HL 69: Quantum Dots: Transport Properties I

Time: Thursday 9:30–12:30 Location: POT 151

HL 69.1 Thu 9:30 POT 151

Transport properties of ferromagnetic-semiconducting hybrid nanowires with well-defined MnAs nanocluster properties — •Matthias T. Elm[1], Ryutaro Kodaira[2], Ryoma Horiguchi[2], Kyohei Kabamoto[2], Shinjiro Hara[2], and Peter J. Klar[1] — [1]I. Physikalisches Institut, Justus Liebig University, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — [2]Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo 060-8628, Japan

For the realization of nano-spintronic devices current research focuses on the preparation and characterization of dilute magnetic semiconducting III-V nanowires. An alternative are hybrid nanowires with ferromagnetic nanoclusters, which exhibit well-defined magnetic and structural properties. Here we present the structural and electrical characterization of MnAs/InAs nanowire hybrids, which are prepared by selective-area growth of the nanowires followed by the endotaxy of MnAs nanoclusters. By varying the growth conditions, size, distribution and number of nanoclusters can be accurately controlled. Using SEM, EDX, HR-TEM as well as MFM, the structural and magnetic properties of the nanoclusters were investigated. First magnetotransport measurements reveal the large impact of the clusters on the transport properties in the nanowires. While single InAs nanowires show universal conductance fluctuations as well as a large positive magnetoresistance at low temperatures, a linear negative magnetoresistance is observed for hybrid nanowires with MnAs clusters completely penetrating the nanowires.

HL 69.2 Thu 9:45 POT 151

Influence of Dimensionality on Tunneling into a Quantum Dot — •Jan K. Kühne and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Deutschland

We study the transport properties of a system of self-assembled InAs quantum dots at low temperatures. Especially, we investigate the influence of the dimensionality of the connected leads on the tunneling into a dot. The transport properties depend on a variety of parameters, such as temperature, size of the dots, magnetic field and the thickness of the tunneling barriers. Measuring shot noise reveals more information about our system than a current or conductance measurement alone. In particular the asymmetry of the tunneling rates can only be observed in the noise signal. Additionally, interaction effects between electrons are known to suppress or enhance shot noise [1].
By changing the current directions of our sample we encounter different behavior of the Fano factor and the shape of the resonance step. This can be explained by a change of dimensionality in the leads and therefore another density of states. By using a Master equation theory we are able to extract the corresponding tunneling rates from our measurements [2]. Further, we are interested in the effect of an applied magnetic field on the transport and noise behavior of our system.

[1] A. Nauen, et al., Phys. Rev. B 70, 033305 (2004).
[2] G. Kiesslich, et al., Phys. Rev. B 68, 125320 (2003).

HL 69.3 Thu 10:00 POT 151

Development of a new device for CV spectroscopy of InAs quantum dots under internal illumination — •Pia Eickelmann[1,2], Sven Scholz[1], Andreas D. Wieck[1], and Arne Ludwig[1] — [1]Chair for Applied Solid State Physics, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum — [2]leaving to Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg

Semiconductor quantum dots are one of the most interesting candidates for the realization of quantum information and communication. Therefore, these materials are investigated by several methods, for example by capacitance-voltage (CV) spectroscopy. The spectra for the conduction band states of InAs quantum dots under illumination by an external LED show additional charging peaks which are assigned to the charging of excitonic states in the quantum dots. [1]

In this talk we present a new device, on which CV spectroscopy can be measured under internal excitation of excitons in InAs quantum dots. In detail a quantum dot LED (QLED) containing five quantum dot layers of similar properties is epitaxially grown on a p-i-n-diode with embedded quantum dots. The CV structure and QLED can be contacted separately. Thus, it is possible to excite optically excitons in the CV-structure, using the QLED within the device. Hence, a purely electrical writing and reading out of the quantum state is possible. In the long term, this could be developed into a quantum memory by slight changes in the sample structure and the experimental setup.

[1] P. A. Labud et al., PRL 112, 046803 (2014)

HL 69.4 Thu 10:15 POT 151

Reflectometry readout of Ge hole spin qubits — •Josip Kukučka, Lada Vukušić, Hannes Watzinger, Elisabeth Lausecker, and Georgios Katsaros — IST Austria

Group IV materials and in particular Si have attracted much interest for the realization of a spin qubit especially since coherence times of almost one second were reported for an electron spin in isotopically purified samples [1]. In our group we are working with hole spin qubits confined in quantum dots formed in Ge hut wires. Due to the recently shown almost purely heavy-hole character of the confined hole states [2], not only long dephasing times but also fast spin manipulation times are expected for this type of hole spin qubit. In order to measure dephasing times, a series of spin-dynamic experiments are going to be performed. Fast qubit state readout is required for these experiments. We have implemented and optimized radio-frequency ohmic reflectometry [3]. The influence of the printed circuit board layout and resonance circuit elements on the sensitivity of the measurements will be addressed. In order to further simplify the sample fabrication and readout protocol, we are currently developing gate reflectometry [4,5], which will use already defined gates that are needed for the electrostatic definition of a double quantum dot system. First results will be presented. [1] Muhonen, J. T et al. Nature Nanotechnology 9, 986 (2014) [2] Watzinger, H. et al. Nano Lett. 16, 6879*6885 (2016) [3] Ares, N. et al. Phys. Rev. Applied 5, 034011 (2016) [4] Colless, J. I. et al. Phys. Rev. Lett. 110, 046805 (2013) [5] Gonzalez-Zalba, M. F. et al. Nature Communications 6, 6084 (2015)

HL 69.5 Thu 10:30 POT 151

Transmon qubits based on InAs/Al core/shell nanowire Josephson junctions — •Patrick Zellekens[1,2], Steffen Schlör[3], Arthur Leis[1,2], Nicholas Güsken[1,2], Torsten Rieger[1,2], Mihail Ion Lepsa[1,2], Alexander Pawlis[1,2], Detlev Grützmacher[1,2], Martin Weides[3], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institut 9, Forschungszentrum Jülich, Germany — [2]JARA - Fundamentals of Future Information Technologies — [3]Physikalisches Institut, Karlsruher Institut für Technologie

State-of-the-art qubits, like the Cooper pair box, are typically tuned in frequency by a magnetic field. Our goal is to fabricate an electrically tunable qubit, using a semiconductor nanowire Josephson junction as nonlinear element. If a gate voltage is applied to the nanowire, the charge carrier concentration is changed, which effectively leads to a change in the critical current and the kinetic inductance of the junction. Thereby it is possible to tune the resonance frequency of the qubit into the excitation frequency of the microwave cavity without a flux bias. The main limitation for the qubit performance is the semiconductor-superconductor interface. Here, the InAs nanowires grown by molecular beam epitaxy were in-situ covered by an Al shell. This procedure ensures a clean interface without any contamination. The electrical properties of the InAs nanowires was tuned by means of Te doping. Based on these InAs/Al core/shell nanowires Josephson junctions were fabricated. Subsequently, the junctions were electrically characterized at low temperature. Finally, implementations as building blocks for 3-dimensional transmon qubits will be shown.

Coffee Break

HL 69.6 Thu 11:15 POT 151

Optimal feedback control of a single-electron transistor. — •Timo Wagner[1], Philipp Strasberg[2], Johannes C. Bayer[1], Eddy P. Rugeramigabo[1], Tobias Brandes[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität, Appelstr. 2, D-30167 Hannover, Germany — [2]Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

Recently we reported the strong suppression of shot noise in a closed-loop feedback controlled single-electron transistor [1]. The implemented feedback loop compensates the time-dependent fluctuations between the single electron-tunneling events, leading to a highly accurate and stable tunneling current [1,2]. Our technique is analog to the generation of squeezed light in quantum optics, using in-loop photo detection [3]. Here we investigate the optimal feedback response, achieving the maximum suppression of shot-noise. For the optimal response the saturation value of the second cumulant of the full counting statistics [4] is found to be given by the electron target number. Astonishingly the feedback works even for target numbers much smaller than one.

[1] T. Wagner, et al. Nature Nanotech. (doi:10.1038/nnano.2016.225)
[2] T. Brandes, Phys. Rev. Lett. 105, 06060 (2010)
[3] S. Machida, Y. Yamamoto, Opt. Commun. 57, 290 (1986)
[4] S. Gustavson, et al., Surf. Sci. Rep. 64, 191 (2009)

HL 69.7 Thu 11:30 POT 151

Time-resolved optical detection of electron tunneling into a single self-assembled quantum dot — •Annika Kurzmann[1], Jens Kerski[1], Arne Ludwig[2], Andreas D. Wieck[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany. — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany.

Self-assembled quantum dots (QDs) as artificial atoms are promising building blocks for QD lasers and single photon sources and have been intensively investigated in optical and transport measurements. While transport measurements are still limited to measurements of ensembles of self-assembled QDs, optical measurements give access to single QDs [1].

We demonstrate here an optical detection scheme to observe quantum jumps for single electron tunneling into a single self-assembled QD. The detection scheme is based on driving the excitonic transition into resonance fluorescence [2], which is quenched in the presence of an additional electron. The observed random telegraph signal of single electron tunneling is evaluated using counting statistics. This reveals the interactions and correlations between excitons and electrons and gives direct access to the statistics of the fluctuations, i.e. shot noise and Fano factor. A reduced Fano factor is observed for equal tunneling rates into and out of the QD, due to an enhanced correlation between the electron tunneling events.

[1] A. Kurzmann et al., Phys. Rev. Lett. **117**, 017401 (2016).
[2] C. Matthiesen et al., Nat. Commun. **4**, 1600 (2013).

HL 69.8 Thu 11:45 POT 151

Low dimensional transport phenomena in modulation-doped GaAs-based core-multishell nanowire field-effect transistors — •Jonathan Becker[1], Dominik M. Irber[1,2], Nari Jeon[2], Jakob Seidl[1], Damon J. Carrad[1], Stephanie Morkötter[1], Bernhard Loitsch[1], Sonja Matich[1], Markus Döblinger[3], Gerhard Abstreiter[1], Jonathan J. Finley[1], Lincoln J. Lauhon[2], Matthew Grayson[4], and Gregor Koblmüller[1] — [1]Walter Schottky Institut, Garching, 85748, Germany — [2]Dept. of Materials Science & Engineering, Northwestern Univ., Evanston, Il 60208, U.S.A. — [3]Dept. of Chemistry, LMU München, Munich 81377, Germany — [4]Dept. of Electrical Eng. & Computer Sci., Northwestern Univ., Evanston, Il 60208, U.S.A.

In this work we present evidence of 1D quantization in the electronic subband-structure of novel δ-doped GaAs/AlAs core-multishell Ω-gated NWFET devices at low-temperature. The device is adapted from our previous studies of Si-δ-doped GaAs-AlGaAs core-shell NWFETs, which exhibit sharp switching characteristics (SS of 70 mV/dec at 300K) and low-temperature electron mobilities of $\approx$5000 cm^2/Vs of the 2DEG channel confined at the core-shell interface. We find a series of clear conductance steps of distinct subbands in the diffusive regime. Self-consistent Schrödinger-Poisson calculations of the electronic structure reveal a series of quantized degenerate and non-degenerate subbands in good agreement with the experimentally observed degeneracies and level spacings.

HL 69.9 Thu 12:00 POT 151

Heavy-hole states in Ge hut wires — •Hannes Watzinger[1], Christoph Kloeffel[2], Lada Vukušić[1], Marta Rossell[3,4], Violetta Sessi[5], Josip Kukučka[1], Raimund Kirchschlager[1], Elisabeth Lausecker[1], Alisha Truhlar[1], Martin Glaser[6], Friedrich Schäffler[6], Armando Rastelli[6], Andreas Fuhrer[4], Daniel Loss[2], and Georgios Katsaros[1] — [1]IST Austria, 3400 Klosterneuburg, Austria — [2]University of Basel, 4056 Basel, Switzerland — [3]Empa, 8600 Dübendorf, Switzerland — [4]IBM Research Zürich, 8803 Rüschlikon, Switzerland — [5]TU Dresden, 01062 Dresden, Germany — [6]JKU, 4040 Linz, Austria

Holes confined in group IV quantum dots are promising candidates for the realization of spin qubits. In our group we study holes which are confined in SiGe self-assembled nanostructures [1]. Here we focus on transport measurements through so called Ge hut wires [2]. The g-factors, obtained from magnetic field spectroscopy, show a high in-plane and out-of-plane anisotropy of up to 18, which depends on the number of holes confined in the quantum dot. Numerical simulations are in very good agreement with our experimental findings and reveal a heavy-hole character of the low energy states [3]; such is important for achieving long dephasing times. This work is supported by the EC FP7 ICT project no. 323841, the ERC Starting Grant no. 335497 and the FWF-I-1190-N20 project.

[1] Katsaros, G. et al., Nature Nano. 5, 458-464 (2010); [2] Zhang, J. J. et al. PRL 109, 085502 (2012); Watzinger, H. et al. APL Mater. 2, 076102 (2014) [3] Watzinger, H. et al. Nanolett. 16, 6879-6885 (2016)

HL 69.10 Thu 12:15 POT 151

Toward a metrological quantification of the conversion efficiency in GaAs nanowire based photodetectors — •Davide Cammi[1], Beatrice Rodiek[2], Ksenia Zimmermann[1], Martin Friedl[3], Nick Morgan[3], Anna Fontcuberta i Morral[3], Stefan Kück[2], and Tobias Voss[1] — [1]Institut für Halbleitertechnik (IHT) und Laboratory for Emerging Nanometrology (LENA), TU Braunschweig, Hans-Sommer-Straße 66, 38106 Braunschweig — [2]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [3]Laboratory of Semiconductor Materials (LMSC), Ecole Polytechnique Fédérale de Lausanne (EPFL), Route Cantonale, 1015 Lausanne, Schweiz

The design of novel photodetectors based on semiconductor nanowires with diameters of few hundred nanometers or below may lead to a significant enhancement of the photoconductive gain and an increase of the detection speed in comparison to the corresponding planar technology. However, a precise quantification of the photodetection performance of such devices requires the development of a metrological procedure for their calibration. In this contribution, we discuss the main challenges and the steps which are required, in order to achieve this goal. In particular, we propose an experimental approach which combines optical and electrical methods for the determination of a two-dimensional, spatially resolved mapping of the device*s photoresponse. We focus the investigation in particular on contacted single GaAs nanowires, which act as photodetectors in the near infrared spectral range.