HL 6 Quantum dots and wires: Transport properties I

Time: Monday 10:15–13:15 Room: BEY 118

HL 6.1 Mon 10:15 BEY 118

Electrical and optical characterisation of GaN and InN Nanowires — •Thomas Richter[1], Michel Marso[1], Ralph Meijers[1], Ratan Debnath[1], Toma Stoica[1,2], Raffaella Calarco[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich,52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest, Romania

Nanostructures such as semiconductor nanowires have an increasing interest as possible candidates for novel nanodevice concepts beyond CMOS. This is strongly motivated by their high versatility and practical applications in optical, electrical and chemical devices. Despite promising achievements by researchers all over the world, fundamental physical properties of those nanoscaled devices are still unclear. Electrical transport and optical behavior of these whiskers are interesting fields of research. We report on the reproducible growth of GaN and InN nanowires by plasma-assisted molecular beam epitaxy on Si (111) substrates. To improve the growth conditions the wires have been analysed by cathodoluminescence spectroscopy. For the electrical characterisation they have been transferred to a Si (100) substrate covered with a layer of SiO_2. Subsequently single nanowire devices have been fabricated by e-beam lithography for individually chosen nanowires. Electrical transport properties of the resulting metal-semiconductor-metal nanostructures are analyzed by means of current voltage measurements in dark and under UV-illumination at different temperatures.

HL 6.2 Mon 10:30 BEY 118

Low temperature electronic transport in vertical sub-100 nm resonant tunneling diodes — •Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1], Jakob Wensorra[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten and Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

Using a top down approach, vertical GaAs/AlAs resonant tunneling diodes (RTD) with lateral dimensions down to 50 nm have been processed.

DC electrical measurements at very low temperatures have been carried out both in linear and nonlinear regimes. Investigations at room temperature have already shown that the electronic transport properties in these nanodevices are strongly influenced by the lateral depletion region, leading to a new interesting behavior [1]. The actual study allows to evaluate the suggested quantum collimation model, which was used to explain qualitatively the room temperature transport characteristics of the sub-100 nm RTDs.

[1] J. Wensorra, K. M. Indlekofer, M. I. Lepsa, A. Förster, and H. Lüth, Nano Letters, DOI: 10.1021/nl051781a.

HL 6.3 Mon 10:45 BEY 118

Resonant Tunneling in GaAs/AlAs Nanocolumns Improved by Quantum Collimation — •Jakob Wensorra[1], Klaus Michael Indlekofer[1], Mihail Ion Lepsa[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten and Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

DC electrical measurements on top-down processed resonant tunneling GaAs/AlAs nanocolumns have been carried out at room temperature. The dependence of the I-V characteristics on the device dimension has shown that 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. In the I-V characteristics, a clearly pronounced region of negative differential conductance has been observed, down to 50 nm lateral dimensions. Simulations of the 2D-potential map of the device structure by means of a self-consistent semi-classical drift-diffusion solver suggest a transport model based on a quantum collimation effect [1] due to a sadle point in the potential profile. For the ultimately scaled structures, this quantum collimation effect can lead to a distinct improvement of the nanodevice performance at room temperature.

[1] J. Wensorra, K. M. Indlekofer, M. I. Lepsa, A. Förster, and H. Lüth, Nano Letters 10.121/nl051781a (2005).

HL 6.4 Mon 11:00 BEY 118

Enhanced Shot Noise in Tunneling through coupled InAs Quantum Dots — •P. Barthold[1], N. Maire[1], F. Hohls[1,2], R. J. Haug[1], and K. Pierz[3] — [1]Institut für Festkörperphysik, Universität Hannover, Appelstraße 2, 30167 Hannover — [2]Cavendish Laboratory, University of Cambridge Madingley Road, Cambridge CB3 0HE, UK — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We investigate the noise properties of vertically coupled self-assembled InAs quantum dots (QDs) and find a surprising enhancement of shot noise.

The two layers of InAs QDs are surrounded by AlAs tunneling barriers. GaAs acts as a 3-dimensional emitter and collector. Depending on the external bias voltage we find peaks in the I/V-characteristic that correspond to electron transport through a stack of two vertically coupled QDs. We find enhanced shot noise at these peaks. For the noise measurements we focus on one peak in the I/V-characteristic. The so-called Fano factor α is introduced to compare the measured shot noise S with the full-Poissonian noise $S_{full} = 2eI$ that is expected for a single tunneling barrier: $\alpha := S/2eI$. At both sides of the peak the Fano factor α rises to values of $\alpha = 1.4$, while the noise is reduced on the top of the peak ($\alpha < 1$). The Fano factor α shows a significant temperature dependence while the peak in the I/V-characteristic changes only slightly. We discuss the different coupling mechanisms which can lead to such an enhanced shot noise.

HL 6.5 Mon 11:15 BEY 118

Resonances in the transport through one-dimensional constrictions in silicon based MOS field effect transistors — •Carsten Kentsch, Wolfgang Henschel, and Dieter Kern — Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen

Recently silicon has attracted attention towards the realization of spin based qubits as its main isotope has no nuclear spin and therefore a reduced probability of scattering with the base material can be expected. Spin-polarized electrons exist in the edge-states of two-dimensional electron gases at high magnetic fields. They are individually accessible by suitable constrictions and therefore can be useful to study the scattering between the spin-states by measuring electric current.

Hall-bar devices consisting of a silicon MOS field effect transistor with embedded split-gates below the top gate have been fabricated and characterized at. 1.5 Kelvin and magnetic fields of up to 8 Tesla. Transport through constrictions induced by the split gates shows fluctuations which can be interpreted as the effect of transmission resonances in a one-dimensional channel of a length comparable with the split-gate dimensions.

HL 6.6 Mon 11:30 BEY 118

Probing a Kondo correlated quantum dot with spin spectroscopy — •M. C. Rogge[1], D. Kupidura[1], M. Reinwald[2], W. Wegscheider[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We investigate Kondo effect and spin blockade observed on a many-electron quantum dot and study the magnetic field dependence. The quantum dot is built using local anodic oxidation. In a 3He/4He dilution refrigerator the magnetic field dependence of the differential conductance is measured. At lower fields a pronounced Kondo chessboard pattern is found which is replaced by spin blockade at higher fields. In an intermediate regime both effects are visible and the spin of the tunneling electron in the Kondo regime is detected. We make use of this combined effect to gain information about the internal spin configuration of our quantum dot. We find that the data cannot be explained assuming regular filling of electronic orbitals. Instead spin polarized filling seems to be probable. We compare our results with other publications of chessboard patterns and find a correlation with the electron number.

HL 6.7 Mon 11:45 BEY 118

Conductance and frequency dependent noise of a quantum dot spin valve — •Matthias Braun[1], Jürgen König[1], and Jan Martinek[2] — [1]Theoretische Physik III, Ruhr-Universit"at Bochum, D-44780 Bochum — [2]Institute of Molecular Physics, Polish Academy of Science, 60-179 Poznań, Poland

We discuss the transport properties of a single-level quantum dot weakly coupled to ferromagnetic leads with non-collinear magnetizations. The conductance of such a device directly depends on the non-equilibrium spin on the quantum dot [1]. The dot spin undergoes an interaction induced intrinsic spin precession [2], which can suppress magnetoresistance and can lead to a negative differential conductance. Spin relaxation can be addressed by an all electrical Hanle setup [3]. While the conductance is sensitive to the time average dot spin only, the time dependent spin dynamics can be observed in the current-current correlation function.

[1] M. Braun, J. König, and J. Martinek, PRB **70**, 195345 (2004)
[2] J. König and J. Martinek, PRL **90**, 166602 (2003)
[3] M. Braun, J. König, and J. Martinek, EPL **72**, 294 (2005)

HL 6.8 Mon 12:00 BEY 118

Freely Suspended Quantum Dots — •Clemens Rössler[1], Stefan Ludwig[1], Jörg P. Kotthaus[1], Dieter Schuh[2], and Werner Wegscheider[2] — [1]Center for NanoScience and Sektion Physik, Ludwig-Maximilians-Universität, Geschwister Scholl Platz 1, 80539 München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, 93040 Regensburg, Germany

Electrons in quantum dots are confined in all three spatial directions. The confinement leads to a quantisation of the eigenenergy of the electron states. Semiconductor quantum dots are promising candidates for the realisation of quantum bits (qubits). Similar to a classical bit a qubit is based on two states, e.g. the charge state of a single electron in a tunnel coupled double quantum dot. In such a system the interaction with phonons is a major source of decoherence.

In order to investigate the electron-phonon coupling we employ phonon cavities that are nanoscale bridges excavated from an AlGaAs/GaAs heterostructure. The latter contains a two-dimensional electron system (2DES). By use of top gates we locally deplete the 2DEG and, thus, define a freely suspended quantum dot on the bridge. In this way we couple a phonon cavity with a charge cavity.

This setup allows the observation of coupled electro-mechanical modes [1]. The tunability of the modified phonon spectrum of the nanobridge will allow to investigate the electron-phonon interaction by means of transport experiments.

[1] E. M. Höhberger et al., PRL 92, 046804 (2004).

HL 6.9 Mon 12:15 BEY 118

Tunneling resonances in quantum dots: Coulomb interaction modifies the width — •Björn Kubala[1], Jens Könemann[2], Jürgen König[1], and Rolf J. Haug[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Institut für Festkörperphysik, Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Single-electron tunneling through a zero-dimensional state in an asymmetric double-barrier resonant-tunneling structure is studied [1]. The broadening of steps in the I–V characteristics is found to strongly depend on the polarity of the applied bias voltage. Based on a qualitative picture for the finite-life-time broadening of the quantum dot states and a quantitative comparison of the experimental data with a non-equilibrium transport theory, we identify this polarity dependence as a clear signature of Coulomb interaction.

[1] J. Könemann, B. Kubala, J. König, and R. J. Haug, cond-mat/0506505 (unpublished).

HL 6.10 Mon 12:30 BEY 118

Quantum dot system in high magnetic field: From weak to strong tunnel coupling — •Eleonora Storace, Jürgen Weis, and Klaus von Klitzing — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

Electrical transport measurements are performed on a quantum dot (QD) system defined as an in-plane structure via etching through a GaAs/AlGaAs heterostructure. Applying a perpendicular magnetic field and increasing afterwards the coupling between the leads and the QD, peaks and valleys of the conductance traces show a smooth transition from the Coulomb blockade oscillations regime to a constant value that is a multiple of e^2/h, suggesting the formation of a direct channel between source and drain leads. This behavior is explained considering that, since the geometrical extension of the QD itself is rather large, compressible and incompressible strips are formed along the whole structure and, in the case of strong coupling, the electron wavefunctions in the outer compressible strips in the leads can overlap with the ones in the QD. Tuning the magnetic field through different values of Landau levels filling factor, several electron configurations can be studied; in particular, it is possible to define a situation in which a compressible droplet is present inside the dot region in co-existence with the direct channel, giving rise to an interfering phenomenon known as Fano effect.

HL 6.11 Mon 12:45 BEY 118

Carrier storage time of milliseconds at room temperature in self-organized quantum dots — •A. Marent[1], M. Geller[1], A. P. Vasiev[2], E. S. Semenova[2], A. E. Zhukov[2], V. M. Ustinov[2], and D. Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]A. F. Ioffe Physico-Technical Institute, Russian Academy of Sience, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia

Self-organized quantum dots (QDs) are promising building blocks for future memory devices. The first milestone is a carrier retention time in the order of milliseconds at room temperature, the typical refresh time of a dynamic random access memory (DRAM). We showed previously, that holes in InAs/GaAs QDs exhibit a ground state localization energy of about 200 meV. This leads to a storage time at room temperature in the order of nanoseconds, which is not sufficient for a memory device. Here, we studied the carrier storage and emission from InAs/GaAs QDs with an additional AlGaAs barrier with deep level transient spectroscopy (DLTS). The thermal emission from the hole ground states over the entire AlGaAs barrier shows a pronounced peak at 300 K for a reference time of 5 ms. That means, we measure a storage time in the order of milliseconds at room temperature, the crucial DRAM refresh time. In addition, we determined the thermal activation energy for hole emission from the ground states over the entire AlGaAs barrier to ∼580 meV.

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HL 6.12 Mon 13:00 BEY 118

Acoustoelectric current transport through a double quantum dot — •Jens Ebbecke[1], Nick Fletcher[2], and JT Janssen[2] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, Universitätsstr. 1, 86159 Augsburg — [2]National Physical Laboratory, Queens Road, Teddington TW11 0LW, United Kingdom

We present acoustoelectric current measurements through a double quantum dot. Due to background impurity potential fluctuations an unintentional quantum dot is situated next to an intentionally induced single dot. By changing the top gate voltages, each of the two dots alone can be addressed separately but also a situation can be realized where both dots are coupled and form a double quantum dot system. In the regime that is dominated by the conduction through the intentional quantum dot quantized charge transport has been realized mediated by surface acoustic waves. Based on the measurements on this device we propose a mechanism for a parallel double quantum dot turnstile that can be used as a spin entangler.