

O 52: Graphene II

Time: Wednesday 15:00–17:15

Location: H31

O 52.1 Wed 15:00 H31

Direct writing of 1 nm thin graphenoid nanoribbons and nanosieves — ●MARK SCHNIETZ¹, ANDREY TURCHANIN¹, CHRISTOPH NOTTBOHM¹, ANDRÉ BEYER¹, HARUN SOLAK², PETER HINZE³, THOMAS WEIMANN³, and ARMIN GÖLZHÄUSER¹ — ¹Physik supramolekularer Systeme, Fakultät für Physik, Universität Bielefeld — ²Laboratory for Micro and Nanotechnology, Paul Scherrer Institute, Villigen — ³Physikalisch-Technische Bundesanstalt, Braunschweig

Graphenoid nanosheets are fabricated by electron/photon induced cross-linking of aromatic self-assembled monolayers (SAMs). The cross-linking results in mechanically stable carbon nanosheets with the thickness of a single molecule (~ 1 nm) and with a distinct chemical functionality. The nanosheets can be lifted from the substrate and transferred onto another solid substrate or holey structure, where they become free-standing membranes.[1] By vacuum annealing the electrical conductivity of nanosheets can be tuned introducing an insulator to conductor transition.[2] The sizes and shapes of the graphenoid nanosheets are flexibly adjusted by electron beam/EUV interference lithography. In this contribution we demonstrate the fabrication of large area graphenoid nanoribbons and suspended nanosieves with lateral dimensions of the periodic features down to ~ 30 nm.[3, 4]

[1] C. T. Nottbohm et al, Ultramicroscopy 108, 88 (2008)

[2] A. Turchanin et al, Adv. Mater. 21, 1233 (2009)

[3] M. Schnietz et al, Small DOI: 10.1002/sml.200901283

[4] C. T. Nottbohm et al, J. Vac. Sci. Technol. B (2009) in press

O 52.2 Wed 15:15 H31

Decoupling epitaxial graphene from SiC(0001) surface by a germanium buffer layer — ●KONSTANTIN EMTSEV and ULRICH STARKE — Max-Planck Institute for Solid State Research, Stuttgart, Germany

Epitaxial graphene layers formed on SiC surfaces are currently intensively investigated with respect to their electronic, structural, and electrical transport properties [1]. On the SiC(0001) surface graphene layers are separated from the substrate by an interfacial carbon layer. The latter has a graphene-like atomic arrangement with complex $(6\sqrt{3} \times 6\sqrt{3})R30^\circ$ periodicity but lacks characteristic π -bands due to strong hybridization with the substrate [2]. In this work we demonstrate that the interfacial layer can be converted into quasi-freestanding graphene upon intercalation of Ge atoms at the interface. The electronic properties of the surface and the atomic structures of the newly formed interfaces were characterized by ARPES, XPS, and LEED. Deposition of germanium on the $6\sqrt{3}$ reconstructed SiC(0001) surface and subsequent annealing steps were carried out in UHV following Kubler et al. [3]. Decoupling of the interface layer by intercalating Ge atoms begins at temperature of about 700°C as evident by the development of the electronic band structure characteristic of graphene. Depending on the amount of Ge deposited as well as on the annealing temperature the graphene layer exhibits electron or hole doping.

[1] Th. Seyller et al., Phys. Stat. Sol.(b), 245, 1436 (2008).

[2] K. V. Emtsev et al., Phys. Rev. B, 77, 155303 (2008).

[3] L. Kubler et al., Phys. Rev. B, 72, 115319 (2005).

O 52.3 Wed 15:30 H31

SPM on epitaxial graphene on SiC — ●MARKUS DUSCHL and FRANZ J. GIESSIBL — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg

For some years, graphene has been of wide interest due to its extraordinary properties. First measurements done on exfoliated graphene in ambient conditions indicate that it might be possible to determine the number of graphite layers by force spectroscopy [1]. The stiffness increases with a decreasing number of layers, down to graphene. We compare these measurements to data taken with a combined STM and AFM in UHV at room temperature on epitaxial graphene grown on SiC [2].

[1] Hiermaier, V. Diploma Thesis, July 2009

[2] Seyller, T. et al. Nature Mater. 8, 203-207 (2009)

O 52.4 Wed 15:45 H31

Defect-induced electron scattering and metal-insulator transition in graphene — AARON BOSTWICK¹, JESSICA MCCHESENEY^{1,2}, KONSTANTIN EMTSEV³, THOMAS SEYLLER³, ●KARSTEN HORN²,

STEPHEN D. KEVAN⁴, and ELI ROTENBERG¹ — ¹Advanced Light Source, Lawrence Berkeley Lab, California USA — ²Fritz-Haber-Institut der MPG, Berlin — ³Institut für Physik der Kondensierten Materie, Universität Erlangen — ⁴Department of Physics, University of Oregon, USA

The influence of adsorbate-induced defects on the electronic properties of graphene are of great current interest. Here we show, using angle-resolved photoemission and conductivity measurements, that potassium and hydrogen adsorption on graphene induce very different types of defects in graphene prepared on SiC(0001). Whereas potassium acts as an electron donor, but causes only weak defect scattering, hydrogen locally saturates a carbon bond. This acts as a lattice defect, leading to a sharp reduction in conductivity, by several orders of magnitude even for coverages below 1 % of a monolayer. Angle-resolved photoemission spectra reveal a concomitant change in the electron scattering rate and the dispersion of the graphene bands near the Fermi level. These changes are interpreted in terms of a breakdown of the quasiparticle picture and strong charge carrier localization through the hydrogen-induced defects.

O 52.5 Wed 16:00 H31

Quasi-free Standing Epitaxial Graphene on SiC by Hydrogen Intercalation — ●CAMILLA COLETTI¹, CHRISTIAN RIEDL¹, TAKAYUKI IWASAKI¹, ALEXEI A. ZAKHAROV², and ULRICH STARKE¹ — ¹Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany — ²MAX-Lab, Lund University, Box 118, Lund, S-22100, Sweden

Epitaxial graphene grown on silicon carbide (SiC) is an appealing material for future electronic applications. It combines most of the exciting properties of free standing graphene to a manufacturing friendly planar structure. Most of the remaining skepticism towards this material is related to the the strong interaction with the SiC substrate. The SiC surface is covalently bound to the first carbon layer, which act as a buffer-layer and therefore fails in displaying graphene properties. The undesired effects originating from this strong coupling, such as intrinsic n-type doping and degraded transport properties, affect the overlying graphene layers. Annealing the samples in molecular hydrogen offers an elegant solution to the problem of graphene-SiC coupling. ARPES, CLPES and LEEM demonstrate that hydrogen atoms migrate through the graphene layers, intercalate between the SiC substrate and the buffer-layer and bind to the Si atoms of the SiC(0001) surface. Thus the buffer-layer, decoupled from the SiC substrate, is turned into a quasi-free standing graphene monolayer. Similarly, epitaxial monolayer graphene turns into a decoupled bilayer. The intercalation process represents a highly promising route towards epitaxial graphene based nanoelectronics.

O 52.6 Wed 16:15 H31

X-ray absorption and magnetic circular dichroism of graphene/Ni(111) — MARTIN WESER¹, YVONNE REHDER¹, KARSTEN HORN¹, MURIEL SICOT², MIKHAIL FONIN², ALEKSEJ PREOBRAJENSKI³, ELENA VOLOSHINA⁴, and ●YURIY DEKOV¹ — ¹Fritz-Haber Institut der Max-Planck-Gesellschaft, Berlin, Germany — ²Universität Konstanz, Germany — ³MAX-lab, Lund, Sweden — ⁴Freie Universität Berlin, Germany

A long electronic mean free path and negligible spin-orbit coupling in graphene render this material ideal for applications based on ballistic transport like the spin field effect transistor and the perfect spin-filtering device. The model system, graphene/Ni(111), is of special interest, providing an ideal interface between graphene and ferromagnetic material, from a structural point of view. Here we present the studies of the electronic and magnetic properties of the lattice-matched graphene/Ni(111) interface which were performed by means of angle-resolved x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) at the Ni $L_{2,3}$ and C K absorption edges. The XAS $C 1s \rightarrow \pi^*, \sigma^*$ spectra show pronounced changes as the angle, α , between the electrical vector of the light and surface normal is varied, reflecting the symmetry of the final state. XMCD reveals an induced magnetic moment of the carbon atoms in the graphene layer aligned parallel to the Ni $3d$ magnetization. Our experimental results are discussed in the light of recent density-functional theory calculations and previous results on the observation of induced magnetism in

non-magnetic materials. (See M. Weser *et al.*, arXiv:0907.4344v1).

O 52.7 Wed 16:30 H31

An ab initio study of graphenen nanoribbons doped with boron clusters — CEM ÖZDOĞAN¹, ●JENS KUNSTMANN², ALEXANDER QUANDT³, and HOLGER FEHSKE³ — ¹Department of Computer Engineering, Cankaya University, Ankara, Turkey — ²Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, Germany — ³Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, Germany

We present results from an ab initio study of graphene and graphene nanoribbons (GNR) doped with B₇ clusters. We already showed that this system might serve as a blueprint for the controlled layout of graphene based nanodevices, where the semiconducting properties are supplemented by parts of the graphene matrix and the metallic wiring is provided by chains of boron clusters [1,2]. We study how the B₇ clusters alter the physical properties of GNRs. A special focus is put on the magnetic properties of zigzag GNRs. [1] A. Quandt, C. Özdoğan, J. Kunstmann, and H. Fehske, *Nanotechnology* **19**, 335707 (2008). [2] A. Quandt, C. Özdoğan, J. Kunstmann, and H. Fehske, *phys. stat. solidi (b)* **245**, 2077 (2008).

O 52.8 Wed 16:45 H31

Effect of Noble-Metal Contacts on the Electronic Structure of Graphene — ●ANDREI VARYKHALOV¹, MARKUS R. SCHOLZ¹, TIMUR K. KIM², and OLIVER RADER¹ — ¹Helmholtz-Zentrum Berlin für Materialien und Energie — ²Institute for Solid State Research, IFW Dresden

Graphene-metal contacts are crucial for a future planar bipolar nanoelectronics. We investigated these contacts by angle-resolved photoemission at high resolution using noble-metal intercalation. We ob-

serve that doping level and band gap depend strongly on which noble metal is intercalated. As predicted from first principles, strong electron doping is provided by Cu ($\Delta E_F \sim -310$ meV) and Ag (~ -560 meV) but also unexpected large gaps appear ($E_g = 180$ and 320 meV, respectively). Au affects the neutral state of graphene much less than predicted moving the Dirac point E_D by only $\Delta E_F \sim +55$ meV above the Fermi level. In order to investigate whether or not graphene/Au is gapless also above E_D , we adsorbed potassium and gadolinium on top of the graphene. Both act as efficient donors but potassium opens a substantial band gap due to symmetry breaking while E_D is well below E_F and gapless after doping by gadolinium. We propose that the large 9×9 unit cell of the graphene/Au interface amplifies via quantum interference the decoupling of the graphene from its substrate which leads to the quasifreestanding electronic structure of graphene.

O 52.9 Wed 17:00 H31

Resonant Raman scattering of chemically functionalized graphene — ●NILS SCHEUSCHNER¹, DIMITRIOS TASIS², KOSTAS PAPAGELIS², and JANINA MAULTZSCH¹ — ¹Institut für Festkörperphysik, TU Berlin, Germany — ²Materials Science Department, University of Patras, 26504 Patras, Greece

We present resonant Raman scattering of graphene functionalized with polyvinylalcohol (PVA). Raman spectroscopy is a powerful tool for characterization of carbon nanostructures. Functionalization of graphene is a promising way to modify its electronic structure, for example in order to open a band gap. To study the interaction between PVA and graphene with respect to their electronic and vibrational structure, we analyse the Raman spectra of the G mode and the double resonant defect mode. Furthermore, we use tip-enhanced Raman spectroscopy (TERS) for structural and spectroscopic information with high spatial resolution of the sample.