HL 11: Transport

Time: Monday 14:00–17:45 Location: H14

HL 11.1 Mon 14:00 H14

Quantized magnetic confinement in quantum wires — •Mihai Cerchez[1], Alexey Tarasov[1], Stefan Hugger[1], Hengyi Xu[1], Thomas Heinzel[1], Igor Zozoulenko[2], Urszula Gasser-Szerer[3], Dirk Reuter[4], and Andreas Wieck[4] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Linköping University, Norrköping, Sweden — [3]ETH, Zürich, Switzerland — [4]Ruhr-Universität Bochum, Germany

We report the experimental observation of magnetically bound electronic states in a quantum wire (QWR), built by AFM lithography in a GaAs/AlxGa1-xAs heterostructure with a two-dimensional electron gas (2DEG) at 45 nm below the surface. A strong, inhomogeneous magnetic field is produced in the central region of the wire under the edge of a Dy ferromagnetic film evaporated on top and magnetized along the wire. Electronic transport measurements on the QWR are performed as a function of a superimposed, homogeneous perpendicular magnetic field. When the homogeneous field is applied in the opposite direction to the field produced by the ferromagnetic film, such that the magnetic field changes sign twice inside the QWR, we observe resonances in the conductance, which we interpret as bound electronic states induced by the inhomogeneous diamagnetic shift of the wire modes. Supported by simulations using a recursive Green function technique, we identify in the LDOS two types of bound states, one bonding state (ring-like) associated to a maximum in the transmission probability and therefore in conductance, and an anti-bonding state associated to reflection resonances.

HL 11.2 Mon 14:15 H14

The effect of gate control on the electrical conductivity of InAs nanowires — •Karl Weis[1,2], Christian Volk[1,2], Stephan Wirths[1,2], Sergio Estévez Hernández[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Andreas Penz[1,2], Stefan Trellenkamp[1,2], Jürgen Schubert[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

Semiconductor nanowires are an interesting step on the road to zero-dimensional systems. InAs is an especially suitable material because ohmic contacts can be prepared straightforwardly. Provided sufficient gate control, quantum dots can be formed.

Here, the electronic transport properties of nominally undoped InAs nanowires grown by metal-organic vapour phase epitaxy are examined. Their typical length and diameter are 5 μm and 100 nm, respectively. The gate control is studied for different gate geometries, e. g. fingers, back- and top-gates. Furthermore, we compare the performance of high-k dielectrics, e. g. $GdScO_3$ or $LaLuO_3$, with standard dielectrics like SiO_2 or Si_3N_4. Four-terminal transport measurements are performed both at room temperature as well as at low temperatures down to 30 mK.

Field effect transistor measurements performed at room temperature show that by using high-k dielectrics, the I_{on}/I_{off} ratio can be improved by at least one order of magnitude.

HL 11.3 Mon 14:30 H14

The influence of doping on the electronic transport properties of InAs nanowires — •Stephan Wirths[1,2], Karl Weis[1,2], Christian Volk[1,2], Shima Alagha[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Stefan Trellenkamp[1,2], Hans Lüth[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institut für Bio- und Nanosysteme (IBN-1), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

The investigation of the electrical conductivity of semiconductor nanowires is a crucial step on the road to zero-dimensional electronic systems. Especially the effect of Si-doping on the resistivity plays an important role and has not been investigated, yet.

We study the electronic transport properties of n-doped InAs:Si nanowires grown by metal organic vapor phase epitaxy. Nominally undoped wires and Si-doped wires with four different dopant concentrations are examined. Two- and four-terminal transport measurements are performed both at room temperature and at low temperatures down to 4 K. In addition, by using a SiO_2 back gate, we yield field effect transistor characteristics. Hence, the depending of conductivity on the gate voltage is determined. Moreover, we investigate the temperature dependency of transport properties.

For the lowest dopant concentration we quantify $\rho = (3.8 \pm 0.8) \times 10^{-4}\,\Omega$m and $\rho = (1.8 \pm 0.4) \times 10^{-5}\,\Omega$m for the highest dopant concentration. The values of ρ were averaged over approximately 10 to 30 wires. We can conclude, that Si-doping decreases the resistivity.

HL 11.4 Mon 14:45 H14

Universal and reconfigurable logic gates in a compact three-terminal resonant tunneling diode — •Fabian Hartmann, Lukas Worschech, Tae Yang Kim, and Alfred Forchel — Universität Würzburg, Physikalisches Institut, Lehrstuhl für Technische Physik, Am Hubland, 97074 Würzburg

Submicron-sized mesas of resonant tunneling diodes (RTDs) with split drain contacts have been realized and the current-voltage characteristics have been studied in the bistable regime at room temperature. Dynamically biased, the RTDs show noise-triggered firing of spike-like signals and can act as reconfigurable universal logic gates for small voltage changes of a few mV at the input branches. These observations are interpreted in terms of a stochastic nonlinear processes. The logic gate operation shows gain for the fired-signal bursts with transconductance slopes exceeding the thermal limit. The RTD junction can be easily integrated to arrays of multiple inputs and have thus the potential to mimic neurons in nanoelectronic circuits.

HL 11.5 Mon 15:00 H14

Fast initialization of dynamic quantum dots — •Philipp Mirovsky, Bernd Kaestner, Christoph Leicht, Klaus Pierz, Thomas Weimann, and Hans Werner Schumacher — PTB, 38116 Braunschweig, Germany

We present experimental studies on dynamic quantum dots, formed within non adiabatic single electron pumps. We employ etched AlGaAs/GaAs nanowires crossed by three metal top gates, set to negative voltages to define a dot. By applying radio frequency signals of frequency f to the outermost gate, electrons are pumped through the dot. Directly after the loading electrons from source into the dot it is decoupled from the environment. The electron number is controlled by a plunger gate. During the second half of the cycle the pump transports the electrons previously loaded inside the dot to drain. Measuring the produced pumping current divided by e*f we obtain the population of the dot averaged over many cycles. In this way we are able to study the initialization conditions without the need for other single-charge detector system. This pumping mechanism also represents an alternative path to the realization of a high current high accuracy quantum standard for electrical current.

HL 11.6 Mon 15:15 H14

Electromigration in Ag-Nanowires with a Single Grain Boundary — •Simon Sindermann, Christian Witt, Michael Horn-von Hoegen, Günther Dumpich, and Frank-J. Meyer zu Heringdorf — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE) University Duisburg-Essen

Electromigration is the dominating cause of interconnect failure. For the electromigration transport of material, it is known that grain boundaries play a significant role as an important diffusion path in addition to surface diffusion. In former experiments, we avoided grain boundaries and examined electromigration effects in single-crystalline Ag nanowires. Here, we present a new approach of controlled fabrication of nanowires with isolated grain boundaries. On Si(111), Ag islands are known to form areas of different crystallographic orientations, Ag(111) and Ag(001), which can be distinguished by Photoemission Electron Microscopy (PEEM). Using a focused ion beam (FIB) we erode Ag from the islands such that a wire-like area in the vicinity of the grain boundary remains. After contacting the wires by ion beam induced Pt deposition, we study the electromigration *in-situ* by scanning electron microscopy, combined with a four wire resistance measurement.

HL 11.7 Mon 15:30 H14

Boltzmann equation approach to ballistic rectification at a

potential step — •Daniel Urban and Jürgen König — Universität Duisburg-Essen and CeNIDE, Duisburg, Germany

We consider the device studied experimentally in Ref. [1]. It consists of a two-dimensional electron gas patterned such that two regions are separated by a potential step. Application of a bias voltage parallel to the potential step results in a transverse voltage (proportional to the square of the bias voltage). This effect can be exploited for rectification, since – due to the symmetry of the device – the transverse voltage does not depend on the bias polarity.

We model the electrons by means of the Boltzmann equation. In doing so we allow for non-parabolic dispersion and energy dependent scattering times. In order to capture the rectification effect, the distribution function has to be calculated to second order in the applied electric field. Based on the calculated distribution function we determine the transverse voltage. While its magnitude does not agree with the measured values in Ref. [1], qualitative features are reproduced: It depends quadratically on the applied bias and increases with increased mobility.

[1] A. Ganczarczyk *et al.*, preprint: arXiv:0804.0689v3 (2009).

HL 11.8 Mon 15:45 H14

Negative bend resistance in a nanoscale epitaxial graphene cross junction — •Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Florian Speck[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Technische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg

We report on the observation of inertial-ballistic transport in nanoscale cross junctions fabricated from epitaxial graphene grown on SiC(0001). Ballistic transport is indicated by a negative bend resistance which vanishes with increasing temperature.

The advanced morphology of graphene films on SiC(0001) grown in an Ar atmosphere [1] yields improved transport properties [2] and an electron mean free path of $l_e = 58$ nm at $T = 4.2$ K. The mean free path exceeds the device dimensions for a 50 nm wide orthogonal cross junction, and a negative bend resistance of $R_{12,43} \approx -170\ \Omega$ observed at $T = 4.2$ K indicates ballistic transport. With increasing temperature a transition from the ballistic to the diffusive transport regime is indicated by a change of sign in $R_{12,43}$. For cross junctions with leads of width $b = 80$ nm no negative bend resistance is observed, which is in accordance with the estimated mean free path ($l_e < 80$ nm).

[1] K.V. Emtsev, *et al.*, Nature Mater. **8**, 203 (2009).

[2] S. Weingart, *et al.*, Physica E, *doi:*10.1016/j.physe.2009.11.006.

15 Min. Coffee Break

HL 11.9 Mon 16:15 H14

Ballistic quantum spin Hall state of HgTe quantum wells in a strong magnetic field — •Tkachov Grigory[1,2] and Hankiewicz Ewelina[2] — [1]Max Planck Institut PKS, Dresden — [2]Institut für Theoretische Physik, Universität Würzburg

Recently novel two-dimensional electronic state - quantum spin Hall (QSH) state - has been theoretically proposed and experimentally realized in HgTe quantum wells [1]. It is observed in a zero magnetic field and for this reason is distinct from quantum Hall states. We show theoretically [2] that the QSH state persists in strong quantizing fields, turning into a quantum Hall one if the Fermi level is driven out of the band gap. We find that near such a transition the longitudinal ballistic conductance of edge channels vanishes due to the combined effect of edge-spectrum nonlinearity and channel backscattering. This contrasts the usual behavior of the zero-field conductance which increases as the Fermi level is pushed from the band gap into the metallic-type conduction (or valence) band [1]. The combined effect of the spectral nonlinearity and backscattering is found to cause power-law suppression of the edge conductance with magnetic field, accompanied by spatial redistribution of the QSH channels. Our findings can be used for the detection and characterization of the QSH state in the recently achieved ballistic regime [1], still remaining largely unexplored.

1. M. König et al., Science **318**, 766 (2007); A. Roth et al., Science **325**, 294 (2009).

2. G. Tkachov and E. M. Hankiewicz, arXiv: 0909.4428.

HL 11.10 Mon 16:30 H14

Transport Measurements on a GaAs/AlGaAs High Mobility Sample — •Lina Bockhorn[1], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]ETH Zürich, Schafmattstr. 16, 8093 Zürich, Switzerland

We study the fractional Quantum-Hall effect in very high mobility two-dimensional electron systems (2DES). Hall bars are created by photolithography on a GaAs/AlGaAs quantum well containing a 2DES. The 2DES have an electron density of $n_e \approx 2.95 \cdot 10^{11}\mathrm{cm}^{-2}$ and a mobility of $\mu \approx 14.9 \cdot 10^6\mathrm{cm}^2/\mathrm{Vs}$ at 1.5 K. Similar parameters were obtained after cooling the sample slowly to the cryostat's base temperature (40 mK). For a given density of electrons we study the longitudinal resistance R_{xx} over a short range around zero magnetic field. The measurements carried out for several temperatures and different currents were applied to the Hall bar. A peak was observed at zero magnetic field for the temperature dependent measurements, as well as for the current dependent measurements. The maximum value of R_{xx}(B=0 T) is independent of the temperature and the applied current. The behavior of the longitudinal resistance for the temperature and the current dependent measurements is astonishing. Not only the fixed peak at the zero point is unusual, but also the distribution of the longitudinal resistance next to the peak. This region shows a different behavior for temperature variation than for different currents applied to the Hall bar. This clearly shows that the behavior for different currents is not a temperature dependent effect.

HL 11.11 Mon 16:45 H14

Transport in dually-gated suspended bilayer graphene devices in electric and magnetic fields — •R. Thomas Weitz, Monica T. Allen, Ben E. Feldman, Jens Martin, and Amir Yacoby — Department of Physics, Harvard University, Cambridge, MA, USA

The layer pseudospin of bilayer graphene can be controlled by applying an electric field E across the flake. We demonstrate control over this pseudospin in suspended bilayer graphene devices with suspended top gates. At zero magnetic field B, we observe a significantly larger increase in resistance at the charge neutrality point with growing E than had been reported before, indicative of the high sample quality. At finite B, the 8-fold degeneracy of the lowest Landau level is lifted due to electron-electron interactions [1]. The strength and nature of these symmetry broken filling factors are found to be depended on E. The nu=1 and 2 states can be enhanced with E. In the nu=0 state phase transitions between two insulating phases are observed. The position of this transition in the E-B plane is marked by an increased conductance and depends on the relative strengths of B and E. [1] B. E. Feldman et al. Nature Physics

HL 11.12 Mon 17:00 H14

On the self-consistent calculation of the electric Hall potential — •Tobias Kramer, Christoph Kreisbeck, and Viktor Krueckl — Institute for Theoretical Physics, Uni Regensburg

Using a first-principles many-body simulation of a Hall bar, we study the necessary conditions for the formation of the Hall potential: (i) Ohmic contacts with metallic reservoirs, (ii) electron-electron interactions, and (iii) confinement to a finite system. By propagating thousands of interacting electrons over million time-steps we capture the build-up of the self-consistent potential, which resembles results obtained by conformal-mapping methods. As shown by a microscopic model of the current injection, the Hall effect is linked to specific boundary conditions at the particle reservoirs.

HL 11.13 Mon 17:15 H14

Activation of acceptor levels in Mn implanted Si by pulsed laser annealing — •Lin Li[1,2], Shengqiang Zhou[2], Danilo Bürger[2], Peter Oesterlin[3], Jürgen Fassbender[2], Manfred Helm[2], Shude Yao[1], and Heidemarie Schmidt[2] — [1]State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China — [2]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden- Rossendorf e.V., Bautzner Landstraße 128, 01328 Dresden, Germany — [3]INNOVAVENT GmbH, Bertha-von-Suttner-Str. 5, 37085 Göttingen, Germany

Nearly intrinsic Si wafers were implanted with Mn ions. The implanted Si films were annealed by pulsed laser annealing (PLA) or rapid thermal annealing (RTA). Activation of acceptors was only realized in the PLA films with a free hole concentration of 4*1017 cm-3, compared to the activation of donors in RTA films with a free electron concentration of 6*1015 cm-3. The PLA films reveal negative magnetoresistance with MR= 0.5% at 20 K and 30 K and at 7 T, hinting towards spin polarization of holes. Ferromagnetism was probed for both RTA and PLA

films by a SQUID magnetometer at low temperatures. The formation of ferromagnetic MnSi1.7 nanoparticles has been proven in RTA films by synchrotron radiation X-ray (SR-XRD) measurements [1] and could be excluded in Mn implanted Si annealed by PLA.

HL 11.14 Mon 17:30 H14

Interaction between quantum dots and a two-dimensional system — •Florian Lau[1], Gerold Kiesslich[1], Andreas Marent[2], Tobias Nowozin[2], Tobias Brandes[1], and Dieter Bimberg[2] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Novel types of memories will combine the advantage of non-volatility of the Flash-memory and the performance and endurance of the DRAM. One of the most promising options for charge-based memories is the use on self-organized quantum dots (QDs) as memory units. Recently, a QD-based memory concept was introduced with the potential to fulfill all requirements concerning storage/access time, endurance and scalability [1].

We investigated the read-out in such a QD-based memory by studying the coupling between InAs/GaAs QDs and an adjacent two-dimensional hole gas (2DHG). Self-consistent solutions of Poisson- and drift-diffusion equations yield the dependence of the charge carrier concentration on a variety of parameters such as the number of charge carriers stored in the QDs or the distance between the QDs and the 2DHG. Furthermore, the effect of charged QDs on the mobility of the 2DHG is discussed in terms of a memory-function approach. The simulation results are compared with measurements performed on a memory structure based on InAs/GaAs QDs.

[1] M.Geller, A. Marent, T. Nowozin, D. Bimberg, N. Akcay, and N. Öncan, Appl. Phys. Lett. **92**, 092108 (2008).