O 82: Graphene IV

Time: Friday 11:15–13:00 Location: H31

O 82.1 Fri 11:15 H31

Spin-Splitting of Graphene/Au/SiC investigated with Spin- and Angle-Resolved Photoemission Spectroscopy — •Isabella Gierz[1], Fabian Meier[2], Bartosz Slomski[2], Jan Hugo Dil[2], Jürg Osterwalder[3], Christian R. Ast[1], and Klaus Kern[1,4] — [1]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [3]Physik-Institut, Universität Zürich, CH-8057 Zürich, Switzerland — [4]Institut de Physique des Nanostructures, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Due to its high carrier mobility graphene is a promising candidate for electronics applications. For possible applications in the field of spintronics, however, a spin-splitting of the graphene band structure is required. In order to lift the spin degeneracy in graphene we exploit the Rashba-Bychkov effect where the presence of heavy elements with a strong atomic spin-orbit interaction in a symmetry-broken environment leads to a spin-splitting of the two-dimensional band structure on a crystal surface. The intrinsic spin-orbit interaction of carbon is negligible but [1] predicts that defects, i.e. local distortions of the graphene lattice from sp^2 to sp^3 hybridization, lead to a strong enhancement of the spin-orbit coupling. Furthermore, we have shown recently that it is possible to intercalate epitaxial graphene on SiC with gold atoms, thereby adding heavy atoms to the system. We present spin- and angle-resolved photoemission spectroscopy measurements on pristine epitaxial graphene as well as gold intercalated graphene on SiC.

[1] A. H. Castro Neto et al., *Phys. Rev. Lett.*, **103**, 026804 (2009)

O 82.2 Fri 11:30 H31

High Resolution Electron Energy Loss Spectroscopy on Graphene/SiC(0001) — •Roland J. Koch[1], Michael Endlich[1], Thomas Haensel[1], Syed Imad-U. Ahmed[1], Thomas Seyller[2], and Juergen A. Schaefer[1,3] — [1]Institut für Physik and Institut für Mikro- und Nanotechnologien, TU-Ilmenau, Ilmenau, Germany — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erlangen-Nürnberg, Germany — [3]Department of Physics, Montana State University, Bozeman, Montana, USA

The recent experimental realization of single-layer graphene sheets has led to intense efforts to understand its electronic and vibrational properties in the context of solid state materials physics. In this contribution we investigate the interaction of epitaxial graphene with SiC(0001) using high resolution electron energy loss spectroscopy (HREELS). The focus in this contribution is on the coupling of charge carriers in semi-metallic graphene with the optical phonons of SiC(0001). Due to this coupling the surface optical phonons, the so called Fuchs-Kliewer phonons, completely vanish and two new modes ω_- and ω_+ are observed instead. The energetic position and intensity of these modes depend strongly upon the momentum transferred parallel to the interface ($q_\parallel$), which we investigated in the regime of 0.005 $\AA^{-1}$ to 0.03 $\AA^{-1}$. Simulating our HREELS-data using dielectric theory and solving the Poisson- and Schrödinger equations self consistently allows us to determine the carrier density distribution and the conduction band edge normal to the plane of the graphene/SiC heterostructure.

O 82.3 Fri 11:45 H31

AFM imaging of graphene under ambient conditions — •Michael Enzelberger[1], Viatcheslav Dremov[1], Florian Speck[2], Catharina Knieke[3], Angela Berger[3], Thomas Seyller[2], Wolfgang Peukert[3], and Paul Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany. — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Germany. — [3]Lehrstuhl für Feststoff- und Grenzflächenverfahrenstechnik, Universität Erlangen-Nürnberg, Germany.

Routine checks of graphene properties during device production can be facilitated significantly, when these measurements can be carried out under ambient conditions. We report on AFM investigations of epitaxial graphene on SiC(0001) and ball-milled graphite. Tapping-mode AFM and Kelvin-probe force microscopy (KPFM) were applied to reveal morphology and work function distribution. Although the absolute values of the work function differences are not meaningful under ambient conditions, the work function contrast from the KPFM data allows to distinguish between single-, bi- and trilayer graphene. Ball-milled graphite shows small flakes of single or multilayer graphene which are covered with surfactant molecules on either side. Also stacks of several graphene sheets separated by surfactant molecules were observed.

O 82.4 Fri 12:00 H31

Low Temperature Epitaxial Graphene on SiC by Carbon Deposition — •Ameer Al-Temimy, Christian Riedl, and Ulrich Starke — Max Planck Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

Epitaxial graphene displays unconventional electronic properties that make it an interesting material for carbon based nanolectronics. The epitaxial growth of graphene on silicon carbide (SiC) is a promising route to achieve large graphene samples. Conventionally, on SiC(0001) in an ultrahigh vacuum (UHV) system, monolayer graphene is prepared by annealing to about 1200 °C. Using low energy electron diffraction (LEED) and angle-resolved ultraviolet photoelectron spectroscopy (ARUPS) we demonstrate that monolayer graphene can also be grown at a lower temperature of about 950 °C under simultaneous carbon deposition. As shown by atomic force microscopy (AFM) the approach of carbon deposition modifies the growth dynamics of graphene so that the initial surface morphology of the SiC crystal is preserved in contrast to the conventional method. On SiC(000$\bar{1}$), LEED demonstrates that the carbon evaporation induced epitaxial graphene grows with a predominant lattice orientation of 0° with respect to the substrate instead of 30° as observed for the conventional UHV preparation. The new approach of carbon evaporation on SiC crystals opens up pathways in the investigation of SiC surface phase diagrams and for low temperature procedures in graphene growth.

O 82.5 Fri 12:15 H31

Quasi-freestanding Graphene on SiC(0001) — •Florian Speck[1], Markus Ostler[1], Jonas Röhrl[1], Johannes Jobst[2], Daniel Waldmann[2], Martin Hundhausen[1], Lothar Ley[1], Heiko B. Weber[2], and Thomas Seyller[1] — [1]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Germany — [2]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Germany

Epitaxial graphene thermally grown on SiC(0001) is a first choice candidate for the development of graphene-based electronics. The graphene layer directly in contact with the substrate is covalently bound and forms the $(6\sqrt{3} \times 6\sqrt{3})R30°$ reconstruction. It lacks the electronic properties of graphene and is thus called buffer layer. Only the next graphene layer, which resides on top of the buffer layer, exhibits the characteristic Dirac cone. Hydrogen can saturate dangling bonds on Si and SiC surfaces and is therefore a promising candidate for a chemical modification of the interface. Riedl et al. demonstrated the conversion of the buffer layer into monolayer graphene by annealing in hydrogen [1]. Here we present a comprehensive spectroscopic study on buffer layer and monolayer graphene samples annealed in hydrogen. Si-H bonds at the interface are detected by infrared absorption spectroscopy, proving the intercalation of hydrogen underneath the buffer layer. The graphene layer formed by this process interacts only weakly with the substrate. Raman spectroscopy indicates the presence of short range defect sites. Hall effect measurements show p-type conduction with hole mobilities up to $1250\,cm^2V^{-1}s^{-1}$ at room temperature.

[1] C. Riedl et al., arXiv:0911.1953v1

O 82.6 Fri 12:30 H31

Crystal Symmetry and Stress in Epitaxial Graphene Films — •Diedrich Schmidt[1] and Taisuke Ohta[2] — [1]Department of Physical Chemistry II, Ruhr-University Bochum, 44780 Germany — [2]Sandia National Laboratories, Albuquerque, NM 87185 USA

We performed combined confocal Raman microspectroscopy and atomic force microscopy (AFM) studies to address discrepancies in the reported electronic properties and characteristic Raman bands of monolayer epitaxial graphene. Monolayer graphene was made by sublimation of Si from a SiC substrate at elevated temperature in an argon environment [1]. Our samples exhibit variation in both the G and 2D peak positions presumably due to strain; similar to previous work [2]. However, our monolayer films show large areas of uniform compressive strain covering $\geq$40% of the surface with nearly equivalent coverage of smaller, quasi strain-relieved regions which are oriented at multiples of

30° to each other. AFM phase data confirm the quasi strain-relieved areas seen in Raman microspectroscopy are physical effects that exist within the monolayer film, or that are induced in the film by interactions with the interface layer. Due to the high symmetry of the C-rich interface layer [3], we propose that these regions are controlled by the interface layer.

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[1] K. V. Emtsev, *et al.*, *Nature Materials* **8**, 203 (2009).
[2] J. A. Robinson, *et al.*, *Nano Letters* **9**, 964 (2009).
[3] K. V. Emstev, *et al.*, *Phys. Rev. B* **77**, 155303 (2008).

O 82.7 Fri 12:45 H31

Plasmons in epitaxial graphene: influence of steps and doping concentration — •Thomas Langer[1,2], Herbert Pfnür[1], Christoph Tegenkamp[1], and Hans Werner Schumacher[2] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]PTB, D-38116 Braunschweig

Collective excitations of the two dimensional electron gas in epitaxial graphene grown on SiC(0001) have been studied. Structural properties were analyzed by XPS and SPA-LEED. The influence of surface defects on the dispersion and the lifetime of the sheet plasmon has been investigated in detail by angle resolved EELS. The step concentration (10-100nm terrace length) has been varied by using differently ex-situ treated samples and by varying the sublimation rates. The dispersion, which does not depend on the defect concentration, is almost linear and differs strongly from a $\sqrt{k}$ behaviour, which is often found for 2DEG. The strong blueshift in the short wavelength regime can be attributed to nonlocal effects within the highly correlated electron system. For the pristine graphene layer the dispersion shows a pronounced dip at the position of k_F, which vanishes after adsorption of 4F-TCNQ. Hence the position can be used to control the filling of the conduction band. The lifetime of the plasmons is inversely proportional to the step density and to the wavelength. As the phase velocities of the plasmons deduced from the linear dispersion coincide with the Fermi velocity of the electrons, steps only have to act as a momentum source to couple effectively plasmons to the electron-hole continuum, thus reducing effectivly the lifetime outside the Landau regime.