HL 81: Graphene: Transport

Time: Thursday 14:30–17:15 Location: POT 151

HL 81.1 Thu 14:30 POT 151

Acoustic phonons and spin coherence in graphene nanoribbons — •Matthias Droth and Guido Burkard — University of Konstanz, 78457 Konstanz, Germany

A spintronics approach to quantum information science is considered promising due to the readily available expertise in solid state physics and possibly long coherence times [1]. We investigate a qubit implementation as real electron spin in graphene nanoribbon quantum dots. This system is particularly interesting because it allows for non-local coupling of qubits [2]. Spin coherence is determined by the coupling to nuclear spins and the lattice and the relaxation time T_1 only depends on interaction with phonons. Starting from a continuum model, we derive a full phonon field theory for acoustical phonon modes in a graphene nanoribbon and at the center of the Brillouin zone. We consider fixed boundary conditions at the edges of the quasi-one-dimensional nanoribbon as well as open boundaries. In the latter case, the usual q^2-dependence for out-of-plane modes in bulk is cut off at the zone center (near $q = 0$), where we find a linear dispersion. The transverse and longitudinal sound velocities of the in-plane modes match the literature values for comparable systems [3] and, as expected, all modes approach bulk behavior for wavelengths much smaller than the ribbon width.

[1] D. Loss and D. P. DiVincenzo, Phys. Rev. A **57** (1998).
[2] B. Trauzettel et al., Nature Physics **3** (2007).
[3] L. A. Falkovsky, Phys. Lett. A **372** (2008).

HL 81.2 Thu 14:45 POT 151

p-type doping in graphene nanostructures and electron-phonon coupling of LO-LA phonons in graphene identified by Raman spectroscopy — •Stefanie Heydrich, Michael Hirmer, Christoph Preis, Daniel Hutzler, Jonathan Eroms, Dieter Weiss, Tobias Korn, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We present recent results on graphene etched with antidot lattices and an analysis of the LO-LA phonon around the K-point and its electron-phonon coupling constant.

We utilize fast, high-resolution scans to map graphene antidot flakes on Si/SiO2-substrates. The Raman spectrum is evaluated and height, position and FWHM of the characteristic G (1580 cm^{-1}), D (1350 cm^{-1}) and 2D (2700 cm^{-1}) peaks are plotted for each point.

In flakes patterned with antidot lattices, we find a stiffening of the G-peak on the structured areas compared to unstructured parts, which is due to a p-type doping in the patterned areas [1].

Additionally, we studied the LO-LA mode at the K-point in plain graphene. When exciting with higher laser energies, the peak softens and acquires a pronounced triangular shape. We also extracted the electron-phonon coupling constant [2], which yields an experimental value of about 7x10^{-3}.

[1] S. Heydrich, M. Hirmer, C. Preis et al., Appl. Phys. Lett. **97**, 043113 (2010)
[2] V. Fal′ko, private communication

HL 81.3 Thu 15:00 POT 151

Spin Transport and Spin Precession in Bilayer Graphene with Transparent and Tunneling Ferromagnetic Contacts — •Bastian Birkner, Jonathan Eroms, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

We achieved electrical spin injection with a DC current from a ferromagnetic material (Co) into bilayer graphene with transparent and with tunneling contacts. The approximately 1.4 nm thick AlOx tunnel barrier is produced by depositing Al over the entire sample at 180 K and subsequent oxidation at room temperature. AFM pictures reveal that the Al deposition at low temperature leads to a homogenous tunnel barrier. The I-V-characteristics of the Co/AlOx/graphene junction show non-linear behavior suggesting the absence of pinholes. For both, transparent and tunneling contacts we obtain a clear spin signal in a non-local four terminal scheme whose sign depends on the magnetization orientation (parallel/antiparallel) of the ferromagnetic electrodes. By applying a perpendicular magnetic field we also detect spin precession (Hanle effect) which confirms that the non-local spin signal originates from spin injection and spin transport. Fitting of these Hanle curves yields the spin relaxation time and length as well as the spin injection efficiency. By comparing the results for transparent and tunneling contacts we find that the tunnel barrier enhances the spin signal by a factor 100 and the spin injection efficiency from 1.7 percent to 5 percent.

HL 81.4 Thu 15:15 POT 151

Dynamic Hall effect driven by circularly polarized light in graphene — •J. Karch[1], P. Olbrich[1], M. Schmalzbauer[1], C. Zoth[1], C. Brinsteiner[1], M. Fehrenbacher[1], U. Wurstbauer[1], M. M. Glazov[2], S. A. Tarasenko[2], E. L. Ivchenko[2], D. Weiss[1], J. Eroms[1], R. Yakimova[3], S. Lara-Avila[4], S. Kubatkin[4], and S. D. Ganichev[1] — [1]Terahertz Center, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Linköping University, Linköping, Sweden — [4]Chalmers University of Technology, Göteborg, Sweden

We report the observation of the circular ac Hall effect where the current is solely driven by the crossed ac electric and magnetic fields of circularly polarized radiation [1]. To demonstrate the existence of this effect we studied monolayer graphene sheets. We show that illuminating an unbiased sample with circularly polarized terahertz radiation at room temperature generates - under oblique incidence - an electric current perpendicular to the plane of incidence, whose sign is reversed by switching the radiation helicity. Alike the classical dc Hall effect, the voltage is caused by crossed electric and magnetic fields which are, however, rotating with the light's frequency. The effect is studied in both exfoliated graphene on SiO_2 substrates and epitaxial samples thermally grown on SiC. The photocurrent experiments are carried out using a cw and a high power pulsed terahertz laser. Besides the circular ac Hall effect we observe helicity dependent currents at normal incidence stemming from the illumination of the graphene edges.

[1] J. Karch et al., Phys. Rev. Lett. **105**, 227402 (2010).

HL 81.5 Thu 15:30 POT 151

Magnetotransport property of multigraphene in pulsed magnetic fields up to 62 T — José Luis Barzola Quiquia[1], Humberto Peredo[1], Srujana Dusari[1], •Prasanta Kumar Muduli[1], Carsten Putzke[2], and Thomas Herrmannsdörfer[2] — [1]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, D-04103 Leipzig, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD), Forschungszentrum Dresden-Rossendorf, D-01314 Dresden, Germany

Many properties of the graphene like Dirac fermions, quantum Hall effect and fractional quantum Hall effect can be also observed in few-layers graphene or multigraphene samples. Therefore, magnetotransport study in multigraphene is an interesting area of research. In particular, the high-field properties of multigraphene are rather unknown. Most of the previous studies at high magnetic field were done on bulk graphite. However, those measurements do not reflect the intrinsic properties of graphite due to the influence of lattice defects and impurities. In order to investigate many aspects of high-field phenomena, we have made a detailed study of magnetic field-dependent longitudinal and Hall resistance in micrometer-sized and 30 nm thick multigraphene samples in pulsed magnetic field up to 62 T. We found that most of the features observed in the longitudinal and Hall resistance can be explained in a simple two-band model with nearly compensation of electrons and holes. The magnetoresistance and Hall resistance was found to saturate at high fields as expected within the two-band model. At low temperature, however, the magnetoresistance does not saturate above 20 T.

15 min. break

HL 81.6 Thu 16:00 POT 151

Scanning irradiation of polymers by low-energy ions — •Stefan Lücken, Yuri Koval, and Paul Müller — Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany

We have already shown that nearly any polymer can be graphitized by low-energy ion irradiation. The surface consists of nanometer-sized graphite/graphene flakes [1]. In order to increase the size of these flakes and to enhance the conductivity of the graphitized surface, we introduce a new method of irradiation. A narrow ion beam is scanned gradually across the polymer surface. Using conductivity vs. temperature measurements, we compare samples produced with different parameters of irradiation, like fluence of ions, speed of scanning, and temperature of the samples. We have observed that a decreased width of the beam correlates to an enhanced conductivity of the surface both at room temperature and at 4.2 K. Compared to flood irradiation the conductivity becomes significantly less temperature dependent. We expect further improvements by optimizing beam width and scanning speed.

[1] I. Lazareva, Y. Koval, M. Alam, S. Strömsdörfer, P. Müller, Appl. Phys. Lett. 90, 262108 (2007).

HL 81.7 Thu 16:15 POT 151

Transport measurements on twisted graphene monolayer systems — •Hennrik Schmidt, Thomas Lüdtke, Patrick Barthold, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

A system of two stacked graphene monolayers which are rotated with respect to Bernal stacking exhibits electrical properties quite different to samples of single monolayers or single crystal bilayer systems(1)(2). Magnetotransport measurements at different carrier concentrations are performed on decoupled monolayers being jointly contacted. Two superimposed Shubnikov-de Haas oscillations are observed with a Berrys phase of π each, indicating parallel transport through two graphene monolayers. In the Hall resistance plateaus are observed according to the minima of these oscillations. The bottom layer screens the other one both from backgate voltage and substrate influence leading to a lower carrier concentration but also significantly increased mobilities and scattering times in the upper layer. From temperature dependent measurements the cyclotron masses are obtained showing higher values than expected for a single monolayer. This indicates a reduced Fermi velocity and therefore an interaction of the two layers. In the vicinity of the charge neutrality point an asymetric temperature damping is observed.

(1)H. Schmidt, T. Lüdtke, P. Barthold, E. McCann, V. I. Fal'ko, and R. J. Haug, Appl. Phys. Lett. 93, 172108 (2008)
(2)H. Schmidt, T. Lüdtke, P. Barthold, and R. J. Haug, Phys. Rev. B, 81, 121403(R) (2010)

HL 81.8 Thu 16:30 POT 151

Investigating Aharonov-Bohm oscillations in a monolayer graphene ring structure — •Dmitri Smirnov, Hennrik Schmidt, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We analyse the electronical properties of a monolayer graphene ring. Graphene is obtained by micromechanical cleavage of natural graphite and is placed on a silicon substrate with a 285nm thick silicon dioxide. Monolayer graphene is found and identified via the optical microscope. The ring is formed using plasma etching and has an average radius of 280nm. After that the sample is contacted using standard electron beam lithography. Magnetotransport measurements are performed in a He3 cryostat with a base temperature of 0.5 Kelvin by varying the magnetic field up to 13 Tesla and the charge carrier concentration using an applied back gate voltage. Shubnikov-de-Haas oscillations and Quantum-Hall measurements through the ring show characteristic properties of monolayer graphene. We also observe Aharonov-Bohm oscillations for various charge carrier concentrations for both electron and holes with a period in magnetic field that fits the size of the ring.

HL 81.9 Thu 16:45 POT 151

Graphene solution-gated field effect transistor arrays for sensing applications — •Lucas H. Hess, Pardis Ratsami, Max Seifert, Moritz Hauf, Markus Dankerl, Ian D. Sharp, Martin Stutzmann, and Jose A. Garrido — Walter Schottky Institut, Technische Universität München, Germany

Biosensing and bioelectronic applications have enormously profited from employing field effect transistors (FETs) as transducing devices, mainly due to their intrinsic amplification capability and the high integration offered by semiconductor technology. The sensitivity of so-called solution-gated FETs (SGFETs) largely depends on the charge carrier mobility and the distance between the conductive channel and the surface. On both counts, graphene appears as an ideal candidate for the development of highly sensitive SGFETs. In this work, microscopic graphene SGFET arrays are fabricated on large-scale graphene samples and characterized in aqueous environments. Both, in the electron and hole regime, the measured transconductances are significantly higher than in comparable devices based on silicon or group-III nitride transistors. The low-frequency noise of graphene SGFETs is investigated, revealing an effective gate noise of tens of μV, which compares very well with low-noise silicon devices currently used in bioelectronic applications. An on-chip structure is used for Hall-effect measurements allowing the direct determination of carrier concentrations and mobilities under electrolytic gate control. In combination with a model for the microscopic structure of water at the interface, the effect of the gate potential on charge transport in the graphene layer is analyzed.

HL 81.10 Thu 17:00 POT 151

Polymer Brushes on Graphene — •Max Seifert[1], Marin Steenackers[1,2], Alexander Gigler[3], Ning Zhang[2], Frank Deubel[2], Candy Xuan Lim[4], Kiang Loh[4], José Garrido[1], Rainer Jordan[2,5], Martin Stutzmann[1], and Ian Sharp[1] — [1]Walter Schottky Institut, TU München, Germany — [2]Wacker-Lehrstuhl für Makromolekulare Chemie, TU München, Germany — [3]CeNS and Department of Earth and Environmental Sciences, LMU München, Germany — [4]Department of Chemistry, National University of Singapore, Singapore — [5]Professur für Makromolekulare Chemie, Department Chemie, TU Dresden, Germany

We show that the direct photografting and photopolymerization of styrene yields polystyrene brush layers covalently bound to graphene. The broad applicability of this technique is demonstrated via polymerization on CVD grown graphene on Cu, epitaxial single and few layer graphene on SiC, and reduced graphene oxide. Scanning confocal Raman spectroscopy reveals that photopolymerization results in no significant disruption of the basal plane conjugation of graphene. Atomic force microscopy on few layer graphene reveals delamination due to intercalative polymerization. Finally, direct photopolymerization was attempted with a range of other vinyl monomers, none of which exhibited reactivity with graphene. However, in an alternative route we demonstrate that unreactive monomers can be locally grafted via an intermediate carbon layer formed by electron-beam-induced carbon deposition on the graphene surface.