HL 3 III-V semiconductors I

Time: Monday 10:15–13:15 Room: POT 51

HL 3.1 Mon 10:15 POT 51

Surface concentration mapping of InAs/GaAs quantum dots — •S. Heun[1], G. Biasiol[1], G. B. Golinelli[2], A. Locatelli[3], T. O. Mentes[3], F. Z. Guo[4], C. Hofer[5], C. Teichert[5], and L. Sorba[1,2] — [1]Laboratorio TASC INFM-CNR, 34012 Trieste, Italy — [2]Universita degli Studi di Modena e Reggio Emilia, 41100 Modena, Italy — [3]Sincrotrone Trieste, 34012 Trieste, Italy — [4]JASRI/SPring-8, 1-1-1, Kouto, Mikazuki, Sayo, Hyogo 679-5198, Japan — [5]Institute of Physics, University of Leoben, 8700 Leoben, Austria

With x-ray photoemission electron microscopy we obtained two-dimensional maps of the in-plane surface composition of InAs/GaAs self-assembled quantum dots [1]. This provides complementary information to cross-sectional studies of InAs dots, which could open the way to a full 3D mapping of the dot composition and to a better knowledge of their formation mechanisms. Besides, the extreme surface sensitivity of our technique (photoelectron escape depth 0.5 nm) yields information essentially on the composition of the growth front. Our data clearly demonstrate that the surface composition of the dots is neither pure InAs nor homogeneous $In_xGa_{1-x}As$, but we observe an In concentration gradient from the center (high concentration) to the borders (lower concentration) of the dots. In addition, we observe a strong In segregation ($x \approx 0.9$) to the surface of the dots and of the surrounding wetting layer. Such segregation, well known for two-dimensional InAs/GaAs growth, had not been directly observed so far on top of the dots, and should be considered to model size and composition of GaAs-overgrown structures.

[1] G. Biasiol *et al.*, Appl. Phys. Lett. **87** (21), in press (2005).

HL 3.2 Mon 10:30 POT 51

Spin polarization in a two dimensional electron gas with spin-orbit interaction — •Mathias Duckheim and Daniel Loss — Department of Physics and Astronomy, University of Basel, Switzerland

Spin-orbit interaction in semiconductor structures can be visualized as an effective magnetic field with direction and magnitude depending on the electron momentum. It thus offers indirect control of the spin via the orbital degree of freedom and can be utilized to achieve coherent spin manipulation by tuning electric gates. In this context, we calculate the polarization of electrons in a disordered, two-dimensional semiconductor structure with spin-orbit interaction in a corresponding field configuration and find an analytical result for a finite measureable magnetization.

HL 3.3 Mon 10:45 POT 51

Carbon doped high mobility hole gases — •Christian Gerl, Johannes Bauer, Ursula Wurstbauer, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D- 93040 Regensburg

Two dimensional hole gases (2DHGs) in the GaAs/AlGaAs heterosystem are of renewed interest since their quality has been increased by utilizing Carbon as an acceptor for MBE growth [1, 2]. They exhibit a pronounced Rashba effect, a mechanism that is proposed for spintronic applications in which a macroscopic electric field gives rise to a spin splitting of subbands for finite values of k [3]. The Shubnikov-de-Haas effect can be used to determine the individual subband populations. We introduce Carbon doped 2DHGs in the (100) and (110) crystallographic direction in various structure designs with low temperature mobilities beyond $10^6 cm^2/Vs$, grown in our MBE system. Applying a surface gate bias to the samples the tunability of the Rashba induced spin splitting as well as the density dependence of the hole mobility is analyzed.

[1] B. Gribic, Appl. Phys. Lett. 85, 2277 (2004) [2] C. Gerl, Appl. Phys. Lett. 86, 252105 (2005) [3] Y. A. Bychkov, J. Phys. C 17, 6039 (1984)

HL 3.4 Mon 11:00 POT 51

Evidence of material mixing during local anodic oxidation nanolithography — •S. Heun[1], G. Mori[1], M. Lazzarino[1], D. Ercolani[1], G. Biasiol[1], A. Locatelli[2], and L. Sorba[1] — [1]Laboratorio Nazionale TASC INFM-CNR, 34012 Trieste, Italy — [2]Sincrotrone Trieste, 34012 Trieste, Italy

We investigated the chemical properties of nanostructures fabricated by local anodic oxidation (LAO) on epitaxial GaAs/AlAs/GaAs layers by means of laterally-resolved photoemission spectroscopy. We find evidence for the unexpected presence of Al compounds located in the topmost surface layers of the LAO structures. We studied the evolution of the surface chemical composition of these nanostructures as a function of x-ray exposure time (photon energy hv=130 eV), and we found a reduction in the amount of the surface Ga oxide compounds with respect to the Al compounds [1]. Our results cannot be explained within the framework of the commonly accepted mechanism that describes the growth of the LAO oxides in terms of diffusion of oxygen-rich ions through the growing oxide. A more general mechanism that explains our experimental findings is proposed [2].

[1] G. Mori, M. Lazzarino, D. Ercolani, G. Biasiol, A. Locatelli, L. Sorba, and S. Heun, Nucl. Instrum. Methods Phys. Res. B, in press.
[2] G. Mori, M. Lazzarino, D. Ercolani, G. Biasiol, L. Sorba, S. Heun, and A. Locatelli, J. Appl. Phys., in press.

HL 3.5 Mon 11:15 POT 51

Agglomeration of As Antisites in As-rich LT-GaAs: Nucleation without a critical nucleus size — •Torsten E.M. Staab[1], Risto M. Nieminen[2], Martina Luysberg[3], and Thomas Frauenheim[4] — [1]Helmholtz Institut für Strahlen- und Kernphysik,Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 14-16,D-53115 Bonn, Germany — [2]Laboratory of Physics, Helsinki University of Technology,P.O. Box 1100, FIN–02015 HUT, Finland — [3]Institut für Festkörperforschung,Forschungszentrum Jülich, D–52425 Jülich, Germany — [4]University GH Paderborn, Department of Physics, Theoretical Physics, D–33098 Paderborn, Germany

To investigate the early stages of nucleation and growth of As precipitations in GaAs grown at low substrate temperature (LT-GaAs) we make use of a self-consistent-charge density-functional based tight-binding method. Since already a pair of As-antisite shows a significant binding energy which increases when attaching more As-antisites, there is no critical nucleus size. Provided that all excess As has precipitated the clusters may grow in size since the binding energies increase with increasing agglomeration size. These findings close the gap between experimental investigation of point defects and the detection of nanometer-size precipitations in the TEM [1].

[1] T.E.M. Staab, R.M. Nieminen, M. Luysberg, and Th. Frauenheim, *Phys. Rev. Lett.* **95** (2005) 12550

HL 3.6 Mon 11:30 POT 51

Resonant Tunneling through space-charge layers at GaAs surfaces — •S. Loth[1], M. Wenderoth[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

Recent work in the field of the tunneling magneto resistance showed that charge transport through tunnel junctions has to be treated beyond Bardeen's basic model: the tunnel process must be described within the framework of the complex band structure [1]. Usually this approach is not necessary for the interpretation of Scanning Tunneling Microscope (STM) measurements, because the current is mediated by real states in the sample and by evanescent states only in the vacuum gap. We demonstrate that for a class of well known experiments - Scanning Tunneling Spectroscopy (STS) on GaAs - the evanescent gap states are most relevant:

We studied p-doped GaAs {110} cleavage surfaces with a low temperature STM. The observed negative differential conductivity is due to a resonant enhancement of the tunneling probability through the depletion layer mediated by individual shallow acceptors. Energetically and spatially resolved spectra show that the pronounced anisotropic contrast pattern of shallow acceptors occurs exclusively for the energy interval of this specific transport channel. Our results indicate that structural properties of the complex band structure can be probed with the STM.

[1] P. Mavropoulos et al., Phys. Rev. Lett. **85**, 1088 (2000).

HL 3.7 Mon 11:45 POT 51

Atomically resolved imaging of the GaAsN(110) surface — •V. Vossebürger[1], D. Martin[1], L. Ivanova[1], A. Lenz[1], R. Timm[1], H. Eisele[1], M. Dähne[1], O. Schuhmann[2], L. Geelhaar[2], and H. Riechert[2] — [1]Technische Universität Berlin, Institut fürFestkörperphysik, Hardenbergstr. 36, D-10623 Berlin — [2]Infinion Technologies, Corporate Research Photonics,D-81730 München

$GaAs_{1-x}N_x$ is a highly interesting material because of its giant composition dependent optical bowing, which is theoretically described by the band anticrossing model (BAC)[1].
In order to determine the arrangement of nitrogen atoms in GaAsN alloys with low nitrogen concentration x between 1% and 2% as well as its electronic structure, cross-sectional scanning tunneling microscopy (XSTM) and spectroscopy (XSTS) experiments were performed of GaAsN layers in GaAs grown by molecular beam epitaxy (MBE).
Using high resolution voltage dependent XSTM images and simultaneously acquired XSTS images, we derive a structure model of the GaAsN(110) surface. In differential conductance spectra, displaying the local density of states, we observe a reduced band gap and an additional nitrogen-induced state. This state is related to the theoretically found band splitting in the BAC model.
This work was supported by the SFB 296, and project Da 408/8 of the DPG.
[1] W. Shan et al., Phys. Rev. Lett. **82**, 1221 (1999)

HL 3.8 Mon 12:00 POT 51

Structure and scanning tunneling microscopy images of Au adsorbed on GaAs(111)B-($\sqrt{3}\times\sqrt{3}$)-$R30°$ — •Hongsuk Yi[1], Peter Kratzer[1], Emelie Hilner[2], Anders Mikkelsen[2], and Edwin Lundgren[2] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, D-14195Berlin, Germany — [2]Institute of Physics, LundUniversity, Box 118, SE-22100 Lund, Sweden

Adsorption of gold on GaAs surfaces is interesting both for metallic contacts and for "catalyzing"growth of GaAs nanorods. Recently, it has been observed that small amounts of Au induce a well-ordered ($\sqrt{3}\times\sqrt{3}$) reconstruction on the GaAs(111)B surface, replacing the (2×2) As-trimer structure of the clean surface. We investigate the stable adsorption sites and simulate scanning tunneling microscopy (STM) images of Au absorbed on the GaAs(111)B surface, using the GGA approximation of density functional theory, and plane-wave/pseudopotential calculations.

We propose an energetically favorable model for the Au/GaAs(111)B-($\sqrt{3}\times\sqrt{3}$) surface with one Au per unit cell located in a threefold hollow site. From the calculated potential energy surface we obtain a diffusion barrier height of 0.45 eV for Au adatoms. In the simulated filled-state STM images the Au atoms appear as triangular structures whose edges point towards neighboring As atoms. The proposed structural model is in agreement with experimental data from low-energy electron diffraction and STM.

HL 3.9 Mon 12:15 POT 51

Scanning Tunneling Spectroscopy on single Mn-acceptors in InAs — •Felix Marczinowski[1], Jens Wiebe[1], Focko Meier[1], Katsushi Hashimoto[1], Markus Morgenstern[2], Roland Wiesendanger[1], Jiang-Ming Tang[3], and Michael E. Flatté[3] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]2. Physikalisches Institut, RWTH-Aachen, Templergraben 55, 52056 Aachen — [3]OSTC and Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242, USA

Ferromagnetic semiconductors like InMnAs receive a great amount of interest as the pivotal material for future spintronic devices. Recent experiments using STM suggest that the anisotropic shape of the acceptor wave function might affect the interaction of the magnetic dopants. [1,2] We performed scanning tunneling spectroscopy on Mn-doped InAs at low temperatures. In STM images, we find an anisotropic, cross-like shape of the Mn, which fits nicely to the Mn-acceptor wave function as calculated with the tight binding method. In contrast to the GaAs-case[1], Mn appears as a cross-like protrusion in the occupied density-of-states (DOS), and as a cross-like depression in the unoccupied DOS. These differences are probably explained by the different band-bending properties of InAs and GaAs. Additionally, we found several discrete states in dI/dU-curves which also reflect the symmetry of the Mn-acceptor wave function. The similarity of our findings to the GaAs-case[1] suggest that the cross-like shape is universal for Mn-acceptors in III-V-semiconductors.
[1] Yakunin *et al.*, PRL **92**, 216806 (2004)
[2] Arseev *et al.*, JETP Lett. **77**, 172 (2003)

HL 3.10 Mon 12:30 POT 51

Nitrogen induced properties in $Ga_{1-x}In_xN_yAs_{1-y}$ observed by cross-sectional scanning tunneling microscopy — •D. Martin[1], V. Vossebürger[1], L. Ivanova[1], A. Lenz[1], R. Timm[1], H. Eisele[1], M. Dähne[1], O. Schumann[2], L. Geelhaar[2], and H. Riechert[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Infineon Technologies, Corporate Research Photonics, 81730 München, Germany

The incorporation of nitrogen at low concentrations of up to 5% in GaInAs alloys induces a massive redshift in emission wavelength. In this way semiconductor laser diodes can reach the industrially important emission wavelengths of 1.3 μm and 1.55 μm. In order to improve the efficiency of these devices, a detailed investigation of the spatial and electronical properties of the GaInNAs alloy induced by nitrogen and indium atoms is required.
GaInNAs layers with different In and N concentrations embedded in GaAs were grown using molecular beam epitaxy. Cross-sectional scanning tunneling microscopy was used to study the spatial composition of GaInNAs alloys on an atomic scale. From high resolution images of the $Ga_{1-x}In_xN_yAs_{1-y}(110)$ surface (with $0.013 \le x \le 0.087$ and $0.004 \le y \le 0.029$), details on the spatial distribution of indium and nitrogen atoms were derived.
This work was supported by the SFB 296 and project Da 408/8 of the DPG.

HL 3.11 Mon 12:45 POT 51

Atomistic and Continuum Description of Acoustic Phonons in Nanostructures — •Frank Grosse and Roland Zimmermann — Halbleitertheore, Institut für Physik an der Humboldt-Unversität Newtonstr. 15 12489 Berlin

Acoustic phonon spectra are calculated for semiconductor nanostructures. An irregular three-dimensional shape or realistic crystallographic symmetries allow only a numerical determination. Phonons are described within continuum linear elasticity theory as well as with atomistic models, which interaction parameters are determined by ab initio density functional calculations. Nanoparticles, especially when embedded in a different material, may be under substantial inhomogeneous stress. It is confirmed by atomistic calculations that their acoustic phonon modes can be described by modified inhomogeneous elastic constants going beyond linear elasticity. Implications for the dephasing of optical excitations in nanoparticles due to electron-acoustic phonon interaction are discussed.

HL 3.12 Mon 13:00 POT 51

Carrier transport by acoustic fields in InP-based structures — •Markus Beck[1], Maurício M. de Lima[1], Jörg Rudolph[1], Richard Nötzel[2], and Paulo V. Santos[1] — [1]Paul Drude Institut für Festkörperelektronik, Berlin, Germany — [2]Technische Universiteit, Eindhoven, Netherlands

We investigate the modulation of the optical properties and the ambipolar transport of photogenerated electrons and holes by surface acoustic waves (SAWs) in InGaAsP structures. The generation of SAWs using interdigital transducers (IDTs) in InP-based materials is limited by the low piezoelectric coupling. We succeed to generate strong SAW fields by coating them with a piezoelectric ZnO film (typically, 0.5 μm-thick) deposited using a low temperature ($< 200°$C) process. The insertion loss of acoustic delay lines on ZnO-coated InP-substrates could be reduced to 10 dB. The photoluminescence intensity of InGaAsP structures with emission wavelength of 1470 nm at 5 K is drastically reduced under acoustic excitation. This effect is attributed to the spatial separation and transport of the photogenerated electrons and holes by the piezoelectric field, as previously observed for GaAs. The carriers are acoustically transported over distances on the order of 200 μm. The photoluminescence from the transported carrier can be retrieved by forcing their recombination in an area where the ZnO film has been removed. These results demonstrate that acoustic fields can be used to control carriers in InP-based structures operating at telecommunication wavelengths. (Supported by the EU-ePIXnet consortium)