HL 50: Graphene and Carbon Nanotubes

Time: Thursday 9:30–12:15 Location: H15

HL 50.1 Thu 9:30 H15

Electronic properties of twisted graphene monolayers — •Hennrik Schmidt, Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We investigate the transport properties of two stacked graphene monolayers with a rotational stacking fault in respect to Bernal stacking. Using micromechanical cleavage of graphite as preparation methode, flakes of different thickness, also including folded samples, are deposited on top of a silicon wafer with a 330 nm thick silicon oxide. This folded monolayer graphene forms a system of two very closely spaced layers, decoupled due to the misorientation. Magneto–transport measurements on this decoupled monolayers conducting in parallel are performed variing perpendicular applied magnetic field, backgate voltage and temperature. From the Shubnikov–de Haas oscillations, carrier densities are obtained, being different for the two layers due to screening. Mobilities and scattering times are calculated for both layers and exhibit significantly higher values in the top layer, indicating weaker substrate influence. From the temperature dependence of the Shubnikov–de Haas oscillations, the cyclotron masses are obtained, yielding higher values than for a single monolayer. These masses correspond to reduced Fermi velocities of down to $0.66{\cdot}10^6 m/s$, being consistent with theory.

[1] H. Schmidt, T. Lüdtke, P. Barthold, E. McCann, V. I. Fal'ko, and R. J. Haug, Appl. Phys. Lett. 93, 172108 (2008)

HL 50.2 Thu 9:45 H15

What's the color of graphene ? Black and dark or white and bright ? — •Rainer Stöhr[1], Roman Kolesov[1], Fedor Jelezko[1], Jens Pflaum[2], and Jörg Wrachtrup[1] — [1]3rd Physics Institute, Stuttgart University — [2]Julius-Maximilians-University of Würzburg, Experimental Physics VI and Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern)

In this contribution, we report on the first, to our knowledge, study of non-linear optical properties of graphene and thin graphite flakes. We particularly focus on graphene under picosecond pulsed infrared excitation yielding to a spectrally broad non-linear upconverted luminescence. Several key experiments are discussed to illustrate its characteristics and to clarify its nature. Comparing the effective non-linear coefficient d_{eff} of that process with that of other highly non-linear materials shows that graphene reveals extraordinary performance in terms of its non-linear optical properties. Through rigorous study of this upconverted luminescence as a function of the number of graphite layers, incident laser power and substrate material we introduce a new and superior tool for imaging and quantifying single and multilayered graphene flakes. Comparing this new imaging method with standard techniques like atomic force microscopy and Raman spectroscopy will evidence its excellent properties in terms of imaging quality and the unambiguous thickness determination of multilayer graphene flakes up to twenty layers.

HL 50.3 Thu 10:00 H15

Photon helicity driven electric currents in graphene — •J. Karch[1], P. Olbrich[1], M. Schmalzbauer[1], Ch. Brinsteiner[1], J. Eroms[1], U. Wurstbauer[1], M.M. Glazov[2], S.A. Tarasenko[2], E.L. Ivchenko[2], D. Weiss[1], and S.D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia

We report on the observation of photon helicity driven photocurrents in graphene. The currents are generated in single layer graphene by terahertz radiation from a cw molecular gas laser operating at a wavelength of 118mkm. The photocurrents are measured at normal incidence and reverse their signs upon reversing the radiation helicity. Besides a photon helicity dependent current we also observe a photocurrent in response to linearly polarized radiation. The microscopic mechanisms governing these effects are discussed. The in-plane photocurrents induced by normal incidence of radiation are forbidden by symmetry in an ideal infinite graphene structure. The appearance of such currents are an evidence for a symmetry reduction, for instance, caused by the shape asymmetry of the real finite-size sample, which results in the edge photogalvanic effect. The helicity-dependent and -independent signals demonstrate also a strong dependence on the light incidence angle, i.e. there are remarkable contributions to the photocurrent being odd in the incidence angle. These effects can be attributed to currents in the bulk of the sample and can be described by the circular photon drag effect stemming from the transfer of the photon momentum to the electron subsystem in graphene.

HL 50.4 Thu 10:15 H15

Electronic structures and screening effects in bilayer graphene nanoribbons — •Hengyi Xu[1], Thomas Heinzel[1], and Igor Zozoulenko[2] — [1]Heinrich-Heine-Universität, Düsseldorf — [2]Linköping University, Sweden

Graphene is considered as a promising material for future microelectronics in which the externally controllable of the resistance is crucial. To achieve this purpose, a number of mechanisms to induce an energy gap in single-layer graphene are proposed. Graphene bilayers, however, provide an alternative way to realize this task. Here, we study the electronic properties of bilayer graphene nanoribbons in the presence of a single gate using the tight-binding approach. The Coulomb interactions are incorporated in a self-consistent way within the Hartree approximation. We calculate the density and Hartree potential profiles and compare them with those of the single-layer graphene. It is shown that the fluctuations of the density and potential of bilayers are suppressed and their values decrease due to the Coulomb interaction between layers in contrast to the single-layer graphene. For sufficient thin dielectrics and high external voltages, the potentials of graphene layers diverge clearly and the differences grow linearly as gate voltages increases. This potential difference results in the electron-hole asymmetry of electronic spectrum and energy gaps around the neutrality point in the otherwise metallic graphene bilayers. The sizes of energy gaps are studied as a functions of external gate voltages. The relevant electrostatics of double- and single-gate geometries of bilayer is also discussed.

HL 50.5 Thu 10:30 H15

Inter-valley plasmons and local-field effects in graphene — •Sergey Mikhailov[1] and Timur Tudorovskiy[1,2] — [1]Institute of Physics, University of Augsburg, Germany — [2]Department of Physics, Philipps-University of Marburg, Germany

We develop a theory of the linear electromagnetic response of graphene to a scalar-potential field taking into account local field effects [1]. The electromagnetic properties of graphene are characterized by an infinite dielectric matrix over reciprocal lattice vectors. The spectrum of collective excitations (plasmons) is then determined by the determinant of this matrix. We have calculated the dielectric matrix and the spectrum of plasma waves in graphene using the tight binding approximation.

In the long-wavelength limit (the plasmon wavevector is small as compared to the inverse lattice constant) our results reproduce those obtained in the Dirac model [2]. For the wavevectors close to the corners of the hexagon-shaped Brillouin zone we have found (arXiv:0910.2163v1) new low-frequency two-dimensional plasmon modes with a linear spectrum. These intra-band inter-valley plasmons are related to the electronic transitions between the two nearest Dirac cones in the electronic Brillouin zone. Their group velocity exceeds the Fermi velocity of graphene electrons and their Landau damping vanishes at zero temperature.

This work was supported by the Deutsche Forschungsgemeinschaft.

[1] S. L. Adler, Phys. Rev. 126, 413 (1962)

[2] B. Wunsch et. al., New J. Phys. 8, 318 (2006); E. H. Hwang and S. Das Sarma, Phys. Rev. B 75, 205418 (2007)

15 Min. Coffee Break

HL 50.6 Thu 11:00 H15

Hysteresis in the Field Effect of Bilayer Graphene at Low Temperatures — •Patrick Barthold, Thomas Lüdtke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We present transport measurements on single crystal bilayer graphene at low temperatures down to 1.5 K. In the field effect a strong hysteresis is observed. The bilayer graphene is deposited via micromechanical cleavage on top of a 265 nm SiO_2/Si substrate. Using standard e-beam lithography the device is structured and leads are evaporated to the device (Ti/Au). As the field effect is measured at T=1.5 K in a four-terminal setup the neutrality point varies in dependence of the direction the back-gate voltage is swept. This splitting in the neutrality points (hysteresis) changes with different sweeping rates. At the lowest rate (6.6 mV/s) the splitting is almost zero, whereas it rises with faster rates. By applying a perpendicular magnetic field to the device the hysteresis changes dramatically. We attribute this behaviour to molecular adsorbates which act as charge traps.

HL 50.7 Thu 11:15 H15

Phase coherent transport in graphene nanoribbons — •Silvia Schmidmeier, Daniel Neumaier, Dieter Weiss, and Jonathan Eroms — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

Quantum interference effects result in quantum corrections of the conductivity. One of these corrections, which results from interference of electron waves that are scattered by disorder and form closed trajectories, cause a decrease of conductivity and is well-known as weak localization. Another correction of the conductivity is due to universal conductance fluctuations, which appear when the phase coherence length is comparable to the sample length.

Here we investigate electronic transport in graphene nanoribbons (GNR). The lateral confinement of the charge carriers in the quasi one-dimensional ribbons creates an energy gap near the charge neutrality point, where the gap depends on the width of the GNR. The GNRs were fabricated by electron beam lithography and plasma etching techniques. Widths of 50nm were achieved. We measured the magnetoconductance in a perpendicular magnetic field for different temperatures down to 20mK. These measurements allowed us to determine the phase coherence length both from weak localization as well as from the amplitude of the universal conductance fluctuations. At mK temperatures the phase coherence length exceeds the lateral dimensions of the GNR, indicating that etching does not destroy the phase coherent properties of the sample.

HL 50.8 Thu 11:30 H15

Magnetotransport behaviour of Graphene on GaAs — •Ulrich Wurstbauer, Ursula Wurstbauer, Jonathan Eroms, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

The influence of the substrate on the transport properties of graphene generated recently some interest. To clarify the role of the underlying substrate, we perform (magneto)-transport experiments of graphene and few-layer graphene on (001)-GaAs substrates, grown by molecular beam epitaxy. The graphitic flakes on GaAs were detected and their morphology was characterized by scanning electron and atomic force microscopy.

We found that graphene follows the curvature of the sustaining substrate very closely. Low-temperature transport measurements of graphene on these substrates reveal a conventional electric field dependence indicated by a resistance maximum at the charge neutrality point. It turns out that the intrinsic doping on GaAs substrates is always hole like. Magnetotransport measurements in the low-field region display a superposition of universal conductance fluctuations and weak localization, both more pronounced on GaAs substrates than on SiO_2 and visible up to 75 K. Additionally, in the high field region Hall-effect and Shubnikov-de Haas oscillations were observed indicating quantized transport.

HL 50.9 Thu 11:45 H15

Time-resolved ultrafast photocurrent spectroscopy using THz stripline circuits on carbon nanotubes — •Leonhard Prechtel[1], Li Song[2], Stefan Manus[2], Dieter Schuh[3], Werner Wegscheider[3,4], and Alexander Holleitner[1,2] — [1]Walter Schottky Institut and Physik Department, TUM Garching, Germany — [2]Fakultät für Physik and Center for NanoScience (CeNS), LMU München, Germany — [3]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [4]Laboratorium für Festkörperphysik, HPF E 7, ETH Zürich, Switzerland

The exciton dynamics in carbon nanotube devices are typically detected in a time-resolved way by optical techniques such as the transient absorption technique and the time-resolved photoluminescence spectroscopy. Both methods focus mainly on the dynamics of charge carriers within carbon nanotubes. Many questions remain concerning the separation and the transport of photo-generated charge carriers to source and drain leads. We address these questions by a novel ultrafast photocurrent spectroscopy, which is based on a common pump-probe technique. The experimental setup with a picosecond time-resolution will be introduced, and first results of the time-resolved photocurrent of carbon nanotubes will be shown. We will discuss polarization and charge separation effects within the carbon nanotubes as well as the influence of hot phonons, the bath temperature, and the bias voltage on the photocurrent across carbon nanotubes.

HL 50.10 Thu 12:00 H15

Low-temperature transport through suspended single-wall nanotube resonators — •Daniel Schmid, Dominik Preusche, Christoph Strunk, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Suspended carbon nanotubes not only present fascinating electronic properties, but also provide excelling high-frequency and low-dissipation mechanical resonators. In addition, recent work has shown direct strong interaction between electronic tunneling and mechanical motion in the Coulomb blockade regime. We present results on transport through such nano-electromechanical devices at ultra-low temperature, using a recently developed technique to detect the nanomechanical motion in dc current signals. Different contact metals are discussed for their influence on electronic transport and their suitability.