HL 101: Graphene IV: Electronic Properties and Structure

Time: Friday 10:30–13:00 Location: S051

HL 101.1 Fri 10:30 S051

Graphene tunable transparency to tunneling electrons: A direct tool to measure the local coupling. — •Héctor González Herrero[1], Antonio Javier Martínez Galera[2], Miguel Moreno Ugeda[3], Delia Fernández Torre[4], Pablo Pou[4], Rubén Pérez[4], José María Gómez Rodríguez[1], and Iván Brihuega[1] — [1]Dept. Física de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain — [2]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany — [3]CIC nanoGUNE, E-20018 Donostia-San Sebastian, Spain — [4]Dept. Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

Graphene grown on metals has proven to be an excellent approach to obtain high quality graphene films. However, special care has to be taken in order to understand the interaction of graphene with the substrate since it can strongly modify its properties.

We have grown one monolayer graphene on Cu (111) by using a new technique. By means of low temperature STM/STS experiments, complemented by density functional theory calculations, we have obtained information about the structural and electronic properties of our graphene samples with atomic precision and high energy resolution. Our work shows that depending on the STM tip apex and the tunnel parameters we can get access to either the graphene layer, the copper surface underneath or even both at the same time. Moreover, this approach can also be applied to investigate the interaction of point defects in the graphene layer with the underlying substrate .

HL 101.2 Fri 10:45 S051

Excitons and the XNLD of higly oriented pyrolytic graphite and graphene - theory and experiment — •Dominik Legut[1], Robert Laskowski[2], Peter M. Oppeneer[3], Christine Jansing[4], Markus Gilbert[4], Andreas Gaupp[4], Hans-Christoph Mertins[4], Andrey Sokolov[5], Suk-Ho Choi[6], Hud Wahab[7], and Heiko Timmers[7] — [1]IT4Innovations Centre, VSB-TU Ostrava, Ostrava, Czech Republic — [2]Institute of High Performance Computing, A*STAR, Singapore — [3]Department of Physics and Astronomy, Uppsala, Sweden — [4]FH Münster, Steinfurt, Germany — [5]HZB, Berlin, Germany — [6]Department of Applied Physics, Kyung Hee University, Korea — [7]University of New South Wales Canberra, Canberra BC, Australia

Reflection spectra of the x-ray natural linear dichroism (XNLD) were calculated on highly oriented pyrolytic graphite (HOPG) and graphene. The π- and σ-excitations stemming from the carbon K-edge are considered. It was computed in the single electron picture within the framework of the standart DFT as the first step. For the better descriptions of the core-hole quasiparticle one can model the Slater transition state employing the supercell calculation with partial hole on one of the carbon atoms with the electron charge distributed over the valence states. Another approach is to solve Bethe-Salpeter equations for the many-body electronic effects. The latter approach clearly identify the excitonic features of π- and σ-excitations HOPG. The spectral shape of the reflectance and XNLD of all three modeles are compared with the experimental data.

HL 101.3 Fri 11:00 S051

Direct measurement of chiral symmetry breaking in strained graphene by STM — Alexander Georgi[1], •Peter Nemes-Incze[1], Ramon Carillo-Bastos[2], Martin Schneider[3], Dinesh Subramaninam[1], Torge Mashoff[4], Daiara Faria[2,5], Silvia Viola Kusminskiy[3], Dawei Zhai[2], Marcus Liebmann[1], Marco Pratzer[1], Ludger Wirtz[6], Nancy Sandler[2], and Markus Morgenstern[1] — [1]RWTH Aachen Univ. and JARA-FIT, Aachen, Germany — [2]Ohio Univ., Athens, Ohio, USA — [3]Freie Univ. Berlin, Berlin, Germany — [4]Johannes Gutenberg-Univ., Mainz, Germany — [5]Univ. Federal Fluminense, Niterói, Brazil — [6]Univ. of Luxembourg, Luxembourg

The breaking of reflection symmetry has important consequences for pseudospin 1/2 particles, such as those used to describe low-energy excitations in graphene. Here we show that forces exerted by the tip of a scanning tunneling microscope induce mechanical strain on sub-nm length scales that acts as a gauge field breaking the chiral symmetry of the system. The parity violation manifests itself as a redistribution of the local density of states between the two sublattices by up to 30%. The effect can be understood as a pseudospin polarization due to a pseudo-Zeeman shift produced by the strain induced pseudo-magnetic field. This interpretation is supported by tight binding simulations and effective Dirac model calculations. The tunable pseudo-magnetic field might be used for the ultra fast separation of electrons of different valleys providing a switchable valley filter as a basic element for valleytronics.

HL 101.4 Fri 11:15 S051

Layer symmetry breaking field and conductivity in graphene twist bilayer — •Nicolas Ray, Sam Shallcross, and Oleg Pankratov — Lehrstuhl für theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7 B2, 91058 Erlangen, Germany

The rich electronic structure of the graphene twist bilayer includes both a decoupled large angle limit and a strongly coupled small angle limit [1]. We consider the in-plane conductivity via a linearised Boltzmann equation [2] over the full angle range, both with and without a layer-perpendicular electric field. The layer perpendicular electric field is shown to lead to a strong suppression of conductivity at certain "hot spots" in the twist angle and energy phase space.

[1] S. Shallcross et al., Phys. Rev. B 87, 245403, 2013; [2] E. Mariani et al., Phys. Rev. B 86, 165448, 2012.

HL 101.5 Fri 11:30 S051

How partial dislocations may make bilayer graphene both an insulator and a conductor — Heiko Weber[1] and •Sam Shallcross[2] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7 A3, 91058 Erlangen, Germany — [2]Lehrstuhl für theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7 B2, 91058 Erlangen, Germany

Recently imaged partial dislocations in bilayer graphene [1] have been shown to have a profound impact on transport properties for the case of bilayer graphene on SiC [2]. We demonstrate that the presence of only a few partial dislocations in high quality suspended bilayer graphene can both destroy the intrinsic minimal conductivity of the structurally perfect bilayer, or even enhance it, depending only on the configuration of the partials. The provides a natural explanation for the peculiar behaviour of suspended bilayer graphene, in which seemingly very similar samples are found to be either insulating or conducting in nature.

[1] B. Butz, C. Dolle, F. Niekiel, K. Weber, D. Waldmann, H. B. Weber, B. Meyer, E. Spiecker, Nature 505, 533 (2014). [2] F. Kisslinger, C. Ott, C. Heide, E. Kampert, B. Butz, E. Spiecker, S. Shallcross, H. B. Weber, Nature Physics 11, 650 (2015).

HL 101.6 Fri 11:45 S051

Electronic structure of partial dislocations in bilayer graphene — Dominik Weckbecker and •Sam Shallcross — Lehrstuhl für theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7 B2, 91058 Erlangen, Germany

We present electronic structure calculations for the partial dislocations recently imaged in bilayer graphene on SiC [1,2]. We use an effective field method which allows us to treat both a realistic experimental situation of many disordered dislocations in a sample area of a square micrometer as well as model systems in which the dislocations are ordered. We find near the Dirac point a charge pooling on the bilayer graphene segments, as well as a curious energy dependent localization on the partial lines and partial nodes. We consider the presence of an external out-of-plane magnetic field and identify current circulations associated with partial lines.

[1] B. Butz, C. Dolle, F. Niekiel, K. Weber, D. Waldmann, H. B. Weber, B. Meyer, E. Spiecker, Nature 505, 533 (2014). [2] F. Kisslinger, C. Ott, C. Heide, E. Kampert, B. Butz, E. Spiecker, S. Shallcross, H. B. Weber, Nature Physics 11, 650 (2015).

HL 101.7 Fri 12:00 S051

Deformation in graphene and few layer graphenes: interlayer gauge fields and optical deformations — •Nicolas Ray[1], Fabian Rost[1], Reena Gupta[2], Sangeeta Sharma[2], Oleg Pankratov[1], and Sam Shallcross[1] — [1]Lehrstuhl für theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7 B2, 91058 Erlangen, Germany — [2]Max-Planck-Institute for Microstructure Physics, Weinberg 2, 06120 Halle, Germany

We present a general theory of deformations in graphene and few layer graphenes. In single layer graphene we consider both acoustic and optical deformations, and show that the latter can generate chiral gap opening fields. For the case of few layer graphenes we derive a general interlayer gauge term that relates the local stacking vector to an off-diagonal non-Abelian field. We show that this general result reduces to well known cases such as the Bernal or twist graphene bilayer, but can also be used to treat more complex situations such as partial dislocations in bilayer graphene.

HL 101.8 Fri 12:15 S051

Substrate nanofacets as a stamp for graphene charge carrier modulations — •Jan Honolka[1], Martin Vondracek[1], Ladislav Fekete[1], Jaromir Kopecek[1], Jan Lancok[1], Dipankar Kalita[2], Johann Coraux[2], and Vincent Bouchiat[2] — [1]Institute of Physics, ASCR, CZ-Prague — [2]Department Nanosciences, CNRS, F-Grenoble

We report on 1D quasiperiodic modulations of graphene electron doping, probed by spatial mapping of the electronic band structure in wave-vector-resolved photoemission microscopy (k-PEEM).

Sampling local topography and diffraction, we show that a nanometer-scale periodic structuration and electronic doping by several 0.1eV can be achieved straightforwardly in graphene, as-grown by CVD on high-index vicinal copper. The pattern consists of a rooftop-like alternance of Cu facets of distinctive symmetries, formed by surface energy minimization at the atomic scale, which drives copper and carbon mass-transfers during high-temperature CVD.

The general concept of this work can be extended towards other chemical vapor deposited 2D systems of current interest such as semiconducting transition metal dichalcogenides, e.g. MoS_2, insulating hexagonal boron nitride (h-BN) monolayers, and respective hybrid structures.

HL 101.9 Fri 12:30 S051

Fermi surface nesting in the graphene twist bilayer — •Maximilian Fleischmann, Dominik Weckbecker, Nicolas Ray, Oleg Pankratov, and Sam Shallcross — Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7B2, 91058 Erlangen

Two mutually rotated layers of graphene exhibit an electronic structure that depends profoundly on the rotation angle of the two layers [1]. This rich electronic structure invites the possibility of significant band engineering control in the small angle limit [2]. We demonstrate that the small angle limit exhibits a massive Fermi surface nesting in the presence of a perpendicular electric field of strength greater than ~ 100 mV/Å. We describe in detail the unusual band topology in this nested region of the energy field phase space, and discuss some of the many body effects likely to be induced by such strong Fermi surface nesting.

[1] S. Shallcross et al., Phys. Rev. B **87**, 245403, 2013.
[2] D. Weckbecker et al., *submitted*

HL 101.10 Fri 12:45 S051

Force-induced dynamic STM mapping and picking of freestanding graphene membranes — •Bernd Uder, Wolf-Rüdiger Hannes, and Uwe Hartmann — Fachrichtung Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

Scanning Tunneling Microscopy (STM) of freely suspended membranes only a few atomic layers thick is inherently challenging. Membrane and tip instabilities are easily induced and must be controlled by careful adjustment of scan and regulation parameters. So far only little STM work has been reported on this surface type. We demonstrate seamless imaging of few-layered suspended graphene, from 10μm x 10μm scan width down to 25nm x 25nm. On the scale of 5 - 10nm, we observe corrugations rippled in one dimension. Larger structures are resolved by choosing scan parameters such that vibrational modes are triggered in certain reproducible regions, possibly corresponding to monolayer regions or fragments. Bias voltage ramps are employed for controlled and reversible membrane picking with the observation of flipping processes of the rippled structure.