O 34: Focused Session: Epitaxial Graphene IV

Time: Wednesday 10:30–13:00 Location: SCH 251

Topical Talk O 34.1 Wed 10:30 SCH 251

Looking through the Dirac window: Graphene on Ir(111) — •Carsten Busse — II. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany

Epitaxial graphene can be grown by catalytic decomposition of hydrocarbons on Ir(111). Scanning tunneling microscopy reveals that C/Ir(111) has a high degree of structural quality (μm-sized domains, coherent overgrowth of surface defects). The system is characterized by weak metal-graphene bonding and shows a pronounced moiré superstructure. The growth process can be tuned to yield different morphologies ranging from compact, nm-sized flakes to uniform sample coverage on the mm-scale.

The Dirac cone in the electronic structure of free graphene (i. e. the linear dispersion relation for electrons close to the Fermi energy) is preserved in this system. The substrate induces slight p-doping and the superstructure leads to the opening of additional mini-gaps. The localized, possibly spin-polarized electronic edge state predicted for zigzag edges in free graphene can be observed for nanoflakes on Ir(111).

C/Ir(111) is a template for the growth of metal cluster lattices showing a narrow size distribution and exceptional thermal stability. The clusters bind strongly via a rehybridization of C from sp^2 to sp^3 leading to the formation of covalent carbon-metal bonds. This effect is rather general and has been observed for a range of cluster materials.

Contributions to this work by R. Brako, J. Coraux, R. Djemour, T. Gerber, P. J. Feibelman, M. Kralj, P. Pervan, I. Pleticosić, T. Michely, and A. T. N'Diaye are acknowledged.

Topical Talk O 34.2 Wed 11:00 SCH 251

Exotic properties of graphene at interfaces: spin filtering and mass generation — •Jeroen van den Brink — Universiteit Leiden, The Netherlands — Stanford University, USA

We investigate a number of exotic electronic properties of graphene at interfaces by means of ab initio density functional calculations.

First we show that it is possible to generate a mass for the Dirac fermions in graphene by putting it on a hexagonal boron nitride substrate. The breaking of the two-sublattice symmetry causes the opening of band gap of about 53 meV [1]. This gap can greatly improve room temperature pinch-off characteristics of graphene-based field effect transistors [2].

Second we investigate the spin filtering properties of graphite and graphene. Based upon the observations (i) that their in-plane lattice constants match almost perfectly and (ii) that their electronic structures overlap in reciprocal space for one spin direction only, we predict perfect spin filtering for interfaces between graphite and (111) fcc or (0001) hcp Ni or Co [3,4]. The spin filtering is quite insensitive to roughness and disorder.

[1] Giovannetti et al., Phys. Rev. B. 76, 073103 (2007).
[2] Van den Brink, Nature Nanotechnology 2, 199 (2007).
[3] Karpan et al., Phys. Rev. Lett. 99, 176602 (2007).
[4] Karpan et al., Phys. Rev. B. 78, 195419 (2008).

O 34.3 Wed 11:30 SCH 251

Compressive strain relaxation through wrinkle formation in epitaxial graphene on Ir(111) — •Alpha T. N'Diaye[1], Raoul van Gastel[2], Johann Coraux[1], Rabia Djemour[1], Dirk Wall[3], Niemma Buckanie[3], Frank-J. Meyer zu Heringdorf[3], Bene Poelsema[2], Thomas Michely[1], and Carsten Bussse[1] — [1]II. Phys. Inst., Universität zu Köln — [2]MESA+ Institute for Nanotechnology, University of Twente, The Netherlands — [3]Institut für Exp. Physik, Universität Duisburg–Essen, Germany

The growth of epitaxial graphene is often accompanied by the growth of prodruded elongated structures (e.g. on Pt(111)[1], 6H-SiC [2], Ir(111)) which are sometimes interpreted as nanotubes or srcolls.

With scanning tunneling microscopy and low energy electron microscopy we have observed the growth of such structures during the growth of epitaxial graphene by chemical vapour deposition of ethene on Ir(111) . We suggest an alternative mechanism for the formation of such structures: Graphene is grown at elevated temperatures ($\approx$ 1200 K). During cooldown compressive strain is induced due to the different thermal expansion coefficients of graphene and the iridium substrate. This strain can be partly relaxed through the formation of wrinkles in the graphene sheet. The remaining compressive strain at 300 K ($\approx$ 0.4%) corresponds to a lock-in temperature between 700 K and 800 K. The length of wrinkles per surface area can be used to deduce the amount of compressive strain which they compensate for.

[1] D.E. Starr et al. Surface Science, 600 (2006) 2688-2695
[2] V. Derycke et al. Nano Letters, Vol. 2, No. 10 (2002) 1043-1046

O 34.4 Wed 11:45 SCH 251

Manipulation of the electronic structure of graphene on Ir(111) — •Marko Kralj[1], Ivo Pletikosić[1], Petar Pervan[1], Milorad Milun[1], Alpha N'Diaye[2], Carsten Busse[2], and Thomas Michely[2] — [1]Institut za fiziku, Zagreb, Croatia — [2]II. Physikalisches Institut, Köln, Germany

Epitaxial graphene on Ir(111) exhibits effects of the 2.5 nm moiré superperiodicity which is due to the mismatch of graphene and iridium lattices. Angle resolved photoelectron spectroscopy (ARPES) reveals intact Dirac cone, slight p-doping (0.1 eV) and opening of minigaps in the band structure of graphene due to the superperiodic potential of the order of 100 mV [1].

In this work, electronic doping of graphene by alkalis (Na, Cs, K) at varying concentrations shifted the position of the Dirac point up to 1.4 eV below the Fermi energy. Moreover, upon the intercalation of alkalis the effects of the superperiodicity vanished and the minigaps disappeared. In the (maximum doping) regime where graphene Fermi surface becomes pronouncedly trigonal, an anisotropic effect of the pi-band dispersion renormalization was clearly observed. We interpret this as a signature of an enhanced electron-phonon coupling in doped graphene.

[1] I. Pletikosić et al., arXiv:0807.2770.

O 34.5 Wed 12:00 SCH 251

Pt and other transition metal cluster lattices on graphene — •Timm Gerber, Alpha T. N'Diaye, Rabia Djemour, Johann Coraux, Carsten Bussse, and Thomas Michely — II. Physikalisches Institut, Universität zu Köln

Highly ordered arrays of Ir Clusters had been obtained by depositing Ir on a Ir(111) surface covered with a graphene monolayer. The periodicity of these arrays is determined by the moiré pattern of graphene on Ir(111). [1]

In order to show that other materials form clusters on the same substrate we deposited Pt, W and Re instead of Ir. Pt is of great interest due to its catalytic properties. The optimum deposition temperature varies for each deposit: At room temperature, we obtained highly ordered cluster lattices of Pt as well as of W. Pt clusters are stable up to 500K. By evaporating Re at 200K we obtained as well highly ordered lattices which were stable at room temperature.

Based on the binding mechanism of the clusters to graphene – local diamond formation between the cluster and the substrate – we propose criteria for the ability of a material to form a cluster lattice. These involve the cohesive strength, the lattice parameter and the valence orbital radius of the deposit.

[1] A. T. N'Diaye et al. PRL 97, 215501 (2006)

O 34.6 Wed 12:15 SCH 251

Imaging atomic structure of graphene on metallic substrates — •Mikhail Fonin[1], Ole Zander[1], Sönke Voss[1], Ulrich Rüdiger[1], and Yury S. Dedkov[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin, Germany

Unusual transport properties of graphene, a single monolayer of graphite, have stimulated an intense activity for developing graphene-based nanoelectronics. From the technological point of view the observation of large carrier mobilities and ballistic transport up to room temperature are the most intriguing features. However, the potential for applicable graphene-based electronics rests not only on device performance but also on the ability to fabricate uniform graphene layers on large length scales. Unlike exfoliation techniques, epitaxially grown graphene layers offer a realistic solution for large-scale fabrication and patterning of graphene structures.

In this study, growth and structure of graphene on Ni(111) and Rh(111) has been investigated by means of scanning tunneling microscopy. We show that graphene prepared on Ni(111) forms a flat monolayer exhibiting remarkably large-scale continuity of carbon lat-

tice over terraces and containing only a very low density of defects. Whereas prepared on Rh(111), graphene forms a nanomesh. Depending on the preparation conditions graphene layer on Rh(111) shows either a single phase and very good rotational alignment or a multiphase with coexisting different superstructures.

O 34.7 Wed 12:30 SCH 251

Rashba-type effect in the graphene/Ni(111) system (interchanged with O 34.8) — •Yuriy Dedkov[1], Mikhail Fonin[2], Ulrich Rüdiger[2], and Clemens Laubschat[3] — [1]FHI Berlin — [2]Uni Konstanz — [3]TU Dresden

A high efficiency spin-FET device requires a long spin relaxation time compared to the mean time of transport through the channel combined with a sufficient difference of the spin rotation angles between two states ("0"and "1") as well as an insensitivity of spin rotation to the carrier energy. Long electronic mean free paths and negligible spin-orbit coupling in the carbon-based systems, i.e., large spin relaxation times, make graphene an ideal material for the observation of nearly ballistic spin transport and thus realization of the spin-FET. Here we report on angle-resolved photoemission studies of the electronic π states of high-quality epitaxial graphene layers on a Ni(111) surface. In this system the electron binding energy of the π states shows a strong dependence on the magnetization reversal of the Ni film. The observed extraordinarily large energy shift up to 225 meV of the graphene-derived π band peak position for opposite magnetization directions is attributed to a manifestation of the Rashba-type interaction between spin-polarized electrons in the π band and the large gradient of the effective electric field at the graphene/Ni interface. Our findings show that an electron spin in the graphene layer can be manipulated in a controlled way and have important implications for graphene based spintronic devices.

O 34.8 Wed 12:45 SCH 251

Quasifreestanding graphene on metallic substrates: preparation, structure, properties (interchanged with O 34.7) — •A. Varykhalov[1], A. Shikin[2], J. Sanchez-Barriga[1], E. Vescovo[3], D. Marchenko[2], A. Rybkin[2], D. Usachov[2], C. Biswas[1], and O. Rader[1] — [1]HZB, BESSY-II, Berlin, Germany — [2]St.-Petersburg State University, Russia — [3]NSLS, USA

Quasifreestanding graphene was prepared by cracking of propylene on metallic Ni(111) and Co(0001) followed by intercalation of Au monolayer into the interface between graphene and its substrate. Structural properties of such graphene as well as intercalation kinetics were monitored by means of scanning tunneling microscopy and angle-resolved photoelectron spectroscopy. Our high-resolution photoemission study reveal quasiparticles in the vicinity of the Fermi level due to interaction between graphene and Au. We demonstrate that in quasifreestanding graphene on Au, that Dirac crossing energy and Fermi energy coincide meaning charge neutrality and electronic properties are identical to those of ideal graphene. Using spin-resolved photoemission we show that the π-band of graphene on Au is spin-split and spin-polarized according to the Rashba model. Photoemission measurements allow us to conclude that *hybridization* between graphene band and spin-orbit split electronic states in high-Z material Au is responsible for the observed spin-polarization. Results are compared to the case of graphene on light material Cu where no spin-polarization and no interfacial hybridization were evidenced. Additionally we emphasize the protective role of graphene showing the band structure of graphene/Au/Ni(111) sampled before and after exposure to atmosphere.