

O 77: Graphene V

Time: Thursday 15:00–17:00

Location: WIL B321

O 77.1 Thu 15:00 WIL B321

Large area quasi-free standing two to four layer graphene on SiC(0001) — ●CAMILLA COLETTI¹, STIVEN FORTI¹, KONSTANTIN V. EMTSEV¹, KEVIN M. DANIELS², BIPLOB K. DAAS², MVS CHANDRASHEKHAR², ALEXEI A. ZAKHAROV³, and ULRICH STARKE¹ — ¹Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany — ²University of South Carolina, 301 S. Main St, Columbia, SC 29208, USA — ³MAX-lab, Lund University, Lund, S-22100, Sweden

Graphene epitaxially grown on SiC substrates is an appealing candidate for a wide variety of electronic applications, provided that large area, charge neutral layers can be produced. We have recently reported that hydrogen intercalation can be used to obtain technologically promising undoped quasi-free standing monolayer graphene [1]. In this work we demonstrate that by intercalating hydrogen we can also obtain large-area undoped quasi-free standing bi-, tri- and tetralayer graphene on SiC(0001). LEEM analysis shows that the thickness of the quasi-free standing graphene is homogenous on a scale of tens of micrometers. High resolution ARPES provides evidence that intercalated graphene can reach, upon UHV annealing, charge neutrality within a few meV. Furthermore, this work devotes particular attention to the electronic and structural properties of quasi-free standing trilayer graphene. A combined evaluation of ARPES and LEEM data allows us to shine light on the trilayer stacking sequence, whose determination and control are necessary for advances in graphene-based electronics. [1] C.Riedl et al., Phys. Rev. Lett. 103, 246804 (2009)

O 77.2 Thu 15:15 WIL B321

Intercalation of ferromagnetic metals underneath graphene on Rh(111) — ●MIKHAIL FONIN¹, PHILIPP LEICHT¹, MURIEL SICOT¹, and YURIY S. DEDKOV² — ¹Fachbereich Physik, Universität Konstanz, 78457 Konstanz — ²Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin

Structure and electronic properties of atomically sharp interfaces between graphene and transition metal surfaces are both of fundamental and technological interest in view of possible device applications. Insertion of other metals between graphene and TM surface (intercalation) can be used to controllably modify the electronic or even magnetic properties of the graphene/metal interfaces.

Here, we present a systematic scanning tunneling microscopy (STM) study of the intercalation process of ferromagnetic metals (Fe, Co, Ni) underneath graphene monolayer on the Rh(111) surface. Ferromagnetic metals were shown to be intercalated effectively at temperatures starting about 300 K yielding single monoatomically thin epitaxial islands underneath the graphene film. Atomically-resolved imaging of the graphene surface after intercalation shows no considerable changes of the moiré structure on top of intercalated metal islands. The strongly bound areas of the moiré structure were found to suppress the lateral growth of metallic islands. We show that in the temperature range of 300-600 K the intercalation process involves diffusion through defects in the graphene layer such as domain boundaries or point defects.

O 77.3 Thu 15:30 WIL B321

Electronic and Magnetic Properties of the graphene/Fe/Ni(111) System: XMCD and ARPES studies — ●MARTIN WESER¹, ELENA VOLOSHINA², KARSTEN HORN¹, and YURIY DEDKOV¹ — ¹Fritz-Haber Institut der Max-Planck Gesellschaft, 14195 Berlin, Germany — ²Institut für Chemie und Biochemie, Freie Universität Berlin, 14195 Berlin, Germany

In our latest works we have demonstrated by means of XMCD and spin-resolved PES that the net magnetic moment of about 0.05-0.1 μ_B per carbon atom is induced in the graphene layer via its contact with ferromagnetic Ni(111) substrate. The magnetic properties of the graphene layer in this system are expected to be improved via intercalation of thin Fe layers underneath graphene on Ni(111) due to the larger magnetic moment of an Fe atom. Here we present studies of the electronic and magnetic properties of the graphene/Fe/Ni(111) intercalation-like system by means of PES, XAS, and XMCD at the Ni, Fe $L_{2,3}$ and C K absorption edges. The presented results reveals an induced magnetic moment of the carbon atoms in the graphene layer aligned parallel to the Ni $3d$ and Fe $3d$ magnetization. It is found that intercalation

of Fe changes drastically the magnetic response from the graphene layer. Obtained experimental results are compared with DFT calculations and magnetic moment of carbon atoms in the graphene layer is estimated before and after Fe intercalation in the graphene/Ni(111) system.

O 77.4 Thu 15:45 WIL B321

Effect of the graphene moiré on Ir(111) on intercalated Eu patterns — ●DANIEL F. FÖRSTER¹, STEFAN SCHUMACHER¹, TIM WEHLING³, MARIN PETROVIĆ⁴, IVA ŠRUT⁴, MARKO KRALJ⁴, PETAR PERVAN⁴, CARSTEN BUSSE¹, ACHIM ROSCH², and THOMAS MICHELY¹ — ¹II. Physikalisches Institut, Universität zu Köln, Zùlpicher Str. 77, 50937 Köln — ²Institut für Theoretische Physik, Universität zu Köln, Zùlpicher Str. 77, 50937 Köln — ³I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg — ⁴Institut za fiziku, Bijenička 46, HR-10000 Zagreb

The electronic properties of graphene on a given substrate may be tailored by adsorption or intercalation.

We have grown Eu on graphene on Ir(111) between 45 K and 720 K with deposited amounts Θ in the monolayer regime. STM and LEED measurements, supported by DFT calculations, were used to determine the structure. Upon adsorption at 720 K Eu intercalates through point defects in the graphene. It forms intercalated line (small Θ) and line+island (larger Θ) patterns. Surprisingly, the line and island widths and spacings are integer units of the moiré cell dimensions. Depending on Θ the intercalated layer forms a $p(2 \times 2)$ or a $(\sqrt{3} \times \sqrt{3})R30^\circ$ superstructure with respect to the graphene lattice. As these structures are commensurate the moiré of graphene on Ir(111) is preserved. The intercalation patterns may be understood as a combined effect of the inhomogeneous binding of graphene to Ir(111) within the moiré unit cell and of the elastic energy changes in graphene associated with intercalation.

O 77.5 Thu 16:00 WIL B321

Doping of epitaxial graphene on Ir(111) — ●IVA ŠRUT¹, MARIN PETROVIĆ¹, PETAR PERVAN¹, MILORAD MILUN¹, DANIEL FÖRSTER², CARSTEN BUSSE², THOMAS MICHELY², and MARKO KRALJ¹ — ¹Institut za fiziku, Bijenička 46, 10000 Zagreb, Croatia — ²II. Physikalisches Institut, Zùlpicher Str. 77, 50937 Köln, Germany

Graphene's remarkable electronic properties give rise to great expectations of this new material for future electronic devices and spintronic applications. For such purposes a manipulation of its electronic band structure is desired. We have shown that it is possible to engineer the electronic structure of graphene by fine-tuning the Dirac cone of the epitaxial graphene on Ir(111). We had intercalated several different materials, which led to the n-type doping of graphene: Cs, Li, Eu, and their combination. Doping with a specific material leads to different fine effects, such as: (a) gradual or stepwise doping, (b) apparent gap opening at the Dirac point and (c) group velocity changes. We study these effects through direct comparison of the band structure measured by angle resolved photoemission spectroscopy (ARPES).

O 77.6 Thu 16:15 WIL B321

Epitaxial graphene on Ir(111): How it forms mountains and how it gets a Rashba surface state out into the fresh air — ●ANDREI VARYKHALOV — Helmholtz-Zentrum Berlin, 12489 Berlin

A new phase of epitaxial graphene on Ir(111) is discovered. It occurs as a periodic array of pyramids with giant height corrugation of 3.5 Å, is free of carbide, and can be easily recognized by its unique LEED pattern. The corrugation is 10× larger than for the known Moiré-type phases of graphene/Ir [1] which suggests that a novel formation mechanism is at work. STM, XPS, ARPES, as well as LEED simulations of pyramid-shaped graphene and Moiré-type control samples indicate that the pyramids occur by relief of lateral strain from a chiral dislocation network which renders them a prospective playground for quasi-Landau quantization of Dirac fermions in giant pseudomagnetic fields [2]. The bare Ir(111) harbors fascinating electronic and spin properties as well. By spin-ARPES we reveal a previously unobserved giant (α_R of the order of 10^{-10} eVm) Rashba-type spin splitting of a prominent Ir surface state. It will be shown that this spin-orbit split surface state is not affected when Ir(111) is epitaxially covered with graphene. Moreover, it will be demonstrated that graphene itself pro-

fects the Ir surface so efficiently that the surface state remains stable in ambient atmosphere. This behavior is explained based on topological properties of this surface state.

[1] A. T. N'Diaye et al., *Phys. Rev. Lett.* **97**, 215501 (2006) and refs. therein; [2] F. Guinea et al., *Nat. Phys.* **6**, 30 (2010); N. Levy et al., *Science* **329**, 544 (2010).

O 77.7 Thu 16:30 WIL B321

Mobility of molecular liquid layers confined between graphene and mica — ●MARTIN DORN, NIKOLAI SEVERIN, PHILIPP LANGE, PATRICK AMSALEM, NORBERT KOCH, and JÜRGEN P. RABE — Humboldt-Universität zu Berlin, Department of Physics, Germany

Properties of water confined to a nano-scale are of scientific and technological interest ranging from lubrication to protein folding. Water has been demonstrated to remain liquid at room temperature when confined to different geometries ranging from confinement between two flat walls to nanopores. Recently crystalline molecular layers of water on mica surfaces have been reported, based on the visualization of graphene conforming to their surface [1]. We argue that the stable graphene topography may be caused by entrapped contaminations at the graphene-mica interface and not by the crystallinity of water. We find that contamination-free graphenes deposited on mica surfaces exhibit an atomically flat topography in the entire area independently on the ambient humidity during preparation. From this we conclude a substantial mobility of the water layer confined at the graphene-mica interface. Based on these and further experiments with confined molecular layers of other contaminated liquids we propose a model for the stabilization of the graphene topography on the liquid molecular

films.

[1] K. Xu, P. Cao, J.R. Heath, *Science* **329** (2010) 1188.

O 77.8 Thu 16:45 WIL B321

Novel routes towards the chemical functionalization of graphenoid and graphene: Janus nanomembranes — ZHIKUN ZHENG¹, CHRISTOPH NOTTBOHM¹, ●ANDREY TURCHANIN¹, HEIKO MUZIK¹, ANDRÉ BEYER¹, MIKE HEILEMANN¹, MARKUS SAUER², and ARMIN GÖLZHÄUSER¹ — ¹Fakultät für Physik, Universität Bielefeld — ²Biotechnology & Biophysics, Julius-Maximilians-University Würzburg

The chemical functionalization of graphene is essential for the use in molecular sensors or nanoelectromechanical components. However, a functionalization is difficult to achieve for graphene single crystals due to their chemical inertness. Here we present a route towards the chemical functionalization of graphenoid carbon nanomembranes fabricated from self-assembled monolayers. These 1 nm thick membranes possess amino functionalities on their top sides and thiol functionalities on their bottom sides. It is demonstrated how such two-dimensional (2D) "Janus membranes" can be used for the selective immobilizations of functional molecules. As a proof of concept, we functionalized both sides with different fluorescent dyes. The functionalization is observed by X-ray photoelectron spectroscopy and fluorescence resonant energy transfer. The potential of Janus nanomembranes as a 2D-platform for the chemical functionalization of graphene is discussed.

Z. Zheng, C.T. Nottbohm, A. Turchanin, H. Muzik, A. Beyer, M. Heilemann, M. Sauer, A. Gözlhäuser, *Angew. Chem. Int. Ed.* **49** (2010) 8493-8497