MA 13: Graphene - Electronic Properties and Transport 2 (jointly with DS, HL, MA, and O)

Time: Tuesday 9:30–12:45 Location: H17

MA 13.1 Tue 9:30 H17

Transport properties of high-quality reduced graphene oxide — •Michael Enzelberger[1], Siegfried Eigler[2], Philipp Hofmann[1], Stefan Grimm[2], Andreas Hirsch[2], and Paul Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials, Universität Erlangen-Nürnberg — [2]Department of Chemistry and Pharmacy, and Institute of Advanced Materials and Processes (ZMP), Universität Erlangen-Nürnberg

Chemical production of graphene, especially reducing graphene oxide has gained a lot of interest in recent years. Yet the transport properties of such materials are usually not compatible to those of graphene.

We have found a way to overcome this problem using a modification of the standard Hummer's method. Single flakes of reduced graphene oxide have been investigated. The graphene oxide was deposited onto a SiO_2/Si substrate and subsequently reduced using hydrogen iodine. The resulting reduced graphene oxide samples were patterned by electron beam lithography. We have characterized the quality of the samples by combining Raman spectroscopy and Hall mobility measurements in magnetic fields up to $14\,T$ and temperatures down to $0.3\,K$.

High-quality samples had a Raman D/G ratio of better than 1 and showed Hall mobilities exceeding 1000 cm^2/Vs. This is nearly two orders of magnitude higher than what is known for standard reduced graphene oxide. The best samples even show Shubnikov-de Haas oscillations and Hall plateaus.

MA 13.2 Tue 9:45 H17

Magnetoresistance of Nanocrystalline Graphene — •Daniel Steininger[1], Paul Linsmaier[1], Ina Schneider[1], Christoph Strunk[1], Matthias Büenfeld[2], Nils-Eike Weber[2], Andrey Turchanin[2], Miriam Grothe[3], and Thomas Weimann[3] — [1]Institute for Experimental and Applied Physics, University of Regensburg, Universitätsstr. 31, D-93053 Regensburg, Germany — [2]Faculty of Physics, University of Bielefeld,Universitätsstr.25, D-33615 Bielefeld, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We report on the magnetotransport in Hall bar structures of nanocrystalline graphene. The graphene sheets were prepared by electron-beam-induced cross-linking and subsequent pyrolysis of aromatic self-assembled monolayers [1]. The I-V characteristics show considerably non-linear behaviour at low temperatures. One low resistive sample ($\approx$ 200 kOhm/sq at T = 4 K) shows positive magnetoresistance values up to + 20 % in the perpendicular magnetic field for temperatures below 6 K, while above this temperature the magnetoresistance becomes negative. Measurements of the transversal voltage in the linear regime exhibit anomalous behaviour which cannot be explained by the conventional Hall effect. If the magnetic field is aligned parallel to the graphene sheet the magnetorestance exhibits large positive values up to + 300 %. Measurements on a highly resistive sample ($\approx$ 30 MOhm/sq at T = 4 K) reveal a non-monotonic behaviour of the magnetoresistance in a perpendicular magnetic field.

[1] A. Turchanin et al., ACS Nano 5 (2011) 3896-3904.

MA 13.3 Tue 10:00 H17

Quantum Monte Carlo Study of Edge-State Magnetism on Chiral Graphene Nanoribbons — Michael Golor[1], Thomas C. Lang[1,2], and •Stefan Wessel[1] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen — [2]Department of Physics, Boston University

We investigate the edge-state magnetism of chiral graphene nanoribbons using projective Quantum Monte Carlo (QMC) simulations and a self-consistent mean-field approximation of the Hubbard model. Previous QMC simulations support edge-state ferromagnetism in sufficiently wide zigzag terminated ribbons. We extended these calculations to include the class of chiral graphene nanoribbons and investigate the influence of chirality and ribbon width on spin-spin correlations. The static magnetic correlations are found to rapidly increase with the width of the ribbons for all chiralities, such that already for ribbons of moderate widths we observe a strong trend towards mean-field-type ferromagnetic correlations along the edges. We extract dynamical edge state signatures which can be used to detect edge-state magnetism by scanning tunneling microscopy.

MA 13.4 Tue 10:15 H17

Even-odd effects in NSN scattering problems: Application to graphene nanoribbons — •Francois Crepin[1], Hans Hettmansperger[1], Patrik Recher[2], and Bjoern Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Wuerzburg, 97074 Wuerzburg, Germany — [2]Institute for Mathematical Physics, TU Braunschweig, 38106 Braunschweig, Germany

We study crossed Andreev reflection (CAR) of electrons or holes in normal metal-superconductor-normal metal junctions and highlight some very strong effects of the underlying lattice. In particular, we demonstrate that for sharp interfaces and under certain, albeit generic, symmetry conditions, the CAR probability exactly vanishes for an even number of atoms in the superconducting region. This even-odd effect applies notably to NSN junctions made of graphene nano-ribbons with armchair edges and for zigzag edges with somewhat more restrictive conditions. We analyze its robustness towards smoothing of the boundaries or doping of the sample.

MA 13.5 Tue 10:30 H17

Efficient quantum transport simulation for bulk graphene heterojunctions: Klein backscattering revisited — •Ming-Hao Liu and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

The quantum transport formalism based on tight-binding models is known to be powerful in dealing with a wide range of open physical systems subject to external driving forces but is, at the same time, limited by the memory requirement's increasing with the number of atomic sites in the scattering region. Here we demonstrate how to achieve an accurate simulation of quantum transport feasible for experimentally sized bulk graphene heterojunctions at a strongly reduced computational cost [1]. Without free tuning parameters, we show excellent agreement with recent experiments on Klein backscattering [2,3].

[1] M.-H. Liu and K. Richter, Phys. Rev. B **86**, 115455 (2012).
[2] A. F. Young and P. Kim, Nat. Phys. **5**, 222 (2009).
[3] S.-G. Nam, D.-K. Ki, J. W. Park, Y. Kim, J. S. Kim, and H.-J. Lee, Nanotechnology **22**, 415203 (2011).

MA 13.6 Tue 10:45 H17

Combined effect of vacancies and strain on the conductance of graphene nanoribbons — •Thomas Lehmann, Dmitry A. Ryndyk, and Gianaurelio Cuniberti — Institute for Materials Science, Dresden University of Technology, 01062 Dresden, Germany

The understanding and engineering of electron properties of carbon-based nanostructures, in particular graphene nanoribbons, is an important challenge for modern theory of nanoscale systems. We investigate the influence of vacancy defects and uniaxial strain on the electronic transport properties of intermediate-scale graphene nanoribbons using the numerical approach based on the semi-empirical or ab initio based tight-binding model, the Landauer-Büttiker formalism and the recursion method for Green functions. We calculate the transmission of graphene nanoribbons in the quantum coherent regime with different types and concentration of defects. Further, we apply uniform planar tension to non-ideal graphene ribbons with randomly distributed and oriented single and double vacancies and Stone-Wales defects. Since transport characteristics of graphene are found to be very sensitive to edge termination and aspect ratio and it has been shown that energy gaps can emerge under critical strain, the interplay of both effects needs to be studied.

15 min. break

MA 13.7 Tue 11:15 H17

Spin conductance of diffusive graphene nanoribbons — •Jan Bundesmann[1], Ming-Hao Liu[1], Inanc Adagideli[2], and Klaus Richter[1] — [1]University of Regensburg, Regensburg, Germany — [2]Sabanci University, Istanbul, Turkey

Graphene, when cut along a zigzag edge, shows a strongly increased density of states at energies close to the charge neutrality point. The electron states that are the source of this increased DOS are pseudospin-polarized, i.e. they occupy mainly one sublattice, while their wavefunction decays exponentially from the zigzag edge.

In such systems one expects magnetic ordering which anifests as an antiferromagnetic alignment of the two sublattices. Due to the pseudospin polarization of the states finite local magnetic moments appear along the edges.

We investigate how the formation of these local magnetic moments influences charge and spin transport in graphene. It will be shown how this can lead to a finite spin conductance of a single graphene nanoribbon and that within the localized transport regime the spin conductance fluctuations exhibit universal behaviour in the sense that they don't depend on the exact modelling of the magnetization and even a large amount of edge roughness does not lead to deviations from this universal behaviour.

MA 13.8 Tue 11:30 H17

Superlattice Effects on Electronic- and Transport Properties of Nanomaterials — •Fedor Tkatschenko, Viktor Krueckl, and Klaus Richter — Universität Regensbug, Germany

As recently discoverded by various groups [1,2] the electronic properties of two dimensional systems such as graphene show interesting characteristics in presence of superlattices including the emergence of extra Dirac points accompanied by an anisotropic velocity renormalization. Other interesting effects are Bloch-oscillations in presence of resonant Zener tunneling [3] giving rise to a negative differential conductance in the current voltage characteristics.

We focus on a scalar superlattice system extended by a constant mass term which opens a gap between the valance and conduction band in the minibandstructure. Analytical calculations within the effective Dirac model show that it is possible to tune the energy gap by variation of the superlattice amplitude. By additional numerical calculations based on the tight-binding model we confirm the analytical results.

[1] L. Brey and H. Fertig, Phys. Rev. Lett. **103**, 046809 (2009)
[2] M. Barbier, P. Vasilopoulos, and F. Peeters, Phys. Rev. B **81**, 075438 (2010)
[3] V. Krueckl and K. Richter, Phys. Rev. B **85**, 115433 (2012)

MA 13.9 Tue 11:45 H17

Hot Spots and Boundary Conditions in the Quantum Hall Effect — •Tobias Kramer — Universitaet Regensburg, Inst. Theor. Physik, Germany

I discuss the influence of metallic boundary conditions due to the device contacts on the observation and current distribution in the quantum Hall effects. The current density differs in the presence of hot-spots completely from the often assumed edge-state transport picture. A model for transport in graphene [1] based on the self-consistent solution of the classical Hall effect [2] is put forward.

[1] T. Kramer, C. Kreisbeck, V. Krueckl, E. Heller, R. Parrott, and C.-T. Liang, Phys. Rev. B **81**, 081410(R) (2010)
[2] T. Kramer, V. Krueckl, E. Heller, and R. Parrott, Phys. Rev. B **81**, 205306 (2010)

MA 13.10 Tue 12:00 H17

Current resonances in graphene with time dependent potential barriers — Sergey E. Savel'ev[1], •Wolfgang Häusler[2], and Peter Hänggi[2] — [1]Department of Physics, Loughborough University, United Kingdom — [2]Universität Augsburg, Germany

A method is derived to solve the massless Dirac-Weyl equation describing electron transport in a mono-layer of graphene with a scalar potential barrier $U(x,t)$, homogeneous in the y-direction, of arbitrary x- and time dependence. Resonant enhancement of both electron backscattering and currents, across and along the barrier, is predicted when the modulation frequencies satisfy certain resonance conditions. These conditions resemble those for Shapiro-steps of driven Josephson junctions. Surprisingly, we find a non-zero y-component of the current for carriers of zero momentum along the y-axis.

[1] Sergey E. Savel'ev, Wolfgang Häusler, Peter Hänggi, Phys. Rev. Lett. **109**, 226602 (2012).

MA 13.11 Tue 12:15 H17

Mie scattering analogon in graphene: particle confinement, scattering resonances, and Fano effect — •Rafael Leslie Heinisch, Christian Schulz, Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald

We study the scattering of an incident electron by a circular step in a graphene monolayer in analogy to Mie scattering of light by a sphere. Klein tunnelling results in the absence of backscattering and often entails enhanced forward scattering. For low electron energies we identify sharp resonances originating from quasi-bound states at the dot. The energy and dot radius dependent temporary electron trapping significantly increases the electron density in the dot and induces a vortex pattern in the current field. The angle-resolved scattering exhibits Fano resonances which - counter-intuitive for Klein tunnelling - dramatically suppress forward scattering.

This work is supported by the DFG through SPP 1459.

MA 13.12 Tue 12:30 H17

Mechanical strain on graphene nanoribbons in contact with metal electrodes — •Arezoo Dianat, Dmitry A. Ryndyk, and Gianaurelio Cuniberti — Institute for Materials Science, Dresden University of Technology, 01062 Dresden, Germany

Carbon-based materials are recently of great interest for electronic devices. One of the important issues in graphene based nanoelectronics is to control its electronic and transport properties. The manipulation of electronic properties of graphene nanoribbons (GNR) has been suggested via mechanical strain, vacancies and chemical doping. From modeling point of view, few studies have been reported to investigate the electronic properties of mechanically stretched GNR in a contact with metal electrodes. In this work, we aim to elucidate the combined effects of mechanical strain and the role of metal contact area on the electronic and transport properties of GNR.

The structural and electronical properties of stretched GNR on Nickel and Palladium surfaces with different contact area and suspended strained graphene junction between metal electrodes are investigated by means of density functional theory using Vienna Ab initio Simulation Package (VASP). The structure stability as well as stress-strain curve are analyzed for several strain coefficients.