

O 22: Focused Session: Epitaxial Graphene III

Time: Tuesday 10:30–13:00

Location: SCH 251

Topical Talk

O 22.1 Tue 10:30 SCH 251
Structural and electronic properties of graphene on Ru(0001) — ●SEBASTIAN GÜNTHER — Department Chemie, Ludwig-Maximilians-Universität München, Butenandtstr. 11, 81377 München, Germany

STM on clean and Au covered graphene on Ru(0001) revealed a surprisingly large apparent height corrugation of 0.8-1.2 Å within the unit cell of the imaged moiré structure with a size of $\sim (11 \times 11)$ Ru lattice spacings. Up to then graphene was thought to be a rather flat 2-dim network, weakly interacting with metal substrates. In order to understand whether graphene can form a strongly corrugated layer on a transition metal substrate and what type of interaction between carbon and substrate is formed, we performed ARPES measurements, SXRD and a LEED I(V) analysis. In ARPES strong electronic interaction between C and Ru could be evidenced by the observation of a large gap of the graphene pi-band at the K-point of the Brillouin zone. Further details of the electronic structure were found and will be discussed. The geometric configuration of the g-Ru(0001) was addressed by SXRD and LEED I(V) measurements. SXRD proved that in fact the periodic moiré consists of a much larger unit cell of (25×25) g on (23×23) Ru size with a superimposed (2×2) symmetry. Crystal truncation rod data indicated pronounced buckling of the underlying Ru atoms evidencing strong interaction of C and Ru atoms. Finally, a LEED I(V) analysis proved both the large height modulation of the graphene layer of ~ 1.5 Å as well as strong vertical and lateral atom displacements in the underlying Ru layers.

Topical Talk

O 22.2 Tue 11:00 SCH 251
Unraveling the strong interaction between graphene monolayer and Ru(0001) : a DFT-based STM and STS study — ●MARIE-LAURE BOCQUET and BIN WANG — Laboratoire de Chimie, Ecole Normale Supérieure de Lyon, Lyon, France

In this talk, I will refer to recently published experimental Scanning Tunneling Microscopy experiments resolving the $(12 \times 12)C / (11 \times 11)$ Ru Moiré superstructure and will propose a detailed comparison with large-scale ab initio periodic calculations.

I will show that, in contrast to expectations, the measured electronic corrugation of the Moiré pattern mainly originates from a geometric buckling of the graphene sheet of 1.5 Å, induced by alternating weak and strong chemical interactions with Ru. This finding holds when considering smaller (10×10) Ru and larger (12×12) Ru coincidence structures in the calculations. The chemical bonding in the strong contact regions, leads to three recently measured properties nicely reproduced by the calculations :

- the STM transparency of carbon atoms directly above surface Ru atoms;
- the asymmetry between low- and high- lying carbon electronic states probed by STS spectroscopy ;
- the considerable band gap opening in the graphene states.

Finally I will review similar studies of graphene monolayer on various metal surfaces which allow us to classify the metals in two separate classes, one in which graphene is chemisorbed and one in which it is physisorbed.

O 22.3 Tue 11:30 SCH 251
Adsorption of organic molecules on C/Ru(0001) - a combined STM and TPD study — ●MICHAEL ROOS, HARRY E. HOSTER, and R. JÜRGEN BEHM — Institute of Surface Chemistry and Catalysis, Ulm University, D-89069 Ulm, Germany

Bis(terpyridine)derivatives (BTP) form highly ordered hydrogen bonded 2D networks on graphite (HOPG) at both the solid/liquid [1,2] and the solid/gas [3,4] interface. These structures depend on the positions of the N-Atoms, which can be varied in the synthesis [1,2]. As recently found by temperature programmed desorption (TPD), the high translational and rotational mobility of BTP molecules on HOPG gives rise to a distinct entropic stabilization of the first monolayer. In this talk, we will show that this mobility is reduced when the HOPG substrate is replaced by a graphene monolayer on Ru(0001) with its Moiré-like corrugation [5]. As will be shown for two different BTP isomers, this lower mobility becomes apparent both in the 2D structures and in the desorption rates of the resulting adlayers.

- [1] C. Meier et al., J. Phys. Chem. B 109, 21015 (2005).

- [2] C. Meier et al., Angew. Chem. Int. Ed. 47, 3821 (2008).
 [3] H. E. Hoster et al., Langmuir 23, 11570 (2007).
 [4] A. Breitruck et al., Surf. Sci. 601, 4200 (2007).
 [5] S. Marchini et al., Phys. Rev. B 76, 075429 (2007).

O 22.4 Tue 11:45 SCH 251
Novel 1 nm thin carbon nanosheets — ●ANDREY TURCHANIN¹, ANDRE BEYER¹, CHRISTOPH T. NOTTBOHM¹, XIANGHUI ZHANG¹, RAINER STOSCH², ALLA SOLIGUBENKO³, JOACHIM MAYER³, PETER HINZE², THOMAS WEIMANN², and ARMIN GÖLZHÄUSER¹ — ¹Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld — ²Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — ³Gemeinschaftslabor für Elektronenmikroskopie, RWTH Aachen, 52074 Aachen

We present a route for the fabrication of novel ultrathin (~ 1 nm) carbon films and membranes, whose electrical behavior can be tuned from insulating to conducting. Self-assembled monolayers of biphenyls are cross-linked by electrons, detached from the surfaces and subsequently pyrolyzed. This transformation was characterized by a variety of complementary spectroscopic and microscopic techniques. Above 1000K, the cross-linked aromatic monolayer forms a mechanically stable graphitic phase consisting of nanosize patches of graphene. The transition is accompanied by a drop of the sheet resistivity from $\sim 10^8$ to 10^2 k Ω /sq and a mechanical stiffening of the nanomembranes from ~ 10 to 50 GPa. The technical applicability of the nanosheets is discussed.

- [1] W. Geyer et al, Appl. Phys. Lett. 75, 2401 (1999)
 [2] W. Eck et al, Adv. Mater., 17, 2583 (2005)
 [3] A. Turchanin et al, Appl. Phys. Lett., 90, 053102 (2007)
 [4] C. T. Nottbohm et al, Ultramicroscopy, 108, 88 (2008)

O 22.5 Tue 12:00 SCH 251
In-situ Raman spectroscopy and In-situ optical microscopy of graphene growth on polycrystalline nickel — ●STEFAN THIELE¹, MARIO HOFMANN¹, KYEONG-JAE LEE¹, HOOTAN FAHRHAT¹, ALFONSO REINA¹, JUERGEN A. SCHAEFER², and JING KONG¹ — ¹Department of Materials Science and Engineering, Department of Electrical Engineering and Computer Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — ²Institut für Physik and Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, P. O. Box 100565, 98684 Ilmenau, Germany

Due to our experience in nanotube growth, two modes of graphene growth on polycr. Ni should be possible [1]. It is possible that graphene growth is starting immediately after hydrocarbon gas injection [2] similar to the carbon nanotube growth or carbon atoms could dissolve into nickel and graphene is only growing when the carbon is precipitating out of the nickel during the cool down [3]. We used In-situ Raman spectroscopy and In-situ optical microscopy to investigate the large area graphene growth on polycrystalline nickel substrates [1] to proof one of the above theories. For the period of our growth process at high temperatures no Raman signal of graphene was detected. During the cool down process we observed an increasing film growth in the temperature range of 800- 900°C and subsequently a rising Raman signal, which is not changed significantly at lower temperatures. Further details will be discussed at the conference. [1] A. Reina et al., Nanoletters, in press, [2] Qingkai Yu et al., APL 93, 113103 (2008), [3] S. Moshkalyov et al., Mat. Sci. Eng. B 112, 147 (2004)

O 22.6 Tue 12:15 SCH 251
Ambient pressure CVD grown and transferred graphene: STM and UPS study — ●ROLAND J. KOCH^{1,2}, ALFONSO REINA¹, JUERGEN A. SCHAEFER², and JING KONG¹ — ¹Department of Materials Science and Engineering, Department of Electrical Engineering and Computer Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — ²Institut für Physik and Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, P. O. Box 100565, 98684 Ilmenau, Germany

We used polycrystalline nickel as a substrate to synthesize few layer graphene (FLG) via Chemical Vapor Deposition (CVD). These samples have been analyzed using scanning tunneling microscopy (STM) and ultra violet photoelectron spectroscopy (UPS). In addition, the

FLG transferred to other Ni and Si/SiO₂ samples were characterized. Large Moiré patterns have been observed by STM on both, the transferred and the not transferred samples, indicating a stacking disorder between first and second graphene layer. This is in line with results of FLG grown on SiC by Si sublimation [Varchon et al., Phys. Rev. B 77, 165415 2008]. The UPS measurements show a strong correlation of the quality and structure of the graphene films and a final state effect above vacuum level.

O 22.7 Tue 12:30 SCH 251

Synthesis and characterization of graphite monolayers on Ni (111)- and polycrystalline Ni-surfaces — KATHARINA KLOECKNER, ROLAND J. KOCH, SYED-IMAD U. AHMED, and •JUERGEN A. SCHAEFER — Institut für Physik and Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, P. O. Box 100565, 98684 Ilmenau, Germany

To understand the fundamental surface science related properties of two different substrate surfaces, Ni (111) and polycrystalline Ni, adsorption experiments of CO and propene (C₃H₆) are investigated. Since the adsorption of CO on metal surfaces has been studied very intensively in the past, a very thorough characterization of the different surfaces studied in this contribution is possible. Simultaneously, CO adsorption is a good reference for residual gas adsorption, which is dominated by CO. Propene has been chosen to study the catalytic dehydrogenation on nickel as well as graphene formation. Different stages of interaction were controlled via High Resolution Electron Energy Loss Spectroscopy (HREELS) and X-ray Photoelectron Spectroscopy (XPS).

O 22.8 Tue 12:45 SCH 251

Electronic structure of the graphene twist bilayer — •SAM SHALLCROSS¹, SANGEETA SHARMA², and OLEG PANKRATOV¹ — ¹Lehrstuhl für Theoretische Festkörperphysik, Staudtstr. 7-B2, 91058 Erlangen — ²Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany

While the Bernal stacked AB graphene bilayer has received great attention, this represents only one degree of freedom between graphene layers, i.e., the translational degree of freedom. It has recently been realised that the rotational degree of freedom between such layers is in many instances of great importance, e.g. in explaining the single layer graphene type behaviour for graphene layers grown on the C-face of SiC [1,2]. We shall explore this degree of freedom between graphene layers via the simple prototype of the "graphene twist bilayer". This analysis, based on a simple application of Diophantine algebra, leads to the conclusion that such systems may either (i) become *completely* electronically decoupled for some $\theta < \theta_0$, or, (ii) decouple only in *specific regions* of the Brillouin zone. Using a standard tight-binding technique, we thoroughly explore the graphene twist bilayer, and establish that this system belongs to class (ii), and decouples only in the vicinity of the Dirac point, but that this decoupling occurs for all rotation angles. We consider the small angle limit and show that in this limit the Dirac spectrum has a considerably damped Fermi velocity, and exists only in a much reduced energy window.

[1] J. Hass et al., Phys. Rev. Lett., 100:125504, 2008. [2] S. Shallcross, S. Sharma, and O. A. Pankratov, Phys. Rev. Lett., 101:056803, 2008.