimente und der Schichtcharakterisierung werden auch die Eigenschaften von ersten fertig prozessierten AlInN/GaN-HEMTs diskutiert werden.

HL 7.6 Mon 12:15 H17

MOVPE Wachstum und Charakterisierung von AlInN Schichten auf Si(111) — •C. Hums, A. Gadanecz, A. Dadgar, J. Bläsing, T. Hempel, A. Krtschil, A. Dietz, J. Christen und A. Krost — Otto-von-Guericke-Universität Magdeburg, FNW/IEP/AHE, Universitätsplatz 2, 39106 Magdeburg

Das große Potential von AlInN / GaN Heterostrukturen für elektronische und opto-elektronische Bauelemente wurde durch das MOVPE Wachstum von hoch reflektierenden Bragg-Spiegeln und n-Kanal FETs bereits demonstriert. AlInN wächst bei einer Indiumkonzentration von $\approx$ 17 % gitterangepasst auf GaN. Auf Grund der pyroelektrischen Eigenschaften bei gitterangepasstem Wachstum auf GaN wurde von Dadgar et al. ein n-Kanal FET realisiert. Um eine nitridische Hochtemperatur-CMOS-Logik zu realisieren, ist zusätzlich ein p-Kanal FET notwendig. Dieser wird im selben Materialsystem ab einer Indium Konzentration von $\approx$ 34 % bei pseudomorphem Wachstum auf GaN durch die dann vorhandenen starken piezoelektrischen Felder prognostiziert. Mittels MOVPE wurden $Al_{1-x}In_xN$ Schichten mit Konzentrationen von $0.09 < x < 1$ gewachsen und mit FEREM und Röntgenbeugung charakterisiert. Es kann gezeigt werden, daß $Al_{1-x}In_xN$ bis zu $x < 0.5$ mischbar ist. Bei höheren Konzentrationen kommt es zur Phasenseparation, wobei sich eine stabile Phase mit

$x \approx 0.6$ ausbildet. Mit steigendem Indiumgehalt nimmt die Qualität der Morpholgie ab. Um pseudomorphe Schichten mit hohen Konzentrationen herstellen zu können, wurde detaillert der Zusammenhang zwischen Indiumgehalt, Schichtdicke und Verspannung untersucht.

HL 7.7 Mon 12:30 H17

Thermal stability and structural properties of AlInN grown on Si(111) by metalorganic vapor phase epitaxy — •Aniko Gadanecz, Jürgen Bläsing, Armin Dadgar, Christoph Hums, Thomas Hempel, and Alois Krost — Otto-von-Guericke Universität Magdeburg, FNW/IEP/AHE, Postfach 4120, 39016 Magdeburg

AlInN layers with In concentrations between 9..22 % and maximal thickness of 100 nm were grown by MOVPE on GaN/Si(111). Depending on the In concentration the layers are fully pseudomorphic or exhibit relaxed/pseudomorphic parts.

The thermal stability of such layers was investigated between 30 and 960 °C. It is significantly affected by the degree of relaxation: after different thermal treatment, the relaxed areas show decreasing quality, a loss of Indium and a pronounced phase separation. Additionally, with increasing lattice mismatch, a higher extension of relaxed regions under thermal treatment is observable.

Morphological characteristics, as the values of twist and lattice constants, In-sublimation and the degree of relaxation in the alloy were determined by high resolution X-ray diffraction and field emission scanning electron microscopy (FESEM).

HL 7.8 Mon 12:45 H17

Comparison of the electronic band formation and band structure of GaN_xAs_{1-x} and GaN_xP_{1-x} — •Martin Güngerich[1], Wolfram Heimbrodt[1], Gerhard Weiser[1], Bernardette Kunert[1], Kerstin Volz[1], Peter Jens Klar[2], and John Franz Geisz[3] — [1]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universität, Renthof 5, D-35032 Marburg, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [3]National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401, USA

Incorporation of an increasing amount of N into GaAs causes a strong red shift of the fundamental band gap (E_-) which is accompanied by the blue shift of a higher lying band of N impurity states (E_+). This repulsive behaviour is successfully parameterized by a phenomenological two-level band-anticrossing (BAC) model. In GaP:N the energetic ordering of host and impurity states is reversed compared to GaAs:N because the localized levels lie within the host band gap. We show that the simple BAC model fails to describe the evolution of the lowest conduction states in GaN_xP_{1-x}. Photocurrent and electromodulated reflection measurements of GaN_xP_{1-x} support a BAC-related blue shift of its E_+ band which in this material originates from the GaP-like lowest direct band gap. On the other hand, electromodulated absorption and pressure-dependent photoluminescence studies indicate that the wide energy distribution of the lower-lying N-related states leads to an anticrossing interaction involving many N levels.

HL 8: Invited Talk Fischer

Time: Monday 14:00–14:45 Location: H15

Invited Talk HL 8.1 Mon 14:00 H15

Coupling phenomena in dual electron waveguide structures — •Saskia Fischer[1], Sven Bucholz[1], Gabriela Aptetrii[1], Ulrich Kunze[1], Dieter Schuh[2], and Gerhard Abstreiter[3] — [1]Werkstoffe und Nanoelektronik, Ruhr-Univ. Bochum, D-44789 Bochum — [2]Ang. und Experimentelle Physik, Univ. Regensburg, D-93040 Regensburg — [3]Walter-Schottky Institut,Technische Univ. München, D-85748 München

A review is given on coupling phenomena between two one-dimensional electron systems (1DES) in dual electron waveguide structures realized as quantum point contacts or short quantum wires. Dual 1DES can be prepared from GaAs/AlGaAs heterostructures hosting high-mobility two-dimensional electron gases. Today, the merits of nanolithography allow a standard fabrication of 1DES with subband spacings of more than 10 meV. Therefore, high-resolution transport and magnetotransport spectroscopy can be performed which reveals directly the 1D subband structure of each quantum conductor and the energy splittings of mode-coupled levels [1]. Operation at liquid helium temperature and above is demonstrated. Mode coupling between degenerate 1D subbands depends on the symmetry of the confining potential and the coupling strength. Examples will be discussed for spatially coincident and tunnel-coupled vertically stacked dual 1DES [2,3]. [1] S.F. Fischer, *et al.*, Nature Physics **2**, 91-96 (2006). [2] S.F. Fischer, *et al.*, Phys. Rev. B **71**, 195330 (2005). [3] S.F. Fischer, *et al.*, Phys.Rev. B **74**, 115324 (2006).

HL 9: Semiconductor Laser II

Time: Monday 14:45–17:15 Location: H13

HL 9.1 Mon 14:45 H13

Nichtgleichgewichtsrechnungen in Halbleiterlaserstrukturen — •Eckhard Kühn[1], Angela Thränhardt[1], Sangam Chatterjee[1], Christoph Lange[1], Peter Brick[2], Wolfgang Diehl[2], Swantje Horst[1], Kristian Hantke[1], Wendel Wohlleben[3], Marcus Motzkus[3], Wolfgang Stolz[1], Wolfgang Rühle[1] und Stephan Koch[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Deutschland — [2]Osram Semiconductors, Regensburg, Deutschland — [3]Fachbereich Chemie, Philipps Universität Marburg, Deutschland

Wir präsentieren ein mikroskopisches Modell zur Beschreibung von Nichtgleichgewichtsladungsträgerverteilungen in Halbleiterquantenfilmlaserstrukturen. In optisch gepumpten Systemen wie z.B. Halbleiterscheibenlasern erzeugt der anregende Laserstrahl eine Verteilung von Ladungsträgern, die keine thermische Gleichgewichtsverteilung darstellt. Erst durch stoßinduzierte Relaxationsprozesse kann sich eine Fermiverteilung einstellen. Unser Modell beschreibt die Erzeugung und Relaxation von Ladungsträgern im Quantenfilm unter Berücksichtigung des Pauli-Prinzips auf Basis der halbklassischen Maxwell-Halbleiter Bloch Gleichungen.

Die resultierenden dynamischen Prozesse finden auf unterschiedlichen Zeitskalen statt. Auf die Thermalisation innerhalb der einzelnen Bänder folgt ein Regime mit deutlich verschiedenen Ladungsträger- und Gittertemperaturen. Die daraus abgeleitete zeitliche Entwicklung der Gittererwärmung zeigt gute Übereinstimmung mit dem Experiment. Thermische Effekte wie das Überrollen eines VECSELs lassen sich qualitativ gut reproduzieren.

HL 9.2 Mon 15:00 H13

Non-equilibrium quantum transport theory for quantum cascade lasers — •Tillmann Kubis and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present fully self-consistent non-equilibrium Green's function (NEGF) calculations of various quantum cascade laser structures (QCL) including all relevant coherent and incoherent scattering mechanisms. We have developed an implementation of the NEGF formalism that takes into account acoustic and polar-optical phonon scattering as well as impurity and interface roughness scattering within the self-consistent Born approximation. The complete momentum and energy dependence of all scattering mechanisms is accounted for. This is known to have a significant influence on all QCL device characteristics yet has been neglected in previous work. The electron-electron scatter-

ing is incorporated self-consistently within the Hartree approximation. The coupling between the lesser and the retarded Green's function is fully taken into account. In this way, all scattering states, transition probabilities between them, and their occupancies are calculated self-consistently instead of semi-classically. Our calculations yield I-V characteristics and optical gain that agree nicely with experiment. In spite of realistic dephasing, we observe multi-barrier tunneling and coherent formation of occupation inversion. Incoherent scattering mechanisms appear to assist tunneling but reduce the optical gain significantly.

HL 9.3 Mon 15:15 H13

Dynamic behavior of 1050nm semiconductor disk lasers — •Wolfgang Diehl[1,3], Sangam Chatterjee[2], Swantje Horst[2], Kristian Hantke[2], Wolfgang Rühle[2], Michael Furitsch[1], Stefan Illek[1], Ines Pietzonka[1], Johann Luft[1], Wolfgang Stolz[3], and Peter Brick[1] — [1]Osram Opto Semiconductors, Leibnizstr. 4, D-93055 Regensburg, Germany — [2]Faculty of Physics and Material Science Center, Philipps-Universität Marburg, Renthof 5, D-33032 Marburg, Germany — [3]Philipps-University Marburg, Hans Meerwein Str., D-35032 Marburg, Germany

We have investigated the lasing dynamics of semiconductor disk lasers emitting at 1050nm. Pulse durations of 500ns and 5000ns were used for excitation pump wavelength of 808nm for barrier pumping and 940nm for direct well pumping. Without resonator due to the high pump densities of up to 10kW/cm^2 high order transitions in the QW as well as band filling effects can be observed. With a resonator present, the photoluminescence overshoots and is subsequently clamped on a time scale of 40ns to 80ns depending on the pump power. This behavior can be explained with rate-equation modell using microscopically calculated gain and luminescence spectra.

HL 9.4 Mon 15:30 H13

Coulomb effects on luminescence spectra and radiative recombination times — •Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps-University, Renthof 5, 35032 Marburg, Germany

Semiconductor laser structures are of great technological importance while they also offer a unique possibility to study fundamental properties of light-matter interaction. Typically, lasers operate at room temperature or above such that appreciable phonon scattering has to be considered for a realistic description. At the same time, phase-space filling and Coulomb effects such as screening or Auger recombination are important for laser systems, and strong internal electric fields can furthermore complicate the analysis.

Here, a microscopic theory based on Bloch electrons and holes in a two-band approximation is applied in order to compute absorption and luminescence spectra for GaAs-type quantum wells at room temperature. Special focus is set to investigate the effect of Coulomb interaction on the linewidth of the luminescence spectra and on the radiative recombination rates. Since spontaneous emission provides an unavoidable loss mechanism, precise knowledge is important in order to correctly predict laser threshhold densities. Density dependent recombination rates are computed and contrasted with the common assumption of a quadratic increase with density. It is found that even for densities clearly beyond the transparency point a free-carrier model is insufficient for a correct estimate of the radiative recombination rates.

HL 9.5 Mon 15:45 H13

High modal gain and low threshold temperature dependence of InGaAlAs quantum dot lasers with increased dot density — •Thomas Schlereth, Christian Schneider, Wolfgang Kaiser, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The growth, morphology and spectral properties of $In_xGa_{1-x}As$ and $In_xGa_{1-x-y}Al_yAs$ quantum dots (QDs) were studied. The emission wavelength of the QDs can be tuned in a wide range by varying the In and Al content. Furthermore, an increase in Al concentration results in an enhancement of dot density and a decrease of dot size. This phenomenon can be explained by the lower migration ability of Al compared to In.

By adjusting the In and Al content, lasers with different dot species (InGaAs and InGaAlAs), and different dot densities (factor of ∼2.5), yet similar emission wavelengths (∼920 nm) have been realized. Both laser samples exhibit high internal quantum efficiencies and low internal absorptions of 0.83 and ∼2cm^{-1} for the InGaAs and 0.79 and ∼1 cm^{-1} for the InGaAlAs sample. The sample containing InGaAlAs QDs, however, shows a factor of ∼1.6 higher modal gain (∼63 cm^{-1}), and a lower threshold current density, which we attribute mainly to the higher dot density. Characteristic temperatures as high as 174 K for the Al-containing QD laser and 144 K for the InGaAs QD laser were found between 15°C and 85°C.

HL 9.6 Mon 16:00 H13

Low threshold high efficiency InAs/InGaAlAs/InP ∼1.55 μm quantum dash-in-a-well lasers — •Sebastian Hein, André Somers, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

In this work the dash-in-a-well (DWELL) design was used to improve the basic characteristics of InP-based quantum dash lasers. By embedding self-assembled InAs QDashes in a quantum well threshold current densities could be reduced due to an enhanced carrier capture of the QDashes. However the well layers reduce the energy barrier and hence lower the energy levels of the QDashes resulting in a longer emission wavelength. Though the QDash emission wavelength can be tuned over a wide range by varying the thickness of the QDash layers, the critical layer thickness for the formation of QDashes poses a lower limit to adjustment. Employing an adapted $InAs/In_{0.53}Ga_{0.37}Al_{0.10}As/In_{0.53}Ga_{0.23}Al_{0.24}As$ DWELL design, threshold current densities could be significantly reduced while maintaining an emission wavelength near 1.55 μm. Cavity length dependent measurements of as-grown devices lead to an extrapolated transparency current density of 165 A/cm^2 per dash layer and a very high internal differential efficiency of 0.89. With 0.6 mm long devices a very high external differential efficiency of 0.20 W/A per facet was achieved.

HL 9.7 Mon 16:15 H13

Optical characterisation of Ga(AsSb) heterostructures — •Christina Bückers, Gunnar Blume, Angela Thränhardt, Christoph Schlichenmaier, Peter J. Klar, Gerhard Weiser, and Stephan W. Koch — Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universiät Marburg

Ga(AsSb)/GaAs is one of the most promising material systems for room temperature VCSEL (vertical cavity surface emitting laser) operation at 1.3μm or even longer wavelengths. To enable emission in the desired regime Sb fractions of about 30-40% are required. An unresolved question remains the band alignment of Ga(AsSb) embedded between GaAs: While holes are certainly localised in the Ga(AsSb) layer, the confinement of the electrons is controversially discussed. This has major implications for the lasing performance.

In order to characterise the band alignment, Ga(AsSb)/GaAs quantum well structures are investigated. The lineshape of electroabsorption (EA) spectra is analysed by microscopic theory which offers an accurate determination of the conduction band offset between different layers: The calculations demonstrate that the offset is the most sensitive parameter for the lineshape of the EA spectra. Comparison of theoretical and measured spectra indicates a type II band alignment between Ga(AsSb) and GaAs with a conduction band offset of 40±20meV. Furthermore, information about the internal electric field in the quantum well region can be extracted.

HL 9.8 Mon 16:30 H13

Optische Eigenschaften von (GaIn)(NAs) und Ga(AsSb) - ein Vergleich — •Angela Thränhardt[1], Christina Bückers[1], Christoph Schlichenmaier[1], Stephan W. Koch[1], Jörg Hader[2] und Jerome V. Moloney[2] — [1]Philipps-Universität Marburg, Fachbereich Physik, Renthof 5, 35032 Marburg — [2]Arizona Center for Mathematical Sciences, The University of Arizona, Tucson, AZ 85721, USA

Der Wellenlängenbereich von 1.3mum bis 1.55 mum ist wegen des dort angesiedelten Dispersions- und Absorptionsminimums von Glasfasern ein für Laseranwendungen hochinteressantes Regime. Insbesondere GaAs-basierte Materialsysteme ermöglichen eine einfache Realisierung von oberflächenemittierenden Lasern. Zwei Kandidaten, die sich hier anbieten, sind die verdünnten Nitride sowie Ga(AsSb). In diesem Beitrag wird gezeigt, dass die optischen Eigenschaften beider Materialsysteme mikroskopisch realistisch modellierbar sind, und ein detaillierter Vergleich im Bezug auf typische Lasereigenschaften wie Gewinn und Linienbreitenfaktor präsentiert.

HL 9.9 Mon 16:45 H13

Charging Effects in Electrically Pumped Semiconductor Quantum Wells — •Ada Becker, Walter Hoyer, Mackillo Kira,

and Stephan W. Koch — Department of Physics and Material Sciences, Philipps-University, Renthof 5. 35037 Marburg, Germany

In electrically pumped quantum-well lasers, population inversion results from the capture of barrier electrons and holes into the active region. In principle, unequal electron and hole masses lead to different in-scattering rates of charge carriers implying charging inside the quantum well. However, typical experiments do not show significant charging-induced effects.

A microscopic theory for barrier and quantum-well charge carriers is presented to explain the absence of a net charge by the screening effect of the barrier electrons. It is shown that their dynamics almost completely compensates the charging of the quantum well. Furthermore, a collective oscillation with the plasma frequency is predicted, which may give rise to terahertz emission.

HL 9.10 Mon 17:00 H13

coherence properties of high-β semiconductor micropillar lasers — •Serkan Ates[1], Sven Ulrich[1], Stephan Reitzenstein[2], Andreas Löffler[2], Alfred Forchel[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We will present our latest results of low temperature (T = 4 K) microphotoluminescence (μ-PL), first-order field correlation $g^{(1)}(\tau)$, and second-order field correlation $g^{(2)}(\tau)$ measurements on high-β (≤ 0.12) semiconductor micropillar lasers with (InGa)As/GaAs quantum dots (QDs) as a gain material. A first identification of an onset of lasing was observed from μ-PL measurements which yield a smooth transition from spontaneous into stimulated emission in the input-output intensity characteristics. Based on these results, power-dependent $g^{(1)}(\tau)$ measurements have been performed by Michelson interferometry to investigate the coherence properties of the emission throughout the transition regime. While the visibility of the emission's self interference yield a Gaussian behavior below the smooth lasing onset with a coherence time of $\tau_c \approx 30$ ps, we observed a gradual change to a Lorentzian profile around the transition region. With increasing excitation, our measurements reveal a strong increase in τ_c (x10) of the emission which therefore reflects the change of emission characteristics from thermal to (mainly) stimulated (coherent) light. This observation was approved by $g^{(2)}(\tau)$ correlation measurements which showed a strong reduction of intensity fluctuations above the transition regime.

HL 10: Organic semiconductors

Time: Monday 14:45–16:00 Location: H14

HL 10.1 Mon 14:45 H14

Temperature dependence and anisotropy of charge-carrier mobilities in crystalline durene — •Frank Ortmann, Karsten Hannewald, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena

We report on the theoretical analysis of charge-carrier mobilities in durene crystals. The crystal is studied with DFT methods to examine structural, vibrational, and electronic properties. On that basis we employ a Holstein-Peierls model (see Hannewald et al. PRB **69**, 075211 (2004); PRB **69**, 075212 (2004)) to simulate the temperature dependence of the mobilities. The relation between the anisotropy of electron/hole mobilities and the band structure as well as lattice vibrations is discussed.

HL 10.2 Mon 15:00 H14

Electronic transport in polypyrrole thin films — •Thomas Heinzel and Cesar Bof Bufon — Institut für Physik der kondensierten Materie, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

We demonstrate that polypyrrole (PPy) films can be prepareded in lithographically defined patterns by vapor-phase polymerization. This technique allows the preparation of the PPy thin films (thicknesses between 6 nm and 170 nm) with low roughness onto a processed silicon substrate.[1]

The PPy thin films form granular systems, where the grains are separated by barriers which contain a certain level of dopants. The system shows an electronic transport strongly influenced by Coulomb interactions. The temperature dependence of the differential conductance exhibit an Efros-Shklovskii like hopping. The localization length was observed to depend on the applied electric field.

The PPy films can be used as an oxygen detectors. In addition, the operation of a PPy thin-film field-effect transistor at room temperature is demonstrated. Transport measurements indicate that the device works as Schottky barrier-type field-effect transistor.[1]

[1] C. Bof Bufon and T. heinzel, Appl. Phys. Lett. 89, 012104 (2006).

HL 10.3 Mon 15:15 H14

The colours of perylene pigments: Interference between Frenkel excitons and charge transfer (CT) states — •L. Gisslen and R. Scholz — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

The oscillator strength of optical transitions in molecular crystals arises mainly from neutral excitations of the molecules, resulting in Bloch waves known as Frenkel excitons. However, if the underlying transitions are close to resonant with CT states, both types of crystal excitations are mixed via electron and hole transfer, resulting in complex absorption lineshapes. As a basis for our exciton model including Frenkel and CT states, we determine the deformation patterns in the relaxed excited state and in anionic or cationic molecules with density functional methods. The electron and hole transfer parameters are deduced from the splitting of the Kohn-Sham orbitals in a stacked dimer. The sign and size of these transfer parameters depend on the geometric arrangment of the stack neighbours, so that the interference of Frenkel and CT transitions may result in a strong modulation of the absorption lineshape. As the relative energetic arrangement of Frenkel and CT states is difficult to calculate with high precision, we treat the difference $E_F - E_{CT}$ as the only free fit parameter of the model. From an analysis of five perylene derivatives [PTCDI, PTCDA, DiMe-PTCDI, N,N'-bis(3,5-xylyl)perylene-3,4:9,10-bis(dicarboximide), and N,N'-bis(2-phenylpropyl)perylene-3,4:9,10-bis(dicarboximide)] we derive a monotonous dependence of the energetic difference between Frenkel and CT states on the length of the stacking vector.

HL 10.4 Mon 15:30 H14

Temperature Dependence of the Trap State Distribution in C_{60} Crystals — •A. Ohlinger[1], A. Biebersdorf[1], R. Dietmüller[1], T.A. Klar[1], J. Feldmann[1], D.V. Talapin[2], and H. Weller[2] — [1]Photonics and Optoelectronics Group, Physics Department and CeNS, Ludwig-Maximilians-Universität München, Germany — [2]Institute of Physical Chemistry, University of Hamburg, Germany

Materials comprising C_{60} are of great interest and are used in optoelectronic devices such as FETs, photoconductors or photovoltaic devices. Charge transport in C_{60} crystals is dominated by trap states. The density of these trap states is commonly assumed to decay exponentially with the energetic depth from the conductivity edge.

In this contribution, we quantitatively determine the parameters of the trap state distribution by photodoping C_{60} microcrystals. We find the characteristic trap depth to decrease by nearly 40% during the phase transition of the C_{60} crystals from the fcc to the sc phase between 250 K and 200 K and the activation energy drops by approximately 50%. The conductivity below 200 K is predominately governed by trap states which are introduced by oxygen. In contrast, at room temperature trap states are dominantly related to the rotation of the C_{60} molecules. Calculations based on our data show that the number of trap states at room temperature is about 100 times larger than below 200 K.

For the future we expect that photodoping will be used to determine characteristic parameters of trap states in other amorphous organic or inorganic semiconductors, as well.

HL 10.5 Mon 15:45 H14

Resonant Raman spectra of pentacene in the UV range — •L. Gisslen[1], C. Himcinschi[2], J. Pflaum[3], and R. Scholz[1] — [1]Walter Schottky Institut, Technische Universität München, Germany

— [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]3. Physikalisches Institut, Universität Stuttgart, Germany

Pentacene has two prominent absorption bands, one in the visible and one in the near UV, the first being based on the HOMO-LUMO transition, the second on an interference between the transitions HOMO→LUMO+2 and HOMO-2→LUMO. In order to investigate the deformation in the relaxed excited state related to the transition in the UV, we have performed resonant Raman spectroscopy in that region. The experimental observation of the Raman spectra from a pentacene crystal was realised using a LabRam HR800 UV spectrometer in a micro-configuration. Light from a He-Cd laser at a wavelength of 325 nm was focused with the microscope, resulting in a beam diameter of ≈ 1.5 μm on the sample, with a laser power of ≈ 0.5 mW measured under the objective of the microscope. Resonant Raman spectra were recorded in the Stokes region between 200 cm^{-1} and 2000 cm^{-1}. The intensity distribution differs strongly from Raman data obtained in resonance with the HOMO-LUMO transition, revealing different deformation patterns. The latter are determined by geometry optimisation of the excited states with time-dependent density function theory (DFT). For both transitions, the measured intensity distributions are well reproduced by the calculations.

HL 11: Quantum dots and wires: Transport properties I

Time: Monday 14:45–17:30 Location: H15

HL 11.1 Mon 14:45 H15

Quantum gates between capacitively coupled double quantum dot two-spin qubits — •Dimitrije Stepanenko and Guido Burkard — Department of Physics and Astronomy, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We study the two-qubit controlled-not gate operating on qubits encoded in the spin state of a pair of electrons in a double quantum dot. We assume that the electrons can tunnel between the two quantum dots encoding a single qubit, while tunneling between the quantum dots that belong to different qubits is forbidden. Therefore, the two qubits interact exclusively through the direct Coulomb repulsion of the electrons. We find that entangling two-qubit gates can be performed by the electrical biasing of quantum dots and/or tuning of the tunneling matrix elements between the quantum dots within the qubits. The entangling interaction can be controlled by tuning the bias through the resonance between the singly-occupied and doubly-occupied singlet ground states of a double quantum dot.

HL 11.2 Mon 15:00 H15

Scaling analysis of transport properties of GaAs-based nanocolumns — •Jakob Wensorra[1], Klaus Michael Indlekofer[1], Mihail Ion Lepsa[1], Katharina Peter[1], Arno Förster[2], and Hans Lüth[1] — [1]Centre of Nanoelectronic Systems for Information Technology (IBN-1), Research Center Jülich, 52425 Jülich, Germany — [2]Aachen University of Applied Sciences, Section Jülich, D-52428 Jülich, Germany

Semiconductor nanocolumns are ideal systems not only for basic research in the field of quantum transport but also for finding novel nanodevice concepts for information technology. By means of built-in heterostructures, one can easily implement tunnel barriers and quantum well structures within such nanocolumns, with tailored electronic transport properties.

We present a scaling analysis of quantum transport properties of GaAs-based resonant tunnelling nanocolumns down to 30 nm lateral dimensions. The electronic transport properties of the smallest devices are strongly influenced by the lateral depletion region, which defines the vertical conductive channel within the device. Simulations of the 2D-potential map of the device structure suggest a transport model based on a quantum collimation effect due to a saddle point in the potential profile. For structures with a lateral dimension of 60 nm - 45nm, this quantum collimation effect leads to a distinct improvement of the nanodevice performance at room temperature. For the lowest dimensions (< 45 nm) we observe a degradation of device performance due to a depletion of the channel within the nanocolumns.

HL 11.3 Mon 15:15 H15

Trägheitsballistische Gleichrichtung und Halleffekt in nanoskaligen Si/SiGe-Kreuzstrukturen — •Egmont Fritz[1], Ulrich Wieser[1], Ulrich Kunze[1] und Thomas Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerChrysler Forschungszentrum Ulm, D-89081 Ulm

Wir untersuchen den Einfluss eines externen Magnetfeldes auf den trägheitsballistischen Elektronentransport in mesoskopischen Si/SiGe-Gleichrichterstrukturen. Ausgehend von einer Si/SiGe-Heterostruktur mit einem eingebetteten 2DEG hoher Elektronenbeweglichkeit werden laterale gabelförmige Strukturen präpariert, bei denen drei 250 nm breite parallele Wellenleiter geradlinig in einen 1 μm breiten Stamm münden. Die Bauelementgeometrie erlaubt die Unterscheidung verschiedener Gleichrichtermechanismen. Legt man an die beiden äußeren schmalen Wellenleiter eine antisymmetrische Spannung an, lässt sich sowohl am mittleren Wellenleiter als auch im Stamm ein modenkontrolliertes gleichgerichtetes Spannungssignal messen. Auf Grund der zum Stamm orientierten Impulskomponente der injizierten Elektronen ist im Stamm zusätzlich ein gleichgerichtetes trägheitsballistisches Signal überlagert, das durch Differenzbildung extrahiert werden kann. Wir zeigen die Auswirkungen eines schichtsenkrechten Magnetfeldes auf diese Signale. Wird die Eingangsspannung zwischen dem zentralen Wellenleiter und dem Stamm angelegt, ermöglicht die Geometrie, den Einfluss ballistischer Elektronen auf die Hall-Spannung zu untersuchen, die in dieser Messkonfiguration zwischen den beiden äußeren Wellenleitern abgegriffen wird.

HL 11.4 Mon 15:30 H15

Charge detection for ballistic electron spectroscopy — •Frank Hohls[1,2], Michael Pepper[2], Jonathan P. Griffiths[2], Geb A.C. Jones[2], and David A. Ritchie[2] — [1]Institut für Festkörperphysik, Universität Hannover — [2]Cavendish Laboratory, University of Cambridge, UK

We have shown that a quantum dot can be used for the direct energy resolved detection of ballistic electrons [1]. This allows us to measure the energy and angle distribution of ballistic electrons injected by e.g. a quantum wire or another dot. In the original scheme the usable energy range was limited by the presence of excited states to a few 100 μeV.

Here we will present a modified detector design that allows us to extend the energy range to at least 1 meV. We largely increase the excitation energy by using a small quantum dot on the transition between 0 and 1 electron. The readout is performed by a nearby quantum point contact utilised as charge detector. The average charge on the dot is a direct function of the density of electrons attempting to enter the dot at its resonance energy.

We apply this scheme to assess the energy spectrum of non-equilibrium ballistic electrons that are injected by a quantum point contact and have traversed a few micrometer through a two-dimensional electron system. We discuss the energy distribution and scattering mechanisms.

[1] F. Hohls *et al.*, Appl. Phys. Lett. 89, 212103 (2006).

HL 11.5 Mon 15:45 H15

Transportmeasurements on quantum dots formed in a GaAs/AlGaAs quantum ring — •A. Mühle[1], R. J. Haug[1], and W. Wegscheider[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-92040 Regensburg

We present transport measurements of a quantum ring formed in a GaAs/AlGaAs heterostructure. This ring was fabricated by atomic force microscope lithography utilizing local anodic oxidation [1]. Using in-plane gates, the energy of the electrons in the arms of the rings as well as the coupling of the structures to the leads can be controlled.

When the structure is operated in the regime with weak coupling to the leads, sweeping the gates shows different sets of Coulomb-blockade lines, thus revealing the existence of three different dots formed in the arms of the ring.

By analyzing the structure's transport features, the dots are characterized and their spatial distribution in the ring is determined.

[1] U. F. Keyser et al., Phys. Rev. Lett. **90**, 196601-1 (2003)

15 min. break

HL 11.6 Mon 16:15 H15

New aspects of electronic transport in GaAs/AlAs nanocolumns — •Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1], Jakob Wensorra[1], Katharina Peter[1], Arno Förster[2], Hans Lüth[1], and Detlev Grützmacher[1] — [1]Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

Vertical sub-100nm GaAs nanocolumns with an embedded GaAs/AlAs resonant tunneling heterostructure have been processed using a top down approach [1, 2].

Electronic transport properties are investigated using DC electrical measurements. The results show that specific discrete features in the energy spectrum of the structure can be probed even at room temperature. We observe a multi-peaked I-V curve which is enhanced for a certain range of column diameters. The experimental findings can be explained qualitatively by a transport model based on a non-uniform lateral quantization profile. The latter results from the formation of a saddle-point in front of the double barrier quantum well (DBQW) region [1].

[1] J. Wensorra, K.M. Indlekofer, M.I. Lepsa, A. Förster, and H. Lüth, Nano Letters, 5, 2470 (2005).

[2] J. Wensorra, M.I. Lepsa, K.M. Indlekofer, A. Förster, P. Jaschinsky, B. Voigtländer, G. Pirug, and H. Lüth, Phys. Stat. Sol. (a) 203, 3559 (2006).

HL 11.7 Mon 16:30 H15

SOI-Based Single-Electron Transistors Fabricated by a Combination of Self-Assembly and Self-Alignment Techniques — •Conrad R. Wolf, Klaus Thonke, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

We present a technique to fabricate single-electron transistors (SETs) with silicon quantum dots (QDs) as conducting islands making use of a combination of self-assembly and self-alignment effects. Starting from an ultra-thin silicon-on-insulator (SOI) substrate we employ self-assembled gold colloidal particles as an etch mask. Quantum dots are then fabricated by applying a CF_4 reactive ion etch (RIE) process to remove the silicon layer everywhere except below the gold colloids. A 100-200 nm wide metal wire together with side gate electrodes is patterned by electron beam lithography (EBL) onto the QD-covered sample and a nanometer-sized gap is created in these wires by a controlled electromigration process. The metal wires will preferentially break at the positions of the QDs, because the metal layer is dilated there resulting in a locally higher current density. This leads to a self-alignment effect of the evolving nano-electrodes with respect to the QDs. The native oxide layer covering the silicon QDs is used as a tunneling barrier. Its thickness can optionally be adjusted in a controlled manner by self-limiting thermal oxidation to obtain an accurate tunneling resistance. The devices are electrically characterized at liquid helium temperature and show clear Coulomb blockade behavior, Coulomb staircase features as well as the so-called Coulomb diamonds, typical for SETs.

HL 11.8 Mon 16:45 H15

Nonequilibrium transport through quantum point contacts — •Andreas Helzel, Leonid Litvin, Werner Wegscheider, and Christoph Strunk — Institut für experimentelle und angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany

We investigate the nonequilibrium transport properties through a quantum point contact (QPC) defined by split gates on top of a GaAs/AlGaAs heterostructure with a 230 nm deep 2 DEG. At low temperatures the QPC develops a resonant structure in the differential conductance around zero bias below half of a conductance quantum. Then with increasing conductance this resonance splits in two peaks even in absence of magnetic field. Recent theory [1] suggests for this double peak a double Anderson-impurity arising in the QPC. As already measured before, between 0.7 and 1 conductance quantum a Kondo anomaly can be seen. But in our case with satellites next to it, that merge out of the mentioned split peaks. The Kondo effect can appear in a QPC by a trapped spin in a potential valley arising due to the nonlinear screening of the gate potential in the 2DEG.

[1] T. Rejec, Y. Meir, Nature 442 (2006)

HL 11.9 Mon 17:00 H15

Random-telegraph-signal noise and device variability in ballistic nanotube transistors — •Neng-Ping Wang[1], Stefan Heinze[1], and Jerry Tersoff[2] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg — [2]IBM Research Division, T. J. Watson Research Center, Yorktown Heights, NY 10598, USA

The last few years have seen remarkable progress in carbon nanotube field-effect transistors (CNFETs). High performance and even ballistic transport have been demonstrated, and there is increasing focus on integrating such transistors into operational device circuits. Device integration requires stable and uniform behavior of the individual transistors. However, all materials exhibit some low-frequency electrical noise; and such noise increases inversely with the system size, so it is important to develop a microscopic understanding of noise in nanotubes.

In field-effect transistors, charge trapping in the gate oxide is known to cause low-frequency noise and threshold shifts. Here we calculate the effect of single trapped charges in a CNFET, using the nonequilibrium Greens function method in a tight-binding approximation. We find that a single charge can shift and even rescale the entire transfer characteristic of the device. This can explain both the large "random telegraph signal" (RTS) noise and the large variations between nominally identical devices. We examine the dependence on both the thickness and dielectric constant of the gate dielectric, suggesting routes to reduce electrical noise.

HL 11.10 Mon 17:15 H15

Source gating enhanced threshold hysteresis in electron Y-branch switches with quantum dots — •Christian R. Müller, Lukas Worschech, Philipp Höpfner, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

On the basis of modulation doped GaAs/AlGaAs heterostructures with self-assembled InGaAs quantum dots embedded in the undoped spacer, Y-branched nanojunctions controlled by four independent side-gates were fabricated by electron beam lithography and etching techniques. Charging of the quantum dots in the Y-junction is demonstrated by pronounced threshold hysteresis. Interestingly, the gate voltage at which the quantum dots are discharged shifts to lower values with increasing Fermi energy of the source indicating that the charges in the sources have a considerable gate effect on the channel. In particular, by switching the Fermi energy of the source a drastically enhanced threshold hysteresis was observed.

HL 12: Quantum dots and wires: Optical properties I

Time: Monday 14:45–18:00 Location: H17

HL 12.1 Mon 14:45 H17

Origin of the excitonic dipole moment in InAs/GaAs Quantum Dots: A Tight-Binding Study — •Alexander Kleinsorge[1], Thomas Hammerschmidt[1], Peter Kratzer[2,1], and Matthias Scheffler[1] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, D-47048 Duisburg, Germany

With the help of electronic structure calculations, the electronic and optical properties of quantum dots (QDs) can be related to their atomic structure. We employ the empirical sp^3s^* tight-binding approach, including 2nd-nearest-neighbor interactions and spin-orbit coupling, preceded by structural relaxation using a potential of the Abell-Tersoff type. We are able to treat large systems (up to 10^6 atoms, folded-spectrum method). We apply our method to buried InAs QDs in GaAs, comparing different inverted pyramid shapes and composition profiles. Because of the different shape of the electron and hole wavefunctions (WF), the exciton is associated with a dipole moment which

causes the experimentally observed Stark shift. We investigate how the relative position of an electron or hole state in a QD depends on its size in different inverted-pyramid shape boundaries. The presence of the wetting layer (WL) is found to affect the localization of the hole WF and thus the magnitude of the dipole moment, and for flat QD (height $<$ 4nm) even its sign. If an inversion of the dipole is observed experimentally for flat quantum dots, we interprete this as indication that the WL below the QD must have been dissolved.

HL 12.2 Mon 15:00 H17

Mode locking of electron spin coherences in singly charged InGaAs/GaAs quantum dots — •Alex Greilich[1], Dmitri Yakovlev[1], Andrew Shabaev[2], Alexander Efros[2], Irina Yugova[1], Ruth Oulton[1], Victorina Stavarache[3], Dirk Reuter[3], Andreas Wieck[3], and Manfred Bayer[1] — [1]Experimentelle Physik II, Universität Dortmund, D-44221 Dortmund, Germany — [2]Naval Research Laboratory, Washington, DC 20375, USA — [3]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

We report an optical technique based on time-resolved Faraday rotation measurements of the electron spin dynamics in an ensemble of QDs to recover the coherence time of a single QD. The measured spin coherence time T_2 is 3 microseconds, which is three orders of magnitude longer than the ensemble dephasing time of about 2 nanoseconds. A periodic train of circularly polarized light pulses from a mode-locked laser synchronizes the precession of the spins to the laser repetition rate T_R, transferring the mode-locking into the spin system. This synchronization leads to constructive interference of the electron spin polarization in time. The interference gives also the possibility for all-optical coherent manipulation of spin ensembles: the electron spins can be clocked by two trains of pump pulses with a fixed temporal delay T_D. After this pulse sequence, the QD ensemble shows multiple echo-like Faraday rotation signals with a period equal to the pump pulse separation.

HL 12.3 Mon 15:15 H17

Implementation and application of a $\mathbf{k}\cdot\mathbf{p}$-formalism to study electronic structure and Coulomb matrix elements for semiconductor nanostructures — •Oliver Marquardt, Tilmann Hickel, Blazej Grabowski, Sixten Boeck, and Jörg Neugebauer — Max-Planck Institut für Eisenforschung

In order to theoretically predict optical and electronic properties of semiconductor nanostructures such as quantum dots and wires, the eigenvalues and -states of the electrons and holes as well as the Coulomb interaction elements are needed. In order to investigate the effect of shape, size and material composition of larger nanostructures we employed $\mathbf{k}\cdot\mathbf{p}$ perturbation theory. For this purpose, we have extended our DFT package S/Phi/nX, which was originally developed as a plane wave-pseudopotential code, to calculate $\mathbf{k}\cdot\mathbf{p}$ kinetic energies both for zincblende and wurtzite structures. This strategy allows us to make use of fast minimization routines and the excellent preconditioners available in plane-wave codes as well as an efficient calculation of the Coulomb matrix in reciprocal space. Based on this approach we have studied a wide variety of quantum dots and nano wires with a particular focus on group-III-nitrides in the cubic and wurtzite phase. The results allow a direct interpretation of recent experiments on nitride based quantum dots.

HL 12.4 Mon 15:30 H17

Phonon dephasing in optical control of a single spin in a quantum dot — •Anna Grodecka[1,2], Carsten Weber[1], Paweł Machnikowski[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institute of Physics, Wrocław University of Technology, Wybrzeze Wyspiańskiego 27, 50-370 Wrocław, Poland

Unique and designable properties of quantum dots together with the availability of fast optical control methods indicate that these systems may be considered as attractive candidates for use as qubits. It is advantageous to store the logical values in spin states of an electron in a quantum dot (due to the long decoherence time) and perform the operations using optical coupling to the charge degrees of freedom (short switching time). However, quantum dots are embedded in a surrounding crystal and the confined carriers interact with phonons, which leads to a loss of coherence.

Within a density matrix approach, we consider the carrier-phonon dynamics in the optical control of a single spin in a quantum dot. Using perturbative methods we study the phonon-induced decoherence accompanying a single qubit gate: an arbitrary rotation between two selected electron spin states performed via spin-flip Raman transitions and virtual excitation of a trion state.

HL 12.5 Mon 15:45 H17

Spin Injection into Single InGaAs Quantum Dots — Mohsen Ghali[1], Tilmar Kümmell[1], •Robert Arians[1], Gerd Bacher[1], Jan Wenisch[2], Suddhasatta Mahapatra[2], and Karl Brunner[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Bismarckstraße 81, 47057 Duisburg — [2]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg

Single quantum dots are highly interesting candidates for potential spin-based devices. In order to implement a technology that utilizes the spin as an information carrier, one needs to initialize, store and detect a single spin. While diluted magnetic semiconductors like ZnMnSe have been proven to be an efficient source of spin polarized carriers, InAs-based quantum dots provide high spin stability with relaxation times up to milliseconds.

Using magneto-micro photoluminescence experiments, we found an efficient spin injection from a n-ZnMnSe layer into an InAs single quantum dot (SQD) in a p-i-n diode structure resulting in a circular polarization degree of up to 60% at B=5T. In contrast, no polarized light emission due to spin injection was obtained in an undoped reference structure. Furthermore, a pronounced dependence of the spin injection efficiency on the external bias is found resulting in a strong decrease of the SQD circular polarization degree when external biasing is applied in the forward direction. The experiments emphasize the impact of excess energy and current flow on the spin injection efficiency in a SQD.

HL 12.6 Mon 16:00 H17

Colloidal Quantum Dots in High-Q Pillar Microcavities — •Verena Kohnle[1], Matthias Kahl[1], Tim Thomay[1], Katja Beha[1], Jörg Merlein[1], Matthias Hagner[1], Andreas Halm[1], Alfred Leitenstorfer[1], Rudolf Bratschitsch[1], Jan Ziegler[2], Thomas Nann[2], Yuri Fedutik[3], Mikhail Artemyev[3], Ulrike Woggon[3], and Fabian Pérez-Willard[4] — [1]Fachbereich für Physik, Centrum für angewandte Photonik, Universität Konstanz, Konstanz, Germany — [2]School of Chemical Sciences and Pharmacy, University of East Anglia, Norwich, UK — [3]Experimentelle Physik IIb, Universität Dortmund, Dortmund, Germany — [4]DFG Center for Functional Nanostructures, Universität Karlsruhe, Karlsruhe, Germany

We have fabricated high-Q pillar resonators with colloidal CdSe/ZnS quantum dots or rods as light emitters by focused ion beam (FIB) milling. First, a planar dielectric cavity is formed by two Bragg mirrors, each consisting of sputtered pairs of alternating TiO2 and SiO2 layers. Subsequently, micropillar waveguides with diameters in the range from 5100 nm down to 610 nm are cut out of the planar resonator via FIB. Photoluminescence measurements of quantum dots in the resonator show a blue shift of the fundamental cavity mode with decreasing pillar diameter. This result demonstrates the presence of three-dimensional light confinement. The spectral position of the observed cavity modes may be calculated by modeling the pillar resonator as a waveguide with an effective refractive index. The theoretical results are in excellent agreement with the experimentally observed pillar mode patterns and frequencies.

15 min. break

HL 12.7 Mon 16:30 H17

A Gallium Nitride Single-Photon Source Operating at 200 K — •Stephan Götzinger[1], Charles Santori[1], Yoshihisa Yamamoto[1], Satoshi Kako[2], Katsuyuki Hoshino[2], and Yasuhiko Arakawa[2] — [1]E. L. Ginzton Laboratory, Stanford University, Stanford, California 94305, U.S.A. — [2]Institute of Industrial Science, University of Tokyo, 4-6-1 Komaba, Meguro-ku. Tokyo,153-8505, Japan

Nitride semiconductors have emerged as important materials for blue and ultraviolet light-emitting diodes with numerous commercial applications. However, their large bandgaps make these materials also interesting for quantum information applications, such as quantum cryptography.

We report on a single-photon source based on a gallium nitride semiconductor quantum dot emitting at a record-short wavelength of 355nm. The power dependence of the second order coherence function suggests a two-level model for photon antibunching, where the anti-

bunching timescale converges to the exciton decay time in the weak-excitation limit. This is supported by fluorescence lifetime measurements on single quantum dots. In temperature dependent measurements, photon antibunching was observed up to 200K, a temperature easily reachable with thermo-electric cooling [1].

[1] S. Kako et. al., Nature Materials 5, 887 (2006).

HL 12.8 Mon 16:45 H17

Single quantum dot lasing effects in high quality AlAs/GaAs micropillar cavities — •Carolin Hofmann[1], Stephan Reitzenstein[1], Steffen Münch[1], Andreas Löffler[1], Martin Kamp[1], Anatoli Bazhenov[1,2], Alexander Gorbunov[1,2], Vladimir Kulakovski[1,2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Würzburg, Germany — [2]Institute for Solid State Physics, Russian Academy of Science, Chernogolovka, Russia

We report on lasing effects based on individual quantum dots (QDs) in optically pumped high-Q micropillar laser-structures. The laser-structures are based on planar GaAs/AlAs microcavities with a low density layer of InGaAs QDs embedded as active material in the center of a λ-cavity. Lasing associated with ultra-high spontaneous coupling factors is identified by the change of a linear to a superlinear input-output characteristic at the transition from spontaneous emission to laser operation. We will show that laser characteristics such as threshold pump power are strongly influenced by the gain-contribution of single QDs. In particular, the threshold pump power can be controlled by the spectral detuning between a single QD and the lasing mode with a lowering of the threshold power when the QD is brought on resonance. The single dot influence is confirmed by photon correlation experiments which show a transition from antibunching with $g^{(2)}(0) = 0.36$ at low excitation powers to $g^{(2)}(0) = 1$ at about 4 times the threshold power in the on-resonance case.

HL 12.9 Mon 17:00 H17

Dephasing of the Nonlinear Optical Spin Dynamics in Doped Semiconductor Quantum Dots — •Carsten Weber[1], Anna Grodecka[1,2], Paweł Machnikowski[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Institute of Physics, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

An understanding of the dephasing processes of the states involved in spin optical control schemes is essential for applications in quantum information theory and spintronics. We study the phonon-induced decoherence effects on the nonlinear dynamics and pump-probe spectra of a doped semiconductor quantum dot used for optical control of a spin, using density-matrix theory. While the consideration of the Coulomb coupling is exact, the electron-phonon interaction is treated perturbatively for low temperatures. The mediation between the two electronic spin states is achieved via the excitation of a trion state which interacts with the environment.

HL 12.10 Mon 17:15 H17

Coulomb corrections to group velocity slow-down in quantum-dot quantum coherence — •Stephan Michael[1], Hans Christian Schneider[1], and Weng Wah Chow[2] — [1]Physics Department, Kaiserslautern University, P.O. Box 3049, 67653 Kaiserslautern, Germany — [2]Sandia National Laboratories, Albuquerque, NM 87185-1086

Coherent effects such as electromagnetically induced transparency (EIT) and amplification without inversion (AWI) are well known in atomic few-level systems. This talk presents theoretical results on the realization of EIT and group-velocity slowdown in self organized quantum-dot systems. Many-particle effects introduce differences to the independent-particle treatment typically used for describing atomic quantum coherence. In particular, Hartree-Fock renormalizations can lead to over two orders of magnitude reduction in the predicted pump-intensity requirement for group-velocity slowdown. Results are presented for the slow-down factor and slow-down-bandwidth product in a pulsed InGaAs-GaAs quantum-dot lambda scheme, and the influence of light propagation effects is also briefly discussed.

HL 12.11 Mon 17:30 H17

Exciton Aharonov-Bohm Effect and Emission Kinetics in Non-circular Nanorings — •Michal Grochol, Frank Grosse, and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

The exciton Aharonov-Bohm effect (X-ABE), an oscillatory component in the energy with magnetic field, has been studied recently in semiconductor quantum dots [1] and nanorings of type I and II [2]. The close relation between X-ABE and exciton persistent current induced by the optical excitation has been revealed. Moreover, the exciton emission kinetics, even though within a simplified model [3], has been investigated and limitations for the observability of X-ABE in circular nanorings have been found. Here we present calculations of the absorption and photoluminesce spectra, and wave functions for a non-circular nanoring having only one symmetry axis. It is shown that lowering the circular symmetry weakens X-ABE in general. However, if the asymmetry is small the observability of the X-ABE can be improved substantially accompanied by a change of the oscillation period compared to the circular case. This model represents a further step towards more realistic description of nanorings.

[1] M. Grochol, F. Grosse, and R. Zimmermann, Phys. Stat. Sol. (C) **3**, 2518 (2006)

[2] M. Grochol, F. Grosse, and R. Zimmermann, Phys. Rev. B, **74**, 115416 (2006).

[3] M. Grochol, F. Grosse, and R. Zimmermann, Phys. Stat. Sol (B) **243**, 3834 (2006)

HL 12.12 Mon 17:45 H17

Phonons in semiconductor nanostructures — •Andreas Knittel and Frank Grosse — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Phonons in semiconductor nanostructures like quantum dots affect the dephasing of optical excitations decisively. In our presented work, the inhomogeneous, atomistic nature of the problem is simulated by employing a valence-force field description. The parameters are taken either directly from experiment or are calculated by density functional theory. The investigated structures include quantum dots of different shapes and alloy compositions. They consist of compounds with either zincblende or wurtzite crystal structure, therefore capturing the equilibrium structures of III-V and group III-nitrides. The phonon density of states is determined by calculating the velocity correlation function in a molecular dynamics simulation. We present also a comparison to continuum elasticity solutions of the wave equation for acoustical phonons.

HL 13: Poster 1

Time: Monday 15:00–17:30 Location: Poster A

HL 13.1 Mon 15:00 Poster A

Anomalously localized electronic states in three-dimensional disordered systems — •Philipp Cain and Michael Schreiber — Institut für Physik, Technische Universität, D-09107 Chemnitz

We study the Anderson model of localization at the metal-insulator transition in the band centre of three-dimensional disordered samples. For the critical disorder we determine a large number of wave functions of the model and study the distribution of the wave function amplitudes. Deviations from the scaling of multifractal correlation functions allow us to discriminate anomalously localized states from the usual critical states. The thus identified anomalously localized states lead to deviations of the critical properties and have to be eliminated from the ensemble average for a characterization of criticality.

HL 13.2 Mon 15:00 Poster A

The application of multigrid methods to the Helmholtz/Anderson problem — •Rudolf Roemer and Sarah Mallion — Centre for Scientific Computing, University of Warwick, Coventry, UK

The similarities of the Helmholtz equation to the Schrödinger equation

make it an ideal testing ground for programs designed to solve the latter. Multigrid methods are one way of solving the superficially similar Laplace equation and they can be highly efficient and easily adaptable to the specifics of an individual problem. The very nature of the multigrid process however, with its repeated interpolation and smoothing steps prevents it from converging to rapidly oscillating solutions such as those occurring with the Helmholtz equation. This is particularly problematic when the diagonal term includes randomness - the Anderson model. We propose the use of the comparatively slower varying WKB ansatz as an assumed form for the solution to the Helmholtz equation. This, with appropriately set of re-derived discrete differential operators, has the potential to negate the inherent problems of the Laplacian multigrid solver and allows convergence even to the highly oscillating solutions of the Helmholtz equation.

HL 13.3 Mon 15:00 Poster A

Interface influence on optical properties of Si-SiO_2 structures — •Kaori Seino, Jan-Martin Wagner, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena, Germany

Prototypical Si-based systems to study quantum-size effects are short-period Si-SiO_2 multiple quantum wells (MQWs). The application of Si-SiO_2 layered system in multi-junction solar cells for future photovoltaics requires an optimum band structure design. Their fabrication as nm-scale superlattice allows a band-gap tuning. The understanding of optical properties in Si-SiO_2 multilayer structures is essential for their application.

Here we present results for optical properties of Si-SiO_2 MQWs obtained by means of first-principles calculations. The calculations for optical properties have been widely performed within the independent-particle approximation. We investigate the dependence on the thickness of the silicon layer, varying in the range from 1 to 4 nm, for several structural interface elements ensuring dangling-bond passivation at the interface. Our results demonstrate vertical confinement effects on the optical properties for both the fundamental gap and the oscillator strength of Si-SiO_2 superlattices with nm-sized layers.

HL 13.4 Mon 15:00 Poster A

Einfluss akustischer Oberflächenwellen auf die Leitfähigkeit von Graphen — •Jörg Kinzel, Jens Ebbecke, Markus Regler und Achim Wixforth — Universität Augsburg

Monolagige Graphitschichten, die als Graphen bezeichnet werden, eröffnen einen neuen Weg zu einem zweidimensionalen Elektronengas (2DEG), wobei vor allem die lineare Energiedispersion der Leitungselektronen besondere Eigenschaften hervorruft.
Je nach Anzahl der a-b Gitterebenen zeigt Graphen halbleitende oder halbmetallische Eigenschaften, wobei sich im Falle eines 2DEG auch die erwartenden Shubnikov-de Haas Oszillationen bzw. der Quanten Hall Effekt beobachten lassen, bei letzterem sind die Plateaus der Hallspannung jedoch um $\frac{1}{2}\frac{h}{4e^2}$ verschoben. [1]

In dieser Arbeit wird der Einfluss eines mittels akustischer Oberflächenwellen induzierten Hochfrequenzfeldes auf den Ladungstransport in Graphenschichten untersucht, die aus einem makroskopischen Graphitstück hergestellt wurden.

[1] K. S. Novoselov et. al., Nature 438, 197 (2005)

HL 13.5 Mon 15:00 Poster A

Investigating the properties of ternary chalcogenide alloys with Density Functional Theory employing PAW potentials — •Pascal Rausch, Stephan Kremers, and Matthias Wuttig — I. Physikalisches Institut (1A), RWTH Aachen, 52056 Aachen

For modern data storage applications like PC-RAMs, phase change alloys play a crucial role. In order to understand physical properties of suitable materials, e.g. the electronic band structures, first principles calculations have proven to yield valuable insight. The ultimate goal is to deduce design rules for phase change alloys with superior properties. To perform density functional calculations, the use of pseudopotentials is necessary. Trouiller-Martins/Hamann type pseudopotentials are well established, but to refine the methods, so called Plane Augmented Wave (PAW) pseudopotentials are an interesting option. They provide the same numerical efficiency while keeping the correct physical information in the core region. PAW were used to perform calculations on materials such as $Ge_1Sb_2Te_4$ or GeTe to validate their effectiveness. In addition new ternary chalcogenide materials, which show slow converging behaviour using Trouiller-Martins/Hamann type pseudopotentials, were investigated with respect to their electronic structure.

HL 13.6 Mon 15:00 Poster A

Ionenstrahlgestützte Molekularstrahlepitaxie von Gadoliniumnitrid-Schichten — •Julius Mennig, Jürgen Gerlach, Thomas Höche und Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstr. 15, 04318 Leipzig

Seit einigen Jahren sind Seltenerd-Nitride in den Blickpunkt verschiedener Forschungsgruppen gerückt, insbesondere Gadoliniumnitrid (GdN)[1]. Die elektronischen Eigenschaften dieses ferromagnetischen Materials (Curie-Temperatur: 60 K) sind noch nicht vollständig geklärt. Theoretische Modelle variieren von halbmetallisch über halbleitend bis zu isolierend, experimentelle Daten sind aufgrund der geringen kristallinen Qualität der bisher hergestellten Schichten mehrdeutig.

In diesem Beitrag werden Herstellung und Charakterisierung von epitaktischen GdN-Schichten auf MgO präsentiert. Sie wurden mittels Ionenstrahlgestützter Molekularstrahlepitaxie unter Variation der Substrattemperatur zwischen 150 °C und 750 °C abgeschieden. Aufgrund der hohen Affinität des GdN zu Sauerstoff waren Schutzschichten (hier GaN) nötig. Kombinierte SIMS- und ERDA-Analysen weisen auf einen geringen Sauerstoffgehalt in den Schichten hin. *In situ* RHEED- und *ex situ* XRD-Messungen zeigen epitaktisches Wachstum und eine hohe kristalline Qualität der Schichten mit starker Abhängigkeit von der Substrattemperatur. Jedoch tendieren diese (100)-orientierten Schichten zu Verzwillingung.

[1] F. Leuenberger, A. Parge, W. Felsch, K. Fauth, and M. Hessler, Phys. Rev. B 72 (2005) 014427.

HL 13.7 Mon 15:00 Poster A

Effect of hydrogen an silicon co-doping on the magnetic properties of GaGdN grown by MBE — •Martin Roever, Dong-Du Mai, Amilcar Bedoya Pinto, Henning Schuhmann, Tore Niermann, Joerg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

With the aim of understanding the observed room-temperature giant magnetic moment of highly diluted GaGdN we report on the growth and characterisation of hydrogen and silicon co-doped GaGdN as well as of GaGdN without co-doping. The layers were grown by plasma assisted MBE on MOCVD GaN templates grown on sapphire. Growth was performed at optimised conditions for GaN in the slightly metal rich regime at a substrate temperature of $760°C$. All samples have been doped with Gd and SIMS measurements reveal a Gd concentration between $10^{17}cm^{-3}$ and $10^{21}cm^{-3}$. Not intentionally co-doped samples show ferromagnetism at room temperature with weak coercivity. Another series of samples, co-doped with activated hydrogen, shows ferromagnetic behaviour at room temperature, too. The coercivity is enhanced, but the overall magnetisation is weaker compared with the non co-doped samples. Because the ferromagnetism in GaGdN is believed to be mediated by electrons the doping with silicon, a n-type dopant in GaN, should increase the magnetisation in this system. Electrical and optical characterisation of all samples are in progress.

HL 13.8 Mon 15:00 Poster A

Preparation, characterization and measurements of graphene layers on SiO_2 substrates — •Ulrich Stöberl, Tobias Feil, Michael Huber, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

In the last two years quite a number of fundamental experimental results on graphene were published and sparked a lot of interest in this new material. Graphene is a monolayer of graphite and comes up with some new characteristics such as a linear dispersion relation or its field effect which allows to tune via a gate voltage from an electron to a hole system. Furthermore graphene is theoretically well understood; although it was not available for experiments yet. We present the preparation of graphene layers of different thicknesses. Starting materials are highly ordered pyrolytic graphite (HOPG) and graphite flakes. Different techniques are used to superimpose the graphene layers to the SiO_2. We show first gate voltage dependent measurements in van-der-Pauw geometry. Additionally the roughness of multi layer graphene surfaces with different thicknesses was determined by means of AFM.

HL 13.9 Mon 15:00 Poster A

All-electron implementation of the *GW* approximation within the FLAPW method — •Christoph Friedrich, Arno

Schindlmayr, and Stefan Blügel — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany

The *GW* approximation for the electronic self-energy yields quasiparticle band structures in very good agreement with experiment, but almost all implementations so far are based on the pseudopotential approach, which limits their range of applicability. We develop an implementation within the full-potential linearised augmented plane-wave (FLAPW) method, which treats core and valence electrons on the same footing. Furthermore, there is no artificial partitioning of core and valence densities. Within this method a large variety of materials can be treated, including d- and f-electron systems, oxides and magnetic systems. Our implementation uses a mixed basis set for the representation of basis-function products. The expansion of the wave function around the Γ point employing $\mathbf{k} \cdot \mathbf{p}$ perturbation theory allows to treat the divergence of the Coulomb interaction analytically. Here the anisotropy of the dielectric matrix is fully taken into account. As a demonstration we show convergence tests and first results. Financial support from the Deutsche Forschungsgemeinschaft through the Priority Program 1145 is gratefully acknowledged.

HL 13.10 Mon 15:00 Poster A

Adiabatic-Connection Fluctuation-Dissipation Theorem for rare-gas crystals — •Judith Harl and Georg Kresse — Sensengasse 8/12 , 1090 Wien, Österreich

Kohn-Sham density functional theory (DFT) has shown to be an efficient and adequate method to describe a wide range of materials properties. Nevertheless, absolute energies are not within chemical accuracy and the Van-der-Waals interaction is not reproduced correctly due to the inaccurate representation of the long range part of the correlation energy. Improvements can be achieved by the adiabatic-connection fluctuation-dissipation theorem (ACFDT), which links the dielectric response of the non-interacting Kohn-Sham system to the correlation energy. Since calculations of the dynamical response function became tractable, first ACFDT calculations, mostly in the random-phase approximation (RPA), have been undertaken [1,2]. In the present work we focus on the rare gas crystals (Ne,Ar,Kr), representative for weakly bonded Van-der-Waals systems. In the local density approximation (LDA) the DFT lattice constants and cohesive energies show large deviations from experiment and the generalised gradient approximation (GGA) fails completely. Applying the ACFDT-RPA, we found that the error in the lattice constant is decreased from 10% for Ne and 6% for Ar (LDA) to under 1%. For Kr the lattice constant is within 3.5% of experiment. The error in the cohesive energy becomes 4 times smaller than in the LDA.

[1] F. Furche, Phys. Rev. B 64 (2001) 195120.
[3] A. Marini et al., Phys. Rev. Lett. 96 (2006) 136404.

HL 13.11 Mon 15:00 Poster A

Efficient implementation of the exact nonlocal exchange potential within the FLAPW method — •Markus Betzinger, Christoph Friedrich, Gustav Bihlmayer, and Stefan Blügel — Institut für Festkörperphysik, Forschungszentrum Jülich, 52425 Jülich, Germany

The exact nonlocal exchange potential is an important ingredient in Hartree-Fock and density-functional calculations employing hybrid functionals (PBE0, B3LYP, etc.) as well as the optimized effective potential (OEP) (exact exchange) method. Hybrid functionals have been shown to be superior to local-density and generalized gradient-type functionals for clusters and molecules, while the OEP exchange-only approach is known to improve on the electronic band structure of semiconductors. In all methods the evaluation of the exchange potential is the most time-consuming step. While straightforward in Gaussian and plane-wave basis sets, its efficient implementation in the highly accurate full-potential linearized augmented plane-wave method (FLAPW) is still a challenge. Our approach uses a mixed basis which is specifically designed for basis-function products. After representing the Coulomb interaction in this basis, the exchange matrix elements can be written as Brillouin-zone (BZ) integrals over vector-matrix-vector products. The Coulomb interaction goes to infinity in the center of the BZ leading to a divergency in the integrand. The divergent part can be separated from the numerical integral and treated analytically. We show first results. Financial support from the Deutsche Forschungsgemeinschaft through the Priority Program 1145 is gratefully acknowledged.

HL 13.12 Mon 15:00 Poster A

FIR spectroscopy of nanostructured meandering conducting stripes fabricated by AFM nanolithography — •Steffen Groth, Kevin Rachor, Carsten Graf von Westarp, Tobias Krohn, Nikolai Mecking, and Detlef Heitmann — Institut für angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

We perform far infrared (FIR) photoconductivity spectroscopy on nanostructured meandering conducting stripes fabricated by atomic force microscope (AFM) nanolithography. For this purpose we have established the technique of anodic oxidation to pattern an oxide barrier directly on a GaAs/AlGaAs shallow high electron mobility transistor heterostructure with a two dimensional electron system (2 DES) confined 35 nm below the surface. This technique enables us to prepare barriers with a geometrical thickness of less than 200 nm and lateral structures of different geometry and size down to 300 nm width and up to 180 μm long. The conducting stripe width is furthermore tuneable by sweeping the applied gate voltage. The measurements on the nano Hall bars were performed in a He^3 cryostat at a sample temperature of 300 mK in a magnetic field up to 8 T. Transport measurements in the conducting stripes show typical behaviour of 1D subbands. In FIR spectroscopy we observe confined plasmon modes. We have also patterned a line of resonators with accurately defined geometry. Resonances depending on the size of the resonators are predicted for exitation by FIR radiation.

The Authors thank the DFG for support through the SFB 508.

HL 13.13 Mon 15:00 Poster A

Optical Modes in Semiconductor Microtube Resonators — •Christoph Matthias Schultz, Hagen Rehberg, Christian Strelow, Holger Welsch, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

In our recent work we demonstrate that microtubes can act as optical ring resonators [1]. These microtubes are prepared by optical lithography and wet-etching techniques using the self-rolling mechanism of strained bilayers. We observe sharp modes which were probed by the photoluminescence of either InAs quantum dots or InGaAs quantum wells embedded in the tube's wall. The modes show a specific fine structure. We analyze the mode energies regarding the localization along the tube's axis and other typical tube parameters. Our previous theoretical model [1] was expanded by an approximation taking into account the actual tube geometry. The modes show anisotropic radiation behavior. We discuss the possibility of unidirectional emission of light.

We acknowledge financial support from the Deutsche Forschungsgesellschaft via SFB 508 and the Graduiertenkolleg 1286.

[1]: T.Kipp *et al.*, Phys. Rev. Lett. **96**, 077403 (2006)

HL 13.14 Mon 15:00 Poster A

FIR Spectroscopy on Carbon-doped Two-Dimensional Hole Systems — •Kevin Rachor[1], Carsten Graf von Westarp[1], Detlef Heitmann[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

The recent development of Carbon-doped AlGaAs heterostructures on (100) substrates permits an experimental access to two-dimensional hole systems (2DHS) with high mobilities and no anisotropy [1]. Using a Fourier transform spectrometer we perform broadband far infrared transmission experiments on such samples. Cyclotron resonances measured in perpendicular magnetic fields up to 14 T at 1.6 K are presented here revealing the complicated band structure of hole systems. The dispersion is non-linear yielding an increasing effective mass form $m^* = 0.40\,m_e$ to $0.42\,m_e$ for increasing magnetic fields. For B smaller than 11 T the cyclotron resonances splits into two resonances. Tilting the sample increases this splitting. A possible explication is a coupling between the cyclotron (intraband) and the heavy hole-light hole intersubband resonance. Surprisingly, additional broadenings of the cyclotron resonance for magnetic fields higher than 12 T are observed.

The authors are grateful to the DFG for support through SFB 508.
[1] B. Grbić, C. Ellenberger, T. Ihn, K. Ensslin, D. Reuter, and A. D. Wieck. *Magnetotransport in C-doped AlGaAs heterostructures.* Appl. Phys. Lett. **85**, 2277 (2004).

HL 13.15 Mon 15:00 Poster A

Frequenzaufgelöste Spektroskopie an GaAs/(AlGa)As-

Heterostrukturen — •Jonas Haunschild[1], Sangam Chatterjee[1], Peter Thomas[1], Wolfgang W. Rühle[1], Andreas D. Wieck[2], Galina Khitrova[3] und Hyatt M. Gibbs[3] — [1]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [3]College of Optical Sciences, The University of Arizona, Tucson, Arizona 85721, USA

Die frequenzaufgelöste Spektroskopie bietet die Möglichkeit, die Lebensdauerverteilung photogenerierter Ladungsträger über viele Dekaden hinweg mittels Photolumineszenz (PL) zu untersuchen. Aus der um 90° phasenverschobenen Komponente des modulierten PL-Signals kann dabei auf die Lebensdauer der angeregten Zustände geschlossen werden. Im Experiment wird ein HeNe-Laser bei 632,8 nm eingesetzt. Der Laser wird von 10 Hz bis 10 MHz moduliert. Somit können Lebensdauern von 100 ms bis 100 ns erfasst werden. An einer Probe mit 60x8,2 nm GaAs-Quantenfilmen zwischen 10 nm AlAs-Barrieren wurde eine Doppelstruktur der Lebensdauerverteilung mit Maxima bei 1 ms und 1 μs gefunden. An einer Probe mit zwölf unterschiedlichen GaAs-Quantenfilmen von Schichtdicken zwischen 3,3 nm bis 19,8 nm wird der Einfluss von Unordnungseffekten auf die Lebensdauerverteilung der Ladungsträger untersucht. Die quantenmechanischen Rechnungen mit Unordnungspotentialen deuten auf eine Verbreiterung der Lebensdauerverteilung mit zunehmender Unordnung hin.

HL 13.16 Mon 15:00 Poster A

The band structure of indium oxide: indirect vs. direct band gap — Paul Erhart, •Péter Ágoston, Andreas Klein, and Karsten Albe — Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstraße 23, 64287 Darmstadt

The nature of the band gap of indium oxide is still a matter of debate. Based on optical measurements the presence of an indirect band gap has been suggested, which is 0.9 to 1.1 eV smaller than the direct band gap at the Γ-point. This could be caused by strong mixing of O-2p and In-4d orbitals off Γ. We have performed extensive density functional theory calculations using the LDA+U and GGA+U method to elucidate the contribution of the In-4d states and the effect of spin-orbit coupling on the valence band structure. Although an indirect band gap is obtained the energy difference between the overall valence band maximum and the highest occupied level at the Γ-point is less than 50 meV. It is concluded that the experimental observation cannot be related to the electronic structure of the bulk material.

HL 13.17 Mon 15:00 Poster A

Light absorption of silicon nanoparticles — •Andreas Gondorf[1], Cedrik Meier[1], Stephan Lüttjohann[1], Matthias Offer[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics, University of Duisburg-Essen, Lotharstrasse 1, D-47048 Duisburg, Germany — [2]Combustion and Gas Dynamics, University of Duisburg-Essen, Lotharstrasse 1, D-47048 Duisburg, Germany

We have studied silicon nanoparticles fabricated by gas-phase condensation and in-flight sintering using absorption and photoluminescence (PL) spectroscopy. We observe a quantum size effect in PL as well as in absorption spectroscopy. From an analysis of the absorption spectra we are able to identify the character of the band gap of the nanoparticles as indirect. This result is supported by measurements of the decay time of the photoluminescence of excitons. The decay time is four orders of magnitude larger than in direct semiconductors. Moreover, we are able to observe the influence of the particle size distribution in the absorption spectra. The size distribution follows the lognormal distribution. In order to explain the surprisingly small dependence of the absorption edge on the mean particle diameter, we discuss a model which takes into acount the lognormal size distribution.

HL 13.18 Mon 15:00 Poster A

Anisotropic optical properties and excitonic structure of ZnO between 2.5 and 32eV — •Christoph Cobet[1], Munise Rakel[1,2], Christoph Werner[1], Wolfgang Richter[2,3], and Norbert Esser[1,2] — [1]ISAS - Institute for Analytical Sciences, Department Berlin, Albert-Einstein-Str. 9, D-12489 Berlin — [2]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, D-10623 Berlin — [3]Dipartimento di Fisica, C139 Roma II (Tor Vergata), Via della Ricerca Scientifica 1, I-00133 Rome

The dielectric response functions of bulk ZnO for polarisations parallel and perpendicular to the c-axis are obtained in the spectral range from 2.5 to 32 eV by analysis of ellipsometric data. The optical absorption of ZnO in the direct band gap region is highly complex and cannot be explained only in terms of interband or pure excitonic absorption. The main peaks can be divided into two classes, which also differ in their temperature dependence: The dominant exciton absorptions and the so called exciton-phonon complexes. It is shown that the ordering of valence band maxima at k=0 is $\Gamma_9 - \Gamma_7 - \Gamma_7$ analog to the most wurtzite compounds. At higher energies electronic transitions involving Zn-3d and O-2s bands are detected. Although the O2s-levels are core-like, they show a residual anisotropy. Finally, the plasmon frequency was recorded to be $\hbar\omega_p$=18.95 eV for $E \perp c$ and 18.12 eV for $E \parallel c$, respectively.

HL 13.19 Mon 15:00 Poster A

Ta_2O_5/SiO_2 dielectric DBR mirrors for ZnO based microcavities and VCSEL structures — •Alexander Franke, Björn Diez, Thomas Hempel, Jürgen Christen, Annett Diez, Sören Heinze, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

For the realization of polariton lasers in ZnO and ZnO-based microcavities the fabrication of high quality Distributed Bragg Reflectors (DBRs) is essential. Epitaxial growth e.g. of MgZnO-based DBR has not been reported so far. We produce suitable DBRs operating resonantly at the bound exciton luminescence in ZnO (E = 3.36 eV) using electron beam (EB) evaporation and sputter technique. The DBRs are made of ten $\lambda/4$ multilayers of SiO_2 and Ta_2O_5 dielectric films yielding a high reflectivity of larger than 99 % and a wide stop band of about 720 meV FWHM. This assembly exhibit a high transmission at the spectral position of the E = 3.81 eV line of a HeCd laser allowing efficient optical pumping of the active region without losses. As the active region we use a $3\lambda/2$ thick ZnO layer. The ZnO was reactively sputtered using a Zn target in an Ar and O_2 atmosphere. To further improve the quality of the active ZnO layer and in particular its surface morphology MOCVD growth of polycrystalline ZnO is used replacing the sputtering step in a second sample set.

HL 13.20 Mon 15:00 Poster A

Magnetotransport measurements on GaMnAs and on GaMnAs/MnAs hybrid structures — •Matthias Elm[1], Jörg Teubert[1], Wolfram Heimbrodt[1], Peter Jens Klar[2], Matthias Reinwald[3], and Werner Wegscheider[3] — [1]Department of Physics and Material Science Center, Philipps-University of Marburg, Germany — [2]1. Physics Institute Justus Liebig University of Giessen, Germany — [3]Institute of Applied and Experimental Physics II, University of Regensburg, Germany

GaMnAs alloys on (311)A substrate grown by LT-MBE and corresponding GaAs:Mn/MnAs hybrid structures obtained by thermal annealing have been investigated. A controlled thermal annealing of highly Mn doped GaAs layers leads to the formation of MnAs nanocrystals by segregation effects. Increasing annealing temperature leads to increasing cluster size. GaMnAs layers and GaAs:Mn/MnAs hybrids have been studied by magnetotransport for different orientations of the applied external magnetic field. The measurements were performed on Hall-bars with a length of 650 μm and a width of 200 μm in a temperature range from 2 to 280 K in magnetic fields up to 10 Tesla. The transport behaviour of the alloy samples and the hybrids show distinct differences. In contrast to the hybrid structures the alloys show also a clear angle dependence in the transport behaviour. The results were used in order to determine the anisotropic parameters.

HL 13.21 Mon 15:00 Poster A

Effect of localized B and N states on the magneto-transport of (B,Ga,In)As and (Ga,In)(N,As) — •Jörg Teubert[1], Peter Klar[2], Wolfram Heimbrodt[1], Volker Gottschalch[3], Andrew Lindsay[4], and Eoin OReilly[4] — [1]Faculty of Physics and Material Sciences Center, Philipps-University of Marburg, Germany — [2]1. Physics Institute Justus Liebig University of Giessen, Germany — [3]Faculty of Chemistry and Mineralogy, University of Leipzig, Germany — [4]Tyndall National Institute, Lee Maltings, Cork, Ireland

The incorporation of both B or N into GaAs is expected to cause the formation of highly localized levels resonant with the conduction band. Whereas in the case of N the interaction between these localized levels and extended band states has considerable effect on the electonic band structure, the effects of B-incorporation on the electronic properties are generally believed to be rather small.

Magneto-transport properties of n- and p-type (B,Ga,In)As and (Ga,In)(N,As) were studied in the temperature range from 2 to 300 K and in magnetic fields up to 10 T and at hydrostatic pressures up

to 16 kbar. The magneto-transport in (B,Ga,In)As and (Ga,In)(N,As) is very similar. P-type samples show normal semiconductor behaviour whereas the electron transport in both alloys is strongly affected by the interaction of the free carriers with the density of states of localized B and N impurity states, respectively. A possible transition from band-like transport to hopping-like transport in (B,Ga,In)As at low temperature and low carrier concentration or high pressure will be discussed.

HL 13.22 Mon 15:00 Poster A

A block-tridiagonalization algorithm for quantum transport calculations — •Michael Wimmer and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg

There is a great variety of numerical algorithms for the calculation of coherent quantum transport. Usually, these algorithms have two things in common: They are based on tight-binding Hamiltonians and, in order to work efficiently, the Hamiltonian matrix must be in block-tridiagonal form. In general, this form is optimal - i.e. the algorithm runs most efficiently - if the blocks are as small as possible and equally sized. Even for very symmetric structures it can be difficult to construct the optimal form by hand, for complex structures it is even more difficult.

We present an algorithm based on heuristic graph partitioning techniques that brings a Hamiltonian matrix into an optimal block-tridiagonal form. It can be used as input for serial and parallel transport algorithms. Based upon that algorithm and the recursive Green's function method, we have developed a code for coherent transport calculations that is suited for any tight-binding model and can also deal with multiterminal structures.

HL 13.23 Mon 15:00 Poster A

Design and realization of micromechanical cantilevers for magnetization studies of two-dimensional electron systems in nanostructures — •T. Windisch[1], O. Roesler[1], J. I. Springborn[1], N. Ruhe[1], Ch. Heyn[1], D. Heitmann[1], M. A. Wilde[2], and D. Grundler[2] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, D-20355 Hamburg — [2]Physik Department E10, Technische Universität München, James-Franck-Straße 1, D-85748 Garching

We have designed and realized micromechanical cantilever magnetometers (MCMs) which allows us to measure the magnetization M of small arrays of nanostructures incorporating a low-dimensional electron system. According to $M = -(\partial U/\partial B)_{N,T}$ (B is the magnetic field) at low temperature T provides direct information about the magnetic field dependence of the ground state energy U. To get a high signal-to-noise ratio for a small electron number N we first optimized the shape, thickness and width of our MCMs using finite-element simulations (FEM). To test the developed sensor layout we secondly fabricated MCMs from a specifically designed GaAs heterostructure by electron beam lithography and etching of sacrificial layers. The lateral size was about 40 μm × 120 μm. Using interferometric fiber optics we readout the MCMs at T = 300 mK and measured the de Haas-van Alphen effect of an integrated two-dimensional electron system. We report the FEM optimization study and our experimental results. We thank the Deutsche Forschungsgemeinschaft for financial support via SFB 508 and the excellence cluster Nanosystems Initiative Munich.

HL 13.24 Mon 15:00 Poster A

Magnetization measurements of low-dimensional electron systems by static and dynamic cantilever magnetometry — •A. Krohn[1], J. I. Springborn[1], N. Ruhe[1], M. A. Wilde[2], D. Heitmann[1], and D. Grundler[2] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg — [2]Technische Universität München, Department E10, James-Franck-Strasse 1, 85748 Garching

A direct way to achieve information about the ground state of an electron system in semiconductors is to measure the magnetization $M = -\partial F/\partial B$ (F is the free energy). We use a cantilever magnetometer based on a fiber-optics interferometer to study the magnetization of a two-dimensional electron system (2DES) at a temperature down to 0.3 K and a magnetic field B of up to 14.5 T. We apply two different modi simultaneously: The well established static measurement of M and a dynamic technique where we modulate the gate voltage applied to the 2DES. By the latter technique we detect $\partial M/\partial N_s$ (N_s is the carrier density). By the novel set-up we are thus able to compare the static magnetization and the dynamic susceptibility measured on the same 2DES. In our experiment we investigate a 2DES in an inverted high electron mobility transistor structure and monitor the de Haas-van Alphen oscillations by the two different techniques. The 2DES has a maximum carrier density of $6 \cdot 10^{11}$ cm^{-2} and mobility of 45,000 cm^2/Vs at 0.3 K. We find that the magnetic data agree within about 10%. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB508 and GR1640/1.

HL 13.25 Mon 15:00 Poster A

Quantum dot as a thermal rectifier — Ralf Scheibner[1], •Christian Praetorius[1], Ines Hense[1], Markus König[1], Dirk Reuter[2], Andreas Wieck[2], Hartmut Buhmann[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany

A magnetic field parallel to the plane of a 2DEG is used to control the energy distribution of states in a gate defined quantum dot. In high magnetic fields, rearrangements in the spin system favor states with a high orbital quantum number and introduce an asymmetry in the coupling of the quantum dot to its leads. We investigate the electric, thermo-electric, and thermal transport properties in this case of an asymmetric quantum dot-lead coupling. Thermovoltage measurements agree well with numerical analysis on the basis of a resonant tunneling model for transport using measurements data from non-linear conductance measurements. Further theoretical model investigations reveal that the quantum dot intrinsically acts as a thermal rectifier.

HL 13.26 Mon 15:00 Poster A

Spectrally resolved far-infrared photoresponse in quasi-Corbino quantum Hall systems — •Christian Notthoff and Axel Lorke — Festkörperphysik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

We present far-infrared (FIR) photoresponse measurements on different quasi-Corbino-shaped GaAs/AlGaAs heterostructures in the integer quantum Hall regime. We use a FT-FIR-Spectrometer as source and the sample it self as well as a Si-bolometer(for transmission measurements) as a detector. Contrary to the classical Hallbar-geometry, which exhibits their maximum sensitivity just below and above an integer filling factor [1,2], our samples show their max sensitivity at the integer filling factor. We find a sharp photoresponse-signal centred at the cyclotron-frequency with a nearly Lorenzian shape, which rapidly decreases in amplitude by varying the magnetic field away from an integer filling factor. Both observations show that the observed photoresponse is clearly not a bolometric effect but rather a direct result from resonat inter-Landau-level transition.

[1] J. Appl. Phys., Vol89, No 7 (April 2001) [2] PRB 63, 085320 (Oktober 2004)

HL 13.27 Mon 15:00 Poster A

Wigner-Crystalline Order of Two-Dimensional Electron Systems in High Magnetic Fields — •Guenther Meissner and Uwe Schmitt — Theoretische Physik, Universitaet des Saarlandes, Postfach 15 11 50, D-66041 Saarbruecken

A unified many-body approach which has been shown to allow for studying the nature of novel liquid and solid phases of interacting two-dimensional electrons in high magnetic fields is reexamined. Effects on collective excitations from including weak random disorder and from considering various quasi particles of composites of electrons and magnetic flux quanta are discussed in view of recent microwave resonance and inelastic light scattering experiments on high quality two-dimensional electron systems. The insulator terminating the series of fractional quantum Hall liquids at high magnetic fields is identified with the electron quantum solid being related to the Wigner crystal.

HL 13.28 Mon 15:00 Poster A

Doping efficiency and donor binding energy in high mobility AlAs quantum wells — Claudius Knaak, •Shivaji Dasgupta, Max Bichler, Anna Fontcuberta i Morral, Gerhard Abstreiter, and Matthew Grayson — Walter Schottky Institute, Technische Universität München, Am Coulombwall 3, Garching

We present a quantitative study of the energy band diagram for the X-point conduction band E_X for high mobility (001) oriented AlAs quantum wells (QW). Saturation of the dark electron density of the two dimensional electron system (2DES) was observed at 2×10^{11}/cm^2 for an incrementally doped series of the samples, allowing the doping efficiency of the Si delta doping layers in $Al_xGa_1 - x$As (x =0.45) to

be calibrated. In addition, we report the binding energy of the donors to be an essential factor in analyzing the conduction band diagram to explain the saturation density. In a double-sided doped AlAs QWs charging effects from dilute charge traps in the substrate [1] can be neglected because they will be screened by the bottom Si-delta doping layer. Our model is further complemented by a detailed study of the persistent photoconductivity. After a cold 4 K illumination, a peculiar rise in density to $4 \times 10^{11}/\mathrm{cm}^2$ is seen upon thermally annealing the samples in the dark at 40 K. Similar studies are also reported for high mobility (110) oriented AlAs QW substrates.

[1] De Poortere, et al. Phys. Rev. B 67, 153303 (2003).

HL 13.29 Mon 15:00 Poster A

Formation of Bloch-oscillations and plasma frequency in femtosecond excited semiconductors — •Klaus Morawetz[1,2], Pavel Lipavsky[3], and Michael Schreiber[1] — [1]Institute of Physics, Chemnitz University of Technology, *09107 Chemnitz, Germany — [2]Max Planck Institute for the Physics of Complex*Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Faculty of Mathematics and Physics, Charles University, *Ke Karlovu 3, 12116 Prague 2, Czech Republic

Starting from a quantum kinetic equation including the mean field and a conserving relaxation-time approximation we derive an analytic formula which describes the time dependence of the dielectric function in a plasma created by a short intense laser pulse with an additional external electric field bias. This formula reproduces universal features of the formation of collective modes seen in recent experimental data of femtosecond spectroscopy, [Phys. Rev. B 72 (2005) 233203-1-5], and describes the appearance of additional Bloch oscillations due to the finite bias. The long-time limit of the response function coincides with the field-dependent dielectric function derived earlier. [Phys. Rev. E 50 (1994) 474-479]

HL 13.30 Mon 15:00 Poster A

Nonequilibrium Green's functions approach to artificial atoms: Nonequilibrium behavior — •Karsten Balzer[1], Michael Bonitz[1], Nils-Erik Dahlen[2], and Robert van Leeuwen[2] — [1]ITAP, Christian-Albrechts-Universität Kiel, Leibnizstr. 15, 24098 Kiel, Germany — [2]Theoretical Chemistry, Materials Science Center, Rijksuniversiteit Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Using a nonequilibrium Green's functions (NEGF) approach, we compute the temporal behavior of quantum confined particles, which is of relevance for quantum dots, metal clusters or ions in traps. In the framework of applications to e.g. strong laser fields these systems are known to show interesting nonequilibrium behavior as well as nonlinear effects.

The dynamical properties are obtained by numerically solving the Keldysh-Kadanoff-Baym equations (KKBE) for the two-time NEGF, where initial correlations [1,2] are included self-consistently starting from a correlated thermal equilibrium Green's function for a confined system of N charged fermions. This method is shown to conserve density, momentum and total energy. In addition, we use an appropriate basis representation of the NEGF, which successfully worked to examine small molecules [2]. The results include the intra- and interband response of the system to a strong time-dependent electric field.

[1] Introduction to Computational Methods in Many-Body Physics, M. Bonitz and D. Semkat, Rinton Press (2006). [2] N. E. Dahlen, R. van Leeuwen and A. Stan, J. Phys.: Conf. Ser. 35 (2006).

HL 13.31 Mon 15:00 Poster A

Laser-induced nonthermal melting in InSb: What is the mechanism? — •Waldemar Töws, Christian Sippel, Christian Gilfert, Jessica Walkenhorst, Eeuwe Sieds Zijlstra, and Martin Garcia — Theoretische Physik, Fachbereich Naturwissenschaften, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

A recent experiment [A. M. Lindenberg et al., Science **308**, 392 (2005)] performed on InSb suggests that ultrafast laser-induced nonthermal melting occurs due to a flattening of interatomic potentials. This study was based on Debye-Waller theory, applied in the time-domain and for non-equilibrium processes. We analyzed the nonthermal melting of InSb by using (i) first-principles electronic structure calculations for the interatomic potentials (ii) dynamical models to find the structure factors under different nonequilibrium conditions. Combining the two methods mentioned above we discuss the different possible scenarios for the lattice dynamics during the first 100 fs after the laser excitation.

HL 13.32 Mon 15:00 Poster A

Quantum potential for confined charged particles in nonequilibrium — •Andrea Fromm[1], Michael Bonitz[1], and James Dufty[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15, 24098 Kiel — [2]Physics Department, University of Florida, Gainesville

In thermal equilibrium the idea to describe quantum systems by retaining the classical structure of the equations, but replacing the original potential by an effective potential, that takes into account quantum effects, has been successfully used for external potentials, see e.g. [1], and for pair potentials, see e.g. [2]. From the calculated quantum potential follows a quantum mechanical force, that can be applied in classical simulations like molecular dynamic, see e.g. [3]. Here we extend this concept to systems in nonequilibrium [4]. We consider an electron system in a weakly inhomogeneous confinement potential and a strong electric field. Using the equation of motion for the nonequilibrium Green's functions, an equation for the quantum potential is derived and soluted by iteration. In the classical spectral function the original potential is replaced by the quantum potential and the spectral function is analysed for the special case of a harmonic potential and a constant electric field. The appropriate quantum mechanical density of states is calculated.

[1] D. Bohm, Phys. Rev. 85, 166 and 180 (1986). [2] A.V. Filinov, M. Bonitz, W. Ebeling, J. Phys. A: Math. Gen. 36 (2003). [3] A.V. Filinov, V.O. Golubnychiy, M. Bonitz, W. Ebeling, J.W. Dufty, Phys. Rev. E 70 (1986). [4] M. Bonitz, J.W. Dufty, Cond. Matt. Phys. 7 (2004).

HL 13.33 Mon 15:00 Poster A

Terahertz Emission by Drift and Diffusion — •Guillermo Acuna, Federico Buersgens, Christian Lang, and Roland Kersting — University of Munich, Munich, Germany

Many charge carrier dynamics that follow femtosecond laser excitation can be used to generate terahertz (THz) radiation in semiconductors. Examples are the ultrafast onset of current surges in an electric field or the Dember effect, which arises due to different electron and hole diffusivities. The individual contributions to the emitted THz signal are still under discussion. In this work we present an experiment that gives quantitative insight into the charge carrier dynamics that lead to THz emission. We perform time resolved THz studies on a semi-insulating GaAs structure with periodically poled surface electrodes. The emission processes are distinguished by their dependence on the applied electrical field. Most surprising is that the THz signal depends on the applied electrical field, although the alternating direction of the driving field should lead to a cancellation of the far-field emission. This emission process is explained by electron acceleration in regions with inhomogeneous fields. Other dynamics that become visible by their specific terahertz emission are the Dember effect, the intervalley transfer of electrons, and the hole current at high field strengths.

HL 13.34 Mon 15:00 Poster A

Semiconductor quantum rings as a source for ultrafast magnetic and chiral light pulses — •Moskalenko A.S.[1], Matos-Abiague A.[2], and Berakdar J.[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [2]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

We investigate temporal behavior of non-equilibrium electron states in semiconductor quantum rings driven by (sub)picosecond half-cycle electromagnetic pulses and pulse sequences. These states carry time-dependent charge polarization and current [1,2]. We demonstrate how they can be used for generation of ultrafast magnetic [3] and chiral light pulses and sequences of such pulses.

[1] A. Matos-Abiague and J. Berakdar, Phys. Rev. B 70, 195338 (2004).

[2] A. Matos-Abiague and J. Berakdar, Phys. Rev. Lett. 94, 166801 (2005).

[3] A.S. Moskalenko, A. Matos-Abiague, and J. Berakdar, Phys. Rev. B 74, 161303 (2006).

HL 13.35 Mon 15:00 Poster A

Effects of initial spin polarization and external magnetic fields on the electron spin dephasing in a two dimensional electron system — •Dominik Stich[1], Robert Schulz[1], Andreas Maurer[1], Tobias Korn[1], Dieter Schuh[1], Werner Wegscheider[1], Jun Zhou[2], Ming Wei Wu[2], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik II, Universität Regens-

burg, D-93040 Regensburg, Germany — [2]Hefei National Laboratory, University of Science and Technology of China, Hefei, 230026, China

Understanding the properties of electron spin dephasing is a very crucial detail for any future spin-electronic device. We investigated the electron spin dynamics in a high mobility (1.6×10^6 cm^2/Vs) two dimensional electron system in a one side n-doped (2.1×10^{11} cm^2) 20 nm wide GaAs-AlGaAs single quantum well by conducting time-resolved Faraday rotation (TRFR) measurements in the range from zero to high magnetic fields (up to 10T) which are applied in the Voigt configuration. We found that the spin dephasing time T_2* is strongly depending on the initial degree of spin polarization P and on the applied magnetic field. Besides that, we also found that the electron g-factor is increasing with decreasing P. At very low sample temperatures (1.5 K) we also observed zero field spin oscillations [Brand et al. PRL 89, 236601(2002)]. Our measurements are in good accordance with the calculations done by Wu et al. that are based on solving the many body kinetic Bloch equations.

We acknowledge support by the Deutsche Forschungsgemeinschaft via project SCHU1171/1 and SFB 689 TP B4.

HL 13.36 Mon 15:00 Poster A

Photoluminescence and ultrafast spectroscopy on GaAs quantum wells close to a GaMnAs layer — •Robert Schulz, Tobias Korn, Andreas Maurer, Dominik Stich, Ursula Wurstbauer, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik II, Universität Regensburg, 93040 Regensburg, Germany

We study nonmagnetic GaAs quantum wells (QW) embedded in an AlGaAs/GaAs heterostructure close to a ferromagnetic GaMnAs layer. We present photoluminescence (PL) data of two QWs at different distances to the GaMnAs layer measured at 4 K: one QW is close (3 to 10 nm) to the GaMnAs layer, the other one is 120 nm away and used as a reference. The PL signal of the QW close to the Ga(Mn)As layer shows a significant broadening and quenching depending on the barrier width. This may be due to two effects: (i) Backdiffusion of Mn through the barrier into the upper QW during sample growth. (ii) Tunnelling of photoexcited charge carriers through the barrier into the low-bandgap Ga(Mn)As layer.

Additionally, time-resolved pump-probe experiments show that the carrier lifetime in the upper QW in comparison with the reference QW is significantly reduced. In contrast, the spin lifetime is four times larger, which we attribute to the D'Yakonov-Perel mechanism: Mn ions within the upper QW act as momentum scattering centers und thus increase the spin lifetime.

We acknowledge support by the DFG via project SCHU1171/1 and SFB 689 TP B4.

HL 13.37 Mon 15:00 Poster A

Temperature dependent MOVPE growth of InN quantum dots investigated by in-situ spectroscopic ellipsometry — •Simon Ploch, Christian Meissner, Massimo Drago, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institute of Solid States Physics, Hardenbergstrasse 36, 10623 Berlin, Germany

The band edge of indium nitride is the lowest among the nitride semiconductors. A successful growth of InN quantum dots is promissing for possible applications in infrared LEDs and laser diodes. This work presents in-situ spectroscopic ellipsometry (SE) measurements of non-capped MOVPE grown quantum dots on GaN/sapphire, which allows to control their properties during the formation process.

In a first series we varied the temperature between 540°C and 620°C by a constant V/III ratio of 15.000. SE reveals a strong dependence on the growth rate, dot formation and density by the temperature. In order to an correctly interpretation of the in-situ SE data, the epitaxial structures are characterised ex-situ by atomic force microscopy (AFM) and photoluminescence. The additional influence on the quantum dot size is given by different growth times, between 30 s and 4 min, and verified by the AFM measurements. Finally, we have analyzed the effects of different V/III ratios.

HL 13.38 Mon 15:00 Poster A

Reverse Deep Level Transient Spectroscopy on InAs Quantum Dots — •Christiane Konetzni, Andreas Schramm, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstraße 11c, 20355 Hamburg

With transient capacitance spectroscopy we study self-assembled InAs quantum dots on (001) GaAs. The quantum dots were grown with solid-source molecular beam epitaxy (MBE) and are embedded in n-doped GaAs Schottky diodes. We apply conventional deep level transient spectroscopy (DLTS) and reverse deep level transient spectroscopy (R-DLTS) to study the s- and p-type quantum-dot levels as well as wettinglayer states. In DLTS experiments the capacitance transients reflect the electron emission rates, whereas in the R-DLTS measurements the transients depend on the electron capture rates. We compare spectra obtained with these methods and point out the advantages of experiments with R-DLTS.

HL 13.39 Mon 15:00 Poster A

Investigation of Heterojunction Sharpness of III-V-Nanowhiskers by Analytical (S)TEM Measurements — •Daniela Sudfeld[1], Jochen Kästner[1], Günter Dumpich[1], Ingo Regolin[2], Werner Prost[2], and Franz Josef Tegude[2] — [1]Department of Physics, Experimental Physics - AG Farle, University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [2]Solid State Electronics Dept., University of Duisburg-Essen, Lotharstr. 55, ZHO, D-47048 Duisburg

High crystal quality single GaAs/InGaAs/GaAs and GaAs/GaP/GaAs nanowhiskers were grown by MOVPE on (111)B GaAs substrates using the VLS growth mode. Energy-dispersive X-ray spectroscopy (EDS) measurements were performed to investigate (1) the interface sharpness of group-III versus group-V transitions, and (2) lateral transitions attributed to a parasitic conventional layer growth forming a core-shell structure perpendicular to the growth direction. The results show that group-III transitions exhibit long tails attributed to a memory effect of the group-III species in the Au droplet, while lateral sharp core-shell GaAs/InGaAs/GaAs heterojunctions were found [1]. In contrast, the transition of the GaAs/GaP/GaAs whisker is much sharper due to a lacking memory effect of group-V species in the seed particle. These results provide important rules for an appropriate design of heterojunction nanowhisker devices. Acknowledgement: This work was supported by the DFG (SFB 445). Reference: [1] I. Regolin et al., Journal of Crystal Growth (2006), in press.

HL 13.40 Mon 15:00 Poster A

Magnetization of tunneling coupled double-layer quantum dots — •J. Topp[1], O. Roesler[1], D. Reuter[2], A.D. Wieck[2], D. Grundler[3], and D. Heitmann[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, D-20355 Hamburg — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum — [3]Physik-Department E10, Technische Universität München, James-Franck-Straße 1, D-85747 Garching

We have experimentally investigated the magnetization M of large arrays of double-layer quantum dots. The dots were prepared from a modulation-doped AlGaAs/GaAs heterostructure containing two quantum wells separated by a 1 nm thick tunneling barrier. We used electron beam lithography and reactive ion etching to create a hexagonal-closed-packed array of up to $6 \cdot 10^6$ dots with identical diameters of down to 300 nm. To investigate the magnetization $M = -(\partial U/\partial B)_{N,T}$ (U is the inner energy and N the electron number) these dots were integrated to a micromechanical cantilever magnetometer operated at a temperature $T = 20$ mK. Measuring M in magnetic fields B up to 16 T we have thereby monitored the electronic ground state energy U of double-layer quantum dots. From these data we extract the electron-electron interaction and tunneling-gap energy. The authors thank the Deutsche Forschungsgemeinschaft for financial support through SFB 508 and through the excellence cluster "Nanosystems Initiative Munich (NIM)".

HL 13.41 Mon 15:00 Poster A

From a gate voltage scale to an energy scale in capacitance voltage spectroscopy of InAs quantum dots — •Arne Ludwig, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Self-assembled InAs quantum dots can be investigated by capacitance voltage (C-V) spectroscopy to obtain an addition spectra of bound states. To extract quantization and interaction energies from the measurement, the gate voltage scales have to be converted to an energy scale. In literature, different approaches are used, mainly based on a simple geometric lever arm law.

In this contribution, we will apply different methods to C-V measurements on high quality n- as well as p-type samples and compare the results. Especially, for the first time we try to take the band bend-

ing due to the charge on the quantum dots into account. By doing so, we find -compared to lever arm method- smaller values for the relevant energies.

HL 13.42 Mon 15:00 Poster A

Entanglement decay in semiconductor quantum dots — •Katarzyna Roszak[1,2], Pawel Machnikowski[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Institute of Physics, Wroclaw University of Technology, Wybrzerze Wyspianskiego 27, 50-370 Wroclaw, Poland

Entanglement is a vital component in all quantum computing schemes; for maintaining entanglement coherence must be sustained in multipartite systems. We study the evolution of entanglement in initially completely entangled states of two excitons confined in one or two semiconductor quantum dots under partial pure dephasing induced by a phonon bath. The decay of entanglement (measured by the entanglement of formation) shows two qualitatively different scenarios for different initial states; in some cases the state may become separable (completely disentangled) at a finite time (the pure dephasing is still only partial). It turns out that these states can be easily characterized. The appearance of the effect additionally depends on the coupling strength (as does pure dephasing) and subsequently on temperature. The effect of separation between the dots is also studied; it reflects the crossover from a common-reservoir regime (a biexciton state in one quantum dot) to separate reservoirs (two, well separated dots).

HL 13.43 Mon 15:00 Poster A

Temperature dependent photocurrent spectroscopy of a single InGaAs quantum dot — •Marc C. Hübner[1], Stefan Stufler[1], Patrick Ester[1], Steffen Michaelis de Vasconcellos[1], Artur Zrenner[1], and Max Bichler[2] — [1]Universität Paderborn, Fakultät Naturwissenschaften, Department Physik, Warburger Straße 100, 33098 Paderborn, Germany — [2]Walter Schottky Institut, TU München, Am Coulombwall, 85748 Garching, Germany

Semiconductor quantum dots (QDs) exhibit discrete energy levels which can be described as two-level systems if resonant excitation within spectrally narrow regions is applied. Here we present cw excitation-experiments, carried out in a variable temperature setup up to 70 K allowing for investigations of coupling mechanisms to acoustic phonons.

We have measured the photocurrent (PC) of a single InGaAs QD using a tuneable TiSa laser for resonant excitation. If a sufficiently high reverse bias voltage is applied, photogenerated carriers tunnel out of the QD. By tuning the excitation wavelength the spectral absorption of a single QD can be monitored via the PC. Within a limited range, a PC spectrum can be obtained by a sweep of the bias voltage at fixed laser wavelength. Tuning the applied voltage allows us to vary the linewidth, due to changing tunnelling probabilities. Increasing the temperature significantly shifts the transition energies of the QD to the red, extends the boundaries of the PC regime due to enhanced thermionic emission and also shows effect on the Rabi oscillations of the system.

HL 13.44 Mon 15:00 Poster A

Preparation of silicon nanoparticle films for single particle spectroscopy — •Matthias Offer[1], Cedrik Meier[1], Stephan Lüttjohann[1], Andreas Gondorf[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen, Lotharstrasse 1, D-47048 Duisburg, Germany — [2]Institute of Combustion and Gas Dynamics, University of Duisburg-Essen, Lotharstrasse 1, D-47048 Duisburg, Germany

A major obstacle for spectroscopy of single nanoparticles, obtained by chemical synthesis is the difficulty to deposit dilute layers of isolated nanoparticles on a suitable substrate. In the case of silicon nanoparticles, which are synthesized from the gas-phase without, e.g., organic surface functionalization or modification, there is also a strong tendency towards agglomeration. By dispersing the nanoparticles in different solutions, we have been able to deposit films of isolated particles. We use different organic and aqueous solvents. In the latter case, we find that by varying the pH value we can modify the zeta-potential and reach a stabilized solution. After deposition, we find ring-like structures with a particle-size gradient that leads to a position-dependent energy shift in the PL signal. This can be explained in the framework of the DLVO theory. We compare the deposition results for silicon nanoparticles to results obtained using commercially available PbS nanoparticles with functionalized surfaces.

HL 13.45 Mon 15:00 Poster A

Optical size effects in ultra fine ZnO nanowires — Daniel Stichtenoth[1], Tore Niermann[2], Pai-Chun Chang[3], Chung-Jen Chien[3], Jia Grace Lu[4], and •Carsten Ronning[1] — [1]II. Institute of Physics, University of Göttingen — [2]IV. Institute of Physics, University of Göttingen — [3]Department of Chemical Engineering, UC Irvine — [4]Department of Physics, University of South California

ZnO nanowires as one-dimensional materials are expected to display novel and unique physical properties. For the optical properties the origin of these can be (1) the large surface to volume ratio, (2) the waveguiding property of nanowires, and (3) the reduced dimensionality, which results in a quantum confinement. Due to the rather small exciton bohr radius in ZnO the latter effect is expected just for wires with a diameter of less than 5 nm. Here, we present luminescence studies of ZnO nanowires with diameters in the expected range of confinement effects. The nanowires were synthesized using two different techniques and TEM studies show beside excellent crystal quality, diameters between 4 nm and 40 nm. Temperature dependent photoluminescence measurements were carried out on the as grown samples. At low temperatures a feature at 3.366 eV, which can be attributed to surface-bound excitons, dominates the spectra. With increasing temperature we observed emerging of up to four phonon replica of the free excitonic transition which are blue shifted in the case of the ultra fine nanowires. An intense green luminescence as found by other groups could even at room temperature not be observed. We will discuss the obtained results with respect to literature.

HL 13.46 Mon 15:00 Poster A

Photoluminescence Spectroscopy of CdSe/CdS(/ZnS) Quantum Dots — •Torben Menke[1], Gerwin Chilla[1], Marija Nikolic[3], Andreas Frömsdorf[2], Tobias Kipp[1], Detlef Heitmann[1], Horst Weller[2], and Sephan Förster[2] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg — [2]Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg — [3]Faculty of Technology and Metallurgy, University of Belgrade, Karnegijeva 4, 11000 Belgrade, Serbia

We investigate chemically synthesized nanocrystal quantum dots by photoluminescence (PL) spectroscopy. Our CdSe-core nanocrystals, fabricated as core-shell and core-shell-shell variants, are embedded in a thin polymer matrix on silicon substrates or spin coated directly on sapphire substrates. The nanocrystal density on the substrate is chosen to be so low, that both, ensemble and single nanocrystal PL experiments are possible. In our ensemble measurements, we have in particular studied the photostability of the photoluminescence signal for temperatures T=4-300K and for different excitation densities. We found the expected red-shift of the photoluminescence with increasing temperature and indication for a high stability of the photon efficiency. In microscopic photoluminescence measurements on single nanocrystals we found crystals with an impressive stability concerning photobleaching. The blinking behavior shows that these nanocrystals are predominantly in the on-state. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via the SFB 508.

HL 13.47 Mon 15:00 Poster A

Resonant micro-Raman spectroscopy on few InAs quantum dots — •Tim Köppen, Thomas Brocke, Tobias Kipp, Andreas Schramm, Christian Heyn, and Detlef Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung der Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

We investigate the electronic excitations in InAs quantum dots under the exploitation of resonant inelastic light scattering. In contrast to earlier measurements at the $E_0 + \Delta$ gap ($\sim$1.65 eV) [1], we now excite resonantly at the E_0 gap ($\sim$1.2 eV) using a TiSa-laser in the near-infrared regime. Furthermore we now use a microscope setup focussing the exciting laser to a diameter of about 1.8 μm. Although there are still about 250 quantum dots under the laser spot, we observe very few sharp lines of individual quantum dots which arise due to resonant excitation. We can distinguish between Raman signals of electronic excitations and photoluminescense signals which reside in the same energy range.

This project is supported by the Deutsche Forschungsgemeinschaft via SFB 508 “Quantenmaterialien”.

[1] T. Brocke et al., *Phys. Rev. Lett.* **91**, 257401 (2003)

HL 13.48 Mon 15:00 Poster A

Optical properties of Mn-doped ZnS nanowires — Daniel Stichtenoth[1], Sebastian Geburt[1], Tobias Niebling[2], Peter J Klar[2], and •Carsten Ronning[1] — [1]II. Institute of Physics, University of Göttingen — [2]Dept. of Physics, University of Marburg

Doping of semiconductor nanostructures via ion implantation offers the advantage of precise control of the doping concentration in both lateral and depth direction beyond any solubility limit. In this study, single crystal ZnS nanowires with varying diameter were synthesized according to the VLS mechanism and subsequently dispersed on top of Si substrates. The nanowires were implanted with 55Mn choosing varying ion fluences over 6 orders of magnitude. The range of the ions, set by the implantation energy, matched the diameter of the nanowires, and post-implantation annealing procedures were done under vacuum conditions in order to remove the introduced damage. Electron spin resonance measurements showed that after these procedures the Mn substitute Zn sites in the lattice. The treated nanowires were investigated by time resolved PL measurements, where the well-known long-living 4T1 - 6A1 intra 3d transition of Mn+2 was observed. Correlations between the lifetime of this intra 3d transition and the Mn concentration as well as the diameter of the wires will be discussed in detail.

HL 13.49 Mon 15:00 Poster A

Raman studies of surface phonons in CdSe and CdS quantum dots embedded in dielectric media — •Yuriy Azhniuk[1], Volodymyr Dzhagan[2], Stepan Kuchmii[3], Alexandra Raevskaya[3], Alexandr Stroyuk[3], Mykhailo Valakh[2], and Dietrich Zahn[4] — [1]Institute of Electron Physics, Uzhhorod, Ukraine — [2]Institute of Semiconductor Physics, Kyiv, Ukraine — [3]Institute of Physical Chemistry, Kyiv, Ukraine — [4]Chemnitz University of Technology, Chemnitz, Germany

Contribution of surface phonons strongly affects Raman spectra of quantum dots (QDs). In spite of a number of studies for CdSe and CdS, there is still no unique opinion on the behaviour of surface phonon parameters on the QD size. Moreover, since surface phonons are localized near the QD / host matrix interface, they can be sensitive to the type of host media as well as to the shell type for capped QDs.

Here we present resonant micro-Raman studies of surface phonons of bare and capped colloidal CdSe and CdS QDs in different organic media (gelatine, polyvinyl alcohol, polyacrylamide) as well as those grown in silicate glass. Measurements were performed using a Dilor XY 800 spectrometer and different Ar laser lines for excitation.

The dependences obtained for the surface phonon frequency, halfwidth as well as surface-to-LO phonon intensity ratio on the QD size, excitation wavelength, type of host media, passivating shell are analyzed. The results are compared with the calculations in the framework of a dielectric continuum model. The differences observed can be related to the QD surface reconstruction.

HL 13.50 Mon 15:00 Poster A

Tunable quantum dots in InAs nanowires — •Marc Scheffler[1], Stevan Nadj-Perge[1], Leo P. Kouwenhoven[1], Magnus T. Borgström[2], and Erik P. A. M. Bakkers[2] — [1]Kavli Institute of NanoScience, Delft University of Technology, POB 5046, 2600GA Delft, The Netherlands — [2]Philips Research Laboratories, High Tech Campus 4, 5656 AE Eindhoven, The Netherlands

Semiconductor nanowires are a versatile system to study electronic transport at mesoscopic length scales. Here InAs nanowires are particularly interesting due to the large spin-orbit coupling and furthermore promising for devices due to the comparably easy processing for Ohmic contacts.

We study the electronic transport in of individual InAs nanowire devices at low temperatures. Here we use different gate geometries to tune the charge carrier density either globally (for the complete wire) or locally. In particular, we use local top gates to create barriers that define tunable quantum dots. Towards our final goal of spin manipulation of single electrons, we focus on a tunable double dot. We present stability diagrams and discuss the influence of different quantum dot geometries.

HL 13.51 Mon 15:00 Poster A

Noise at a Fermi edge singularity — •N. Maire[1], F. Hohls[1], T. Lüdtke[1], K. Pierz[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We investigate self-assembled InAs quantum dots embedded in a GaAs-AlAs-GaAs heterostructure. We observe distinct steps in the I-V characteristic corresponding to resonant tunneling through individual quantum dots. At high magnetic fields (B > 12 T) we measure an additional peak like current overshoot at these steps. The overshoot increases with increasing magnetic field and decreasing temperature. We find that this feature stems from an electron-electron interaction effect between the electron on the dot and the electrons in the lead, a so called Fermi Edge Singularity (FES) effect.

We investigate the noise characteristic at the FES at a magnetic field of 15 T and and at a temperature of 0.4 K. We observe a 1/f and a frequency independent noise, the so called shot noise. The shot noise power is suppressed compared to the noise power of a single tunneling barrier as it is indeed expected for a double barrier resonant tunneling structure. The striking feature is an additional strong suppression of the shot noise power in parallel to the current overshoot induced by the FES effect. We find that this suppression is too strong to be explained by typical theoretical models which do not include the interaction between the lead and the dot.

[1] N. Maire et al., cond-mat/0609738

HL 13.52 Mon 15:00 Poster A

Einfluss der Elektronen-Injektion auf den trägheitsballistischen Transport in nanoskaligen Si/SiGe-Wellenleiterstrukturen — •Gang Qiao[1], Ulrich Wieser[1], Ulrich Kunze[1] und Thomas Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, — [2]DaimlerCrysler Forschungszentrum Ulm, D-89081 Ulm

Ausgehend von einer modulationsdotierten Si/SiGe-Heterostruktur mit hoher Elektronenbeweglichkeit werden nanoskalige mehrfach verzweigte elektronische Wellenleiter präpariert, um daran trägheitsballistische Effekte im Elektronentransport zu untersuchen. Die Wellenleiterstrukturen sind aus einem zentralen orthogonalen Kreuz und zwei zusätzlichen Verzweigungen zusammengesetzt, die längs der vertikalen Kreuz-Achse auf beiden Seiten der Kreuzungsstelle angebracht sind. In beide Verzweigungen mündet je ein parallel zur horizontalen Kreuz-Achse orientierter, geradliniger Wellenleiter. Zwischen der zentralen Kreuzungsstelle und einem dieser Wellenleiter wird eine lokale Barriere erzeugt. Die Barriere soll eine effiziente Injektion ballistischer Elektronen ermöglichen und kann durch eine nanoskalige Gate-Elektrode quer zur vertikalen Kreuz-Achse oder durch eine Engstelle in dieser Achse erzeugt werden. Mit 2- und 4-Punkt Messungen der lokalen und nichtlokalen I-U-Kennlinien wird bei $T = 4.2$ K der Einfluss der Injektionsbedingungen auf trägheitsballistische Effekte untersucht. Im Regime heißer Elektronen findet sich in den lokalen I-U-Kennlinien ein negativ differenzieller Leitwert, der auf die Emission eines Intervalley-Phonons zurückgeführt wird.

HL 13.53 Mon 15:00 Poster A

Mode spectroscopy of tunnel-coupled asymmetric quantum point contacts — •S. S. Buchholz[1], S. F. Fischer[1], U. Kunze[1], D. Schuh[2] und Gerhard Abstreiter[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Walter Schottky Institut, Technische Universität München

Semiconductor electron waveguides separated by a tunneling barrier show interesting coupling phenomena based on coherent electron transport. Vertically stacked quantum point contacts (QPCs) of equal width (symmetric configuration) have recently been investigated [1], [2]. Atomic force microscope lithography and wet chemical etching [3] allow the preparation of large one-dimensional (1D) subband separations (> 10 meV). Here, we present in analogy tunnel-coupled QPCs of unequal width (asymmetric configuration). A top gate voltage (V_{tg}) controls the occupation of 1D subbands in both QPCs, a back gate voltage (V_{bg}) influences the occupation of mainly the bottom QPC, and cooling under back gate voltage allows the tuning of the bottom QPC confining potential. We record the conductance and transconductance with respect to V_{tg}, V_{bg} and magnetic field, and observe a lift of subband degeneracy for modes with equal parity in high perpendicular magnetic fields (> 3 T). In longitudinal magnetic fields the coupling induced energy splittings indicate an oscillatory behavior.[1] S.F. Fischer *et al.*, Nature Physics **2**, 91 (2006). [2] S.F. Fischer *et al.*, Phys. Rev. B **74**, 115324 (2006). [3] U. Kunze, Supperlatt. Microstruct. **31**, 3 (2002).

HL 13.54 Mon 15:00 Poster A

Quantum Thermal Conductance of Electrons in a One-Dimensional Wire — •O. Chiatti[1], J. T. Nicholls[2], Y. Y. Proskuryakov[3], N. Lumpkin[4], I. Farrer[4], and D. A. Ritchie[4]

— [1]Forschungszentrum Dresden-Rossendorf, Hochfeld-Magnetlabor Dresden (HLD), 01328 Dresden, Germany — [2]Department of Physics, Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK — [3]Department of Physics, Durham University, Durham DH1 3LE, UK — [4]Department of Physics, Cavendish Laboratory, Cambridge CB3 0HE, UK

An electron thermometer is used to measure the temperature rise of approximately 2×10^5 electrons in a two-dimensional box, due to heat flow into the box through a ballistic one-dimensional (1D) constriction. Using a simple model we deduce the thermal conductance $\kappa(V_g)$ of the 1D constriction, which we compare to its electrical conductance characteristics. For the first four 1D subbands the heat carried by the electrons passing through the wire is proportional to its electrical conductance $G(V_g)$. In the vicinity of the *0.7 structure* this proportionality breaks down, and a plateau at the thermal-conductance quantum, $\pi^2 k_B^2 T/3h$, is observed. [*Phys. Rev. Lett.* **97**, 056601 (2006)]

HL 13.55 Mon 15:00 Poster A

Einzelelektronentransport durch Kohlenstoffnanoröhren mittels akustischer Oberflächenwellen — •Markus Regler, Jens Ebbecke und Achim Wixforth — Institut für Physik, Experimentalphysik 1, Universität Augsburg, Universitätsstr.1, 86159 Augsburg

Kohlenstoffnanoröhren (KNR) stellen seit ihrer Entdeckung ein breites Forschungsgebiet dar. KNR bilden ideale eindimensionale Leiter und zeigen abhängig vom Umfang metallische oder halbleitende Eigenschaften. Sie bieten so Anwendungen etwa als Transistoren an.

Eine weitere Anwendungsmöglichkeit ist der Transport einzelner Elektronen mit Hilfe von akustischen Oberflächenwellen (AOW) durch eine solche Röhre. Dazu werden die KNR auf einem piezoelektrischen Substrat ($LiNbO_3$) mit Metallelektroden (Au/Ti, Pd/Ti) kontaktiert. Dabei bilden sich zwischen den Röhren und den Elektroden Tunnelbarrieren, so dass für genügend kleine Kontaktabstände ($\approx 1\mu m$) in der KNR ein Quantenpunkt (QP) entsteht. Mit zusätzlich angebrachten Gateelektroden können die Zustände im QP beeinflusst werden.

Wird eine AOW angeregt, deren Wellenlänge dem doppelten Kontaktabstand entspricht, führt dies zu einer Modulation der Barrieren. Bei verminderter Barrierenhöhe wird den Elektronen das Tunneln in den bzw. aus dem QP erleichtert, so dass pro Wellenzyklus ein Elektron durch den QP transportiert wird. Für den resultierenden Strom gilt: $I = e \cdot f$ (e: Elementarladung, f: Frequenz der AOW). Die verwendeten Frequenzen liegen im Bereich von wenigen GHz, der Strom daher in der Größenordnung von Nanoampere. Eine Anwendung solcher Bauteile wäre beispielsweise ein zukünftiger Stromstandard.

HL 13.56 Mon 15:00 Poster A

SAW-induced current in ratchets on GaAs/AlGaAs heterostructures as function of dimensionality and temperature. — •Marcin Malecha, Jens Ebbecke, and Achim Wixforth — Universität Augsburg, Institut für Physik, Lehrstuhl für Experimentalphysik I, Universitätsstr. 1, D-86159 Augsburg

Ratchets are basically non-symmetrical systems. In quantum regime, the most important feature of a ratchet structure is its asymmetric tunnelling barrier. Because the particle tunnelling depends not only on the height but also the shape of the barrier (unlike the classical regime) a net current flow will adjust and its direction strongly depends on the energy distribution of considered particles at given temperature. We are investigating current transport through ratchet structures on GaAs/AlGaAs heterostructures using surface acoustic waves at different temperatures. We examine the behaviour of the driven electrons due to changing the dimensionality of the 2-dimensional electron gas to 1D (nanowires) or 0D (quantum dots) by applying potential on in-plane gates. Because of the built-in broken centrosymmetry of ratchet structures the change of dimensionality has a pronounced effect on the induced net current. We present our initial results and current status of our research.

HL 13.57 Mon 15:00 Poster A

Excitonic Aharonov-Bohm effect in the presence of an electric field — •Andrea Fischer and Rudolf Römer — Department of Physics and Centre for Scientific Computing, University of Warwick, Coventry CV4 7AL, UK

We theoretically study exciton absorption on a ring threaded by a magnetic flux and in the presence of a lateral electric field. For the case when the attraction between an electron and a hole is short ranged, we use a self-consistent Ansatz to obtain a solution to the problem. We demonstrate that despite the electrical neutrality of the exciton, for a fixed electric field, both the spectral position of the exciton peak in the absorption and the corresponding oscillator strength oscillate with magnetic flux. We show that for a fixed magnetic flux, the amplitude of oscillation first increases slightly but later decreases strongly with increasing electric field.

HL 13.58 Mon 15:00 Poster A

Spectroscopy of quantum dots with ballistic electrons — •Ines Hense[1], Christian Praetorius[1], Ralf Scheibner[1], Markus König[1], Carsten Danz[1], Dirk Reuter[2], Andreas Wieck[2], Hartmut Buhmann[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut, Lehrstuhl für Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany. — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany.

In contrast to conventional methods ballistic electron injection via quantum point contacts (QPC) assures that the quantum dot (QD) system remains in undisturbed thermal equilibrium with its leads throughout the measurement. This is important especially if hybridisation effects between QD states and the leads are expected.

Here, we present data on gate defined GaAs QDs with opposed QPC injectors in a distance of 2 μm, which is well below the elastic mean free path. Using an ac+dc electron injection and lock-in detection the energy selective QD transmission spectra can be explored in a wide parameter range. The non-local resistance and the transmission clearly reflect the energy spectrum of the QD under investigation. Special attention is paid to the regime where spin correlations (e.g. Kondo effect) dominate the transport properties of the QD system.

HL 13.59 Mon 15:00 Poster A

Preparation and Characterization of spin filters on InAs — •Jan Jacob, Sebastian von Oehsen, Guido Meier, Toru Matsuyama, and Ulrich Merkt — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

Highly spin-polarized currents are needed for spintronic devices. The injection rate of polarized currents in ferromagnet-semiconductor hybrid devices is poor. Several all-semiconductor three-terminal devices are proposed for semiconductors with a strong and tunable spin-orbit interaction [1,2]. We investigate Y-shaped devices on InAs heterostructures. We prepare sidegates to decrease the number of conductance channels in the two-dimensional electron system. In such a geometry the spin-orbit interaction is supposed to cause currents with opposite spin polarizations in the outgoing leads of the Y-shaped device. We employ electron-beam lithography and reactive-ion etching to obtain structures with minimal channel width of 100 nm and channel length from 500 nm to 1500 nm. These lengths are comparable to the elastic mean free path of the electrons. With two spin filters in series we aim at the detection of a spin-polarized current within a conductivity measurement.

[1] M. Yamamoto, T. Ohtsuki, and B. Kramer, Phys. Rev. B **72**, 115321 (2005)

[2] J.I. Ohe, M. Yamamoto, T. Ohtsuki, and J. Nitta, Phys. Rev. B **72**, 041308 (2005)

HL 13.60 Mon 15:00 Poster A

Surface acoustic wave mediated lateral electron spin transport with ferromagnetic tunnel contact spin injection — •Jens Ebbecke and Achim Wixforth — Lehrstuhl für Experimentalphysik I, Universitätsstr. 1, 86159 Augsburg, Germany

The motivation is to develop a spintronics device with electric spin injection, lateral electron spin transport by surface acoustic wave and optical or electrical readout. Also surface gates are possible for spin state manipulation. We present a detailed description of the idea and results of initial experiments.

HL 13.61 Mon 15:00 Poster A

Geometric spin transformation in quantum dot loops — •Burkhard Scharfenberger, Pablo San-Jose, and Gerd Schön — Institut für Theoretische Festkörperphysik, Universität Karlsruhe, 76128 Karlsruhe

Upon adiabatic variation of control parameters, the wave function of a quantum mechanical system, starting initially in an a non-degenerate eigenstate, acquires a Berry-phase purely dependending on the geometry of the choosen path in parameter-space [1]. In the case of k-fold degeneracies this Berry-phase is extended to a general U(k) transfor-

mation [2].
The inherent stability of such a geometric effect against dynamic perturbations has lead to proposals to employ it in the encoding and manipulation of quantum information [3]. We investigate the transformation of an electron spin when it is pumped adiabatically around a loop of N quantum dots in a 2 dimensional electron gas with finite spin-orbit interaction. In the absence of magnetic fields, the two (pseudo-)spin states form a degenerate subspace and the resulting rotation of the electron spin within this subspace depend on the ratio of loop-radius/spin orbit length. Thus, if the loop is comparable in size to the spin-orbit-length, arbitrary rotations become possible controlled by shape and size of the loop.
[1] M.V. Berry, Proc. R. Soc. Lond. A 392, 45 (1984)
[2] F. Wilczek and A. Zee, Phys. Rev. Lett. 52, 2111 (1984)
[3] J.J Jones et al., Nature 403, 869 (2000)

HL 13.62 Mon 15:00 Poster A

Spin relaxation in narrow wires of a two-dimensional electron gas — Peter Schwab[1], Michael Dzierzawa[1], •Cosimo Gorini[1], and Roberto Raimondi[2] — [1]Universität Augsburg, Augsburg, Germany — [2]Universita' degli Studi Roma Tre, Rome, Italy

How does an initially homogeneous spin-polarization in a confined two-dimensional electron gas with Rashba spin-orbit coupling evolve in time? How does the relaxation time depend on system size? Motivated by a recent experiment [1], we study these questions for systems of a size much larger than the Fermi wavelength but comparable and even shorter than the spin-relaxation length [2]. We approach the problem relying on the quasiclassical Green's function method [3]. The confinement causes the appearance of boundary modes, whose influence on the overall spin relaxation becomes crucial when decreasing the wire width below the spin relaxation length. Depending on the boundary conditions spin relaxation may become faster or slower than in a bulk system.
[1] A. W. Holleitner, V. Sih, R. C. Myers, A. C. Gossard and D. Awschalom, Phys. Rev. Lett. **97**, 036805 (2006).
[2] P. Schwab, M. Dzierzawa, C. Gorini and R. Raimondi, Phys. Rev. B **74**, 155316 (2006).
[3] P. Schwab and R. Raimondi, Ann. Phys. (Leipzig) **12**, 471 (2003).

HL 13.63 Mon 15:00 Poster A

GaMnAs on patterned GaAs(001) substrates: Growth and magnetotransport — •Joachim Daeubler, Michael Glunk, Thomas Hummel, Wladimir Schoch, Wolfgang Limmer, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm, Germany

A new type of GaMnAs microstructures with laterally confined electronic and magnetic properties has been realized in a bottom-up procedure by growing GaMnAs films on $[1\bar{1}0]$-oriented ridge structures with (113)A sidewalls and (001) top layers prepared on GaAs(001) substrates [1]. Previous studies on planar GaMnAs samples have revealed different incorporation of Mn and excess As in (001) and (113)A layers [2]. Accordingly, temperature- and field-dependent magnetotransport measurements on the overgrown ridge structures clearly demonstrate the coexistence of electronic and magnetic properties specific for (001) and (113)A GaMnAs in one single sample. This introduces an additional degree of freedom in the development of new functional structures.

[1] W. Limmer, J. Daeubler, M. Glunk, T. Hummel, W. Schoch, and R. Sauer, Microelectron. J. 37, 1535 (2006).
[2] J. Daeubler, M. Glunck, W. Schoch, W. Limmer, R. Sauer, Appl. Phys. Lett. 88, 051904 (2006).

HL 13.64 Mon 15:00 Poster A

Tunneling anisotropic magnetoresistance effect in a p+-(Ga,Mn)As/n+-GaAs Esaki diode — •Mariusz Ciorga[1], Andreas Einwanger[1], Janusz Sadowski[1,2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany — [2]MAX-Lab, Lund University, SE-221 00, Lund, Sweden

We report on the investigation of Tunneling Anisotropic Magnetoresistance effect in single Esaki diode p+-(Ga,Mn)As/n+-GaAs devices in an in-plane magnetic field configuration We performed two types of measurement scans. In the angle scan the value of an external magnetic field H was kept constant while the sample was rotated i.e. the angle between H and the chosen crystallographic axis of (Ga,Mn)As was being changed. This type of scans gave us information about underlying magnetic anisotropy of measured devices. In the field scans the above angle was fixed and the magnetic field was swept from the saturation at one field direction to saturation at the opposite direction. We observed the spin-valve-like signal with the amplitude of ˜0.5%. The pattern of the observed magnetic reversal process strongly depends on the observed magnetic anisotropy of the (Ga,Mn)As layer. For samples with an uniaxial anisotropy along [100] directions the sign of the spin-valve-like signal can be changed by a simple rotation of the magnetic field by 90°. This is not the case when device shows an uniaxial anisotropy along [110] directions. The type of the anisotropy is found to be strongly shaped, in a random way, during processing of the wafer.

HL 13.65 Mon 15:00 Poster A

Non-local spin-valve signal in magnetotransport measurements on p+-(Ga,Mn)As/n+-GaAs Esaki diode devices. — •Andreas Einwanger[1], Mariusz Ciorga[1], Janusz Sadowski[1,2], Dieter Schuh[1], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany — [2]Present address: MAX-Lab, Lund University, SE-221 00, Lund, Sweden

We have fabricated devices to investigate all-electrical injection/detection of spin-polarized carriers from ferromagnetic (Ga,Mn)As layer into the non-magnetic GaAs layer in a lateral transport geometry. The Esaki diode structures p+-(Ga,Mn)As/n+-GaAs are used as injector/detector contacts to circumvent the problem of fast spin relaxation of holes injected from a p-type ferromagnet into GaAs. Under a reverse bias applied to such a structure spin-polarized electrons, with longer spin relaxation times than holes, tunnel from (Ga,Mn)As valence band through the depletion layer into GaAs conduction band [1]. We report on the first results of our magnetotransport experiments in a non-local lateral spin valve geometry.

[1]. M. Kohda et al., Jpn. J. Appl. Phys 40, L1274 (2001).

HL 13.66 Mon 15:00 Poster A

Transiente Störstellenspektroskopie an Cu(In,Ga)Se2-Dünnschichtsolarzellen — •Martin Knipper und Jürgen Parisi — Abteilung Energie- und Halbleiterforschung, Institut für Physik, Universität Oldenburg, 26111 Oldenburg

Dünnschichtsolarzellen auf Basis von Cu(In,Ga)Se2 (CIGS) haben auf Grund ihrer günstigen Eigenschaften (z.B. hohes Absorptionsvermögen) die Serienreife erreicht. Wir untersuchen diese Solarzellen mit Hilfe der transienten Störstellenspektroskopie (DLTS) und Admittanzspektroskopie für ein tiefergehendes Verständnis der bulk-Effekte. Durch die Messung der Kapazitätstransiente bei verschiedenen Temperaturen kann die Aktivierungsenergie bestimmt werden. Ein energetisches Tiefenprofil der Defekte konnte durch die Variation der Sperrspannung und Pulshöhe bestimmt werden. Weiter wird der Einfluss der Bulkdefekte auf die Solarzellenparameter insbesondere auf die Effizienz der Solarzelle untersucht.

HL 13.67 Mon 15:00 Poster A

Polymer-Fullerene Bulk-Heterojunction Solar Cells With Additional ZnO:Al Layer — •Daniel Rauh[1,2], Volker Lorrmann[1,2], Carsten Deibel[2], Vladimir Dyakonov[1,2], and Ingo Riedel[1] — [1]Div. Functional Materials for Energy Technology, ZAE Bayern e.V., Am Hubland, D-97074 Würzburg, Germany — [2]Experimental Physics VI (Energy Research), Faculty of Physics and Astronomy, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg, Germany

We investigated novel functional layers of ZnO:Al serving as a buffer layer between the absorber and the light reflecting metal electrode of organic bulk heterojunction solar cells. The reason for introducing such a layer is twofold: 1. The ZnO:Al layer serves as an optical spacer readjusting the electric field distribution throughout the device, thus causing improved light absorption within the absorber. 2. n-type ZnO:Al is expected to enhance the selectivity of the metal electrode serving as a hole blocking layer. Our optical simulations clearly demonstrate that the gain in absorption do not exceed 20 % upon introduction of an optical spacer. We synthesized nanoparticular ZnO:Al and produced thin films for devices with the aforementioned cell structure and compared the photovoltaic performance with reference devices. To discriminate between the effects of improved light absorption and enhanced selectivity of the metal electrode we combined optical simulations and electrical interface characterization.

HL 13.68 Mon 15:00 Poster A

Identification and Quantification of Local Absorber Proper-

ties of Cu(In,Ga)Se2 from Sub-Micron Resolved PL and Optical Transmission — •Levent Gütay and Gottfried Bauer — Institute for Physics, University of Oldenburg, 26111 Oldenburg, Germany

We have analyzed Cu(In,Ga)Se2 absorber layers with a confocal microscope setup designed for photoluminescence (PL) and optical transmission experiments with lateral resolution in the 1-micron scale and below. We present results for inhomogeneities of optoelectronic properties of Cu(In1-xGax)Se2-absorbers in terms of fluctuations of the local band gap and of splitting of quasi-Fermi-levels which can be extracted from spectrally resolved PL data. From optical transmission spectra we get additional data for local band gaps and their fluctuations. The optical threshold for photon absorption/emission in Cu(In1-xGax)Se2 is a complicated function of wavelength/photon energy that cannot be reduced to a single parameter band gap, we plot photon energies for different degrees of absorption (e.g. $\alpha = 10\hat{}n$ 1/cm, with n = 2,3,4) as pseudo-band gap energy. We summarize fluctuations in Fermi level splitting and optical pseudo band gap energies in histograms and discuss their local interdependence in terms of correlation factors.

HL 13.69 Mon 15:00 Poster A

Optical and electrical properties of sputtered copper oxide thin films — •Swen Graubner, Stefan Merita, and Bruno Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen

In order to promote the understanding of CuxO sputtering, we deposited several series of thin-films under various conditions. Substrate temperature was changed, ranging from room temperature to 700 K. Argon and oxygen flow were varied in the region of up to 5 sccm. The morphology of the deposited CuxO thin-films was investigated by x-ray diffraction, EDX and REM. It could be shown that the oxygen flow directly influences whether Cu(II)O or CuO is formed. Electrical measurements were done to gain information about specific resistivity, carrier concentration and mobility. Optical absorption and transmission experiments gave information about the band-edge properties of the investigated CuxO thin films.

HL 13.70 Mon 15:00 Poster A

Turn-on dynamics and modulation response in semiconductor quantum dot lasers — •Ermin Malić, Moritz Bormann, Philipp Hövel, Matthias Kuntz, Dieter Bimberg, Andreas Knorr, and Eckehard Schöll — Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We present a theoretical simulation of the turn-on dynamics of InAs/GaAs quantum dot semiconductor lasers driven by an electrical current pulse. Our approach goes beyond standard phenomenological rate equations. It contains microscopically calculated Coulomb scattering rates describing Auger transitions between quantum dots and the wetting layer. In agreement with experimental results, we predict a strong damping of relaxation oscillations on a nanosecond time scale. Our simulations explicitly take the strongly nonlinear dependence of the Coulomb scattering rates on the wetting layer charge carrier densities, and we show their crucial importance for the understanding of the turn-on dynamics of quantum dot lasers.

HL 13.71 Mon 15:00 Poster A

DC-transport characteristics of Silicon-on-Insulator FET with 55nm thick silicon films at low doping levels — •Pagra Truman, Petra Uhlmann, and Manfred Stamm — Leibniz Institute of Polymer Research Dresden, Hohe Str. 6, Germany

Silicon-on-Insulator (SOI) FET with nanoscale silicon films at low doping levels have potential for (bio-)sensing applications but still the device properties are not fully understood yet: With decreasing film thickness the energy band structure of the silicon film becomes strongly affected by the existence of interfacial states. Furthermore for film thicknesses below the maximum depletion length the device properties can no longer be described by a semiclassical approach. We investigate n-channel normally-on SOIFET devices and observe for positive gate bias close to ideal MOSFET device characteristics whereas for negative gate bias the transistor does not turn to the off-state but instead becomes insensitive to the gate. Additonally the impact of the W/Ti and Ti/Au metal contacts on the device properties is studied: Exceeding a certain gate voltage level device characteristics become similar to the ones of a Schottky-barrier MOSFET. It is worth mentioning that the W/Ti and Ti/Au contacts have not been annealed.

HL 13.72 Mon 15:00 Poster A

Laterale, zweidimensionale npn-Übergänge: Eine neue Methode für Positionsdetektoren — •C. Werner, D. Reuter und A.D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

Wir haben auf Basis von $Al_{0,33}Ga_{0,67}As/In_{0,11}Ga_{0,89}As/GaAs$-Heterostrukturen laterale, zweidimensionale npn-Übergänge erzeugt, indem wir eine in der MBE gewachsene p-modulationsdotierte Heterostruktur durch lokale Implantation von Siliziumionen überkompensiert und so lokal ein zweidimensionales Elektronengas erzeugt haben.

Verbindet man die beiden n-dotierten Bereiche mit einem Widerstand und strahlt mit einem fokussierten Laserstrahl auf den p-dotierten Bereich, so ist der Spannungsabfall über dem Widerstand proportional zu der Position des Laserstrahls senkrecht zu den beiden p-n-Übergängen, wobei die Empfindlichkeit 1 mV/μm beträgt. Damit ist es möglich, die Positionsveränderungen des Laserstrahls im Nanometerbereich zu bestimmen.

Zusätzlich ist es uns durch eine andere Implantationsgeometrie gelungen, die Position auch in zwei Raumrichtungen bestimmen zu können, wobei sich die Messungen der beiden Raumrichtungen nicht beeinflussen.

HL 13.73 Mon 15:00 Poster A

Influence of thermal annealing on the memory effect in MIS structures containing crystalline Si nanoparticles — Nicola Nedev[1], Diana Nesheva[2], Emil Manolov[2], Rudolf Brüggemann[3], •Sebastian Meier[3], Kiril Kirilov[4], and Zelma Levi[2] — [1]Instituto de Ingenieria Universidad Autónoma de Baja California, Benito Juárez Blvd., s/n, C.P. 21280, Mexicali, Baja California, México. — [2]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tzarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria. — [3]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany. — [4]Department of Solid State Physics and Microelectronics, Sofia University "St. Kliment Ohridski", 5 James Bourchier, 1164 Sofia, Bulgaria.

Silicon nanocrystals embedded in a SiO_2 matrix are fabricated by thermal annealing of Metal/SiO_2/SiO_x/c-Si structures (x=1.15) at 1000 °C in N_2 atmosphere for 30 or 60 min. High frequency C-V measurements demonstrate that both types of sample can be charged negatively or positively by applying a positive or negative bias voltage to the gate. The clockwise hysteresis windows of 30 and 60 min annealed samples are about 7 and 5.5 V for the ± 12 V scanning range ($E_{ox} = \pm$ 2.4 MV/cm), respectively. Although the samples annealed for 60 min have a smaller hysteresis window, they have two important advantages compared to the 30 min annealed ones: a lower defect density at the c-Si wafer/SiO_2 interface and a smaller value of the fixed oxide charge close to this interface.

HL 13.74 Mon 15:00 Poster A

The design and fabrication of an electron pump with in-plane gate transistors by focused ion beam implantation — •M. Draghici, D. Salloch, A. Melnikov, D. Reuter, and A. D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

In the last decade, there has been a considerable interest especially in the metrological community to design and develop a device capable to deliver a current with an extremely high accuracy. The Coulomb blockade and single electron tunneling effects in small junctions made possible devices, which manipulate individual electrons [1]. A drawback is the very sophisticated routine for tuning and operating the pump. Another approach was to fabricate devices for which the charge transport through an 1D-channel formed in an $Al_xGa_{1-x}As$ heterostructure is done using surface acoustic waves of few GHz [2]. The advantage is that the current extends to the nanoampere range. We present an electron pump with in-plane gate (IPG) transistors [3] fabricated by focused ion beam implantation. Although, the device is operating at low frequencies (tens of kHz), it is capable to produce a current more than one order of magnitude higher than the electron pumps based on Coulomb blockade and single electron tunneling effects. The maskless fabrication process does not require any alignment between the sources, the drains and the gates of the IPG transistors.

[1] L. J. Geerligs *et al.*, Phys. Rev. Lett. **64**, 2691 (1990).
[2] V. I. Talyanskii *et al.*, Phys. Rev. B **56**, 15180 (1997).
[3] A. D. Wieck, K. Ploog, Appl. Phys. Lett. **56**, 928 (1990).

HL 13.75 Mon 15:00 Poster A

Functionalized macroporous silicon structures for ir-radiation and chemical sensing applications — •Benjamin Gesemann and Ralf Wehrspohn — Microstructure based material design group, MLU Halle-Wittenberg, Heinrich-Damerow-Strasse 4, D-06120 Halle

In recent years ordered macroporous silicon structures have been used for photonic crystal studies. Beside that they also offer a huge potential for ir-radiation and chemical sensing applications.

We enhanced processes to fabricate high aspect ratio ordered membrane structures with complex shapes for functional devices. The μm-sized porosity as well as mm- and cm-sized outer and inner shapes for a functional chip-design can be etched in a single process. We will show measurements and calculations for thermal emission- as well as gas sensing properties of functionalized coated macroporous silicon devices.

HL 13.76 Mon 15:00 Poster A

***In situ* spectroscopy and characterisation of organic solar cells** — •F. Holch, J. Pernpeintner, A. Schöll, and E. Umbach — Universität Würzburg, Experimentelle Physik II, 97074 Würzburg

Electronic devices based on organic semiconductors belong to a field of growing interest in fundamental and application related research. The different experimental methods and preparation techniques often complicate a comprehensive understanding of fundamental properties and their impact on device performance. We present first results from a new project focussing on organic solar cells using relatively small organic molecules. For a better understanding of the limiting parameters basic questions such as the determination of energy levels in the active layer as well as the bandoffsets/–alignment at the organic hetero–interface and contacts will be addressed using photoelectron spectroscopy (UPS) and inverse photoelectron spectroscopy (IPES). *In situ* electrical measurements (IV) help to associate fundamental results with device characteristics such as efficiency and fill factor. In order to avoid uncontrolled contamination, the complete fabrication (active layer and contacts) and characterisation is performed under clean and well defined conditions in UHV. As a benefit of this approach the influence of contamination occurring, e.g., during the fabrication process or device operation can be analysed systematically. Moreover, metal deposition methods are optimised in order to reduce damage to the sensitive organic layer. The interplay between interface morphology and interaction will be investigated by XPS using a peeling technique, which has already been successfully applied to Au/DIP contacts.

HL 13.77 Mon 15:00 Poster A

Open circuit voltage of organic solar cells - experiment and simulation — •Matthias Roosz[1], Carsten Deibel[1], Ingo Riedel[2], Vladimir Dyakonov[1,2], David Cheyns[3], Jan Genoe[3], and Paul Heremans[3] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Div. Functional Materials for Energy Technology, ZAE Bayern e.V., Am Hubland, D-97074 Würzburg, Germany — [3]IMEC, Polymer & Molecular Electronics, Kapeldreef 75, B-3001 Leuven, Belgium

Polymer photovoltaic devices are promising alternatives to inorganic solar cells due to their low-cost fabrication of large areas. However, as the power conversion efficiency of organic solar cells needs to be further increased, investigations of the basic principles are indispensible.

The open-circuit voltage as a key parameter of organic solar cells is studied by both simulation and device characterization. We present an analytic model for bilayer devices employing Poisson-equation and the balance between drift/diffusion-current which is compared to bilayer polymer-fullerene solar cells. Light intensity and temperature dependance will be discussed.

HL 13.78 Mon 15:00 Poster A

Investigation of electronic traps in organic transport layers via thermally stimulated current measurements — •Julia Schafferhans[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Div. Functional Materials for Energy Technology, ZAE Bayern e.V., Am Hubland, 97074 Würzburg, Germany

Charge transport in disordered organic semiconductors is generally described as thermally activated hopping in a gaussian distribution of localized states. The presence of charge traps is critical to the performance of organic electronic devices, since trapped charge carriers do no longer contribute to current flow. We investigate the depth and the density of trap states in the polymer poly(3-hexylthiophene) (P3HT) by applying the thermally stimulated current (TSC) technique. In particular, we present experimental data on the influence of doping the polymer with fullerene derivatives, which are relevant for the application in organic photovoltaics.

HL 13.79 Mon 15:00 Poster A

Photoinduced polarons in conjugated polymer-fullerene composites studied with light-induced electron-spin resonance — •Andreas Sperlich[1], Moritz Liedtke[1,2], Johannes Sieger[1], Carsten Deibel[1], Ingo Riedel[1,2], Vladimir Dyakonov[1,2], and Nazario Martin[3] — [1]Experimental Physics VI, Physical Institute, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D97074 Würzburg, Germany — [3]Departamento de Quimica Organica, Facultad de Quimica, Universidad Complutense, E-28040 Madrid

Electron-spin resonance (ESR) and light induced electron spin resonance (LESR) studies of photogenerated polarons in films of polymer and of polymer-fullerene composites were performed. Investigated materials are regio-regular and regio-random poly(3-hexylthiophene) (RR-P3HT / RRa-P3HT), [6,6] phenyl-C61-butyric acid methyl ester (PCBM) and a novel C70-derivate. In pure polymer-films a single polaron-signal is detected with ESR; it is significantly enhanced under illumination. Polymer-fullerene composites show two distinct polaron signals below 200K. The efficiency of the charge carrier generation in these polymer-fullerene-composites is relevant for applications in organic solar cell devices.

HL 13.80 Mon 15:00 Poster A

Injection studies on the guest-host system: terrylene in para-terphenyl — •Bernhard Grotz, Fedor Jelezko, Jörg Wrachtrup, and Jens Pflaum — 3. Physikalisches Institut, Universität Stuttgart, Germany

Efficient charge carrier injection accompanied by recombination on individual lattice sites are the substantial requirements to detect single molecule electroluminescence in organic host-guest systems, the latter defining key elements for quantum cryptographic application. But comparing the positions of the contributing energy levels as well as the properties of metal-organic interfaces the injection often is restricted by the substantial level-offset and by the formation of interface dipoles, etc.

We address this problem by injection studies on the terrylene doped para-terphenyl guest-host system, a prominent candidate for single photon sources [1] and widely studied by optical techniques. The crystalline samples were prepared either by Lipsett-growth or by spin casting on glass. In a first attempt, direct electron injection in PPX capped and uncapped Lipsett-grown crystals was provided at energies between 10-1000eV in UHV. From spectral measurements of the luminescence we conclude the possibility of electron injection and subsequent transport to and recombination on the terrylene dopant in the para-terphenyl matrix. We will discuss further extensions to this approach, to achieve higher recombination efficiencies as well as higher local resolutions.

[1] B. Lounis, W.E. Moerner, Nature, 407, 491 (2000)

HL 14: Si/Ge

Time: Monday 16:00–17:30 Location: H14

HL 14.1 Mon 16:00 H14

Defect band formation at grain boundaries in laser-crystallized polycrystalline SiGe thin films — •M. Weizman[1], L.-P. Scheller[1], N. H. Nickel[1], and B. Yan[2] — [1]Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Ovonic Corporation 1100 West Maple Road Troy, MI 48084, USA

Polycrystalline silicon-germanium (poly-SiGe) alloys are considered as a promising material for thin film solar cells due to their enhanced optical absorption in comparison to poly-Si. The SiGe thin films investigated in this study were fabricated on glass substrates by the following steps. Initially, amorphous silicon-germanium films (a-$Si_{1-x}Ge_x$:H) were deposited by glow-discharge decomposition of a mixture of disilane, germane, and hydrogen to a thickness of 100 to 255 nm. The Ge content, x, of the resulting samples was varied over the entire range $0 < x < 1$. At the second processing step, the amorphous samples were crystallized employing a XeCl excimer laser. Electron spin resonance (ESR) measurements done on these samples at low temperatures ($5 < T < 60$ K) reveal that at a critical Ge content of about $x = 0.5$ the ESR signal vanishes completely for the Ge rich alloys and instead a broad signal caused by electron cyclotron resonance (ECR) appears. This result is interpreted as the formation of a defect band at the grain boundaries at a critical dangling bound defect density which is in the range of $5 \cdot 10^{18}$ cm^{-3}. Angle resolved measurements of the ECR signal as well as conductivity measurements are also presented in order to support this hypothesis.

HL 14.2 Mon 16:15 H14

Structural and electronic properties of ultra-thin polycrystalline Si layers on glass substrates — Tobias Antesberger, •Christian Jaeger, Michael Scholz, and Martin Stutzmann — Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

Polycrystalline silicon thin films on glass substrates are attractive for large area electronics and solar cell applications. A promising method to obtain large-grained high quality polycrystalline films by re-crystallization of an amorphous precursor material is the aluminum-induced layer exchange (ALILE). Here, an Al/amorphous Si layer stack, separated by a thin oxide film, is annealed at temperatures up to the eutectic temperature of 577 °C, leading to an exchange of the positions of the initial layers and the crystallization of the amorphous Si. We have studied the structural properties of ultra-thin polycrystalline layers (10 nm - 100 nm) prepared with ALILE by means of X-ray diffraction measurements and Raman spectroscopy, providing evidence of a good crystalline quality. The electronic properties investigated by conductivity and Hall effect measurements show a decreasing carrier density and an increasing mobility with increasing layer thickness. Hydrogen passivation leads to partially depleted layers due to compensation caused by surface states. This effect is investigated by electron spin resonance and spin-dependent transport.

HL 14.3 Mon 16:30 H14

Study of the disproportionation in bulk amorphous germanium monoxide — •Andreas Schacht[1], Christian Sternemann[1], Achim Hohl[2], Henning Sternemann[1], Michael Paulus[1], and Metin Tolan[1] — [1]Dept. Phys. / DELTA, University of Dortmund, D-44221 Dortmund — [2]Institute for Materials Science, Darmstadt University of Technology, D-64287 Darmstadt

Measurements of the x-ray absorption near-edge structure at the Ge K-edge of ex-situ annealed amorphous germanium monoxide samples, i.e. GeO_x ($x \approx 1$), were accomplished in partial fluorescence yield mode at BL9 of the synchrotron radiation source DELTA utilising a spectrometer in Rowland geometry. A systematic temperature dependence was observed for the near-edge structure within the first 10 eV above the Ge K-edge and could be related to the disproportionation process of amorphous germanium monoxide into germanium and germanium dioxide. The onset of the observed disproportionation process was estimated to a temperature of $245 \pm 25°$ C. Full disproportionation into germanium and germanium dioxide was observed at an annealing temperature of $525 \pm 50°$ C. Also crystallisation of samples sets in for temperatures above 525° C which could be confirmed by x-ray diffraction.

HL 14.4 Mon 16:45 H14

Metallic conduction in undoped laser-crystallized polycrystalline silicon-germanium thin films — •L.-P. Scheller[1], M. Weizman[1], N. H. Nickel[1], and B. Yan[2] — [1]Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany — [2]United Solar Ovonic Corporation, 1100 West Maple Road Troy, MI 48084, USA

Due to its enhanced optical absorption in the IR and visible spectral range polycrystalline silicon-germanium (poly-SiGe) could become a promising new absorber material for future thin film and tandem solar cells.

The poly-SiGe samples investigated in this study were fabricated in the following way. First, amorphous undoped SiGe (a-SiGe:H) films with a germanium content between 33% and 100% were deposited on quartz substrates. Then, these a-SiGe:H samples were laser-crystallized with a pulsed XeCl excimer laser both by a step-by-step process and by a single laser pulse. Carrier transport in these samples was investigated by Hall and conductivity measurements in a temperature range of 20 K to 300 K.

Although the amorphous base material is undoped, many samples show p-type conduction with astonishing high conductivities in the range of 0.1 to 10 $(\Omega\text{cm})^{-1}$. In addition, the Ge-rich samples exhibit metallic behavior with nearly constant conductivity down to 20 K. Further, a subsequent remote hydrogen plasma treatment leads to a pronounced decrease in conductivity. This surprising behavior is explained in terms of carrier transport in a defect band induced by dangling bond defects at the grain boundaries.

HL 14.5 Mon 17:00 H14

Low-temperature molecular beam epitaxy on polycrystalline Si and Ge seed layers — •Michael Scholz[1], Yuelong Huang[2], Sebastian Gatz[1], Andreas Lambertz[2], Friedhelm Finger[2], Reinhard Carius[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Am Coulombwall 3, Technische Universität München, 85748 Garching Germany — [2]Institut fuer Photovoltaik, Forschungszentrum Jülich, Leo-Brandt-Straße,

An interesting approach for low-temperature preparation of polycrystalline silicon-germanium (poly-SiGe) layers with promising structural and electrical properties on non-crystalline substrates is the aluminum-induced layer exchange (ALILE). Here, a bilayer structure of amorphous Silicon-Germanium (a-SiGe) and Aluminum is deposited e.g. on a glass substrate and heated to temperatures below the eutectic temperature of the ternary Al-Si-Ge alloy system (420°C). If they are separated by a thin oxide, the two layers exchange their respective positions and a coherent poly-SiGe film is formed. The Aluminum layer can be used as back contact in a seed layer concept for photovoltaic devices, provided that low-temperature epitaxial overgrowth of the seed layer can be achieved.

To this end, we have studied the epitaxial growth of Si, SiGe and Ge using both very high frequency plasma enhanced chemical vapor deposition (VHF-PECVD) and electron-beam evaporation. The structural and optical properties will be discussed and results from a first photovoltaic device will be presented.

HL 14.6 Mon 17:15 H14

Functional Spin-Coated Nanocrystalline Silicon Layers on Plastic Substrates — •Robert Lechner[1], Roland Dietmüller[1], Andre R. Stegner[1], Rui N. Pereira[1], Martin S. Brandt[1], André Ebbers[2], Frank-Martin Petrat[2], Martin Trocha[2], Hartmut Wiggers[3], and Martin Stutzmann[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching — [2]Degussa AG, Paul-Baumann-Str. 1, 45764 Marl — [3]Universität Duisburg-Essen, Institut für Verbrennung und Gasdynamik, Lotharstr. 1, 47048 Duisburg

Semiconducting silicon nanoparticles are possible candidates for various applications in the field of printable electronics and for low cost solar cells. Its natural abundance and non-toxicity make silicon the favorable choice out of a large variety of nanoparticle materials which in principle enable high carrier mobility and stability under atmospheric conditions.

Here, we present results obtained by pulsed laser annealing of spin-coated silicon nanoparticle dispersions on flexible plastic substrates. These nanoparticles are successfully doped during their formation in

a microwave reactor by the addition of diborane and phosphine to the precursor gases. The structural properties of the films before and after the laser treatment are discussed and the conductivity is found to increase by several orders of magnitude. Furthermore, spectrally resolved photoconductivity allows a detailed analysis of electronic transport in spin-on nanoparticular silicon films. In addition, device concepts based on these films will be discussed.

HL 15: Preparation and characterization

Time: Monday 17:15–18:00 Location: H13

HL 15.1 Mon 17:15 H13

Synthesis and photoelectrical properties of CdS nanowires — •Holger Jens Böttcher, Cristina Gomez-Navarro, Marko Burghard, and Klaus Kern — Max-Planck-Institute for Solid State Research, Stuttgart, Germany

Semiconductor nanowires (NW) are emerging as versatile nanoscale building blocks of optoelectronic devices. In this context, extensive research is currently directed toward developing controlled synthesis procedures and microscopic characterization methods for NW. In this talk, the growth of Cadmium sulfide (CdS) NW via a solvothermal method will be presented. Investigations by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), transmission microscopy (TEM), thermal gravimetric analysis (TGA) and μ-PL spectroscopy demonstrate that the utilised synthesis approach yields pure, structurally uniform and single-crystalline NW. Dark electrical transport measurements, complemented by spatially resolved photoconductivity experiments, were performed on individual NW in order to investigate the carrier transport in CdS NW.

HL 15.2 Mon 17:30 H13

Nano-DLTS based on SCM for spatially resolved electrical defect spectroscopy — •Andre Krtschil, Hartmut Witte, Carsten Baer, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, PO Box 4120, 39016 Magdeburg, Germany

Conventional techniques for electrical defect characterization like deep level transient spectroscopy (DLTS) suffer from one major problem. They only can provide information on the overall defect content in a macroscopic part of the sample. Otherwise, local defect state characteristics are requested if specific types of structural defects or distinct layers in a device stack should be analyzed.

In this contribution we describe the nano-DLTS technique which overcomes these limitations. Nano-DLTS combines the idea of macroscopic DLTS with the high spatial resolution of the scanning capacitance microscopy approach. Thus, it allows the analysis of local capacitance transients due to an external bias voltage pulse with a spatial resolution of some tens of nanometers. The thermal activation energy of the corresponding defect states can be determined from isothermal nano-DLTS scans at different temperatures.To demonstrate the broad applicability of nano-DLTS, we will show results for different semiconductor layers (silicon, zinc oxide, and gallium nitride) as well as of a more complex GaN-based light emitting diode. In the latter case, the sample is beveled to provide access to inner layers and interfaces during local defect spectroscopy experiments. Furthermore, experimental setup, advantages, and limitations of nano-DLTS will be discussed.

HL 15.3 Mon 17:45 H13

Determination of potential microdistributions in semiconductors by means of Electron Holography — •Andreas Lenk[1], Petr Formanek[1], Daniel Wolf[1], Hannes Lichte[1], and Uwe Mühle[2] — [1]Institute of Structure Physics, Triebenberg Laboratory, Technische Universitaet Dresden, 01062 Dresden, Germany — [2]Qimonda Dresden GmbH & Co. OHG

Nowadays, FIB systems and TEM's are commonly used tools for physical failure analysis in both semiconductor industry and materials research. As a promising extension of TEM, electron holography provides indispensable additional information, such as 2D profiles of variations of the local electrostatic potential in the semiconductor matrix. The distribution of dopants in the material can be calculated from those profiles.

However, like normal TEM, electron holography delivers 2D projections of 3D object information. Artefacts on the object's surface, which were introduced e.g. by the 30kV gallium ions of the FIB during preparation, falsify such projections. For quantitative measurement, it is very important to distinguish between true material properties and artificially generated features.

Therefore, FIB-lamellae have been cross-sectioned and investigated with electron holography. It is shown that the gallium ions of a FIB do not only amorphize the crystalline silicon laterally, but also decrease the electric potential near the surface of the lamella. To understand the corresponding effects on 2D projections, electron holography was combined with tomographic imaging techniques.

HL 16: Invited Talk Norris

Time: Tuesday 9:15–10:00 Location: H15

Invited Talk HL 16.1 Tue 9:15 H15

Why has doping been difficult in colloidal semiconductor quantum dots? — •David J. Norris — Department of Chemical Engineering & Materials Science, University of Minnesota, Minneapolis, MN 55455 USA

Doping - the intentional introduction of impurities into a material - is fundamental to controlling the properties of bulk semiconductors. The prospect of new technologies has motivated efforts to dope semiconductor nanocrystals since their discovery two decades ago. Despite some successes, many of these efforts have failed, for reasons that remain mysterious. For example, Mn impurities can be incorporated into nanocrystals of CdS and ZnSe, but not into CdSe - despite comparable bulk solubilities near 50 percent. These difficulties, which have hindered development of new nanocrystalline materials, are often attributed to "self-purification", an allegedly intrinsic mechanism whereby impurities are expelled to the nearby surface. We propose instead that doping is controlled by the initial adsorption of impurities on the nanocrystal surface during growth. We find that adsorption - and therefore doping efficiency - is determined by three main factors: surface morphology, nanocrystal shape, and surfactants in the growth solution. Calculated Mn adsorption energies and equilibrium shapes for several nanocrystals lead to specific doping predictions. These are confirmed by measuring how the Mn concentration in ZnSe varies with nanocrystal size and shape. Finally, we use our predictions to incorporate Mn into previously undopable CdSe nanocrystals. This success establishes that earlier difficulties with doping are not intrinsic, and suggests that a variety of doped nanocrystals - for applications from solar cells to bioimaging - can be anticipated.

HL 17: Invited Talk Limmer

Time: Tuesday 10:00–10:45 Location: H15

Invited Talk HL 17.1 Tue 10:00 H15

Magnetic anisotropy and magnetization switching in ferromagnetic GaMnAs — •Wolfgang Limmer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm, Germany

Characteristic features of semiconductor spintronics such as the anisotropic magnetoresistance or the spin-polarization of charge carriers are intimately connected with the macroscopic magnetization in a ferromagnetic semiconductor. The orientation of the magnetization is controlled by magnetic anisotropy which predominantly arises from crystal symmetry, sample geometry, and strain. A detailed knowledge of this anisotropy is indispensable for the design of novel spintronic devices.

In this talk, angle-dependent magnetotransport is demonstrated to be an excellent tool for probing magnetic anisotropy as an alternative to the standard ferromagnetic-resonance method. Moreover, its ability to trace the movement of the magnetization vector in a variable external magnetic field makes it ideally suitable for studying magnetization switching, a potential basic effect in future logical devices. Experimental data recorded from a variety of different GaMnAs samples are analyzed by means of model calculations which are based on a series expansion of the resistivity tensor, a numerical minimization of the free enthalpy with respect to the magnetization orientation, and the assumption that the GaMnAs layers under study consist of single ferromagnetic domains.

HL 18: Photonic crystals I

Time: Tuesday 10:45–12:45 Location: H13

HL 18.1 Tue 10:45 H13

Photonic Crystal functional elements based on optically anisotropic materials and large-scale devices — •Patrick Mack[1,2], Daniel Hermann[1], Matthias Schillinger[1], Sergei Mingaleev[1,3], and Kurt Busch[1] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe (TH), Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Germany — [3]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine

We present device designs in macroporous silicon photonic crystals based on the infiltration of individual pores with liquid crystals which yield actively tunable photonic devices. These designs have been developed via a photonic Wannier function approach that allows the characterization of such devices via complex transmittance and reflectance coefficients. As a result, individual devices may be represented by small frequency-dependent scattering matrices. In turn, these scattering matrices form the basis of a quantitative circuit theory that allows to design complex functional elements that are very hard to handle with other simulation techniques.

HL 18.2 Tue 11:00 H13

Fabrication of 3D photonic crystal structures by two-photon polymerization technique — •Aleksandr Ovsianikov and Boris Chichkov — Hollerithallee 8

Two-photon polymerization technique can be considered as an enabling technology for the fabrication of 3D photonic crystals, especially those with introduced defects. Here, we report on our recent progress in the fabrication of 3D polymeric photonic crystals and investigation of their optical properties. Most of the materials used for 2PP were developed for lithographic applications and have a refractive index of the order of 1.6. We have investigated many of such materials and their structurability by 2PP technique. Further prospects of 2PP technology will be discussed.

HL 18.3 Tue 11:15 H13

Plasmon hybridization in stacked cut-wire metamaterials near metal films — •na liu[1], hongcang guo[1], liwei fu[1], heinz Schweizer[1], stefan kaiser[2], and harald giessen[1] — [1]4. Physikalisches Institut,Universitaet Stuttgart, Pfaffenwaldring 57, 70500, stuttgart, Germany — [2]1. Physikalisches Institut,Universitaet Stuttgart, Pfaffenwaldring 57, 70500, stuttgart, Germany

Abstract: We introduce a simple and convenient method to stack artificial units for metamaterials in the third dimension. Cut-wires and cut-wire pairs are placed above a metal film so that image cut-wires or cut-wire pairs are induced by the metal mirror when illuminated by light [1], which is equivalent to stacking two or four layers of cut-wires. The optical properties of cut-wires and cut-wire pairs above metal mirrors are investigated experimentally and numerically. The resonant plasmon modes are interpreted utilizing directly stacked cut-wire structures according to the method of plasmon hybridization [2]. Furthermore, the frequencies of different plasmon modes as a function of cut-wire separation are explored numerically. This method should pave the road towards a fundamental understanding of the electronic and optical properties of 3D metamaterials.

[1] V. A. Podolskiy, A. K. Sarchev, and V. M. Shalaev, Opt. Express 2003, 11, 735. [2] E. Prodan, C. Radloff, N. J. Halas, and P. Norlander, Science 2003, 302, 419.

HL 18.4 Tue 11:30 H13

Wasserstoffsensor auf Basis metallischer photonischer Kristalle — •Regina Orzekowsky, Andreas Seidel und Harald Giessen — 4. Physikalisches Institut, Universität Stuttgart, Germany

Aus Sicherheitsgründen sind günstige Wasserstoffsensoren Voraussetzung für die marktreife Umsetzung von wasserstoffbetriebenen Fahrzeugen oder elektronischen Geräten. Bisher sind Wasserstoffsensoren sehr teuer und benötigen elektrische Leitungen in einer potentiell explosionsgefährdeten Umgebung. Wir stellen einen optischen Wasserstoffsensor auf Basis eines metallischen oder dielektrischen photonischen Kristalls vor. Wir verwenden dabei eine Wolfram-Trioxid-Wellenleiterschicht unter einem Gitter aus metallischen oder dielektischen Nanodrähten. Die Nanostrukturen werden mit Interferenzlithographie oder Elektronenstrahllithographie hergestellt. Die optischen Eigenschaften der Wellenleiterschicht und somit die Polaritonresonanzen des metallischen photonischen Kristalls werden durch den gasochromen Effekt verändert. Das Detektionsprinzip wird erklärt und die Funktionsweise des Wasserstoffsensors experimentell nachgewiesen. Da unser Detektionsprinzip auf einem optischen Effekt beruht, kann das sensitive Element von der Elektronik isoliert und dadurch sicherer werden. Wir erwarten, daß dieser Sensor sowohl billiger in der Herstellung als herkömmliche Wasserstoffsensoren sein wird, als auch gleichzeitig robust, klein und wiederverwendbar.

HL 18.5 Tue 11:45 H13

Fabrication of silicon inverse woodpile photonic crystals — •Martin Hermatschweiler[1], Martin Wegener[1,2], Geoffrey Allen Ozin[3], Alexandra Ledermann[2], and Georg von Freymann[2] — [1]DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH), 76131 Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe — [3]Department of Chemistry, University of Toronto, Toronto, Ontario M5S 3H6, Canada

We fabricate silicon inverse woodpile structures for the first time. Direct laser writing of polymeric templates and a novel silicon-single-inversion procedure [1] lead to structures with gap/midgap ratios of 14.2% centered at 2.5 μm wavelength.

First, polymer templates are fabricated by direct laser writing or other means. Next, we deposit a thin silica coating via atomic layer deposition (ALD) on the polymer and - without removing the polymer - infiltrate the composite structure with Si via Si chemical vapor deposition (CVD). The silica shell provides sufficient and reliable stabilization for the high temperature CVD process. Finally, the silica is etched out and the polymer is calcined in air, leading to a Si inverse woodpile structure. Optical measurements and comparison to band-structure and scattering-matrix calculations reveal a gap/midgap ratio of 14.2% centered at 2.5 μm. An optimized structure could open a band

gap with a gap/midgap ratio of up to 20.5%.

[1] M. Hermatschweiler et al., submitted (2006).

HL 18.6 Tue 12:00 H13

Strong Circular Dichroism from Chiral 3D Photonic Crystals — •Michael Thiel[1], Manuel Decker[2], Martin Wegener[1], Stefan Linden[2], and Georg v. Freymann[2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Wolfgang-Gaede-Straße 1, D-76131 Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe

Chiral photonic crystals allow for photonic stop bands for circularly polarized light connected with pronounced circular dichroism[1] which can potentially be used for applications, e.g., as compact *thin-film* optical diodes[2]. We have fabricated high-quality polymeric 3D spiral photonic crystals[3] via direct laser writing[4]. The measured transmittance spectra of these low-index contrast structures reveal spectral regions where the transmittance is below 5 % for one circular polarization and larger than 95 % for the other – for just eight lattice constants along the propagation direction[1]. These polarization stop bands occur if the pitch of the light spiral matches the pitch of the dielectric spiral. As expected from the symmetry, the transmittance spectra are closely similar if both the sense of rotation of the dielectric spirals and that of the incident light field are changed simultaneously. Our experimental results agree well with theory. Additionally, we present a novel chiral 3D layer-by-layer structure as an alternative to the discussed circular dichroitic 3D spiral photonic crystals.

[1]*M. Thiel et. al., Adv. Mater., in press (2006). [2]*J. Hwang et. al., Nature Mater., 4, 383 (2005). [3]*K. K. Seet et. al., Adv. Mater., 17, 541 (2005). [4]*M. Deubel et. al., Nature Mater., 3, 444 (2004).

HL 18.7 Tue 12:15 H13

Silicon-based Photonic Crystal Gas Sensors — •Stefan Schweizer[1], Torsten Geppert[1], Andreas von Rhein[1], Susanne Hartwig[2], Jürgen Wöllenstein[2], Armin Lambrecht[2], and Ralf Wehrspohn[1] — [1]Institut für Physik, Universität Halle-Wittenberg, 06099 Halle — [2]Fraunhofer Institut Physikalische Messtechnik, Heidenhofstr. 8, 79110 Freiburg

The bandstructure of photonic crystals offers intriguing possibilities for the manipulation of electromagnetic waves. We suggest utilization of photonic crystals as an optical sensor in the infrared spectral region for qualitative and quantitative gas analysis. Taking advantage of the low group velocity and certain mode distributions for some k-points in the bandstructure of a photonic crystal should enable the realization of very compact sensor devices for mobile applications. We prepared sensing elements based on macroporous silicon photonic crystals consisting of up to 1000 of pore rows and measured the transmission with and without gas through the porous sensing element. We observed an enhancement in sensitivity of about 3 to 4 compared to a gas cell without a photonic crystal. Limitations of this technology being based on low group velocity modes inside photonic crystals are discussed.

HL 18.8 Tue 12:30 H13

GaAs pyramids as alternative micro-cavities — •Matthias Karl[1], Frank M. Weber[1], Jaime Lupaca-Schomber[1], Wolfgang Löffler[1], Shunfeng Li[1], Thorsten Passow[1], Jacques Hawecker[2], Dagmar Gerthsen[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

Pyramidal resonators are promising optical micro-cavities since they have great potential as small-mode volume resonators to enhance light-matter interaction.

Our resonators are fabricated from a molecular-beam epitaxy-grown layer structure containing an AlAs/GaAs distributed Bragg reflector as the bottom mirror. The pyramidal resonators on top are achieved by a combination of electron-beam lithography and wet chemical etching utilizing an AlAs sacrificial layer. The pyramids contain In(Ga)As quantum dots which – excited by a 532 nm cw laser – serve as a broad-band light source in the spectral range from 900 nm to 1000 nm. Optical cavity modes in these pyramids are identified and investigated using temperature-dependent measurements in a confocal microphotoluminescence set-up.

HL 19: Spin controlled transport I

Time: Tuesday 10:45–13:00 Location: H14

HL 19.1 Tue 10:45 H14

Control of electron spin and orbital resonance in quantum dots through spin-orbit interactions — •Peter Stano and Jaroslav Fabian — University of Regensburg

Dynamics of a single electron in coupled lateral quantum dots in the presence of a static and oscillating electric and magnetic fields as well as phonon-induced relaxation and decoherence is investigated. Using symmetry arguments it is shown that spin and orbital resonance can be efficiently controlled by spin-orbit couplings. The so called easy passage configuration is shown to be particularly suitable for magnetic manipulation of spin qubits, ensuring long spin relaxation time and protecting the spin qubit from electric field disturbances connected with on-chip manipulation.

HL 19.2 Tue 11:00 H14

Spin transport anisotropy in (110) GaAs — •Odilon D. D. Couto Jr[1], Fernando Iikawa[2], Jörg Rudolph[1], Rudolf Hey[1], and Paulo V. Santos[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin, Germany — [2]Universidade Estadual de Campinas, IFGW, CP-6165, Campinas-SP, 13083-970, Brazil

Mobile piezoelectric potentials are used to coherently transport electron spins in GaAs (110) quantum wells (QW) over distances exceeding 60 μm. We demonstrate that the dynamics of mobile spins under external magnetic fields depends on the direction of motion in the QW plane. The weak piezoelectric fields impart a non-vanishing average velocity to the carriers, allowing for the direct observation of the carrier momentum dependence of the spin polarization dynamics. While transport along [001] direction presents high in-plane spin relaxation rates, transport along [$\bar{1}$10] shows a much weaker external field dependence due to the non-vanishing internal magnetic field. We show that the anisotropy is an intrinsic property of the underling GaAs matrix, associated with the bulk inversion asymmetry contribution to the SO-coupling.

HL 19.3 Tue 11:15 H14

Magnetotransport through nanoscale constrictions in ferromagnetic (001)-(Ga,Mn)As — •Markus Schlapps[1], Matthias Döppe[1], Stefan Geissler[1], Thomas Imlohn[1], Janusz Sadowski[2], Werner Wegscheider[1], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

The resistance measured across a small (Ga,Mn)As island detached by nanoconstrictions from (Ga,Mn)As input leads displays unusual magnetoresistance (MR) behavior [1,2]. As in previous studies [1] a huge magnetoresistance was found for nanoconstrictions in the tunneling regime. For slightly wider junctions (on the verge of tunneling) we observed an enhanced anisotropic magnetoresistance together with pronounced jumps as a function of the in-plane magnetic field [3]. This behavior is ascribed to in-plane switching of the magnetization into the easy axis. We investigate the angular dependence of the MR for a tunneling device and discuss the correlation to the TAMR (Tunneling Anisotropic Magneto Resistance) that has been reported previously [2]. In addition we present data of (Ga,Mn)As wires with only one nanoconstriction.

[1] C. Rüster et al.: PRL 91, 216602 (2003)
[2] A. D. Giddings et al.: PRL 94, 127202 (2005)
[3] M. Schlapps et al.: phys. stat. sol. (a) 203, No. 14, 3597 (2006)

HL 19.4 Tue 11:30 H14

Tunneling Anisotropic Magnetoresistance and Spin-Orbit Coupling in tunnel structures with single-crystal GaAs barriers — •Michael Lobenhofer[1], Jürgen Moser[1], Eva Brinkmeier[1], Alex Matos-Abiague[2], Dieter Schuh[1], Werner Wegscheider[1], Jaroslav Fabian[2], and Dieter Weiss[1] — [1]Institut für Experi-

mentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg

We report the observation of tunneling anisotropic magnetoresistance effect (TAMR) in tunnel structures with single-crystal GaAs barriers. A stack of Fe, GaAs and Au, with iron grown epitaxially on the GaAs tunnel barrier, shows pronounced spin-valve-like signatures. Measurements of the tunneling resistance in a constant high in-plane magnetic field show a uniaxial anisotropy depending on the direction of the saturated magnetization of the iron layer. Depending on the bias voltage the high resistance state is either observed for the magnetization **M** oriented in [110] or in [-110] direction. This is the first observation of a TAMR effect in sandwiches involving a conventional ferromagnet like iron. We propose a theoretical model in which the C_{2v} symmetry, resulting from the interference of Bychkov-Rashba and Dresselhaus spin-orbit interactions, is transferred to the tunnelling probability, giving rise to the two-fold symmetry observed in the TAMR experiments.

HL 19.5 Tue 11:45 H14

Lithographic engineering of anisotropies in (Ga,Mn)As — •K. Pappert[1], S. Hümpfner[1], M. Sawicki[2], J. Wenisch[1], K. Brunner[1], C. Gould[1], G. Schmidt[1], T. Dietl[2], and Laurens W. Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Institute of Physics, Polish Academy of Sciences, al. Lotnikow 32/46, PL-02668 Warszawa, Poland

The focus of ferromagnetic semiconductor research is shifting from material issues towards device functionalities. So far demonstrated device concepts are mainly based on the strong magnetic anisotropy present in materials like (Ga,Mn)As. However, until now all regions of a device always inherited the magnetic anisotropy properties of the (Ga,Mn)As layer. Here we present a method to *locally* engineer the magnetic anisotropy by lithographic patterning and the associated strain relaxation. SQUID magnetometry studies on arrays of structures and transport studies on individually contacted nanobars will be shown, evidencing full anisotropy control over the whole temperature range from 4 K up to the Curie temperature of the material. The nanobars fabricated from standard in-plane (Ga,Mn)As layers show uniaxial magnetic anisotropy along the long axis of the bar irrespective of their crystal orientation. These results pave the way for new, more complex, semiconductor spintronics devices. Allowing the combination of functional elements of different magnetic anisotropy within the same device, this method can form the basis of novel device schemes relying upon the interaction between their tailored components. We acknowledge financial support from the EU (NANOSPIN FP6-IST-015728).

HL 19.6 Tue 12:00 H14

Transport experiments on ferromagnet/semiconductor hybrid structures — •Valentin Fedl, Andreas Wittmann, and Dirk Grundler — Physik Department E10, Fakultät für Physik, Technische Universität München, James Franck Str., 85748 Garching

We report transport experiments on ferromagnet/semiconductor hybrid structures. The interface between the two dimensional electron system in InAs and the metal is created by in situ cleavage of the InAs heterostructure followed by thermal evaporation of Fe or Co. Au is taken as a nonmagnetic reference. The InAs/metal interfaces show an Ohmic behavior. To understand the magnetotransport of such hybrid structures we first measure the specific resistance of the metal films as a function of temperature. The data is interpreted using the Fuchs-Sondheimer formalism[1,2]. Second we determine the interface resistance by using the transmission line method[3]. The interface quality is judged through comparison of the experimentally obtained value with the Sharvin resistance[4]. Third we investigate spin injection in mesoscopic devices by exploiting the Hanle effect[5,6]. The aim is to relate the spin injection rate to the interface quality and resistance.

[1] K. Fuchs, Proc. Cambridge Phil. Soc. 34, 100 (1938), [2] E. H. Sondheimer, Advan. Phys. 1, 1 (1952), [3] D. C. Look, Electrical Characterization of GaAs Materials and Devices, John Wiley & Sohns Ltd., Sussex (1989), [4] Yu. V. Sharvin, Sov. Phys. *JETP 21, 655-656 (1965), [5] Johnson & Silsbee, Phys. Rev. B 37, 10 (1987), [6] Lou et al., Phys. Rev. Let. 96, 176603 (2006)

HL 19.7 Tue 12:15 H14

Anisotropic current-induced spin accumulation in the two-dimensional electron gas with spin-orbit coupling — •Maxim Trushin and John Schliemann — Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

We investigate the magnetoelectric (or inverse spin-galvanic) effect in the two dimensional electron gases with both Rashba and Dresselhaus spin-orbit coupling using an exact solution of the Boltzmann equation for electron spin and momentum. Regarding the spin degree of freedom, our solution neglects off-diagonal elements of the semiclassical distribution matrix in the eigenbasis (or helicity basis) of the single-particle Hamiltonian, an approximation which is shown to be valid at sufficiently high temperatures common in experiments. Using this solution, we discover the anisotropy of the current induced spin accumulation, though the conductivity remains isotropic. To conclude, our analytical study is expected to be a reliable starting point for further investigations of spin dependent electron transport. (See cond-mat/0611328 for details.)

HL 19.8 Tue 12:30 H14

Picosecond Polarization Detector for Infrared and Terahertz Radiation — •J. Kiermaier[1], W. Weber[1], S.N. Danilov[1], D. Schuh[1], Ch. Gerl[1], W. Wegscheider[1], D. Bougeard[2], Gerhard Abstreiter[2], W. Prettl[1], and S.D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Walter-Schottky Institute, TU Munich, 85748 Garching, Germany

We report on a room temperature detector allowing to measure and characterize the state of polarization of infrared and terahertz laser radiation with picosecond time resolution. The ellipticity of radiation is analyzed applying simultaneously the circular and the linear photogalvanic effect (CPGE, LPGE) as well as the photon drag effect [1], which are monitored by different units in one single detector. Access to radiation helicity is provided by CPGE in quantum wells (QWs) resulting in a signal proportional to the radiation helicity. To reconstruct the whole state of radiation polarization we use additionally LPGE which is sensitive to linear polarization and the photon-drag effect which is polarization insensitive providing a reference of radiation power. For detector elements based on CPGE and LPGE we applied (113)-grown SiGe or GaAs QWs. The photon drag detector was prepared from germanium crystals irradiated along the [100]-crystallographic axis. The detector units are connected to an analytical part, which converts the measured signals into explicit information about the polarization state of the incoming laser beam.

[1] S.D. Ganichev, and W. Prettl, Intense Terahertz Excitation of Semiconductors, Oxford University Press, (2006).

HL 19.9 Tue 12:45 H14

Spin Photocurrents and Circular Photon Drag Effect in (110)-grown Quantum Well Structures — •H. Diehl[1], V. A. Shalygin[2], Ch. Hoffmann[1], S. N. Danilov[1], Th. Herrle[1], S. A. Tarasenko[3], E. L. Ivchenko[3], V. V. Belkov[3], D. Schuh[1], Ch. Gerl[1], W. Wegscheider[1], W. Prettl[1], and S. D. Ganichev[1] — [1]Faculty Physics, University of Regensburg, Regensburg, Germany — [2]St. Petersburg State Polytechnic University, St. Petersburg, Russia — [3]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

We report on the observation of spin photocurrents [1] in (110)-grown GaAs/AlGaAs quantum well structures. Investigated effects comprise the circular photogalvanic effect and the circular photon drag effect predicted long time ago but so far not observed. The measurements of photocurrents are carried out by excitation with infrared or terahertz radiation yielding inter-subband transitions between the lowest and the first excited subbands or intra-subband (Drude-like) absorption of the radiation, respectively. The experimental data are well described by analytical expressions derived from a phenomenological theory. The circular photon drag current in the longitudinal direction reverses its sign as the circular polarization of radiation changes from right handed to left handed and is related to transfer of both linear and angular photon momentum to the electron system. A microscopic model of the circular photon drag effect is developed demonstrating that the generated current has spin dependent origin.

[1] S.D. Ganichev and W. Prettl, Intense Terahertz Excitation of Semiconductors, (Oxford University Press, 2006).

HL 20: Symposium Bose-Einstein Kondensation in Halbleitern

Time: Tuesday 10:45–12:45 Location: H15

Invited Talk HL 20.1 Tue 10:45 H15

Polariton Condensation in CdTe Microcavities: interaction and coherence — J. Kasprzak[1], M. Richard[2], S. Kundermann[2], A. Baas[2], P. Jeambrun[2], J. Keeling[3], F. M. Marchetti[4], M. H. Szymanska[5], R. André[1], J. L. Staehli[2], P. B. Littlewood[4], B. Deveaud[2], and •Daniel Le Si Dang[1] — [1]Laboratoire de Spectrométrie Physique, CNRS-Université J. Fourier-Grenoble, France — [2]Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland — [3]M.I.T., Cambridge (Ma.), USA — [4]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom — [5]Clarendon Laboratory, University of Oxford, Oxford, United Kingdom

Polaritons in semiconductor microcavities are quasi-particles which result from the strong coupling between confined photons and electronic excitations. These bosons are 10^9 times lighter than rubidium atoms, thus permitting BEC to occur at low density and high temperature. In this talk we present evidence for polariton condensation at around 20 K in a CdTe microcavity [Bose-Einstein condensation of exciton polaritons, Kasprzak et al., Nature 443, 409 (2006)]. We show also how the spontaneous coherence of the polariton condensate differs from the ideal case of non interacting bosons. We gratefully acknowledge support from the EU Network HPRN-CT-2002-00298 "Photon-mediated phenomena in semiconductor nanostructures".

Invited Talk HL 20.2 Tue 11:15 H15

On the way to an excitonic Bose-Einstein condensate: New experiments in Cuprous Oxide. — •Heinrich Stolz[1] and Dietmar Fröhlich[2] — [1]Institut für Physik, Universität Rostock, Universitätsplatz 3, 18055 Rostock — [2]Institut für Physik, Universität Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund

The lowest exciton transitions in Cu_2O are considered to be an ideal system to observe Bose-Einstein condensation (BEC). Despite the large experimental efforts, (for a review see Ref. [1]), a clear evidence for an excitonic BEC was not given up to now. In this contribution we present temperature and excitation power dependent absorption measurements of the paraexciton, which is the lowest exciton state of the yellow series, via the polariton effect using a tunable single frequency laser. At 10 Tesla we get in high quality samples an absorption coefficient of about 80 cm-1 and a line width of 80 neV at T=1.2K and μW laser power. The absorption line shows a blue-shift and a broadening with increasing intensity. Both effects can be explained quantitatively by taking acoustic phonon scattering and a density dependent exciton-exciton interaction into account. Under these excitation conditions we observe in phonon sidebands of the paraexciton emission a sharp peak at the low energy side. The possibility that it reflects resonant Raman scattering or a transition from k = 0 excitons and thus a BEC is discussed, based on its characteristic density and temperature dependence. [1] D. W. Snoke, Science **298**, 1368 (2002).

Invited Talk HL 20.3 Tue 11:45 H15

Challenges on the way towards Bose-Einstein condensation of excitons — •Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

Starting with the ideal Bose gas in a trap, necessary prerequisites for reaching condensation in exciton systems are discussed, and actual experimental attempts are critically reviewed. More details are given on high-density excitons in coupled quantum wells with a lateral trap. Taking into account the strong dipole-dipole repulsion between these spatially indirect excitons, we have implemented a dynamical T matrix approach and present numerical results. The spectral lineshape of the emitted luminescence as well as its angular characteristics provide clear signatures for the approach to condensation which, however, has not been reached yet.

Invited Talk HL 20.4 Tue 12:15 H15

Signatures of excitonic condensates in quantum Hall bilayers — •Lars Tiemann[1], Rodney Wiersma[1], Sjoerd Lok[1], Werner Dietsche[1], Klaus v. Klitzing[1], and Koji Muraki[2] — [1]Max-Planck Institute für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [2]NTT Basic Research Laboratories, Atsugi, Japan

Experiments on two closely spaced 2D electron double layers under strong perpendicular magnetic fields, where each layer's filling factor is near 1/2, show signatures of a Bose-Einstein condensate of interlayer excitons. In drag experiments, where a current is flowing in only one layer, a quantized Hall voltage of h/e^2 over both layers is observed while the longitudinal voltages vanish. This behavior is regarded as a consequence of interlayer lectron-hole pairs (=excitons) residing in the same quantum mechanical state, analogue to atomic Bose-Einstein condensates. Complementary experiments with counter flowing currents in both layers imply a superfluid-like transport mode of these interlayer excitons. While all previous work focused on Hall bars, our recent experiments performed on a ring structure reveal that the radial (or σ_{xx}) conductance in the current-carrying layer only slowly diminishes with decreasing temperature and a given coupling strength. In contrast to Hall bars, voltages of equal value build up over both layers even in the weak coupling limit and at temperatures exceeding 0.3 K. In the limit of T $\longrightarrow$ 0 K and sufficiently strong coupling between the two layers, the conductance vanishes altogether and the voltages over both layers equal the externally applied excitation voltage.

HL 21: III-V semiconductors II

Time: Tuesday 11:00–13:00 Location: H17

HL 21.1 Tue 11:00 H17

The Mn Acceptor in InAs: Depth-Dependent Shape and Supression of the Conduction Band — Jens Wiebe[1], •Felix Marczinowski[1], Jian-Ming Tang[2], Michael E. Flatté[2], Markus Morgenstern[3], and Roland Wiesendanger[1] — [1]Institut für Angewandte Physik, Universität Hamburg — [2]Optical Science and Technology Center and Department of Physics and Astronomy, University of Iowa, USA — [3]II. Institut für Physik B, RWTH Aachen

Recent work using scanning tunneling spectroscopy (STS) revealed that acceptors in III/V semiconductors appear strongly anisotropic and their mirror asymmetry regarding the (001) plane depends on the binding energy E_b. While the energetically deep acceptor Mn in GaAs has a symmetric cross like shape [1], shallow acceptors like Zn show an asymmetric triangular feature [2]. We analyzed the relatively deep acceptor Mn in InAs ($E_b = 30meV$) by STS and find a dependency of the shape on the depth below the (110) surface. Deeper Mn acceptors appear as a cross with a low asymmetry which is reproduced by a bulk tight-binding model (TBM). Mn acceptors closer to the surface show a strong asymmetry of the cross resulting in a triangular feature. A possible explanation is the strengthening of the asymmetry by surface relaxation. The influence of the acceptor on the conduction band (CB) has also been studied by STS and TBM calculations. The CB density of states shows a supression close to the Mn which is surrounded by an oscillation reflecting the anisotropy of the acceptor state.

[1] A. M. Yakunin et al., Phys. Rev. Lett. 92, 216806 (2004)
[2] S. Loth et al., Phys. Rev. Lett. 96, 066403 (2006)

HL 21.2 Tue 11:15 H17

Exciton transport by surface acoustic waves — •Jörg Rudolph, Rudolf Hey, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

We present a novel approach for the transport of excitons in GaAs quantum wells (QW) using the mobile strain field of a surface acoustic wave (SAW). The strain field of a SAW travelling along the [100] direction on a (001)GaAs structure leads to a moving lateral type-I band gap modulation. Long-living indirect excitons photoexcited in a double-quantum well structure are trapped close to the positions of minimum band gap and transported with the acoustic velocity. The transport is detected by spatially resolved photoluminescence (PL) to image excitonic recombination away from the excitation spot. We investigate

the dependence of the transport on the applied acoustic power and extract information about the exciton mobility. Mechanisms for exciton confinement in the SAW-induced potential are discussed.

HL 21.3 Tue 11:30 H17

The Fe center in III-V and II-VI semiconductors — •Enno Malguth and Axel Hoffmann — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A comprehensive review of the Fe impurity in binary III-V and II-VI compounds is given with focus on GaN and ZnO. In this context, new results on the effective-mass-like state consisting of a valence band hole bound to Fe^{2+} are presented. In connection with diluted magnetic semiconductors, transition metal impurities particularly in wide band semiconductors have regained considerable interest. Focussing on Fe we give an overview on general phenomena such as charge states, electronic structure, charge transfer processes, Jahn-Teller effect etc. which have been investigated over the last couple of decades. The (Fe^{2+}, h_{VB}) state which has been observed in a range of III-V materials may play a central role in realizing carrier mediated ferromagnetism. By means of temperature and stress dependent absorption experiments we are able to give a good understanding of an experimentally observed deviation of the ground state from effective-mass theory. A conclusive model of the bound state's ground state is given taking into account exchange interaction between the hole and Fe^{2+} states.

HL 21.4 Tue 11:45 H17

Formation of MOVPE grown InAs quantum dots on GaAs(001):Si investigated with in-situ STM — •Raimund Kremzow[1], Markus Pristovsek[1], Bert Rähmer[1], Markus Breusing[1], Michael Kneissl[1], and Wolfgang Richter[2] — [1]TU-Berlin, Institut für Festkörperphysik, Sekr. PN6-1, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Dipartimento di Fisica, Roma II (Tor Vergata), Via della Ricerca Scientifica 1, 00133 Rome, Italy

Metal-Organic Vapour Phase Epitaxy (MOVPE) is the most important growth method for III-V-semiconductor structures. However, in-situ measurement techniques during MOVPE are constrained by the typical pressures of 20-100 mbar and temperatures of 450°C - 1100°C to optical techniques, which do not reveal microscopic details. Therefore, we have designed and built the first in-situ scanning tunnelling microscope (STM) capable of measuring the topography of semiconductor surfaces continuously during the growth of nanostructures in MOVPE up to 700°C. We will present our latest results, e.g. the first measurements of Ostwald-ripening of InAs quantum dots on a GaAs(001) surface. After the growth of InAs quantum dots a sequence of in-situ STM images were recorded at a sample temperature of 475°C. Three different structures (quantum dots, small and big clusters) could be differentiated. During the Ostwald-ripening the density of the small clusters seems to be constant, while the small quantum dots vanished exponentially and the big clusters increased slightly.

This newly developed in-situ STM tool could also enable effective control of semiconductor nanostructures during MOVPE growth.

HL 21.5 Tue 12:00 H17

Temperature dependent Electron Landé g-Factor and Interband Matrix Element in GaAs — •Jens Hübner, Stefanie Döhrmann, Daniel Hägele, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University Hannover, Appelstr. 2, 30167 Hannover

High precision measurements of the electron Landé g-factor in GaAs are presented using spin quantum beat spectroscopy at low excitation densities and temperatures ranging from 2.6 to 300 K. Influences of nuclear spin polarization at low temperatures have been fully compensated. Comparing these measurements with available data for the temperature dependent effective mass reveals an unexpected strong temperature dependence of the interband matrix element and resolves a long lasting discrepancy between experiment and kp - theory. The strong decrease of the interband matrix element with increasing temperature is explained by phonon induced fluctuations of the interatomic spacing and adiabatic following of the electrons.

HL 21.6 Tue 12:15 H17

Spin Noise Spectroscopy in GaAs — •Michael Römer, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Gottfried Wilhelm Leibniz University of Hannover, Appelstr. 2, 30167 Hannover

We successfully employ spin noise spectroscopy in semiconductor materials as a new sensitive tool to measure the spin-coherence time of electrons and the electron Landé g–factor in n-GaAs nearly interaction free [1]. Our technique avoids common problems like carrier heating and electron spin relaxation due to spin interaction with optically created holes.

Spin noise spectroscopy in semiconductors empowers us to measure extremely long spin coherence times in excess of 200 ns at low temperatures, which may have been masked in the past by effects like those mentioned above.

We furthermore discuss the measured noise power and spin-coherence time in dependence of the probe energy position, sample temperature and doping concentration. The results compare very well with a theory based on Poisson distribution probability.

The spin noise spectrum is measured by below band-gap Faraday-rotation in n-doped GaAs at low temperatures with high frequency spectrum analysis techniques.

[1] M. Oestreich, M. Römer, R. Haug, and D. Hägele, "Spin Noise Spectroscopy in GaAs", Phys. Rev. Lett. **95**, 216603 (2005).

HL 21.7 Tue 12:30 H17

Scanning Tunneling Spectroscopy of Si donors in GaAs {110} — •K. Teichmann, M. Wenderoth, S. Loth, and R. G. Ulbrich — Universität Göttingen, IV. Physikalisches Institut, Germany

Silicon donors in highly n-doped GaAs ($6.5{\times}10^{18}\mathrm{cm}^{-3}$) are investigated by Cross-Sectional Scanning Tunneling Microscopy in UHV at 8K. Donors near the surface of the {110} cleavage planes are studied by spatially resolved I(V)-spectroscopy.

The dopant atoms are identified by their bias dependent topographic and spectroscopic properties. In addition to the known features at negative and small positive voltages, our measurements on single donors show an additional transport channel for larger positive bias voltages. The current distribution has a circular symmetric structure. The diameter is bias dependent, and can extend up to several nanometers around the donor. The minimal bias voltage of the current onset is localized above the donors. We discuss different scenarios - including tip induced band bending - that can lead to the observed ring-like shapes.

This work was supported by the DFG, SFB 602.

HL 21.8 Tue 12:45 H17

GaMnAs grown on (001), (311) and (110) GaAs — •Ursula Wurstbauer, Dieter Schuh, and Werner Wegscheider — Universität Regensburg

In order to realize new spintronic devices based on Mn-doped GaAs heterostructures, one has to understand in detail and improve the properties in GaMnAs. For this reason, an accurate control of the effective Mn x concentration and the carrier density is necessary in this hole mediated ferromagnetic semiconductor GaMnAs. So far it is known, that these parameters critically depend on the incorporation of Mn atoms in the host lattice and on lattice defects, mainly As antisites and Mn interstitials, both acting as double donors, which are caused by the unavoidable low temperature MBE growth. In our experiments, we have grown GaMnAs layers on differently oriented GaAs substrates to compare the influence of growth and post-growth-treatment parameters on the Mn incorporation and, hence on T_C. We obtain the carrier density p by measuring the anomalous Hall Effect and the concentration of As-antisites from the lattice constant of LT-GaAs layers by X-ray diffraction. Further we show, that by avoiding As-antisites with a low As_4/Ga flux ratio and by reducing the Mn-interstitials by post growth annealing the carrier density and corresponding T_C increases to 152K for layers grown on (001) GaAs, to 110K for layers on (311)A and 89K for layers on (110). In addition, the possibility to overgrow cleaved (110) surfaces with GaMnAs of a high quality enables the growth of more complicated heterostructures like magnetic bipolar heterojunctions. We acknowledge the support by the DFG via SFB 689.

HL 22: Photonic crystals II

Time: Tuesday 14:00–16:45 Location: H13

HL 22.1 Tue 14:00 H13

Three-dimensional polymer and silicon inverse photonic quasicrystals for infrared frequencies — •Alexandra Ledermann[1], Ludovico Cademartiri[2], Martin Hermatschweiler[1], Costanza Toninelli[3], Geoffrey Ozin[2], Diederik Wiersma[3], Martin Wegener[1], and Georg von Freymann[1] — [1]Institut für Nanotechnologie, Forschunszentrum Karlsruhe, DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]Department of Chemistry, University of Toronto — [3]European Laboratory for Nonlinear Spectroscopy (LENS) and INFM, Firence

Quasicrystals (QC) represent a class of solids which lack translational symmetry, but exhibit perfect long-range order and reveal well-defined rotational symmetries, not necessarily consistent with periodicity. Using direct laser writing [1] we fabricate three-dimensional icosahedral SU-8 photonic QC of high quality, characterized by electron microscope images and visible-light Laue diffraction experiments [2]. Reflectance measurements indicate a stop band in the infrared. These SU-8 structures serve as templates for a subsequent novel silicon inversion procedure [3]. Electron microscope images and Laue diffraction patterns prove the successful fabrication of the silicon inverse photonic QC. This work paves the road for future work on low- or high-index contrast photonic QC.

[1] M. Deubel et al., Nature Materials, 3, 444 (2004).
[2] A. Ledermann et al., Nature Materials, 5, 942 (2006).
[3] M. Hermatschweiler et al., submitted (2006).

HL 22.2 Tue 14:15 H13

Group delay measurements on photonic crystal resonators — •Magdalena Gellner, Thomas Sünner, Andreas Löffler, Martin Kamp, and Alfred Forchel — Technische Physik, Am Hubland, D-97074 Würzburg

We have investigated the group delay of light propagating through photonic crystal (PhC) resonators. The resonators are defined in 250nm thick GaAs membranes. The design of the resonators is based on a PhC heterostructure, which combines waveguide sections with different lattice constants along a W1 waveguide to confine the light. The 'mirrors' of the resonator have a lattice constants of 400nm along the waveguide, the lattice constant of the cavity is 410nm. The lattice constant perpendicular to the waveguide remains unchanged in order to maintain matching lattices. The group delay was measured by detecting the phase shift of a microwave signal which was modulated onto the light of a tunable laser source with an emission wavelength of 1.5μm. The group delay was found to increase linearly with the quality factor of the resonator, in good agreement with the prediction of a model where the PhC resonator is replaced by an equivalent Fabry-Perot resonator. A maximum group delay of 132ps was observed for a resonator with a quality factor of 82000. The mirror segments of this resonator had a length of 12 lattice periods. Taking this as a measure of the length of the resonator, we have achieved an effective propagation speed of 7.9*10ˆ4 m/s, which is equivalent to c/3800.

HL 22.3 Tue 14:30 H13

Corrugated metallic surfaces for negative permeability in the visible spectral range — •Heinz Schweizer[1], Liwei Fu[1], Hedwig Gräbeldinger[1], Hongcang Guo[1], Na Liu[1], Stefan Kaiser[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart — [2]1. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart

In order to achieve left-handed metamaterials, simultaneous negative permittivity and permeability are sufficient. Negative permittivity is normally realized through plasmonic oscillation of electrons in metals. However, a naturally occurring negative permeability does not exist at optical frequencies. At GHz frequencies, negative permeability can be realized by split ring resonators (SRR) with the magnetic field component penetrating the ring and the electric field component along the SRR-arms. At optical frequencies SRRs can be fabricated, but the plane matrix configuration of SRRs is usually unfavorable to achieve a negative n. We design a novel metallic meander structure which acts as an SRR, to fully couple the magnetic field into U-shaped metallic structures for obtaining negative permeability at optical frequencies. The structure is realized on ridge-patterned dielectric substrates with deposition of 20 nm Au. Samples with a period of 200-350 nm in steps of 50 nm were fabricated using E-beam lithography. With the H-field along the ridge and the k-direction normal to the substrate, the S-parameters were simulated and the effective parameters were retrieved. Simulations show that large values of permeability down to -7 between 600 nm and 900 nm can be obtained.

HL 22.4 Tue 14:45 H13

Silicon-based photonic crystal waveguides — •Daniel Pergande[1], Alexey Milenin[2], Werner Sievers[3], and Ralf Wehrspohn[1] — [1]Microstructure-based Materials Design Group, Institute of Physics, University of Halle-Wittenberg — [2]Max Planck Institute of Microstructure Physics, Halle — [3]Department of Physics, University Paderborn

In PhCs the photonic band structure (PhBS) replaces the dispersion relation of photons in a homogenous dielectric medium. The PhBS results from scattering and interference of light at periodically alternating domains of material with different dielectric constants.

Silicon is the dominating material in today's microelectronics, especially in modern telecommunications, and therefore a lot of experience in microstructuring of silicon exists. Its high dielectric constant makes it a promising candidate for PhC fabrication. Furthermore, the possibility of integrating electronics and optics on one chip is of great advantage for silicon-based PhC devices.

We present ridge waveguides and PhC waveguides etched in a high-index-contrast material made of a thin silicon slab embedded in two silica layers. Hence fully symmetrical structures can be realized and two important conditions for low-loss guiding of light in PhC waveguides can be matched: The symmetry avoids polarization mixing and the high index contrast leads to strong confinement of light, so the PhC waveguides allow theoretically lossless guiding of light because of operating completely below the lightcone. This opens the door for fully new applications.

HL 22.5 Tue 15:00 H13

Numerical study of optical negative index metamaterials based on embedded nano-meander structures — •Liwei Fu, Heinz Schweizer, Hongcang Guo, Na Liu, and Harald Giessen — 4. Physikalisches Institut, Pfaffenwaldring 57, 70550 Stuttgart

For the realization of a left-handed metamaterial or negative index metamaterial, a longitudinal capacitance and a shunt inductance in a transmission line model are required to achieve simultaneously negative permeability and permittivty. In our new approach to negative index materials at optical frequencies, a meander metallic structure on a ridge-patterned substrate is designed for obtaining the longitudinal capacitance. Thin metal films are added for shunt inductance. In this way, two degrees of freedom can be used to adjust the permeability and permittivity spectrum with respect to each other in frequency. The distance of the metal films to the meander can be used as a parameter to obtain an overlap of the real part of negative permittivity and permeability. With this composite nanostructure embedded in SiO2, a negative refractive index can be obtained between 800 nm to 1200 nm with a real part of -2 and a figure of merit of 1.5.

15 min. break

HL 22.6 Tue 15:30 H13

Defocused Imaging of Single Quantum Dots in Photonic Crystals — •Rebecca Wagner and Frank Cichos — Molecular Nanophotonics, Universität Leipzig, Linnéstraße 5, 04103 Leipzig

Photonic crystals are materials with a periodically varying dielectric constant, which introduces a photonic band structure and photonic band gaps by multiple scattering of light on this spatially modulated refractive index. The spatial variation of the refractive index immediately implies that the optical density of states inside a photonic crystal has to be a local property too. Thus a detailed examination and especially the efficient use of even weak photonic systems requires a local probe for the study of local optical properties. So far this has only been achieved for 2D photonic structures by means of near field scanning microscopy. We show with extensive numerical calculations and experimental studies, that single quantum dots can be used as local

probes for the study of the optical properties of photonic crystals. As an example, anisotropic light propagation in photonic crystals is measured by imaging a single quantum dot with defocused fluorescence microscopy. A numerical fitting procedure is applied to invert the obtained experimental results to the angular dependence of the photonic stop band. Models are presented how a fractional local optical density of states can be defined and how it influences the emission of single chromophores inside photonic crystals.

HL 22.7 Tue 15:45 H13

Thickness dependence of the optical properties of split ring resonator metamaterials — •Hongcang Guo[1], Na Liu[1], Liwei Fu[1], Heinz Schweizer[1], Stefan Kaiser[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany — [2]1st Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

We study the thickness dependence of the resonant properties of split-ring-resonators (SRRs) in the optical regime using experiments and numerical simulations. It is shown that the so-called LC resonance frequency of an SRR increases with its thickness, rather than being constant as indicated by the inductor-capacitor (LC) circuit model. An equivalent cut-wire model based on plasmonic interpretation is applied to analyze the resonant behavior of SRRs, and good agreement between experiment and numerical simulation is obtained. It is proven that the plasmonic interpretation of metamaterials resonances is an appropriate model when studying SRR optical behavior.

[1]. C. Rockstuhl, F. Lederer, C. Etrich, T. Zentgraf, J. Kuhl, and H. Giessen, Optics Express 14, 8827 (2006). [2]. H. C. Guo, N. Liu, L. W. Fu, H. Schweizer, S. Kaiser, and H. Giessen, accepted in Phys. stat. sol. (b).

HL 22.8 Tue 16:00 H13

Phase-matched nondegenerate four-wave mixing in one-dimensional photonic crystals — •Christiane Becker[1,2], Martin Wegener[1,2], Sean Wong[1,2], and Georg von Freymann[1,2] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, Postfach 3640, D-76021 Karlsruhe — [2]DFG-Center for Functional Nanostructures, Universität Karlsruhe (TH), D-76128 Karlsruhe

Photonic crystals are a promising class of materials for nonlinear optics. They posses an effective material dispersion relation of light that differs strongly from the dispersion of bulk material. Hence, the important phase matching condition for efficient frequency conversion can be achieved using photonic crystals while it is not possible using bulk material. We report on nondegenerate four-wave mixing in the near infrared using a one-dimensional chalcogenide-glass based photonic crystal. For 76 lattice constants, we find a 3.5-fold enhancement of the mixing signal with respect to the optimum-thickness bulk chalcogenide film. The key is the ability to tailor the dispersion relation of light in the photonic crystal, allowing for phase matching. Numerical calculations agree well with the experiments.

HL 22.9 Tue 16:15 H13

Novel photonic bio-sensors based on silicon nanostructures — •Dominic Dorfner, Ulrich Rant, Jonathan Finley, and Gerhard Abstreiter — Walter Schottky Institute, Garching, Germany

Silicon photonic nanostructures are of widespread interest for applications in integrated photonics. In particular, photonic crystal resonators confine light to ultra small volumes and exhibit cavity modes with high optical finesse. We take advantage of these properties to investigate bio-sensor applications based on the linear optical response of the system.

We use a silicon-on-insulator material system to establish 250nm thick freestanding membrane structures perforated with a triangular pattern of air-holes separated by 400nm. By decreasing the diameter of one hole, a cavity with an extremely small mode volume ($V < \frac{1}{2}(\frac{\lambda}{n})^3 \approx 0.01\mu m^3$) is formed. We characterized these structures with μ-photo-luminescence spectroscopy by covering the surface with colloidal PbSe quantum dots embedded in a polymer matrix. First experiments lead to a quality-factor $Q \approx 800$ and the dependence on geometric parameters is in excellent agreement to our calculations. Simulations predict a sensitivity of $\Delta n/n = 0.001$ to surface refractive index variation in aqueous environment upon covering 10nm of the membrane surface with bio-molecules. Since the sensitive area is in the range of μm^2 we predict a sensitivity approaching the single molecule regime.

Photonic crystal waveguide resonators enable bio-functionalization techniques on the surface and offer a unique possibility to carry out research on the interaction of photons with single bio-molecules.

HL 22.10 Tue 16:30 H13

Characterization of metamaterials based on split-ring-resonators — •Pia Weinmann, Martin Kamp, and Alfred Forchel — Technische Physik, Am Hubland, D-97074 Würzburg

Negative index materials are materials which have a negative permeability and permittivity in a certain frequency range. These metamaterials have recently attracted considerable attention due to their fascinating optical properties and potential applications. The challenge in realizing such metamaterials is to achieve a negative magnetic response. One possible approach is based on U-shaped Split-Ring-Resonators (SRR), which effectively operate as small LC-oscillators. The resonance of these structures leads to a negative effective permeability. In order to act as an effective medium, the spacing of the resonators has to be much smaller (usually a tenth) of the desired resonance wavelength. The resonace wavelength can be controlled by adjusting the dimensions of the Split-Ring-Resonators. We have investigated different resonator structures with magnetic resonances in the mid IR region. The structures were fabricated on silicon substrates by E-beam lithography, evaporation of gold and lift-off. The transmission of the samples in the range from 1.5 to 8μm was measured using a Fourier-Transform Infrared Spectrometer. Measurements on SRRs with different sizes and geometries show a clear dependence of the LC-resonance on structural dimensions. We have also investigated structures consisting of two gold wires separated by an insulating layer, which also provide the desired magnetic resonance.

HL 23: Spin controlled transport II

Time: Tuesday 14:00–16:00 Location: H14

HL 23.1 Tue 14:00 H14

Electrical detection of donor Rabi flops — •Hans Huebl[1], Andre Stegner[1], Felix Hoehne[1], Christoph Boehme[2], Klaus Lips[3], Martin Stutzmann[1], and Martin Brandt[1] — [1]Walter Schottky Institut, Garching, Germany — [2]University of Utah, Salt Lake City, USA — [3]Hahn Meitner Institut, Berlin,Germany

Due to its potential compatibility with existing microelectronics, the proposal for a silicon based quantum computer by Kane is being pursued intensively. In this concept, the nuclear spins of single ^{31}P donors serve as qubits. Exchange coupling between donor-bound electrons, whose spins experience hyperfine interaction with their nuclei enables two and more qubit operations. An experimentally unsolved key issue is the readout of the ^{31}P quantum state. We demonstrate the measurement of the spin state of ^{31}P donor electrons in silicon and the observation of Rabi flops by purely electric means, carrying out pulsed electrically detected magnetic resonance experiments (pEDMR). Resonant microwave pulses are used to induce coherent manipulation of an ensemble of ^{31}P electron spins by electron spin resonance. The resulting change of spin-dependent charge-carrier recombination between the ^{31}P donor and paramagnetic localized states at the silicon surface is then detected by a transient photoconductivity measurement after the coherent excitation is turned off. The electron spin information is shown to be coupled through the hyperfine interaction to the phosphorus nucleus, suggesting that recombination-based readout of nuclear spins is feasible.

HL 23.2 Tue 14:15 H14

Fast polarization switching in room temperature Spin-VCSEL — •Stephan Hövel[1], Nils Gerhardt[1], Martin Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2], and Andreas Wieck[2] — [1]Optoelectronic Devices and Materials, Ruhr-University Bochum, IC2/133, Universitätsstr. 150, 44780 Bochum, Germany — [2]Applied

solid state physics, Ruhr-University Bochum, NB03/58, Universitätsstr. 150, 44780 Bochum, Germany

Spin controlled vertical-cavity surface-emitting lasers (VCSELs) are very promising devices for future spintronic applications, because of their ability to amplify electron spin information. We could show amplified polarization degrees by all optical test experiments in an InGaAs/GaAs-VCSEL at room temperature [1, 2]. Here we present time-resolved polarization measurements of the optically pumped VCSEL showing a fast switching behaviour on a ps timescale between opposite circular polarization states in a single laser pulse. The complex polarization dynamics do not depend on carrier density, spin polarization or excitation wavelength alone, but are additionally influenced by inhomogenities and strain of the sample structure. Understanding the polarization dynamics is therefore a key issue on the way to electrically pumped Spin-VCSELs. Taking the time-resolved polarization measurements into account, design considerations for a future electrically pumped Spin-VCSEL for both room temperature as well as highly modulated polarization switching will be discussed.

[1] S. Hövel et al., Electronics Letters 41, 251 [2] N. Gerhardt et al., Electronics Letters 42, 88

HL 23.3 Tue 14:30 H14

Bulk inversion and structure inversion asymmetry in (110) semiconductor quantum wells — •P. Olbrich[1], V. V. Belkov[1,2], D. Schuh[1], W. Wegscheider[1], W. Prettl[1], and S. D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, 93040, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Instituete, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Quantum well structures prepared on (110)-oriented GaAs substrates are interesting for spintronics because of considerably longer spin relaxation times compared to (001)-oriented QWs. This is due to vanishing Rashba spin splitting in symmetrically grown (110)-oriented QWs. In asymmetric QWs the advantage of long spin relaxation times fades away. Here we demonstrate that the recently observed magneto-gyrotropic effect (MPGE) [1] provides a simple and direct access to symmetry properties of QWs. We show that excitation of symmetric (110)-oriented QWs with THz radiation results in the MPGE only for the magnetic field aligned parallel to growth direction while it vanishes for an in-plane magnetic field. For asymmetric QWs even the in-plane magnetic field causes an electric current whose strength increases with rising degree of asymmetry. Our measurements show that for (110)-grown QWs it is sufficient to have symmetrical doping from the both sides of QWs in order to exclude Rashba spin-splitting.

[1] S.D. Ganichev, V.V. Bel'kov, S.A. Tarasenko, S.N. Danilov, S. Giglberger, Ch. Hoffmann, E.L. Ivchenko, D. Weiss, W. Wegscheider, Ch. Gerl, D. Schuh, J. Stahl, J. De Boeck, G. Borghs, and W. Prettl, *Nature Physics* (London) **2**, 609 (2006).

HL 23.4 Tue 14:45 H14

Pure Spin Currents and Rashba Spin-Splitting in GaN Heterojunctions — •Wolfgang Weber[1], S. Seidl[1], L.E. Golub[2], S.N. Danilov[1], V.V. Belkov[1,2], W. Prettl[1], Z.D. Kvon[3], Hyun-Ick Cho[4], Jung-Hee Lee[4], and S.D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Institut of semiconductor physics, Novosibirsk, 630090 Russia — [4]Kyungpook National University, Korea

Gallium nitride is a potentially interesting material system for spintronics since it is expected to become ferromagnetic with a Curie-temperature above room temperature if doped with manganese and long spin relaxation times are detected in this material. Recently we observed that also a substantial Rashba spin-splitting in the electron band structure due to a large piezoelectric effect is present allowing spin manipulation by an electric field [1]. Here we report on the observation of a pure spin current in AlGaN/GaN heterostructures, an effect caused by the structural inversion asymmetry. It is achieved by spin-dependent scattering of electrons due a term in the scattering matrix elements linear in wavevector k. Experiments were carried out on hexagonal (0001)-oriented GaN heterostructures applying linear or circular polarized infrared and terahertz radiation. The effect has been detected in a wide range of temperatures from technologically important room temperature to 4.2 K.

[1] W. Weber, S.D. Ganichev et.al., Appl. Phys. Lett. **87**, 262106 (2005).

HL 23.5 Tue 15:00 H14

Spin-Orbit Coupling in AlGaN/GaN 2-Dimensional Electron Gases — •Sergio Cabañas, Nicolas Thillosen, Nicoleta Kaluza, Patrick Lehnen, Vitaliy Guzenko, Hilde Hardtdegen, and Thomas Schäpers — Institute of Bio- and Nanosystemes (IBN-1) and CNI Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, 52425 Jülich, Germany

AlGaN/GaN is a very promising material system for spin electronic devices, because for GaN-based diluted magnetic semiconductors Curie temperatures above room temperature have been predicted theoretically and confirmed experimentally. We have investigated weak antilocalization in AlGaN/GaN heterostructures. By fitting the experimental curves to a theoretical model we found that the decrease of the peak height in the conductivity with temperature is solely due to the decrease of the phase coherence length. Measurements on gated samples showed that the spin-orbit scattering length is constant for all carrier concentrations. This behavior is due to the fact that the spin-orbit scattering due to crystal inversion asymmetry is the dominant contribution. Although GaN is a large band gap material, the spin-orbit scattering length has a relatively small value of approximately 300 nm, which makes this material interesting for spin electron devices relying on spin precession. If a magnetic field is applied parallel to the plane of the 2-dimensional electron gas the weak antilocalization can be suppressed. We attribute the vanishing of the weak antilocalization peak to the additional contribution of the Zeeman energy competing with the characteristic spin-orbit energy.

HL 23.6 Tue 15:15 H14

Spin-orbit coupling in InGaSb-based two-dimensional electron gas — •Vitaliy Guzenko[1], Masashi Akabori[2], Thomas Schäpers[1], Sergio Cabañas[1], Taku Sato[2], Toshi-kazu Suzuki[2], and Syoji Yamada[2] — [1]Institute of Bio- and Nanosystems (IBN 1), Reserach Centre Jülich, 52425 Jülich, Germany — [2]Center for Nano-Materials and Technology (CNMT), Japan Advanced Institute of Science and Technology (JAIST), 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan

Two-dimensional electron gases (2DEG) formed in high-mobility InGaSb-based heterostructures with high indium content are promising candidates for spintronic applications because of their strong spin-orbit coupling and large g-factor. To investigate these properties magnetoconductance measurements around zero magnetic field (localization measurements) as well as in strong magnetic fields (coincidence method) were performed. A pronounced enhancement of magnetoconductance at $B = 0$ T due to the weak antilocalization effect was observed, which is an unambiguous indication of the spin-orbit coupling in these samples. Experimental curves measured as a function of temperature could be fitted by a theoretical model [1], and a quantitative estimation of the characteristic scattering times was done. By the coincidence method g-factor as large as 31 could be determined. By applying an additional constant magnetic field in the plane of 2DEG a strong suppression of the weak antilocalization peak was achieved. This is a qualitative confirmation of the result of the coincidence measurements. [1] M.M.Glazov and L.E.Golub, Semicond. **40** (2006) 1209.

HL 23.7 Tue 15:30 H14

Digital magneto resistance in ferromagnetic resonant tunneling diodes — •Christian Ertler and Jaroslav Fabian — Institute of Theoretical Physics, University of Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany

The development of ferromagnetic dilute magnetic semiconductors has paved the way for novel all semiconductor spintronic device concepts. For example, spin dependent resonant tunneling in magnetic double barrier heterostructures with either a ferromagnetic or a paramagnetic quantum well have already been investigated both experimentally and theoretically.

In this talk a novel spintronic device, which consists of two serial connected resonant tunneling diodes, is proposed. One diode is non-magnetic whereas the other comprises a ferromagnetic emitter and quantum well. Using a selfconsistent coherent transport model we show that the current-voltage characteristic of the ferromagnetic diode can be strongly modulated by changing the relative orientation of the magnetizations in the emitter and quantum well, respectively. By a continuous change of the relative magnetization angle the total resistance exhibits a discrete jump realizing digital magneto resistance. The interplay between the emitter's Fermi energy level and the relative magnetization orientations allows to tailor the current voltage characteristics of the ferromagnetic diode from ohmic to negative differential resistance regime at low voltages. The proposed spintronic device might be useful for a very fast detection of magnetically stored

information or magnetic random access memory applications.

HL 23.8 Tue 15:45 H14

Giant anisotropic magnetoresistance in ultrathin (Ga,Mn)As films — •R.R. Gareev, M. Döppe, M. Schlapps, J. Sadowski, M. Sperl, G. Bayreuther, W. Wegscheider, and D. Weiss — 1Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31 D-93040 Regensburg

We report on the giant anisotropic magnetoresistance (GAMR) effect, which we observed in ultrathin (Ga,Mn)As films close to the metal-insulator transition (MIT). We prepared 5nm-thick $Ga_{0.95}Mn_{0.05}As$ films ontop (Al,Ga)As buffer layer followed by subsequent annealing. Finally, for films with optimized carrier-mediated ferromagnetism and a well-defined MIT we obtained the Curie temperature $Tc \approx 90K$ and hole concentration $p \approx 4 * 10^{20} cm^{-3}$. We studied magneto-transport properties using Hall bars for different orientations of magnetic field H and both longitudinal Rxx and transverse Rxy components of resistance. We found that below MIT ($T < 20K$) both Rxx and Rxy components become comparable. Moreover, both components show enhanced magnetization-regulated magnetoresistance, which we relate to delocalization of carriers dependent on orientations of magnetization and current. In the planar geometry of H both Rxx and Rxy demonstrate reproducible multi-step switching patterns, which are symmetric to the direction of H. In the planar geometry of H the AMR is enhanced and exceeds 100

HL 24: Quantum dots and wires: Transport properties II

Time: Tuesday 14:00–17:00 Location: H15

HL 24.1 Tue 14:00 H15

The 0.7-anomaly in the conductance of a quantum point-contact and its interpretation in a Kondo model — •Monika Fleischer[1], Daniel Schefzyk[1], David Wharam[1], David Ritchie[2], and Michael Pepper[2] — [1]Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen, Germany — [2]Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, United Kingdom

Starting from the earliest transport measurements on quantum point-contacts, the existence of a so-called "0.7-anomaly" can often be observed in the differential conductance around $0.7 \cdot 2e^2/h$, in addition to the quantized steps at multiples of $2e^2/h$. This anomaly has since been found to be an intrinsic feature, presumably of spin-related origin. Still, there exists no theory to fully describe it. In a model suggested by Cronenwett et al. [1], it is analyzed in the framework of Kondo physics, postulating a localized spin-state in the point-contact region at low electron densities - a possibility which has recently been theoretically confirmed by Rejec and Meir [2]. In this talk, measurements are presented that exhibit a distinct 0.7-anomaly in the first and 0.7-analogue in the second step as well as a zero bias anomaly in the nonlinear data of the first step. An analysis of these characteristics in view of the proposed Kondo model shows that in many respects, the phenomenology of the data is well described by it, but that a number of open questions remain.

[1] S. Cronenwett et al., Phys. Rev. Lett. 88, 226805 (2002).
[2] T. Rejec and Y. Meir, Nature 442, 900 (2006).

HL 24.2 Tue 14:15 H15

Sound-wave-like collective electronic excitations in atomic-scale conductive chains — •Tadaaki NAGAO — National Institue for Materials Science (NIMS), Tsukuba

In his pioneering work in 1950, Tomonaga has theoretically proven the existence of a sound-wave like excitation in one-dimensional array of Fermi particles that follows Bose statistics [1]. We have been searching for such one-dimensional (1D) collective excitation in high electron density-limit in atomic-scale conductive chains supported on semiconductor substrates. Electron energy loss spectroscopy using highly collimated slow electron beam has detected a characteristic sound wave-like excitations that propagate along the chains showing strong anisotropy [2]. These excitations are strongly dipole active and their lifetime rapidly drops as a function of momentum. From these features, the observed losses are identified as one-dimensional collective excitation (plasmon) that Tomonaga has mentioned. These plasmons shows highly metallic feature such as high intensity near the elastic peak, but at low temperatures (<70K), some of these plasmons show reduced density of states which indicates gap opening at the Fermi level, due to Peierls-type metal to insulator transition. [1] S. Tomonaga, Progress of Theoretical Physics Vol. 5, No.4, 544 (1950). [2] T. Nagao, S. Yaginuma, T. Inaoka, S. Sakurai, Phys. Rev. Lett. 97, 116802 (2006).

HL 24.3 Tue 14:30 H15

Theory of super-Poissonian noise in tunneling through a quantum dot stack — •Gerold Kiesslich[1], Eckehard Schöll[1], Frank Hohls[2], and Rolf Haug[2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin — [2]Institut für Festkörperphysik, Universität Hannover, Appelstr. 2, D-30167 Hannover

The tunneling current through two layers of self-organized quantum dots which are vertically aligned (quantum dot stacks) provides sharp resonances in the current-voltage characteristics when the bias voltage is varied. The additional measurement of the shot noise reveals positive temporal correlations (super-Poissonian noise) close to these current peaks [1] associated with a bunching of tunneling events. This phenomenon is discussed in terms of a sequential tunneling model for a single quantum dot stack demonstrating that it can be explained by the sole effect of Coulomb interaction between electrons inside the stack [2].

[1] P. Barthold, F. Hohls, N. Maire, K. Pierz, and R. J. Haug. Phys. Rev. Lett. **96**, 246804 (2006).
[2] G. Kiesslich, E. Schöll, F. Hohls, and R. J. Haug. in preparation (2007).

HL 24.4 Tue 14:45 H15

Full counting statistics on a single dot device — •C. Fricke[1], F. Hohls[1], M. Reinwald[2], W. Wegscheider[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We show full counting statistics analysis on a coupled system including a quantum dot and a quantum point contact. We use a GaAs / AlGaAs heterostructure containing a two-dimensional electron system (2DES) 34 nm below the surface. The lateral quantum dot and the quantum point contact (QPC) are defined by the atomic force microscope (AFM) using local anodic oxidation (LAO). Our device allows us to control independently the quantum point contact and all tunnelling barriers of the quantum dot. We perform time resolved measurements [1] of the current through the QPC detector. We are able to detect individual electrons entering or leaving the dot up to a tunnelling rate of 30 KHz. We use these features to directly analyze counting statistic of single electrons passing through the quantum dot [2].

[1] L. M. K. Vandersypen et al., Appl. Phys. Lett. 85, 4394 (2004)
[2] S. Gustavsson et al., Phys. Ref. Lett. 96, 076605 (2006)

HL 24.5 Tue 15:00 H15

Quantum Description of Nuclear Spin Cooling in a Quantum Dot — Henning Christ, Ignacio Cirac, and •Geza Giedke — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching

We study theoretically the cooling of an ensemble of nuclear spins coupled to the spin of a localized electron in a quantum dot. We obtain a master equation for the state of the nuclear spins interacting with a sequence of polarized electrons that allows to study quantitatively the cooling process including the effect of nuclear spin coherences, which can lead to "dark states" of the nuclear system in which further cooling is inhibited. We show that the inhomogeneous Knight field mitigates this effect strongly and that the remaining dark state limitations can be overcome by very few shifts of the electron wave function, allowing for cooling far beyond the dark state limit. Numerical integration of the master equation indicates that polarizations larger than 90% can be achieved within a millisecond timescale.

HL 24.6 Tue 15:15 H15

Magnetic-field-induced modification of the wave-functions in InAs quantum dots — •Wen Lei[1], Oliver Wibbelhoff[1], Christian Notthoff[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Department of Physics, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany — [2]Solid State Physics, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum, Germany

The wave-function of electrons and holes in quantum dots (QDs) are very important for their properties and device applications. In this work, we present the wave-function mapping of InAs quantum dots by C-V spectroscopy under additional perpendicular magnetic field. Without perpendicular magnetic field, the energy states commonly labeled as "p-states" show an x-y-symmetry, oriented along the [110] and [1-10] crystal axes. When a perpendicular magnetic field (Bz) is applied, the magnetic forces are expected to mix the x- and y- states such that two circularly symmetric states (P+ and P-) with different angular momenta (l=+1 and l=-1) develop. Contrary to these expectations, we observe that the wave-functions of P+ and P- states behave differently. With increasing the perpendicular magnetic field, the wave-function of P+ state gradually develops circular symmetry with a node in the center, as expected from the theory. Surprisingly, the P- state behaves similarly but exhibits the characters of a *s-state* under high perpendicular magnetic field. The possible reasons for this unusual behavior of P- state are proposed and discussed.

15 min. break

HL 24.7 Tue 15:45 H15

Simulation of quantum transport in semiconductor nanocolumns with non-uniform lateral confinement — •Katharina Peter, Klaus Michael Indlekofer, Jakob Wensorra, Mihail Ion Lepsa, Hans Lüth, and Detlev Grützmacher — Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, D-52425 Jülich

Semiconductor nanocolumns have attracted great interest due to their unique transport properties.

We present a numerical simulation of electronic transport in semiconductor nanocolumns based on a Green's function approach. With this simulation we investigate the effects of the presence of a saddle-point in the potential caused by doping and Fermi-level pinning [1]. Due to this confining potential, mixing of the lateral modes can occur which gives rise to additional fine structures in the current-voltage characteristics.

Assuming cylindrical symmetry of the column we expand the lateral wave function in a basis of Bessel functions to calculate the non-equilibrium Green's functions, which provide the electron density and the current in the nanocolumn.

[1]K. M. Indlekofer, M. Goryll, J. Wensorra, M. I. Lepsa, cond-mat/0609057, submitted (2006)

HL 24.8 Tue 16:00 H15

Multiple Transitions of the Spin Configuration in Quantum Dots — •Maximilian C. Rogge, C. Fühner, and R. J. Haug — Institut für Festkörperphysik, Universität Hannover, Appelstr. 2, 30167 Hannover

We have found multiple transitions of the spin configuration in a lateral quantum dot in high magnetic fields reflecting a sort of Hund's rule. These transitions are detected in a combined spin blockade/Kondo effect chessboard pattern. Both effects show well known patterns of periodic features with equal periodicity. The transitions of the spin configuration appear either as a swap of the spin blockade pattern or as a swap in the Kondo pattern. These swaps reflect a change of the spin configuration at the edge of the two-Landau-level quantum dot with increasing electron number. A change of the spin polarization back and forth is observed rather than a continuously increasing spin polarization.

[1] M. C. Rogge, C. Fühner, R. J. Haug, Phys. Rev. Lett. **97**, 176801 (2006)

HL 24.9 Tue 16:15 H15

Quantenkinetik eines Quantendraht-Quantenpunkt-Systems: Wellenfrontdynamik nach räumlich homogener Anregung — •Doris Reiter, Vollrath Martin Axt und Tillmann Kuhn — Institut für Festkörpertheorie, Westfälische Wilhelms Universität Münster,Deutschland

Wir betrachten die räumlich homogene, optische Anregung eines Halbleiter Quantendrahts mit einem eingebetteten Quantenpunkt. Nach der Anregung führen phonon-induzierte Streuprozesse zu Übergängen zwischen den delokalisierten Drahtzuständen und den lokalisierten Zuständen im Quantenpunkt. Durch die Lokalität der Streuprozesse entstehen räumliche Inhomogenitäten in der Ladungsträgerdynamik, die u.a. zum Aufbau einer sich entlang des Drahtes ausbreitenden Wellenfront führen. Die Dynamik wird quantenkinetisch berechnet, so dass sowohl die Energie-Zeit als auch die Orts-Impuls Unschärfen vollständig berücksichtigt werden. Eine wichtige Rolle in der theoretischen Beschreibung spielen Kohärenzen zwischen den Zuständen. Es zeigt sich, dass auch im hier betrachteten Fall der homogenen Anregung Kohärenzen notwendig sind, um eine physikalisch sinnvolle Beschreibung der raumzeitlichen Dynamik des Systems zu erhalten.

HL 24.10 Tue 16:30 H15

Realistic simulation of nanowire transistors: A multi-configurational approach to Coulomb effects — •Klaus Michael Indlekofer[1], Joachim Knoch[1], and Joerg Appenzeller[2] — [1]CNI, IBN-1, Research Center Jülich GmbH, D-52425 Jülich, Germany — [2]IBM T. J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York 10598, USA

We employ a novel multi-configurational Green's function approach (MCSCG) [1,2] for the simulation of Coulomb effects in nanowire transistors. The improvement of the MCSCG stems from a self-consistent adaptive division of the large channel Hilbert space into a small subsystem of resonantly trapped states for which a many-body Fock space approach becomes numerically feasible and a strongly coupled rest which can be treated adequately on a mean-field level. The Fock space description allows for the calculation of few-electron Coulomb charging effects beyond mean-field.

We compare a conventional mean-field non-equilibrium Green's function calculation with the results of the MCSCG. Using the MCSCG method, Coulomb diamonds are obtained at low temperatures while under high temperature conditions the mean-field approximation is retained. From the simulated Coulomb-blockade characteristics we derive effective system capacitances. Quantum confinement effects give rise to corrections, which are crucial for the interpretation of experimentally determined capacitances.

[1] K.M. Indlekofer et al., Phys. Rev. B **72**, 125308 (2005).
[2] K.M. Indlekofer et al., Phys. Rev. B **74**, 113310 (2006).

HL 24.11 Tue 16:45 H15

Theory of quantum computation with all-electronic Mach-Zehnder interferometers — •Tobias Zibold and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present a realistic theoretical analysis of an all-electronic Mach-Zehnder interferometer realized by two electrostatically defined quantum wires in a GaAs/AlGaAs 2DEG. In contrast to electronic Mach-Zehnder interferometers based on quantum Hall edge channels, no magnetic fields are employed. The phase shift between the quantum wires can be controlled electrostatically by the same external gates that also define the quantum wires. This allows for a simple layout of the gates with none of the lateral scales below 40 nm. We calculate the ballistic I-V characteristics of the fully three-dimensional, open device using a single-band effective mass description for the electronic Hamiltonian including the Hartree potential self-consistently. We show that the interferometer can be employed as a single qubit gate. The DC I-V characteristics exhibit multiple pronounced switches that can be attributed to rotations of the qubit on the Bloch sphere. We find that these rotations depend critically on the crossing of two resonances in the coupling windows that connect the quantum wires and act as beam-splitters. Thus, the size of the coupling windows is most important for the operation of the Mach-Zehnder interferometer as a single qubit gate.

HL 25: Quantum dots and wires: Optical properties II

Time: Tuesday 14:00–17:00 Location: H17

HL 25.1 Tue 14:00 H17

Raumtemperatur-Emission von CdSe/ZnSSe/MgS Einzel-Quantenpunkten — •Robert Arians[1], Tilmar Kümmell[1], Gerd Bacher[1], Arne Gust[2], Carsten Kruse[2] und Detlef Hommel[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, 47057 Duisburg — [2]Institut für Festkörperphysik, Universität Bremen, 28359 Bremen

Ein essentieller Schritt zur Realisierung einer auf Quantenpunkten basierenden Raumtemperatur-Einzelphotonenquelle ist die Detektion des Emissionssignals eines einzelnen Quantenpunktes bei Raumtemperatur. Hierzu sind Materialsysteme mit großem elektronischen Einschluss und hoher Quantenausbeute erforderlich.

Wir untersuchen selbstorganisierte, epitaktisch gewachsene CdSe-Quantenpunkte mittels Mikro-Photolumineszenz-Messungen. Im Vergleich zu CdSe/ZnSe-Quantenpunkten zeigen Quantenpunkte, die in ZnSSe/MgS-Barrieren eingebettet sind, eine deutlich erhöhte Quantenausbeute bei 300 K. Zwischen 4 K und 300 K wird eine Reduktion der Emissionsintensität von lediglich einem Faktor 3 beobachtet. Dadurch ist es gelungen, Raumtemperatur-Emission von einzelnen Quantenpunkten nachzuweisen. Bei Raumtemperatur finden wir eine Linienbreite von 25 meV, vergleichbar mit der Biexziton-Bindungsenergie in diesem Materialsystem. Diese Eigenschaften machen das System CdSe/ZnSSe/MgS zu einem attraktiven Kandidaten für Einzelphoton-Bauelemente.

HL 25.2 Tue 14:15 H17

Optical properties of single InGaN quantum dots — •Sandra Herlufsen, Kathrin Sebald, Henning Lohmeyer, Jürgen Gutowski, Tomohiro Yamaguchi, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Germany

InGaN quantum dots (QDs) are a promising material for laser structures in the blue to UV spectral region. Before the development of such devices, it is necessary to fully understand the optical properties of the QDs. We will present micro-photoluminescence (μ-PL) measurements on single InGaN QDs grown by metal-organic vapor phase epitaxy. Access to their optical properties can be obtained through the investigations of mesa structures prepared by focused-ion-beam etching. Results achieved by μ-PL measurements will be reported in dependence on the excitation density. The observation of antibinding multiexciton complexes as well as indications for recombination processes from excited states of these complexes will be discussed. The assignment of different emission lines to the same QD was possible on the base of the investigation of the spectral diffusion which occurs due to temporal trapping of carriers in the vicinity of the QD. Temperature dependent μ-PL measurements give indications for the localisation depth of the QDs. Furthermore, the polarisation characteristics of single-QD emission was investigated in order to gain information about the shape and the orientation of the QDs in the sample.

HL 25.3 Tue 14:30 H17

Optically detected resonance studies of diluted magnetic semiconductor quantum dots — •Michael Gerbracht[1], Gregor Bartsch[1], Piotr Wojnar[2], Dmitri Yakovlev[1], Ulrike Woggon[1], Jacek Kossut[2], and Manfred Bayer[1] — [1]Experimentelle Physik II, Universität Dortmund, Otto-Hahn-Str. 4, D-44227 Dortmund, Germany — [2]Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warszawa, Poland

Diluted magnetic semiconductor quantum dots (Cd,Mn)Te/ZnTe grown by molecular-beam epitaxy have been studied by optically detected resonance (ODR) technique in magnetic fields up to 15 T. The photoluminescence (PL) of samples has been measured with and without additional illumination of far infrared (FIR) radiation with photon energies of 7.6, 10.5 and 12.8 meV. Strong changes of the excitonic photoluminescence induced by FIR radiation have been found at magnetic fields below 1T. Measurements performed for different FIR energies, various temperatures and for samples with different Mn contents varied from 0 up to 4% allow us to conclude that the ODR signal is caused by heating of the spin system of magnetic Mn ions. Also the competition of intrinsic and exchange contributions to the Zeeman splitting of excitonic states have been recognized as a decrease of the Zeeman splitting at high magnetic fields.

HL 25.4 Tue 14:45 H17

Low treshold stimulated emission in Yb-doped ZnO-nanowires — •Sebastian Geburt[1], Daniel Stichtenoth[1], Sven Müller[1], Wilma Dewald[1], Carsten Ronning[1], Juan Wang[2], and Quan Li[2] — [1]II. Institute of physics, University of Göttingen, Freidrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Department of Physics, Chinese University of Hong Kong, Shatin, Hong Kong

Rare earth elements embedded in suitable matrices show optical active intra-4f-transitions with long life-times. Such states are necessary e.g. for the realization of Nd:YAG-lasers. Because of their geometry, semiconductor nanowires could act as cavity; therefore, rare earth doped semiconductor nanowires may be suitable for nanosized lasers.

ZnO nanowires were grown by the VLS mechanism using the vapour transport technique, dispersed in 2-propanol and spincoated on clean Si-substrates. Yb was implanted with a box like profile and different fluences. In order to remove the implantation damage, the nanowires were annealed at 700°C for 30min in oxygen atmosphere.

The morphology was examined by SEM and HR-TEM. The remaining implantation damage increased with increasing fluences, thin nanowires showed a stronger morphology change and roughening of the surface occured. EDX and EELS measurements showed effective incorporation of the RE elements with the desired concentrations. The optical properties were investigated using PL. The measurements showed a sharp intense peak at 1.26eV associated with intra-4f-transitions of Yb with a low quenching up to room temperature. The power dependend measurements indicate stimulated emission.

HL 25.5 Tue 15:00 H17

Thermal annealing of selected individual quantum dots — •Robert Seguin, Andrei Schliwa, Tim Germann, Sven Rodt, Konstantin Pötschke, Udo Pohl, and Dieter Bimberg — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, D-10623 Berlin, Germany

Cathodoluminescence spectra of single InAs/GaAs quantum dots were recorded before and after consecutive thermal annealing steps. The annealing process leads to an overall blueshift of the spectra indicating In/Ga interdiffusion. Excitonic fine-structure splitting and binding energies of charged and neutral excitonic complexes were monitored. A drastic reduction of the fine-structure splitting from 170 μeV to less than 20 μeV can be observed accompanied by a change of the character of the biexciton from anti-binding to binding with respect to the exciton. Tailoring the fine-structure splitting is especially important for the use of single quantum dots in opto-electronic devices for quantum key distribution where a degeneracy of the exciton ground state (i.e. a fine-structure splitting below the homogeneous linewidth) is required for the on-demand production of entangled photon pairs.

HL 25.6 Tue 15:15 H17

Temperature-induced crossover between bright and dark exciton emission in silicon nanoparticles — •Cedrik Meier[1], Stephan Lüttjohann[1], Matthias Offer[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Physics Department, University of Duisburg-Essen, D-47048 Duisburg, Germany — [2]Combustion \& Gas Dynamics, University of Duisburg-Essen, D-47048 Duisburg, Germany

Silicon nanoparticles are attractive candidates for photovoltaic and optoelectronics applications, as they allow to combine the advantages of a semiconducting material with the ease of handling of dispersed particles. Moreover, the availability of silicon and the scalability of heterogenous gas-phase synthesis routes are promising for low-cost devices. We have studied the excitonic fine structure of silicon nanoparticles by time-resolved and magnetic-field dependent photoluminescence. The results are analyzed using the common model of an excitonic fine structure consisting of a bright and a dark exciton. We find that the radiative recombination rates of both excitons differ only by a factor of eight. This makes it possible to thermally switch the nature of the recombination from bright-exciton-like to dark exciton-like. The validity of our model is further supported by magnetic-field dependent measurements, in which effects of state mixing are observed. We show that silicon nanoparticles offer a unique possibility to directly assess dark exciton photoluminescence.

15 min. break

HL 25.7 Tue 15:45 H17

Influence of $In_{0.15}Ga_{0.85}As$ capping layers on the valence and conduction band structure of InAs quantum dots — •Mirja Richter[1,2], Dirk Reuter[1], Jean-Yves Duboz[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications, CNRS, Sophia-Antipolis, F-06560 Valbonne

We have prepared self-assembled InAs quantum dots (QDs) capped by GaAs and $In_{0.15}Ga_{0.85}As$, respectively, by molecular beam epitaxy. The $In_{0.15}Ga_{0.85}As$ cap layer shifts the ground state photoluminescence (PL) emission from 1261 nm to 1319 nm, which might be useful for telecommunication purposes. The QDs were embedded into n- or p-type capacitance-voltage ($C(V)$) structures to investigate the conduction and valance band states, respectively. The red-shift of the interband transitions due to the $In_{0.15}Ga_{0.85}As$ layer observed in PL is compared to the shift of the corresponding energy levels obtained from $C(V)$ measurements. The shifts of the ground states obtained from $C(V)$ spectroscopy sum up to 42 meV, which is in good agreement with 43 meV observed in PL measurements. A small difference could be caused by a change in the exciton binding energy. From the 42 meV overall red-shift, 83 % originate from the conduction and only 17 % from the valence band. This is probably due to the smaller effective mass in the conduction band, so that here changes in the confinement potential result in larger changes in the energy levels.

HL 25.8 Tue 16:00 H17

Optical Investigations of Single Pairs of Vertically Stacked Asymmetric InP Quantum Dots — •Matthias Reischle[1], Gareth Beirne[1], Robert Rossbach[1], Michael Jetter[1], Heinz Schweizer[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Coupled quantum dots (QD) are interesting candidates for future devices, such as, quantum gates for quantum computers. While most of the previous studies concentrated on double dot systems with similar dot sizes relatively few studies have concentrated on asymmetric quantum dot pairs. Nevertheless, this system is easier to realize, as QDs naturally exhibit size inhomogenities.

Single vertically stacked pairs of InP QDs that are separated by different barrier widths have been investigated. We could, on average, produce smaller upper dots that emit at higher energies than the bottom layer of dots. This arrangement allows for the tunneling of carriers from the small dots to the large dots. We have found that coupling is clearly present for a small barrier width, while for a large barrier width the dots are found to act independently. A transition from primarily electron tunneling to exciton tunneling with decreasing barrier width has also been found by comparing the photoluminescence spectra. In addition, from time-resolved measurements we could estimate the tunneling times which are in accordance with those presented previously in the literature. Finally we simulate our results using a simple rate equation model which supports the proposed tunneling mechanism.

HL 25.9 Tue 16:15 H17

Time-resolved optical spectroscopy of lateral InGaAs quantum dot molecules — •Claus Hermannstädter[1], Gareth Beirne[1], Lijuan Wang[2], Armando Rastelli[2], Oliver Schmidt[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

We demonstrate direct control over the level of lateral quantum coupling between two self-assembled InGaAs/GaAs quantum dots. These coupled systems which we refer to as lateral quantum dot molecules are, due to their unique growth technique, all aligned along the [1-10] crystal direction. Electrodes on the sample surface allow for the application of a lateral electric field. By applying an electric field parallel to the coupling-axis the degree of coupling can be manipulated as manifested by the shift of the emission energies and relative intensities of the characteristic photoluminescence lines [1]. Time-correlated single-photon counting experiments performed on single molecules provide access to both the rise and decay characteristics of the molecule emission lines. Typical decay times for the excitonic recombination are on the order of 1 ns, about half the latter value for biexcitonic recombination, and intermediate for charged excitonic recombination. An analysis of the exciton rise behavior strongly indicates that electron tunneling is the predominant coupling mechanism in the molecules.

[1] G. J. Beirne, C. Hermannstädter, L. Wang, A. Rastelli, O. G. Schmidt and P. Michler, Phys. Rev. Lett. 96, 137401 (2006).

HL 25.10 Tue 16:30 H17

Gain reduction in Semiconductor Quantum Dots — •Michael Lorke, Jan Seebeck, Paul Gartner, and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen

In recent years, semiconductor quantum dots (QDs) have been studied extensively due to possible applications in optoelectronic devices like LEDs, lasers, or amplifiers. In the rapid emerging field of quantum information technology, QDs have been successfully used to demonstrate the generation of single photons or correlated photon pairs. Furthermore, the strong coupling regime for QD emitters in optical microcavities has been demonstrated. A common aspect in these fundamental studies and for practical applications of QDs is the critical role of dephasing processes. They determine the homogeneous linewidth of the QD resonances, limit the coherence properties of QD lasers and theirultrafast emission dynamics, and have a strong influence on coherentoptical nonlinearities.

A microscopic theory is used to study the optical properties of semiconductor quantum dots. The dephasing of a coherent excitation and line-shifts of the interband transitions due to carrier-carrier Coulomb interaction and carrier-phonon interaction are determined from a quantum kinetic treatment of correlation processes which includes non-Markovian effects.

We find a strong saturation and even reduction of the optical gain with increasing carrier density. For this dependencies of the peak gain on carrier density we present new fitting functions for these dependencies.

HL 25.11 Tue 16:45 H17

Phonon interactions in InGaAs/GaAs quantum dots — •Stefan Werner, Patrick Zimmer, André Strittmatter, and Axel Hoffmann — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623, Berlin, Germany

In recent years, carrier-phonon interactions in semiconductor quantum dots have attracted considerable attention. They are important to understand the electronic properties of such systems, like carrier relaxation processes. Some are convinced that carriers confined in quantum dots are strongly coupled to the longitudinal optical (LO) vibrations of the semiconductor lattice. We report on exciton-phonon interactions in InGaAs/GaAs quantum dots. Photoluminescence and time-resolved experiments were performed on different MOCVD-grown InGaAs/GaAs samples to observe and investigate varying phonon interactions. In our measurements we observed photoluminescence peaks constantly shifting with varied excitation energy. The energy gap between the laser-peak and the observed two-peak structure remained unchanged. The ΔE-values of 33,8 meV and 36,9 meV precisely fit to the QD LO-Phonon mode and to the interface mode, respectively. The very short radiative lifetime also points to inelastically scattered phonons, i.e. Raman scattering.

HL 26: Interfaces/surfaces

Time: Tuesday 16:00–17:00 Location: H14

HL 26.1 Tue 16:00 H14

Exact solution for the capacitance of a current-free Schottky diode — •Matthias Schmidt, Holger von Wenckstern, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Halbleiterphysik, Linnéstraße 5

C-V measurements on Schottky diodes are a widely used technique to determine doping profiles and barrier heights of the sample. Commonly the Schottky approximation (completely depleted space charge region) is assumed to be valid. This is not the case for moderate forward bias. We present an exact solution for the capacitance of a homogenously doped space charge region considering free carriers. Within the framework of this solution the free carrier concentration in the bulk material of a Schottky diode can be extracted from C-V data measured at different temperatures. The theoretical results will be used to evalutate experimental data.

HL 26.2 Tue 16:15 H14

Polarity of Space Charge Fields in Second-Harmonic Generation Spectra of Si(100)/SiO_2 Interfaces — Armin Rumpel[1], Bastian Manschwetus[1], Gerhard Lilienkamp[1], Harald Schmidt[2], and •Winfried Daum[1] — [1]Institut für Physik und Physikalische Technologien, TU Clausthal, Leibnizstr. 4, D-38678 Clausthal-Zellerfeld — [2]Institut für Metallurgie, TU Clausthal, Robert-Koch-Str. 42, D-38678 Clausthal-Zellerfeld

Optical second-harmonic generation (SHG) spectra of Si(100)/SiO_2 interfaces exhibit characteristic differences for positively or negatively charged space charge regions (SCRs). These differences originate from interference of second-harmonic light generated in the SCR with that generated by Si atoms in the immediate proximity to the oxide, and characterize the direction of the electric field of the SCR. The spectra are analyzed and modelled by Si interband resonances of the interface and of the SCR. The sensitivity of SHG to the polarity of the space charge is demonstrated for the negative space charge at alkali-modified Si(100)/SiO_2 interfaces, and for the positively charged accumulation layer caused by laser-induced surface traps in thin oxides. The shape of SHG spectra of Si(100)/SiO_2 interfaces in the 3.3-3.8 eV energy range is a signature of the sign of the prevailing interface/oxide charge at silicon interfaces.

HL 26.3 Tue 16:30 H14

Noninvasive Detection of Alkali Metal Ion Contaminations of Si(100)/SiO_2 Interfaces by Optical Second-Harmonic Generation — •Armin Rumpel[1], Bastian Manschwetus[1], Gerhard Lilienkamp[1], Harald Schmidt[2], and Winfried Daum[1] — [1]Institut für Physik und Physikalische Technologien, TU Clausthal, Leibnizstr. 4, D-38678 Clausthal-Zellerfeld — [2]Institut für Metallurgie, TU Clausthal, Robert-Koch-Str. 42, D-38678 Clausthal-Zellerfeld

Optical second-harmonic generation (SHG) is demonstrated as a non-destructive probe of alkali metal ion contaminations in Si(100)/SiO_2 gate oxide systems. Accumulation of sodium or potassium ions in the near-interface region of the oxide leads to a strong resonant enhancement of the SHG signal between 3.2 eV and 3.8 eV. This enhancement is caused by dc-electric-field-induced SHG in a negatively charged space charge region of the semiconductor. The temperature dependence of the SHG signal from a potassium-contaminated Si(100)/SiO_2 system, measured for a two-photon energy of 3.3 eV, exhibits a slow initial decrease followed by a steep rise of the signal at a temperature of about 380°C. The decrease of the signal is caused by the temperature dependence of the E_1 interband resonance while the strong increase indicates the onset of potassium diffusion from the surface of the oxide to the near-interface region. The accumulation of potassium near the Si(100)/SiO_2 interface of the heated sample has been verified by SIMS measurements.

HL 26.4 Tue 16:45 H14

electron microscopy on axiotaxy of $CrSi_2$ on Si(001) - from the micrometer- to the angstrom-scale — •Meiken Falke[1], Frank Allenstein[1], Olga Filonenko[1], Gunter Beddies[1], Steffen Schulze[1], Michael Hietschold[1], Koen De Keyser[2], and Christophe Detavernier[2] — [1]Instute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Universiteit Gent, Dept. of Solid-state Science, Krijgslaan 281/S1, 9000 Gent, Belgium

A recently [1] identified new type of thin film texture, the so-called axiotaxy, was found in thin CrSi2 films on Si (001) substrate. The films were grown under UHV conditions by MBE using a thin template. Two different epitaxial orientations forming additional domains respectively were identified using TEM and XRD. Additionally, EBSD and XRD pole-figures show a considerable part of the silicide film to consist of small crystallites with a texture axis inclined to the substrate. This texture with the rotation axis different from the substrate surface normal, called axiotaxy, provides one-dimensional periodicity at the crystallite substrate interface which seems to be energetically preferred and representing an initial growth state, probably common in many thin film systems. In particular $CrSi_2$ planes with plane distances close to the Si (110)- type distance are parallel to the four on Si(001) possible (110)-type substrate planes. The one-dimensional periodicity at the interface was investigated by conventional high resolution and aberration corrected transmission electron microscopy.

[1] C. Detavernier at al., Nature 426 (6979): 641-645 DEC 11 2003

HL 27: II-VI semiconductors

Time: Wednesday 14:15–17:30 Location: H13

HL 27.1 Wed 14:15 H13

Neue ungewöhnliche Diffusionsprofile in II-VI Halbleitern — •Jörg Kronenberg[1], Frank Wagner[1], Herbert Wolf[1], Thomas Wichert[1] und ISOLDE Collaboration[2] — [1]Technische Physik, Universität des Saarlandes, 66041 Saarbrücken — [2]CERN, CH-1211 Genf 23, Schweiz

Nach Implantation von ^{111}Ag und ^{67}Cu in die Halbleiter CdTe und CdZnTe und Diffusion unter Cd-Druck werden symmetrische Profilformen beobachtet, die in der Mitte des Kristalls eine hohe und in den bis 250 μm tiefen Randzonen eine niedrige Ag bzw. Cu Konzentration zeigen [1]. Diese unterscheiden sich von gewöhnlichen Diffusionsprofilen, die sich in einer monotonen Abnahme des Konzentrationsprofils äußern. In den hier vorgestellten Experimenten wurde untersucht, ob ähnliche Diffusionsprofile auch mit anderen Dotieratomen in II-VI Halbleitern beobachtet werden können. Hierfür wurden in CdTe, CdZnTe und CdS ^{24}Na, ^{43}K, ^{56}Mn, ^{65}Ni und ^{59}Fe mit einer Energie von 60 keV in 500 μm bis 800 μm dicke CdTe, CdS oder CdZnTe Einkristalle implantiert und diese zwischen 750 K und 900 K getempert. Ähnliche Effekte wie für Ag oder Cu in CdTe konnten für ^{24}Na in CdTe und CdS sowie für ^{65}Ni in CdZnTe beobachtet werden. Für ^{43}K, ^{56}Mn und ^{59}Fe dagegen konnten in keinem der drei untersuchten Materialien solche Profile gefunden werden.

Gefördert durch das BMBF, Projekte 05KK1TSB/7 und CZE 3/002.

[1] H.Wolf *et al.*, Phys. Rev. Lett. 94 (2005) 125901.

HL 27.2 Wed 14:30 H13

Characterization of $Mg_xZn_{1-x}O$-layers grown by plasma assisted molecular beam epitaxy — •Thomas Andreas Wassner, Bernhard Laumer, Stefan Maier, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

$Mg_xZn_{1-x}O$ layers have been grown epitaxially on (0001)- and (11-20)-sapphire by plasma assisted molecular beam epitaxy. Structural analysis was carried out by high resolution X-ray diffraction to extract the lattice parameters as well as the density of edge- and screw dislocations as a function of the Mg content. The impact of Mg incorporation on the optical properties was investigated by temperature-dependent photoluminescence spectroscopy and photothermal deflec-

tion spectroscopy. The corresponding electronic properties were investigated by Hall measurements. Furthermore, the influence of the growth parameters (e.g. the substrate temperature) on the resulting Mg content in the layers will be addressed.

HL 27.3 Wed 14:45 H13

Conductivity measurements on ZnO/YBaCuO — •Nilotpal Ghosh[1], Heidemarie Schmidt[1], Qingyu Xu[1], Lars Hartmann[1], Holger Hochmuth[1], Michael Lorenz[1], Gerald Wagner[2], and Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany — [2]Institut für Mineralogie, Kristallographie und Materialwissenschaft, Linnéstr. 5,04103 Leipzig, Germany

200 nm magnetic ZnO films were grown on $Y_1B_2Cu_3O_7$(YBCO) films on sapphire by pulsed laser deposition for future Andreev Reflection (AR) study and to compare with previous spin polarization results [1]. Initial critical current density of 6×10^6 A/cm^2 of YBCO at 77K [2] slightly reduced after growth of granular ZnO film and critical temperature was above 77K. Four-point transport measurements across ZnO/YBCO junction (area $\gg 1$ mm^2) resulted in nonlinear I-V characteristics in 5-150 K. Noisy conductivity fluctuations noticed at lower T at 0 bias were probably due to large junction area lying in Maxwell range (where $d \gg l$, d = contact radius, l = mean free path). Fitting of conductivity data after Blonder-Tinkham-Klapwijk theory showed that superconducting gap (Δ) of YBCO and interface dependent ZnO/YBCO barrier strength (Z) amount to $\Delta \leq 20.4$ (± 1) meV and $Z \geq 0.74$ (± 0.23) respectively. Smaller junction area AR measurements and Point contact AR measurements are underway. [1] L. Hartmann,etal, J. Phys. D.: Appl. Phys. 39(2006)1. [2] M.Lorenz, etal,IEEE Transactions on Applied Superconductivity 11 (2001) 3209.

HL 27.4 Wed 15:00 H13

II-VI based magnetic resonant tunneling devices — •Daniel Supp[1], Taras Slobodskyy[1], Anatoly Slobodskyy[1], Tanya Borzenko[1], Charles Gould[1], Georg Schmidt[1], Laurens W. Molenkamp[1], and David Sanchez[2] — [1]Experimentelle Physik 3, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Departament de Fisica, Universitat de les Illes Baleares, E-07122 Palma de Mallorca, Spain

Resonant tunneling diodes (RTDs) with magnetic materials are promising spin-transport devices, since their spin-dependent filter effect makes it possible to manipulate and detect the spins of electrons. To realize such a device in ZnMnSe is itself generally quite arduous. We have however developed a technique using a proper buffer stack to not only reliably fabricate them, but also to produce different variations of the layout, as for example RTDs with a magnetic injector, double RTDs or RTDs with a double quantum-well. Structured devices at the micron and sub-micron scale allow us to further analyze them and enhance their usability. Our structures confirm the spin-polarization of the current and gated RTDs are good candidates for transistor effects and studies of vertical quantum dots.

This work was funded in part by the DFG and ONR.

HL 27.5 Wed 15:15 H13

Optimierung von ZnSe-basierten leitfähigen Bragg-Spiegeln — •Kai Otte, Carsten Kruse und Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee, 28359 Bremen

Hochreflektive Bragg-Spiegel (DBR) sind ein Schlüsselbaustein für oberflächenemittierende Laserdioden mit Vertikalresonator (VCSEL). Diese Spiegel, bestehend aus einer ZnSSe Schicht als Hochindexmaterial und einem MgS/ZnSe Übergitter als Niedrigindexmaterial wurden mittels Molekularstrahlepitaxie auf GaAs Substraten gewachsen. Mit diesen Schichten können Reflektivitäten von über 99% erreicht werden. Das ZnSe Materialsystem ermöglicht das Wachstum von DBRs im Wellenlängenbereich von 460nm bis über 600 nm.

Die Optimierung des Wachstums dieser Spiegel ist von entscheidender Bedeutung hinsichtlich der optischen und elektrischen Eigenschaften von VCSELn.

Dotierte DBRs ermöglichen die Herstellung von elektrisch betriebenen VCSEL-Strukturen. Die erzielbare Leitfähigkeit hängt stark von der Art der Dotierung und der Periodenzahl der Bragg-Spiegel ab.

HL 27.6 Wed 15:30 H13

Spin polarization in $Zn_{0.95}Co_{0.05}O$:(Al,Cu) thin films — •Lars Hartmann, Qingyu Xu, Heidemarie Schmidt, Holger Hochmuth, Michael Lorenz, Chris Sturm, Christoph Meinecke, Annette Setzer, Pablo Esquinazi, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

ZnCoO:Al, ZnCoO:(Al,Cu), and reference samples without Co have been grown by pulsed laser deposition to investigate the influence of Co-dopants and Cu-codopants on the magneto transport properties of ZnO. Positive magnetoresistance (MR) and anomalous Hall effect (AHE) have been observed for ZnCoO:(Al,Cu). Negative MR was observed in the Cu-codoped ZnO reference sample without Co [1]. Spin dependent scattering by isolated magnetic Cu impurities causes the observed negative MR in the reference sample [2]. The modeling of negative MR yields an electron spin polarization of 42% at 5 K and a Curie temperature T_C of 45 K. Possibly due to the complete ionization of intrinsic donors or Al donors in ZnO, above 50 K the MR is dramatically reduced. We also observed clear AHE in the Cu-codoped ZnCoO thin film. The AHE cannot be observed in ZnCoO without Cu-codopants. The observed temperature dependence of positive MR and magnetization hints towards a direct dependence of both effects. The simulation and understanding of the positive MR will provide key information for the enhancement of the intrinsic magnetization.

[1]L. Hartmann et al., J. Phys. D: Appl. Phys. **39** (2006). [2]M. Csontos et. al, Phys. Rev. Lett. **95** (2005).

15 min. break

HL 27.7 Wed 16:00 H13

Sputter deposition at high substrate temperatures and characterization of ZnO, ZnO:P and ZnO:N films — •Sebastian Eisermann, Joachim Sann, Swen Graubner, Christian Neumann, Stefan Lautenschläger, Niklas Volbers, Angelika Polity, and Bruno Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Deutschland

Pure ZnO, phosphorous and nitrogen doped ZnO thin films have been prepared on quartz glass, sapphire, gallium nitride, and zinc oxide substrates at temperatures up to 750°C by radio-frequency (RF) sputtering using pure ZnO and doped ZnO/P2O5 (1wt%) ceramic targets in pure argon, in a mixture of argon and oxygen or in a mixture of argon, oxygen and nitrogen (N2).

By optimizing the sputter parameters, such as sputtering power, temperature of the substrate or Ar/O2/N2 sputtering gas ratios, high quality films were obtained. The thin film crystallinity and surface morphology has been investigated with X-ray diffraction (XRD), atomic force (AFM) and scanning electron microscopy (SEM). Optical properties have been examined by measuring optical transmission and photoluminescence (PL) spectra. Hall measurements were carried out to check electric properties. Secondary Ion Mass Spectrometry (SIMS) measurements have been performed to determine the distribution of phosphor and nitrogen, respectively, in the doped layers.

HL 27.8 Wed 16:15 H13

Magnetization dynamics in parabolic and half-parabolic quantum wells based on (Cd,Mn)Te diluted magnetic semiconductors — •Marcel Arlt, Martin Kneip, Dimitri Yakovlev, and Manfred Bayer — Experimentelle Physik 2a, Otto-Hahn-Str.4, 44227 Dortmund

The technological concept of "digital alloying" brought about by molecular-beam epitaxy turned out to be a very effective tool for tailoring static and dynamic properties of diluted magnetic semiconductor nanostructures. We have investigated parabolic and half parabolic quantum wells (PQWs and HPQWs) by digital growth technique and show the possibility to accelerate the temporal evolution of magnetization dynamics. Spin-lattice relaxation dynamics of the Mn-spin system has been measured by time-resolved photoluminescence for the sample temperature of 2.5K and external magnetic fields up to 10T. Mn spin system has been heated by pulsed photoexcitation and evolution of emission line energy has been detected by gated CCD (1). Two-exponential decay was found in HPQW, contrary to single-exponential one in PQW. Effects of spin diffusion in the Mn spin system on the magnetization dynamics are discussed. (1) M.K. Kneip et al., Appl. Phys. Lett. 88, 152105 (2006).

HL 27.9 Wed 16:30 H13

Near bandgap photoluminescence spectroscopy of ZnO nanowires embedded in PMMA — •Jan-Peter Richters, Lars Wischmeier, Ilja Rückmann, and Jürgen Gutowski — Institute of

solid state physics, University of Bremen, P.O. Box 330440, D-28334 Bremen

Due to their large surface-to-volume ratio and the photon confinement, ZnO nanowires are expected to be good candidates for applications in nanoscaled optoelectronics in the blue spectral region and for sensor applications. For some reasons it is useful to embed the ZnO nanowires into a surrounding matrix to influence the surface or interface states and the waveguiding properties. Here, we report about studies of the low-temperature photoluminescence (PL) of ZnO nanowires embedded in the polymer PMMA. For this we used VLS grown ZnO nanowire ensembles to prepare insular wire samples. Wires were stripped from the ensemble, dissolved in PMMA and acetone, and finally spin-coated on aluminium substrates. For measurements on single wires we used a micro-PL setup. PL spectra of the nanowire ensemble, of single wires without matrix and single wires embedded in PMMA were studied and compared. In general the near-band-edge spectra are dominated by D^0X bound-exciton lines, by an asymmetric surface exciton band (SX), and by phonon replicas. Due to the PMMA matrix the intensity ratios of the above mentioned lines are strongly changed. Additionally the green defect luminescence is suppressed.

HL 27.10 Wed 16:45 H13

Photocurrent spectroscopy of deep levels in ZnO thin films — •Heiko Frenzel, Holger von Wenckstern, Alexander Weber, Heidemarie Schmidt, Gisela Biehne, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

Fourier transform infrared photocurrent (FTIR-PC) spectroscopy has been used as complementary method to deep level transient spectroscopy (DLTS) to investigate deep defect levels in ZnO thin films grown by pulsed laser deposition (PLD) on a-sapphire substrate. FTIR-PC spectra of undoped ZnO layers show several well-resolved features between 100 meV and 500 meV due to transitions from deep defect states either to the conduction band or to the valence band. In addition to the commonly observed intrinsic levels E1 at ∼110 meV and E3 at ∼320 meV, FTIR-PC is also able to probe transitions with smaller electron capture cross-sections like L1 at ∼160 meV and L2 at ∼260 meV which are typically not observable in ZnO thin films via DLTS. Influences of growth and annealing conditions have been investigated to gather informations about the microscopic origin of deep levels in ZnO. Further results will be shown including Co- and Mn-doped ZnO thin films [1] and a N^+-implanted ZnO single crystal [2], where acceptor like transitions are visible.
[1] M. Diaconu *et al.*, Solid State Communications **137**, 417 (2006).
[2] G. Brauer *et al.*, Phys. Rev. B **74**, 045208 (2006).

HL 27.11 Wed 17:00 H13

Density of states and optical properties of MgO, ZnO and CdO — •André Schleife, Frank Fuchs, Claudia Rödl, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

In the last years ZnO attracted interest because of its potential application for optical devices. Alloys or heterostructures of ZnO with MgO and CdO or even magnetic materials (for spintronic applications) are discussed. From a theoretical point of view the (semicore) d-electrons are a challenging problem.

Employing first-principles calculations, the theoretical understanding has been pushed forward into two directions: First, using non-local functionals in the context of a generalized Kohn-Sham approach we obtain a DFT starting point which is more suitable for a perturbation-theory calculation of quasiparticle energies using the GW-approximation. This enables us to compute densities of states (DOS) from first principles which are in good agreement with experimental results. Second, ab initio optical spectra for the bulk have been calculated by solving the Bethe-Salpeter equation. This approach allows the investigation of bound states below the quasiparticle-gap as well as the computation of the dielectric function which is compared with measurements.

We present promising results and we are confident of being able to extend the application of this approach towards the parameter-free description of alloys or even heterostructures of these oxides.

HL 27.12 Wed 17:15 H13

Resonant Raman Scattering and Recombination Dynamics in Homoepitaxial-Grown and Single Crystal ZnO — •Markus R. Wagner[1], Patrick Zimmer[1], Axel Hoffmann[1], Stefan Lautenschläger[2], Joachim Sann[2], and Bruno K. Meyer[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen

Resonant Raman scattering in ZnO at low temperatures is investigated by applying a frequency doubled titan-saphire laser as tunable excitation source. The influence of exciton phonon interactions such as the deformation potential for non-polar optical phonons and the Fröhlich interaction for polar LO modes are discussed. We present experimental evidence for resonant Raman scattering in ZnO involving bound exciton. A strong enhancement of the $2E_1(LO)$ Raman mode for resonant excitation at energies of the dominant bound exciton lines is apparent. The magnitude of the resonance enhancement for the $2E_1(LO)$ Raman mode is found to vary in dependence of the resonantly excited bound exciton complex and is particular strong for excitation energies matching the I_8 line. These results will be discussed in terms of different coupling strengths of the Fröhlich interaction with the neutral and ionized bound exciton complexes. In addition, the recombination and decay dynamics of the bound excitons, phonon replicas and resonantly enhanced Raman modes are discussed. For resonant excitation, a decay constant of the $2E_1(LO)$ Raman mode is found, which is considerably longer as for regular Raman scattering. This result is discussed considering scattering via real excitonic versus virtual states.

HL 28: Optical properties

Time: Wednesday 14:15–16:30 Location: H14

HL 28.1 Wed 14:15 H14

Localized Optical Modes in Microtube Resonators containing InGaAs Quantum Wells — •Christian Strelow, Hagen Rehberg, Christoph Matthias Schultz, Holger Welsch, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

We report on optical modes in semiconductor microtube resonators containing InGaAs quantum wells. Self-supporting microtubes were fabricated by optical lithography and wet etching processes utilizing the self-rolling mechanism of a strained InAlGaAs/AlGaAs bilayer. On the low energy side of the quantum well emission we observe a signal of sharp modes ($Q \sim 2000$) which is about 10 times stronger than the background. Modes on the high energy side show much smaller Q-factors ($Q \sim 280$) caused by reabsorption of light. The modes are localized due to a confinement along the axis of the tube. We study the spatial intensity distributions. A theoretical model considering the tube as a rolled-up waveguide yields mode energies, which agree very well to the experimental results.

We acknowledge financial support from the Deutsche Forschungsgesellschaft via SFB 508 and the Graduiertenkolleg 1286.

HL 28.2 Wed 14:30 H14

Quantum kinetic theory of the electron-phonon-interaction in semiconductor intersubband systems — •Stefan Declair, Stefan Butscher, and Anreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The effect of quantum kinetic (non-Markovian) electron-phonon interaction for semiconductor intersubband transitions is investigated for acoustical and optical phonons. We discuss their influence to line width at low temperature. In this regime, even in weakly coupled systems, we find that electron-phonon interaction can lead to suppression of Coulomb binding effects (1).
(1) S.Butscher and A. Knorr, Phys. Rev. Lett. 97, 197401 (2006).

HL 28.3 Wed 14:45 H14

Microscopic investigations of luminescence from multi-

ple quantum-well structures — •Marco Werchner, Martin Schafer, Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps-University, Renthof 5, D-35032 Marburg, Germany

Multiple quantum-well (QW) structures provide one-dimensional realizations of resonant photonic crystals where the periodic arrangement of emitters can drastically influence the photonic modes. As a consequence, luminescence from multiple QWs can be considerably different from the single QW case. The theoretical modeling of such non-classical light emission of multiple QWs requires a consistent treatment by a microscopic theory for the quantum-well electrons and the quantized light field.

It is shown that the radiative coupling between the periodically spaced QWs yields a strong reduction of the normalized light emission. This incoherent subradiant effect is shown to increase with increasing QW number. It is present for all QW spacings but strongest for Bragg structures. Clearly, the suppression of the radiative decay results in an enhancement of the exciton lifetime. Moreover, the direct creation of ground-state excitons is shown to be possible via the radiative coupling between the QWs.

HL 28.4 Wed 15:00 H14

Optical Deep Level Transient Spectroscopy on ZnO — •R. Weirauch, R. Pickenhain, H. v. Wenckstern, M. Lorenz, G. Biehne, and M. Grundmann — Institut für Experimentelle Physik II,Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

We investigate the optical activity of deep defects in ZnO thin films grown by pulsed laser deposition on sapphire substrates using Optical Deep Level Transient Spectroscopy (ODLTS). The high quality Schottky diodes [1] are investigated by CV, IV, photocurrent spectroscopy and DLTS [2] prior to the ODLTS measurements. Measurements at the low temperature side of the thermal DLTS peak and utilizing a lock-in correlation function are necessary conditions to assure that thermal emission rates from the traps can be neglected [3]. We observe optical induced carrier emission and absorption processes and determine the optical cross sections of deep levels within the space charge region of a Schottky barrier.

[1] H. v. Wenckstern, G. Biehne, R. A. Rahman, H. Hochmuth, M. Lorenz, M. Grundmann, Appl. Phys. Lett. **88**, 092102 (2006).
[2] H. v. Wenckstern, S. Weinhold, G. Biehne, R. Pickenhain, H. Schmidt, H. Hochmuth, and M. Grundmann Adv. in Sol. Stat. Phys., Vol. **45**, 263, (2005).
[3] R. Pickenhain, H. Schmidt, V. Gottschalch, J. Appl. Phys. **88** 2, 948, (2000).

HL 28.5 Wed 15:15 H14

Carrier Capture by Ionized Impurities in ZnO Epilayers — •Frank Bertram, Juergen Christen, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Universitaetsplatz 2, 39106 Magdeburg

The kinetics of relaxation and recombination processes of excitons in an epitaxial-grown thick ZnO layer has been examined using time-resolved cathodoluminescence. The unique feature of this technique allows the full analysis of excitation from thermal equilibrium into true steady state condition and the subsequent relaxation back into thermal equilibrium. The high quality 8 μm thick ZnO epi-layer under study was grown by MOVPE on an optimized ZnO/GaN/sapphire template. At T = 4 K the luminescence is dominated by the impurity bound exciton (BE) I_8. The free exciton X_A, the BEs I_1, I_2, and I_6, as well as I_9 are clearly visible. No spectral shift with time is observed for all excitons - neither during onset nor during decay. However, a distinct change in intensity ratio of I_8 and I_9 as compared to I_1 and I_2 is found in time delayed spectra. The excitons bound to a neutral impurity I_8 and I_9 exhibit a delayed, strictly mono-exponential decay over three orders of magnitude which is initially fed by the capture of the free exciton X_A ($\tau_{loc} \geq 95ps$). In complete contrast, the ionized impurity bound excitons I_1 and I_2 show a non-exponential decay starting with a very fast initial decay followed by a slower component exhibiting strong persistence. The fast initial drop results from the carrier capture by the ionized donors ($\tau_{capture}(I_{1,2}) \geq 300ps$) resulting in their neutralization - thus feeding the neutral bound excitons.

HL 28.6 Wed 15:30 H14

Cathodoluminescence spectroscopy of point defects in AlN — •Barbara Bastek[1], Frank Bertram[1], Thomas Hempel[1], Juergen Christen[1], Armin Dadgar[1,2], and Alois Krost[1,2] — [1]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]AZZURRO Semiconductors AG, Magdeburg, Germany

A set of AlN layers MOVPE grown on (111) Si-substrate is characterized by spectrally resolved cathodoluminescence (CL) microscopy at temperatures from 5K to 300K. The growth conditions were systematically changed: III-V-ratio, growth temperature (T_G) and pressure. A clear correlation between the growth conditions and the luminescence intensity of four different defects in the samples is found and their thermalization is analyzed. In all samples a broad band occurs at 3.28eV which is assigned to the oxygen-DX-center. We observe a strong thermal activation of this defect, perfectly described by an Arrhenius-function yielding an activation energy of 9meV and a quenching energy of 85meV, respectively. For growth under extensive N-supply, this band competes with (D^0, X) and a second defect band shows up at 4.6eV which we assign to the Al-vacancy. The intensity of V_{AL} decreases monotonously with rising temperature and the Arrhenius-fit yields two quenching energies of 9meV and 55meV. In contrast, for moderate N-supply during growth V_{AL} is completely gone and (D^0, X) dominates the spectrum. At high T_G a weak CL band appears at 3.91eV, which we tentatively assign to a Si-related DX-center accounting for the Si substrate. This defect shows a slight activation with rising temperature, however, the quenching dominates its temperature dependence.

HL 28.7 Wed 15:45 H14

Micro-Photoluminescence studies of individual InP-nanowires grown by low pressure MOVPE — •Steffen Münch[1], Stephan Reitzenstein[1], Carolin Hofmann[1], Alfred Forchel[1], Shanna Crankshaw[2,3], Linus Chuang[2,3], Michael Moewe[2,3], and Connie Chang-Hasnain[2,3] — [1]Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Applied Science and Technology group, University of California at Berkeley, Berkeley, California, 94720 — [3]Department of Electrical and Computer Engineering, University of California at Berkeley, Berkeley, California, 94720

Optical studies have been performed on individual InP nanowires grown by low pressure MOCVD on B-doped (100) Si substrates using Gold catalysts. By means of micro photoluminescence experiments at low temperature we determined the radial confinement potential of individual nanowires. Confinement energies between 25 and 56 meV were derived which are related to the radial confinement of the electron and hole wave function in nanowires with diameters between 14 and 21 nm. The high quality of the nanowires is reflected in narrow emission peaks with full width at half maximum of only 2 meV. Temperature dependent investigations reveal that thermally activated nonradiative recombination processes lead to a decrease of photoluminescence intensity above approx. 25 K which is associated with a decrease of the photoluminescence decay time from about 2.5 ns at 4 K down to about 1.4 ns at 27 K.

HL 28.8 Wed 16:00 H14

Fringe field induced modification of the coherent spin dynamics in GaAs — Patric E. Hohage[1], •Jörg Nannen[1], Tilmar Kümmell[1], Gerd Bacher[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Werkstoffe der Elektrotechnik, University Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg, Germany — [2]Angewandte Festkörperphysik, Ruhr-University Bochum, Universitätsstr. 150, 44780 Bochum, Germany

Ferromagnet-semiconductor hybrids are promising candidates for spin manipulation in potential spintronic devices. Using time-resolved Kerr rotation, we studied the coherent evolution of electron spin states in both ferromagnet-GaAs hybrids and pure n-GaAs bulk crystals. The experiments on n-GaAs allow us to extract the oscillation frequency of the electron spin beats up to room temperature, which is controlled by the electron g factor and the external magnetic field. By defining lithographically microscale ferromagnets on top of the semiconductor, we are able to locally manipulate the oscillation frequency of the electron spins due to the influence of the additional ferromagnetic fringe field. Compared to reference measurements in bulk GaAs, we find an enhancement of the electron spin precession frequency e.g. of 1.1 GHz at an external magnetic field of 1 T by using Co wires with a width of 6 μm and an interwire distance of 1 μm. Thus, even tiny fringe fields in the order of several mT result in a measurable change of the precession frequency.

HL 28.9 Wed 16:15 H14

Hochauflösende Spektroskopie an 1S-Paraexzitonen in Cu_2O — •Jan Brandt[1], Dietmar Fröhlich[1], Christian Sandfort[1], Manfred Bayer[1], Heinrich Stolz[2] und Nobuko Naka[3] — [1]Institut für Physik, Universität Dortmund, D-44221 Dortmund, Deutschland — [2]Fachbereich Physik, Universität Rostock, D-18051, Deutschland — [3]Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan

Wir präsentieren Ergebnisse zur optischen Resonanz des 1S-Paraexzitons der gelben Serie in Cu_2O. Mittels hochauflösender Laserspektroskopie ($\Delta E <$ 10neV) wurden in Magnetfeldern bis 10T die Temperatur- und Dichteabhängigkeit der Transmission untersucht. Das 1S-Paraexziton ist ein reiner Spin-Triplet-Zustand und hat Γ_2^+-Symmetrie. Daher ist die optischen Anregung in allen Ordnungen verboten. Durch Anlegen eines Magnetfeldes mischt es mit den 1S-Orthoexzitonen und wird quadrupolerlaubt. In spannungsfrei montierten Proben wurden bei 1.2K Linienbreiten bis 80neV gemessen. Aus den Transmissionsexperimenten werden die Kopplung der Paraexzitonen an LA-Phononen abgeleitet und Rückschlüsse zur Exziton-Exziton-Wechselwirkung gezogen und ein entsprechendes Modell präsentiert.

HL 29: Symposium THZ interactions

Time: Wednesday 14:15–16:45 Location: H15

Invited Talk HL 29.1 Wed 14:15 H15

Interaction of semiconductor laser dynamics with THz radiation — •Martin Hofmann — AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, 44780 Bochum

We discuss the generation and detection of THz radiation with semiconductor diode lasers. First, we analyse the generation of THz radiation by investigating a semiconductor laser in an external cavity arrangement that supports two colour operation with tunable difference frequency. Weak tunable THz emission is detected directly out of the diode laser, i.e. without external photomixing. We discuss the physical mechanisms underlying this direct THz emission and the potential of this concept in terms of THz bandwidth and an increase of the emitted THz power.

In the second part of the talk, the opposite process, i.e. THz detection with diode lasers is investigated. For that purpose, we inject THz radiation into the active region of a diode laser and analyse its dynamics under this injection. We observe a voltage variation over the p-n-junction depending on the injected THz power and compare the measured signal to the response of a standard Golay cell.

Finally, we review our results with particular emphasis on completely diode-laser based THz imaging or spectroscopy systems.

Invited Talk HL 29.2 Wed 14:45 H15

Ultrafast THz Spectroscopy of Carrier Correlations in Complex Materials — •Robert A. Kaindl — Department of Physics, UC Berkeley and Materials Sciences Division, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Coulomb interactions in a many-body system can lead to correlated states with fundamentally new physical properties. I will discuss experiments that employ coherent THz pulses and direct field-resolved detection to probe time-varying correlations of photoexcited electron-hole pairs and Cooper pair condensates. The THz electromagnetic response of short-lived exciton states in bulk and nanoscale semiconductors shows characteristic inter-level transitions in analogy to atoms. Intra-excitonic spectroscopy provides new tools to measure and control exciton gases. I will review experiments that trace the temperature, density, excitation energy, and time dependence of intra-excitonic resonances, to directly map out excitonic phase diagrams and to follow exciton formation and ionization kinetics. Moreover, in single-walled carbon nanotubes, THz pulses enable a contact-less detection of charge conductivity. In high-Tc superconductors, the THz-frequency electromagnetic response couples directly to Cooper pair condensates and to quasiparticle excitations. We observe transient changes in the THz conductivity of Bi-2212 that occur after ultrafast depletion of the superconducting condensate. The temporal decay reveals a bimolecular kinetics of charge pair formation. Work performed in collaboration with M. A. Carnahan, D. Hägele, R. Huber, B. A. Schmid, Y. Ma, G. Fleming, S. Oh, J. Eckstein, and D. S. Chemla.

Invited Talk HL 29.3 Wed 15:15 H15

Interaction of THz Radiation with Semiconductor Nanostructures: Microscopic Theory — •Stephan Koch and Mackillo Kira — Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, 35032 Marburg

In this talk we review our microscopic approach to treat the interaction of excited semiconductor nanostructures with THz radiation. We use a systematic expansion of the relevant many-body interaction contributions, showing that THz absorption must involve at least two- or more-particle correlations. This feature uniquely qualifies THz spectroscopy as a method to directly detect and identify many-body correlations in a system of incoherent quasi-particle excitations. Applications of the theory to analyze excitonic population generation [1,2], the dynamic build-up of plasmon excitations [3,4], excitonic population inversion and THz gain [5], as well as THz generation in two-color semiconductor lasers [6] will be discussed.

[1] R. A. Kaindl et al., Nature 423, 734 (2003) [2] M. Kira et al., Solid State. Com. 129, 733 (2004) [3] R. Huber et al., Nature 414, 286 (2001) [4] M. Kira and S.W. Koch, Prog. Quant. Electron. (2007) [5] M. Kira and S.W. Koch, Phys. Rev. Lett. 93, 076402 (2004) [6] S. Hoffmann et al., Appl. Phys. Lett. 84, 3585 (2004)

Invited Talk HL 29.4 Wed 15:45 H15

Nonlinear terahertz and midinfrared response of n-type GaAs — •Michael Woerner[1], Peter Gaal[1], Wilhelm Kühn[1], Klaus Reimann[1], Thomas Elsaesser[1], Rudolph Hey[2], and Klaus Ploog[2] — [1]Max-Born-Institut , Berlin — [2]Paul-Drude-Institut, Berlin

In most THz experiments the THz radiation is used as a linear probe. Using THz radiation for nonlinear excitation requires the ability to generate high enough THz intensities. Our recent development of a simple and reliable method to generate THz pulses with high electric field amplitudes [1] has paved the way for nonlinear optics in the THz regime. We present two experiments on n-type GaAs which are in strong contrast to the predictions of Drude theory: (i) Nonlinear propagation of intense THz pulses through a thin n-type GaAs layer shows a coherent emission at 2 THz with a picosecond decay of the emitted field, despite the ultrafast carrier-carrier scattering at a sample temperature of 300 K [2]. While the linear THz response is in agreement with the Drude response of free electrons, the nonlinear response is dominated by the super-radiant decay of optically inverted impurity transitions. (ii) A nonlinear THz pump–midinfrared probe experiment shows a quantum kinetic phenomenon of the electron–LO phonon dynamics. Ultrafast acceleration of free carriers in n-type GaAs in a strong THz field results in an oscillatory occurrence of midinfrared gain/absorption with the LO phonon frequency. [1] T. Bartel et al., Opt. Lett. 30, 2805 (2005). [2] P. Gaal et al., Phys. Rev. Lett. 96, 187402 (2006).

Invited Talk HL 29.5 Wed 16:15 H15

Terahertz near-field microscopy — •Roland Kersting[1], Federico Buersgens[1], and Gyu Cheon Cho[2] — [1]University of Munich, Munich, Germany — [2]IMRA America, Ann Arbor, MI, USA

Many efforts in modern semiconductor physics target the integration of nano-objects and one important step towards this goal is the characterization of the nano-materials' electronic properties. Terahertz spectroscopy allows for studying the electronic response directly in the time domain, but the long wavelength of THz radiation (1 THz corresponds to about 0.3 mm) limits the spatial resolution to rather macroscopic scales.

In this contribution we present an apertureless near-field scanning optical microscope (ANSOM) for the THz range, which allows for spatial resolutions down to 150 nm. These extreme subwavelength resolutions are achieved by concentrating the incident THz radiation with a metal tip to a near-field spot, which's diameter is comparable to the tip's apex. The unexpected high image contrast of the THz-ANSOM results from a novel imaging process where the dielectric response of the material shifts the THz resonance of the sampling metal tip. The method is suitable for investigating the dielectric response of electrons in semiconductors. Currently, the sensitivity is sufficient to map as

few as 5000 electrons. Further developments in apertureless terahertz microscopy may open up new vistas towards the contactless characterization of electronic quantum states in semiconductors.

HL 30: Hybrid systems

Time: Wednesday 14:15–14:45 Location: H17

HL 30.1 Wed 14:15 H17

Nanomechanical control of an optical antenna — •Annika Zuschlag, Jörg Merlein, Matthias Kahl, Alexander Sell, Andreas Halm, Johannes Boneberg, Paul Leiderer, Alfred Leitenstorfer, and Rudolf Bratschitsch — Fachbereich Physik und Centrum für angewandte Photonik (CAP), Universität Konstanz, D-78464 Konstanz, Germany

We mechanically tune the length and feedgap of a single gold bowtie antenna by precise nanomanipulation with the tip of an atomic force microscope. The nanoantenna consists of two gold nanotriangles fabricated with a colloidal nanomask. The optical response of the nanostructure is determined via dark-field scattering spectroscopy. We find no unique single antenna resonance. Instead, the plasmon mode splits into two dipole resonances. The exact three-dimensional shape of the nanoantenna is the reason for this effect, as may be seen in discrete dipole approximation calculations of the backscattering spectra of single nanostructures with differently-shaped antenna arms.

HL 30.2 Wed 14:30 H17

Hybrid Systems made out of Carbon Nanotubes and the Photosynthetic Reaction Center I (PS I) — Itai Carmeli[2], Markus Mangold[1], Bernd Zebli[1], Klaus-Dieter Hof[1], Ludmila Frolov[2], Chanoch Carmeli[2], Shacher Richter[2], and •Alexander Holleitner[1] — [1]Center of NanoScience (CeNS) and Department für Physik, LMU München, Germany — [2]Center for NanoScience, Tel Aviv University, Israel

We study the nanoelectronic properties of hybrid systems made out of carbon nanotubes (CNTs) and the photosynthetic reaction center (PS I). Generally, the utilized PS I can be found in the thylakoid membranes of cyanobacteria and it mediates light-induced electron transfer in the photosynthesis [1]. The nano-sized dimension, the generation of 1V photovoltage, the energy yield of approximately 58%, and a quantum efficiency of almost 100% makes the PS I reaction center a promising unit for applications in molecular nano-optoelectronics. Utilizing a unique Cys mutation at the end of PS I by genetic engineering, we demonstrate that the reaction center can be coupled to carbon nanotubes (CNTs) via chemical self-assembly using carbodiimide chemistry [2]. The method allows studying hybrid nanosystems for the construction of optoelectronic devices based on PSI-CNTs heterostructures. Three different architectures of PSI-CNTs hybrid structures are presented which allow exploiting the potential of PS I as an integrated part of CNT devices for optoelectronic applications. [1] K. Brettel, Biochimica et Biophysica Acta 1318 , 322 (1997); [2] I. Carmeli, B. Zebli, L. Frolov, C. Carmeli, S. Richter, and A.W. Holleitner (2007).

HL 31: Quantum dots and wires: Optical properties III

Time: Wednesday 14:45–18:00 Location: H17

HL 31.1 Wed 14:45 H17

Measurement and control of spin and charge interactions in a single quantum dot molecule — •Emily Clark[1], Hubert Krenner[1], Christoph Scheurer[2], Toshihira Nakaoka[3], Max Bichler[1], Gerhard Abstreiter[1], and Jonathan Finley[1] — [1]Walter Schottky Institut, Technical University of Munich, Am Coulombwall 3, 85748 Garching, Germany — [2]Lehrstuhl für Theoretische Chemie, Technische Universität München, Lichtenbergstraße 4, 85748 Garching, Germany — [3]University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo, 153-8505, Japan

We report experiments in which we electrically manipulate coupled exciton states (neutral and negatively charged single excitons) in individual QD-molecules (QDMs). The samples investigated consist of a single pair of vertically stacked, self assembled $In_{0.5}Ga_{0.5}As$ QDMs embedded into the intrinsic region of an n-type GaAs Schottky photodiode. By tuning the electric field oriented along the axis of the QDM, via the gate voltage, electrons can be predictably injected into the QDM from the back contact. Field dependant micro-Photoluminescence measurements reveal a complex series of anti-crossing features from neutral excitons, negatively charged excitons and double charged excitons as the field is lowered. Each multi-particle configuration couples at a distinct field and unique energetic splitting, allowing for the unambiguous assignment of each spectral feature. We directly probe Coulomb and Pauli blockade effects and inter-dot tunnel coupling using fully optical techniques. See: H.J. Krenner, et. al Phys. Rev. Lett. 97, 076403 (2006)

HL 31.2 Wed 15:00 H17

Polarized emission lines from A- and B-type excitonic complexes in single InGaN/GaN quantum dots — •Momme Winkelnkemper[1,2], Robert Seguin[1], Sven Rodt[1], Andrei Schliwa[1], Lars Reissmann[1], Andre Strittmatter[1], Axel Hoffmann[1], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, D-14195 Berlin, Germany

Nitride-based semiconductor nanostructures have been widely studied in the last decade and revolutionary optoelectronic devices have emerged from this effort.

In this talk we report on a combined experimental and theoretical study of the optoelectronic properties of single InGaN/GaN quantum dots (QDs). Using single-QD cathodoluminescence, complex spectra with up to five emission lines per QD are observed. The lines are polarized along the orthogonal crystal directions [1 1 -2 0] and [-1 1 0 0].

Realistic eight-band k.p calculations reveal that the polarization of the emission lines is owed to the valence band structure of wurtzite group-III nitrides and the strain distribution within the QDs; it can be explained by excitonic recombinations involving hole states which are either formed by the A or the B valence band. The mechanism responsible for the polarization is a general feature of all wurtzite nitride-based QDs and is essential for the understanding of recombination processes in nitride QDs.

HL 31.3 Wed 15:15 H17

Switch-on process of an electrically pumped singlequantum dot — •Erik Stock[1], Anatol Lochmann[1], Till Warming[1], Dieter Bimberg[1], Vladimir A. Haisler[2], A. I. Toropov[2], A.K. Bakarov[2], and A.K. Kalagin[2] — [1]Technische Universität Berlin, Institut fürFestkörperphysik, Sekr. PN 5-2, Hardenbergstr. 36, 10623 Berlin,Germany — [2]Institute of Semiconductor Physics,Lavrenteva avenue 13, 630090 Novosibirsk, Russia

Self-organized single quantum dots (QD) are of great interest for the realization of single-photon sources. One of the main features is the possibility to generate entangled photons, which can be achieved by exciton and biexciton emission of a single QD with a fine structure splitting less then the homogeneous broadening.

We demonstrate electrically pumped single InAs/GaAs QD emission in a pin-diode with submicron oxide current aperture. This QD-LED allows pumping of just one single QD. Via the pump current exciton and biexciton emission can be controlled as required for entangled photons sources. In highly resolved spectra we observe the switch-on of the electroluminescence: First a single emission lines becomes visible. With increasing current this emission shifts towards higher energy and splits into up to three emission lines separated by $\sim 70\mu$eV. At higher

current they rejoin to form a single unpolarized emission line and stay on a fixed emission energy. This splitting of emission may influence the entanglement of emitted photon pairs and has to be considered for the development of electrically driven single photon sources.

HL 31.4 Wed 15:30 H17

Enhancement of electron spin coherence by optical preparation of nuclear spins — •Dimitrije Stepanenko[1], Guido Burkard[1], Geza Giedke[2], and Atac Imamoglu[3] — [1]Department of Physics and Astronomy, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Max Planck Institute for Quantum Optics, Hans Kopfermann Str. 1, Garching, Germany — [3]Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We study a large ensemble of nuclear spins interacting with a single electron spin in a quantum dot under optical excitation and photon detection. When a pair of applied laser fields satisfy two-photon resonance between the two ground electronic spin states, detection of light scattering from the intermediate exciton state acts as a weak quantum measurement of the effective magnetic (Overhauser) field due to the nuclear spins. If the spin were driven into a coherent population trapping state where no light scattering takes place, then the nuclear state would be projected into an eigenstate of the Overhauser field operator and electron decoherence due to nuclear spins would be suppressed: we show that this limit can be approached by adapting the laser frequencies when a photon is detected. We use a Lindblad equation to describe the time evolution of the driven system under photon emission and detection. Numerically, we find an increase of the electron coherence time from 5 ns to 500 ns after a preparation time of 10 microseconds.

HL 31.5 Wed 15:45 H17

Reliable parallel electrical initialization of spin-polarized electrons in InGaAs/GaAs quantum dots — W. Löffler, C. Mauser, J. Lupaca-Schomber, S. Li, T. Passow, H. Reimer, C. Klingshirn, M. Hetterich, and •H. Kalt — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

We show that electron spins can be initialized electrically with near 100% fidelity in InGaAs/GaAs quantum dots. This is done by injecting spin-polarized electrons from a semimagnetic spin-aligner layer (ZnMnSe) into the quantum dots. At a moderate external magnetic field (3-6 Tesla), we observe only emission from one of the Zeeman doublet states in the quantum dot. That means the initialization error is below our experimental resolution of about one percent. This result is surprising as the polarization of quantum dot ensembles is far below unity. To reveal the origin of this discrepancy, statistical analysis of the electron spin in many different quantum dots has been done.

HL 31.6 Wed 16:00 H17

Photon Statistics Of Semiconductor Microcavity Lasers — •Christopher Gies, Jan Wiersig, Michael Lorke, and Frank Jahnke — Institut für Theoretische Physik, Universität Bremen, Deutschland

When it comes to laser phenomena in quantum dot-based systems, usually atomic models are employed to analyze the characteristic behavior. We introduce a semiconductor theory, originating from a microscopic Hamiltonian, to describe lasing from quantum dots embedded in microcavities. The theory goes beyond two-level atomic models and includes modified contributions of spontaneous and stimulated emission as well as many-body effects. An extended version, which incorporates carrier-photon correlations, provides direct access to the photon autocorrelation function and thereby to the statistical properties of the laser emission. In comparison to atomic models, we find deviations in the dependence of the input/output curve on the spontaneous emission coupling factor. Our theory is presented together with measurements of first- and second-order coherence of quantum-dot micropillar lasers, obtained in the group of P. Michler.

15 min. break

HL 31.7 Wed 16:30 H17

Spin dynamics of coupled nuclear-electron system over millitesla magnetic fields in n-doped quantum dots — •Thomas Auer[1], Sergey Verbin[2], Roman Cherbunin[2], Ruth Oulton[3], Dmitri Yakovlev[1], Manfred Bayer[1], Dirk Reuter[4], and Andreas Wieck[4] — [1]Experimentelle Physik 2, Otto-Hahn-Strasse 4, 44227 Dortmund — [2]V. A. Fock Institute, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]University of Sheffield, Hicks Building, Hounsfield Rd, S3 7RH, Sheffield, UK — [4]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum

The hyperfine interaction between electrons and nuclei in quantum dots has a significant effect on the spin dynamics of both systems. The nuclear system may be polarized by optically pumping with spin polarized electrons, such that the often very large fields generated have a significant effect on the spin dynamics of the electron. In turn, the effective field from the electron (Knight field <1 mT) also strongly influences the spin dynamics of the polarized nuclei. By applying external magnetic fields of the same magnitude (few mT) one may access a rich variety of complex interactions between the two systems. We demonstrate that the Knight field, which is crucial in allowing nuclear polarization to occur at 0T, may be partially compensated by an external field. In addition, we demonstrate that the strongly-coupled electron-nuclear system, which in the absence of applied field forms a stable configuration with a sub-second spin lifetime, is strongly perturbed by the application of mT fields, with the lifetimes dramatically modified depending on field orientation.

HL 31.8 Wed 16:45 H17

Quantum kinetics of polarons in semiconductor quantum dots — •Jan Seebeck[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute for Materials Physics, Bucharest-Magurele, Romania

For applications of semiconductor quantum dots (QDs) in optoelectronic devices efficient carrier scattering processes are necessary. We study carrier-phonon scattering within a quantum kinetic theory of the interacting many-body system, where carriers are described as polarons. At elevated temperatures and low carrier densities, the interaction of carriers with LO phonons in semiconductor QDs leads to fast scattering channels even in QDs where the level spacing does not match the LO-phonon energy.

To investigate carrier dynamics experimentally, most pump-probe experiments are performed at low temperatures. We show, that even at low temperatures fast carrier scattering can be obtained with our theory due to the combined influence of polaron satellites and non-Markovian effects.

HL 31.9 Wed 17:00 H17

Influence of a lateral electric field on a semiconductor quantum dot — •Sandra Ritter[1], Norman Baer[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute for Material Physics, Bucharest-Magurele, Romania

We study semiconductor quantum dots in a homogeneous electric field which is oriented perpendicular to the growth direction. Assuming a harmonic confinement potential, three different methods for determining the single excitonic ground state are compared.
The first one determines the transition energies of the interacting system where Coulomb matrix elements are calculated from single-particle wave functions in the electric field. It can be solved analytically and gives insight into different physical mechanisms.
The second one minimizes the whole system energetically by using a variational procedure. This method is more accurate since it gives a smaller 1X ground state energy. However, its accuracy relies on a suitable choice of the test function.
For the third method it is assumed that the electron and hole single particle energies are identical. Then the Hamiltonian can be separated into a field independent center-of-mass contribution and a relative motion part that is subject to the electric field. The resulting shifts of the transition energies due to the electric field are determined.

HL 31.10 Wed 17:15 H17

Calculation of the vibronic progressions observed in the photoluminescence of Si nanocrystals — •Davoud Pouladsaz[1,2] and Reinhard Scholz[1] — [1]Walter Schottky Institut, Technische UniversitätMünchen, Am Coulombwall 3, 85748 Garching — [2]Institut für Physik, Technische UniversitätChemnitz, 09107 Chemnitz, Germany

The optical properties of H-passivated silicon nanocrystals are determined by the energetics of the frontier orbitals and their dependence on the deformation in the relaxed excited state. For tetrahedral nanocrystals up to a diameter of 1.5 nm, we have optimized the geometries in the electronic ground state and in the relaxed excited state with den-

sity functional theory (DFT) and time-dependent DFT, respectively. In the excited state, the modified occupation numbers of the frontier orbitals define an anisotropic change of the electronic charge density. Therefore, the deformation in the relaxed excited state consists of a symmetry conserving part and of a symmetry-breaking distortion from T_d towards D_{2d}. The projection of these different parts of the deformation pattern onto the vibrational modes in the electronic ground state generates the vibronic progressions observed in photoluminescence (PL). The lineshapes obtained from this projection scheme are compared with available experimental data, resulting in similar PL energies and linewidths.

HL 31.11 Wed 17:30 H17

Room-temperature storage of excitons in elongated semiconductor nanocrystals — •Robert Kraus[1], Pavlos Lagoudakis[1], Andrey Rogach[1], John Lupton[2], Jochen Feldmann[1], Dmitriy Talapin[3], and Horst Weller[3] — [1]Lehrstuhl für Photonik und Optoelektronik, Ludwig-Maximilians-Universität München — [2]Department of Physics, University of Utah, Salt Lake City, USA — [3]Institut für Physikalische Chemie, Universität Hamburg

The excited state of colloidal nanostructures consisting of a spherical CdSe core overgrown with a rod-like CdS shell can be perturbed effectively by electric fields.[1-3] Field-induced fluorescence quenching coincides with a suppression of radiative rate without increasing ionization. After turning off the electric field, a significant fraction of quenched - and therefore stored - excitons recombines radiatively, even for a duration of the electric field pulse of up to 100 μs. Application of an electric field not only promotes the separation of electron and hole wave function but also influences the depopulation dynamics of localised states on the surface of the nanocrystal. This leads to a significant change in the exponent of the characteristic power law decay of the delayed luminescence. Furthermore, exciton storage selects the most polarisable particles, therefore a significant quantum confined Stark shift of ˜15 meV along with a correlated broadening of the spectrum is visible in the time-resolved emission of the ensemble at room temperature.

[1] J. Müller et al., Phys. Rev. Lett. 93, 167402 (2004)
[2] R. Kraus et al., Phys. Rev. Lett. in press (2006)
[3] J. Müller et al., NanoLett. 5, 2044 (2005)

HL 31.12 Wed 17:45 H17

Single InGaAs Quantum Dots Embedded in Electrically Active Photonic Crystal Nanocavities — •Felix Hofbauer, Michael Kaniber, Max Bichler, Gerhard Böhm, Gerhard Abstreiter, and Jonathan Finley — Walter Schottky Institut, Am Coulombwall 3, TU München, 85748 Garching, Germany

We present investigations of the coupling of single InGaAs quantum dots (QDs) to both extended and strongly localised optical modes in electrical contacted 2D photonic crystal (PC) nanostructures. The samples investigated consist of an 180nm thick, free-standing GaAs membrane into which a PC is formed by etching a triangular lattice of air holes. Low mode-volume ($V < (\lambda/n)^3$) and high-Q (~ 2000) cavities are introduced by single missing hole defects. Embedding the QDs into the intrinsic region of a p-i-n diode enables us to apply static electric fields to QDs in the cavity and control the energy detuning between the dot and cavity using the quantum confined Stark effect.

The active PC nanocavities were studied using spatially resolved luminescence and photocurrent absorption spectroscopy. Quenching of the PL is observed for fields > 50 kV/cm due to carrier tunneling escape from the dots that occurs over timescales faster than the radiative lifetime. By measuring the PL quenching as a function of position on the PC and nanocavity we electrically probe the local density of photonic states via a shift of the threshold voltage. Also investigations of the exciton lifetime and PL intensity of single QDs as a function of spectral detuning from the cavity mode are made.

Supported financially via Sonderforschungsbereich-631

HL 32: C/diamond

Time: Wednesday 16:30–18:00 Location: H14

HL 32.1 Wed 16:30 H14

Diameter and density controlled synthesis of high quality carbon nanotubes via predefined gas phase prepared catalyst particles — •Franziska Schäffel, Christian Kramberger, Mark Rümmeli, Daniel Grimm, Thomas Gemming, Thomas Pichler, Bernd Büchner, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

Due to their excellent mechanical and electronic properties carbon nanotubes (CNTs) are promising candidates for the integration into nano-electro-mechanical systems such as nanorelays and actuators or transistors. Effective control of the CNT growth and positioning is however mandatory for the realization of any of these applications. We report on an innovative technique to grow CNT by chemical vapour deposition (CVD) using cyclohexane. Here, the catalyst particles are synthesized separately by inert-gas condensation using DC magnetron sputtering at pressures in the mbar range. This allows for the production of pure catalyst particles with a narrow particle size distribution. The particles act as individual nucleation sites for the growth of CNTs. The size of the particles and their spatial distribution template the diameter and the density of the resulting CNT, respectively. This use of separately generated particles provides significant advantages such as the possibility to engineer the size, morphology, spatial distribution, and mutual separation of the CNTs *prior* to the CVD process. The opportunity to characterize the catalyst particles prior to the CVD reaction together with post-CVD studies of the resulting CNTs provides superior insight into the CNT growth process.

HL 32.2 Wed 16:45 H14

Pressure-induced phenomena in single-walled carbon nanotubes — •K. Thirunavukkuarasu[1], C.A. Kuntscher[1], Á. Pekker[2], K. Kamarás[2], F. Hennrich[3], M. Kappes[3,4], and Y. Iwasa[5] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, P.O.Box 49, Budapest, Hungary H 1525 — [3]Institut für Nanotechnologie, Forschungzentrum Karlsruhe, D-76021 Karlsruhe, Germany — [4]Physikalische Chemie, Universität Karlsruhe, D-76128 Karlsruhe, Germany — [5]Institute for Materials Research, Tohoku University, Sendai 980-8577 (Japan)

The study of single-walled carbon nanotubes (SWNTs) under high pressure has attracted much interest recently as the application of pressure induces structural deformations of the SWNTs and also tunes the intertube interactions by changing the distances between the tubes. Both should significantly affect the properties of the SWNTs.

We studied the optical response of thin films of both unoriented and oriented SWNTs over a broad frequency range (IR-VIS) and for pressures up to 8 GPa. The effect of pressure on oriented nanotubes caused major changes in the optical properties only for the polarization along the nanotube axis. We will discuss in detail the effect of pressure on the electronic properties like interband transitions for the different SWNT films.

Supported by the DFG, Emmy Noether-program. Provision of beamtime at the ANKA Angströmquelle Karlsruhe is acknowledged.

HL 32.3 Wed 17:00 H14

Suppressed formation of electron-hole droplets in diamond under strain — •Nobuko Naka, Junko Omachi, and Makoto Kuwata-Gonokami — Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan

Recent advances in growing high-purity single crystal diamonds have led to new opportunities to investigate the optical properties of high-density electron-hole systems created by photo-excitation in diamond. At low temperature, droplets (EHD) of electron-hole pairs in the liquid phase coexist with excitons or plasmas in the gas phase [1,2]. Shimano et al. [2] studied the formation dynamics of the EHD by applying time-resolved luminescence spectroscopy to a type IIa diamond crystal grown by high-temperature, high-pressure synthesis. The luminescence signal originating from EHD has a rise time of 60 ps, while plasma luminescence emerges within the experimental resolution. From temperature dependence measurements, they reported a critical temperature of 165 K for the EHD formation. Although this temperature is much higher than the ones reported for silicon and germanium, EHD in diamond are stabilized due to a delicate balance

of the correlation, exchange, kinetic, and excitonic Coulomb energies. We report on suppressed EHD formation in a diamond crystal under strain perturbation.

[1] K. Thonke et al., Diamond Relat. Mater. 9, 428 (2000), N. Teofilov et al., ibid. 12, 636 (2003).

[2] R. Shimano et al., Phys. Rev. Lett. 88, 057404 (2002).

HL 32.4 Wed 17:15 H14

Metal-insulator transition and superconductivity in heavily boron-doped single crystal diamond — •Philipp Achatz[1,2,3], Etienne Bustarret[1], and Thierry Klein[1] — [1]CNRS Grenoble/LEPES, 25 Avenue des Martyrs, 38042 Grenoble, France — [2]CEA Grenoble/DRFMC/SPSMS, 17 Avenue des Martyrs, 38054 Grenoble, France — [3]Walter Schottky Institut, TU München, Am Coulombwall 3, 85748 Garching, Germany

The superconducting properties of diamond epilayers grown along {001} and doped with boron ($0.3 < n_B < 3$ at. %) have been investigated at low temperatures down to about 50 mK by a.c. and d.c. resistivity, as well as by a.c. magnetic susceptibility, and the phase diagram of this type II superconductor was established. Further, the results show that the critical boron concentration n_c is the same for the normal to superconducting and for the non-metal to metal transitions, on the order of 0.3 at. %, in agreement with estimates derived from various theoretical approaches. A variable range hopping behaviour was clearly observed on the insulating side of the transition, and, as expected, the characteristic temperature T_0 tended toward zero at the transition. On the metallic side, the zero temperature conductivity σ_0 scaled with $(n_B/n_c - 1)^\nu$ with $\nu \approx 1$. The critical temperature T_c remained high in the vicinity of the metal-non metal transition, and it was rather found to scale with $(n_B/n_c - 1)^{1/2}$. These results led us to propose that the electron-phonon coupling parameter λ remains large down to $n_B/n_c \approx 1.1$, and to examine the metal-insulator transition and the parameter set (λ, μ) in terms of scaling laws.

HL 32.5 Wed 17:30 H14

Electronic and optical properties of diamond/organic semiconductor heterostructures — •Wojciech Gajewski[1], Jose Garrido[1], Martin Niedermeier[1], Oliver Williams[2], Ken Haenen[2], and Martin Stutzmann[1] — [1]Walter Schottky Institute, TU München, Am Coulombwall 3, 85748 Garching, Germany — [2]Institute for Materials Research, University of Hasselt, Wetenschapspark 1, BE-3590 Diepenbeek, Belgium

Different diamond substrates (single crystalline: SCD, poly-crystalline: PCD and nano-crystalline: NCD) were used to investigate the electronic and optical properties of the diamond/organic semiconductor heterostructures. Layers of a poly[ethynyl-(2-decyloxy-5-methoxy)benzene] - PEB, pentacene and 4-nitro-biphenyl-4-diazonium cations - Ph-Ph-NO2 were prepared by spin coating, thermal evaporation and grafting, respectively. The measurements of the electronic transport along the organic layer were performed using a Hg probe as well as Hall effect measurements in the temperature range 70 - 400K. The I-V characteristics of the B-doped diamond/organic semiconductor heterostructures were measured at room temperature by means of the Hg probe. Undoped IIa and undoped PCD films were used for a study of the optical and optoelectronic properties of prepared heterostructures. The influence of the organic layer homogenity and layer thickness on the optical properties will be discussed. Furthermore, preliminary data on perpendicular and parallel transport in the heterostructures layer will be reported.

HL 32.6 Wed 17:45 H14

The interface between diamond and aqueous electrolyte — •Markus Dankerl, Andreas Reitinger, Andreas Härtl, Jose Antonio Garrido, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching.

C-H as well as C-O surface termination of diamond are both stable in electrolyte, but have different electrochemical characteristics. C-H terminated diamond shows the particularly interesting property of being surface conductive with holes as charge carriers. As the surface conductivity of undoped single crystalline diamond is influenced by pH, ionic strength and applied potential through the electrolyte, the design of ISFETs becomes possible. We report new results concerning the characterization of the diamond surface in contact with an aqueous electrolyte using electrochemical and electronic methods. In particular, ISFETs based on single crystalline diamond are investigated with respect to the influence of pH on the surface conductivity and the carrier concentration in the two dimensional hole gas. To this end Hall effect measurements are conducted on the conductive diamond surface in electrolyte. The screening effect of monovalent and divalent salts on the surface potential is likewise investigated. The results are discussed in the context of the influence of the parameters on the charge carriers.

HL 33: New materials

Time: Wednesday 16:45–17:45 Location: H15

HL 33.1 Wed 16:45 H15

Study of the Ba giant dipole resonance in Ba_8Si_{46} with non-resonant inelastic x-ray scattering — •Sternemann Henning[1], Sternemann Christian[1], Tse John S.[2], Desgreniers Serge[3], Vankó György[4], Schacht Andreas[1], Soininen Juha Aleksi[5], and Tolan Metin[1] — [1]Dept. Phys. / DELTA, University of Dortmund, D-44221 Dortmund — [2]Dept. Phys. & Engn. Phys., University of Saskatchewan, Canada — [3]Dept. Phys., University of Ottawa, Canada — [4]ESRF, Grenoble, France — [5]Div. X-ray Physics, Dept. Physical Sciences, University of Helsinki, Finland

Atomic Ba shows a giant dipole resonance arising from collective $4d$ electron motion above the energetic threshold of the $N_{IV,V}$ edges. We will present the first experimental observation of the Ba resonance in the complex silicon clathrate network of Ba_8Si_{46}. The measurements were done at different momentum transfers using non-resonant inelastic x-ray scattering. The giant resonance spectra were modeled within the time-dependent local density approximation using a real-space multiple-scattering approach. The resulting spectra show very good agreement with the experiment. Separate calculations for $Ba@Si_{20}$ and $Ba@Si_{24}$ demonstrate the sensitivity of the resonance concerning the local environment of the Ba atom. Thus, a combined study of absorption edges and the fine-structure of the giant resonance by means of non-resonant inelastic x-ray scattering yields the possibility to study electronic and structural changes in pressure-induced phase transitions of the clathrate simultanously. The experimental setup for such studies will also be presented.

HL 33.2 Wed 17:00 H15

Interstitial Mn in Si: half-metallic heterostructures studied by density-functional theory — Hua Wu[1,2], •Peter Kratzer[3], and Matthias Scheffler[2] — [1]II. Physikalisches Institut, Universität zu Köln, D-50973 Köln, Germany — [2]Fritz-Haber-Institut der MPG, D-14195 Berlin, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, D- 47048 Duisburg, Germany

Adding magnetic functionality to the most common semiconductor, Si, is in its infancy. So far, research on Mn-doped Si has concentrated on substitutional Mn (Mn_{sub}) as done for Mn-doped GaAs and Ge, although Mn_{sub} impurities in Si are energetically less stable than interstitial Mn (Mn_{int}). In this work, we investigate the role of Mn_{int} impurities for ferromagnetism in Si, and propose a novel type of heterostructures with Mn_{int} δ-doping. Using density-functional theory within the generalized gradient approximation, we show that Si-based heterostructures with 1/4 layer δ-doping of Mn_{int} are half-metallic. For Mn_{int} concentrations of 1/2 or 1 layer, the δ-doped heterostructures still display a high spin-polarization of conduction electrons, about 85% and 60%, respectively. The proposed heterostructures are more stable than previously assumed δ-layers of Mn_{sub}. Contrary to widespread belief, the present study demonstrates that interstitial Mn can be utilized to tune the magnetic properties of Si, and thus provides a new clue for Si-based spintronics materials.

HL 33.3 Wed 17:15 H15

Coupling Phenomena of Surface Plasmons — •Stephan Schwieger, Erich Runge, and Parinda Vasa — Technische Universität Ilmenau, Institut für Physik, Fachgebiet Theoretische Physik I, Postfach 100565, 98684 Ilmenau

Surface plasmons on an array of nanometer-sized metal wires, which is embedded in a multilayer system, are studied numerically. We investigate the coupling of different plasmonic modes as well as the coupling of plasmonic modes with light. These couplings influence fundamental properties of the excited surface plasmons as e.g. theire life time and details of their dispersion relation. We discuss the dependence of these couplings on the geometry of the nano-wire arrays as well as on the dielectric proporties of the adjescent layers.

HL 33.4 Wed 17:30 H15

Strukturelle und thermoelektrische Eigenschaften von epitaktischen IV-VI-MBE-Schichten legiert mit Zinn — •Jan König[1], Joachim Nurnus[2], Armin Lambrecht[1] und Harald Böttner[1] — [1]Fraunhofer Institut für Physikalische Messtechnik, Heidenhofstr. 8, 79110 Freiburg, Deutschland — [2]Micropelt GmbH, Emmy-Noether-Staße 2, 79110 Freiburg, Deutschland

IV-VI Halbleiterverbindungen sind bekannte Materialien mit hervorragenden thermoelektrischen Eigenschaften bei Temperaturen um 700K. Durch die Verwendung von Mischkristallen können die thermoelektrischen Eigenschaften durch eine Reduzierung der thermischen Leitfähigkeit mittels Legierungsstreuung optimiert werden. Außerdem kann durch Mischkristalle die Bandlücke für die thermoelektrische Anwendungstemperatur hin optimert werden. Dieses Konzept wird seit vielen Jahren an Massivmaterialien erprobt. Jedoch bestehen nur sehr wenige Daten über Dünnschichthalbleiter. Daher wurden mittels MBE mit Zinn legierte IV-VI-Schichten hergestellt. Es wird über die strukturellen (SEM-, EDX- und FT-IR Untersuchungen) und die thermoelektrischen Eigenschaften (Seebeck-Koeffizient- und Hall-Effekt-Messungen für Ladungsträgerkonzentration, Beweglichkeit und elektrische Leitfähigkeit) dieser Schichten berichtet. Zusammen mit der Bestimmung der thermischen Leitfähigkeit parallel zu Schichtebene wurde eine komplette thermoelektrische Qualifizierung erreicht.

HL 34: Invited Talk Reuter

Time: Thursday 9:15–10:00 Location: H15

Invited Talk HL 34.1 Thu 9:15 H15

Momentum space wave functions in InAs quantum dots mapped by capacitance voltage spectroscopy — •Dirk Reuter — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

It is long known that capacitance-voltage (C-V) spectroscopy is a versatile method to measure the addition spectra of conduction band states in self-assembled InAs quantum dots (QDs) grown on GaAs. From the spectra, quantization as well as interaction energies can be extracted and compared to theoretical models. Recently, this method was also applied to the valence band states of InAs QDs and I will discuss the electron and the hole charging in comparison.

Performing C-V spectroscopy at higher frequencies makes the technique sensitive to the tunnelling dynamics. By applying an in-plane magnetic field, the sensitivity to the tunnelling rate can be used to map the in-plane momentum space wave functions corresponding to the individual QD energy levels. I will discuss this technique briefly and present wave function maps for the electron and the hole system, respectively. The wave functions are anisotropic along the high-symmetry crystal directions, which points to an anisotropic lateral confinement potential. In addition, the wave function measurements reveal that the valence band states are more complex than the conduction band states. This will be discussed in detail and compared to the relevant theoretical models.

HL 35: Devices

Time: Thursday 10:00–12:45 Location: H13

HL 35.1 Thu 10:00 H13

Recent Advances in Complementary Tunneling FETs — •Martin Sterkel, Bernhard Fabel, Thomas Maul, Linda Nowack, and Walter Hansch — Institute for Technical Electronics, Technical University Munich, Arcisstr. 21, D-80333 München

Scaling MOSFETs becomes more and more difficult. The Tunneling Field Effect Transistor (TFET) is a possible successor of today's MOSFETs with high scaling capabilities.

The basic structure of the TFET is a reverse biased *pin*-diode with a MOS-gate on top of the intrinsic region. Depending on the applied gate-source voltage the electrical behaviour between the drain and the source contacts can be switched from the characteristics of a *pin*-diode to that of an Esaki diode. Hence, the working principle of a TFET is gate controlled interband tunneling. Both a positive and a negative gate-source voltage results in the formation of a tunnel junction, either on the *pi*- or the *ni*- interface. Therefore, complementary devices can be fabricated. Since the active region of the device has a lateral extension of approximately 10 nm, the TFET can be scaled down to less than 20 nm without severe short channel effects (SCE).

Planar TFETs were fabricated on silicon substrates by using standard CMOS technology. The p^+ source and n^+ drain regions were formed by Rapid Thermal Diffusion from Spin-On-Dopands. The fabrication process and the final devices are completely analyzed by using spectral ellipsometry, SIMS and various electrical measurement techniques. Selected results of these measurements are presented, discussed and compared with simulations.

HL 35.2 Thu 10:15 H13

MOSFET controlled Emission from Micro Field Emitter Tips — •Thomas Maul, Bernhard Fabel, Linda Nowack, Martin Sterkel, and Walter Hansch — Institute for Technical Electronics, Technical University Munich, Arcisstr. 21, 80333 Munich, Germany

Current stabilized field emitters are an ongoing subject to research and development for a couple of years, especially for flat panel displays. Alongside to this development field emitters are a promising candidate for economic multiplicative exposure of photo resists for nanostructures in future semiconductor manufacturing. As yet unrecoverable irregularities in manufacturing and resulting ageing of emitter tips during operation (e.g. combustion and adsorption of contaminations) lead to a drastic variance of emission between different tips and over time. So it is necessary to adjust the emission current in a different way. This submission shows ways to stabilize the current of field emitters by integrating emitter tips in drain contacts of MOSFETs and control the emission herewith. Experimental results are shown as well as simulations.

HL 35.3 Thu 10:30 H13

A non-volatile memory device based on self-organized quantum dots — •Andreas Marent, Martin Geller, David Feise, Konstantin Pötschke, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

DRAM and Flash are the most important semiconductor memories, both having their advantages and disadvantages in storage/access time and endurance. A future memory cell should combine the advantages of DRAM and Flash to an ultimate memory with long endurance ($>10^{15}$ write/erase cycles), long storage time (>10 years), fast write/read access time (<1 ns) and scalability towards single electron functionality yielding ultimately small power consumption.
We present a memory concept based on self-organized quantum dots (QDs) with the potential to fulfill all requirements concerning storage/access time, endurance and scalability [1]. In InAs QDs with $Al_{0.9}Ga_{0.1}As$ we demonstrate a hole storage time of seconds at room temperature. Futher enhanced storage time up to 10 years is expected for different material combinations such as In(Ga)Sb in AlAs. Futhermore, an average time for hole capture and relaxation at room temperature of 0.3 ps is observed for InAs/GaAs QDs . Thus, in comparison

to a DRAM cell, a four order of magnitude faster write time is possible in such a QD-based memory.

[1] M. Geller, A. Marent, and D. Bimberg, Auf Halbleiter-Nanostrukturen basierender nicht-flüchtiger Speicher "A non-volatile memory based on semiconductor nanostructure", CPT patent application, submitted (2006).

HL 35.4 Thu 10:45 H13

Geometrical spin dephasing in quantum dots — •Pablo San-Jose[1], Gergely Zarand[2], Alexander Shnirman[1], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe,D-76128 Karlsruhe, Germany. — [2]Institute of Physics, Technical University Budapest, Budapest, H-1521, Hungary.

We study the relaxation and dephasing of electron spins in quantum dots that is mediated by spin-orbit coupling, and show that higher order contributions provide a relaxation mechanism that dominates in the limit of low magnetic fields. This relaxation is of geometrical origin. We further observe that in the low-field limit the relaxation processes are dominated by coupling to electron-hole excitations rather than by phonons. We also consider the possibility of spin manipulation by spin-orbit induced geometric phases.

HL 35.5 Thu 11:00 H13

Silicon Epitaxy for vertical Tunnel Field-Effect-Transistors — •Markus Schindler, Oliver Senftleben, Mathias Born, Krishna Kumar Bhuwalka, Matthias Schmidt, and Ignaz Eisele — Institute of Physics, Department of Electrical Engineering, University of the German Federal Armed Forces Munich, Werner-Heisenberg-Weg 39, 85577 Neubiberg,Germany

The vertical tunnel field-effect-transistor (TFET) has been proposed as a candidate for future CMOS structures. The main features are exponentially increasing drain current-gate voltage characteristics and symmetric performance in n- and p-channel operation. Since the tunneling junction is less than 5 nm deposition processes with atomically sharp doping transitions are needed. Dopant diffusion and hence process temperature must be limited. Vertical TFET-structures were already grown by MBE, but a low-temperature CVD-based process suitable for an industrial production enviroment is still lacking. We investigated p- and n-type doped Si-layers grown in a commercial low pressure-CVD-system. The deposition temperature was under 650°C and the samples were characterized by secondary-ion-mass-spectroscopy (SIMS) and scanning electron microscopy (SEM). Deposition rates and doping incorporation show very high efficiency compared to conventional silane/dichlorosilane based epitaxy. As demonstrators we present experimental verification of p-channel tunnel FETs down to i-zones of 70 nm and 25 nm. I-V-characteristics are weakly dependent on temperature and nearly independent on channel length.

15 min. break

HL 35.6 Thu 11:30 H13

Characterisation of ultrathin ALD-Al_2O_3 films in MOS devices — •Bernhard Fabel[1], Martin Sterkel[1], Thomas Maul[1], Linda Nowack[1], Walter Hansch[1], Florian Speck[2], Kunyuan Gao[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Institute for Technical Electronics, Technical University Munich, Arcisstr. 21, D-80333 München — [2]Institute for Technical Physics, University Erlangen-Nürnberg, Erwin-Rommel-Str. 1, D91058 Erlangen

We present to you a comprehensive study of the electrical impact of different precursors and post deposition treatments to the ALD system of aluminium oxide. These ultrathin (EOT < 2 nm) aluminium oxide Al_2O_3 films were fabricated with different secondary precursors in an standard ALD furnace. The focus was on ozon and water synthesised films as well as mixed processes using both precursors. The electrical parameters were obtained from MOS capacitances and MOSFET devices, leading to a complete evaluation of the film properties for future CMOS applications. Additional physical characterisations (TEM, XPS, etc.) allow to match the electrical behaviour with the microscopic structure of the films in dependence of depostion conditions.

HL 35.7 Thu 11:45 H13

Butted Source Contact Field Effect Transistor — •Marcus Weis, Michael Fulde, and Doris Schmitt-Landsiedel — Lehrstuhl für Technische Elektronik, TU München

With scaling technology and smaller feature sizes alternative transistor structures gain momentum as replacement or in addition to traditional CMOS technology. In this work we investigate a novel device, the Butted Source Contact Field Effect Transistor (BSC-FET).

An experimental BSC device was investigated with a structure similar to the MOSFET structure, where the deep implants at source and drain are different. However the channel source and drain extension implants are equal as in a MOSFET. This BSC-FET is representative for a device with a very shallow source implant. The impact of this structure regarding general device behaviour and consequences for circuit design is objective to this investigation.

Implementation into 130nm, 90nm, 65nm standard processes are presented and compared. The BSC-FET offers better short channel effects like reduction of Drain Induced Barrier Lowering (DIBL). The output conductance is lower compared to CMOS which is especially interesting for analog applications. In some applications the integrated substrate contact can be of advantage, as it can reduce total chip area up to 3%. Due to the inherent substrate contact of the BSC-FET a tripple well process is needed for stacked devices.

HL 35.8 Thu 12:00 H13

Acoustically driven integrated Mach-Zehnder-Interferometer — Markus Beck[1], Mauricio de Lima[2], Rudolf Hey[1], and •Paulo Santos[1] — [1]Paul–Drude–Institut für Festkörperelktronik, Hausvogteiplatz 5-7, D-10117 Berlin, Germany — [2]Materials Science Institute, University of Valencia, P. O. Box 22085, E-46071 Valencia, Spain

We demonstrate a compact modulator based on conventional ridge waveguides (WGs) monolithically fabricated on GaAs. The modulator consists of a Mach-Zehnder interferometer (MZI) driven by a surface acoustic wave (SAW) in the GHz range, which modulates the refractive index in the two arms of the interferometer. The effect on the interference is maximized by choosing the spatial separation between the arms to be an odd multiple of the acoustic wavelength λ_{SAW} in order to modulate the arms with opposite phases. The modulated waveguide length is minimized by using a focusing interdigital transducer to generate a narrow and intense acoustic beam. Peak-to-peak modulation exceeding 90% of the average transmission is demonstrated with a modulated waveguide length of approximately 15 μm, which is significantly shorter than for comparable approaches.

HL 35.9 Thu 12:15 H13

Beitrag abgesagt — •XXX XXX —

HL 35.10 Thu 12:30 H13

Gated Hallbars and Pseuod MOSFETs for mobility measurements on biaxially tenisle strained silicon on insulator layers — •Sebastian Frederik Feste[1], Joachim Knoch[2], and Siegfried Mantl[1] — [1]Forschungszentrum Jülich, Institut für Bio- und Nanosysteme 1 (IBN 1-IT), Deutschland — [2]IBM Rüschlikon, Zürich, Schweiz

We studied the mobility enhancement in biaxially tensile strained silicon on insulator (SSOI) layers with gated Hallbar MOSFETs and Pseudo-MOSFETs with Schottky contacts. The SSOI was fabricated by layer transfer of a strained-Si/SiGe virtual substrate to an oxidized wafer. The final structure was obtained by wet etching of the remaining SiGe. Hall measurements allow a measurement of the carrier concentration and mobility. The advantage of this method is the direct measurement of the inversion layer carrier concentration so that no assumption about the gate capacitance is necessary. Psi-MOSFETs allow one to preform transistor-like measurements on SOI wafers without the need for actual device processing. They can therefore be used as a quick-turnaround tool for SOI wafer characterization. The dependence of the extracted mobility on the Schottky barrier height and the channel length has been studied and compared to the values obtained form the gated Hallbars. Both techniques show a nearly doubled electron mobility of 580cm^2/Vs for SSOI of different thicknesses compared to SOI.

HL 36: Heterostructures

Time: Thursday 10:00–12:15 Location: H14

HL 36.1 Thu 10:00 H14

Exciton-exciton interaction in coupled quantum wells: Quantifying conditions for Bose-Einstein condensation — •Christoph Schindler and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Spatially indirect electron-hole pairs in coupled quantum wells (CQW) have a reduced Coulomb attraction across the barrier, leading to a small binding energy of the indirect exciton. The repulsion between equal charges (electrons and holes), however, remains strong. Consequently, the interaction between two indirect excitons is dominated at large distances d by a strong dipole-dipole repulsion. Using CQW parameters for the GaAs/AlGaAs system we investigate the XX interaction as a function of d, improving the usual Hartree-Fock approach towards a full solution of the four particle problem. At small d, the fermionic exchange leads to a hard-core repulsive behavior, while at intermediate d van-der-Waals forces appear (depending on the singlet or triplet spin configuration). However, for realistic CQW parameters, no bound state (excitonic molecule) is formed. The generated XX potential is used to calculate XX scattering phase shifts and subsequently a full T matrix which is at the core for describing the approach towards Bose-Einstein condensation of indirect excitons.

HL 36.2 Thu 10:15 H14

Quantum Stark confined strongly correlated indirect excitons in quantum wells — •Patrick Ludwig[1,2], Alexej Filinov[1], Heinrich Stolz[2], and Michael Bonitz[1] — [1]CAU zu Kiel, ITAP, Leibnizstrasse 15, D-24098 Kiel — [2]Universität Rostock, Institut für Physik, Universitätsplatz 3, D-18051 Rostock

We consider small ensembles of optically excited indirect excitons (IE) in a single quantum well (QW). Using Path Integral Monte Carlo (PIMC) we compute from first principle the spatial separation of electrons (e) and holes (h) and the lateral quantum Stark confinement of the IE in the QW which is produced by an external electric field of a single tip electrode. [1] In the proposed setup the e-h pairs form permanent dipoles aligned perpendicular to the QW planes. The accompanied repulsive mutual dipole-dipole-like interaction of the IE prevents formation of biexcitons and e-h droplets and masks, at the same time, the fermionic character of the IE constituents, so that the IE are approximately of bosonic nature [2]. By changing the field strength, the tip to sample distance, the excitation intensity (exciton number) and temperature, the IE properties as well as the IE-IE correlations can be varied in broad ranges. Investigating systems of several tens to hundreds of IE in a ZnSe-based QW with PIMC technique we predict the parameter range at which interesting many-particle states, including exciton crystallization should be observable in experiments.[3]

[1] P. Ludwig et al., phys. stat. sol. (b) **243**, No. 10 2363-2366 (2006)

[2] A. Filinov et al., phys. stat. sol. (c) **3**, No. 7, 2457-2460 (2006)

[3] A. Filinov et al., J. Phys: Conf. Series **35**, 197 (2006)

HL 36.3 Thu 10:30 H14

Semiconductor Laser Emission in Realistic Dielectric Structures — •Martin Schafer[1], Walter Hoyer[1], Mackillo Kira[1], Stephan W. Koch[1], Matthias Reichelt[2], Joerg Hader[2], and Jerome Moloney[2] — [1]Department of Physics and Material Sciences Center, Philipps-University, Renthof 5, D-35032 Marburg, Germany — [2]Arizona Center for Mathematical Sciences, University of Arizona, Tucson, Arizona

Photoluminescence measurements provide an important tool for the characterization of laser devices. It is well known that realistic dielectric structures can strongly alter the quantum-well photoluminescence with respect to its emission in free space.

In order to investigate the modifications of photoluminescence spectra for different dielectric structures, a microscopical many-body theory is combined with a quantum theory of the electro-magnetic field, that is expanded in terms of the mode functions of the dielectric structure. In the strong coupling regime, a complete treatment of the stimulated emission is essential. For weak coupling between the quantum-well and the light field, the luminescence modifications can be obtained by multiplying the pure quantum-well emission with a frequency dependent filter function.

HL 36.4 Thu 10:45 H14

Exciton-Polaritons at room temperature in a planar ZnO resonator structure — •Rüdiger Schmidt-Grund, Bernd Rheinländer, Christian Czekalla, Gabriele Benndorf, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

The wurtzite-structure II-VI-semiconductor ZnO has currently gained substantial interest because of its attractive properties for possible applications in optoelectronics. Due to the large binding energy of about 60meV, excitons in ZnO are stable at room temperature. This makes ZnO based resonators attractive for Bose-Einstein condensation of exciton-polaritons and therefore for the realization of cavity coupled exciton-polariton lasers operating at room temperature.

We report on coupling of exciton and photon modes observed in an all oxide planar resonator consisting of a $\lambda/2$ ZnO cavity, which acts simultaneously as active medium. It is embedded between lower and upper Bragg reflectors consisting of $\lambda/4$ stacks of the materials ZrO_2 and MgO (each 10.5 layer pairs). The resonator structure has been deposited using pulsed-laser deposition on sapphire substrate. The exciton-polariton modes have been observed in both reflectivity and photoluminescence measurements at temperatures between 4K and 306K and at room temperature at various incidence angles respective exit angles of the light. We have observed an energy splitting of the exciton-polariton branches of about 50meV, which is as large as the best values reached for the well known material system AlInGaN.

HL 36.5 Thu 11:00 H14

Drift Mobility of Long-living Excitons in Coupled GaAs Quantum Wells — •Andreas Gärtner[1], Dieter Schuh[2], Alexander Holleitner[1], and Jörg Kotthaus[1] — [1]Department für Physik and Center for NanoScience, Ludwig-Maximilians-Universität, D-80539 München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg, Germany

Photo-generated electron-hole pairs in quantum well devices can be manipulated in lifetime and position via a mesoscopic voltage-controlled electrostatic landscape [1]. Here we employ the quantum confined Stark effect in a coupled double quantum well to generate spatially indirect excitons with lifetimes exceeding 1 μs and to study their motion induced by a controlled spatial variation of the out-of-plane electric field [2,3]. Macroscopic drift of excitons is studied in a time-of-flight experiment employing a laterally graded electrostatic potential induced via a current-carrying resistive gate [2]. This allows us to determine the drift mobility of such long-living excitons. Across several hundreds of microns a drift mobility exceeding $10^5\,\mathrm{cm}^2/\mathrm{eVs}$ is observed for temperatures below 10 K. With increasing temperature the excitonic mobility decreases due to exciton-phonon scattering.

[1] for a recent review, see e.g.: J. P. Kotthaus, Phys. Stat. Sol. b **243**, 3754 (2006). [2] A. Gärtner, A. W. Holleitner, J. P. Kotthaus, D. Schuh, Appl. Phys. Lett. **89**, 052108 (2006). [3] A. Gärtner, D. Schuh, J. P. Kotthaus, Physica E **32**, 195 (2006).

HL 36.6 Thu 11:15 H14

Intersubband-dephasing in an undoped multi-quantum well — •Martin Wagner[1], Dominik Stehr[1], Harald Schneider[1], Stefan Winnerl[1], Manfred Helm[1], Max Andrews[2], Tomas Roch[2], and Gottfried Strasser[2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden-Rossendorf, Postfach 510119, 01314 Dresden — [2]Institut für Festkörperelektronik, TU Wien, Floragasse 7, 1040 Wien, Österreich

We have investigated the dephasing time associated with intersubband transitions of photocarriers in an undoped GaAs/AlGaAs multi quantum-well heterostructure. Our measurements were performed directly in the time-domain. After optical generation of electron-hole pairs across the band-gap, a resonant THz-pulse excited the electrons to the second subband and generated a coherent polarization involving the ground and the first excited subbands. The re-radiation from this polarization was detected by a cross-correlation technique with a second THz-pulse. The polarization was observed to decay with short decay-times between 50 fs and approx. 200 fs. They depend on

the carrier concentration which was adjusted by the optical excitation power. These time constants determine directly the linewidth of this intersubband transition. At low temperatures, the dephasing signals show a pronounced beating at all optical excitation powers which we attribute to excitonic effects such that more than two energy levels are involved in the interaction with the THz-pulse.

By varying the excitation power, we also found a strong depolarization shift of the absorption line.

HL 36.7 Thu 11:30 H14

Interface and Luminescence Properties of Pulsed Laser Deposited $Mg_xZn_{1-x}O$/ZnO Quantum Wells with Strong Confinement — •Susanne Heitsch, Gregor Zimmermann, Alexander Müller, Jörg Lenzner, Holger Hochmuth, Gabriele Benndorf, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstraße 5, D-04103 Leipzig, Germany

$Mg_xZn_{1-x}O$/ZnO/$Mg_xZn_{1-x}O$ quantum wells (QWs) ($0.12 \leq x \leq 0.15$) have been grown on a-plane sapphire substrates by pulsed laser deposition. The nominal ZnO well layer thickness ranges from 1.2 nm to 6 nm. Atomic force microscopy (AFM) investigations on $Mg_xZn_{1-x}O$ thin films and on ZnO/$Mg_xZn_{1-x}O$ heterostructures confirm the smoothness of the interfaces in the QWs (root mean square roughness of ~ 0.5 nm) and the film-like structure of the ZnO layers. We confirmed the lateral homogeneity of the Mg distribution in the $Mg_xZn_{1-x}O$ barrier layers by scanning cathodoluminescence measurements. The QWs show a bright and laterally homogeneous luminescence, suggesting good crystalline quality of the ZnO wells. The measured QW photoluminescence energies are compared with calculated values and display the presence of the quantum-confined Stark effect. As a result of quantum confinement a high-energy shift of the ZnO excitonic photoluminescence of 222 meV is observed in the thinnest QW.

HL 36.8 Thu 11:45 H14

Two-dimensional electron systems under microwave irradiation: Influence of contacts. — •Sergey Mikhailov[1] and Akira Satou[2] — [1]Institute for Theoretical Physics II, University of Augsburg, D-86135 Augsburg, Germany — [2]Computer Solid State Physics Laboratory, University of Aizu, Aizu-Wakamatsu 965-8580, Japan

A growing interest to the behavior of two-dimensional (2D) electron systems under the microwave irradiation was being observed in the few past years. A number of recently discovered phenomena, such as the retardation effects, the microwave induced zero resistance states, frequency sensitive detection and spectroscopy of microwave radiation, have attracted attention due to their importance for basic and applied physics.

At low (microwave) frequencies the influence of realistic dielectric environment, in particular, the presence of metallic contacts, may be crucially important. In this work we theoretically study the role of contacts in the excitation of plasma waves in 2D electron systems. We show that, dependent on parameters of the system, the energy of the incident radiation may be effectively transformed into the 2D plasmons or 2D plasmon-polaritons, or reflected back from the 2D layer without exciting any eigen modes of the system. Results of this work may be important for proper understanding of the recently observed microwave induced phenomena in 2D electron systems.

HL 36.9 Thu 12:00 H14

Tunneling Spectroscopy on the Interface of an Operating pin-Diode — •S. Loth[1], M. Wenderoth[1], K. Teichmann[1], L. Winking[1], R. G. Ulbrich[1], S. Malzer[2], and G. H. Döhler[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Universität Erlangen-Nürnberg, Max-Planck-Research Group, Institute of Optics, Information, and Photonics, Germany

The interface of a GaAs pin-diode heterostructure is investigated by means of Cross Sectional Scanning Tunneling Microscopy at 8K. The internal electric field of the diode is of the order of $10^8 V/m$ and is externally controlled by source and drain contacts during the measurement. The variable field of the diode structure acts perpendicular to the tip induced field. In the experiment this enables the manipulation of charge states and energetic surroundings of single dopant atoms located in the pin-interface. At a fixed tunneling bias voltage the applied source drain voltage allows to shift the different surface resonances of the {110} cleavage surfaces in and out of the tunneling channel. In spatially resolved I(V)-spectroscopies the impact of the changing internal electric field on the band gap conductivity near the dopant atoms and its influence on the tip induced states is deduced.

This work was supported by the DFG, SFB 602, and the German National Academic Foundation.

HL 37: Symposium Graphene

Time: Thursday 10:00–12:30 Location: H15

Invited Talk HL 37.1 Thu 10:00 H15

Photoelectron spectroscopy of graphene on SiC: growth, interface, and electronic structure — A. Bostwick[1], K.V. Emtsev[2], K. Horn[3], E. Huwald[4], L. Ley[2], J.L. McChesney[2], T. Ohta[1,3], J. Riley[4], E. Rotenberg[1], •Th. Seyller[2], and F. Speck[2] — [1]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California, USA — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Germany — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [4]Department of Physics, La Trobe University, Bundoora, Victoria, Australia

The possibilty to grow well ordered, ultra-thin graphite on SiC{0001} surfaces with thicknesses down to a single graphene layer is promising for future applications. Photoelectron spectroscopy (PES) is a versatile technique for investigating a variety of properties of this system which are of fundamental and technological interest. The talk will survey results from recent PES studies with a focus on the growth of ultrahin graphitic layers, the electronic and structural properties of the interface to the SiC substrate, and the electronic structure of the layers.

Invited Talk HL 37.2 Thu 10:30 H15

Raman Imaging of Graphene — Davy Graf, Francoise Molitor, •Klaus Ensslin, Christoph Stampfer, Alain Jungen, and Christopher Hierold — Physics Department, ETH Zurich

We present Raman spectroscopy measurements on single- and few-layer graphene flakes. Using a scanning confocal approach we collect spectral data with spatial resolution, which allows us to directly compare Raman images with scanning force micrographs. Single-layer graphene can be distinguished from double-and few-layer by the width of the D* line: the single peak for single-layer graphene splits into different peaks for the double-layer. We investigate the D-line intensity and find no defects within the flake. We also present transport measurements through few layer graphene systems. The inelastic scattering length is estimated from measurements of universal conductance fluctuations to be of the order of several micrometers at low temperatures.

INVITED TALK

Invited Talk HL 37.3 Thu 11:00 H15

Electronic confinement and coherence in high mobility epitaxial graphene — •Claire Berger — Georgia Institute of Technology, Atlanta, GA-30332, USA — CNRS-Institut Louis Néel, BP166, 38042 Grenoble cedex 9, France

Transport in ultrathin graphite films grown on single-crystal silicon carbide is dominated by the electron-doped epitaxial graphene layer at the interface and shows graphene characteristics. Epitaxial graphene provides a platform for studying the novel electronic properties of this 2D electron gas in a controlled environment. Shubnikov-de Haas oscillations in the magnetoresistance data indicate an anomalous Berry's phase and reveal the Dirac nature of the charge carriers. The system is highly coherent with phase coherence lengths beyond 1 micrometer at cryogenic temperatures, and mobilities exceeding 2.5 square meters per volt-second. In wide structures, evidence is found for weak anti-localization in agreement with recent graphene weak-localization theory. Patterned narrow ribbons show quantum confinement of electrons. Several Hall bar samples reveal anomalous magnetoresistance patterns consisting of large structured non-periodic oscillations that

may be due to a periodic superlattice potential.

Invited Talk HL 37.4 Thu 11:30 H15

News from the quantum Hall effects in graphene — •Uli Zeitler — High Field Magnet Laboratory, Institute for Molecules and Materials, Radboud University Nijmegen, NL-6525 ED Nijmegen

Single-layer and bilayer graphene, only recently synthesized truly two-dimensional crystals [1], display two totally new classes of quantum Hall effects (QHEs). Single-layer graphene can be characterized by chiral massless charged Dirac fermions, leading to a half-integer QHE of four-fold degenerate Landau levels [2,3]. In high magnetic fields (30 T) the QHE persists up to room temperature [4] which may open up new vistas for high temperature quantum metrology. For bilayers, a new-type of integer QHE appears [5] where the $N = 0$ quantum Hall plateau is missing. These observations can be tracked down to relativistic particles with a finite mass. They display an eight-fold degenerate Landau level at zero energy containing both electrons and holes simultaneously.

This work was done in collaboration with Kostya Novoselov, S.V. Morozov, D. Jiang, F. Schedin, and A.K. Geim (University of Manchester); E. McCann and V.I. Fal'ko (Lancaster University) and M.I. Katsnelson and J.C. Maan (Radboud University Nijmegen).

[1] K.S. Novoselov et al., Science 306, 666 (2004). [2] K. Novosolov et al., Nature 438, 197 (2005) [3] Y. Zhang et al., Nature 438, 201 (2005). [4] K. Novosolov et al., to be published. [5] K. Novosolov et al., Nature Physics 2, 177-180 (2006).

Invited Talk HL 37.5 Thu 12:00 H15

The structure of suspended graphene membranes — •J. C. Meyer[1], A. K. Geim[2], M. I. Katsnelson[3], K. S. Novoselov[2], T. Booth[2], D. Obergfell[4], S. Roth[4], C. Girit[1], A. Kis[1], and A. Zettl[1] — [1]Materials Science Dept. Lawrence Berkeley National Laboratory, and Physics Dept. University of California, Berkeley, USA — [2]Manchester Centre for Mesoscience and Nanotechnology, University of Manchester, UK — [3]Institute for Molecules and Materials, University of Nijmegen, Netherlands — [4]Max Planck Institute for solid state research, Stuttgart, Germany

Graphene is a monolayer of carbon atoms that can be viewed as an individual atomic plane extracted from graphite. The charge carriers mimic massless Dirac fermions, and this peculiar electronic structure has been at the focus of the recent interest in this material. But already the structure of graphene is intriguing. The notion of an isolated graphite plane implies a two-dimensional crystal, which can not exist in a free state according to theory. We have now prepared prepared freely suspended graphene monolayers that are not confined in the third dimension, and are attached only at the edges. We investigate structural or mechanical effects of these atomically thin membranes by transmission electron microscopy. Indeed, we observe structural effects that are not found in bulk crystals but are unique to the 2D membrane. The membranes do not remain flat but exhibit random variations in the surface normal of several degrees. This is in qualitative agreement with theoretical predictions for a 2D membrane in a 3D space, however, a rigid theoretical treatment for this particular system is still needed.

HL 38: ZnO I

Time: Thursday 10:00–13:00 Location: H17

HL 38.1 Thu 10:00 H17

Photoluminescence of vanadium-implanted and annealed ZnO thin films — •Michael Lorenz[1], Heidemarie Schmidt[1], Carsten Ronning[2], Sven Müller[2], Mariana Ungureanu[1], Gabriele Benndorf[1], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany — [2]Georg-August-Universität Göttingen, II. Physikalisches Institut, Göttingen, Germany

Within our search for multifunctional ferromagnetic and semiconducting ZnO-based thin film material for spintronic applications we have implanted 250 keV ^{51}V-ions into PLD-grown, about 700 nm thin ZnO films on a-plane sapphire. The implantation was done either at 300°C or at room temperature and several annealings up to 900°C were done after implantation. Low-temperature photoluminescence spectra taken before and after implantation and after annealing show remarkable changes of the intensities of excitonic peaks (UV) and the green defect-related band (VIS) with the implantation fluence and the annealing temperature. Interestingly, after high-temperature annealing the UV / VIS intensity ratio increases with increasing V-implantation fluence. In contradiction to the V-implanted samples, some reference films implanted with Ar-ions show a strong quenching of the excitonic luminescence, as found earlier also for Mn-doped ZnO [1]. This points to a different incorporation of V, Ar, Mn, and Co into the ZnO lattice.

Funded within BMBF Young Scientists Group Nanospintronics.

[1] M. Diaconu, H. Schmidt et. al., Thin Solid Films 486 (2005) 117.

HL 38.2 Thu 10:15 H17

Origin of the near-band-edge photoluminescence in ZnO nanorods realised by vapour phase epitaxy and aqueous chemical growth — •C. Bekeny[1], B. Hilker[1], L. Wischmeier[1], T. Voss[1], B. Postels[2], A. Mofor[2], Andrey Bakin[2], and A. Waag[2] — [1]IFP, University of Bremen, P.O Box 330440, 28334 Bremen — [2]IHT, TU Braunschweig, P.O Box 3329, 38023 Braunschweig

Well established high temperature growth techniques like the vapour-liquid-solid (VLS: 1100°C) and vapour-phase-epitaxy (VPE: 800°C) have been successfully optimized while the low-temperature aqueous chemical growth (ACG: 90°C) is being extended to yield large-scale high quality ZnO nanorods. Here, a detailed and systematic photoluminescence (PL) study is presented to understand the microscopic processes responsible for the near-band-edge (NBE) emission in nanorods obtained from these processes. For the ACG samples, the as-grown nanorods show relatively broad NBE emission (15meV) attributed to the presence of large donor densities. After annealing in various atmospheres at ˜800°C, a significant reduction of the linewidth (˜4meV) and even the appearance of relatively sharp excitonic transitions is explained by the drastic reduction of the donor density. In contrast, the as-grown VPE and VLS samples exhibit well-resolved and sharp peaks resulting from exciton-related transitions. There is a shift in the room-temperature PL peak for VLS and VPE samples and is shown to result from contributions of the free exciton peak, its first and second order phonon replicas and not due to quantum confinement and or laser heating as assumed in literature.

HL 38.3 Thu 10:30 H17

The influence of entropy on the capture cross-section determination in ZnO — Heidemarie Schmidt, Maria Wiebe, •Beatrice Dittes, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

ZnO has great potential for optoelectronic and spintronic applications. Deep level transient spectroscopy (DLTS) has been used to probe the parameters of deep defects in intrinsically n-type conducting, magnetic ZnO [1]. Different groups report on thermal activation energies ranging from 0.12 eV up to 0.6 eV below the conduction band minimum and an abnormally large variation of the capture cross section σ. As shown for other material systems with deep defects exhibiting a Meyer-Neldel Rule (MNR) behavior [2], the large variation of σ is an artifact of an incorrect analysis of DLTS data. Using DLTS data we show that also deep electron defects in ZnO exhibit the MNR behavior. Electron and hole defects in the same material system have to fit along the same MNR line. Therefore, the established isokinetic temperature will also help to fully understand deep hole defects in ZnO.

[1] M. Diaconu, H. Schmidt, H. Hochmuth, M. Lorenz, H. v. Wenckstern, G. Biehne, D. Spemann, M. Grundmann, Sol. Stat. Comm. 137, 417 (2006).

[2] J. A. M. AbuShama et al., Appl. Phys. Lett. 87, 123502 (2006).

HL 38.4 Thu 10:45 H17

The anisotropy of the dielectric function of ZnO films. — •Chris Sturm, Rüdiger Schmidt-Grund, Tsvetan Chavdarov, Bernd Rheinländer, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experi-

mentelle Physik II, Linnéstr. 5, 04103 Leipzig

In the last years, the tensor of the optical dielectric function (DF) of ZnO has been of much interest. Many properties of this tensor are still unknown. We report on the influence of the film thickness and film crystallographic orientation on this dielectric tensor. The a-plane and m-plane ZnO films were deposited on r-plane and m-plane sapphire, respectively, by Pulsed Laser Deposition. The m-plane and a-plane orientation of the ZnO films permits the determination of the two independent components of the dielectric tensor ($\varepsilon_\perp$ and $\varepsilon_\parallel$). The thicknesses of the ZnO films in the different samples vary in a range $(30 - 600)$ nm. The samples were studied by Generalized Spectroscopic Ellipsometry in the energy range $(1,0 - 4,5)$ eV. The DF was obtained with help of a layer stack model and model dielectric function analysis. The DF in the band-gap region is dominated by free excitons. Comparing the DF of m-plane and a-plane ZnO films with each other, a blue shift of the exciton peak energy was found for the a-plane ZnO films. A blue shift and an increasing line broadening of the exciton peaks with decreasing film thickness were found for both film orientations. This behavior is attributed mainly to strain effects since thickness non-uniformity, free charge carrier and surface overlayer effects can be excluded as responsible for the blue shift and the line broadening.

HL 38.5 Thu 11:00 H17

Depletion layer spectroscopy on bulk and thin film ZnO — •H. von Wenckstern, H. Schmidt, G. Biehne, R. Pickenhain, M. Lorenz, and M. Grundmann — Universität Leipzig, Fakultät für Physik, Linnéstrasse 5, 04103 Leipzig

Experimental investigations of deep defects in ZnO (especially the characterization of minority traps) are scanty. Hole traps with E_t $\sim$ 150 meV and 280 meV, respectively, were found by deep level transient spectroscopy (DLTS) for N^+ implanted ZnO crystals [1], however, systematic investigations are necessary to conclude on the macroscopic origin of these defects. Minority and majority carrier traps in bulk ZnO and epitaxial PLD ZnO thin films are investigated by means of depletion layer spectroscopy. For that, high-speed Pd/ZnO Schottky diodes [2], *pn* hetero- or *pn* homojunctions [1] are prepared and investigated for temperatures ranging from 20 K to 330 K. The density (N_t) and thermal activation energy (E_t) of shallow majority carrier defects, and N_t, E_t, and the capture cross section σ of deep majority and minority carrier traps are discussed.

[1] H. von Wenckstern, R. Pickenhain, H. Schmidt, M. Brandt, G. Biehne, M. Lorenz, M. Grundmann and G. Brauer, Appl. Phys. Lett. **89**, 092122 (2006).
[2] H. von Wenckstern, G. Biehne, R. A. Rahman, H. Hochmuth, M. Lorenz, and M. Grundmann, Appl. Phys. Lett. **88**, 092102 (2006).

HL 38.6 Thu 11:15 H17

Cathodoluminescence study of ZnO and $Zn_{1-x}Mg_xO$ nanopillars on different substrates — •Martin Schirra, Anton Reiser, Raoul Schneider, Günther Prinz, Klaus Thonke, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm

ZnO nanopillars are potential candidates for future sensor and optoelectronic devices. Any application calls for optimal structural and optical properties of such pillars. In the present study *single* nanopillars, mainly grown by the vapor-liquid-solid process, were investigated by spatially resolved cathodoluminescence in a scanning electron microscope (SEM-CL) at low temperatures (10K) and low acceleration voltages (2kV).
In order to achieve at the same time high SEM resolution and CL sensitivity, a new concept was realized based on a field-emitter type SEM and light collection by a glass fiber. ZnO nanopillars on sapphire substrate exhibit free and bound exciton recombination with narrow linewidths indicating high purity and high crystal quality. ZnO nanopillars on a GaN template show broad luminescence in the near-band edge region due to the incorporation of Ga into the pillars. Corresponding Ga concentrations are estimated. Nanopillars grown homoepitaxially on a ZnO thin film show mainly two donor bound exciton lines with narrow linewidths which are presumably related. Ternary $Zn_{1-x}Mg_xO$ nanopillars are also grown by the vapor-liquid-solid process. Incorporation of Mg into the ZnO matrix is demonstrated by blue-shifts of the luminescence, and the Mg concentration is determined.

15 min. break

HL 38.7 Thu 11:45 H17

A Zincoxide Microwire Laser — •Christian Czekalla, Andreas Rahm, Jörg Lenzner, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103, Leipzig, Germany

We report the observation of stimulated emission from hexagonally shaped zinc oxide (ZnO) microcrystals observed by spatially resolved photoluminescence (PL) and high excitation spectroscopy. The structures were synthesized by thermal evaporation of a pressed ZnO-graphite target at ambient pressure. They show a high PL signal under low excitation conditions. Under high optical excitation, the observed PL spectra show an additional peak at 3,15 eV. This is most probably related to an inelastic exciton-exciton scattering process (P-band). The gain reported for ZnO [1] cannot overcome the high losses caused by the short distance of the mirrors. Hence, ZnO microwires per se cannot be expected to act as a cavity for the emitted light. However, stimulated emission as a result of single pass gain will be demonstrated. A superlinear dependency of the peak intensity on the excitation and the observed spectral narrowing indicate lasing with a threshold of 150 kW/cm^2.
[1] Y. Chen *et al*, Appl. Phys. Lett. **78**, 11 (2001).

HL 38.8 Thu 12:00 H17

Luminescence properties of ordered ZnO single crystal nanorod arrays — •Huijuan Zhou, Markus Wissinger, Johannes Fallert, Robert Hausschild, Felix Stelzl, Mario Hauser, Claus Klingshirn, and Heinz Kalt — Institut für angewandte Physik, Universität Karlsruhe (TH), Karlsruhe, Germany

ZnO is an important material for blue/ultraviolet (UV) light emitting diode or laser diode. The practical application depends to great extend on the crystal quality of ZnO. By a controlled vapor phase transportation growth method we have recently fabricated high quality ordered ZnO nanorod arrays, which may be promising candidates for UV emitting devices. The ZnO nanorods are [0001] oriented single crystals with diameter of 250-300 nm and length of 2.5-4.7 μm, perpendicularly grown on GaN substrate.

The luminescence properties of the nanorods are studied extensively. Low temperature measurements show well separated bound exciton and free A-exciton emission in the UV region of the spectra, indicating high sample quality. By using the combination of a confocal microscopy and a 50 fs Ti:Sapphire laser, time resolved micro-photoluminescence (μ-TRPL) spectra are measured on single nanorods. Power dependent measurements demonstrate lasing behavior of the rods.

HL 38.9 Thu 12:15 H17

Nitrogen related centres in ammonia treated ZnO — •Joachim Sann[1], Jan Stehr[1], Albrecht Hofstätter[1], Detlev M. Hofmann[1], Bruno K. Meyer[1], Anja Neumann[2], Miriam Plana[2], Martin Lerch[2], Ute Haboeck[3], Axel Hoffmann[3], and Christian Thomsen[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität-Giessen, Heinrich-Buff-Ring16, — [2]Institut für Chemie, Technische Universität Berlin, Straße des 17. Juni 135, — [3]Institut für Festkörperphysik, Technische Universität Berlin, Hardenberg Str. 36

Ammonia (NH_3) is rather frequently used for the p-type doping of ZnO due to its higher chemical reactivity compared to other gases like N_2. We investigated the formation of defects in ZnO that has been subjected to heat treatments in ammonia atmosphere by photoluminescence, electron paramagnetic resonance and Raman spectroscopy. For annealing temperatures of about 550 °C we found Zn interstitials and Zn interstitial - nitrogen complex centres. We relate the Zn interstitials to the I_{3a} excitons and the complex centres to a recombination at 3.193 eV. For annealing temperatures of about 650 °C we find the N centres substituting oxygen. The incorporation of nitrogen is evident from Raman spectroscopy where the N related modes are observed.

HL 38.10 Thu 12:30 H17

Zeitaufgelöste Photolumineszenz-Spektroskopie an undotierten und Cr-dotierten ZnO Nanopartikeln — •Lars Schneider[1], Gerd Bacher[1], Wei Jin[2] und Markus Winterer[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen — [2]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen

ZnO ein viel versprechender Kandidat für optoelektronische Anwen-

dungen im UV und verspricht Ferromagnetismus bei Raumtemperatur. Wir präsentieren zeitaufgelöste und zeitintegrierte Photolumineszenzmessungen an undotierten und Cr-dotierten ZnO Nanopartikeln. Die Tieftemperaturspektren der undotierten Partikel werden durch mehrere schmale Linien dominiert, die der Rekombination freier und gebundener Exzitonen und ihrer Phononreplika zugeschrieben werden. Die schmale Linienbreite (FWHM) von 2.9 meV ist ein Hinweis für die gute optische Qualität der Nanopartikel, die selbst bei Raumtemperatur eine ausgeprägte, bandkantennahe Emission ermöglicht. Eine Analyse der Zerfallskonstanten erlaubt die Bestimmung charakteristischer Rekombinationszeiten donator- und akzeptorgebundener sowie freier Exzitonen. Für Cr-dotierte ZnO-Nanopartikel konnte eine ähnlich gute optische Qualität festgestellt werden. EELS- und EXAFS-Messungen zeigen eindeutig den Einbau von Cr in die Gitterstruktur des ZnO. Magnetolumineszenz-Messungen zeigen allerdings keinen signifikanten Einfluss der magnetischen Ionen auf die magnetooptischen Eigenschaften des ZnO. Dies lässt sich mit Hilfe von XANES- und EXAFS-Messungen erklären, die zeigen, dass Chrom als Cr3+ nicht substitutionell in das Wurtzit-Gitter eingebaut wird.

HL 38.11 Thu 12:45 H17

Cathodoluminescence study of ZnO layers grown on GaN — •Raoul Schneider, Martin Schirra, Anton Reiser, Günther Prinz, Rolf Sauer, and Klaus Thonke — Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm

Growth of ZnO layers on GaN substrates benefits from the small lattice mismatch of the two materials. We report on cathodoluminescence studies of ZnO layers grown by a modified CVD process on GaN templates deposited on sapphire substrates. The measurements were performed in a field-emitter type scanning electron microscope (FE-SEM) at low temperature and low acceleration voltages resulting in high spatial resolution below 80nm. A versatile detection system has been developed, which allows us to record single CL spectra, line scans and monochromatic CL images. Line scans across the GaN/ZnO interface reveal relaxation of strain and incorporation of Ga from the template into the ZnO layer. Monochromatic CL images of the edge and of the surface show a homogeneous distribution of the near band edge luminescence apart from single defects. First results of micro-Raman measurements are compared to the CL results.

HL 39: Impurities/amorphous semiconductors

Time: Thursday 12:15–13:00 Location: H14

HL 39.1 Thu 12:15 H14

Defect density profiling by absorption depth dependent thermally stimulated currents in microcrystalline silicon — •Sven Burdorf, Nacera Souffi, Gottfried Bauer, and Rudolf Brüggemann — Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg

The defect density profile of an inhomogeneous microcrystalline silicon sample (μc-Si:H) is studied using the experimental technique of thermally stimulated currents (TSC). The TSC measurements are carried out with initial excitation conditions that differ by the absorption depths of the light illuminating the sample. The measured TSC spectra do not change with varying absorption depths. The determination of the densities of gap states leads to the conclusion that the defect density near the surface is at least one order of magnitude larger than the average defect density over the entire sample. In addition, constant photocurrent method (CPM) results support this interpretation.

HL 39.2 Thu 12:30 H14

Influence of doping and codoping on the electronic and optical properties of Si nanocrystallites — •Luis Ramos, Jürgen Furthmüller, and Friedhelm Bechstedt — Friedrich-Schiller-Universität Jena, Institut für Festkörpertheorie und -optik, Max-Wien-Platz 1 D-07743 Jena, Germany

Quantum confinement in Si nanocrystallites (NCs) leads to interesting optical and electronic properties that can be useful in optoelectronics, photovoltaics, and nanoelectronics. Since doping is a fundamental process in semiconductors, investigations have been performed to establish the doping efficiency in Si NCs in comparison with bulk. Recent experiments confirm that codoping with group-III and group-V can enhance the intensity of luminescence in Si NCs by preventing radiationless Auger recombinations, which are the main problem in shallow-impurity doping in Si NCs. Experiments usually refer to an ensemble of Si NCs with a size and shape distribution, what can make the interpretation of the results more difficult. On the other hand, theoretical methods can be used to investigate the electronic properties and optical transitions of a single Si NC.[1] We perform ab initio calculations for doped and codoped Si NCs, which are based on density-functional theory and generalized-gradient approximation to study their electronic and optical properties. The formation energy of the impurities, electronic structure and optical spectra, and radiative lifetimes for doped and codoped Si NCs are discussed.[1] L.E. Ramos, J. Furthmüller, and F. Bechstedt, Appl. Phys. Lett. **87**, 143113 (2005); Phys. Rev. B **72**, 045351 (2005); Phys. Rev. B **70**, 033311 (2004).

HL 39.3 Thu 12:45 H14

Non-periodicity in atomic structure of cadmium sulfide CdS nanoparticles — •Andrey Vorokh[1,2], Andrej A. Rempel[1,2], and Andreas Magerl[2] — [1]Institute of Solid State Chemistry, Russian Academy of Sciences, Pervomaiskaya 91, GSP-145, Ekaterinburg 620219, Russia — [2]Crystallography and Structural Physics, University of Erlangen-Nuremberg, Staudtstrasse 3, 91058 Erlangen, Germany

By means of X-ray diffraction experiment and ab initio calculation of powder diffraction intensity using Debye equation it is shown that the atomic structure of cadmium sulfide (CdS) nanoparticles prepared by wet chemical method is disordered. The disordered atomic structure is a closed packed atomic structure with the tetrahedral coordination for both elements, cadmium and sulfur, but with a non-periodical sequence of the closed-packed planes types A, B, and C. The free energy of the disordered structure is higher in compare with the energy of known for CdS crystalline structures, wurtzite (B4 type, ABABAB. . . sequence of closed-packed planes) and zincblende (B3 type, ABCABC. . . sequence of closed-packed planes).

HL 40: SiC

Time: Thursday 12:30–13:00 Location: H15

HL 40.1 Thu 12:30 H15

Space-charge waves in SiC — •Michaela Lemmer[1], Mirco Imlau[1], Manfred Wöhlecke[1], Mikhail Petrov[2], and Valeriy Bryksin[2] — [1]Department of Physics, University of Osnabrück, Germany — [2]Ioffe Physico-Technical Institute, St.

The phenomenon of space-charge waves (SCW) is comprehensively studied in the field of nonlinear optics. SCW are eigenmodes of spatial-temporal oscillations of a space-charge density appearing in semi-insulating materials in an external electric field. The behaviour of low-frequency SCW, like those found in SiC, depends on the defect structure of the investigated material. As the defect structure in SiC is a promising scientific topic, we apply the method of resonant SCW excitation to a 4H-SiC polytype.

In this case, SCW are excited with an oscillating interference pattern and an externally applied electric field of $0 < E_0 \leq 10$ kV/cm. If the frequency of the interference pattern coincides with the eigenfrequency of the SCW mode, resonant excitation occurs. Because of a relatively low trap concentration in SiC, causing the effect of trap saturation, the general theory has to be modified. With this assumption, all results are found in a good agreement with the theoretical concept. This allows to determine important material parameters of 4H-SiC like the

product of mobility and lifetime of the charge carriers $\mu\tau = (7.4 \pm 0.8) \cdot 10^{-7}$ cm^2/V, the Maxwell relaxation time $\tau_M = (5.3 \pm 0.6) \cdot 10^{-4}$ s, and the effective trap concentration $N_{\text{eff}} = (5 \pm 1) \cdot 10^{13}$ cm^{-3}. Supported by the Deutsche Forschungsgemeinschaft (DFG, projects GRK 695 and 436 RUS 17/15/07).

HL 40.2 Thu 12:45 H15

Biofunctionalization of Silicon Carbide — •Marco Hoeb[1], Sebastian Schoell[1], Martin Huth[2], Bert Nickel[2], Martin Stutzmann[1], Martin Eickhoff[1], and Martin S. Brandt[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universität München, Geschwister-Scholl-Platz 1, 80539 München, Germany

SiC is an attractive semiconductor for biosensor applications, because of its large bandgap and superior stability. However, the SiC-surface chemistry in particular with respect to the covalent attachment of organic molecules has remained largely unexplored. We have investigated the functionalization of n-type 6H-SiC via silanization (APTES), where molecules are bound to a hydroxylated surface. The chemical, structural, and electronic properties of functionalized SiC were investigated on both the Si-terminated (0001) and the C-terminated $(000\bar{1})$ surface, using contact angle, AFM, fluorescence microscopy, XPS, thermal desorption spectroscopy (TDS), SAXS, and current-voltage measurements. Our data indicate a covalent attachment of the organosilane molecules to both the Si- and the C-terminated surface. A homogeneous coverage with active functional amino end groups was demonstrated via fluorescence micropatterning. However, SAXS and TDS suggest a lower average surface coverage on the C-terminated compared to the Si-terminated surface.

HL 41: Metal-insulator transitions

Time: Thursday 12:45–13:00 Location: H13

HL 41.1 Thu 12:45 H13

Ultrafast Insulator-Metal Transition in Vanadium Dioxide: Coherent Lattice Dynamcis and Electronic Correlations — •Rupert Huber[1], Carl Kübler[1], Henri Ehrke[1], Rene Lopez[2,3], Andrej Halabica[2], Richard Haglund[2], and Alfred Leitenstorfer[1] — [1]Fachbereich Physik, Universität Konstanz, 78464 Konstanz, Deutschland — [2]Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA — [3]Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27599, USA

Multi-THz pulses are employed to directly monitor the femtosecond transient behavior of the most important order parameter of the insulator-to-metal phase transition in VO2: the conductivity. Excitation with near infrared light pulses of a duration of 12 fs launches ultrafast dynamics of the ion lattice and the electronic system. Two-dimensional multi-THz measurements allow for a spectral discrimination of structural and electronic contributions revealing their subtle interplay. We find fingerprints of coherent modulations of mid infrared phonons and self-trapping of excitons induced by impulsively excited structural distortions. Wave packet motion at a frequency of 6 THz associated with excitation of V-V dimers is observed. For pump fluences beyond a temperature-dependent threshold, a structurally assisted electronic delocalization emerges within a fraction of the V-V oscillation period.

HL 42: GaN: devices

Time: Thursday 14:00–16:15 Location: H13

HL 42.1 Thu 14:00 H13

Anforderungen an die Schichtstrukturen von grün emittierenden GaInN-Lasern — •Daniel Dräger[1], Carsten Netzel[1], Uwe Rossow[1], Daniel Fuhrmann[1], Andreas Hangleiter[1] und David Schenk[2] — [1]Institut für Angewandte Physik, TU Braunschweig, Deutschland — [2]CRHEA-CNRS, Valbonne, Frankreich

Um effiziente GaInN-Laserstrukturen mit einer Emission im grünen Spektralbereich zu verwirklichen, bedarf es gegenüber blauen GaInN-Laserstrukturen eines neuen Designs der Quantenfilme und der Schichtstrukturen, die die Lasermode führen. Um Parameter dieses neuen Designs zu ermitteln, wurden an GaInN separate confinement Laserstrukturen verschiedener Emissionswellenlänge von 415 bis 485nm, gewachsen auf unterschiedlichen Substraten bei CRHEA-CNRS und an der TU Braunschweig, optische Verstärkungsmessungen durchgeführt und zu den Strukturen theoretische Berechnungen des Confinements und der Verstärkungsspektren vorgenommen. Um den grünen Spektralbereich im Laserbetrieb zu erreichen, muss gegenüber blau emittierenden Laserstrukturen vor allem die Indiumkonzentration stark erhöht werden. Für grün emittierende Strukturen verringert sich der Modeneinschluss im Wellenleiter und damit der Confinementfaktor der Mode in den GaInN-Quantenfilmen. Dem kann mit einer Optimierung der Wellenleiterdicke und einer Erhöhung der Mantelschichtdicken entgegengewirkt werden. Ein Wachstum von Laserstrukturen auf defektreduziertem Substrat führt zu größeren Verstärkungswerten. Die Wachstumsbedingungen müssen aber auf jeweils unterschiedlichen Substraten neu angepasst werden.

HL 42.2 Thu 14:15 H13

Electrical properties of nonpolar cubic $Al_xGa_{1-x}N/GaN$ HFETs — Stefan Potthast[1], •Marcio Peron Franco de Godoy[1], Elena Tschumak[1], Jörg Schörmann[1], Donat Josef As[1], Klaus Lischka[1], Hiroyuki Nagasawa[2], and Masayuki Abe[2] — [1]Universität Paderborn, Department Physik, Warburger Strasse 100, 33095 Paderborn, Germany — [2]HOYA SiC Developement Center, Ltd, 1-17-16 Tanashioda, Sagamihara,Kanagawa 229-1125, Japan

Since polarization fields can limit the performance of heterojunction field-effect transistors (HFETs) some attention has been focused recently on the growth of wurtzite structures with nonpolar orientations e.g., growth along a, m or R directions and also on cubic nitrides. In this contribution we report on the growth of cubic $Al_xGa_{1-x}N/GaN$ HFET structures by radio-frequency plasma assisted molecular beam epitaxy on 3C-SiC substrates with an Al-mole fraction between 0.2 and 0.5. The Mesa structures were realized using reactive ion etching technique. The source and drain contacts were deposited by thermal evaporation using 200 nm thick pure In as contact material. The gate contact was formed by thermal evaporation using Ni as Schottky contact material with a thickness of 50 nm. Analysis of capacity voltage characteristics at T=150 K reveal a clear evidence for the existence of the two-dimensional electron gas. A sheet carrier concentration of $1.6x10^{12}$ cm^{-2} is measured at the interface. The source-drain current-voltage characteristics measured at 150 K exhibited a clear field effect induced by the gate voltage.

HL 42.3 Thu 14:30 H13

Characterization of AlGaN/GaN Enzyme Modified Field Effect Transistors — •Barbara Baur, John Howgate, Vedran Bandalo, Wiebke Steins, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

Enzyme-modified field-effect transistors (EnFETs) were prepared by immobilisation of penicillinase on AlGaN/GaN solution gate field-effect transistors. The stability of the transistor during operation in a liquid environment and the influence of the immobilisation process on enzyme functionality have been investigated by a direct comparison of covalent immobilization and physisorption. Covalent immobilization by Schiff base formation on GaN surfaces modified with an aminopropyltriethoxysilane monolayer exhibits a high reproducibility with respect to the enzyme/substrate affinity. The stability of the enzyme

layer is shown to be significantly increased by reductive amination of the Schiff base bonds to secondary amines.

HL 42.4 Thu 14:45 H13

Untersuchung von V-Defekten in InGaN/GaN Leuchtdioden mit Hilfe der Kelvin Probe Force Microscopy und der Scanning Current Voltage Microscopy — •André Lochthofen[1], Wolfgang Mertin[1], Gerd Bacher[1], Lutz Höppel[2] und Berthold Hahn[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg, Germany

Beim epitaktischen Wachstum von GaN-Heteroschichten auf Saphir oder SiC ergibt sich durch die große Gitterfehlanpassung eine hohe Dichte an Versetzungen. Diese Versetzungen können sich bis zur Oberfläche fortsetzen und dort zu sogenannten V-Defekten führen. Deren Einfluss auf das elektrische Verhalten von GaN-basierenden Leuchtdioden ist von hohem Interesse.

Wir demonstrieren das Potenzial der Raster Sonden Mikroskopie, insbesondere der Kelvin Probe Force Microscopy (KPFM) und der Scanning Current Voltage Microscopy (SIVM), zur Untersuchung des elektrischen Verhaltens von V-Defekten in GaN-Leuchtdioden. Dabei gelang es, KPFM- und SIVM-Messungen an ein und demselben V-Defekt durchzuführen. Die KPFM Messungen zeigen einen deutlichen Abfall der Kelvin Spannung im V-Defekt. Gleichzeitig zeigt die SIVM dort einen signifikanten Stromanstieg. Die Messungen und damit das elektrische Verhalten können durch eine Akkumulation negativer Ladungen an den V-Defekten erklärt werden.

HL 42.5 Thu 15:00 H13

Optical Chemical Sensors Based on GaN/AlN Quantum Dots — •Olaf Weidemann[1], Eva Monroy[2], Gunther Jegert[1], Stafan Birner[1], Martin Stutzmann[1], and Martin Eickhoff[1] — [1]Walter Schottky Institut, TU München, 85748 Garching — [2]DRFMC/SP2M/PSC, CEA-Grenoble, 38054 Grenoble, France

Quantum dots (QDs) are of special interest for both fundamental physics and optoelectronic applications. Controlled growth of ensembles of self-assembled GaN/AlN QDs showing efficient room-temperature luminescence has been demonstrated recently. On the other hand, GaN-based devices have been shown useful to detect chemically induced changes of the surface potential, thereby acting as chemical sensors in liquid or gaseous environments. We demonstrate the applicability of GaN QDs as optical chemical sensors, benefiting from the optical transparency of both the sapphire substrate and the AlN matrix. GaN/AlN QDs have been grown on conductive Si-doped AlGaN backcontact layers and were equipped with catalytic Pt front contacts. The optical response of such a system in terms of a change in luminescence characteristics upon exposure to hydrogen-containing gases is discussed.

HL 42.6 Thu 15:15 H13

Band gap and band parameters of InN from quasiparticle energy calculations based on exact-exchange density-functional theory — Patrick Rinke[1], Matthias Scheffler[1], Abdallah Qteish[2], and •Jörg Neugebauer[3] — [1]Fritz-Haber-Institut der MPG, Berlin - Germany — [2]Yarmouk University, Irbid - Jordan — [3]MPI für Eisenforschung, Düsseldorf - Germany

Despite significant improvements in the fabrication and quality of InN, the exact values of the InN bandgap and of the band parameters are still controversially discussed. We have therefore performed quasiparticle energy calculations in the G_0W_0 approximation using as input the bandstructure obtained in the exact-exchange (EXX) approach. In previous studies we showed that this approach systematically provides bandgaps with an accuracy of ≈0.1 eV. Employing this approach we find a bandgap of 0.7 eV for wurtzite InN [1], suggesting an intrinsic value at the lower end of the experimentally observed range [2]. Taking the Burnstein-Moss effect into account, the increase of the apparent gap with increasing electron concentration is in good agreement with the experimentally observed blue shift of the optical absorption edge. Moreover, the concentration dependence of the effective mass, which results from the non-parabolicity of the conduction band, agrees well with recent experimental findings. The upper range of experimentally observed bandgaps is explained in terms of a defect/impurity model based on the charge neutrality level.

[1] P. Rinke *et al.*, Appl. Phys. Lett. **89**, 161919 (2006)
[2] W. Walukiewicz *et al.*, J. Crystal Growth **269**, 119 (2004)

HL 42.7 Thu 15:30 H13

Optimierung von Nitrid-basierten sichtbaren und ultravioletten Lichtemittern — •Daniel Fuhrmann, Holger Jönen, Uwe Rossow, Carsten Netzel, Lars Hoffmann, Heiko Bremers und Andreas Hangleiter — Institut für Angewandte Physik, Technische Universität Braunschweig

Trotz hoher Defektdichte wurden (Ga,In,Al)N-basierte Lichtemitter im blauen und violetten Spektralbereich mit sehr hohen Quantenausbeuten realisiert. In diesem Beitrag versuchen wir Ursachen für den Abfall der Effizienz sowohl zu grösseren ($\lambda_{peak} > 500nm$) als auch zu kleineren ($\lambda_{peak} < 365nm$) Emissionswellenlängen aufzuzeigen. Daraus ergeben sich Möglichkeiten zur Optimierung sowohl von grün/rot emittierenden InGaN/GaN QWs mit hohem In-Gehalt als auch von In-freien GaN/AlGaN QWs hinsichtlich hoher interner Quantenausbeute (IQE). Es zeigt sich, dass die optischen Eigenschaften und die IQE in beiden Fällen maßgeblich von der strukturellen Qualität der aktiven Zone abhängen. Zusätzlich müssen Unterbau, Spacer, Elektronenbarriere und Deckschicht optimiert werden. Im grünen/roten Spektralbereich kann der starke Abfall der IQE durch das Wachstum dünner QWs mit hohem In-Gehalt minimiert werden. Dabei muß die Degradation des InGaN QWs durch zu hohe Wachstumstemperaturen der Deckschicht verhindert werden. Messungen der IQE an In-freien UV-emittierenden GaN/AlGaN QWs zeigen, dass die die IQE limitierenden Prozesse denen in InGaN/GaN QWs sehr ähnlich sind. Auf gleiche Weise können auch GaN/AlGaN QWs mit hoher IQE hergestellt werden.

HL 42.8 Thu 15:45 H13

Direct Observation of Substrate Modes in 405 nm (Al,In)GaN Laser Diodes — •Harald Braun[1], Christoph Lauterbach[1], Ulrich T. Schwarz[1], Valerio Laino[2], Bernd Witzigmann[2], Christian Rumbolz[3], Marc Schillgalies[3], Alfred Lell[3], Volker Härle[3], and Uwe Strauss[3] — [1]NWF II Physik, Universität Regensburg, Universitätsstr. 31, 93053 Regensburg — [2]Integrated Systems Laboratory, ETH Zurich - Gloriastrasse 35, CH-8092 Zurich, Switzerland — [3]Osram Opto Semiconductors GmbH, Leibnizstr. 2, 93055 Regensburg

In (Al,In)GaN laser diodes high refractive index epitaxial layers like the SiC or GaN substrate can act as parasitic waveguides. The resulting substrate modes cause losses to the mode propagating in the laser waveguide, so an impact on laser threshold and gain spectra can be seen. We also observe the standing wave in the substrate directly by a measurement of the near-field intensity on the cleaved surface of the substrate just below the laser ridge waveguide. The oscillation period of the substrate modes extracted from these measurements varies strongly from sample to sample with nominally the same epitaxial structure. By a simple refractive index model we calculate the corresponding effective refractive index of the laser waveguide and the angle of the far-field side lobe and compare the results with far-field measurements. Furthermore we put forward a complex two-dimensional simulation of the optical field distribution in the laser structure including the SiC or GaN substrate. These simulations allow a quantitative interpretation of the experimental features caused by the substrate modes.

HL 42.9 Thu 16:00 H13

All-optical determination of the lateral electric field in InGaN/GaN quantum wells — •Clemens Vierheilig[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Nikolaus Gmeinwieser[2], Uwe Strauss[2], and Volker Härle[2] — [1]NWF II - Physik, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg — [2]Osram Opto Semiconductors, Wernerwerkstraße 2, 93049 Regensburg

Photogenerated carriers in InGaN/GaN quantum wells are vertically separated by strong internal piezoelectric fields. When exciting the sample with a small laser spot, the initial carrier density follows the excitation profile. Due to the carrier density-dependent screening of the piezoelectric field, a strong lateral dependence of the quasi Fermi-levels for electrons and for holes is induced by the reduction of the quantum confined Stark effect (QCSE). This gradient in the quasi Fermi-levels defines a lateral electric field with different directions for electrons and holes, so that both types of carriers are pushed laterally away from the excitation spot. An additional lateral diffusive motion is induced due to the concentration gradient. From the spatial distribution of the PL-signal of a green emitting InGaN/GaN quantum well test layer, measured by a modified confocal microscope, we calculate a radial electric field with a maximum value of about 110 V/cm.

HL 43: Theory of electronic structure

Time: Thursday 14:00–15:45 Location: H14

HL 43.1 Thu 14:00 H14

Analysis of core-valence linearization in G_0W_0 calculation — •Xinzheng Li[1], Ricardo Gomez-Abal[1], Claudia Ambrosch-Draxl[2], and Matthias Scheffler[1] — [1]Fritz-Haber-Insitut der Max-Planck-Gesellschaft, D-14195, Berlin — [2]Department of Material Physics, A-8700, Leoben

In recent years, the *GW* approach, typically applied as the first order correction to the Kohn-Sham (KS) eigenenergies (G_0W_0 approximation), has achieved great success in describing the single-particle excitations in weakly correlated semiconductors and insulators. For implementation simplicity and computational efficiency, most of the existing codes are based on the pseudopotential (PP) method, in which the self-energy is only calculated from the (pseudo-)valence states. It is already well-known in DFT that such a linear treatment of the core-valence exchange-correlation interaction is not always valid. Non-linear core corrections have to be added in such cases. While within G_0W_0-PP, core-valence interaction can only be included at the KS level, its results always show better agreement with experiment than the all-electron calculations available so far. In this talk, we analyze the reasons for this disturbing discrepancy and the validity of the "core-valence linearization" in the G_0W_0-PP scheme. Calculations are performed using our newly developed all electron G_0W_0 code, based on the Wien2k implementation of the FP-(L)APW+lo method. We compare our all-electron results with those obtained by computing the self-energy from the valence states only as well as with G_0W_0-PP calculations for selected materials (e.g. Si, GaAs, NaCl, ...).

HL 43.2 Thu 14:15 H14

Excitonic Effects in MnO: An Application of Spin-Polarized BSE — •Claudia Rödl, Frank Fuchs, Jürgen Furthmüller, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

As it is desirable to calculate optical spectra also for magnetic materials we approach the problem of evaluating excitation properties for collinear spin-polarized systems within the Bethe-Salpeter equation (BSE). As an interesting test material we choose the antiferromagnetic insulator MnO.

We start with a calculation of the electronic ground state in the framework of density-functional theory (DFT) within the generalized-gradient approximation (GGA) and use the projector-augmented wave (PAW) method to describe the wave functions. In the case of MnO the main problem consists in obtaining reasonable quasiparticle energies. We compute quasiparticle shifts using Hedin's GW approximation in a model scheme.

To treat magnetic materials one has to extend the usual BSE scheme in order to describe the spin degree of freedom. As a consequence the rank of the BSE Hamiltonian doubles resulting in increased computational cost. The optical spectra are determined by solving an initial-value problem instead of a direct diagonalization of the Hamiltonian.

HL 43.3 Thu 14:30 H14

GW Calculations Starting from Generalized Kohn-Sham Schemes — •Frank Fuchs[1], Jürgen Furthmüller[1], Friedhelm Bechstedt[1], Maxim Shishkin[2], and Georg Kresse[2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institut für Materialphysik and Center for Computational Materials Science, Universität Wien, Austria

The GW approximation of Hedin is arguably the most successful approach for the calculation of quasi-particle (QP) energies in extended systems. Its accuracy has been proven for a variety of systems. Usually, the QP eigenvalues are calculated in a perturbative approach, starting from solutions of the Kohn-Sham equations with an exchange-correlation (XC) potential in local density or generalized gradient approximation (LDA/GGA). However, this standard approach fails for a number of systems such as InN or ZnO with shallow 'semi-core' electrons and a much too small or even 'negative gap' in LDA/GGA. Here we present G_0W_0 calculations for various materials which start from solutions of the generalized Kohn-Sham (gKS) equations for the screened exchange (sX), HSE03, PBE0 and HF model of exchange and correlation. The calculations are performed within the framework of the full potential PAW method. The *GW* calculations, with various gKS solution as input, are found to yield a positive gap and *d*-band positions close to the experimental values for all the functionals investigated here. Furthermore, with exception of HF the resulting gaps are almost the same for all the gKS functionals chosen as starting point.

HL 43.4 Thu 14:45 H14

Electron Localization Function, persistent current and Wigner crystal phase in a one-dimensional quantum ring — •Marc Siegmund and Oleg Pankratov — Lst. für Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr.7, 91058 Erlangen

Due to the absence of long-range order in one-dimensional (1D) systems, the existence of a 1D Wigner crystal has been a long debated subject. It was shown [1] that despite the strong fluctuations, already a small pinning potential can stabilize the crystal phase at moderate electron densities. We confirm the existence of a 1D Wigner phase via studying a persistent current in a one-dimensional quantum ring with a single Gaussian impurity. The current is induced by a magnetic flux penetrating the ring. To calculate the current we use Density Functional Theory with OEP approximation for exchange effects. The Wigner crystallization manifests itself as a drastic decrease of the current at a critical value r_S^c. In the limit of a vanishing impurity potential we find a sharp drop of the current, whereas for a finite potential strength the transition is smooth. We interpret the observed behaviour as a pinning of a Wigner crystal phase at $r_S^c \approx 2.2$ (for 0.3 of the flux quantum). This interpretation is supported by the calculation of the Electron Localization Function [2]. The latter shows the delocalized electron distribution for $r_S < r_S^c$, which drastically changes reflecting a strong localization of periodically arranged electrons at $r_S > r_S^c$.

[1] L.I. Glazman et al., Phys. Rev. B **45**, 8454 (1992)
[2] A.D. Becke and K.E. Edgecombe , J. Chem. Phys. **92**, 5397 (1990)

HL 43.5 Thu 15:00 H14

Self-consistent solutions for non-adiabatic electron dynamics within time-dependent density functional theory — •Günther Schwarz, Ilya V. Tokatly, and Oleg Pankratov — Lst. für Theoretische Festkörperphysik, Universität Erlangen-Nürnberg

Based on recent work in our group [1,2] we implemented a scheme to simulate a finite, one-dimensional electron system self-consistently within time-dependent density functional theory (TDDFT) taking non-adiabatic effects in the exchange-correlation potential v_{xc} into account. This is done by calculating the time evolution of the density within the co-moving Lagrangian reference frame. v_{xc} depends on the Cauchy deformation tensor as the basic variable rather than on the electron density or current.

We simulate the collective behavior of an electron liquid in single and double well structures subjected to time-dependent external electric fields. The evolution of the electron density is compared to the common adiabatic local density approximation. In good agreement with the results of non-self-consistent calculations for an analytic test system [3] we find most prominent non-adiabatic effects in regions with strongly varying deformation. Consequences for laser excitations of quantum well systems are discussed.

[1] I. V. Tokatly and O. Pankratov, Phys. Rev. B **67**, 201103(R) (2003).
[2] I. V. Tokatly, Phys. Rev. B **71**, 165105 (2005).
[3] C. A. Ullrich und I. V. Tokatly, Phys. Rev. B **73**, 235102 (2006).

HL 43.6 Thu 15:15 H14

Self-consistent k.p envelope function method for InAs/GaSb broken gap superlattices — •Till Andlauer, Tobias Zibold, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

A novel charge self-consistent k.p envelope function method is presented for the calculation of the electronic structure of type-II semiconductor heterostructures with broken gap. Such heterostructures are relevant for the development of infrared lasers as well as infrared detectors. Standard multi-band k.p approaches fail to yield the correct occupation of electronic states in broken gap heterostructures, because strong hybridization of conduction band and valence band states makes it impossible to occupy electron and hole states separately. In

our method, we occupy all included subbands with electrons according to Fermi statistics and subsequently subtract a positive background charge that guarantees charge neutrality. We present results, such as gaps, subband dispersions, masses, and local charge densities, for strained intrinsic InAs/GaSb (001)-superlattices as a function of layer thickness and bias. We find good agreement for the effective bandgap with experimental data [1,2]. [1] L. L. Chang et al., J. Vac. Sci. Technol. 19, 589 (1981). [2] H. Mosheni et al., Appl. Phys. Lett. 71, 1403 (1997).

HL 43.7 Thu 15:30 H14

The impact of self-consistency and vertex corrections in GW calculations. — •Maxim Shishkin and Georg Kresse — Institut fuer Materialphysik and Centre for Computational Materials Science, Universitaet Wien, A 1090 Wien, Austria

The GW method is a common choice for accurate calculations of electronic band structures in solids. The commonly used single shot GW approximation (G0W0) is plagued by reliance on DFT wavefunctions and energies, which do not always provide a reasonable input. As a remedy to this problem, we present here the results of self-consistent quasiparticle calculations (scGW) [1] with a full update of both eigenvalues and wavefunctions, performed using the VASP code. The obtained gaps are generally overestimated for most of the materials, which is however not surprising as the higher terms in the many body expansion of the Hamiltonian (vertex corrections) are missing. Indeed, it is shown that addition of vertex corrections decreases the gaps, bringing them into much closer agreement with experiment. We propose that the overestimation of scGW gaps can be caused by an inaccurate description of dielectric properties (underestimated static dielectric constants), resulting from neglect of electron-hole interaction in the calculation of polarizabilities and dielectric matrices. The vertex correction contributions, which includes such electron-hole interactions, lead to an increase of dielectric constants to values close to experiment, and a concomitant decrease of the gaps.

[1] M. van Schilfgaarde, T. Kotani, and S. Faleev, Phys. Rev. Lett., vol. 96, 226402 (2006).

HL 44: Semiconductor Microcavities and Entangled States in Quantum Dots

Time: Thursday 14:00–18:15 Location: H15

Invited Talk HL 44.1 Thu 14:00 H15

Electron spin dynamics in quantum dots — •Manfred Bayer — Experimentelle Physik II, Universität Dortmund, D-44221 Dortmund, Germany

Electron spins in quantum dots (QDs) are promising candidates to serve as building blocks for semiconductor based quantum information technologies. Due to the unavoidable inhomogeneities in a QD ensemble it is common believe that coherent manipulations need to be performed on a single dot level. In this contribution we will show that by proper addressing of QDs by pulsed laser protocols it might be possible to perform corresponding studies on QD ensembles, with all the related benefits such as strong spectroscopic response.

For our experiments we have primarily used a time-resolved Faraday rotation technique on (In,Ga)As/GaAs quantum dots single charged with on electron. Using this methodology we will show: (i) trains of circularly polarized laser pulses are extremely efficient to create spin coherence (spin initialization) [1]. (ii) Such pulse trains can be used to synchronize certain spin subsets within the ensemble. From the dependence of the synchronization on the pulse separation the electron spin coherence time can be measured to be 3 μs at cryogenic temperatures [2]. (iii) The spins can be clocked by pulse doublet sequences such that they show periodic coherent responses. The period of these responses can be tailored by the details of the laser excitation [3].

Finally we will also address the impact of the interaction of the electron spins with the background of nuclei, which is considered to be one of the prime reasons for spin dephasing. We will show that under specific conditions a strong interaction between electron and nuclear spins will be established leading to a drastic enhancement of the spin relaxation time.

[1] A. Greilich, R. Oulton, E. A. Zhukov, I. A. Yugova, D. R. Yakovlev, M. Bayer, A. Shabaev, Al. L. Efros, I. A. Merkulov, V. Stavarache, D. Reuter, and A. Wieck, Phys. Rev. Lett. 96, 227401 (2006).

[2] A. Greilich, D. R. Yakovlev, A. Shabaev, Al. L. Efros, I. A. Yugova, R. Oulton, V. Stavarache, D. Reuter, A. Wieck, and M. Bayer, Science 313, 341 (2006).

[3] A. Greilich, M. Wiemann, F.G.G. Hernandez, D.R. Yakovlev, I.A. Yugova, M. Bayer, A. Shabaev, Al.L. Efros, D. Reuter and A.D. Wieck, submitted for publication.

[4] R. Oulton, A. Greilich, S. Yu. Verbin, R. V. Cherbunin, T. Auer, D.R.Yakovlev, M. Bayer, I. A. Merkulov, V. Stavarache, D. Reuter, and A. D. Wieck, submitted for publication.

Invited Talk HL 44.2 Thu 14:30 H15

Electrical control of entangled excitons in self-assembled quantum dot molecules — •Hubert J. Krenner — Walter Schottky Institut, Technical University of Munich, 85748 Garching, Germany

In this talk I will discuss recent experiments in which we electrically manipulate coupled exciton states in individual QD-molecules (QDMs). The samples investigated consist of a single pair of vertically stacked self assembled $In_{0.5}Ga_{0.5}As$ quantum dots embedded into the intrinsic region of an n-type GaAs Schottky photodiode. This device enables us to control the coherent coupling between exciton states in the upper and lower dots by tuning the electric field oriented along the axis of the QD-molecule via the gate voltage. New information is obtained on the charge distribution and spin structure of negatively charged trions in coupled quantum dot nanostructures and we directly probe Coulomb and Pauli blockade effects and inter-dot tunnel coupling using fully optical techniques. Electric field dependent μ-photoluminescence measurements reveal a clear anticrossing between spatially direct (e,h in the same dot) and indirect (e,h in different dots) neutral excitons with coupling energies in the range $2E_{1e+1h} = 1.2 - 3.2meV$.[1] Our experimental findings are shown to be in good accord with realistic calculations of the single exciton spectrum, confirming that the tunnel coupling is mediated by hybridization of the electron component of the exciton wavefunction over the two dots. In contrast, observations for negatively charged excitons are shown to be much richer due to the complex spectrum of negatively charged exciton states ($X^{-1} = 2e + 1h$) that can exist in a QD-molecule.[2] Both inter- and intra-dot Coulomb couplings are directly measured for a wide range of different charge initial X^{-n_e}, $n_e = 0, 1, 2$ states and the tunnel couplings and ground state spin configurations are tuned using electric field. Our findings are in good agreement with realistic calculations providing a fairly complete description of the behaviour of negatively charged excitons in quantum dot molecules.

1 H.J. Krenner et al. Phys. Rev. Lett. 94, 057402, (2005)

2 H.J. Krenner et al. Phys. Rev. Lett. 97, 076403, (2006)

Acknowledgements:

J. J. Finley, E. C. Clark, T. Nakaoka, C. Scheurer, M. Bichler and G. Abstreiter

Invited Talk HL 44.3 Thu 15:00 H15

Quantum optical studies on laterally coupled quantum dots and pillar microcavities — •P. Michler[1], Gareth Beirne[1], C. Hermannstädter[1], S. M. Ulrich[1], Serkan Ates[1], L. Wang[2], A. Rastelli[2], O. G. Schmidt[2], C. Gies[3], J. Wiersing[3], F. Jahnke[3], S. Reitzenstein[4], C. Hoffmann[4], A. Löffler[4], and A. Forchel[4] — [1]Universität Stuttgart, Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart — [2]Max-Planck Institut für Festkörperforschung, Heisenbergstr.1, 70569 Stuttgart — [3]Institut für Theoretische Physik, Universität Bremen, Otto-Hahn-Allee, 28359 Bremen — [4]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg

During the last few years remarkable progress has been achieved in the development of coupled semiconductor quantum dots and high-quality microcavities which might open the way for new applications in the field of quantum information processing. We have fabricated pairs of laterally coupled (In,Ga)As QDs and demonstrate interdot electron coupling using optical techniques. The degree of tunnel coupling can be controlled by applying a static electric field along the quantum dot molecule (QDM) axis. By applying a voltage the electron probability can be reversibly shifted to either QD, and the QDM can be used

to create a wavelength-tunable single photon emitter. Furthermore we present measurements of first- and second-order coherence of quantum-dot micropillar lasers. Our results show a broad threshold region for the observed high-β microcavities. The intensity jump is accompanied by both pronounced photon intensity fluctuations and strong coherence length changes. The results are in good agreement with a novel semiconductor laser theory.

Invited Talk HL 44.4 Thu 15:30 H15

Exciton qubits: From Rabi oscillations towards optoelectronic quantum gates — •Artur Zrenner[1], Stefan Stufler[1], Patrik Ester[1], Steffen Michaelis de Vasconcellos[1], Marc C. Hübner[1], Max Bichler[2], Pawel Machnikowski[3], Vollrath M. Axt[4], and Tilmann Kuhn[4] — [1]Universität Paderborn, Warburger Straße 100, D-33098 Paderborn, Germany — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall, D-85748 Garching, Germany — [3]Instytut Fizyki Politechniki Wrocławskiej, Wybrzeze Wyspiańskiego 27, PL-50-370 Wrocław, Poland — [4]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Straße 10, D-48149 Münster, Germany

In optical experiments on single self-assembled InGaAs quantum dots we detect the exciton ground state transition as an extremely narrow resonance. For the case of pulsed laser fields and in the absence of decoherence, the ground state exciton represents a qubit. Excitations with ps laser pulses result in multiple qubit rotations, which are demonstrated in a quantitative way as Rabi oscillations in photocurrent experiments. By resonant two-photon excitation we are further able to create and control coherent biexciton states. Under the condition of slight electric field induced detuning we observe Ramsey fringes of a single exciton qubit. In those experiments we are able to demonstrate fringes with a spectral half period below the homogeneous linewidth of the quantum dot. With our results we demonstrate voltage controlled qubit manipulations, which are essential for new types of optoelectronic quantum gates and precision quantum measurements.

15 min. break

Invited Talk HL 44.5 Thu 16:15 H15

Optical Semiconductor Microtube Ring Cavities — •Tobias Kipp, Christian Strelow, Holger Welsch, Hagen Rehberg, Christoph M. Schultz, Christian Heyn, and Detlef Heitmann — Institute of Applied Physics, University of Hamburg, Germany

Recently we demonstrated that self-supporting microtubes can act as novel kinds of optical microcavites [1]. These microtubes are fabricated, starting from an epitaxially grown InGaAs/GaAs bilayer and using optical lithography and wet-etching processes, by utilizing the self-rolling mechanism of strained bilayers. The diameters of these microtubes are typically about 5 μm, whereas their walls are only 50-200 nm thick. We incorporate either self-assembled quantum dots or quantum wells as optically active material inside the tube walls. In photoluminescence spectra we find in both cases sharp modes arising from constructive interference of light running around the microtube's axis. The mode structure is in very good agreement to theoretical calculations, modelling the microtube as a closed dielectric waveguide. We discuss possibilities and show evidences of a three-dimensional confinement of light in these novel microtube ring cavities

We gratefully acknowledge financial support of the Deutsche Forschungsgemeinschaft via the SFB 508 and the Graduiertenkolleg 1286.

[1] T. Kipp *et al.*, PRL **96**, 077403 (2006).

Invited Talk HL 44.6 Thu 16:45 H15

Semiconductor quantum dots as entangled light sources — •David Gershoni — Technion - Israel Institute of Technology, Haifa, 32000, Israel

Entangled photon pairs are emitted from a biexciton decay cascade of single quantum dots when spectral filtering is applied. We show this by experimentally measuring the density matrix of the polarization state of the photon pair emitted from a continuously pumped quantum dot. The matrix clearly satisfies the Peres criterion for entanglement. By applying in addition a temporal window, the quantum dot becomes an entangled light source.

Invited Talk HL 44.7 Thu 17:15 H15

Configuration mixing of electronic states in quantum dots — Kroner M.[1], Govorov S.[2], Remi S.[1], Seidl S.[1], Badoleto A.[4], Petroff P.[4], Warburton R.[3], and •Kahled Karrai[1] — [1]Center for NanoScience, Sektion Physik, Ludwig-Maximilians-Universität,Geschwister-Scholl-Platz 1, 80539 München, Germany — [2]Department of Physics and Astronomy, Ohio University, Athens, OH, USA — [3]Department of Physics, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK — [4]Materials Department, University of California, Santa Barbara, CA 93106, USA

Charge tunable self-assembled semiconductor quantum dots are typically charac-terized by extremely sharp lines in their optical absorption and emission spectra. When the probing laser frequency is in resonance with one of such exciton lines, the quantum dot states can couple very strongly to the radiation field, to the point that the photon and electron states hybridize to become indistinguishable. A signature for such coherent dressed states formed under modest laser power is the observation of Rabi oscillations, of ac-stark effect and of cavity quantum electrodynamics in the weak and strong coupling regime. In this talk we present new data showing that when the laser power is further in-creased, a competing pathway for optical excitations in charge tunable quantum dots is revealed through a novel quantum optical interference. The interfering optical excitation channel originates from a weak transition of the charge tunable quantum dot ground state to an electronic continuum of states extended beyond the dot location. We will argue that this effect should apply generally to optically active few-level quantum systems in which one of the levels interacts with a continuum of states. The existence of alternative optical transition channels to localized and delocalized states has implications on coherence is-sues in quantum information processing. We developed a new quantum optical version of the ubiquitous Fano model that describes interactions between localized and extended dressed states. The model is in good qualitative agreement with the data.

Invited Talk HL 44.8 Thu 17:45 H15

Coupled Quantum Dots for Quantum Information — •Tom Reinecke — Naval Research Laboratory, Washington, DC USA

Spins in quantum dots (QDs) are attractive candidates for quantum bits (qubits) for quantum information technologies. A key need is for coherent coupling between qubits that can be manipulated in two-qubit gates needed for quantum logic. Recent advances in the understanding of two different physical systems for this purpose made in joint work involving fabrication, experiment and theory will be discussed.

Vertically coupled InAs quantum dots are formed by Stanski-Krastanov MBE growth on adjacent GaAs layers. We have shown that the quantum tunnel coupling between QDs can be manipulated by an external electric field [1,2]. Electron states, hole states or excitons can be brought into and out of resonance with fields and appropriate sample design [3]. Exchange interactions between spins in coupled QDs have been elucidated, including a novel 'kinetic exchange' interaction [4]. A novel mechanism to turn on interactions between spins optically has been found. Strongly tunable biexciton-exciton cascades of interest in quantum optics have been demonstrated [5]. An electric field dependent g-factor for spin splitting has been found, which provides opportunities for single qubit and two qubit operations with fast electric fields [6].

Coherent ('strong') interactions between QD excitons and cavity photon modes have long been sought as a basis for fast optical coupling between distant QDs and for distributed quantum computing. We have demonstrated this strong coupling with high finesse pillar microcavities and large dipole moment $In_{.30}Ga_{.70}As/GaAs$ QDs [7]. Recently we have also found strong coupling between two quantum dots within the linewidth of a single cavity mode [8].

[1] G. Ortner, M. Bayer, Y. B. Lyanda-Geller T. L. Reinecke and A. Forchel, Phys. Rev. Lett. 94, 157401 (2005).

[2] E.A. Stinaff, M. Scheibner, A.S. Bracker, I. Ponomarev, V.L. Korenev, M.E. Ware, M.F. Doty, T.L. Reinecke and D. Gammon , Science 311, 627 (2005).

[3] A. S. Bracker, M. Sheibner, M. F. Doty, E. A. Stinaff, I. V. Ponomarev, J. C. Kim, L. J. Whitman, T. L. Reinecke and D. Gammon, Appl. Phys. Lett. 89, 233110 92006)

[4] M. Scheibner, M. F. Doty, I. V. Ponomarev, A. S. Bracker, E. A. Stinaff, V. L. Korenev, T. L. Reinecke and D. Gammon, condmat 0607241

[5] M. Scheibner, M.F. Doty, I.V. Ponomarev, A.S. Bracker, E.A. Stinaff, T.L. Reinecke, C. S. Hellberg, D. Gammon (to be published)

[6] M. F. Doty, M. Scheibner, I. V. Ponomarev, E. A. Stinaff, A. S. Bracker, V. L. Korenev, T. L. Reinecke and D. Gammon, Phys. Rev. Lett. 97, 197202 (2006)

[7] J.-P. Reithmaier, G. S*k, A. Löffler, C. Hofmann, S. Kuhn , S. Reitzenstein, L. Keldysh, V.Kulakovskii, T.L. Reinecke, and A. Forchel, Nature 432, 197 (2004).

[8] S. Reitzenstein, A. Löffler, C.Hofmann, J.-P. Reithmaier, M. Kamp, , V.D. Kulakovskii, L.V. Keldysh , T. L. Reinecke and A. Forchel, Optics Letters 31, 1738 (2006)

HL 45: ZnO II

Time: Thursday 14:00–17:30 Location: H17

HL 45.1 Thu 14:00 H17

Optical Investigation of Surface Defects in ZnO Nanostructures — •Johannes Fallert[1], Robert Hauschild[1], Huijuan Zhou[1], Felix Stelzl[1], Markus Wissinger[1], Mario Hauser[1], Dong Sik Kim[2], Margit Zacharias[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Universität Karlsruhe (TH), Karlsruhe, Germany — [2]Max-Planck-Institute of Microstructure Physics, Halle,

The optical properties of different ZnO nanostructures are investigated. Thereby we focus on a photoluminescence (PL) emission band around 3.31 eV. Compared to bulk ZnO this band is observed to be strongly increased in ZnO nanoparticles. We assign the origin of this emission band to acceptors present at the particle surface since this emission band shows a clear dependence on the surface to volume ratio of the particles. Temperature dependent measurements reveal that this band plays a major role up to room temperature. Furthermore, time resolved and intensity dependent measurements have been carried out to confirm this designation and to understand the luminescence dynamics.

HL 45.2 Thu 14:15 H17

Electrical properties of compacted zinc oxide nanoparticles — •Sonja Hartner[1], Hartmut Wiggers[2], and Axel Lorke[1] — [1]Experimental Physics, University of Duisburg-Essen, Lotharstr.1, 47057 Duisburg — [2]Institute of Combustion and Gas Dynamics, University of Duisburg-Essen, Lotharstr.1, 47057 Duisburg

The present study investigates the electrical properties of mechanically compacted pellets of nanosized zinc oxide powders from gas phase synthesis by impedance spectroscopy (IS). The measurements were performed in air and in hydrogen atmosphere at temperatures ranging from 320K to 650K. As expected for semiconducting materials, the spectra measured in air show very poor conductivity under ambient conditions and an increase in conductivity with increasing temperature. Between 500 K and 650 K the activation energy was found to be 604 meV. The impedance spectra exhibit the typical structure known from ionic conductors with a low-frequency Warburg impedance. After annealing at temperatures of about 250 °C in hydrogen atmosphere, the absolute value of the conductivity increases up to four orders of magnitude. The electrical measurements show ohmic behavior over the complete temperature range and the activation energy has changed to -11 meV, meaning positive temperature coefficient conductivity as it is known from metals. The change in electrical behavior under air and hydrogen is reversible and is attributed to a change of the chemical composition. The current understanding is that by exposing zinc oxide to hydrogen gas, oxygen vacancies are formed, providing ZnO1-x with free electrons which contribute to the overall conductivity.

HL 45.3 Thu 14:30 H17

Magnetoresistance in n-type conducting magnetic ZnO films — •Qingyu Xu, Lars Hartmann, Heidemarie Schmidt, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany

The magnetoresistance (MR) of differently alloyed, n-type conducting ZnO films (Co, Mn, Ti, Cu, Nd) prepared by pulsed laser deposition (PLD) on a-plane sapphire substrates in oxygen atmosphere was probed in the temperature range from 5 K to 290 K with magnetic fields up to 6 T. At 5 K, large positive MR was observed in Co [1] and Mn doped ZnO films, while large negative MR was observed in Ti, Cu [2], and Nd doped ZnO films. The positive MR in doped ZnO was attributed to a giant spin splitting enhanced by s-d exchange interactions. This will affect considerably quantum corrections to the conductivity associated with the disorder modified electron-electron interactions [3]. The probed positive MR reveals that the s-d exchange interaction is strong in Co and Mn doped ZnO. Weak s-d exchange interaction has been observed in Ti, Cu, and Nd doped ZnO. Except for the Cu-doped ZnO, these results agree with magnetic circular dichroism results [4]. The positive and negative MR decreases drastically with increasing temperature, being nearly neglectable above 100 K. [1] Q. Xu, et al, Phys. Rev. B 73, 205342 (2006). [2] L. Hartmann, et al, J. Phys. D: Appl. Phys., in press. [3] T. Andrearczyk, et al, Phys. Rev. B 72, 121309(R) (2005). [4] K. Ando, et al, J. Appl. Phys. 89, 7284 (2001).

HL 45.4 Thu 14:45 H17

Hydrogen induced charge state alteration of Mn trace impurities in ZnO — •M. A. Gluba, F. Friedrich, and N. H. Nickel — Hahn-Meitner-Institut Berlin, Abt. Silizium Photovoltaik (SE1), Kekuléstraße 5, 12489 Berlin, Germany

The source of the natural n-type doping of ZnO is still a subject of discussion. However, both theoretical [1] and experimental work [2] show that hydrogen plays a crucial role. To elucidate the paramagnetic behavior of H in ZnO low temperature X-band electron paramagnetic resonance (EPR) measurements were performed. For this purpose EPR spectra were taken from *pressurized-melt-grown* nominally undoped ZnO single crystals before and after hydrogenation.

As-grown ZnO exhibits a single EPR-line at g=1.957 arising from multiple centers, one of which was identified as a hydrogen shallow donor [2]. On the other hand, post-hydrogenated ZnO shows a distincly different EPR spectrum. Besides the intensification of the hydrogen-related line additional fine and hyperfine split lines originating from ^{55}Mn appear. However, these features are not stable. While keeping the samples at room temperature for about four weeks the hydrogen line decays to its initial value. In the same period of time the manganese lines disappear completely. A likely mechanism for this correlation - the change of the Mn charge state due to hydrogen doping - will be discussed.

[1] C. G. Van de Walle, Phys. Rev. Lett. **85**, 1012 (2000)
[2] D. M. Hofmann *et al.*, Phys. Rev. Lett. **88**, 045504 (2002)

HL 45.5 Thu 15:00 H17

Electronic Structure of Europium Impiurities in ZnO — •Przemyslaw Imielski[1], William Brewer[1], Yuriy Manzhur[2], Kay Potzger[3], and Wolf Zeitz[2] — [1]Institut für Experimentalphysik, Freie Universität Berlin, D-14195 Berlin, Germany — [2]Bereich Strukturforschung, Hahn-Meitner-Institut Berlin GmbH, D-14091 Berlin, Germany — [3]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

Utilizing peturbed angular correlation spectroskopy (PAC), the behaviour of isolated europium impurities in ZnO has been investigated. The radioactive probe rare earth atoms 149Gd/149Eu were produced and recoil implanted by nuclear reactions. After annealing at 500 degree Celsius, the first spectrum of a 149Eu(11/2-) quadrupolar interaction has been measured. From spectra of the combined interaction, evidence for the realization of the Eu2+(7/2) ground state has been found.

HL 45.6 Thu 15:15 H17

Effects of annealing on the recombination dynamics of low-temperature grown ZnO nanorods — •B. Hilker[1], C. Bekeny[1], T. Voss[1], J. Gutowski[1], R. Hauschild[2], H. Kalt[2], B. Postels[3], Andrey Bakin[3], and A. Waag[3] — [1]IFP, Universität Bremen, 28334 Bremen — [2]Universität Karlsruhe, 76128 Karlsruhe — [3]IHT, TU Braunschweig, 38023 Braunschweig

We present systematic temperature and excitation density dependent time-resolved photoluminescence (TRPL) measurements of as-grown and annealed ZnO nanorods fabricated by an aqueous chemical growth (ACG) technique at ˜90°C. The as-grown nanorods show strong near-band-edge and rather weak deep-level emission indicating their already good optical quality. At 4K, we find a broad emission line at 3.36eV (line width 30meV) which we attribute to recombination from a donor band formed through the high donor concentration. After annealing in oxygen and nitrogen atmospheres at 600-800°C well-resolved

and sharper excitonic transitions are observed. To understand the recombination dynamics in the nanorods we carried out TRPL measurements using a frequency-doubled femtosecond laser and a streak camera. The as-grown sample shows a very fast monoexponential decay time of ˜10ps independent of temperature and excitation density. In contrast, the annealed samples exhibit a biexponential decay. Each a fast $\tau 1$ and a slow $\tau 2$ time constant have been determined for all annealed samples both of them significantly varying depending on the annealing atmosphere and temperature. This will be discussed on the basis of a phenomenological rate-equation model.

HL 45.7 Thu 15:30 H17

Acceptor doping of ZnO nanowires — •Bingqiang Cao, Michael Lorenz, Andreas Rahm, Christian Czekalla, Holger von Wenckstern, Gabriele Benndorf, Jörg Lenzner, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany

We have grown phosphorous, lithium, and nitrogen doped ZnO nanowires both by carbothermal evaporation [1] and by high-pressure pulsed laser deposition [2] by mixing various amounts of P_2O_5, $Zn_3(PO_4)_2$, Zn_3P_2, Li_2O, Li_3N, and Li_2CO_3 into the ZnO source material. The diameter and length of the acceptor-doped and undoped ZnO wires was in the range from 100 nm to 3 μm and several micrometers, respectively. Cathodoluminescence spectra taken at 10 K on the acceptor doped wires show clearly resolved acceptor-related and donor-acceptor pair peaks, indicating the acceptor incorporation into the ZnO lattice. From these acceptor peak energies, thermal activation energies of the acceptor levels were determined. For comparison, temperature-dependent I-V measurements allow the determination of a (two-terminal) activation energy. Both the optical and electrical measurements will be discussed with dependence on the dopant element, its concentration, the wire geometry, and the growth route. The aim of the work is p-type conducting ZnO nanomaterial for nano p-n-junctions and light emitting devices.

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[1] M. Lorenz et. al. Ann. Phys. (Leipzig) 13 (2004) 39.
[2] M. Lorenz et. al. Appl. Phys. Lett. 86 (2005) 143113.

15 min. break

HL 45.8 Thu 16:00 H17

Homoepitaxial growth of ZnO thin film by pulsed laser deposition (PLD) — •Matthias Brandt, Holger von Wenckstern, Christian Hanisch, Holger Hochmuth, Michael Lorenz, Heidemarie Schmidt, and Marius Grundmann — Universität Leipzig, Semiconductor Physics Group, Institut für ExperimentellePhysik II, Leipzig, Germany

In this work ZnO thin films have been deposited homoepitaxially by PLD on ZnO single crystals grown by the hydrothermal method (purchased from CrysTec GmbH). These wafers have first been investigated by atomic force microscopy (AFM) and were found to show significant surface roughness in the as-received state. Therefore a thermal annealing method has been applied to the wafers prior to thin film growth, in order to improve the surface properties. An overview of the changes during annealing will be presented along with information on the optimal conditions for thermal annealing. Structural, morphological, optical and electrical properties of the thin films grown homoepitaxially on these optimized wafers will be discussed with respect to the growth conditions. Comparisons to properties of thin films grown heteroepitaxially on sapphire (Al_2O_3) and SCAM ($ScAlMgO_4$) will be provided.

HL 45.9 Thu 16:15 H17

Homo-MOVPE von ZnO auf optimierten kommerziellen ZnO-Substraten — •Sören Heinze, Andre Krtschil, Jürgen Bläsing, Armin Dadgar, Thomas Hempel, Jürgen Christen und Alois Krost — Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle PhysikOtto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik

Auf thermisch vorbehandelten ZnO-Substraten wurden mittels metallorganischer Gasphasenepitaxie dünne ZnO-Schichten abgeschieden. Die Qualität der Schichten ist stark abhängig vom Verhältnis des Sauerstoffprecursors (N_2O) zum Zinkprecursor (Dimethylzink) (VI/II-Verhältnis). Ein kleines VI/II-Verhältnis induziert eine raue Oberflächenmorphologie sowie dreidimensionale Pyramiden mit Abmaßen von einigen Mikrometern . Erhöht man das VI/II-Verhältnis, so verringern sich sowohl die Anzahl dieser dreidimensionalen Pyramiden als auch deren Größe. Bei hohen VI/II-Verhältnissen von ca. 25000 sind die Pyramiden komplett verschwunden und man erhält eine noch sehr raue abgeschiedene Schicht. Modifikationen an weiteren Wachstumsparametern wie der Temperatur und dem Reaktordruck verbessern die morphologischen Eigenschaften der Schicht deutlich. Bei höheren Temperaturen wachsen die einzelnen Domänen zusammen und die Schicht wird signifikant glatter. Durch eine Erhöhung des Reaktordrucks konnte das Wachstum bis hin zum Stufenwachstum verbessert werden. Insgesamt werden die Untersuchungsergebnisse der morphologischen, strukturellen, elektrischen und optischen Eigenschaften dieser homoepitaktisch gewachsenen Schichten im Detail vorgestellt.

HL 45.10 Thu 16:30 H17

Homoepitaxially grown ZnO thin films — •Stefan Lautenschläger[1], Christian Neumann[1], Joachim Sann[1], Niklas Volbers[1], Swen Graubner[1], Bruno Meyer[1], Jürgen Bläsing[2], Alois Krost[2], Frank Bertram[2], and Jürgen Christen[2] — [1]I. Physikalisches Institut, Justus- Liebig- Universität Gießen — [2]Institut für Experimentelle Physik, Otto- von- Guericke Universität Magdeburg

We report on homoepitaxially ZnO thin films, grown on chemo- mechanically polished Crystec single crystals. To prepare the substrates for growth we employed a high temperature annealing step, which produced atomically flat surfaces and removed all of the surface and subsurface damage. We used Photoluminescence (PL), Cathodoluminescence (CL), Secondary Ion Mass Spectroscopy (SIMS), Hall measurements, high resolution X-Ray diffraction and Atomic Force Microscopy (AFM) to characterize the epilayers. Two dimensional epitaxial growth was achieved without an additional buffer layer. The substrate had a rocking halfwidth of 27" which can be compared with that of the film of 17". The films had superior band edge luminescence as compared with the substrate for which the green luminescence band is dominating. The impurity content in the substrates, especially Li is reduced by the high temperature annealing step and drops further to the detection limit in the thin films.

HL 45.11 Thu 16:45 H17

Annealing Studies on N and As implanted Zinc Oxide — •Niklas Volbers[1], Stefan Lautenschläger[1], Joachim Sann[1], Kay Potzger[2], and Bruno K. Meyer[1] — [1]I. Physikalisches Institut, Heinrich-Buff-Ring 16, Justus-Liebig-Universität Giessen, D-35392 Giessen, Germany — [2]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 51 01 19, 01314 Dresden, Germany

Both nitrogen and arsenic are considered possible acceptors in order to achieve p-type conductivity in ZnO. Ion implantation provides an accurate and reproducable method to incorporate these dopants into ZnO crystals.

In the presented work, high quality ZnO thin films were grown homoepitaxially on ZnO single crystals via a chemical vapour deposition process and were subsequently implanted with either ^{14}N or ^{75}As ions, using implantation doses of 10^{16} atoms/cm^2. The films were annealed at temperatures of up to 1100°C. Dynamic SIMS measurements show the evolution of the implanted ions in the films and the corresponding motion of residual impurities. In addition, photoluminescence and hall effect measurements were performed to investigate the optical and electrical properties of the as-grown and the annealed samples.

HL 45.12 Thu 17:00 H17

Aqueous chemical growth and application of ZnO nanorods — •Bianca Postels, Anna Kasprzak, Augustine Che Mofor, Hergo-Heinrich Wehmann, Andrey Bakin, and Andreas Waag — Institute of Semiconductor Technology, Technical University Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig, Germany

ZnO finds applications in many fields from sun tan lotion to optoelectronic applications. Especially the tendency of ZnO to form nanostructures opens the path to even more applications. A very promising fabrication process for ZnO nanostructures is the aqueous chemical growth (ACG), since it is a cost efficient and low temperature approach. Using this growth technique we generated wafer-scale ZnO nanorod arrays on Si, sapphire, ITO coated glass and even on flexible polymer substrates. ACG is found to be only weakly influenced by the substrate material and we are also able to control the dimensions of the ZnO nanorods. Another benefit of ACG is the ability to fabricate patterned arrays of ZnO nanorods by a selective growth process on structured metallised surfaces. Results of structural analysis with SEM and XRD are reported. Additionally, optical properties were investigated by PL measurements. First attempts on the preparation of

dye sensitised solar cells (DSSCs) are also reported. Here, the traditional sintered TiO2 nanoparticles are replaced by a densely packed and vertically aligned array of ACG ZnO nanorods. The size and morphology of the ZnO nanorods can be controlled. The influence of the length of the nanorods on the cell properties is investigated. A vapour phase transport technique was also used as alternative growth method.

HL 45.13 Thu 17:15 H17

Investigation of complex formation in pulsed-laser deposited Sb-doped ZnO thin-films — •Felice Friedrich and N. H. Nickel — Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik (SE1), Kekuléstraße 5, 12489 Berlin, Germany

Antimony (Sb) as group V element is a doping candidate for p-type ZnO. However, because of its large atomic size theory predicts that formation of a defect complex is more favorable. Growth temperature might play a critical role in this process. In this study the influence of Sb concentration and deposition temperature on the structural and vibrational properties of Sb-doped ZnO thin-films was investigated.

The samples were grown by pulsed laser deposition (PLD) on MgO substrates. Ceramic targets were produced from ZnO and Sb_2O_3 powder (0-2 at.% Sb). A XeCl excimer laser operating at a fluence of 1.5 J/cm^{-2} was used for the deposition process. The deposition temperature was varied between 450-800°C. The samples were characterized by scanning electron microscopy (SEM), energy dispersive X-ray scattering (EDX) and Raman backscattering spectroscopy.

Firstly, it is observed that a higher Sb concentration leads to a reduced film thickness. Raman measurements show that this is accompanied by a deterioration of the ZnO crystallinity. Secondly, a surprising change of the Raman spectra was observed at a temperature of 600°C. Below this temperature additional Raman modes are observed at 530, 575 and 700 cm^{-1}. Above 600°C the mode at 530 cm^{-1} is strongly suppressed. These results will be discussed in terms of the temperature-dependent formation of Zn-Sb-O complexes.

HL 46: Poster 2

Time: Thursday 15:00–17:30 Location: Poster A

HL 46.1 Thu 15:00 Poster A

Studies of diamond surfaces and metallization for detector applications — •Robert Lovrincic[1], Eleni Berdermann[2], Michal Pomorski[2], and Annemarie Pucci[1] — [1]Kirchhoff-Institut für Physik der Universität Heidelberg — [2]Gesellschaft für Schwerionenforschung Darmstadt

Diamond single crystals have several very favourable characteristics as detector material in high- and low-energy physics experiments. The diamond surface termination and reconstruction play a key role in the device performance. E.g., hydrogen termination gives rise to surface p-conductivity, which is undesirable for detector applications. The surface reconstruction influences the electron affinity and hence the Schottky barrier height of a metal-diamond interface. These properties were studied by means of Fourier transform infrared (FTIR) spectroscopy and low-energy electron diffraction. Another decisive step towards good detector performance is the metallization. Plenty, partially contradictory proposals for the fabrication of electrodes on diamond are published. In the case of diamond detectors however, Chromium-Gold, Titanium-Platinum-Gold and pure Aluminium electrodes are frequently applied. We studied* therefore, chromium film growth on diamond (100) single crystal surfaces by FTIR spectroscopy under ultra high vacuum conditions. This enables us to derive the electrical conductivity of the metal film and of the metal film-diamond interface in a non-destructive, non-contact way.

*Supported by EC Integrated Infrastructure Initiative Hadron Physics, Project RII3-CT-2004-506078

HL 46.2 Thu 15:00 Poster A

Pulsed laser deposition growth and characterisation of aligned graphitic nanostructures on LiNbO3 — •Dominikus Kölbl, Jens Ebbecke, and Achim Wixforth — Universität Augsburg, Universitätstr. 1, 86159 Augsburg

Low dimensional electronic structures attract high interest both for scientific research and possible applications in electrochemical devices and ICs.

We report on aligned structures of graphite growing along certain crystal directions of LiNbO3 by pulsed laser deposition. Scanning electron microscopy analysis showed strong alignment during growth of theses "carbon nano sticks" (CNS) due to pyroelectric fields induced by thermal gradients across the substrate. These CNS reaching aspect-ratios up to 65 (L = 5,7um; d = 88nm) are appropriate onedimensional electronic systems similar to famous carbon nano tubes. We investigated detailed characterization of these CNS grown at different PLD parameters. Furthermore the CNS have been contacted by e-beam lithography in order to perform electrically conduction measurements.

HL 46.3 Thu 15:00 Poster A

Infrared spectroscopy on rotor-stator compounds C_{60}-C_8H_8 and C_{70}-C_8H_8 under pressure — •K. Thirunavukkuarasu[1], C.A. Kuntscher[1], Gy. Bényei[2], I. Jalsovszky[2], G. Klupp[3], K. Kamarás[3], É Kováts[3], and S. Pekker[3] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Department of Organic Chemistry, Eötvös Loránd University, P.O.Box 32, Budapest, Hungary H 1518 — [3]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, P.O.Box 49, Budapest, Hungary H 1525

The fullerene-cubane molecular crystals C_{60}-C_8H_8 and C_{70}-C_8H_8 are the first members of the rotor-stator crystal family [1]. Static C_8H_8 molecules occupy the octahedral voids of the fullerene fcc structure and act as bearings for the rotating fullerene molecules. On cooling, C_{60}-C_8H_8 undergoes an orientational ordering phase transition at 140 K, while C_{70}-C_8H_8 undergoes transitions at around 390 K and 150 K. Under pressure C_{60}-C_8H_8 shows orientational ordering at 0.8 GPa [2]. We performed further pressure-dependent transmittance measurements on both C_{60}-C_8H_8 and C_{70}-C_8H_8 molecular crystals over a broad frequency range (FIR-VIS), for pressures up to 10 GPa. The pressure-induced changes in the vibrational modes of the fullerene and cubane molecules and the shift of the band gap are reported.

Supported by the DFG.

[1] S. Pekker et al., Nature Materials **4**, 764 (2005).

[2] C. A. Kuntscher et al., Phys. Stat. Sol. (b) **243**, 2981 (2006).

HL 46.4 Thu 15:00 Poster A

Transport Measurements through Graphene — •P. Barthold, T. Lüdtke, and R.J. Haug — Institut für Festkörperphysik, Abteilung Nanostrukturen, Gottfried Wilhelm Leibniz Universität Hannover, D-30167 Hannover

We present transport measurements through graphene in dependence of magnetic field and temperature.

We obtained graphene by micromechanical cleavage of natural graphite similar to the technique described in Ref.[1]. An optical microscope and a SEM were used to localize the graphene layers that are deposited on top of SiO_2. These flakes were further investigated with an AFM to select suitable samples and determine their height. By using electron beam lithography we are able to contact the samples. During the measurements the device is situated in a He^4 bath cryostat allowing measurements at temperatures between 1.4 K and 300 K. By varying the magnetic field we characterize the sample. As we apply a backgate voltage we see a peak in the resistivity that we contribute to a field effect.

[1] K. S. Novoselov et al., Proc. Natl. Acad. Sci. USA, vol. 102, p.10451 (2005)

HL 46.5 Thu 15:00 Poster A

High purity single step catalyst particle preparation for the carbon nanotube synthesis — •Franziska Schäffel, Christian Kramberger, Mark Rümmeli, Daniel Grimm, Thomas Gemming, Thomas Pichler, Bernd Büchner, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

Many applications of carbon nanotubes (CNTs) are impeded by a lack of control in positioning and orienting CNTs on substrates. Advances have been made by using catalyst thin films prepared and patterned by shadow masking [1] or lithography [2]. Yet, such thin film techniques

do not offer concurrent control of the size, size distribution, and areal density of the catalyst particles. We present a versatile route to prepare individual nanoparticles in the gas phase by sputtering from a high purity iron target. The route is advantageous in that the preparation of the catalyst particles is accomplished in a single step. The achievable degree of purity is very high as compared to processes where the catalyst preparation requires a series of chemical procedures (see, e.g., [3]). The separate preparation of catalyst and CNTs allows for an effective control of the particle size and density and offers the opportunity to characterize the starting material which cannot be so readily achieved in more conventional CVD processes where the catalyst particles form *in situ*. [1] L. Delzeit et al., J. Phys. Chem. B 106 (2002) 5629. [2] J. Kong et al., Nature 395 (1998) 878; A.J. Hart et al., J. Phys. Chem. B 110 (2006) 8250; M.S. Kabir et al., Nanotechnology 17 (2006) 790. [3] R.D. Bennett et al., Adv. Mater. 18 (2006) 2274.

HL 46.6 Thu 15:00 Poster A

Phosphorus-doped silicon under uniaxial tensile strain — •Nicole Santen and Reiner Vianden — HISKP Universität Bonn, Nußallee 14-16, D-53115 Bonn

The recent application of strained silicon into transistor design has led to significant progress in increasing the performance of devices. However, up to now, little is known about the mechanical behaviour of the strained Si layers and the elastic properties of the deformed semiconductor lattice. The perturbed angular correlation method is ideally suited to study strain related local phenomena in silicon using the acceptor ^{111}In as probe.

In the past, the influence of external uniaxial strain on In acceptors in pure Si and on donor-acceptor pairs in silicon has been investigated intensively. In the course of these studies it was found that the unpaired indium probes on regular lattice sites showed an unexpected reaction to uniaxial strain, which depended on the dopant species. In our current experiments, a strain induced EFG in P-doped silicon has been observed for the first time. In addition, it was found that the reaction of the P-doped silicon lattice to tensile strain applied along different crystal axes showed strong differences.

HL 46.7 Thu 15:00 Poster A

Photo-electric properties of 4H- and 6H-SiC investigated by resonant SCW excitation — •Burkhard Hilling[1], Michaela Lemmer[1], Mirco Imlau[1], Manfred Wöhlecke[1], and Mikhail Petrov[2] — [1]Department of Physics, University of Osnabrück, Germany — [2]Ioffe Physico-Technical Institute, St. Peterburg, Russia

Polytypes of 4H- and 6H-SiC have been investigated with the nonlinear phenomenon of resonant space-charge wave (SCW) excitation at a wavelength of $\lambda = 488$ nm. SCW are eigenmodes of spatial-temporal oscillations of a space-charge density appearing in semi-insulating semiconductors in an external electric field. SCW excitation was performed with an oscillating interference pattern with a frequency of $10 \leq \Omega \leq 3000$ Hz and an externally applied electric field E_0 up to 9 kV/cm. Resonant excitation was found if Ω equals the eigenfrequency of the generated SCW mode. Both amplitude and frequency of the resonance depend primarily on the applied electric field E_0 and the spatial frequency K of the interference pattern. We show that the experimentally obtained dependences on K, E_0 and Ω are in good agreement with the theoretical concept for so-called low-frequency SCW (trap recharging waves). This enables us to determine important material properties from the analysis for both SiC polytypes. These are the effective trap density N_{eff}, the product of mobility and lifetime $\mu\tau$ of the photo-excited charge carriers, and the maxwell relaxation time τ_M. Strengths and disadvantages of SCW excitation for purposes of semiconductor analysis are discussed.

Supported by the DFG (projects GRK 695 and 436 RUS 17/15/07)

HL 46.8 Thu 15:00 Poster A

Influence of anisotropic in-plane strain on the optical properties of (0001)-oriented GaN and ZnO films — •Marcus Röppischer[1], Carsten Buchheim[1], Rüdiger Goldhahn[1], Gerhard Gobsch[1], Florian Furtmayr[2], Thomas Wassner[2], and Martin Eickhoff[2] — [1]Technical University Ilmenau, Institute of Physics — [2]Technical University Munich, Walter-Schottky Institute

The growth of hexagonal (0001)-oriented GaN films on a-plane sapphire substrates causes an anisotropic in-plane strain. It originates from the different lattice constants and thermal expansion coefficients of the substrate parallel and perpendicular to the c-axis. Under those conditions the optical response of the GaN films depends on the light polarization within the surface plane. We have applied photoreflectance spectroscopy in order to study the polarization dependence of the oscillator strength for the free A and B excitonic transitions. The experimental results are in good agreement with theoretical calculations based on the Bir-Pikus strain Hamiltonian and the experimentally determined lattice constants. Corresponding investigations of ZnO films reveal a much lower polarization anisotropy.

HL 46.9 Thu 15:00 Poster A

PL characteristics of site-controlled InGaN nanostructures — •Theodoros Tsifotidis, Michael Jetter, and Peter Michler — Institut für Strahlenphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

InGaN emits in dependence on the Indium concentration light in the blue-green spectral range. The tendency for developing structures in the Stranski-Krastanov growth mode to realise QDs in this material system is quite weak. One possible solution can be a selective growth of GaN/InGaN nanostructures by MOVPE. To realise this a new masking method was applied by using small sized microspheres to produce a capable aperture mask. SEM measurements confirmed hexagonal grown micropyramids at the selected positions. CL measurements on them showed low emission energies in the region of their edges and dots caused by different Indium compositions on the surface. By varying the growth parameters one can influence the Indium distribution on the various surfaces. To deduce capable growth parameters we examined several samples fabricated with varied Indium flow, growth time and growth temperature. Time-integrated and time-resolved ensemble- and *-PL measurements were performed. Additionaly temperature and excitation power dependent experiments were done. This gave us informations about charge carrier dynamics and subsequent the dynamics of Indium composition during the growth process.

HL 46.10 Thu 15:00 Poster A

Characterisation of deep defects in undoped GaN layers with PICTS — •Carsten Baer, Hartmut Witte, Andre Krtschil, Armin Dadgar, and Alois Krost — Institut für Experimentelle Physik, Abteilung Halbleiterepitaxie, Otto-von-Guericke-Universität Magdeburg, 39016 Magdeburg

Undoped semiinsulating GaN layers are already commercially used in FET devices. The device performance of these FETs is strongly influenced by active deep defects which change essential parameters such as cut-off frequency, break down voltage, or temperature dependent behavior of the output characteristics.

In this contribution we describe in detail thermal emissions of deep defects and their dependence on excitation conditions in different highly resistive GaN layers analyzed by Photo-Induced Current Transient Spectroscopy (PICTS). All samples were grown by metal-organic vapor phase epitaxy on silicon or sapphire substrates.

All emission spectra below 300 K were influenced by different excitation wavelengths and intensities. The peak shift of some defects in the calculated spectra is found to be controlled by excitation parameters such as filling rate of the traps, the thermal capture rates, or the life times of the carriers, sometimes resulting in relatively high activation energies. Furthermore, we observe quenching behavior of traps induced by additional illumination with intrinsic light of 690nm. The PICTS spectra are compared with reference results from TSC and nano-DLTS measurements performed at the same samples.

HL 46.11 Thu 15:00 Poster A

Infrared Ellipsometry of cubic and hexagonal InN — •Christian Napierala[1], Pascal Schley[1], Rüdiger Goldhahn[1], Gerhard Gobsch[1], Jörg Schörmann[2], Donat J. As[2], Klaus Lischka[2], Martin Feneberg[3], and Klaus Thonke[3] — [1]Institut für Physik, TU Ilmenau — [2]Department Physics, Universität Paderborn — [3]Institut für Halbleiterphysik, Universität Ulm

Recent experimental studies revealed for both, hexagonal and cubic InN, a band gap below 0.7 eV. Despite the progress in growth, the epitaxial layers suffer from the still high electron density. Under those conditions, the non-parabolicity of the conduction band becomes important when the absorption properties around the gap are discussed or the plasmon excitations in the phonon range are analysed. Using ellipsometry and reflectance measurements we have determined the dielectric function (DF) of the InN polytypes for the two spectral regions. Compared to previous studies a refined analysis of the DF shape is presented. In particular we show how the non-parabolicity influences the plasma frequency and thus the phonon-plasmon coupling. It is demonstrated in addition that the high-frequency dielectric constant is in fact not constant, but depends on the carrier-induced Burstein-Moss shift

of the absorption edge.

HL 46.12 Thu 15:00 Poster A

Untersuchungen zur Temperaturstabilität von InGaN/GaN-Quantenfilmen mit hohem Indiumgehalt — •Holger Jönen, Daniel Fuhrmann, Lars Hoffmann, Heiko Bremers, Carsten Netzel, Uwe Rossow und Andreas Hangleiter — Institut für Angewandte Physik, TU Braunschweig

Beim Wachstum von InGaN/GaN-Quantenfilmstrukturen werden die InGaN-QWs während des nachfolgenden GaN-Wachstums hohen Temperaturen ausgesetzt. Insbesondere bei Proben mit hohem Indiumgehalt ($x_{In} \approx 30\%$) ist dadurch eine Verschlechterung der optischen Eigenschaften zu befürchten. Zur Überprüfung der thermischen Stabilität von InGaN-QWs mit unterschiedlichem In-Gehalt ($10\% \leq x_{In} \leq 35\%$) haben wir einerseits die Wachstumstemperatur der GaN-Deckschicht T_{cap} variiert und zudem die Proben nach dem Wachstum getempert. Die von uns untersuchten Proben werden mittels Niederdruck-MOVPE gewachsen und mit Hilfe von XRD, TEM und AFM charakterisiert. Zur Messung der optischen Eigenschaften und zur Bestimmung der IQE benutzen wir temperatur- und leistungssabhängige PL. Bei den PL-Messungen zeigen die Proben nach dem Tempern eine Abnahme der Intensität, die abhängig ist von der Probenstruktur (x_{In}, T_{cap}) sowie von der Temperatur und der Dauer des Heizvorgangs. Einige Proben weisen darüber hinaus eine Blauverschiebung der Peaklage auf. Eine solche Blauverschiebung sowie eine Abnahme der Oszillatorstärke erhält man auch durch Modellrechnungen, unter der Annahme, dass Indium aus dem QW ins umliegende Material diffundiert und die Grenzflächen aufweichen.

HL 46.13 Thu 15:00 Poster A

Einfluss der Wachstumsbedingungen auf die strukturelle Qualität von AlGaN-Schichten — •Lars Hoffmann, Daniel Fuhrmann, Heiko Bremers, Uwe Rossow und Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik

Die Effizienz UV-emittierender GaN/AlGaN QWs hängt entscheidend von der Qualität der AlGaN-Pufferschicht ab. In dieser Arbeit werden der Einfluss der Wachstumsbedingungen auf die strukturelle Qualität von AlGaN-Schichten und Wege zur Optimierung aufgezeigt. Dazu wurden mittels MOVPE AlGaN-Schichten auf Saphir-Substrat gewachsen. Es wurden die Wachstumsbedingungen einer AlN-Nukleationsschicht variiert und anschließend, bei optimierter AlN-Nukleation, die Wachstumsbedingungen des AlGaNs variiert. Diese Schichten werden dann mittels XRD, TEM, PL und AFM untersucht und es werden Rückschlüsse auf die Qualität der Schichten, ihre Defektdichten, ihre Grenz- und Oberflächen und ihren Verspannungsgrad gezogen. Insbesondere wird herausgestellt, dass der Al-Gehalt (x_{Al}) der AlGaN-Schicht entscheidend von der Wachstumstemperatur abhängt und ihre Qualität mit ihr korrelliert. Es zeigt sich, dass bei gleichbleibenden Wachstumsbedingungen, aber bei tieferer Temperatur gewachsene AlGaN-Schichten, der x_{Al} erhöht ist ($-200°C$: $+5\%$ x_{Al}) und sich die Rocking-Breiten der AlGaN-Schichten mit zunehmendem x_{Al} vergrößert. Ferner lässt sich feststellen, dass die AlGaN-Schichten mit H_2 als Trägergas tendenziell schmalere Rocking-Breiten als die mit N_2 aufweisen. Allerdings zeigen die N_2 Schichten unter dem AFM glattere Oberlächen.

HL 46.14 Thu 15:00 Poster A

Gd- and Eu-implanted GaN — •fang-yuh lo[1], andreas ney[2], alexander melnikov[1], dirk reuter[1], andreas d. wieck[1], stefan potthast[3], klaus lischka[3], sebastién pezzagna[4], and jean-yves duboz[4] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum — [2]Experimentalphysik, Universität Duisburg-Essen, Lotharstr. 1, D-47057 Duisburg — [3]Optoelektronischer Halbleiter, Universität Paderborn, Warburger Straße 100, D-33098 Paderborn — [4]Centre de Recherche sur l'Hétéro-Epitaxie et ses Application, CNRS, Sophia Antipolis, F-06560 Valbonne

GaN is a wide band gap semiconductor, which has vast applications in optoelectronics. Recently, GaN-based diluted magnetic semiconductors have attracted great interest because theoretical work predicted Curie temperatures above 300K. Experimentally, the realization has been different. Very recently, it has been reported that Gd-doped wurzite GaN is ferromagnetic at room temperature. This is independent if the Gd is incorporated during molecular beam epitaxy or implanted afterwards. We will present studies on Gd-implanted wurzite and cubic GaN as well as GaN-based heterostructures. We find that the magnetic properties are better for wurzite GaN. In addition, we have also implanted Eu into wurzite GaN and studied the magnetic properties.

HL 46.15 Thu 15:00 Poster A

Analysis of the Current-Voltage Characteristics and Electroluminescense of GaN-based Light Emitting Diodes — •T. Kolbe[1], J.-R. v. Look[1], M. Kneissl[1,2], A. Knauer[2], V. Hoffmann[2], S. Einfeldt[2], and M. Weyers[2] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdindand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Light Emitting Diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. One of the key challenges in making high brightness blue-violet LEDs is efficient current injection into the active regions of GaN-based p-n junctions. Carrier confinement, series resistance of the p-doped layers, as well as ohmic metal contacts, are particularly problematic in these materials. In this work we present an analysis of the current-voltage characteristics and electroluminescense (EL) of different GaN-based heterostructures in order to optimize current-injection and LED efficiencies. The devices in our investigation were grown by MOVPE on (0001) sapphire substrates. EL measurements are carried out to determine electrical and optical properties which are used as a feedback for the optimisation of the epitaxial growth process. By measuring the forward and reverse bias current-voltage characteristics, leakage currents, diode series resistance and ideality factors can be determined. This allows us to explore the correlation between these parameters and the heterostructure design, e.g. GaN pn-homojunctions and InGaN multiple quantum well (MQW) heterostructures with and without a p-AlGaN electron blocking layers.

HL 46.16 Thu 15:00 Poster A

Near field measurements on 405 nm GaN laser diodes with different ridge widths — •Dominik Scholz[1], Harald Braun[1], Ulrich T. Schwarz[1], Christian Rumbolz[2], Stefanie Brüninghoff[2], Alfred Lell[2], and Uwe Strauss[2] — [1]Naturwissenschaftliche Fakultät II - Physik, Universität Regensburg — [2]Osram Opto Semiconductors GmbH, Leibnizstr.2, 93055 Regensburg

We examine the waveguide mode dynamics of blue (405 nm) gallium nitride (GaN) based laser diodes with different ridge widths from 2 μm to 10 μm. We are able to do time resolved measurements of laser pulses and their dynamics in the near field and in the far field. Therefore we use a self-built scanning near field optical microscope (SNOM). The distance between tip and sample surface is controlled by a servo loop via damping of the resonance curve of a tuning fork attached to the tip. We get a distance of about 50 nm and a lateral resolution of 100 nm which is limited by the optical aperture of the tip. This resolution, in combination with time resolved measuring is good enough to measure the time evolution of laser pulses. We examine the dynamics of lateral modes, filamentation effects and beam steering. Depending on various ridge widths and different current densities we examine mode dynamics and the occurring filamentation effects. Beam steering can be observed in measurements from near field towards the far field.

HL 46.17 Thu 15:00 Poster A

Gain measurements of 405 nm (In, Al)GaN laser diodes using the Hakki-Paoli Method — •Tobias Meyer[1], Harald Braun[1], Ulrich T. Schwarz[1], Marc Schillgalies[2], Christoph Eichler[2], Stephan Lutgen[2], and Uwe Strauss[2] — [1]Naturwissenschaftliche Fakultät II - Physik, Universität Regensburg — [2]Osram Opto Semiconductors GmbH, Leibnizstr. 2, 93055 Regensburg

We use a high spectral resolution setup to measure the electroluminescence (EL) spectra of 405 nm (In, Al)GaN quantum well laser diodes. The Hakki-Paoli method is employed to estimate the optical gain spectrum by analyzing the modulation of the Fabry-Perot modes of the laser resonator below lasing threshold. To obtain the internal loss of the waveguide, the gain spectrum is evaluated at energies below peak gain. We use a theoretical model to simulate the gain spectrum, using the homogeneous and inhomogeneous broadening as fitting parameters. By measuring EL spectra for different carrier densities, we get the differential gain, and the shift of the longitudinal modes leads to the carrier-induced change of the refractive index. We use these parameters to calculate the antiguiding factor. Furthermore, the high spectral resolution allows us to study the mode spectrum evolution at and above the threshold. In addition, we compare our results for diodes with different composition and structure.

HL 46.18 Thu 15:00 Poster A

Study of normal mode coupling in vertical-cavity surface-emitting laser structures by modulation spectroscopy — •Björn Metzger[1], Peter Klar[2], and Wolfram Heimbrodt[1] — [1]Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany — [2]Physics Institute, Justus-Liebig-University of Giessen, Germany

Modulation spectroscopic methods are particularly suitable for characterizing vertical-cavity surface-emitting laser (VCSEL) structures. Many VCSEL structures studied so far show only a weak coupling between the cavity mode and the lowest quantum well exciton in the active region. The spectral line shapes of the corresponding $\Delta R/R$ signals in and off resonance are well understood. However, there are less reports about modulation spectroscopic studies of VCSEL structures with normal mode coupling in the vicinity of resonance and in the strong coupling regime. Here we present contactless electroreflectance (CER) results in the vicinity of resonance on a VCSEL structure with 12 strain-compensated (Ga,In)As/Ga(P,As) quantum wells in the active region of a 2 λ-cavity exhibiting normal mode coupling. The cavity detuning was varied by changing the sample temperature. The CER spectra obtained will be discussed and analyzed in the framework of model calculations and will be compared to those measured on VCSELs in the weak coupling regime.

HL 46.19 Thu 15:00 Poster A

Energy transfer between N-related localized states in $GaP_{1-x}N_x$ — •Tobias Niebling[1], Wolfram Heimbrodt[1], Bernardette Kunnert[1], Kerstin Volz[1], Wolfgang Stolz[1], Peter Jens Klar[2], and John Franz Geisz[3] — [1]Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universität, Renthof 5, D-35032 Marburg, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [3]National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401, USA

Time-resolved photoluminescence results of a series of $GaP_{1-x}N_x$ samples with x up to 0.02 will be presented. The temperature dependence, the concentration dependence as well as the temporal behavior indicate that the photoluminescence is dominated by excitation transfer processes between the various localized N-related states, such as the isolated N-impurity, various N-pair states and higher N-clusters. The excitation transfer processes in conjunction with the concentration-dependent statistics of the various N-related states alone are sufficient to explain the observed red-shift of the luminescence of $GaP_{1-x}N_x$ with increasing x as well as the spectral dependence of the PL decay times. However, this implies that the photoluminescence data alone do not give any conclusive evidence that a transformation from an indirect to a direct-gap semiconductor takes place in Ga(N,P) with increasing N up to 2% as often stated.

HL 46.20 Thu 15:00 Poster A

PAC Untersuchungen mit Seltenen Erden Sonden in Halbleitern mit großer Bandlücke — •Ronan Nedelec[1], Reiner Vianden[1] und ISOLDE Kollaboration[2] — [1]HISKP Universität Bonn, Nußallee 14-16, D-53115 Bonn — [2]ISOLDE, CERN, Schweiz

Die Bedeutung der Gruppe III-Nitride und anderer Halbleiter mit großer Bandlücke wie ZnO in der Forschung wie in der Anwendung hat in den letzten Jahren stetig zugenommen. Dabei geht es vorrangig um die Herstellung von Material, das für die Optoelektronik bei kurzen Wellenlängen geeignet ist. Durch die große Bandlücke sind auch Hochtemperaturanwendungen denkbar. In Verbindung mit Seltenen Erden können Lumineszenzeffekte beobachtet werden, die das gesamte sichtbare Spektrum abdecken. Das flexibelste Herstellungsverfahren für solche Komponenten ist die Ionenimplantation, durch die allerdings Gitterschäden enstehen. Diese müssen zunächst durch eine geeignete Behandlung der Proben beseitigt werden. Die PAC Methode ist ins besondere zur Untersuchung von Fragestellungen in Bezug auf Gitterdefekte sehr gut geeignet. Wir untersuchen die Materialien GaN und ZnO mit dem Sondenkern ^{172}Lu(^{172}Yb) auf ihr Ausheilverhalten, sowie auf das temperaturabhängige Verhalten des elektrischen Feldgradienten am Kernort. Die dabei auftretenden Einflüsse der 4f Elektronen und des Gitterfeldgradienten werden diskutiert.

HL 46.21 Thu 15:00 Poster A

Optical Spectroscopy on Ga(N,As,P)/GaP QW structures for III-V lasers on Si substrates — •Christian Karcher[1], Gunnar Blume[1], Peter Jens Klar[2], Bernardette Kunert[1], Stefan Oberhoff[1], Kerstin Volz[1], Wolfgang Stolz[1], and Wolfram Heimbrodt[1] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]1. Physics Institute Justus Liebig University of Giessen, Germany

Recently lasing was achieved at 280K in GaP based laser structures employing highly strained Ga(N,As) and Ga(N,As,P) single quantum wells in between GaP barriers in the active region. The laser structures have been grown on (100) GaP substrates. This opens actually the field for achieving III-V lasers on Si substrate as the lattice-mismatch between GaP and Si is small. We studied those laser structures and related multiple quantum well structures of different well width and with varying well composition by photoluminescence, photomodulated reflectance, electroreflectance, and high-pressure experiments. The obtained spectra will be discussed and analysed in order to determine fundamental electronic properties like e.g. the band alignment as function of strain and composition. These results are essential for improving the performance of room-temperature laser structures grown on silicon.

HL 46.22 Thu 15:00 Poster A

Time-Resolved Photoluminescence of Nitrogen-Cluster States in Dilute Ga(NAs)/GaAs Heterostructures — •David Köhler[1], Kristian Hantke[1], Swantje Horst[1], Sangam Chatterjee[1], Peter J. Klar[1], Wolfgang Stolz[1], Antonio Polimeni[2], Mario Capizzi[2], and Wolfgang W. Rühle[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]CNISM and Dipartimento di Fisica, Sapienza Universitá di Roma, P. le A. Moro 5, I-00185 Roma, Italy

We measured time-resolved photoluminescence on GaN_xAs_{1-x}/GaAs epitaxial layers grown by metal-organic vapour-phase epitaxy (MOVPE). The nitrogen concentration x for the as-gown samples varied between 0.049% and 0.238%. Additionally, the effective nitrogen content of the x=0.111% sample was reduced to $0\% \leq x_{eff} \leq 0.111\%$ by post-growth hydrogenation. We find distinct PL signals at lower energies than the band-to-band transition. These are attributed to nitrogen-related cluster states formed below the Γ-like conduction-band edge. Higher nitrogen concentrations lead to a redshift of the CB towards the cluster states that are fixed in energy. Furthermore, we present a profound dependence of the PL rise-time on the transition energy. The cluster states show a very long rise time of the PL intensity whereas a fast PL rise-time is found for the band-to-band transition. Therefore, we attribute the PL features at lower energies to zero-phonon nitrogen-cluster states. This is confirmed by TRPL experiments at various temperatures and excitation densities.

HL 46.23 Thu 15:00 Poster A

Annealing of implantation defects in GaN by swift heavy ion irradiation — Anne-Katrin Nix[1], Sven Müller[1], Carsten Ronning[1], Andrey Kamarou[2], Elke Wendler[2], Werner Wesch[2], Christina Trautmann[3], and •Hans Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Institut für Festkörperphysik, Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [3]Gesellschaft für Schwerionenforschung, Planckstasse 1, 64291 Darmstadt, Germany

Direct implantation of ions into semiconductors for doping allows concentration and depth modelling, but results in lattice defects. Thermal annealing is used for recrystallisation, but surface melting and dopant diffusion hampers the annealing effect. Here, we present an annealing method which can avoid these effects. During ion beam irradiation, the material is locally heated during a timespan of 10-12 seconds, surrounding material stays unaffected. The energy of the ions used for annealing should be in the MeV regime because the resulting nuclear energy loss must be low to avoid cluster formation. In addition to this it is necessary that the resulting electronic energy loss is lower than the threshold value for track formation. Mg ions with 100 keV were implanted into GaN with fluences of $3x10^{13}$ ions/cm^2 and 10^{14} ions/cm^2. These samples were irradiated with 578 MeV Cr and 140 MeV Kr, the fluences were $5x10^{11}$ ions/cm^2 and $5x10^{12}$ ions/cm^2 . Directly after implantation and after irradiation, the photoluminescence was examined at low temperature (12 K), the obtained spectra are compared to well known spectra of GaN and GaN:Mg.

HL 46.24 Thu 15:00 Poster A

Doping dependence of vacancy formation kinetics on III-V semiconductor surfaces — •Sebastian Landrock, Philipp Ebert, and Knut Urban — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

We observed by variable-temperature STM the formation of anion and cation vacancies on GaAs and InP (110) surfaces. The formation rates of vacancies are classically described by a pre-exponential factor times the Boltzmann factor, containing the activation barrier and the temperature. The pre-exponential factor arises from vibrational excitations of the crystal lattice and is thus in the order of the Debye frequency, i.e. 10^{12} to 10^{13} Hz. We found, however, striking deviations from this expectation as well as differences between n-type GaAs and p-type GaAs/InP: On p-type GaAs and InP (110) surfaces anion vacancies exhibit pre-exponential factors in the order of 0.001 to 10 Hz (and a barrier of 0.3 to 0.5 eV), while for n-type GaAs we found a pre-exponential factor roughly 10 to 15 orders of magnitudes larger for Ga vacancies. We show that the ultra-low pre-exponential factors on p-type material arise from a rate limiting process, which is a one dimensional adatom diffusion mediating the desorption of anions as di-atom molecules. In contrast, on n-type GaAs the Ga vacancies are formed by atomic desorption.

HL 46.25 Thu 15:00 Poster A

Herstellung und Implantation von ^{172}Lu(^{172}Yb) in GaN — •Riccardo Valentini und Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn, Deutschland

Für optoelektronische Bauteile werden Halbleiter mit großer Bandlücke verwendet, die mit Seltenen Erden dotiert sind. Um deren Verhalten nach der Implantation zu untersuchen, hat sich die Methode der γ-γ-Winkelkorrelation (PAC) bewährt. Ein geeignetes Isotop zur Untersuchung solcher Halbleiter ist ^{172}Yb.

Bisher wurde das Mutterisotop ^{172}Lu am CERN (ISOLDE Facility) hergestellt und implantiert. Die relativ starke Kontamination des ISOLDE-Strahls mit Molkülen gleicher Masse, die 7- bis 10-tägige Dauer des Probentransport zum Messort und die seltene Verfügbarkeit des Isotops an ISOLDE haben uns dazu bewegt das ^{172}Lu vor Ort herzustellen und zu implantieren. Durch Bestrahlung einer Thulium-Folie mit ^{4}He, ^{169}Tm(α,n)^{172}Lu, erfolgt so die Herstellung am Bonner Isochron-Zyklotron und die Implantation am Bonner Isotopenseparator.

Wir führen Testmessungen von ^{172}Lu(^{172}Yb) in GaN durch, um den Herstellungsprozess am Bonner Zyklotron und Isotopenseparator zu optimieren. Die Messungen werden auf einer PAC-Anlage durchgeführt, die das Material LSO als Szintillator benutzt. Dadurch soll eine bessere Energieauflösung, eine höhere Anisotropie und eine kürzere Messzeit erzielt werden.

HL 46.26 Thu 15:00 Poster A

MOVPE-Growth of GaN-nanowires on various III-V-Substrates — •M. Shirnow[1], V. Gottschalch[1], J. Bauer[1], H. Paetzelt[1], G. Wagner[2], and J. Lenzner[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannisallee 29, D-04103 Leipzig — [2]Institut für Mineralogie, Kristallographie und Materialwissenschaften, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig — [3]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig

GaN nanoscale structures (nanowires) have great potential for realizing new optoelectronic devices. We compare the growth of freestanding GaN wires on various substrates and templates using two precursor combinations; 1.1-Dimethylhydrazine (DMHy)/Trimethylgallium (TMGa) and NH_3/Triethylgallium (TEGa). The precursor combination DMHy/TMGa was used for the growth of GaN at low substrate temperatures. By variation of the growth temperature and partial pressure (DMHy/TMGa) a small range of anisotropic growth was found, where cubic GaN wires can grow directly on GaAs substrates. GaN wires deposited on an intermediate BP layer above 750°C show the Wurtzite structure. We grew GaN wires on (0001) and (10-12) Al_2O_3 surfaces using the precursors TEGa and NH_3 and N_2 as the carrier gas in a temperature range from 900 to 1000°C. We used Ni and Au as initiators for vapour-liquid-solid (VLS) wire growth.

HL 46.27 Thu 15:00 Poster A

VLS Growth of III-V compounds — •A. Vogel[1], V. Gottschalch[1], J. Bauer[1], G. Wagner[2], M. Shirnow[1], H. Paetzelt[1], J. Lenzner[3], and W. Schmitz[2] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannisallee 29, D-04103 Leipzig — [2]Institut für Mineralogie, Kristallographie und Materialwissenschaften, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig — [3]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig

The vapour-liquid-solid (VLS) growth method is well-established in fabrication of freestanding III-V-nanowires using metal-organic vapour-phase epitaxy. Some aspects of VLS growth are not yet well understood. The crystalline structure as well as the chemical composition of the catalyst may have great influence on the structure of the grown one-dimensional nanostructures. For this reason we deposited thin gold films varying from 6 to 26 nanometres on GaAs (-1-1-1), c-plane and r-plane sapphire and Si (111). Those films were analyzed using a texture goniometer, atomic force microscopy, transmission electron microscopy, conventional and temperature-sensitive X-ray diffraction offering the opportunity to capture in-situ scans up to 900°C. We discuss the observed possible interactions between substrate, gold and precursor material. The stages of nanowire growth are discussed in detail.

HL 46.28 Thu 15:00 Poster A

BP and $B_xGa_{1-x-y}In_yP$ layer structures grown by MOVPE — •K. Schollbach[1], V. Gottschalch[1], G. Leibiger[2], H. Paetzelt[1], G. Wagner[3], J. Bauer[1], and D. Hirsch[4] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannisallee 29, D-04103 Leipzig — [2]Freiberger Compound Materials GmbH, D-09599 Freiberg — [3]Institut für Mineralogie, Kristallographie und Materialwissenschaften, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig — [4]Leibniz-Institut für Oberflächenmodifizierung e.V., D-04318 Leipzig

BP, ternary $B_xGa_{1-x}P$ and related quaternary alloys like $B_xGa_{1-x-y}In_yP$ are novel indirect transition type materials for light emitters or detectors in the visible spectral range but systematic investigations are rare or missing completely.
We have studied the metal-organic vapor-phase epitaxial growth of BP, $B_xGa_{1-x}P$ and $B_xGa_{1-x-y}In_yP$ thin films on GaP, GaAs and Si substrates using the standard precursor Triethylboron, Trimethylgallium, Trimethylindium and Phosphine. The mole fraction of Boron in the epitaxial alloy-layers was varied from x = 0 to 0.04. The properties of the deposited thin film were determined using double-crystal X-ray diffraction, spectroscopic ellipsometry, chemical-etching techniques, transmission electron microscopy, photoluminescence, Raman scattering, and Secondary Ion Mass Spectroscopy. The influence of the growth conditions on structural quality, boron incorporation, interface quality, and optical properties is discussed.

HL 46.29 Thu 15:00 Poster A

Ausheilverhalten von AlN nach der Implantation von ^{111}In — •Julianna Schmitz, Jakob Penner und Reiner Vianden — Helmholtz - Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn

Nach der Implantation des Isotops ^{111}In in AlN-Filme auf Saphir wurde ein isochrones Ausheilprogramm durchgeführt und die einzelnen Ausheilstadien mit der Methode der gestörten Winkelkorrelation (PAC) untersucht. Bereits in einem niedrigen Temperaturbereich zwischen 200 und 500°C zeigen sich deutliche Veränderungen: Der Anteil von Sonden mit einer weitgehend ungedämpften Wechselwirkung (ν_Q = 28 MHz) steigt bis auf 50%. Orientierungsmessungen bestätigen die Ausrichtung des zugehörigen elektrischen Feldgradienten entlang der c-Achse, wie er für Indium auf einem ungestörten Al-Gitterplatz erwartet wird.

Weitere 40% der Sonden erfahren eine Wechselwirkung, deren Frequenz nach Tempern oberhalb 500°C bis auf ca. 300 MHz steigt. Gleichzeitig nimmt die Dämpfung stark ab. Diesen Anteil könnte man einem Defekt zuordnen. Allerdings zeigt sich bei der Untersuchung der Temperaturabhängigkeit, dass diese Frequenz immer langsamer wird, bis sie oberhalb von 600°C der Gitterfrequenz entspricht. Dieses Verhalten ist reversibel.

Die Resultate werden mit dem bereits gut untersuchten Verhalten von ^{111}In in GaN verglichen.

HL 46.30 Thu 15:00 Poster A

Tunneling Transport Involving Evanescent States in III-V Semiconductors — S. Loth[1], M. Wenderoth[1], •S. Siewers[1], K. Teichmann[1], L. Winking[1], R. G. Ulbrich[1], S. Malzer[2], and G. H. Döhler[2] — [1]Universität Göttingen, IV. Physikalisches Institut, Germany — [2]Universität Erlangen-Nürnberg, Max-Planck-Research Group, Institute of Optics, Information, and Photonics, Germany

Shallow acceptors near the {110} cleavage surfaces of III-V semiconductors are investigated with a Cross-Sectional Tunneling Microscope at 8K. For certain tunneling conditions the acceptors appear as distinct triangular protrusions in the STM images. Energetically and spatially resolved spectroscopies show that the pronounced anisotropic contrast

pattern are due to a tunneling process involving evanescent states in the fundamental band gap of the semiconductor. The dopant atom enhances this transport channel via the resonant tunneling device geometry and provides an energy filter. The lateral resolution of the STM gives access to the spatial and directional dependence of this transport process. To study the properties of this transport mechanism the electronic configuration around the acceptor atom is varied by changing the doping surroundings and using different host materials. Our data indicate that not only the real part but also the complex part of the bulk band structure together with large k-dependent splittings have to be taken into account in the interpretation of STM data.

This work was supported by the DFG, SFB 602, and the German National Academic Foundation.

HL 46.31 Thu 15:00 Poster A

Observation of InN(0001) surface and bulk properties during oxidation — •C. Friedrich[1], T. Schenk[1], M. Drago[1], W. Braun[2], W. Richter[1,4], N. Esser[1,3], P. Vogt[1], and M. Kneissl[1] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]BESSY GmbH, Albert-Einstein-Str. 15, 12489 Berlin, Germany — [3]ISAS Berlin, Albert-Einstein-Str. 9, 12489 Berlin, Germany — [4]Universita Tor Vergata, Via della Ricera Scientifica 1, 00133 Rome, Italy

The determination of the InN electronic bandgap is still not completely solved but is most likely related to quality and purity of the investigated material. The incorporation of oxygen in sputtered InN films was already reported, but the influence on the crystal, optical and electronic properties remains unclear. Here we present a soft x-ray photoemission (SXPS) study of the surface and bulk deoxidation of MOVPE grown InN(0001)/sapphire through thermal annealing. SXPS reveals composition and binding configuration within the surface layers which gives rise to clear C1s and O1s core-level contributions. Thermal annealing at 300°C is sufficient to remove most of these components. Only a stable O1s oxide contribution could not be removed even at 460°C. These results are compared to ellipsometric measurements in different gaseous environments. We could identify surface oxidation occurring in humid ambient below 150°C as well as bulk oxidation around 450°C in dry air. These two different oxidation effects are in good agreement with the SXPS measurements. These results can be used for the optimization of InN surface morphology.

HL 46.32 Thu 15:00 Poster A

InGaAs/GaAsSb tunnel junction in an InP(100)-based low band gap tandem solar cell — •Ulf Seidel, Erol Sagol, Ulrike Bloeck, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institute, Glienicker Str. 100, 14109 Berlin, Germany

III-V multi-junction (m-j) solar cells are currently the most efficient PV devices worldwide. In a m-j solar cell multiple absorbers with different band gaps are connected in series. At present, the world record m-j solar cell was epitaxially grown lattice-matched to GaAs(100) or rather to Ge(100). Regarding the highest theoretical efficiencies there is a lack of an appropriate material with a band gap in the range of 1eV. Therefore, a monolithic low band gap tandem solar cell on the lattice constant of InP(100) was designed with band gaps regarding a 4- or 5-junction solar cell. It can be combined with a high band gap tandem or triple cell via different techniques. The lattice-matched InGaAs (E_g = 0.73 eV) was utilized for the lowest band gap absorber and also lattice-matched InGaAsP for the absorber material around 1 eV. The two sub cells were connected by a new tunnel junction including n-InGaAs and p-GaAsSb. With regard to the sharpness of the InGaAs/GaAsSb interface, we investigated the growth of the GaAsSb layer on different InGaAs surface reconstructions in-situ with reflectance difference spectroscopy (RDS) and in ultra high vacuum with X-ray PES (XPS) and LEED. A significant difference was measured for the Sb to As surface stoichiometry at the GaAsSb layer, indicating that the more established growth of GaAsSb on an As-rich InGaAs surface resulted in a too low Sb-content in the first monolayers of GaAsSb.

HL 46.33 Thu 15:00 Poster A

Optical and structural properties of MOVPE grown InGaN films with varying indium content — •Joachim Stellmach, Martin Leyer, Massimo Drago, Markus Pristovsek, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, Germany

High indium containing InGaN films and quantum wells are of great interest for a number of device applications, laser diodes and LEDs with emission in the particular blue and green wavelength range and beyond. We have systematically studied the temperature dependence of indium incorporation into thick InGaN layers.

The layer were grown on a GaN/sapphire templates with metal-organic vapour phase epitaxy (MOVPE). In order to alter the indium incorporation the growth temperature was varied between 650°C and 850°C. Dependent on the growth temperature the indium content varied between 1,5% – 43%. The layers were analyzed with x-ray diffraction (XRD), atomic force microscopy (AFM), photoluminescence (PL) and transmission spectroscopy.

We observed the lowest indium incorporation at a temperature of 850°C and an increase of the indium content and surface roughness with decreasing temperature. The XRD measurements showed a double peak structure for the sample grown at 750°C, possibly indicating the onset of phase separation in the InGaN films under these growth conditions.

HL 46.34 Thu 15:00 Poster A

Untersuchung des optischen Gewinns an GaAsSb Quantenfilmen — •Michael Schwalm[1], Christoph Lange[1], Sangam Chatterjee[1], Christina Bückers[1], Angela Thränhardt[1], Stephan W. Koch[1], Wolfgang W. Rühle[1], Shane R. Johnson[2], Jiangbo Wang[2] und Young-Hang Zhang[2] — [1]Fachbereich Physik, Philipps-Universität Marburg — [2]Center for Solid State Electronics Research & Department of Electrical Engineering, Arizona State University

Ein Hauptforschungsziel im Bereich der Optoelektronik besteht darin, Emitter im Wellenlängenbereich von 1,3μm bis 1,55μm für glasfaserbasierte oder aber jenseits von 2μm für freie Kommunikation auf Basis des leicht zu handhabbaren Substrats GaAs herzustellen. Eine Möglichkeit, um die Emissionswellenlänge zu erhöhen, ist der Einbau von Antimon in GaAs-Quantenfilme. Untersucht wurde die optische Verstärkung an einer Probenreihe von 7nm dicken GaAs0.64Sb0.36 Quantenfilmen, welche in verschieden dicke GaAs-Barrieren eingebettet sind. Mit Hilfe der Strichlängenmethode, bei der die Probe entlang eines Strichs variabler Länge optisch angeregt und die Emission entlang des gepumpten Kanals spektral aufgelöst gemessen wird, ist der optische Gewinn für eine quasi Dauerstrichanregung direkt zugänglich. Die spektrale Breite der Photolumineszenz und die Emissionseffizienz werden mit zunehmender Dicke der Barrieren größer. Bei allen Proben wird Verstärkung mit einer Brandbreite im Bereich von 200nm und einem Maximalwert bis zwischen 140/cm für 0nm Barrierendicke bis zu 220/cm bei 9nm Barrierendicke beobachtet.

HL 46.35 Thu 15:00 Poster A

MOMBE epitaxial growth of InN on (0001) Sapphire GaN template or LT InN layer — •Jörg Hisek[1], Uwe Rossow[2], Heiko Bremers[2], Daniel Fuhrmann[2], Jochen Aderhold[3], Jürgen Graul[1], and Andreas Hangleiter[2] — [1]LFI, Leibniz Universität Hannover, Schneiderberg 32, 30167 Hannover — [2]Institut für Angewandte Physik, TU Braunschweig, Mendelssohnstr. 2, 38106 Braunschweig — [3]Fraunhofer Wilhelm-Klauditz-Institut, Bienroder Weg 54 E, 38108 Braunschweig

To date the epitaxial growth of high quality InN is still a challenge. Investigations of structural properties require an exact understanding of a re-producible growth mechanism of the used fabrication method.

Epitaxial InN has been grown on c-plane sapphire by means of MOMBE. Herby the metalorganic vapour fluxes have been adjusted by pressure control applying a MFC calibration with nitrogen. A comparison was made between InN layers grown on templates with a thicker GaN buffer layer (grown by MOVPE) and InN grown directly onto prenucleated substrate. The latter method was split into the usage of GaN or InN as nucleation seeds. GaN buffer layer quality sets limitations if the InN is grown on top by an in-situ method. The optimisation of the seeding buffer layer is reported. The most crucial growth parameters found, are substrate temperature and the III/V flux ratio.

Studies by RHEED, HRXRD, AFM, SEM and PL evaluated the morphological and optical properties of the as-grown InN. The without templates grown InN was hexagonal and dominantly N-polar. Electrical measurements revealed high electron mobility.

HL 46.36 Thu 15:00 Poster A

Post growth annealing beahaviour of GaMnAs grown on (001), (311) and (110) GaAs substrates — •Hirmer Michael, Ursula Wurstbauer, Dieter Schuh, and Werner Wegscheider — Universität Regensburg

We report a detailed study of post growth annealing experiments of thin GaMnAs films grown by low temperature molecular beam epi-

taxy (LT-MBE) on (001), (311) and (110) semi-insulating GaAs substrates with layer thickness ranging from 5 nm to 300 nm. Since the ferromagnetism of this zener-like diluted magnetic semiconductor is hole mediated, the ferromagnetic transition temperature T_C can be increased corresponding to $T_C \quad x_{eff} p^{1/3}$ (x_{eff}: effective Mn concentration, p: carrier density) by post growth annealing. This reduces the Mn-interstitial lattice defects, which act as a double donor. We have increased T_C in first annealing experiments at about 190°C for 100h in air from 85K to 150K for layers grown on (001) GaAs, from 75K to 110K for layers on (311)A and from 55K to 89K for layers on (110) oriented substrates [1]. In these experiments, T_C was determined by temperature dependent sheet resistivity measurements and the carrier density by measurements of the anomalous Hall Effect. To further improve the annealing process and to find the optimal annealing parameters (temperature, time, environment...) dependent on Mn concentration, layer thickness and growth direction we in situ monitor the sheet resistivity during the annealing process. We acknowledge the support by the DFG via SFB 689. [1] U. Wurstbauer, M. Sperl, D. Schuh, G. Bayreuther, J. Sadowski, W. Wegscheider, accepted to JCG

HL 46.37 Thu 15:00 Poster A

Measurements of the absolute external luminescence quantum efficiency of ZnO — •Mario Hauser, Alexander Hepting, Robert Hauschild, Felix Stelzl, Johannes Fallert, Markus Wissinger, Huijuan Zhou, Heinz Kalt, and Claus Klingshirn — Universität Karlsruhe (TH), Karlsruhe, Germany

The prospects of ZnO in light emitting devices such as high power blue and UV laser diodes depend crucially on the luminescence quantum efficiency.

The absolute external luminescence quantum efficiency is measured using a temperature controlled integrating sphere (Ulbricht sphere). Temperature dependant and spectrally resolved measurements are carried out from 10 K up to room temperature on commercially available ZnO nanocrystalline powders and laboratory bulk samples. At low temperatures the former show a typical quantum efficiency of 8 to 10 %. The quantum efficiency of the latter varies from 5 to 20 %. Over the considered temperature range a decrease of quantum efficiency of about one order of magnitude depending on sample quality can be observed. A fit to the temperature dependant quantum efficiency of the near band edge emission shows that there is an activated process with an activation energy on the order of 10 meV in all samples. The spectral evolution with temperature of deep defect and near band edge luminescence is discussed.

HL 46.38 Thu 15:00 Poster A

Optical Spectroscopy on Metastable Zincblende MnCrS/ZnSe Heterostructures — •Limei Chen[1], Wolfram Heimbrodt[1], Peter Jens Klar[2], Lorraine David[3], Christine Bradford[3], and Kevin Prior[3] — [1]Department of Physics and Material Sciences Center, Philipps-University Marburg, Germany — [2]I. Institute of Physics, Justus-Liebig-University Giessen, Germany — [3]School of Engineering and Physical Sciences, Heriot-Watt university, Edinburgh, UK

A series of zinkblende MnS/ZnSe heterostructures with varying thickness from 1.8 to 8.6nm and a series of MnCrS/ZnSe heterostructures with different Cr contents up to 50% were grown by molecular beam epitaxy on (100) GaAs substrates with a growth temperature of 240°C. The optical properties of the heterostructures were studied using time-resolved photoluminescence spectroscopy with time scales from microseconds to milliseconds at low temperature(10K). The photoluminescence is dominated by the $^4T_1$ to $^6A_1$ internal transition of the Mn^{2+} ($3d^5$) cations at 590 nm. The decay times of the internal luminescence of MnS layers show only a weak size dependence and do not vary when using different excitation energies, i.e. 355 nm (3.49 eV) exciting above the ZnSe band gap or 532 nm (2.33 eV) excitation exciting directly into the Mn $3d^5$ absorption but below the ZnSe and MnS band gaps. The decay times of the MnCrS layers show no clear size and Cr concentration dependence and are faster than those of the Cr-free MnS layers indicating an energy transfer from the Mn 3d-shell to Cr internal transitions.

HL 46.39 Thu 15:00 Poster A

Optical Characterization of Nanocrystalline ZnO Powders — •Felix Stelzl, Johannes Fallert, Robert Hauschild, Alexander Urban, Huijuan Zhou, Markus Wissinger, Mario Hauser, Claus Klingshirn, and Heinz Kalt — Universität Karlsruhe (TH), Karlsruhe, Germany

In recent times there has been an increasing interest in nanocrystalline ZnO powders, since they promise the future realisation of miocrolasers based upon random lasing [1]. Several commercially available powders have been investigated, as they offer a cheap and reproducible light emitting source in the ultraviolet range. These powders have different average particle sizes which vary from below 100 nm up to above 1 μm. Apart from stationary photoluminescence measurements, time resolved investigations have been conducted to reveal the luminescence dynamics. Furthermore numerical calculations of carrier densities and diffusion properties have been carried out to compliment the experimental results.
[1] H. Cao et al., APL 76, 2997 (2000)

HL 46.40 Thu 15:00 Poster A

Unambiguous identification of the PL-I9-line in zinc oxide — Sven Müller[1], Daniel Stichtenoth[1], Michael Uhrmacher[1], Hans Hofsäss[1], Jens Röder[2], Anjeschka Kulinska[3], and •Carsten Ronning[1] — [1]II. Physikalisches Institut, Georg-August Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Institut für Physikalische und Theoretische Chemie, TU Braunschweig, Hans-Sommer-Str.10, D-38106 Braunschweig, Germany — [3]H. Niewodniczanski Institute of Nuclear Physics, Polish Academie of Science, Radzikowskiego 152, 31-342 Krakow, Poland

The intense luminescence of zinc oxide (ZnO) is usually dominated by transitions of donor bound excitons. The identity of the respective causing donors is in the most cases unknown, but a clear identification can be achieved using radioactive dopants, which undergo an element transition upon decay. Thus, luminescence lines, which vary their intensities with the specific half-life of the respective isotope with increasing measuring time, can be unambiguous assigned to specific elements. We have implanted radioactive ^{111}In with an ion energy of 400 keV into ZnO single crystals. The isotope ^{111}In decays into stable ^{111}Cd with an half-time of 2,8 days; thus, an element transition from a donor to an isoelectronic element within the ZnO crystal occurs upon time. The annealing process (in air,700°C) was monitored by perturbed angular-$\gamma\gamma$-spectroscopy (PAC). The samples were characterised by photoluminescence spectroscopy over a time period of 3 weeks. The obtained results together with additional ion implantation studies with stable ^{115}In and varying ion fluences will be discussed.

HL 46.41 Thu 15:00 Poster A

Optical characterization of acceptors implanted into ZnO — •Joachim Dürr[1], Daniel Stichtenoth[1], Sven Müller[1], Carsten Ronning[1], Lars Wischmeier[2], Chegnui Bekeny[2], and Tobias Voss[2] — [1]II. Institute of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37073 Göttingen, Germany — [2]Institute for Solid State Physics, University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany

Nitrogen and phosphorus are the most promising candidates for p-type doping of ZnO. We doped ZnO bulk crystals using ion implantation because this technique offers several advantages compared to other growth methods, e.g. precise control of the lateral and vertical dopant concentration even beyond solubility limits. After implantation and annealing of the introduced defects we performed photoluminescence measurements in order to monitor the optical activation of the dopants. Temperature- and power-dependent measurements reveal that a new line appearing at 3.23 eV for the N-implanted samples is due to Donor-Acceptor-Pair (DAP) transitions. We investigated the dependence of this feature on co-implantation as well as on the implantation and annealing temperature. First experiments on phosphorus-implanted ZnO will also be presented.

HL 46.42 Thu 15:00 Poster A

Comparison of giant Faraday effects in ZnMnSe and ZnMnO studied by magneto-optic ellipsometry — •Mario Saenger[1], Lars Hartmann[2], Heidemarie Schmidt[2], Michael Hetterich[3], Michael Lorenz[2], Holger Hochmuth[2], Marius Grundmann[2], Tino Hofmann[1], and Mathias Schubert[1] — [1]Nebraska Center for Materials and Nanoscience, Department of Electrical Engineering, University of Nebraska-Lincoln, NE 68588-0511, U.S.A. — [2]Institute for Experimental Physics II, Faculty of Physics and Geosciences, University of Leipzig, Linnéstr. 5, D-04103 Leipzig, Germany — [3]Institute of Applied Physics and Center for Functional Nanostructures (CFN), University of Karlsruhe, Wolfgang-Gaede-Str. 1, D-76131 Karlsruhe Germany

The diluted magnetic semiconductors ZnMnSe and ZnMnO are promising materials to create spin aligners for possible application

in future spintronic devices. At room temperature $Zn_{1-x}Mn_xSe$ is paramagnetic, and reveals giant Faraday magneto-optical effects in the visible spectral range. In contrast, a very weak Faraday effect in $Zn_{0.9}Mn_{0.1}Se$ was found. We report a quantitative analysis of the anisotropic complex dielectric functions for $Zn_{1-x}Mn_xSe$ in external magnetic field using a modified critical-point dielectric function model. Magneto-optic generalized ellipsometry in the Faraday configuration was applied to investigate a series of $Zn_{1-x}Mn_xSe$ samples (x=0, 0.02, 0.14, 0.28) grown by MBE on GaAs (001) substrate, and a $Zn_{0.9}Mn_{0.1}O$ sample grown by PLD on a-plane sapphire substrate. The studied spectral range was from 2 to 3 eV and for magnetic fields up to 1.2 T.

HL 46.43 Thu 15:00 Poster A

Simulation of capacitance - temperature measurements on ZnO Schottky diodes — •Matthias Schmidt, Holger von Wenckstern, Rainer Pickenhain, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Halbleiterphysik, Linnéstraße 5

We investigate theoretically and experimentally the temperature-dependent capacitance of ZnO Schottky diodes. For the experiments we used ZnO single crystals and epitaxial ZnO thin films grown by pulsed laser deposition. The capacitance was measured with an Agilent 4294A capacitance bridge at different temperatures (15K - 300K) and frequencies (5kHz - 1MHz). To explain the experimental results we use a model that considers the binding energy, the electron capture cross section and the concentration of the dominant donor.

HL 46.44 Thu 15:00 Poster A

Electrical properties of ZnO nanorods and layers — •Eva Schlenker[1], Thomas Weimann[2], Peter Hinze[2], Andrey Bakin[1], Ole Peters[1], Augustine Che Mofor[1], Bianca Postels[1], Hamid El-Shaer[1], Hergo-Heinrich Wehmann[1], and Andreas Waag[1] — [1]Institut für Halbleitertechnik, TU Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

ZnO has attracted a lot interest in the scientific community due to its outstanding properties. With a band gap of 3.37 eV and an exciton binding energy of 60 meV it is a promising candidate for micro- and optoelectronic applications. The growth of ZnO nanostructures and epitaxial layers is well under control and their optical and structural properties are already thoroughly characterized. However, due to contacting difficulties, less reports exist on the electrical properties of single ZnO nanostructures.

In this contribution we present various contacting methods in order to explore the electrical properties of individual nanorods either grown by aqueous chemical growth or vapor phase transport. Current-voltage characteristics were obtained by using an atomic force microscope (AFM) with a conductive tip or by patterning contacts with e-beam lithography. The results are compared to the ones obtained from measurements on epitaxially grown ZnO layers and first applications are presented.

HL 46.45 Thu 15:00 Poster A

Synthesis and optical properties of ordered ZnO nanostructures — •Markus Wissinger[1], Huijuan Zhou[1], Johannes Fallert[1], Felix Stelzl[1], Daniel Weissenberger[2], Mario Hauser[1], Robert Hausschild[1], Dagmar Gerthsen[2], Claus Klingshirn[1], and Heinz Kalt[1] — [1]Institut für angewandte Physik, Universität Karlsruhe (TH), Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe (TH), Karlsruhe, Germany

In this work we present the controlled growth of ordered ZnO nanostructures by a vapor phase transportation method in a horizontal tube furnace. The ordered ZnO nanostructures are grown using prestructured gold catalyst patterns, which are produced by electron beam lithography as well as by gold evaporation through a mask of self organized polystyrene balls. The growth is conducted at different temperatures (from 500 to 800 °C) under a constant pressure of several hundred mbar and a constant N_2 flow.

The morphology of the ZnO nanostructures is found to be very sensitive to the substrate material and growth parameters. A GaN substrate appears to be more suitable for perpendicular growth of ⟨0001⟩ ZnO than Si or Sapphire. Low temperature photoluminescence measurements show predominant emission in the UV region of the spectra, indicating high sample quality. Typically three donor bound excitons, $I_4, I_{5/6}, I_9$ and the A-free exciton are observed. The corresponding donors are assumed to be hydrogen, aluminum, and indium, respectively.

HL 46.46 Thu 15:00 Poster A

Growth of ZnO Nanopillars in an Optical Furnace — •Tobias Röder, Günther M. Prinz, Anton Reiser, Martin Schirra, Martin Feneberg, Raoul Schneider, Klaus Thonke, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

First results of ZnO nanopillar production in a new kind of optical furnace are presented. The furnace consists of two largely independent heating zones and allows heating rates of up to 1000°C/min with a maximum temperature around 1100°C. This enables us to investigate the influence of heating rates during the growth of ZnO nanostructures. The pillars are grown on a-plane sapphire substrates by a thermal-carbon process, in which a mixture of zinc oxide and graphite powder is used as source material. We obtained well aligned pillars of different densities with a variety of growth types such as vapor-liquid-solid (VLS) and vapor-solid (VS). The ZnO pillars were investigated by scanning electron microscopy (SEM), photoluminescence (PL) and spatially resolved cathodoluminescence spectroscopy (CL).

HL 46.47 Thu 15:00 Poster A

Electrical Characterization of ZnO Microcrystals — •Andreas Rahm, Holger von Wenckstern, Jörg Lenzner, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physikund Geowissenschaften, Institut für Experimentelle Physik II,Linnéstr. 5, 04103, Leipzig, Germany

We report on the electrical properties of ZnO microcrystals with InGa as well as W ohmic contacts. Nanowires carry charge efficiently and are potentially ideal building blocks for future (opto)electronics. Knowledge about (metal) contacts and electrical conduction properties of ZnO is essential. We have investigated the temperature dependence of ohmic I-V characteristics for several different microcrystals. They were carbothermally grown at 1100 ℃ and ambient pressure [1]. The measurements were performed with a semiconductor parameter analyzer (Agilent 4156C) in the dark in a helium cryostat. In the temperature regime from 200 K up to 300 K all samples show a strongly temperature dependent conduction. At low temperatures, i.e. in the freeze-out range there is an almost temperature-independent conductivity. Based on the assumption that the crystals exhibit a similar temperature dependence of the Hall mobility as bulk ZnO [2], it is possible to estimate the carrier concentration ($1.22\times10^{16} - 1.94\times10^{17}\,cm^{-3}$) as well as the thermal activation energy (18 – 40 meV).

[1] M. Lorenz, J. Lenzner, E.M. Kaidashev, H. Hochmuth, and M. Grundmann, Ann. Phys. (Leipzig) **13**, 39 (2004), [2] H. v. Wenckstern, S. Weinhold, G. Biehne, R. Pickenhain, H. Schmidt, H. Hochmuth, M. Grundmann, Adv. in Sol. Stat. Phys., **45** (2005).

HL 46.48 Thu 15:00 Poster A

MBE growth of high mobility HgTe/HgCdTe heterostructures — •Christoph Brüne, Andreas Roth, Steffen Wiedmann, Joachim Schneider, Markus König, Charles Becker, Hartmut Buhmann, and Laurens Mohlenkamp — Physikalisches Institut, Lehrstuhl für Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Epitaxial grown HgTe/HgCdTe heterostructures became very interesting for electronic applications due to good electrical proberties and a very high Rashba spinorbit spin splitting effect. Up to now quantum well (QW) structures with carrier mobilities of some 10^5 cm^2/Vs at a rather high carrier concentration ($>10^{12}$ cm^{-2}) were available. Our recent work has been focused on the fabrication of high mobility and low carrier density HgTe/HgCdTe single QW structures for magneto transport measurements. Single HgTe QWs with thicknesses between 5 and 12 nm are grown by molecular beam epitaxy (MBE) in between $Hg_xCd_{1-x}Te$ barriers. Iodine doping was employed at a distance of 10 nm from the QW either on one or on both sides. Due to special investigations of the growth conditions mobilities up to 10^6 cm^2/Vs have been achieved for densities of a few 10^{11} cm^{-2}. Simultaneously, Rashba splitting energies with ΔE_R >10 meV have been observed on gated Hallbar structures.

HL 46.49 Thu 15:00 Poster A

Lithographical nanostructure fabrication of high mobility HgTe quantum well structures — •Andreas Roth, Steffen Wiedmann, Joachim Schneider, Markus König, Christoph Brüne, Charles Becker, Hartmut Buhmann, and Laurens Molenkamp — Physikalisches Institut, Lehrstuhl für Experimentelle Physik 3, Univer-

sität Würzburg, Am Hubland, 97074 Würzburg, Germany

Large Rashba energies and high carrier mobilities make HgTe quantum wells structures an interesting material for spintronics applications. However, standard nano fabrication processes can not easily be adapted for HgTe materials due to the low growth temperature. Here, we present a method for nanostructure fabrication using dry etching techniques. It turned out that dry etched samples exhibit superior transport properties compared to wet etched structures with an improved control of the structural dimensions. Thus, for the first time, it was possible to investigate side wall depletion effects in HgTe quantum wells structures, with lateral dimensions down to 100 nm.

HL 46.50 Thu 15:00 Poster A

Optical characterization of hexagonal $Mg_xZn_{1-x}O$ thin films grown by pulsed laser deposition — •Alexander Müller, Gabriele Benndorf, Susanne Heitsch, Holger Hochmuth, Chris Sturm, Rüdiger Schmidt-Grund, Christoph Meinecke, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig, Germany

Ternary alloys of $Mg_xZn_{1-x}O$ have been grown by pulsed laser deposition (PLD) on *a*-plane sapphire substrates. The Mg content in the thin films was varied by using PLD-targets with MgO concentrations between 0 wt.% and 25 wt.% and by applying different oxygen partial pressures from 1.6×10^{-2} mbar to 5×10^{-5} mbar.
In order to characterize the optical properties and to optimize the growth conditions of the layers, we performed photoluminescence (PL) and spectroscopic ellipsometry measurements. The composition of the thin films was determined by Rutherford back scattering spectrometry. A lower O_2 partial pressure during the deposition leads to an increasing Mg content in the layer. Consistently, the band gap energy as well as the PL maximum is shifted to higher energies. PL emission was observed up to a Mg concentration of about 35 % in the thin films. The FWHM of the PL increases with higher Mg content. Furthermore, the dependence of the layer thicknesses and the optical properties on the O_2 partial pressure and target Mg concentration were examined.

HL 46.51 Thu 15:00 Poster A

Electrical Properties of Low Temperature ZnO Layers Grown by MOVPE on GaN/Sapphire Templates — H. Witte, S. Tiefenau, A. Krtschil, •S. Heinze, A. Dadgar, and A. Krost — Institute of Experimental Physics,Otto-von-Guericke-University-Magdeburg, 39016 Magdeburg

High-quality ZnO layers grown by metal-organic vapor phase epitaxy on GaN/sapphire templates typically use a low temperature (LT)-ZnO buffer layer grown at 450 ^{0}C to reduce the lattice mismatch. In general, the LT-ZnO shows high n-type conductivity properties with a donor concentration gradient from the GaN/LT-ZnO interface towards the surface as obtained from differences between the electron concentrations and the net donor concentrations measured by Hall-effect and by CV-characteristic, respectively. In internal photo-voltage spectra signals from near-band-gap (NBG) transitions in GaN as well as in ZnO were observed. These defect-to-band-transitions suggest an accumulation of ZnO- related defects with E_G- 0.03 eV, - 0.11 eV and - 0.2 eV in the near of the GaN/LT-ZnO-interface. They decrease after annealing of the samples at 900 ^{0}C for some minutes and by growing high temperature (HT) ZnO layers on the LT-ZnO buffer. Otherwise, the electron concentrations and the net donor concentrations of these LT-ZnO layers increase. In photo-current and photo-voltage spectra the defect-transition at E_G-0.11 eV dominates in samples annealed above 850 ^{0}C. Furthermore, intensive illumination of LT-ZnO layers decrease temporary the electron concentration drastically. This annealing behaviour of LT-ZnO is contrary to those of the HT-ZnO.

HL 46.52 Thu 15:00 Poster A

Magnetic circular dichroism of Co doped ZnO — •Christoph Knies[1], Swen Graubner[1], Jan Stehr[1], Detlev M. Hofmann[1], Tom Kammermeier[2], Andreas Ney[2], and Nikolai Romanov[3] — [1]University of Giessen, I. Physics Institute, Heinrich-Buff-Ring 16, D-35392 Giessen — [2]Universität Essen-Duisburg, MC-EXT "Maglomat", Experimetalphysik, Universität Duisburg-Essen, Lotharstr. 1, D-47057 Duisburg — [3]A. F. Ioffe Institute, St. Petersburg, Russia

Co doped ZnO is an interesting material for room temperature spintronic applications. Poly-crystalline ZnO samples doped with Co were synthesized in our group by a wet chemical synthesis using dip coating for the film formation. The magnetic properties of the samples were investigated by temperature and magnetic field dependent circular dichroism (MCD) measurements. We observe groups of optical transitions in the near infrared (∼0.9 eV) and visible (∼2.9 eV) spectral range which are caused by Co^{2+} internal excitations. At energies of above 3.0 eV is the onset of a Co^{2+} to Co^{+} charge transfer transition located. The MCD results are discussed in respect to magnetisation measurements which show a hysteresis like behaviour for samples doped with 2% and 5% Co.

HL 46.53 Thu 15:00 Poster A

The local environment of isolated ZnSe:Mn nanparticles — •Andreas Hofmann[1,2], Christina Graf[1,2], Christine Boeglin[3], Vladimir Korsounski[4], Reinhard Neder[4], and Eckart Rühl[1,2] — [1]Freie Universität Berlin, Institut für Chemie und Biochemie, D-14195 Berlin — [2]Universität Würzburg, Institut für Physikalische Chemie, D-97074 Würzburg — [3]Institute de Physique et Chimie des Materiaux de Strasbourg, F-67034 Strasbourg — [4]Universität Würzburg, Institut für Mineralogie, D-97074 Würzburg

The synthesis and characterization of diluted magnetic semiconductor nanoparticles made substantial progress in the last years and it is expected that the combination of the electronic characteristics of semiconductor nanoparticles with the magnetic properties of ferromagnets leads to novel spintronic materials.

ZnSe nanoparticles doped with 0.1-0.3% Mn with respect to Zn were prepared using a high temperature organic approach. Photoluminescence- and electron paramagnetic resonance measurements give strong evidence for an incorporation of Mn inside the ZnSe crystal lattice. The crystal structure of the particles was studied by high resolution transmission electron microscopy and X-ray diffraction. For a more profound study of the local environment of the Mn ions, ZnSe:Mn quantum dots were investigated in X-Ray magnetic circular dichroism experiments. A comparison of the present results with experimental and theoretical data for single Mn shows that the quantum dots contain well separated Mn ions. Neither Mn-Mn coupling nor oxidation to higher Mn-oxidation states were observed.

HL 46.54 Thu 15:00 Poster A

In-situ RHEED Characterization of ZnO and $Mg_xZn_{1-x}O$ thin films — •Christian Wille, Alexander Hirsch, Robert Pilz, Frank Ludwig, and Meinhard Schilling — Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, TU Braunschweig, Hans-Sommer-Straße 66, D-38106 Braunschweig, Germany

Due to its wide and direct band gap ZnO is interesting to be used as semiconductor in oxide superlattices. A possibility to overcome the lattice mismatch between perovskite oxides and hexagonal ZnO is to use cubic $Mg_xZn_{1-x}O$ instead of hexagonal one.

Using Pulsed Laser Deposition (PLD) ZnO and $Mg_xZn_{1-x}O$ thin films were grown on Al_2O_3(0001) and $SrTiO_3$(100) substrates respectively. The epitaxial growth of the films is investigated by in-situ reflection high energy electron diffraction (RHEED) supplemented by x-ray diffraction (XRD) and atomic force microscopy (AFM).

Standard ceramics synthesis is used to prepare the targets. To obtain atomically flat sapphire surfaces an annealing treatment is applied. The surface of the $SrTiO_3$ substrates is atomically flat and TiO_2 terminated after chemical and subsequent annealing treatment. The dependence of the PLD parameters on the growth conditions is analyzed. To obtain maximum information the experiments are planned by means of statistical design of experiments (DOE).

HL 46.55 Thu 15:00 Poster A

Growth of smooth ZnO layers by a modified CVD process — •Anton Reiser[1], Andreas Ladenburger[1], Günther M. Prinz[1], Martin Schirra[1], Uwe Röder[1], Martin Feneberg[1], Johannes Biskupek[2], Ute Kaiser[2], Klaus Thonke[1], and Rolf Sauer[1] — [1]Institut für Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Zentrale Einrichtung Elektronenmikroskopie, Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm, D-89069 Ulm

We grow ZnO layers by a modified CVD process on different substrate materials with growth rates of several micrometers per hour. This process is performed in a simple quartz liner tube at temperatures between 700 and 850 °C at normal pressure, using ZnO powder as source material. The growth can be controlled by the presence of seeding metal particles, allowing the definition of lateral structures. Growth also proceeds without catalyst particles, when a nucleation layer is deposited. The best results for heteroepitaxy are obtained on GaN films grown by MOVPE on c-plane sapphire substrates. In XRD measurements, $\Theta/2\Theta$ scans exhibit smaller halfwidth of the diffraction peaks for the

ZnO single crystal layers than for the GaN templates. TEM images show that the interfaces between ZnO and GaN are atomically flat. For GaN substrates, the optical quality of the ZnO layers is excellent in terms of photoluminescence intensity and halfwidth of the dominant donor bound exciton lines.

HL 46.56 Thu 15:00 Poster A

MOVPE growth study of ZnO wires and layers — •K. Mergenthaler[1], V. Gottschalch[1], H. Paetzelt[1], G. Wagner[2], J. Bauer[1], and G. Benndorf[3] — [1]Institut für Anorganische Chemie, Universität Leipzig, Johannisallee 29, D-04103 Leipzig — [2]Institut für Mineralogie, Kristallographie und Materialwissenschaften, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig — [3]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstr. 3, D-04103 Leipzig

It is necessary for many applications to obtain high-quality single crystal ZnO layers. But the tendency to form nanostructures might be useful for future nanosized devices. In this study we used an atmospheric pressure MOVPE system with two independent gas inlets to avoid parasitic reactions. We varied the temperature from 500 to 800 °C and the VI/II ratio from 1200 to 72000 to find the ideal growth parameters for layers and needle-like growth. Precursors were DEZn and N_2O with N_2 as the carrier gas. We used different substrates (e.g. c-, r-plane sapphire) and analysed both anisotropic growth of ZnO micro- and nano-needles and VLS growth with gold as catalyst. The crystalline quality and the optical properties were analysed by SEM, cathodoluminescence, photoluminescence and x-ray diffraction measurements. The influence of the growth conditions on structural quality, morphology and optical properties is discussed.

HL 46.57 Thu 15:00 Poster A

Optical and structural properties of NiO and NiMnO thin films grown on ZnO and sapphire substrates — •Lars Hartmann[1], Qingyu Xu[1], Heidemarie Schmidt[1], Holger Hochmuth[1], Michael Lorenz[1], Marius Grundmann[1], Pablo Esquinazi[1], Mario Saenger[2], Tino Hofmann[2], Mathias Schubert[2], and Sy-Hwang Liou[3] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstrasse 5, D-04103 Leipzig, Germany — [2]Department of Electrical Engineering, University of Nebraska-Lincoln 209N WSEC P.O. Box 880511 Lincoln, NE 68588-0511, USA — [3]Department of Physics and Astronomy, Nebraska Center for Materials and Nanoscience

Antiferromagnetic NiO is one of the key materials to realize spin valves in diluted magnetic semiconductors. In our current work we present the possibility of epitaxially growing NiO thin films on ZnO and sapphire substrates with different orientations. The magnetic properties of the films have been probed by SQUID measurements and the optical properties have been investigated by spectral ellipsometry from the near IR to the near UV range. The crystal structure and the film orientation was investigated by X-ray diffraction. Combined AFM and MFM measurements are showing a smooth surface structure and provide the possibility to investigate the magnetic properties of the sample surface. Especially the epitaxial growth of NiO on magnetic ZnO is an important step towards the realization of ZnO based spin valves.

HL 46.58 Thu 15:00 Poster A

Magnetic properties of ZnMnO — •Jan Stehr[1], Christoph Knies[1], Detlev Hoffman[1], Wei Xu[2], Yingxue Zhou[2], and Xinyi Zhang[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D- 35392 Giessen — [2]Department of Physics, Fudan University, 220 Handan Road, Shanghai 200433, China

A set of ZnMnO samples grown by MBE on Si with Mn concentrations from 3 % to 30% has been investigated by extended x-ray absorption fine structure (EXAFS) measurements, electron paramagnetic resonance (EPR) and magnetisation measurements. The magnetisation shows a ferromagnetic like hysteresis in samples with Mn concentrations below 10 %. An estimate of the ratio of the net magnetisation to the concentration of saturated magnetisation Mn2+ spins gives only 2 % of the total Mn content. The EPR shows dominating signals originating from concentration broadened, and exchange narrowed Mn2+ ions. The formation of secondary Mn phases is evident from EXAFS for samples with Mn concentrations higher than 20 %.

HL 46.59 Thu 15:00 Poster A

Influence of buffer layers on the structural properties of ZnO grown by plasma assisted molecular beam epitaxy — •Bernhard Laumer, Thomas Wassner, Stefan Maier, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

We have investigated the influence of ZnO and MgO buffer layers on the structural properties of ZnO-films heteroepitaxially grown on (0001)- and (11-20)-sapphire substrates by plasma assisted molecular beam epitaxy. The use of a thin buffer layer facilitates the nucleation process on the sapphire substrate and thus allows the growth of ZnO-films at higher substrate temperatures, leading to a higher surface mobility of the adatoms. A systematic high resolution X-ray diffraction study of symmetric and asymmetric reflexes was carried out to analyze the impact of the buffer growth conditions on the structural properties such as the edge- and screw dislocation densities in the deposited ZnO-films. In addition, the effect of offcut-substrates and buffer layer annealing on the structural quality of the ZnO epilayers has been investigated. The influence of the structural properties on the electrical and optical characteristics (luminescence, conductivity, carrier mobility) of the ZnO layers will also be discussed.

HL 46.60 Thu 15:00 Poster A

Thermische Behandlung kommerzieller ZnO-Substrate zur Restrukturierung der Oberfläche als Vorstufe für die ZnO-Homoepitaxie — •Sören Heinze, Andre Krtschil, Jürgen Bläsing, Armin Dadgar und Alois Krost — Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik

Wir stellen die Ergebnisse einer systematischen thermischen Behandlung kommerziell verfügbarer ZnO-Substrate und deren Charakterisierung mittels Rasterkraftmikroskopie (AFM) und Röntgenbeugung vor. Die Studie hat das Ziel, die ZnO-Substrate so zu präparieren, dass sie für eine nachfolgende metallorganische ZnO-Gasphasenepitaxie auf diesen modifizierten Substraten geeignet sind. Die Substrate wurden in einer Rapid-Thermal-Annealing-Anlage unter konstantem O_2-Fluss mit verschiedenen Temperaturregimes thermisch behandelt. Der Zinkpartialdruck wurde dabei mittels eines Zinkreservoirs in Form von ZnO-Pulver kontrolliert. In Abhängigkeit von der Maximaltemperatur beobachten wir mittels AFM ab 900°C die allmähliche Ausbildung von ZnO-Doppelstufen. Homogen ausgerichtete ZnO-Doppelstufen mit nur geringer Defektdichte sind bei 15-minütigem Ausheilen bei 1100°C zu verzeichnen. Eine Verringerung der Menge des eingewogenen ZnO-Pulvers führt zu einer verstärkten Ausbildung von dreidimensionalen ZnO-Nanosäulen. In Röntgenbeugungsuntersuchungen wurde festgestellt, dass die ungetemperten Substrate stark gekrümmt sind. Diese Krümmung geht durch das Ausheizen zurück. Innerhalb der strukturellen Eigenschaften konnten keine Veränderungen festgestellt werden, was auf eine ausschließliche Modifikation der Oberfläche hinweist.

HL 46.61 Thu 15:00 Poster A

Chlorine in epitaxially grown ZnO — •Felizitas Eylert, Swen Graubner, Stefan Lautenschläger, Christian Neumann, Joachim Sann, Niklas Volbers, and Bruno Meyer — 1. Physikalisches Institut, Justus-Liebig-Universität Gießen

The group-III elements Al, Ga and In introduce shallow donor states into ZnO and are widely used for obtained high free carrier concentrations up to the metallic limit. Much less is known from the group-VII elements, F, Cl and Br. There exists experimental evidence that at least Cl is indeed a shallow donor and produces high n-type conduction when in the CVD growth zinc chloride is used as a precursor. However, solid precursors are difficult to control in the CVD growth. It was therefore, our interest to use gaseous components. We, therefore, grew ZnO layers on GaN templates and ZnO substrates with CH3Cl as precursor for chlorine. We will report on the structural, optical and electrical properties of those films.

HL 46.62 Thu 15:00 Poster A

Structural and electrical investigation of fluorine doped ZnSe — •Marina Panfilova, Alexander Pawlis, Christof Arens, Detlef Schikora, and Klaus Lischka — Universität Paderborn, Department Physik, Warburger Str. 100, 33095 Paderborn

Fluorine doped ZnSe is a promising material for the realization of practical quantum information technology due to the potential of excitons bound to individual fluorine donors with a pure nuclear spin of 1/2. Exploitation of this in a single-photon source requires knowledge of the properties of the fluorine donor in ZnSe. Capacitance-Voltage and Hall-Effect have been measured to estimate the fluorine donor concentration and the carrier background concentration in ZnSe layers. Several ZnSe:F samples were grown by molecular beam epitaxy using various fluxes of fluorine. The fluorine donor concentration is found

to increase with increasing fluorine source temperature. The carrier background concentration was established in the order of 10^{15} cm^{-3}. For the isolation of individual F-atoms different etching techniques were used to fabricate micro-discs and mesa structures with diameter between 10 and 1 μm. Surface and edge morphologies were investigated by atomic force microscopy and scanning electron microscopy. The optical properties of few and individual F-atoms inside mesa and micro-disc structures were measured. Deterministic photon emission from individual F-Donor bound excitons was observed.

HL 46.63 Thu 15:00 Poster A

Polaron and phonon properties in WO_3 thin films — •Mario Saenger[1], Thomas Höing[2], Tino Hofmann[1], and Mathias Schubert[1] — [1]Center for Materials and Nanoscience, Department of Electrical Engineering, University of Nebraska-Lincoln, NE 68588-0511, U.S.A. — [2]FLABEG GmbH. und Co. KG, Glasserstr. 1, D-93437, Furth i. Wald, Germany

We report on the evolution of the optical phonon and polaron mode properties in amorphous tungsten oxide thin films by spectroscopic ellipsometry over the infrared to ultraviolet spectral range upon electrochemical proton and electron intercalation. We obtain a quantitative description for the coloration induced optical constants spectra changes by model dielectric function analysis of the intercalated thin films. Upon increased intercalated charge densities we observe the strong polarity reduction of the tungsten-oxygen bending mode, the formation of a distinct vibration band located above the tungsten oxide phonon modes, a strong increase of polarity together with the red shift of the polaron mode, whereas proton- and moisture-related lattice vibration modes remain unaltered. Our experimental results indicate no actual hydrogen incorporation upon intercalation. From the phonon mode changes we suggest that oxygen extraction related defect generation upon intercalation causes the polaron formation, also indicative for tungsten oxidation-state reduction from W^{6+} to W^{5+}. The red shift of the polaron mode can be explained by increase in polaron-polaron interaction, while its amplitude dependance on the intercalated charge density is concordant with the exponential intercalation model

HL 46.64 Thu 15:00 Poster A

Correlation between structural, optical and electrical properties and the suitability of phase change alloys — •Michael Woda, Christoph Steimer, Daniel Wamwangi, and Matthias Wuttig — I. Insitute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Phase change random access memory (PCRAM) is a very promising candidate to replace Flash memories employed in the non-volatile storage sector. In the active region of this emerging memory, a phase change material is found. This class of materials is already used in rewritable optical data storage. In both application areas the reversible switching between the amorphous and the crystalline state by short current or laser pulses, respectively is used to store data.

A key question that has not yet been answered regards the optimum choice of materials for phase change recording. We present a material selection strategy which classifies carefully chosen alloys, being representative for a larger selection of phase change materials, regarding their suitability for non-volatile storage applications.

XRD and XRR measurements reveal structural properties of the as-deposited, amorphous and the crystalline state, the corresponding local bond arrangements and the change of film density. Ellipsometry measurements determine the optical contrast of the samples while the temperature dependent resistivity is measured by four point probe experiments. Finally the electrical switching behaviour is tested in nanometer size test cells to validate the full functionality of the chosen materials.

HL 46.65 Thu 15:00 Poster A

Resonant photoluminescence up-conversion in a multi quantum well structure mediated by surface acoustic waves — •Stefan Völk[1], Jens Ebbecke[1], Achim Wixforth[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Institut für Physik der Universität Augsburg, Experimentalphysik I, 86135 Augsburg, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We have investigated the excitation emission spectrum of a multi quantum well (MQW) structure under the influence of a surface acoustic wave (SAW). Electron-hole pairs can be excited by laser light in semiconductor structures which form excitons at low temperatures.

The recombination of electron-hole pairs leads to emission of photoluminescence (PL) light. This emission energy is in general equal or smaller than the energy of the optical excitation source. In quantum well (QW) structures the emission energy is defined by the lowest quantized energy levels.

PL up-conversion means that the energy of emitted photons is higher than the excitation energy. Such a process can be observed in MQW structures with QWs of different widths by applying a SAW. We explain this effect through a dynamic conduction and valence band modulation leading to a resonant charge carrrier population of QWs.

HL 46.66 Thu 15:00 Poster A

Crystallization in mass-asymmetric electron-hole bilayers — •Patrick Ludwig[1,2], Alexej Filinov[1,3], Yurii Lozovik[3], Heinrich Stolz[2], and Michael Bonitz[1] — [1]CAU zu Kiel, ITAP, Leibnizstrasse 15, D-24098 Kiel — [2]Universität Rostock, Institut für Physik, Universitätsplatz 3, D-18051 Rostock — [3]Institute of Spectroscopy RAS, Moscow region, Troitsk, 142190, Russia

We focus on the effect of the mass ratio on crystal formation in quantum electron-hole bilayers. Varying the mass ratio M of holes and electrons between 1 and 100 for a fixed layer separation at low temperature and high density, one can tune the hole behavior from delocalized (quantum) to localized (quasi-classical) while the electrons remain delocalized all the time.

As was recently observed for bulk semiconductors [1], holes undergo a phase transition to a crystalline state if the mass ratio exceeds a critical value of $M_{cr} \approx 80$. Here, we extend this analysis to bilayers where M_{cr} can be drastically reduced by properly choosing d and the in-layer particle density. The complicated overlap of correlation and quantum effects of both, electrons and holes, is fully taken care of by performing first-principle path integral Monte Carlo simulations. We present results for two types of e-h bilayers: a mesoscopic system of $N = 36$ particles in a parabolic trap and for a macroscopic system of the same density.

[1] M. Bonitz, V.S. Filinov, V.E. Fortov. P.R. Levashov, and H. Fehske, Phys. Rev. Lett. **95**, 235006 (2005)

HL 46.67 Thu 15:00 Poster A

Effect of doping on the band structure in Spin-LED devices — •N. Höpcke, W. Löffler, C. Sailer, J. Lupaca-Schomber, S. Li, T. Passow, C. Klingshirn, M. Hetterich, and H. Kalt — Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

We develop p-i-n diode structures to initialize and detect the electron spin for investigations on spin dynamics. The spins are aligned in the diluted magnetic semiconductor ZnMnSe. In an InGaAs/GaAs quantum-dot layer the recombination of electrons and holes takes place and the polarization of the emitted light is a direct proof of the electron spin state. Here, we investigate the effect of the doping concentration in the ZnMnSe layer on the bandstructure and thereby on the spin polarization. Decreasing the doping concentration leads to higher polarization at low fields and avoids charging of the quantum dots.

HL 46.68 Thu 15:00 Poster A

Ferroelectric properties of $BaTiO_3$ - ZnO heterojunctions — •Matthias Brandt[1], Holger von Wenckstern[1], Holger Hochmuth[1], Michael Lorenz[1], Marius Grundmann[1], Jürgen Schubert[2], Venkata Voora[3], and Mathias Schubert[3] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany — [2]IBN 1-IT and cni, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Department of Electrical Engineering, University of Nebraska-Lincoln, Lincoln, U.S.A.

Bariumtitanate (BTO), as many materials in the perowskite structure, exhibits a spontaneous polarization which is switchable by an external electric field if the crystal exists in its ferroelectric phase (below the curie temperature of $\approx 120°$C). ZnO, a wurtzite crystal, shows a spontaneous polarization parallel to its crystallographic c axis, regardless of the outer field. Within this work, BTO films have been grown by pulsed laser deposition (PLD) on various substrates (Si, Pt, STO with SRO buffer, STO:Nb). Formation of heterojunctions between these materials leads to the occurrence of unique coupling effects. These cause polarization hysteresis, which we observed in electrical and electro-optical measurements. Structural, optical and electrical properties of these heterojunctions will be compared to results obtained from bare BTO layers. Further a model of the polarization exchange coupling was developed, and will applied to analyze the experimental data.

HL 46.69 Thu 15:00 Poster A

Magnetic bipolar heterojunction based on Ga(Mn)As — •Heigl Stefan, Ursula Wurstbauer, Dieter Schuh, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D-93040 Regensburg

We report on the results of transport measurements on magnetic bipolar GaMnAs heterostructures grown by molecular beam epitaxy. Devices based on spin-polarized bipolar transport employing GaMnAs layers were already proposed by Fabian et al. [1]. We have fabricated GaAs based pn-heterojunctions using silicon for n-type doping, carbon for non magnetic p-type doping and manganese for magnetic pmag - type doping. In a first growth step we deposited a 1 μm thick highly doped n- or p- type GaAs layer on semi insulating (001) GaAs. After ex-situ cleaving the substrate, we have overgrown the (110) cleavage plane with a complementary doped (p-, p_{mag}- or n-type) thin GaAs layer. These devices show the typical I-V characteristic known for pn-junctions. If Mn is used as a dopant, additional features for this magnetic pn-junction appear in the I-V curves when a magnetic field is applied. We acknowledge the support of this work by the DFG via SFB 689 Spinphänomene in reduzierten Dimensionen. [1] I. Zutic, J. Fabian, and S. Das Sarma, Rev. Mod. Phys. 76, 323 (2004)

HL 46.70 Thu 15:00 Poster A

Optical Modes in Pyramidal Microcavities — •Frank M. Weber[1], Matthias Karl[1], Jaime Lupaca-Schomber[1], Wolfgang Löffler[1], Shunfeng Li[1], Thorsten Passow[1], Jacques Hawecker[2], Dagmar Gerthsen[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Universität Karlsruhe (TH) and Center for Functional Nanostructures (CFN), 76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

We investigate the application of pyramidal GaAs structures on GaAs/AlAs distributed Bragg reflectors as optical resonators. The structures are fabricated using electron beam lithography and a wet chemical etching technique. In contrast to self-assembled growth this allows us to engineer the exact geometry of the microcavities. InGaAs quantum dots (QDs) inside the cavity couple to the resonator and the luminescence spectrum of the QD ensemble around 950 nm shows clear peaks. These correspond to optical modes in the pyramid which is confirmed by temperature-dependent measurements. We further investigate and simulate the dependence of the modal density on pyramid size. Complex structures such as pyramids with interconnects which could serve as coupled resonators were also manufactured.

HL 46.71 Thu 15:00 Poster A

Coupled micro-cavities based on GaAs pillars — •Matthias Karl[1], Wolfgang Löffler[1], Shunfeng Li[1], Thorsten Passow[1], Erich Müller[2], Fabián Pérez-Willard[2], Dagmar Gerthsen[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

Pillar-type micro-cavities are studied in our contribution. The pillars are milled with a focused ion beam out of a layer structure with top and bottom AlAs/GaAs distributed Bragg reflectors grown by molecular-beam epitaxy. In(Ga)As quantum dots emitting at around 950 nm are embedded in the middle of the GaAs-based λ-cavity. Optical modes in these pillars are detected by a micro-photoluminescence set-up.

Treating the pillar as a short step-index fiber we are able to model the experimental results with a finite-element method. This allows us to predict the resonances for different pillar diameters as well as for coupled pillar structures. Asymmetric coupled resonators designed by our calculations are investigated experimentally achieving optical modes either localized in one of the pillars or delocalized over the whole structure.

HL 46.72 Thu 15:00 Poster A

Stability of Mesoporous Ultra-low Refractive Index Substrates — •Denan Konjhodzic[1], Matthias Herrmann[2], and Frank Marlow[1] — [1]Max-Planck-Institut für Kohlenforschung, Kaiser-Wilhelm-Platz 1, D-45470 Mülheim an der Ruhr, marlow@mpi-muelheim.mpg.de, www.mpi-muelheim.mpg.de/marlow.html — [2]Technische Universität Chemnitz, Straße der Nationen 62, D-09107 Chemnitz

Mesoporous silica films synthesized by dip-coating in an evaporation-induced self-assembly process have been used for the first time as low-n substrates for 2D photonic crystals [1]. They have wide applications in the field of photonic crystals and optical waveguides. The optimized low refractive index films (n = 1.18) have been synthesized at low humidity conditions, whereas at higher humidity other interestingly structured films are found [2].

In this contribution we investigate the stability of the films in respect to thermal and mechanical stress, as well as the stability upon high humidity treatment and ageing. The structure stability was shown by small angle X-ray scattering and refractive index measurements. The mechanical properties (e.g. Young modulus) were determined from the nanoindentation. Stability of the refractive index was investigated with the angle-dependent interferometry and was found to be high under ambient humidity and temperature conditions.

[1] M. Schmidt et al., Appl. Phys. Lett. 85 (2004) 16
[2] D. Konjhodzic et al., Appl. Phys. A 81 (2005) 425

HL 46.73 Thu 15:00 Poster A

Modified Radiation Dynamics in Nanostructured Materials — •Jens Niegemann, Martin Pototschnig, Lasha Tkeshelashvili, and Kurt Busch — Institut für Theoretische Festkörperphysik, Universität Karlsruhe

Since photonic crystals have been proposed in 1987, the modification of spontaneous emission has been considered as a feature of fundamental interest. Here, we use a high-accuracy time-domain simulation of the coupled Maxwell-Bloch-equations, to investigate the influence of photonic crystals and/or metallic nano-structures on the decay of initially excited two-level atoms. In particular, we investigate the effects of finite sample sizes as well as the influence of non-radiative transitions and dephasing.

All simulations are performed by a non-linear extension of a matrix-exponential integrator based on Krylov-subspace techniques [1]. This method provides highly accurate and stable results while still allowing us to treat lossy, optically anisotropic and dispersive materials as well as CFS-PML boundary conditions. Thus, it is very well suited to study a large variety of experimentally relevant systems.

[1] J. Niegemann, L. Tkeshelashvili, and K. Busch, "Higher-order time-domain simulations of Maxwell's equations using Krylov-subspace methods", J. Comput. Theor. Nanosci. (in press)

HL 46.74 Thu 15:00 Poster A

Simulation of Metallic Nanostructures using Krylov-subspace methods — •Michael König, Jens Niegemann, Lasha Tkeshelashvili, and Kurt Busch — Institut für Theoretische Festkörperphysik, 76128 Karlsruhe, Germany

The Krylov-subspace method provides a stable, highly accurate scheme for the numerical solution of Maxwell's equations. We present an extension of the basic algorithm [1] to include perfectly matched layers and Drude-Lorentz dispersion relations, which are implemented through auxiliary differential equations. This approach allows an accurate and efficient simulation of metallic nanostructures in open, three-dimensional systems. Specifically, we compare numerical calculations for certain metallic model systems with experimental results. In particular, the accuracy and efficiency of our approach allows to investigate local field enhancement effects in metallic nanostructures.

[1] J. Niegemann, L. Tkeshelashvili, and K. Busch, Higher-order time-domain simulations of Maxwell's equations using Krylov-subspace methods, J. Comput. Theor. Nanosci. (in press)

HL 46.75 Thu 15:00 Poster A

Optimized design of plasmonic MSM photodetector — •Jurana Hetterich[1], Georg Bastian[2], Nikolai A. Gippius[3], Sergei G. Tikhodeev[3], Gero von Plessen[4], and Uli Lemmer[1] — [1]Lichttechnisches Institut, Universität Karlsruhe, Kaiserstr. 12, 76131 Karlsruhe, Germany — [2]Fachbereich Technik, Fachhochschule Trier, Schneidershof, 54293 Trier, Germany — [3]A. M. Prokhorov General Physics Institute RAS, Vavilova 38, Moscow 119991, Russia — [4]Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

We present an optimized design for a plasmonic metal-semiconductor-metal (MSM) photodetector with interdigitated electrodes with subwavelength dimensions and a single GaInNAs quantum well as an absorbing layer. Our calculations show that the coupling between localized plasmons and waveguiding modes leads to a strong enhancement of the electromagnetic field near the metallic electrodes, which results in an increased absorption in the quantum well. This allows both high quantum efficiency and fast electrical response of the MSM pho-

todetector. As the localized plasmons in 1D metallic gratings can be excited only by light polarized perpendicular to the slits (TM polarization) the photodetector is expected to be polarization sensitive. With a grating periodicity of 820 nm and electrode finger width of 460 nm a 16-fold increase in the absorption of TM-polarized light in the quantum well is achieved in comparison to a case without electrodes. First experimental results will be shown and compared with the simulation.

HL 46.76 Thu 15:00 Poster A

Electrodeposited ZnO / tetrasulfophthalocyanatonickel (TSPcNi) films: An inorganic / organic hybrid system with infinitely variable composition — Cathrin Boeckler, Armin Feldhoff, and •Torsten Oekermann — Institute of Physical Chemistry and Electrochemistry, Leibniz Universität Hannover, Callinstrasse 3-3A, 30167 Hannover, Germany

Electrodeposition is a low-cost and convenient method for the preparation of inorganic / organic hybrid materials for optoelectronic applications such as dye sensitized solar cells, in which high efficiencies were achieved with electrodeposited nanostructured ZnO / dye films [1]. ZnO / dye hybrid systems investigated so far were based on a ZnO framework, which became instable at higher dye concentrations. We now found that electrodeposited ZnO / TSPcNi hybrid films represent a system which can be infinitely varied in its content. With increasing dye concentration in the deposition bath, a transition from films based on crystalline ZnO, which appear green due to TSPcNi momomers, over blue films with dye dimers or aggregates to deep blue films based on an amorphous dye framework is observed. All films are highly transparent. The electrical and photoelectrical properties are dominated by the respective framework of each film. Consequently, films with a balanced composition show the lowest conductivity, while their photoconductivity is the highest, indicating that both phases take part in the transport of photogenerated electrons.

[1] T. Yoshida, M. Iwaya, H. Ando, T. Oekermann, K. Nonomura, D. Schlettwein, D. Wöhrle, H. Minoura, Chem. Commun. 2004, 400.

HL 46.77 Thu 15:00 Poster A

Scanning capacitance microscopy measurements on Si epilayers — •C. Henkel[1], H. Schmidt[1], C. Sturm[1], M. Grundmann[1], A. Krtschil[2], A. Krost[2], P. Pelzing[3], and A. Möller[3] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, EXPII, Germany — [2]Otto-von-Guericke-Unversität Magdeburg, Institut für Experimentelle Physik, Germany — [3]SGS Institut Fresenius GmbH, 01109 Dresden, Germany

We address the issue of extracting active dopant profile information from scanning capacitance microscopy (SCM) measurements because the direct imaging of dopant distribution and electrically active defects on the nanometer scale is one of the important issues facing semiconductor industry today. The samples are cross sections of differently doped Si epilayers on Si substrates with a native oxide layer as the insulating surface layer in the local metal-oxide semiconductor (MOS) structure. The SCM measurements have been performed at different biases ranging from -3 V to +3 V using a Dimension 3100 from Veeco Instruments. Before probing SCM at systematically increased bias voltages starting from -3V, the conducting tip has been shortly biased by 3V/0V in order to reach equilibrium conditions.We used a realistic one-dimensional MOS model taking into account high frequency effects, contact resistance and a surface layer capacitance to simulate dC/dV-V characteristics measured on the Si epilayers. Finally, by converting the measured SCM data into doping profiles, we demonstrate the capability of the SCM technique for extracting the free charge carrier concentration.

HL 46.78 Thu 15:00 Poster A

Untersuchung von Halbleiter-Nanopartikeln in levitierten flüssigen Mikrotropfen im weichen Röntgenbereich — •René Lewinski[1,2], Sofia Dembski[2], Burkhard Langer[1], Christina Graf[1,2] und Eckart Rühl[1,2] — [1]Institut für Chemie und Biochemie, FU Berlin, Takustr. 3, 14195 Berlin — [2]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg

Halbleiternanopartikel (HNP) haben einzigartige, größenabhängige optische und elektronische Eigenschaften. Die Untersuchung der elektronischen und geometrischen Struktur mittels weicher Röntgenstrahlung erfolgte bisher nur an getrockneten Proben auf Oberflächen, was den Nachteil der unkontrollierten Aufladung der HNP hat. Zudem werden HNP meist in Flüssigkeiten angewendet, wo sich die elektronische Struktur von der auf Oberflächen unterscheidet. Wir haben deshalb HNP in einem Flüssigkeitstropfen dispergiert und in einer elektrodynamischen Falle levitiert. So können HNP mit weicher Röntgenstrahlung untersucht und der Ladungszustand des Tropfens definiert eingestellt werden. Solche Experimente erfordern jedoch Hochvakuumbedingungen, weshalb zur Dispersion der HNP ein hochsiedendes, flüssiges Siloxan-Copolymer verwendet wurde. Die Detektion der Röntgenabsorptionsfeinstruktur im kantennahen Bereich (NEXAFS) erfolgte durch Messung der röntgenangeregten optischen Fluoreszenz, da in der Falle eine Detektion von Ladungsträgern nicht möglich ist. Zunächst wurde das Dispersionsmittel durch Messungen an der Si 2p Kante charakterisiert. Die HNP wurden an der S 2p und Se 3p Kante vermessen.

HL 46.79 Thu 15:00 Poster A

Temperature variations during low-temperature growth of GaMnAs — •Kamil Olejnik, Vit Novak, Miroslav Cukr, and Jiri Oswald — Institute of Physics AS CR, Cukrovarnicka 10, 162 53 Prague, Czech Republic

Substrate temperature is known to be a critical parameter in the low-temperature MBE growth of ferromagnetic GaMnAs layers. We report on significant temperature changes of the GaAs substrate determined by band-gap spectroscopy technique during the growth of the GaMnAs film. Typically, an increase of 20 - 40 degrees is observed within the first 20 nm of the growing layer, depending mainly on the Mn doping level; at the same time no increase of the thermocouple temperature is detected. The effect is attributed to the free carrier and Mn-acceptor related absorption, both increasing along with the increasing Mn content. A mathematical model is formulated based on the heat balance between the thermal sources, radiative cooling and the heat capacity of the substrate. Within the proposed overheating mechanism the onset of the surface roughening during the growth can be ascribed to reaching a certain critical substrate temperature. (Grant Nr.202/04/1519)

HL 47: Transport in high magnetic field/quantum-Hall-effect

Time: Thursday 15:45–18:15 Location: H14

HL 47.1 Thu 15:45 H14

Influence of Interactions on Flux and Back-gate Period of Quantum Hall Interferometers — •Bernd Rosenow and Bertrand Halperin — Department of Physics, Harvard University, Cambridge, MA 02138, USA

In quantum Hall systems with two narrow constrictions, tunneling between opposite edges can give rise to quantum interference and Aharonov-Bohm-like oscillations of the conductance. When there is an integer quantized Hall state within the constrictions, a region between them, with higher electron density, may form a compressible island. Electron-tunneling through this island can lead to residual transport, modulated by Coulomb-blockade type effects. We find that the coupling between the fully occupied lower Landau levels and the higher-partially occupied level gives rise to flux subperiods smaller than one flux quantum. We generalize this scenario to other geometries and to fractional quantum Hall systems, and compare our predictions to experiments.

HL 47.2 Thu 16:00 H14

Investigation of CdSe/ZnSe quantum dots by surface sensitive x-ray diffraction — •Isabella Gierz, Christian Kumpf, and Eberhard Umbach — Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074 Würzburg

In semiconductor heterostructure systems with a lattice mismatch of a few percent between substrate and epilayer nanometer-sized islands form spontaneously during growth. Within these islands electrons are confined in all three dimensions. For future quantum dot applications islands with homogeneous size distribution, a high surface density, and a defect free crystal lattice are needed.

We investigated CdSe/ZnSe quantum dots with a lattice mismatch

of 7%. Grazing incidence x-ray diffraction measurements were performed at the BW2 beamline of HASYLAB using the Risø six-circle diffractometer. The data was analyzed using an iso-strain model developed by I. Kegel [1]. This method allows to determine height, lateral radius, gradient of relaxation, and chemical composition of the islands. Furthermore, we present model calculations for reciprocal space maps and results from AFM measurements to verify the results obtained by Kegel's method.

[1] I. Kegel et al "Nanometer-Scale Resolution of Strain and Interdiffusion in Self-Assembled GaAs/InAs Quantum Dots", Phys. Rev. Lett. **85**, 8 (2000).

HL 47.3 Thu 16:15 H14

Tunneling spectroscopy of the Landau band gaps of two laterally coupled quantum Hall systems — •Matthias Habl[1], Matthias Reinwald[1], Max Bichler[2], Gerhard Abstreiter[2], and Werner Wegscheider[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]Walter Schottky Institut, Technische Universität München, 85748 Garching

With the technique of cleaved-edge overgrowth it is possible to produce AlGaAs/GaAs-heterostructures where two quantum Hall systems are separated by an atomically precise barrier. A small barrier width on the order of the magnetic length ℓ_B leads to a Landau band structure with anticrossings lying in the achievable range of the Fermi level. While Kang *et al.* used modulation-doped 2DESs [1], the gate electrode introduced in our sample structure allows to investigate a certain band gap at different magnetic fields [2]. Therefore, though the barrier has a fixed width of $a = 52\,\text{Å}$ and a height of $V_0 = 268\,\text{meV}$, the effective shape (in units of ℓ_B and $\hbar\omega_c$) of the barrier as well as of the Landau band structure can be tuned by means of the magnetic field while the Fermi level is varied independently. The exact calculation of the one particle energy dispersion yields for an increasing field strength a slight rise of the position of the Landau band gaps on the scale of the cyclotron energy. This phenomenon is confirmed by the experimental data. In addition, interference effects at random tunneling centers in the barrier are discussed in dependence of the electron density.

[1] W. Kang *et al.*, Nature (London) **403**, 59 (2000)
[2] M. Habl *et al.*, Phys. Rev. B **73**, 205305 (2006)

HL 47.4 Thu 16:30 H14

The screening picture of the integer quantized Hall effect — •Afif Siddiki — Physics Dept., ASC, CeNS, LMU Munich, Germany

We implement the self-consistent Thomas-Fermi-Poisson approach to a homogeneous two dimensional electron system. First we summarize the findings of a recent model explaining the exact quantization of the Hall plateaus and the transition between them, within a local Ohm's law. Second we compute the electrostatic potential produced inside a semiconductor structure by a quantum point contact placed at the surface of the semiconductor and biased with appropriate voltages. The model is based on a semianalytical solution of the Laplace equation. Starting from the calculated confining potential, the self-consistent (screened) potential and the electron densities are calculated for finite temperature and magnetic field. We observe that there are mainly three characteristic rearrangements of the incompressible edge states which will determine the current distribution near a QPC.

HL 47.5 Thu 16:45 H14

Edge versus bulk current in the quantum Hall effect regime — •Josef Oswald — Institute of Physics, University of Leoben, Franz Josef Str. 18, A-8700 Leoben, Austria

The question about the role of edge and bulk current for the integer quantum Hall effect (IQHE) is still a major topic of the ongoing discussions. The importance of this question is highlighted by experimental results obtained by probing the lateral potential distribution in the IQHE-regime[1]. In order to compare this experimental results with theory, a transport model is needed, which is able to capture sample properties close to the real experimental conditions like e.g. sample geometry and non-ideal contacts. In recent papers [2,3,4] we have demonstrated, that on the basis of a network model it is possible to account for complex sample geometries and we have further shown, that our network model is able to treat edge and bulk currents on an equal footing. This gives us the ability to address the lateral current distribution in QHE samples. For the pure plateau regime we get a homogeneous distribution of the current in the bulk region, while for the transition regime between plateaus we get an enhancement of the current density near the edges.

[1] E. Ahlswede et al., Physica E12, 165 (2002)
[2] J.Oswald et al., Phys. Rev. B74(15), 153315 (2006)
[3] M.Oswald et al., Phys.Rev. B72(3), 035334 (2005)
[4] J.Oswald et al., J. Phys.: Condens. Matter 18, R101-R138 (2006)

HL 47.6 Thu 17:00 H14

Compressibility stripes for mesoscopic quantum Hall samples — •Christoph Sohrmann and Rudolf A. Römer — University of Warwick, Gibbet Hill Road, Coventry CV47AL, UK

We numerically investigate the interplay of disorder and electron-electron interactions in the integer quantum Hall effect. In particular, we focus on the behaviour of the electronic compressibility as a function of magnetic field and electron density. We find manifestations of non-linear screening and charging effects around integer filling factors, consistent with recent imaging experiments. Our calculations exhibit g-factor enhancement as well as strong overscreening in the centre of the Landau bands. Even though the critical behaviour appears mostly unaffected by interactions, important implications for the phase diagram arise. Our results are in very good agreement with the experimental findings and strongly support the relevance of electron-electron interactions for understanding integer quantum Hall physics.

HL 47.7 Thu 17:15 H14

Phonon Drag in High Landau Levels — •Christian Joas and Jürgen Dietel — Institut für theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin

The information provided by drag measurements in bilayer quantum Hall systems subjected to a perpendicular magnetic field is complementary to conventional transport measurements and thus constitutes a valuable additional tool for the investigation of quantum Hall systems. Most experimental and theoretical work is focused on the study of Coulomb drag, which, for small interlayer separations, yields the dominant contribution to the drag conductivity. For larger interlayer separations, also phonon-mediated interlayer interactions become relevant. In contrast to the case of Coulomb drag, where the drag conductivity is dominated by small momentum tranfers between the layers, the momentum transfers involved in phonon drag can be of the order of the Fermi momentum. By generalizing the linear response theory of Coulomb drag [1] to arbitrary momentum tranfers, we derive a theory of phonon drag in high Landau levels and present analytical and numerical results for the phonon-mediated contribution to the drag conductivity. We show that the temperature dependence of phonon drag differs strongly from the behavior of Coulomb drag. We also compare our results with experiments for phonon drag at zero magnetic field [2].

[1] I. V. Gornyi, A. D. Mirlin, and F. von Oppen, Phys. Rev. B **70**, 245302 (2004). [2] T. J. Gramila, J. P. Eisenstein, A. H. MacDonald, L. N. Pfeiffer, and K. W. West, Phys. Rev. Lett. **66**, 1216 (1991).

HL 47.8 Thu 17:30 H14

Shadow epitaxy technique for fabricating complex coplanar 2D structures — •N. Isik, S. F. Roth, M. Bichler, A. Fontcuberta i Morral, and M. Grayson — Walter Schottky Institute ,Technische Universität München, Am Coulombwall 3, 85748 Garching , Germany

Advanced growth techniques are required to fabricate complex 2D heterostructures, however such approaches often need special postgrowth processes, i.e. regrowth over a patterned back gate, selective ion implantation, cleaved-edge overgrowth, flip-chip bonding, V-groove regrowth. We introduce here a new shadow epitaxy technique whose most important advantage is the ability to grow complex devices with a single growth process, requiring only standard photolithography to achieve a final device. Our technique requires only tall rectangular pieces of GaAs wafer mounted perpendicular to the substrate for creating shadows. During the growth, the substrate is arranged at specific angles relative to the cell positions in the MBE chamber causing specific layers of the heterostructure to be absent in the shadow region. By using this shadow epitaxy technique, two type of structures will be demonstrated. First, localized superlattice shadow structures are analyzed by using scanning electron microscopy (SEM). Second, the transport properties of modulation doped high mobility $n-$ and $p-$ type coplanar 2D shadows will be characterized.

HL 47.9 Thu 17:45 H14

Temperature dependence of high mobility AlAs quantum wells — •Shivaji Dasgupta, Claudius Knaak, Max Bichler, Anna Fontcuberta-i-Morral, Gerhard Abstreiter, and Matthew Grayson — Walter Schottky Institute, Technische Universität München, Am Coulombwall 3, Garching

We present transport characteristics of high mobility n-type AlAs quantum well (QW) substrates grown on two different facets (001) and (110). Measurements were performed down to 330 mK on van der Pauw geometries and on L-shaped Hall bars with the arms oriented along the crystallographic axes to investigate mobility anisotropies. In the (001) oriented QW, the presence of two degenerate valleys of electrons yields a total isotropic conductance with a mobility of 2.4×10^5 cm^2/Vs at 1.4 K, with the mobility saturating below 3 K. In the (110) oriented QW, there should be a single valley with an anisotropic conductance. At 1.4 K we obtain mobilities of 3.4×10^3 cm^2/Vs along the $\langle$ 001 $\rangle$ branch of the L-shaped Hall bar and 1.8×10^4 cm^2/Vs on the $\langle$ -110 $\rangle$ branch. The ratio of 5.8 between the two mobilities matches the ratio between the two anisotropic masses, $m_l/m_t = 1.1/0.19 = 5.8$. The temperature dependence has been analyzed in analogy to mobility limiting processes at low temperatures in GaAs [1], which include remote-ion scattering due to donors, ionized impurity scattering due to interface charge, polar optical phonon scattering, acoustic deformation potential scattering and piezoelectric scattering among others. Evidence of an additional inter-valley scattering term in the mobility will be explored.

[1] Lin, et al. Appl. Phys. Lett. 45, 695 (1984).

HL 47.10 Thu 18:00 H14

Two beam Aharonov-Bohm interference in the integer quantum Hall regime — •Leonid Litvin, Peter Tranitz, Werner Wegscheider, and Christoph Strunk — Uni Regensburg

We have built an electronic Mach-Zehnder interferometer (MZI) [1] using high mobility GaAs/AlGaAs heterostructures with the purpose to study electron interference and shot noise in this system. The maximum interference visibility of our device was near 20% at filling factor ν=1. It was found earlier that the Aharonov-Bohm oscillation amplitude varies nonmonotonically with energy [2]. We confirm this behavior for a MZI 1.5 times bigger in size with about 1.4 times higher electron density. In spite of these difference the characteristic energy in our experiment was found to be 10 μV, similar as in [2]. The interference appears in a broad range of magnetic field between filling factors 1 and 2. The visibility is highest at certain resonances in the transmission of the quantum point contact. [1] Yang Ji *et al.*, Nature **422**, 415 (2003) [2] I. Neder *et al.*, Phys.Rev.Lett. **96**, 016804 (2006).

HL 48: Quantum dots and wires: preparation and characterization II

Time: Thursday 16:15–18:00 Location: H13

HL 48.1 Thu 16:15 H13

Evidence for Reduction of the Critical Nucleus in InAs/GaAs Quantum Dot Stacks — •Thomas Hammerschmidt[1,3], Peter Kratzer[2,3], and Matthias Scheffler[3] — [1]Department of Materials, University of Oxford, Oxford, UK — [2]Fachbereich Physik, Universität Duisburg-Essen, Duisburg, Germany — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Growth of quantum dot (QD) stacks is a possible route to influence the lateral arrangement of self-assembled semiconductor QDs. In stacks of InAs QDs in GaAs, the QDs in a new layer form preferably right above those in the previous layer. Is is surprising, how the weak interactions of surface atoms with the buried QD trigger this 'correlated' growth. In this work we offer a quantitative explanation based on the influence of elastic interactions on the critical nucleus for QD formation.

In particular, we apply a recently developed Abell-Tersoff potential to realistic QD nanostructures. For the formation of a new layer of QDs on a capping layer above a layer of buried QDs, we study systematically the formation energy as a function of lateral distance of buried and free-standing QD. We find it to be minimal if the free-standing QD is placed exactly vertically above the buried QD, in line with the growth correlation observed in most experiments of stacked QD growth. The elastic interactions observed in our calculations lower the energy barrier for QD nucleation by up to 2 eV per QD as compared to nucleation in a single QD layer. The size of the critical nucleus thereby reduces from approximately 70 to not more than 25 InAs units.

HL 48.2 Thu 16:30 H13

InP-quantum dots: Towards high temperature emission — •Wolfgang-Michael Schulz, Robert Rossbach, Michael Jetter, Matthias Reischle, Gareth Beirne, and Peter Michler — Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart, Germany

To increase the carrier confinement and luminescence at elevated temperatures for InP-quantum dots, we embedded them in $Al_{0.50}Ga_{0.50}InP$. Atomic force microscope measurements are showing a bimodal size distribution of uncapped samples, which can also be seen in the photoluminescence measurements. From time-resolved, power- and temperature-dependent PL measurements, we could deduce a confinement energy of 274 meV for small A-type dots and 572 meV for bigger B-type dots. Therefore, the temperature where the thermal reemission of the carriers out of the dots dominates, could be estimated to 160 K for A-type, respectively 250 K for B-type dots. The sample also shows a thermally induced, wetting layer assisted carrier transfer between these bimodal dots, increasing the luminescence intensity of the A-type dots at elevated temperatures. A further increase of the luminescence at elevated temperatures was achieved by placing the QD layer on top of a DBR structure. On account, luminescence up to 460 K was observable. The zero-dimensional behavior was verified with high resolution μ-PL and autocorrelation measurements, showing single photon emission at 4 K.

HL 48.3 Thu 16:45 H13

Growth condition dependence of MOVPE InGaN quantum dots — •Christian Tessarek, Tomohiro Yamaguchi, Jens Dennemarck, Stephan Figge, and Detlef Hommel — Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

InGaN is a very interesting material for optical application due to the blue-green emission. The implementation of InGaN quantum dots into the active region promises an improvement in optical behavior as well as in device performance. The conventional growth method to a strain driven formation of quantum dots is the Stranski-Krastanov growth mode. The problem is the capping process, which causes a dissolution of the dots. We develop a novel two-step growth method. A first In(x)Ga(1-x)N nucleation layer is stabilized by a second In(y)Ga(1-y)N formation layer with different indium compositions (y<x) in the two-step growth method. The existence of quantum dots is confirmed by micro-PL-measurements for this structure [1]. The influence of nucleation layer growth parameters like temperature, (TM)In-flux and thickness is further investigated with PL-measurements. XRD-results will show strain relaxation due to increasing number of stacking layer. First EL-results will be also presented for the implementation of quantum dots into LED device structure. [1] K. Sebald, H. Lohmeyer, J. Gutowski, T. Yamaguchi and D. Hommel, phys. stat. sol. (c) 243, 1661-1664 (2006)

HL 48.4 Thu 17:00 H13

Stability and structure of free-standing III-V nanorods: An ab initio investigation — •Roman Leitsmann and Friedhelm Bechstedt — Friedrich-Schiller Universit\"at Jena, Institut f\"ur Festkörpertheorie und -optik, Max-Wien Platz 1, 07743 Jena

The interest in anisotropic needlelike crystals, especially in the ultimately thin varieties, has been recently stimulated by the potential need as building blocks for nanoscale electronic and photonic devices. Due to their considerable potential for optoelectronics or high-speed electronics nanorods consisting of III-V semiconductors are of special interest. In the most cases the growth direction of III-V semiconductor nanorods is parallel to the [111] axis of the bulk zinc-blende (zb) structure. However, the crystal structure of the nanowires may change noticable, depending on growth conditions and growth method. In particular, changes of the crystal symmetry from the cubic to the hexagonal (wurtzite - w) stacking of the cation-anion bilayers have been observed in many cases.

We report ab initio investigations of hexagon-shaped III-V semiconductor nanowires with varying crystal structure, varying surface passivation, and varying diameter [1]. Their stability is dominated by the free surface energies of the corresponding facets. We observe a phase transition between local zb and w geometry of the rods versus the preparation conditions of the surfaces. The influence of the actual III-V compound InAs, GaAs, and InP remains small.

[1] R. Leitsmann, F. Bechstedt, cond-mat/0611521, Phys. Rev. B,

submitted (2006)

HL 48.5 Thu 17:15 H13

Influence of the electron injection energy on ballistic transport in nanoscale GaAs/AlGaAs cross junctions — •Matthias Wiemann[1], Ayhan Cetinkaya[1], Ulrich Wieser[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Werkstoffe und Nanoelektronik - Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Angewandte Festkörperphysik - Ruhr-Universität Bochum, D-44780 Bochum, Germany

Ballistic electron transport is studied in a modified nanoscale cross junction prepared from a high-mobility GaAs/AlGaAs heterostructure. The device is defined by combining electron-beam lithography with standard photo lithography and is transferred by wet-chemical etching. The lateral geometry is given by a central orthogonal cross junction and two additional branches which orthogonally merge in the vertical bar on each side of the central junction. A potential barrier is formed by a nanoscale Schottky top-gate finger, which crosses the vertical bar near the central cross junction. The barrier enables to vary the kinetic energy of injected electrons. If an input bias is applied between the vertical bar embedding the barrier and an orthogonal lead of the central cross junction, negative bend resistance is found in the nonlocal I-V transfer characteristics. In this configuration V describes the potential difference between the voltage probes opposite to the current leads. If the transfer voltage is detected between the barrier free part of the vertical bar and its neighboring branch, gate-voltage dependent nonlinearities are observed.

HL 48.6 Thu 17:30 H13

Advances in Quantum Dot Fabrication by Cleaved Edge Overgrowth — •Jörg Ehehalt, Christoph Kamseder, Christian Neugirg, Christian Gerl, Dieter Schuh, and Werner Wegscheider — Universität Regensburg, Germany

Single and coupled quantum dot systems with precisely controlled sizes and positions can be fabricated using the Cleaved Edge Overgrowth (CEO) method. They result from quantum mechanical bound states at the intersection of three perpendicular GaAs quantum wells.

Due to the high degree of growth control, these quantum dots are promising candidates for research in areas like quantum computing or photon correlation. However, most applications have been prevented so far by the relatively low confinement energies in these quantum dots of up to 10 meV. This value needs to be significantly increased in order to study excited states, apply external fields without loosing confinement and increase storage times of charge carriers.

Using techniques formerly applied to CEO-grown quantum wires, such as asymmetrical structures and strained layers, the confinement energies can be substantially improved. The properties of these structures are studied by photoluminescence and photoluminescence excitation spectroscopy and compared to theoretical simulations.

These structures are now to be used to generate and detect spin-polarized charges in the quantum dots and study the properties of quantum dot molecules made by arrays of quantum dots. The results can also be applied to fabricate novel quantum wire lasers working at higher temperatures and lower threshold currents.

HL 48.7 Thu 17:45 H13

Spin resonance investigations of P-doped Si nanocrystals: Charge compensation and interface states — •Andre R. Stegner[1], Rui N. Pereira[1], Robert Lechner[1], Roland Dietmüller[1], Martin S. Brandt[1], Hartmut Wiggers[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Universität Duisburg-Essen, Institute for Combustion and Gas Dynamics, Lotharstrasse 1, 47048 Duisburg, Germany

Silicon nanocrystals (Si-ncs) are attracting interest as a possible base material for low cost electronics and solar cells. To explore the full potential of these materials, a detailed understanding and control of doping is crucial. Si-ncs with diameters in the range 4-50 nm were grown in a low pressure microwave plasma reactor using silane and phosphine as precursor gases. In this type of isolated Si-ncs, the surface termination plays an even more significant role than for Si-ncs embedded in amorphous SiO_2 host matrices. Electron paramagnetic resonance (EPR) spectra of highly doped samples exhibit resonances originating from donor-impurity bands and dangling bond defects at the interface between the Si-ncs and their native oxide shell. Additionally, for the particles with low doping level, the characteristic EPR hyperfine signature of the P donor electrons in Si is also observed, providing proof for substitutional incorporation of dispersed P donor atoms in the Si-ncs. The influence of interface states and charge compensation effects are discussed on the basis of hydrogen thermal desorption spectroscopy and Fourier transform infrared absorption spectroscopy data.

HL 49: Graphene

Time: Thursday 17:30–18:15 Location: H17

HL 49.1 Thu 17:30 H17

Fabry-Perot interference in graphene ribbons (SWITCHED WITH TT 27.3) — •Miriam del Valle[1], Carlos Tejedor[2], and Gianaurelio Cuniberti[1] — [1]Institut für Theoretische Physik, Universität Regensburg — [2]Universidad Autónoma de Madrid, Spain

Graphene is in the focus of intense studies, as it represents an archetypal system for investigating low-dimensional quantum phenomena. Moreover, its topology results in a peculiar electronic structure with a massless dispersion near the Fermi level. Here we present a theoretical study on the Fabry-Perot interference patterns of graphene ribbons well contacted to external electrodes and capacitively coupled to a back gate. Our main focus comprises the effects of the orbital mixing between s and p bands and the role of defects.

HL 49.2 Thu 17:45 H17

Spatially inhomogeneous states of charge carriers in graphene — Alexander Chaplik[1] and •Timur Tudorovskiy[2] — [1]Institute of Semiconductor Physics, 630090, Novosibirsk, Russia — [2]AG QChaos, FB Physik, Universität Marburg, Renthof 5, 35032 Marburg, Germany

Monatomic layers of carbon atoms, forming hexagonal lattice (graphene), are studied very intensively at present [1-2]. A "conical" dispersion law for free quasiparticles $E = \pm u|p|$ implies crucial distinctions of their dynamical characteristics from the corresponding characteristics of massive particles. We study an interaction of 2D quasiparticles with impurity potentials assuming that it can be described by the effective equation $u(\boldsymbol{\sigma}\hat{\boldsymbol{p}})\Psi + v(\mathbf{r})\Psi = E\Psi$, where $\boldsymbol{\sigma} = (\sigma_1, \sigma_2)$ are Pauli matrices, $\hat{\boldsymbol{p}} = -i\hbar\nabla$ is momentum operator, u is characteristic velocity and $v(\mathbf{r})$ is an impurity potential.

We consider some simple exactly solvable models of 1D and 2D potential wells from the viewpoint of possibility to localize quasiparticles. It is shown, that in quantum wires transversal (1D) localization is possible, whereas in quantum dots as well as for hydrogen-like donors or acceptors 2D localization is not possible. Scattering cross-sections of electrons (holes) of graphene by an axially symmetric potential well are obtained. It is shown that in the limit of infinitely large energies of incoming particles the cross-section tends to a constant. It is shown that the geometric potential for a curved quantum wire differs from the case of parabolic dispersion law, and cannot form 1D bound states.

[1] K. S. Novoselov et al., *Science*, **306**, 666 (2004).
[2] J. Milton Pereira et al., Phys. Rev. B **74**, 045424 (2006).

HL 49.3 Thu 18:00 H17

Effects of defects and disorder in graphene nanoribbons (SWITCHED WITH TT 27.6) — •Gabriel Niebler, Norbert Nemec, and Gianaurelio Cuniberti — Universität Regensburg

Nanostructured graphene is a promising candidate for future devices at the nanometer scale. Defects and disorder as well as irregular edges cannot be avoided in any realistic setup. We use a π-orbital model for a systematic study of the effects of various kinds of defects on the electronic transport properties of graphene nanoribbons and emphasize differences and similarities to the well known results for carbon nanotubes.

HL 50: Invited Talk Schmult

Time: Friday 10:15–11:00 Location: H15

Invited Talk HL 50.1 Fri 10:15 H15

Quantum Transport in High Mobility GaN/AlGaN 2DEGs and Nanostructures — •Stefan Schmult[1], Alexander Punnoose[1], Michael J. Manfra[1], Hungtao Chou[2], David Goldhaber-Gordon[2], and Richard J. Molnar[3] — [1]Bell Labs, Alcatel-Lucent, Murray Hill, NJ, USA — [2]Stanford University, Stanford, CA, USA — [3]MIT Lincoln Lab, Lexington, MA, USA

We report on the transport properties of high mobility GaN/AlGaN two-dimensional electron gases (2DEGs) grown by molecular beam epitaxy. Using an insulated gate Hall bar structure, the electron density is continuously tuned from 2×10^{12}cm^{-2} down to 2×10^{11}cm^{-2}. At T=0.3K, the 2DEG displays a maximum mobility of 1.67×10^{5}cm^2/Vs at a sheet density of 9.1×10^{11}cm^{-2}. Detailed analysis of the dependence of mobility on 2D density allows us to isolate the primary scattering mechanisms at low carrier density and low temperatures. A detailed study of the weak localization and antilocalization corrections to the classical conductivity identifies that the spin-orbit coupling is of Bychkov-Rashba type. We estimate the values of the coupling constant and the spin relaxation time and find that spin-orbit scattering is not negligible as one might expect for a wide-bandgap material. Recently we have realized electron transport through quantum point contacts (QPCs) and quantum dots (QDs) in GaN/AlGaN nanostructures. True one-dimensional conduction channels in QPCs show well quantized plateaus, which spin-split in high perpendicular magnetic field. The transconductance of a QD depends on its size and exhibits Coulomb oscillations, representing resonant transport through the dot.

HL 51: GaN: preparation and characterization

Time: Friday 11:00–13:30 Location: H13

HL 51.1 Fri 11:00 H13

GaN-based devices on 150 mm Si(001) substrate grown by MOVPE — •F. Schulze[1], A. Dadgar[1,2], A. Krtschil[1], O. Kisel[1], T. Hempel[1], J. Bläsing[1], C. Hums[1], A. Diez[1], L. Reissmann[1], J. Christen[1], and A. Krost[1,2] — [1]Otto-v.-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg — [2]AZZURRO Semiconductors AG, Universitätsplatz 2, 39106 Magdeburg

The Si(001) orientation offers an obvious approach for the monolithic integration of GaN-based electronics and optoelectronics with standard silicon technology, because this substrate orientation is used in mainstream CMOS technology. However, the main challenges are the different lattice symmetries and crystallographic orientations of GaN and Si(001). We present structural and optical investigations on GaN layers on Si(001) grown by metalorganic vapour phase epitaxy (MOVPE). A key parameter to obtain high quality GaN layers on Si(001) is most likely the control of the surface reconstruction of the substrate, which can be influenced by changing the surface energy. The use of 4° off-oriented substrates prefers one type of dimer rows, and thus, the growth of c-axis oriented GaN on Si(001) with one defined in-plane alignment is possible. The crystallographic quality is investigated by x-ray diffraction measurements, Electron Back Scatter Diffraction, FE-SEM imaging, and AFM. By growing an approximately 2.8 μm thick, crack-free GaN buffer, the achieved crystallographic quality allows for fabricating GaN-based LEDs and FET devices on Si(001). Furthermore, we will present some first blue LED samples of the upscaling process up to 150 mm Si(001) substrates.

HL 51.2 Fri 11:15 H13

Nachweis der spontanen Polarisation in GaN mittels UHV-Kathodolumineszenz — •Martina Finke, Daniel Fuhrmann, Uwe Rossow und Andreas Hangleiter — TU Braunschweig, Inst. f. Angewandte Physik, 38106 Braunschweig

Die optischen Eigenschaften von GaN werden stark von den piezoelektrischen und spontanen Feldern beeinflusst, wobei das spontane Feld normalerweise von Oberflächenladungen abgeschirmt wird. Ein Entfernen dieser Ladungen führt dann zu einer Blauverschiebung und Intensitätszunahme der Emission, da der Quantum Confined Stark Effekt durch das Gegenfeld abgeschwächt wird. Kathodolumineszenzmessungen an Proben mit verschiedenen Oberflächenbehandlungen wurden im Ultrahochvakuum durchgeführt. Dabei wurde die Änderung der Energie und Intensität der Lumineszenz abhängig von der Strahlzeit des Elektronenstrahls aufgenommen. Unbehandelte Proben, angeätzte Proben und ausgeheizte Proben wurden bei Raumemperatur und bei 100 Kelvin untersucht. Diese Experimente zeigen, dass eine Änderung der Oberflächenbelegung durch Elektronenbestrahlung oder Ätzen zu einer Aktivierung des spontanen Feldes und damit zu einer Blauverschiebung und Intensitätszunahme der Emission führt. Mit Hilfe von speziellen Proben, bei denen die Tiefe des Quantum Wells variiert wurde, konnte der Aufbau des spontanen Feldes in den Proben nachgewiesen werden. Gleichzeitig wurde auch eine abschirmende Wirkung der von dem Elektronenstrahl erzeugten freien Ladungsträgern auf das spontane Feld beobachtet. Durch den Vergleich mit Photolumineszenzmessungen im UHV sollen diese Effekte überprüft werden.

HL 51.3 Fri 11:30 H13

Vertically increasing well thickness and In content in GaInN MQWs due to V-shaped pits — •Heiko Bremers, Lars Hoffmann, Daniel Fuhrmann, Holger Jönen, Uwe Rossow, and Andreas Hangleiter — TU Braunschweig, Institut für Angewandte Physik, Mendelssohnstr. 2, 38106 Braunschweig

So far the origin of the high efficiencies of light emission in the GaInN based quantum wells (QW's) is still under debate. It is commonly believed that the suppression of non-radiative recombination processes is due to fluctuations of In concentration, which could lead to a localization of carriers. Recently another approach has been proposed which shows that V-shaped pits with reduced well thicknesses on the facets might be responsible for the suppression of non-radiative recombination. In this work we investigate the influence of V-shaped pits on the growth of GaInN-GaN MQW's by TEM and x-ray diffraction measurements. We have grown different MQW's by a low-pressure MOVPE and studied the influence of the number of QW's as well as of the depth of V-shaped pits. During the growth of the samples a material transport takes place from the pits to the c-plane. We show that the thickness of the GaInN QW's and of the GaN barriers is increased due to material transport. With increasing number of quantum wells the diameter of the pits increases, which leads to a superlinear increase of these thicknesses. We present a model which describes the change in thickness due to material transport. Additional photoluminescence measurements performed on our samples exhibit a redshift as well as a broadening with increasing number of quantum wells.

HL 51.4 Fri 11:45 H13

Luminescence properties of high quality non-polar a-plane GaN epilayers — •Martin Noltemeyer, Barbara Bastek, Lars Reissmann, Frank Bertram, Alexander Franke, Jürgen Christen, Matthias Wieneke, Armin Dadgar, and Alois Krost — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

A set of high quality a-plane GaN layers is grown on r-plane sapphire-substrates by MOVPE and characterized by temperature (T) dependent photoluminescence (PL) and cathodoluminescence (CL). The T=4K PL spectra consist of several emission peaks: Near the band edge, a donor bound (D^0, X) at 3.495 eV as well as an acceptor bound exciton (A^0, X) at 3.482 eV can be resolved. Their spectral position corresponds to a compressive strain of 0.9 GPa. An emission at 3.30 eV originating from donor-acceptor-pair recombination (DAP) and accompanied by several LO-phonon replicas. A blue-shift of 34 meV is observed with increasing excitation density and with increasing temperature a high energy peak, i.e. the free-to-bound (e, A^0) emerges. The dominating defect emission at 3.42 eV is attributed to excitons localized at stacking faults (SF) forming a wurtzite/cubic/wurtzite GaN quantum well. Temperature (T) dependent PL studies show a ther-

mal quenching of the SF perfectly following an Arrhenius behavior with three activation energies (25 meV, 4 meV, and 40 meV). The SF peak energy shows an S-shaped T-dependence corresponding to a localization energy of 25 meV. Spatially resolved CL spectroscopy shows a homogeneous intensity distribution of the SF luminescence.

HL 51.5 Fri 12:00 H13

Nonlinear elastic effects in group III-nitrides — •Michal Petrov, Liverios Lymperakis, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung, Max-Planck-Strasse 1, 402 37, Düsseldorf, Germany

The zero-dimensional nature of Quantum Dots (QD) allows the design of novel high performance optoelectronic devices. In group III-nitrides, due to the large lattice mismatch and the stiffness of the material, the quantum dots embedded in the semiconductor matrix are highly strained and the inclusion of nonlinear elastic effects is crucial. However so far experimental and/or theoretical data on the composition and pressure dependence of the elastic constants of AlGaN alloys are lacking. Therefore, we computed the composition and pressure dependence of the bandgaps and the elastic constants of the AlGaN alloys employing planewave pseudopotential calculations within the density functional theory. The calculation of the second and third order elastic constants was performed within the framework of anisotropic hyperelasticity [1]. To model ternary random alloys within a supercell formalism (which intrinsically contains periodic boundary conditions), we considered a number of different ordered configurations based on the concept of Special Quasirandom Structures (SQS). The thus calculated nonlinear coefficients are used as input for a multi-scale scheme based on Finite Elements and k.p theory calculations and allows an accurate description of the binding states and optical Coulomb matrix elements in materials QDs.

[1] P. Dluzewski, Journal of Elasticity **60**, 119 (2000).

HL 51.6 Fri 12:15 H13

Optical Properties of Si- and Mg-Doped GaN Nanorods — •Florian Furtmayr, Martin Vielemeyer, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

Quasi one-dimensional semiconductor single crystals are a key component for future applications in nano-electronics and nano-optics. Using a catalyst free growth technique, GaN-nanorods were fabricated by plasma assisted molecular beam epitaxy on Si(111) substrates. Both Si- and Mg-doping over a wide concentration range was realized and the influence of doping on the growth kinetics has been investigated. In addition, the optical properties were studied by photoluminescence spectroscopy in the temperature range 4K to 100K. Emission from free and donor bound excitons are the dominant effects for undoped samples, whereas the contribution of donor-acceptor recombination increases for increasing doping concentrations. The relation between luminescence characteristics, nanorod geometry, degree of coalescence, and doping concentration is analyzed.

HL 51.7 Fri 12:30 H13

Band gap and Van-Hove singularities of cubic InN — •Pascal Schley[1], Rüdiger Goldhahn[1], Christian Napierala[1], Gerhard Gobsch[1], Jörg Schörmann[2], Donat J. As[2], Klaus Lischka[2], Frank Fuchs[3], and Friedhelm Bechstedt[3] — [1]Institut für Physik, TU Ilmenau — [2]Department Physics, Universität Paderborn — [3]Institut für Festkörpertheorie und -optik, FSU Jena

InN has attracted much interest recently due to the band gap revision for the hexagonal compound from the long-time accepted value of 1.89 eV down to only 0.68 eV. Theoretical calculations predict an even lower gap for the cubic (c-) counterpart. We succeeded in growing single crystalline c-InN films on 3C-SiC substrate with a c-GaN buffer layer by MBE. Ellipsometry was applied in order to determine the dielectric function (DF) of c-InN from the near infrared into the VUV spectral region (data above 4 eV refer to the use of synchrotron radiation at BESSY II). The spectra show pronounced features in the high-energy part which arise from the Van-Hove singularities in the band structure. High-resolution transition energy determination is achieved by fitting the third derivatives of the DF. The values as well as the shape of the DF are in excellent agreement with the results of DFT-LDA calculations for which electron-hole interaction was taken into account. The position of the absorption edge depends clearly on the electron density of the films. Taking into account carrier-induced band gap renormalization and the Burstein-Moss shift we estimate the zero-density band gap of c-InN with 0.62 eV which is by 60 meV lower than for hexagonal InN.

HL 51.8 Fri 12:45 H13

Nonpolar a-plane GaN grown on r-plane sapphire by metal-organic vapor-phase epitaxy — •Matthias Wieneke, Armin Dadgar, Jürgen Bläsing, Andre Krtschil, Thomas Hempel, and Alois Krost — Otto-von-Guericke-University Magdeburg, FNW/IEP, Postbox 4120, 39016 Magdeburg

Conventional GaN based devices grow along the [0001] c-direction. In the c-orientation, the internal spontaneous and the strain-induced piezoelectric polarization generate electric fields at heterointerfaces. These electric fields cause spatial separation of electrons and holes in quantum wells reducing the oscillator strength and red shifting the luminescence. Growing nonpolar wurtzite III-N films, as a-plane GaN for example, are a possibility to avoid polarization effects. (11-20) a-plane GaN films were grown on (1-102) r-plane sapphire by metal-organic vapor-phase epitaxy (MOVPE). By varying growth-parameters as, e.g., V-III ratio, temperature and reactor pressure several sets of samples were grown and the influence to the micro structural properties and surface morphology were studied. The grown films were investigated by high resolution X-ray diffraction (XRD), scanning electron microscopy (SEM) and atomic force microscopy (AFM). It was found that the structural properties of the films and their dependence of some growth-parameters were anisotropic in the in-plane m- and c-direction. Therefore the strain properties of a-plane GaN layers are not biaxial.

HL 51.9 Fri 13:00 H13

MOVPE growth and characterization of Cr-doped GaN — •Yong Suk Cho[1], Nicoleta Kaluza[1], Hilde Hardtdegen[1], Thomas Schaepers[1], Vitaliy Guzenko[1], Klaus Schmalbuch[2], Bernd Beschoten[2], Uwe Breuer[3], Astrid Besmehn[3], Hans-Peter Bochem[1], and Hans Lueth[1] — [1]Institute of Bio- and Nanosystems (IBN-1), Center of Nanoelectronic Systems for Information Technology (CNI), Virtual Institute of Spin Electronics (VISel), Research Center Juelich, 52425 Juelich, Germany — [2]II. Physikalisches Institute and Virtual Institute of Spin Electronics (VISel), RWTH Aachen, 52056 Aachen, Germany — [3]Central Division of Analytical Chemistry (ZCH), Research Center Juelich, 52425 Juelich, Germany

We grew Cr-doped GaN by metal organic vapor phase epitaxy on undoped GaN epilayers. Conventional Ga and N precursors were used and bis(cylcopentadienyl)chromium (Cp_2Cr) was employd as the Cr precursor. We investigated the effects of growth temperature, carrier gas and Cr/Ga source ratio on the Cr incorporation efficiency and on the morphological and magnetic properties of the layers. The concentration of Cr is linearly dependent on source partial pressure. The growth temperature mainly determines morphology and Cr incorporation efficiency in the layer. A certain amount of H_2 in carrier gas helps to make a coalesced surface. Our Cr-doped GaN grown by MOVPE shows remanent magnetization even above room tempeature.

HL 51.10 Fri 13:15 H13

Piezoelectric Fields in Semipolar GaInN/GaN Quantum Wells — •Martin Feneberg[1], Frank Lipski[1], Klaus Thonke[1], Rolf Sauer[1], Thomas Wunderer[2], Peter Brückner[2], and Ferdinand Scholz[2] — [1]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm — [2]Institut für Optoelektronik, Universität Ulm, 89069 Ulm

Piezoelectric fields lower the efficiency of GaInN/GaN quantum well devices via the Quantum Confined Stark Effect (QCSE). To circumvent the problems introduced by the QCSE, growth on nonpolar or semipolar crystal planes can be used. We investigate the piezoelectric field strength on {1-101} semipolar facets of selectively grown GaN stripes by voltage-dependent photoluminescence. We find a reduced piezoelectric field of about -0.1 MV/cm on the semipolar facet compared to about -1.85 MV/cm on a structure grown on the polar {0001} plane for GaInN layers with 15% and 10% indium content, respectively[1]. The indium composition dependence of the piezoelectric field is evaluated and the results are compared to theoretical values of the piezoelectric tensor elements reported in the literature.

[1] Feneberg et al., Appl. Phys. Lett. 89, 242112 (2006).

HL 52: Transport properties

Time: Friday 11:00–13:30 Location: H14

HL 52.1 Fri 11:00 H14

Electronic spin precession and interferometry from spin-orbital entanglement in a double quantum dot — •Pascal Simon[1] and Denis Feinberg[2] — [1]Department of Physics, university of Basel (Switzerland) and LPMMC, University Joseph Fourier & CNRS, Grenoble (France) — [2]laboratoire Louis Néel, CNRS & University Joseph Fourier, Grenoble (France)

A double quantum dot inserted in parallel between two metallic leads allows to entangle the electron spin with the orbital (dot index) degree of freedom. An Aharonov-Bohm orbital phase can then be transferred to the spinor wavefunction, providing a geometrical control of the spin precession around a fixed magnetic field. A fully coherent behaviour is obtained in a mixed orbital/spin Kondo regime. Evidence for the spin precession can be obtained, either using spin-polarized metallic leads or by placing the double dot in one branch of a metallic loop.

HL 52.2 Fri 11:15 H14

Carrier-carrier interaction in 2D and 1D ferromagnetic (Ga,Mn)As — •Daniel Neumaier, Konrad Wagner, Stefan Geissler, Ursula Wurstbauer, Janosch Sadowski, Matthias Reinwald, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany

We investigated the temperature dependency of conductance G of ferromagnetic (Ga,Mn)As mesoscopic wires and films (Tc˜100K) below 1K. The quasi two dimensional samples have a width of 10μm and a length of 60μm, while the quasi one dimensional samples have a width of only 40nm and a length of 7,5μm. The thickness was in both cases between 20nm and 50nm, smaller than the phase coherence length and thermal diffusion length at low T. At low temperatures the conductance of the (Ga,Mn)As samples decreases with decreasing temperature, often ascribed to the Kondo effect. This temperature dependency of G is independent of an externally applied magnetic field in a wide temperature range. A weak localization contribution was only found in some samples below 50mK. By comparing the temperature dependency of the conductance of quasi 2D samples with quasi 1D samples and by applying an external magnetic field, we show that the conductance's temperature dependence can be explained well in terms of enhanced electron-electron interaction, displaying universal behaviour.

HL 52.3 Fri 11:30 H14

Wechselwirkung von Quantenpunkten mit ein- & zweidimensionalen Elektronensystemen — •Bastian Marquardt[1], Marco Russ[1], Cedrik Meier[1], Axel Lorke[1], Dirk Reuter[2] und Andreas Wieck[2] — [1]Festkörperphysik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44799 Bochum

In diesem Beitrag werden die Ergebnisse der Untersuchung der Wechselwirkung von geladenen selbstorganisierten InAs-Quantenpunkten mit einem zweidimensionalen Elektronengas (2DEG) vorgestellt. In Transportmessungen an makroskopischen Leitfähigkeitskanälen wird ein geringer Einfluss der geladenen Quantenpunkte (QP) beobachtet. Um eine Verstärkung des Effektes der QP auf das 2DEG zu erreichen, werden Proben präpariert, in denen das 2DEG durch Split-Gates oder eine geätzte Steg-Struktur in einer weiteren Dimension räumlich eingeschränkt wird. In der Leitfähigkeit, welche an einer Split-Gate Geometrie gemessen worden sind, werden Effekte beobachtet, die auf den Einfluss geladener QP zurückzuführen sind. Desweiteren ist eine Messmethode genutzt worden, mit der es möglich ist den 1D-Leitfähigkeitskanal lateral zu verschieben. So ist man in der Lage das 2DEG über einen größeren Bereich eindimensional abzutasten, um so den Zustand zu erreichen, bei dem der 1D-Kanal durch das Coulomb-Potenzial eines QP vollständig abgeschnürt wird. Der Einfluss des Coulomb-Potenzials eines geladenen QP auf das 2DEG äußert sich in einem leichten Ansteigen der 1D-Leitfähigkeit, wenn die Quantenpunkte kapazitiv geladen werden.

HL 52.4 Fri 11:45 H14

High frequency quantised charge transport through a periodically formed quantum dot — •B. Kästner[1,2], M. D. Blumenthal[2,3], L. Li[2], S. Giblin[2], T. J. B. M. Janssen[2], and M. Pepper[3] — [1]PTB, 38100 Braunschweig, Germany — [2]NPL, Teddington TW11 0LW, UK — [3]University of Cambridge, Cambridge CB3 0HE, UK

We present experimental results on a novel approach to quantised charge pumping. Single electrons are transported through a periodically formed decoupled quantum dot. Phase-shifted sinusoidal radio frequency (RF) signals applied directly to two metallic gates are used to pump electrons through the dot at a current level of 0.54 nA, over an order of magnitude higher than in present single electron pumps. The relative amplitudes of the RF signals applied to the gates determines the direction of the pumped current. This new approach represents an alternative path to the realization of a high current high accuracy quantum standard for electrical current.

HL 52.5 Fri 12:00 H14

Edge effects and elastic scattering in magnetic barriers — Mihai Cerchez[1], •Stefan Hugger[1], Thomas Heinzel[1], and Nico Schulz[2] — [1]Heinrich-Heine Universität, 40225 Düsseldorf — [2]Frauenhofer Institut für angewandte Festkörperphysik, 79108 Freiburg

We have studied the electronic transport through magnetic barriers in two-dimensional electron gases. The experiments were performed on magnetic barriers originating from the stray field of magnetized dysprosium platelets on top of a GaAs-AlGaAs heterostructure. We observed that even for high magnetic barriers, the resistance across the magnetic barrier shows a saturation behavior above a critical barrier amplitude [1]. We simulated the experiments by a semiclassical model based on the Landauer-Büttiker formalism [3], taking into account both edge effects as well as elastic scattering. [2]. The simulations are in excellent quantitative agreement with the experimental results, in particular considering that the model does not contain any fit parameters.

[1] T. Vancura, et al, Phys. Rev. B 62, 5074 (2000)
[2] M. Büttiker, Phys. Rev. Lett. 57, 1761 (1986)
[3] M. Cerchez et al, submitted to Phys. Rev. B.

HL 52.6 Fri 12:15 H14

Quality improvement of MBE grown 2D hole systems in GaAs/AlGaAs — •Christian Gerl, Johannes Bauer, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle & Angewandte Physik, Universität Regensburg

By introducing carbon as p-dopant for GaAs/AlGaAs heterosystems, restrictions from formerly used acceptor materials like beryllium and silicon have been overcome [1]. The carrier mobility in 2 dimensional hole systems (2DHS) reached values of 1.2x10ˆ6 cmˆ2/Vs and 1.1x10ˆ6 cmˆ2/Vs in the (001) and (110) growth directions, respectively [2]. This enhancement in sample quality is essential for detailed investigations on the non parabolic dispersion relation of 2DHSs.

We present magnetotransport measurements of ultra high mobility quantum well and modulation doped single interface structures directly revealing the effect of the structure inversion asymmetry on the Rashba spin-splitting. In addition promising ways to increase the sample quality even further and to prevent a hysteretic dependence of the hole density when an external electric field is applied are suggested.

[1] C. Gerl et al., Appl. Phys. Lett 86, 252105 (2005)
[2] S. Schmult et al. Appl. Phys. Lett 86, 202105 (2005)

HL 52.7 Fri 12:30 H14

CoTiSb as a thermoelectric material — •Joachim Barth[1], Rosa Robert[2], Anke Weidenkaff[2], Kristian Kroth[1], and Claudia Felser[1] — [1]Johannes Gutenberg Universität 55128 Mainz Staudinger Weg 9 — [2]EMPA CH-8600 Dübendorf Überlandstraße 129

The C1b compound CoTiSb has been investigated as a thermoelectric material for power generation. LMTO calculations of the undoped compound are presented. The samples have been prepared by arcmelting under argon atmosphere. Ti has been substituted with V or Y to optimize the figure of merit. The Seebeck coefficient, the thermal conductivity and the electrical conductivity have been measured in the temperature range from 2-600 K.

HL 52.8 Fri 12:45 H14

Photo-induced charge transport in metal–insulator–metal

(MIM) multilayer structures — •Domocos Kovacs[1], Jörg Winter[1], and Detlef Diesing[2] — [1]Institut für Experimentalphysik II, Ruhr-Universität Bochum, 44801 Bochum — [2]Institut für Physikalische Chemie, Universitat Duisburg-Essen, 45141 Essen

The dependence of the photoinduced current in aluminium– alumina–top metal tunnel structures was investigated as a function of the bias voltage at three different wavelengths (266, 355, and 532 nm) of a Nd-YAG laser. With the top metal (Ag, Au) being illuminated, a net current flowing from the top electrode to the bottom electrode at zero bias for all wavelengths is measured. The photocurrent can be modified by a bias voltage applied between the two metals. For each wavelength there is a certain bias value for which the net photo current vanishes. The dependence of the measured current-voltage curves on the top electrode material and on its thickness is reported. The experimental results are compared with the calculations of a model which includes photo-absorption, electronic excitation, and charge transport in both metal electrodes represented by free electron gases and in the oxide layer described by an asymmetric tunnel barrier allowing both electron and hole tunnelling. Based on this model the influence of the metal thickness on the bias dependence of the photo-current will be discussed in terms of the photo-excited carriers lifetime.

HL 52.9 Fri 13:00 H14

Microwave investigations of electronic correlations in the electron glass Si:P — •Elvira Ritz and Martin Dressel — 1.Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Electronic correlations influence the charge transport in Si:P at low energy scales. We study the frequency-dependent complex conductivity of Si:P in a large range of phosphorus concentrations below the metal-insulator transition (MIT). At low temperatures (down to 1.2 K) and low frequencies (50 MHz - 20 GHz) the charge transport in the insulatig Si:P is by hopping between the impurity sites with localized electronic states. The electrodynamic response of this system serves as a model for the so-called electron glasses. The effects of the electron-electron interactions is a crucial issue. We observe the power law corresponding to the Coulomb glass in the lower part of the conductivity spectrum as well as a frequency independent permittivity with a critical behavior in the vicinity of the MIT. The temperature dependence of the dynamical response is also discussed.

HL 52.10 Fri 13:15 H14

Quantum capacitance controlled switching field in in-plane gated Y-branch switches — •Stefan Lang, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We have studied the threshold characteristics and gate efficiencies of in-plane gated electron Y-branch switches controlled by different in-plane gates. Pronounced non-linearities in the threshold voltages indicate that the pinch-off region can be tuned by the side-gates from the stem into the branches. In order to explain the threshold shifts we propose a model based on coupled quantum capacitances and geometrical capacitances including charge trapping. In addition, the model also provides gate-voltage induced changes of the gate efficiency in very good agreement with the experimental findings.

HL 53: Ultra fast phenomena

Time: Friday 11:00–13:45 Location: H15

HL 53.1 Fri 11:00 H15

Aspects of heavy-hole light-hole band mixing effects on the coherent optical generation of charge and spin currents in semiconductor heterostructures — •Bernhard Pasenow[1], Huynh Thanh Duc[1,2], Torsten Meier[1], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg — [2]Ho Chi Minh City Institute of Physics, Viet Nam Center for Natural Science and Technology, 1 Mac Dinh Chi, Ho Chi Minh City, Vietnam

The coherent optical injection and temporal decay of spin and charge currents in semiconductor heterostructures has be described on a microscopic basis including Coulomb and phononic effects up to the level of second-order Born contributions [1,2]. In this talk the previously used two-band effective mass approach is extended to a multi-band approach using realistic microscopic kp matrix elements. Furthermore, the influence of heavy-hole light-hole band-mixing contained in the kp calculation and its effects on the microscopic semiconductor dynamics is demonstrated and discussed [3].

[1] H.T. Duc, T. Meier, and S.W. Koch, Phys. Rev. Lett. 95, 086606 (2005).
[2] H.T. Duc, Q.T. Vu, T. Meier, H. Haug, and S.W. Koch, Phys. Rev. B 74, 165328 (2006)
[3] B. Pasenow, T. Meier, and S.W. Koch, unpublished

HL 53.2 Fri 11:15 H15

Investigation of Coulomb induced coupling in semiconductor nanostructures using 2D Fourier-Transform-Spectroscopy — •Irina Kuznetsova[1], Peter Thomas[1], Torsten Meier[1], Tianhao Zhang[2], and Steven T. Cundiff[2] — [1]Fachbereich Physik, Philipps Universiät Marburg, Renthof 5, 35032 Marburg, Germany — [2]JILA, University of Colorado and National Institute of Standards and Technology, Boulder, CO 80309-0440, USA

Two-Dimensional Fourier-Transform-Spectroscopy (2DFTS) has been used for the experimental investigation of many-body interactions in semiconductor quantum wells [1]. Our theoretical description used for the interpretation of the experimental data is based on a one-dimensional tight-binding model. By comparing Hartree-Fock results with $\chi^{(3)}$ coherent many-body calculations we can identify signatures, which are related to various Coulomb effects. We found that due to Coulomb correlations 2DFTS is strongly dependent on polarization directions of excitation pulses [2]. Dipole matrix elements, dephasing times, delay times, polarization directions of the pulses, and their spectral characteristics strongly influence the signatures at the excitonic resonances, i.e., heavy hole, light hole and mixed ones. This demonstrates that this method provides a wide spectrum of information about Coulomb induced couplings in various systems.

[1] X. Li, T. Zhang, C. N. Borca, and S. T. Cundiff, Phys. Rev. Lett. 96, 057406 (2006).
[2] I. Kuznetsova, P. Thomas, T. Meier, T. Zhang, X. Li, R. P. Mirin, and S. T. Cundiff, submitted to Solid State Comm.

HL 53.3 Fri 11:30 H15

Nonequilibrium Green's functions approach to artificial atoms: Equilibrium properties — •Karsten Balzer[1], Michael Bonitz[1], Nils-Erik Dahlen[2], and Robert van Leuween[2] — [1]ITAP, Universität Kiel, Leibnizstr. 15, 24098 Kiel, Germany — [2]Theoretical Chemistry, Materials Science Center, Rijksuniversiteit Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Quantum confined particles, such as electrons and excitons in semiconductor nanostructures [1], valence electrons in metal clusters or trapped ultra-cold atomic and molecular gases, can be seen as artificial atoms. In order to self-consistently treat confinement and correlation effects we have developed a nonequilibrium Green's functions (NEGF) approach which can be efficiently applied to these systems.

We present results for the correlated equilibrium state for the example of N charged fermions in an oscillator potential which serve as initial data for studying the response to external fields [see poster: K. Balzer et al.]. Extending previous applications for quasi-homogeneous systems [2], we here start in thermal equilibrium at finite densities, solving the Dyson equation on the imaginary branch of the Keldysh-contour. We demonstrate the advantages of using an appropriate basis representation of the NEGF. Throughout, correlation effects are taken into account in full diagrammatically second order, including exchange.

[1] P. Ludwig, A. Filinov, M. Bonitz, and H. Stolz, phys. stat. sol. (b) 243, No. 10 (2006). [2] Introduction to Computational Methods in Many-Body Physics, M. Bonitz and D. Semkat (Eds.) Rinton Press (2006).

HL 53.4 Fri 11:45 H15

Theoretical description of the lattice dynamics in laser-excited InSb — •Jessica Walkenhorst, Christian Gilfert,

Christian Sippel, Waldemar Töws, Eeuwe Sieds Zijlstra, and Martin Garcia — Theoretische Physik, Fachbereich Naturwissenschaften, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

We performed an *ab initio* study of the softening of optical transverse and longitudinal phonons in InSb due to femtosecond laser excitation. We calculated the frequencies of the optical phonons at the Γ point and at the zone boundary as a function of the number of excited carriers. Our study was based on all-electron density functional calculations. We found an increasing softening of the phonon modes for increasing laser fluence. However, the drop of the studied phonon frequencies did not exceed 30% of the initial value, even for very high excitation energies (electronic temperatures). We concluded that no dramatic flattening of the potential surface occurs, as was suggested by recent experiments.

HL 53.5 Fri 12:00 H15

Ultrafast hole-spin dynamics in bulk GaAs — •Michael Krauss and Hans Christian Schneider — Physics Department, Kaiserslautern University, P. O. Box 3049, 67663 Kaiserslautern, Germany

This talk presents theoretical results on hole-spin dynamics in bulk GaAs after optical excitation. The coupled dynamics of spin and orbital angular momentum is determined by solving dynamical Boltzmann equations for carrier-carrier scattering, which include the effect of spin-orbit coupling on the level of a 4-band Luttinger Hamiltonian. Hole-spin relaxation takes place in two stages. In the first regime, on a timescale of a few hundred femtoseconds, pure momentum scattering dominates the dynamics and the anisotropic contributions to the orbital angular momentum, which are created by the optical excitation, are evened out. In the second regime, on a timescale of a few picoseconds, energy relaxation dominates. The hole-spin dynamics can be approximated by a different relaxation time for each of the two regimes. The fast spin relaxation-time in the first regime is in agreement with experimental results for heavy-hole spin relaxation.

HL 53.6 Fri 12:15 H15

Terahertz radiation from a large-area photoconductive device — •Falk Peter, Sven Nitsche, Stephan Winnerl, André Dreyhaupt, Harald Schneider, and Manfred Helm — Institute of Ion-Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany

We present studies of the radiation properties of a photoconductive terahertz (THz) structure [1]. It consists of an interdigitated electrode structure fabricated on GaAs. Illuminating this structure by a femtosecond laser pulses yields accelerated photocarriers, which are the source of THz radiation. For avoiding destructive interference of radiation generated in regions of opposite field direction a second metallization isolated from the first one covers every second electrode spacing. Intense THz radiation with fields of the order of 1 kV/cm is observed.

We use a photoconductive detection antenna for measuring the spatial profile. The detection antenna is placed in a distance of 13 mm from the emitter. The beam profile is resolved for spectral components in the range from 0.5 to 1.5 THz. All beam profiles have Gaussian shape. The divergence increases with decreasing frequency. For wavelengths significantly smaller than the excitation spot size, the results can be well described by Gaussian optics. However, at longer wavelength, where the paraxial approximation fails, diffraction has to be considered in a more general way.

[1] A. Dreyhaupt, S.Winnerl, M.Helm, T. Dekorsy, Opt. Lett. 31, 1546 (2006)

HL 53.7 Fri 12:30 H15

Ultrafast electron relaxation-dynamics in p-doped GaAs — •Yao-Hui Zhu, Hans Christian Schneider, and Martin Aeschlimann — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

Ultrafast electron dynamics in p-doped GaAs is studied by energy- and time-resolved two-photon-photoemission (2PPE). Using this surface sensitive technique allows one to study the carrier dynamics over a wide energy range in the band-bending region at (001) surfaces. Electron relaxation-dynamics is monitored by measuring the energy distribution of photoemitted electrons after an initial nonequilibrium electron distribution has been created by the ultrashort pump laser up to 2 eV above the conduction band minimum. To separate the contributions of the degenerate pump and probe beams to the photoemitted electrons, an electron spin-analyzer and different light polarizations and are used.

The dependence of the observed electron dynamics on the excitation energy is explained well by Boltzmann equation calculations that take into account the carrier-carrier Coulomb interaction. It is found that electron relaxation by scattering of heavy holes into the light-hole band is dominant for the electron relaxation process. Moreover, dynamic screening is crucial for the relaxation of the highly excited electrons at a doping density of $1 \times 10^{19}\,\mathrm{cm}^{-3}$.

HL 53.8 Fri 12:45 H15

Ultrafast dynamics of coherent opticalphonons in α-quartz — •Konrad von Volkmann, Tobias Kampfrath, Lucca Perfetti, Jan Nötzold, Christian Frischkorn, and Martin Wolf — Freie Universität Berlin, Berlin, Germany

Femtosecond laser excitation of coherent phonons gives rise to an oscillatory modulation of the real and imaginary part of the refractive index of α-quartz $\tilde{n}_{quartz} = n + i\,k$. Optical phonon modes are found at 3.9, 6.3, 10.5, 12.2, and 13.9 THz. The observed amplitudes significantly depend on the probe method, either transient absorption (yielding k) or ellipsometry (leading to n).

For both probe mechanisms, we present polarization, pump-wavelength and temperature dependent data and discuss the observed dynamics in terms of impulsive stimulated Raman scattering as excitation mechanism. We find that the phonon peaks shift with temperature towards lower energies accompanied by a drop of the lifetime of the phonons. Together with a pump-fluence independent lifetime, this indicates that the decay mechanism of the phonons is phonon-phonon scattering, rather than electron-hole pair excitation.

HL 53.9 Fri 13:00 H15

Dynamik kohärenter akustischer Phononen in Halbleiterheterostrukturen — •Florian Hudert[1], Thomas Dekorsy[1] und Klaus Köhler[2] — [1]Fachbereich Physik, Universtät Konstanz, 78457 Konstanz — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, 79108 Freiburg

In diesem Beitrag werden wir Untersuchungen zur Dynamik kohärenter akustischer Phononen in Halbleiterheterostrukturen vorstellen. Zu den untersuchten Strukturen gehören AlGaAs/GaAs-Heterostrukturen sowie AlAs/GaAs-Übergitter, die unter anderem auch für die Realisierung von Phononcavities [1] herangezogen werden könnten. Die Dynamik der Phononen wurde dabei mittels Zwei-Farben-Pump-Probe-Spektroskopie in Reflexionsanordnung untersucht, wobei das bereits eingeführte ASOPS (asynchronous optical sampling)-Verfahren angewendet wurde, bei dem zwei asynchron gekoppelte Ti-Saphir Oszillatoren zur Erzeugung von Anrege- und Abfragepuls verwendet werden [2]. Dies ermöglicht Messungen im Bereich zwischen 750 nm und 850 nm mit einer Auflösung von ca. 100 fs über ein Zeitfenster von 1 ns. Es konnten unter Anderem erste Anzeichen für die Entstehung von Cavitymoden beobachtet werden. Diese Experimente liefern wichtige Grundlagen für weitergehende Arbeiten zur Realisierung optisch gepumpter Phononcavities.

[1] A. Huynh, N. D. Lanzillotti-Kimura, B. Jusserand, B. Perrin, A. Fainstein, M. F. Pascual-Winter, E. Peronne, and A. Lemaître, Phys. Rev. Lett. 97, 115502 (2006) [2] A. Bartels, F. Hudert, C. Janke, T. Dekorsy and K. Köhler, Appl. Phys. Lett. 88, 041117 (2006)

HL 53.10 Fri 13:15 H15

Ultraschnelle Ladungsträgerdynamik in GaAsN — •Gregor Klatt[1], Florian Hudert[1], Thomas Dekorsy[1] und Klaus Köhler[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, 79108 Freiburg

Es werden Untersuchungen zur Ladungsträgerdynamik optisch angeregter Ladungsträger in stickstoffhaltigem GaAs anhand zeitaufgelöster Transmissionsmessungen vorgestellt. Ein Zwei-Farben Pump-Probe Aufbau mit einer zeitlichen Auflösung von etwa 100 fs ermöglicht dabei das Anregen und Abfragen bei unterschiedlichen Energien. Das Probelicht wird dazu in einer photonischen Kristallfaser spektral verbreitert, so dass anschließend ein Energiebereich von 1,2-1,45 eV zur Verfügung steht. Damit ist es möglich, die Transmissionsänderungen im Bereich der Bandlücke einer Probe mit 1,4% N-Gehalt ($E_g = 1{,}258$ eV) zu untersuchen. Für Zustände weit entfernt vom Bandminimum wird die Ladungsträgerdynamik durch die Emission von LO-Phononen dominiert, nahe des Bandminimums zeigt sich hingegen eine stark verzögerte Dynamik. Diese verzögerte Dynamik basiert auf der Relaxation in lokale Potentialmimima, die auch in der cw-Photolumineszenz bei tiefen Temperaturen beobachtet werden.

HL 53.11 Fri 13:30 H15

All-optical generation and coherent control of ballistic electrical currents in silicon — •Louis Costa[1,2], Markus Betz[1,2], Marko Spasenovic[1], Alan Bristow[1], and Henry van Driel[1] — [1]Physics Department and Institute for Optical Sciences, University of Toronto, M5S 1A7 Toronto, Canada — [2]Physik-Department, Technische Universität München, 85748 Garching

We report all-optical injection of ballistic currents in unbiased clean silicon at room temperature by using quantum interference between phonon-assisted one- and two-photon absorption pathways. The pump field consists of harmonically related fundamental pulses in the near-infrared ($\lambda = \frac{2\pi c}{\omega} = 1420 \rightarrow 1800$ nm, pulse duration 150 fs) and corresponding second harmonic pulses. As a consequence, we induce indirect optical transitions in silicon, which satisfy $\hbar\omega < E_{\mathrm{G,indirect}} = 1.12$ eV $< 2\hbar\omega < E_{\mathrm{G,direct}} = 3.5$ eV. The generated ultrafast currents emit terahertz radiation which is detected via electro-optic sampling in the far-field. Both the direction and the amplitude of the currents can be coherently controlled by changing the phase parameter $\Delta\phi = 2\phi_\omega - \phi_{2\omega}$ ($\phi_{\omega,2\omega}$ are the phases of the individual pump fields). The mechanism is a third-order nonlinear optical process which already served for the generation of ballistic currents in direct semiconductors like GaAs accomplished in previous theoretical and experimental work. With our experiments we show that this scheme can also surprinsingly be used to generate currents in silicon although phonon participation is present in the optical creation process of the carriers in the indirect semiconductor.