TT 14: TR: Graphene 2

Time: Tuesday 9:30–12:45 Location: H21

TT 14.1 Tue 9:30 H21

Relativistic quantum Corbino effect in graphene — •Adam Rycerz — Institut für Theoretische Physik, Universität Regensburg, D–93040, Germany — Marian Smoluchowski Institute of Physics, Jagiellonian University, Reymonta 4, PL–30059 Kraków, Poland

Electron transport through the Corbino disk in graphene is studied in the presence of uniform magnetic fields. At the Dirac point, we observe conductance oscillations with the flux piercing the disk area Φ_d, characterized by the period $\Phi_0 = (2h/e)\ln(R_o/R_i)$, where R_o (R_i) is the outer (inner) disk radius. The oscillations magnitude increase with the radii ratio and exceed 10% of the average conductance for $R_o/R_i \geqslant 5$ in the case of the normal Corbino setup, or for $R_o/R_i \geqslant 2.2$ in the case of the Andreev-Corbino setup. At a finite but weak doping, the oscillations still appear in a limited range of $|\Phi_d| \leqslant \Phi_d^{max}$, away from which the conductance is strongly suppressed. At large dopings and weak fields we identify the crossover to a ballistic transport regime.

[1] A. Rycerz, arXiv:0909.3018 (unpublished).

TT 14.2 Tue 9:45 H21

Electrical transport and low-temperature scanning tunneling microscopy of microsoldered graphene — •Viktor Geringer[1], Dinesh Subramaniam[1], Ann-Kathrin Michel[1], Bart Szafranek[2], Daniel Schall[2], Alexander Georgi[1], Torge Mashoff[1], Daniel Neumaier[2], Marcus Liebmann[1], and Markus Morgenstern[1] — [1]II. Physikalisches Institut, RWTH Aachen and JARA-FIT, Otto-Blumenthal-Straße, 52074 Aachen — [2]Advanced Microelectronic Center Aachen (AMICA), Otto-Blumenthal-Straße 25, 52074 Aachen

Using the recently developed technique of microsoldering [1], we perform a systematic transport study of the influence of PMMA on graphene flakes revealing a doping effect of up to $\Delta n = 3.8\times10^{12}$ cm^{-2}, but a negligible influence on mobility and gate voltage induced hysteresis. Moreover, we show that the microsoldered graphene is free of contamination and exhibits a very similar intrinsic rippling as has been found for lithographically contacted flakes. Finally, we demonstrate a current induced closing of the previously found phonon gap appearing in scanning tunneling spectroscopy experiments, strongly non-linear features at higher bias probably caused by vibrations of the flake and a B-field induced double peak attributed to the 0. Landau level of graphene.

[1] Ç. Ö. Girit and A. Zettl, Appl. Phys. Lett. 91, 193512 (2007).

TT 14.3 Tue 10:00 H21

Spin injection in graphene spin valve devices via thin MgO barriers — •Tsung-Yeh Yang[1], Julia Samm[1], Marc Drögeler[1], Sebastian Blaeser[1], Frank Volmer[1], Mihaita Popinciuc[1], Jayakumar Balakrishnan[2], Ahmet Avsar[2], Manu Jaiswal[2], Mingang Zheng[2], Bernd Beschoten[1], Barbaros Oezyilmaz[2], and Gernot Güntherodt[1] — [1]II. Physikalisches Institut, RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany — [2]Department of Physics, National University of Singapore, 2 Science Drive 3 Singapore 117542

We report all-electrical spin transport measurements in non-local spin valve structures on graphene at room temperature. The graphene flakes were deposited on Si/SiO_2 substrates by mechanical exfoliation. The application of a back gate voltage allows for continuous control of the charge carrier type and density. Using ferromagnetic Co electrodes, efficient spin injection/detection was realized via thin MgO layers introduced between Co and graphene. Spin valve and Hanle spin precession measurements were performed for various charge carrier densities. The measurements at room temperature reveal the charge carrier mobilities of 4-5x10^3 cm^2/Vs and spin relaxation lengths of about 3 micrometers in the metallic conduction regime. Temperature dependent measurements of the Co/MgO/graphene contacts resistances indicate that the thin MgO layers behave as tunnel barriers.

This work is supported by DFG through FOR 912.

TT 14.4 Tue 10:15 H21

Direct measurement of the electron mean free path in few layer graphene samples — •Srujana Dusari, Jose Barzola-Quiquia, and Pablo Esquinazi — Division of Superconductivity and magnetism, Institute for Experimental Physics II, University of Leipzig, 04103 Leipzig, Germany

The large coherence length of the electrons in graphite is expected to lead to a long electronic mean free path and to a large spin-diffusion length even at room temperature [1]. The aim of this work is the direct measurement of the electron mean free path, Fermi wavelength and mobility and their temperature dependence in multigraphene samples, i.e. micrometer large few layer graphene (FLG) samples with thickness below 100 nm. This is possible by studying the electronic transport through constrictions using specific design and nanostructuring of the sample. By measuring the resistance before and after making constrictions of different size it is possible to obtain the necessary parameters [1]. We developed a new method to avoid Ga+ ion contamination while making the constriction on the samples. First results on the temperature dependence of the mean free path in FLG samples obtained without free parameters will be presented.

[1]. N García, P. Esquinazi, J. Barzola-Quiquia, B. Ming, and D. Spoddig, Phys. Rev. B 78, 035413 (2008).

TT 14.5 Tue 10:30 H21

Electronic properties of graphene nanoribbons under gate electric fields — •Tobias Burnus[1], Daniel Wortmann[1], Yuriy Mokrousov[1], Gustav Bihlmayer[1], Stefan Blügel[1], and Klaus Michael Indlekofer[2] — [1]Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Hochschule RheinMain, Unter den Eichen 5, 65195 Wiesbaden, Germany

Graphene nanoribbons (GNR) hold great future promise for field-effect transistor and quantum dot (QD) devices. The gate electrodes and the electric field distribution play a crucial role. For a realistic description of a quantum dot, the many-body interaction of the few electrons in the quantum dot have to be described properly. The QD itself is formed by the vast number of electrons in a many nanometer long ribbon under the presence of a gate. As a first step, the GNR is calculated using density-functional theory (DFT), where the gate electrode is simulated by an inhomogeneous charge-sheet placed atop of the ribbon. Hereby, all electrons in the GNR are taken into account and one can directly calculate the dielectric constant ε and changes in the charge density due to the applied voltage on the gates. Using this technique, adatoms or different ribbon terminations can be taken into account. Based on the resulting matrix elements, the few electron problem of the GNR QD is treated within a relevant many-body subspace by means of configuration interaction (CI). In the presentation, the first result along this line will be shown. The work is supported by the DFG Research Unit 912 “Coherence and Relaxation Properties of Electron Spins”.

TT 14.6 Tue 10:45 H21

How Graphene-like is Epitaxial Graphene? Quantum Oscillations and Quantum Hall Effect — •Johannes Jobst[1], Daniel Waldmann[1], Florian Speck[2], Roland Hirner[2], Duncan K. Maude[3], Thomas Seyller[2], and Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [3]Laboratoire des Champs Magnétiques Intenses, 25 Avenue des Martyrs, 38042 Grenoble, France

We report on the transport properties – in particular charge carrier density, mobility, conductivity and magnetoconductance – of high-quality single-layer graphene. Graphene was epitaxially grown on the silicon terminated face of a semi-insulating 6H silicon carbide substrate and then patterned into devices of different geometry and size. Large samples as well as submicrometer-sized Hall bars which are entirely lying on atomically flat substrate terraces yield similar transport properties confirming the uniformity of the epitaxial process. In high magnetic fields Shubnikov-de Haas oscillations with the distinct Landau level spectrum of single-layer graphene are clearly visible in samples with different charge carrier densities. When gated close to the Dirac point, the mobility increases substantially, and the graphene-like quantum Hall effect occurs. This proves that epitaxial graphene is ruled by the same pseudo-relativistic physics observed previously in exfoliated graphene.

15 min. break

TT 14.7 Tue 11:15 H21

Top and bottom gated field effect devices on epitaxial graphene — •Daniel Waldmann[1], Johannes Jobst[1], Florian Speck[2], Thomas Seyller[2] und Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erlangen, Germany

We fabricate high-quality epitaxial graphene devices (Hall bars) for electrical transport measurements. In order to tune the charge density in the graphene layer, we developed different gating schemes (top gate and bottom gate). As a top gate we either used an electrochemical gate employing an ionic liquid or a solid state gate using aluminium oxide. A bottom gate has the advantage of leaving the graphene layer open. We have opted for an implanted conducting layer buried in the semi-insulating silicon carbide substrate. Hence, the SiC above the implanted gate serves both as substrate and gate dielectric. We present experimental data from low temperatures to room temperature which cover a broad range of charge densities including the electron hole transition at the Dirac point. Advantages and limitations of each method are discussed.

TT 14.8 Tue 11:30 H21

Giant Rashba splitting in Au-intercalated graphene — •Dmitry Marchenko[1], Andrei Varykhalov[1], Markus R. Scholz[1], Oliver Rader[1], Gustav Bihlmayer[2], and Emmanuel I. Rashba[3] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie — [2]Institut für Festkörperforschung, Forschungszentrum Jülich — [3]Department of Physics and Center for Nanoscale Systems, Harvard University

The use of graphene for spin transport [1] is generally connected to the small size of its intrinsic spin-orbit coupling leading to a splitting of the order of 0.01 to 0.1 meV [2]. This small value can be enhanced by a Rashba effect from a substrate [3] which couples graphene spin and pseudospin [4]. For the graphene-Au interface created by intercalation of a Au monolayer between graphene and Ni(111) a spin-orbit splitting of $\Delta_{so} \sim 13$ meV was measured [3]. By optimized sample preparation, we obtain now Δ_{so} values of the order of 100 meV near the Fermi energy by spin- and angle-resolved photoelectron spectroscopy, i. e., an enhancement by 3 to 4 orders of magnitude relative to the intrinsic values. We discuss the origin of this large splitting with the help of ab initio density functional calculations using the generalized gradient approximation.

[1] N. Tombros et al., Nature 448, 571 (2007)
[2] J. C. Boettger and S. B. Trickey, Phys. Rev. B 75, 121402(R) (2007); C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 226801 (2005)
[3] A. Varykhalov et al., Phys. Rev. Lett. 101, 157601 (2008)
[4] E. I. Rashba, Phys. Rev. B 79, 161409(R) (2009)

TT 14.9 Tue 11:45 H21

Spin relaxation of conduction electrons in Graphene induced by impurities — Martin Gradhand[1], •Dmitry Fedorov[2], Sergey Ostanin[1], Igor Maznichenko[2], Arthur Ernst[1], Peter Zahn[2], and Ingrid Mertig[2,1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Martin-Luther-Universität Halle, Institut für Physik, D-06099 Halle, Germany

Graphene is a very attractive system for future spintronics applications. Experiments [1,2] have shown unexpected fast spin relaxation of conduction electrons in Graphene. A probable explanation is based on the dominance of the Elliott-Yafet spin relaxation mechanism.

Recently, we have developed a fully relativistic ab initio approach, based on the Korringa-Kohn-Rostoker method, for a theoretical study of the Elliott-Yafet mechanism caused by impurities [3]. Here we present our calculations of the spin-flip scattering time in Graphene via the Elliott-Yafet mechanism and estimate the Dyakonov-Perel spin relaxation time.

[1] N. Tombros et al., Nature 448, 571 (2007)
[2] N. Tombros et al., Phys. Rev. Lett. 101, 046601 (2008)
[3] M. Gradhand et al., submitted to Phys. Rev. B (2009)

TT 14.10 Tue 12:00 H21

The x-ray edge problem in graphene — Georg Röder[1], Grigory Tkachov[2], and •Martina Hentschel[1] — [1]MPI für Physik komplexer Systeme, Dresden — [2]Julius-Maximilians-Universität Würzburg

The excitation of a core electron to the conduction band by an x ray leads to the sudden creation of a localized, attractive potential and triggers the many-body responses that contribute to the x-ray edge problem, namely Anderson orthogonality catastrophe and Mahan's exciton (Mahan-Nozieres-DeDominicis response). We study them in mesoscopic systems, in particular for graphene, where the discrete level structure, boundary effects, and the filling-dependent variations in the density of states cause characteristic deviations from the well-understood bulk (metallic) behavior. The vanishing of the density of states at the Dirac points suppresses the orthogonality catastrophe. In the photoabsorption cross section, and for fillings smaller than half-filling, an additional Fermi-edge singularity develops at the Dirac point, similar to the behavior that, in metals, is known as the opening of a second band. We furthermore discuss the role of edge states that occur on zig-zag edges and their influence on the photoabsorption cross section.

TT 14.11 Tue 12:15 H21

Analog of graphene using microwave photonic crystals — •Maksim Miski-Oglu[1], Stefan Bittner[1], Barbara Dietz[1], Pedro Oria Iriarte[1], Achim Richter[1,2], and Florian Schaefer[3] — [1]Institut für Kernphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]ECT*, Villa Tambosi, I-38100 Villazzano (Trento), Italy — [3]LENS, University of Florence, I-50019 Sesto-Fiorentino (Firenze), Italy

A Dirac spectrum has been measured in a microwave photonic crystal consisting of a triangular lattice of metallic cylinders placed between two metallic plates. Up to a certain excitation frequency the wave propagation in this structure is governed by the 2D Helmholz equation with Dirichlet conditions at the boundaries of the cylinders. Microwave power is coupled into the periodioc structure via one dipole antenna and the reflected power is measured. It is proportional to the local density of states at the position of the antenna. In a Dirac spectrum the local density of states tends to zero linearly with the frequency at the Dirac point where two bands approach each other as a pair of cones. This linear character of the dispersion relation is clearly seen in the measured reflection spectra. These and measured wave functions are presented in the talk. It is argued, that these experiments offer the possibility to study a variety of phenomena connected with graphene as well as with QED in the table top experiments in photonic crystals with well controlled parameters.

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TT 14.12 Tue 12:30 H21

Time-resolved spectroscopy of graphene — •Tim Botzem[1], Tobias Plötzing[1], Bart Szafranek[2], Daniel Schall[2], Daniel Neumaier[2], and Heinrich Kurz[1] — [1]Institut für Halbleitertechnik, RWTH Aachen, Gemany — [2]AMICA, AMO GmbH, Aachen, Gemany

In graphene the coupling of various quasi particles accounts for the ultrafast temporal evolution of nonequilibrium carrier distributions. Hence understanding of the relaxation processes is crucial for designing high speed electronic and photonic devices. For investigating the involved quasi particle interactions we apply femtosecond pump-probe spectroscopy (17 fs temporal resolution) on exfoliated graphene mono- and bilayer flakes prepared on transparent sapphire substrates. Relaxation of hot carriers takes place within the first few tens of femtoseconds after excitation, revealing the strong coupling between the different quasi particles involved. A detailed analysis of the dependence on excitation fluence, carrier concentration and fabrication method will be given.