HL 28: Transport properties

Time: Tuesday 9:30–12:00 Location: ER 164

HL 28.1 Tue 9:30 ER 164

Influence of electronic correlations on the frequency-dependent hopping transport in Si:P — •Elvira Ritz and Martin Dressel — 1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550, Stuttgart

At low energy scales charge transport in the insulating Si:P is by activated hopping between the localized donor electron states. Theoretical models for a disordered system with electron-electron interaction are appropriate to interpret the electric conductivity spectra [2]. With a novel and advanced method [3,4] we have measured the complex broadband microwave conductivity of Si:P from 0.1 to 5 GHz in a broad range of phosphorus concentration from 0.56 to 0.95 relative to the critical value $n_c = 3.5 \times 10^{18}$ cm^{-3} corresponding to the metal-insulator transition driven by doping. At T=1.1 K the samples show a super-linear frequency dependence of the conductivity indicating the influence of the Coulomb gap. At higher doping $n \to n_c$, an abrupt drop in the conductivity power law $\sigma_1(\omega) \sim \omega^\alpha$ is observed. The dielectric function ε_1 increases upon doping following a power law in $(1 - n/n_c)$. Dynamic response at elevated temperatures is also discussed.

[1] E. Ritz and M. Dressel, arXiv:0711.1256, in print
[2] B. I. Shklovskii and A. L. Efros, Zh. Eksp. Teor. Fiz. **81**, 406 (1981) [Sov. Phys. JETP **54**, 218 (1981)]
[3] M. Scheffler and M. Dressel, Rev. Sci. Instrum. **76**, 074702 (2005)
[4] E. Ritz and M. Dressel, to be published

HL 28.2 Tue 9:45 ER 164

Ballistic rectification in density-modulated 2D-systems — •Arkadius Ganczarczyk, Christian Notthoff, Bastian Marquardt, and Axel Lorke — Experimental Physics, Universität Duisburg-Essen and CeNIDE, Lotharstraße 1, 47057 Duisburg, Germany

We examine carriers in a 2-dimensional electron gas, which move ballistically along a boundary between two areas with different carrier densities. A voltage in the direction of the density-gradient (perpendicular to the applied current) is observed. The polarity of the transverse voltage depends on the direction of the density gradient and corresponds to a net current, which flows from the higher carrier density area to the lower density area. The direction of the transverse voltage is independent of the current polarity, which demonstrates rectification in the device. We also show that the transverse voltage depends on the relative variation of the carrier densities and the carrier mobility and has a parabolic dependence on the applied longitudinal bias. A theoretical model was developed for ballistic transport in density-modulated 2D-system, which includes the electric field needed to drive the applied current. This model is able to reproduce all major aspects of the experimental measurements. For small longitudinal currents experimental and simulated results agree well. However, the transverse voltage depends linearly on the longitudinal current whereas the experiment shows a parabolic dependence. This indicates that the presence of the transverse voltage cannot be fully described with a simple ballistic model.

HL 28.3 Tue 10:00 ER 164

Electron transmission through magnetic barriers displaced in B-space — Stefan Hugger, •Mihai Cerchez, Hengyi Xu, and Thomas Heinzel — Heinrich-Heine Universität, 40225 Düsseldorf

An inhomogeneous magnetic barrier was created in a Hall bar defined in a GaAs-AlGaAs two-dimensional electron gas, by the stray field present under the edge of a dysprosium magnetic film evaporated on top of the structure [1]. Tilting the sample by small angles around the position in which the field is parallel to the Hall bar in the current direction, one superimposes the perpendicular homogenous component of the applied field, and so shifts the magnetic barrier in B-space, while the magnetic barrier height remains constant to a good approximation. While the magnetic barrier is closed, we show that this experiment changes the balance between different mechanisms of transmission across the magnetic barrier, namely edge orbits, snake orbits and scattering. This produces a minimum in the resistance variation with the perpendicular homogenous field component, position of which depends on the height of the magnetic barrier [2]. The process is simulated with a Landauer-Büttiker model [3] with experimentally determined parameters. The simulations produce excellent agreement to the experiment.

[1] M. Cerchez et al, Phys. Rev. B 75, 035341 (2007)
[2] S. Hugger et al, arXiv:0708.2032, (2007)
[3] M. Büttiker, Phys. Rev. Lett. 57, 1761 (1986)

HL 28.4 Tue 10:15 ER 164

The minimum conductivity of graphene within quasiclassical approach — •Maxim Trushin and John Schliemann — Institut für Theoretische Physik Universität Regensburg D-93040 Regensburg

We investigate the minimum conductivity of graphene within a quasiclassical approach taking into account electron-hole coherence effects (or Zitterbewegung contributions) which stem from the chiral nature of low energy excitations. Relying on an analytical solution of the kinetic equation we study the carrier scattering on both short and long range scatterers. At the end we found a way how to distinguish between samples with the domination of short and long range scatterers from the minimum conductivity measurements. The model proposed qualitatively explains recent experiments with chemical doping of graphene [1]. Our findings concerning the short range scatterers can be found in Ref.[2].

[1] J. H. Chen, C. Jang, M. S. Fuhrer, E. D. Williams, M. Ishigami arXiv:0708.2408
[2] M. Trushin and J. Schliemann arXiv:0706.1888

HL 28.5 Tue 10:30 ER 164

Ab-initio modelling of thermodynamics and kinetics of point defects in indium oxide — •Péter Ágoston[1], Paul Erhart[2], Andreas Klein[1], and Karsten Albe[1] — [1]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt — [2]Lawrence Livermore National Lab, California, USA

The electrical and optical properties of indium oxide films strongly vary with the processing parameters. Especially the oxygen partial pressure and temperature determine properties like electrical conductivity, composition and transparency. Since this material owes its remarkable properties like the intrinsic n-type conductivity to its defect chemistry, it is important to understand both, the equilibrium defect thermodynamics and kinetics of the intrinsic point defects. In this contribution we present a defect model based on DFT total energy calculations using the GGA+U method. Further, the nudged elastic band method is employed in order to obtain a set of migration barriers for each defect species. Due to the complicated crystal structure of indium oxide a Kinetic Monte-Carlo algorithm was implemented, which allows to determine diffusion coefficients. The bulk tracer diffusion constant is predicted as a function of oxygen partial pressure, Fermi level and temperature for the pure material.

HL 28.6 Tue 10:45 ER 164

Flexural phonons in free-standing graphene — •Eros Mariani and Felix von Oppen — Fachbereich Physik, Freie Universitaet Berlin, Arnimallee 14, D-14195 Berlin (Germany)

Rotation and reflection symmetries impose that out-of-plane (flexural) phonons of free-standing graphene membranes have a quadratic dispersion at long wavelength and can be excited by charge carriers in pairs only. As a result, we find that flexural phonons dominate the phonon contribution to the resistivity ρ below a crossover temperature T_x where we obtain an anomalous temperature dependence $\rho \propto T^{5/2} \ln T$. The logarithmic factor arises from renormalizations of the flexural phonon dispersion due to coupling between bending and stretching degrees of freedom of the membrane.

HL 28.7 Tue 11:00 ER 164

electronic transport in graphene nanoribbons calculated with recursive green's functions — •hengyi xu[1], igor zozoulenko[2], and thomas heinzel[1] — [1]Heinrich-Heine Universität, Düsseldorf, Germany — [2]Department of Science and Technology, Linköping University, Sweden

Graphene demonstrates some unique electronic properties. We have developed the recursive Green's function technique within the tight-binding model for the mesoscopic graphene which provides a simple and elegant way of accounting for the effects of the contacts. The

nanoribbon and the contacts are assumed to be made of graphene and are modeled by appropriate on-site and hopping parameters. Based on this technique, we study the electronic states and transport properties of the narrow graphene ribbons with zigzag and armchair edges. The energy spectra with zigzag and armchair edges are similar to those of the armchair and zigzag carbon nanotubes. Using the Landauer formula approach, the mode-dependent conductance through the electrostatic potential barriers in the graphene ribbons is investigated. We found that the quantized conductance as a function of Fermi energy exhibits the coherent oscillations in the zigzag edge graphene. Also, conductance dips are present which are absent in the armchair edge graphene. In addition, electronic transport in the presence of disorder is studied.

HL 28.8 Tue 11:15 ER 164

Electrical transport properties of GaGdN epitaxial layers — •Amilcar Bedoya Pinto, Martin Roever, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut and Virtual Institute of Spin Electronics (VISel), Georg-August Universität Göttingen, D-37077 Göttingen, Germany

In the last years, the rare-earth element Gd has gained great attention as a magnetic dopant in the wide-gap semiconductor GaN, due to the unexpected high magnetic moment per Gd-atom induced in the host matrix at very low Gd-concentrations. In the DMS theory, ferromagnetic coupling is often linked to electrical transport. However, less is known about the electrical transport properties in Gd-doped GaN. For this purpose, GaGdN layers (d=500nm) have been grown by MBE on semi-insulating 6H(0001) SiC substrates. We find that Gd-doping increases the resistivity up to four orders of magnitude compared to unintentionally doped GaN, showing a temperature dependence ($T^{-1/2}$) in the low temperature-range (<60K), which is characteristic of hopping conductivity in an impurity band of localized states in the gap. In order to find out whether this impurity band is created by the spin-splitted f-states of Gd or rather by structural defects, samples with different Gd concentrations are studied. In addition, transport properties of silicon co-doped samples might clarify whether carriers play a role in mediating the observed ferromagnetism in this material system.

HL 28.9 Tue 11:30 ER 164

Real-space-real-time description of quantum transport in finite systems — •Esa Rasanen, Heiko Appel, Alberto Castro, and E.K.U. Gross — Freie Universitat Berlin, Germany

We have applied time-dependent density-functional theory (TDDFT) to investigate the electron flow through various two-dimensional (2D) structures. The finite 2D computing region is divided into (i) the time-independent quantum-dot reservoir initially filled with electrons and (ii) a time-dependent channel which contains a device potential (scattering center) of a desired shape at the center. First, the static Kohn-Sham equation is solved for the electrons in the reservoir. Thereafter, the ground-state Kohn-Sham wave functions are used as initial states and are propagated on the potential landscape smoothly connected to the reservoir, so that the electrons can enter the channel freely at times $t > 0$. The charge flow through the channel and device region is driven solely by the wave-packet dispersion and electron-electron repulsion. There is no external bias. We monitor the current density at different points in space until the unrealistic back-scattering effects due to the finite simulation area distort the description of a real infinite system. In several test cases, however, our approach leads to excellent agreement with the nonequilibrium Green's function method. Until now, we have applied our TDDFT approach in the level of adiabatic local-density approximation to simulate charge transport through quantum rings and quantum-point contacts in static, uniform magnetic fields.

HL 28.10 Tue 11:45 ER 164

Adaptive Finite Element Simulations of Ballistic Semiconductor Devices — •Stephan Kramer[1], Oliver Bendix[2], Kai Bröking[2], Ragnar Fleischmann[2], and Theo Geisel[2] — [1]Institut für Theoretische Physik, 37077 Göttingen — [2]Max-Planck-Institut für Dynamik und Selbstorganisation, 37073 Göttingen

Simulating the quantum mechanics of a ballistic semiconductor device requires the treatment of a stationary Schrödinger equation in a complex geometry with a great variety of boundary conditions. The presence of strong magnetic fields induce steep gradients on the wave function which impose high demands on the numerical methods.

We have implemented a finite-element simulation based on deal.II [1] equipped with several adaption schemes for the triangulation of the domain of the physical problem. This allows for resolving the details of the wave function on different length scales in different parts of the geometry. Especially in the area of the contacts of the device, where we have to calculate the wave function with great accuracy, we can locally employ a high grid resolution, whereas in other regions the mesh is kept coarse. This decreases the computational effort, only making it possible to run simulations for a sufficiently large number of magnetic fields to reproduce experimental results.

We use the computation of the transmission properties of a magnetic focussing device [2] from the scattering matrix as an example to demonstrate the benefits of a locally adaptive simulation code.

[1] www.dealii.org
[2] Nature Physics 3, 464 - 468 (2007)