HL 69: Quantum Dots and Wires: Transport Properties II (mainly Quantum Dots)

Time: Wednesday 17:15–19:15 Location: EW 203

HL 69.1 Wed 17:15 EW 203

Influence of spin relaxation and Coulomb correlations on the dynamics of an open quantum dot — •Benjamin Baxevanis[1], Andreas Beckel[2], Bastian Marquardt[2], Martin Geller[2], Axel Lorke[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen, Duisburg, Germany

The significance of Coulomb interaction and spin relaxation on the time-dependent dynamics of a quantum dot that is weakly coupled to an electronic reservoir is investigated. The two systems are assumed to be initially separated and we calculate the time evolution as the tunneling between the reservoir and the quantum dot is instantly switched on. The charging of a single quantum dot in the sequential tunneling regime is determined by using a master equation for the occupation probabilities. To incorporate many-body effects the eigenstates of a finite number of correlated electrons in the quantum dot obtained by the exact diagonalization method are taken into account.

The electrons in the quantum dot can interact with phonons and the electron spin can couple to their orbital motion or to nuclear spin which leads to relaxation. We consider two types of relaxation processes: 1. an orbital relaxation in the dot, which is instantaneous compared to the tunneling dynamics and 2. a spin relaxation with a time scale, which can be in the order of the tunneling times. We compare how different spin-relaxation times and the Coulomb correlations impact the charging dynamics of the quantum dot.

HL 69.2 Wed 17:30 EW 203

A self-referenced single-electron current source — •Lukas Fricke, Michael Wulf, Frank Hohls, Bernd Kaestner, Ralf Dolata, Philipp Mirovsky, Klaus Pierz, Thomas Weimann, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

A promising candidate for a quantum-based current source is the non-adiabatic electron pump [1], based on a dynamic quantum dot in a semiconducting nanostructure. High current outputs [2] and parallelization [3] for further increased currents have been demonstrated. However, to employ this device as a new current standard or as an on-demand electron source, a high pumping reliability and therefore a measure of single-electron pump accuracy is needed.

We demonstrate a mesoscopic circuit employing a series of semiconducting dynamic quantum dots in combination with metallic single electron transistors (SET) able to monitor the electrostatic potential between the pumps on the single-electron level and thereby individual pump errors. We operate the pumps in a single-shot mode, pumping one electron from node to node with a fidelity verified by the SETs. The rare pump errors can be identified and attributed to each pump so that the compound device acts as a highly accurate self-referenced quantum current source [4].

[1] B. Kaestner et al., Phys. Rev. B 77, 153301 (2008)
[2] M. D. Blumenthal et al., Nat. Phys. 3, 343 (2007)
[3] P. Mirovsky et al., Appl. Phys. Lett. 97, 252104 (2010)
[4] M. Wulf and A. B. Zorin, e-print arXiv:0811.3927

HL 69.3 Wed 17:45 EW 203

Transient capacitance measurements on GaAs quantum dots — •Jochen Kerbst, Pascal Schoof, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstr 11, 20355 Hamburg

We investigate the basic physical properties of GaAs quantum dots (QDs) like activation energy for charge carrier emission and capture cross section. For this we embed a layer with QDs in the depletion zone of a Si-doped AlGaAs Schottky barrier and apply Deep Level Transient Spectroscopy (DLTS) [1]. The self assembled GaAs QDs are fabricated in a molecular beam epitaxy (MBE) system by first generating nanoholes in Si-doped AlGaAs utilizing Local Droplet Etching (LDE) [2]. Subsequent filling of the nanoholes with GaAs provides GaAs quantum dots with highly controlled structural properties. This is followed by a further n:AlGaAs layer and a metal gate electrode. For the DLTS measurements we have to separate QD electronic features from deep donors inside the surrounding AlGaAs-matrix. Therefore we have characterized the deep donor levels in AlGaAs as function of the Al concentration.

[1] D.V. Lang, JAP 45, 3023 (1974)
[2] Z. M. Wang, B. L. Liang, K. A. Sablon, G. J. Salamo, Appl. Phys. Lett. 90, 113120 (2007)

HL 69.4 Wed 18:00 EW 203

The influence of charged quantum dots on the transport properties of a two dimensional system — •Simon Wisotzki[1], Andreas Beckel[1], Bastian Marquardt[1], Martin Geller[1], Tobias Nowozin[2], Andreas Marent[2], Dieter Bimberg[2], and Axel Lorke[1] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [2]Institute for Solid State Physics, Technische Universitaet Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

A crucial point for electrically controlled quantum and memory devices, based on self-assembled quantum dots (QDs), is the read-out of their charge/spin state. Coupling the zero-dimensional QDs to a two-dimensional electron or hole gas (2DEG, 2DHG) by Coulomb interaction enables a non-destructive read-out by a measurement of the conductivity of the two-dimensional system. A time-resolved transport spectroscopy technique was used to separately determine the contributions of the change in charge carrier concentration and mobility to the overall change of conductivity of a 2DEG while charging the QDs with electrons. Here, the influence of individual holes stored inside these QDs on the transport properties of the 2DHG was investigated. We were able to separately determine the contribution of charged QDs as Coulomb scatterers and their influence on the charge carrier density in the 2DHG. Our results enable a deeper understanding of the interfacing between QDs and a 2DEG/2DHG, which is essential for the development of QD based memories, quantum devices or velocity modulated transistors (VMT).

HL 69.5 Wed 18:15 EW 203

Deep-Level Transient Spectroscopy on GaSb/GaAs and $In_{0.25}Ga_{0.75}As$/GaP quantum dots — •Leo Bonato[1], Tobias Nowozin[1], Gernot Stracke[1], Alexander Glacki[1], Andreas Marent[1], Dieter Bimberg[1], Robert Young[2], and Manus Hayne[2] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Department of Physics, Lancaster University, Lancaster, LA1 4YW, United Kingdom

Aiming to use self-organized quantum dots (QDs) as storage units for novel memory devices [1], we studied the charge-carrier dynamics during the processes of charging and discharging QDs by using Deep-Level Transient Spectroscopy (DLTS). Since they are the most promising material systems for increasing the storage time in a quantum dot based memory, we investigated type-II GaSb/GaAs QDs and type-I $In_{0.25}Ga_{0.75}As$ QDs on a GaAs interlayer in GaP and extracted localization energies and capture cross sections.

[1] A. Marent et al., *The QD-Flash: A quantum dot-based memory device*, Semicond. Sci. Technol. 26 (2011) 014026

HL 69.6 Wed 18:30 EW 203

HRTEM investigation of InAs/GaAs sub-monolayer structures — •Felix Kiessling[1], Tore Niermann[1], Jan-Hindrik Schulze[2], Tim David Germann[2], André Strittmatter[2], Udo W. Pohl[2], Dieter Bimberg[2], and Michael Lehmann[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

A promising idea of achieving polarization independent quantum dots (QD) is the deposition of InAs-sub-monolayers (SML) above Stranski-Krastanov $In_xGa_{1-x}As$-QDs. The strain of the QDs influences the growth of the SML stacks. We studied stacks of ten nominal 0.18 nm thick SML of InAs above $In_{0.26}Ga_{0.73}As$ QDs in a CS-corrected FEI Titan 80-300 TEM. In high-resolution TEM-images we could resolve the distinct single layers of the SML stacks. In thin areas, Geometric Phase Analysis is useful to find lattice mismatches caused by the Indium deposition. Furthermore we used the chemical sensitive (002) reflection in the systematic row to observe the Indium in the GaAs-substrate. In a specimen with 1.7 monolayer thick InAs depositions, this chemical sensitive reflection makes it possible to determine the segregation of Indium into the GaAs-substrate.

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HL 69.7 Wed 18:45 EW 203

Carrier dynamics in MODFETs with embedded quantum dots — •Michael Narodovitch, Tobias Nowozin, Andreas Marent, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Due to their confining properties self-organized quantum dots (QDs) could have the potential to be used as storage units inside future memory devices. We have studied an AlGaAs-MODFET structure with an embedded layer of self-organized InAs quantum dots. Since the hole charge inside the QDs is coupled to the two-dimensional hole gas (2DHG) underneath the QD layer, the emission and capture processes between the QDs and the 2DHG can be directly observed in the source/drain current. By using the 2DHG as detector, we have studied the carrier dynamics of the QDs at various temperatures for different initial charge states in the QDs.

HL 69.8 Wed 19:00 EW 203

Growth of InN based nanostructures on patterned substrates using MOVPE — •Andreas Winden[1,2], Martin Mikulics[1,2], Toma Stoica[1,2], Martina von der Ahe[1,2], Anna Haab[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute -9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA – Fundamentals of Future Information Technology

Due to its small direct band gap indium nitride expands the potential of group III-nitride optoelectronic device applications to the telecommunication wavelength range. Since InN layers exhibit a large lattice mismatch to commonly used substrates, the growth of nanostructures could provide a way to more crystalline perfection and therefore better optical properties. However, the control of their position and size is still challenging. In this contribution we report on the heteroepitaxial selective area growth (SAG) of InN nanostructures on hole-patterned SiO_2/GaN/sapphire templates. The influences of growth temperature and time as well as V/III ratio on morphological and optical properties were investigated by scanning electron microscopy, room- and low-temperature (micro-)photoluminescence and Raman spectroscopy. It is found that especially the growth temperature has a major influence on the selectivity. Hence, nucleation on the patterned mask could be avoided and pyramidal shaped InN nanostructures with a base side length down to 40 nm could be achieved in a small growth temperature window around 650 °C. Furthermore micro-PL measurements demonstrate a band edge luminescence at room temperature even from individual InN nanostructures.