

O 55: Graphene

Time: Tuesday 18:30–20:30

Location: P2-EG

O 55.1 Tue 18:30 P2-EG

Inelastic electron tunnelling into graphene bilayers on Ir(111) — ●ALEXANDER TRIES, JOHANNES HALLE, NICOLAS NÉEL, and JÖRG KRÖGER — Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany

Physical vapour deposition of C onto graphene-covered Ir(111) has been used to fabricate graphene nanoflakes. Due to C atom intercalation the flakes form underneath graphene. Scanning tunnelling microscopy with atomic resolution reveals that the lattices of the upper graphene layer and the flakes are rotated with respect to each other. Spectra of the differential conductance show the hole-like Ir(111) surface resonance on top of the graphene-flake stackings. Graphene phonons with wave vectors comparable to the Brillouin zone dimensions leave their signatures in inelastic electron tunnelling spectra. Funding by the Deutsche Forschungsgemeinschaft through Grant No. KR 2912/10-1 is acknowledged.

O 55.2 Tue 18:30 P2-EG

The effect of defects on the band structure of graphene near the Dirac point — ●PIOTR KOT^{1,2}, JONATHAN PARNELL², SINA HABIBIAN², and CHRISTIAN R. AST¹ — ¹Max Planck Institute for Solid State Research, Stuttgart, Germany — ²University of British Columbia, Vancouver, Canada

Using a simple real-space tight-binding model, we present the effect of defects on the band structure of graphene in momentum space near the Dirac point. While several of the calculated defects strongly alter the band dispersion and line width near the Dirac point, we find that a band gap forms only in systems where atoms are missing from one sublattice. Another finding of note is that some specific defects open a band gap with broadened, but not entirely delocalized, states in the gap. These band gaps with broadened states strongly resemble "elongated" Dirac points that have been experimentally found by photoemission spectroscopy and have been discussed in the literature. We surmise that these "elongated" Dirac points are, at least in part, due to specific defects in the graphene. Our findings also point to obstacles to opening a band gap in graphene, which have to be considered.

O 55.3 Tue 18:30 P2-EG

Scanning tunneling microscopy and spectroscopy on graphene/h-BN/SiO₂/Si devices — ●LENA STOPPEL, FABIAN PASCHKE, JULIA TESCH, SAMUEL BOUVRON, YURIY S. DEDKOV, and MIKHAIL FONIN — Department of Physics, University of Konstanz, Germany

Exceptional transport properties of graphene, a two-dimensional honeycomb lattice of sp²-bonded carbon atoms, make it a promising material for applications in microelectronics and sensing.

Here, we present a systematic scanning tunneling microscopy (STM) study of graphene on h-BN/SiO₂/Si substrates. We use wet chemical transfer of CVD-grown multilayer hexagonal boron nitride (h-BN) and CVD-grown monolayer graphene onto a silicon chip with a thin insulating silicon dioxide layer. The transfer method was optimized in a way that STM measurements reveal large surface areas of clean graphene, showing the honeycomb atomic lattice and a Moiré pattern due to the underlying h-BN. We also perform scanning tunneling spectroscopy measurements to investigate the electronic properties of graphene. In a similar procedure graphene was transferred onto metal dichalcogenides, and the electronic properties were investigated.

O 55.4 Tue 18:30 P2-EG

Novel preparation technique for high quality graphene on boron nitride samples for combined electrical transport and STM measurements — ●TJORVEN JOHNSEN, MICHAEL WEIMER, PETER NEMES-INCZE, and MARKUS MORGENSTERN — II. Physikalisches Institut B, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen

Whereas in electrical transport experiments suspended graphene samples or samples sandwiched between to boron nitride flakes show the highest mobility due to low charge disorder they are not accessible for scanning tunneling microscopy (STM). STM requires a graphene flake that is supported by a substrate and features an exposed surface. Here we present a novel technique to prepare such graphene samples on boron nitride substrates. A mica support is used to pick up boron

nitride and graphene flakes from SiO₂ substrates. The graphene flake is contacted by gold evaporation through a shadow mask. In contrast to other fabrication methods we avoid any polymers in the process that works without any wet chemistry leading to a dry and polymer free transfer and contacting process for 2D materials. In addition to the low density of adsorbates on the graphene surface the clean and flat boron nitride substrate leads to high quality graphene samples.

O 55.5 Tue 18:30 P2-EG

Graphene growth on SiC(0001) without step bunching — ●JAKOB LIDZBA, MARTINA WANKE, FLORIAN SPECK, and THOMAS SEYLLER — Professur für Technische Physik, Institut für Physik, TU Chemnitz, Reichenhainer Straße 70, 09126 Chemnitz, Germany

Epitaxial growth of graphene on SiC(0001) is a well-established method for the production of high-quality graphene layers [1]. The growth process is accompanied by a step bunching of the SiC and the concomitant formation of so-called macrosteps. Since the growth of graphene layers starts at the step edges, this prevents the formation of uniform graphene films. Therefore it is crucial to find a way of controlling their development. Kruskopf et al. stated, that the H-etch pretreatment is responsible for strong step bunching. However, the formation of high steps at the surface can be suppressed by separating the processes of buffer layer and graphene growth [2,3]. In this study we test different parameters for the growth process of monolayer graphene to avoid step bunching and therefore improve the growth process. Thickness of the graphene layers and chemical composition of the surface were determined from XPS spectra, while AFM was used to examine the topography of the sample surfaces.

[1] K.V. Emtsev et al., Nature Mater. **8**, 203 (2009).[2] M. Kruskopf et al., J. Phys.: Condens. Matter **27**, 185303 (2015).[3] M. Kruskopf et al., 2D Mater. **3**, 041002 (2016).

O 55.6 Tue 18:30 P2-EG

Preparation of epitaxial graphene on 4H-SiC(0001) — ●HASSAN KAKAG, FLORIAN SPECK, MARTINA WANKE, and THOMAS SEYLLER — Professur für Technische Physik, TU Chemnitz, Reichenhainer Str. 70, D-09126 Chemnitz, Germany

The growth of epitaxial graphene (EG) on 6H-SiC(0001) in argon under atmospheric pressure provides high-quality graphene layers at large scale [1]. The present study is focused on the optimization of hydrogen etching and growth of EG on the (0001) surfaces of the other commonly available polytype 4H-SiC. Etching in hydrogen as well as sublimation growth is carried out in a hot-wall reactor [2]. The dependence of the etching behavior on the hydrogen flow rate and annealing temperature was studied in the range of 0.2-3.0 slm and 1350-1500 °C, respectively. Furthermore, the influence of process temperature and annealing time on the graphene growth was investigated. Surface composition and graphene thickness were obtained from XPS. The surface morphology after hydrogen etching and graphene growth was investigated by AFM. The onset of graphitization is witnessed by the formation of the (6√3×6√3)R30° reconstruction at 1450 °C for an annealing time of 15 min. The best result of monolayer graphene growth was achieved with an annealing time of 15 min at a temperature of 1700 °C. In addition, bilayer graphene growth at step edges of the terraced SiC substrate was observed at 15 and 30 min annealing time. The substrate steps are mostly ordered and of similar height.

[1] K. V. Emtsev et al., Nature Mater. **8**, 203 (2009).[2] M. Ostler et al., Phys. Status Solidi B **247**, 2924 (2010).

O 55.7 Tue 18:30 P2-EG

Role of the tunnelling junction elements in photon emission from Au/Mica, Au/Cr/Mica, graphene/Cu systems — ●HAKKI TUNÇ ÇİFTÇİ¹, BERK ZENGİN¹, UMUT KAMBER¹, CEM KINCAL¹, DİLEK YILDIZ^{1,2}, and OĞUZHAN GÜRLÜ¹ — ¹Istanbul Technical University, Istanbul, Turkey — ²University of Basel, Basel, Switzerland

Photon emission occurrence from the tunnel junction relies on the material, apex and the cleanness of the tip of a scanning tunnelling microscope (STM). Certainly the surface electronic properties of the sample as well as its morphology directly determines the nature of the emitted photons. Minute and almost untraceable variance of chemical composition of the surfaces has a serious effect on the same phe-

nomenon. For instance, chromium diffusion on to the surface in the Au/Cr/Mica system was shown to affect the local photon emission properties of the Au surface due to tunnelling injected electrons. The knowhow gathered from such studies was employed in the investigation of the photon emission measurements performed with a photon STM on Graphene/Copper system. Being able to identify the influence of tip effects and the local chemistry of the surface paved the way to a deconvoluted method of investigation of the correlation between photon emissivity of Graphene/Cu interface to the local surface orientation.

O 55.8 Tue 18:30 P2-EG

Graphene formation on thin epitaxial grown Cu(111)-foils by chemical vapor deposition of acetone — ●JENS NEUROHR¹, SAMUEL GRANDTHYLL¹, MICHAEL WEINL², MATTHIAS SCHRECK², KARIN JACOBS¹, and FRANK MÜLLER¹ — ¹Experimental Physics, Saarland University, 66041 Saarbruecken, Germany — ²Experimental Physics 4, University of Augsburg, 86135 Augsburg, Germany

In comparison to the standard growth of graphene on copper via the CVD-process, an oxygen containing precursor (acetone) has been used for graphene formation on thin single crystalline Cu(111)-foils. In contrast to some literature reports, graphene formation can be obtained at quite low temperatures of about 700°C [1,2]. Graphene growth on the Cu(111)-foils was investigated by X-ray photoelectron spectroscopy (XPS), X-ray photoelectron diffraction (XPD), low energy electron diffraction (LEED), Fermi surface mapping(FSM), and scanning tunnel microscopy (STM) revealing nearly one monolayer coverage of mostly $\pm 1.65^\circ$ rotated domains.

References:

- [1] L. Gao, J. R. Guestand N. P. Guisinger Nano Letters 10.1021/nl1016706
 [2] H. K. Yu, K. Balasubramanian, K. Kim, J.-L. Lee, M. Maiti, C. Ropers, J. Krieg, K. Kern and A. M. Wodtke ACS Nano 10.1021/nn503476

O 55.9 Tue 18:30 P2-EG

Analysis of local variations of the electronic properties of monolayer and bilayer graphene/HOPG — ●ANNE HOLTSCH and UWE HARTMANN — Universität des Saarlandes, P.O. Box 151150, 66041 Saarbrücken

Cleaving a hopg bulk material can occasionally result in formation of graphene. Compared to other substrates hopg has the advantage that occurring Moiré patterns solely have their origin in rotation of the graphene lattice with respect to the hopg lattice orientation. We investigate the topography of the Moiré superstructure by scanning tunnelling measurement (STM) and changes of the electronic properties of graphene induced by the Moiré pattern and variation in amount of graphene layers using scanning tunnelling spectroscopy (STS).

The formation of a Moiré pattern goes along with corrugation of the graphene sheet. But STM measurements of bilayer graphene where both layers are aligned without rotation but the system itself is rotated towards the substrate do not show any corrugation. A possible Moiré pattern in the lower layer does not permeate to the top layer leading to the conclusion that the occurrence of a Moiré pattern is an effect restricted to the topmost graphene layer.

In a monolayer graphene with corrugation due to a Moiré pattern the distance of the graphene layer to the substrate adjusts the size of a band gap opening. For small distance the monolayer can behave bilayer-like. With increasing distance the size of the band gap decreases.

O 55.10 Tue 18:30 P2-EG

Sulfur intercalation of epitaxial graphene on 6H-SiC(0001) — ●SANTHA J. PANIGRAHI, FLORIAN SPECK, ADRIAN SCHÜTZE, MARTINA WANKE, and THOMAS SEYLLER — Professur für Technische Physik, TU Chemnitz, Reichenhainer Str. 70, D-09126 Chemnitz, Germany

During the initial stages of the sublimation growth of epitaxial graphene on SiC(0001), a carbon-rich ($6\sqrt{3} \times 6\sqrt{3}$)R30° reconstruction, also referred to as buffer layer (BL), is formed at the interface to the SiC. Despite being structurally graphene-like, covalent interaction with the topmost Si atoms of the substrate renders the BL electronically inactive. Upon intercalation, these bonds to the substrate are broken. The BL is decoupled from the SiC substrate and the electronic properties of graphene are restored.

In this contribution, we show that upon annealing in a CVD-like setup at temperatures between 600 and 850 °C in the presence of sul-

fur, the BL can be decoupled from the SiC substrate. We investigate the sulfur intercalation employing a combination of experimental techniques such as X-ray photoelectron spectroscopy, low energy electron diffraction and atomic force microscopy to study chemical composition and structural properties.

O 55.11 Tue 18:30 P2-EG

Dimerization of activated Coronene on HOPG — ●JÜRGEN WEIPPERT¹, JULIAN BACHMANN¹, JEAN-FRANCOIS GREISCH^{1,2}, ARTUR BÖTTCHER¹, and MANFRED M. KAPPES^{1,2} — ¹Institute of Physical Chemistry, Karlsruhe Institute of Technology (KIT), Fritz-Haber-Weg 2, 76131 Karlsruhe, Germany — ²Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

We have studied the dimerization of Coronene (Cor) as a model reaction for the fabrication of tailored graphene nanoribbons (GNR). Low energy ion beam deposition of both intact monomers as well as dehydrogenated congeners was used to grow the corresponding films. The composition of the incident cationic beam can be tuned by changing the electron impact energy and by varying the selected mass range. Thermal desorption measurements indicate that this leads to the on-surface formation of Cor dimers presumably already during the film growth. We find two different reaction channels: (a) $2(\text{Cor-2H})^*(\text{Cor-2H})_2$ and (b) $(\text{Cor-2H})+\text{Cor}^*(\text{Cor-H})_2$. While the monomers sublime at 460K the dimers $(\text{Cor-2H})_2$ sublime around 800K. The thermal desorption spectra indicate that the binding energy and the pre-exponential factor ($EB=2.9$ eV, $v=1017$ s⁻¹) of on-surface-formed dimers $(\text{Cor-2H})_2$ are comparable to that of directly deposited Dicoronylene. We have also explored the structures of the corresponding $(\text{Cor-2H})_2$ and $(\text{Cor-H})_2$ species using a combination of laser ablation and ion mobility measurements.

O 55.12 Tue 18:30 P2-EG

Response of the electronic structure of graphene to pressure, temperature and humidity — ●HAYDAR ALTUÇ YILDIRIM, UMUT KAMBER, CEM KINCAL, and OĞUZHAN GÜRLÜ — Istanbul Technical University, Istanbul, Turkey

Since its first isolation, the detection of gas molecules as well as humidity and temperature by use of graphene have been a matter of interest. We have used atmospheric pressure Chemical Vapor Deposition (AP-CVD) grown graphene and various transfer techniques to produce graphene based sensors on dielectric substrates. A controlled atmosphere chamber was designed and built to investigate the response of the resistivity of graphene to varying pressure, temperature and humidity. Comparison of the measurements taken by custom made graphene devices and a precise commercial sensor have shown similar responses. Upon changing the surface temperature of the graphene device we were able to control the adsorption of the water molecules. Effects of graphene growth parameters and transfer processes on to dielectrics, as well as ageing and temperature over humidity sensing capacity of graphene based devices will be presented.

O 55.13 Tue 18:30 P2-EG

A comparative study of the oxidation of PAHs using atomic oxygen — ●JÜRGEN WEIPPERT¹, VINCENT GEWIESE¹, PHILIPP HUBER¹, ARTUR BÖTTCHER¹, and MANFRED M. KAPPES^{1,2} — ¹Institute of Physical Chemistry, Karlsruhe Institute of Technology (KIT), Fritz-Haber-Weg 2, 76131 Karlsruhe, Germany — ²Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

We have studied the oxidation of PAH films (Coronene, Hexabenzocoronene, Rubrene) as model systems for fabrication of tailored nanographene oxides. The corresponding PAH films were grown by low energy ion beam deposition. The as-prepared PAH films were then exposed to a flux of atomic oxygen at room temperature. UPS and XPS based analysis of the chemical composition of the resulting oxidized films reveals a broad spectrum of PAH oxides dominated by epoxy and ether species. The interaction of flat PAHs with the substrate modifies the oxidation pathways in submonolayers cf. multilayers: epoxides are replaced by lactones as the dominating oxide with the exception of non-planar Rubrene. According to theoretical predictions we attribute this specific influence of theHOPG substrate to mobile epoxy functionalities which are produced by reaction of HOPG with incident O atoms. These can approach the adsorbed PAH molecules along the surface * thus destabilizing their molecular rims.

O 55.14 Tue 18:30 P2-EG

Intercalated porphines at the BN/Cu(111) interface: structure, electronic properties and function — •JACOB DUCKE¹, ALEXANDER RISS¹, ALEJANDRO PÉREZ PAZ², ANGEL RUBIO³, JOHANNES V. BARTH¹, and WILLI AUWÄRTER¹ — ¹Physik-Department E20, Technische Universität München, 85748 Garching, Germany — ²ETSF, Universidad del País Vasco, 20018 San Sebastián, Spain — ³Max Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany

The technological applicability of surface-supported molecular materials is often restricted by their limited stability. While covalent bonding can potentially enhance thermal stability, many of the currently researched molecular functionalities are sensitive to and impaired by

the gaseous or liquid environment.

In this work we present the fabrication of heterostructures consisting of porphines that are sandwiched between a copper surface and an insulating BN monolayer. Due to the electronic transparency of the BN layer, the intercalated molecules can be characterized and manipulated using scanning tunneling microscopy (STM). While the presence of the capping BN layer influences the self-assembly, we show that intrinsic molecular functionalities as switching between different tautomers or self-metalation are preserved. Such metal/molecule/insulator structures provide an opportunity to protect organic materials from atmospheric pressure, and might also be used to control chemical reactions through geometric confinement.