O 33: Poster Graphene: Electronic Structure and Excitations

Time: Tuesday 13:30–15:30 Location: P3

O 33.1 Tue 13:30 P3

Reversible transition between (10×10) **and** (11×11) **phases of Pb intercalated EG on 6H/SiC(0001)** — •Sergii Sologub[1,2], Markus Gruschwitz[2], Bharti Matta[3], Andres David Pena Unigarro[2], Philipp Rosenzweig[3], Sibylle Gemming[2], Kathrin Küster[3], Ulrich Starke[3], and Christoph Tegenkamp[2] — [1]Institute of Physics, NAS of Ukraine, Kyiv — [2]Institut für Physik, TU Chemnitz, Chemnitz — [3]Max-Planck-Institut für Festkörperforschung, Stuttgart

Epitaxial graphene (EG) obtained by intercalation of a buffer layer on 6H/SiC(0001) with Pb atoms is the subject of intensive experimental and theoretical studies due to its charge neutrality, the band gap opening and proximity superconductivity. The hallmark of Pb-intercalated EG is the formation of diffraction spots with (10×10) or (11×11) periodicity in the high-resolution LEED patterns. The correlation between these phases and corresponding microstructure, i.e. "striped" and "bubble" Pb intercalated phases, were examined by STM and by dark field imaging in a photoemission electron microscope. We have also established a recipe to reversibly switch between the (10×10) and (11×11) structures. In addition, the ratio of areas occupied by these coexisting phases could be estimated from the intensity ratio of second order LEED spots. Importantly, the degree and ease of intercalation strongly depends on the defect density of the initial buffer layer. The transformation between the different phases can be rationalized by the low diffusion barrier of Pb on SiC observed by density functional calculations.

O 33.2 Tue 13:30 P3

Confinement-mediated intercalation of metals in epitaxial graphene: Unlocking room temperature intercalation — •Kathrin Küster[1], Stefan Wundrack[2,3], Markus Gruschwitz[4], Sawani Datta[1], Bharti Matta[1], Teresa Tschirner[2], Marius Eckert[2,3], Rainer Stosch[2], Christoph Tegenkamp[4], Ulrich Starke[1], Klaus Pierz[2], and Andrey Bakin[2] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Institut für Halbleitertechnik - TU-Braunschweig — [4]Institut für Physik, TU Chemnitz

Intercalation of materials underneath epitaxial graphene is an effective way to tune graphene's properties but also to stabilize otherwise unstable 2D materials. Usually, this procedure requires extreme conditions like ultra-high vacuum and elevated temperatures often above 400 °C. Within the DFG research unit FOR 5242 we also investigate alternative routes of intercalation under more accessible conditions. Here, we report on the intercalation of Ga and In under monolayer graphene at ambient conditions. A multi-technique approach combining spectromicroscopy techniques with density functional theory calculations gives detailed insights into the intercalation pathways and the diffusion of the intercalants at the interface between graphene and the SiC substrate. It is evident that the intercalated atoms are strongly bound to the topography of the SiC terraces during their diffusion and exhibit anomalies in their diffusion behavior. The monolayer graphene is transformed into a decoupled bilayer upon intercalation and the intercalated materials develop their own metallic 2D electronic structure.

O 33.3 Tue 13:30 P3

Proximity-effects in epitaxial graphene: recent highlights of our Research Unit FOR5242 — S. Gemming[1], I. Gierz-Pehla[2], K. Küster[3], K. Pierz[4], Th. Seyller[1], U. Starke[3], •C. Tegenkamp[1], T. Wehling[5], and M. Wenderoth[6] — [1]Institut für Physik, TU Chemnitz — [2]Institut für Experimentelle und Angewandte Physik, U Regensburg — [3]Institut für Festkörperforschung, MPI Stuttgart — [4]Physikalisch-Technische Bundesanstalt, Braunschweig — [5]Institut für Theoretische Physik, U Hamburg — [6]IV. Physikalische Institut, U Göttingen

Proximity effects in low dimensional electron gases are essential for the design of new quantum materials with tailored electronic, magnetic and optical properties. A recent example is superconductivity in twisted bilayer graphene. Our Research Unit FOR 5242 studies the influence of proximity-induced spin-orbit interaction (SOI), electronic correlations as well as local electric fields on 2D electron gases, using epitaxial graphene (EG) on SiC substrates as a model system. EG is known for its flexible functionalization schemes including intercalation and adsorption, enabling control of the doping level, hybridization effects, and the strength of the Coulomb interaction. Here, we highlight a few of our recent results including (1) the use of EG for quantum Hall resistance standards, (2) SOI in graphene induced by 2D Pb layers, (3) Mott-Hubbard physics realized by the intercalation of Sn and Si, (4) many-body effects in extremely doped EG and (5) novel 2D interface layers. For further details see www.for5242.de

O 33.4 Tue 13:30 P3

Quasi-freestanding monolayer graphene achieved by Pb intercalation — •S Wolff[1], P Schädlich[1], A D Peña Unigarro[1], B Matta[2], G Ghosal[1], F Schölzel[1], P Richter[1], M Hutter[3], M Stettner[3], K Küster[2], C Kumpf[3], S Gemming[1], U Starke[2], C Tegenkamp[1], and T Seyller[1] — [1]Institute of Physics, TU Chemnitz — [2]MPI für Festkörperforschung, Stuttgart — [3]Peter Grünberg Institut, Forschungszentrum Jülich

Intercalation is a promising approach for tailoring the electronic structure of epitaxial graphene on SiC. Beyond that, it enables the formation of otherwise unstable 2D phases of elements and opens a route to study the interplay between the two 2D materials and the substrate. We have studied the Pb intercalation process under the buffer layer in detail using low-energy electron microscopy (LEEM), photoelectron spectroscopy (PES), scanning tunneling microscopy (STM), density functional theory calculations (DFT) and X-ray standing wave (XSW). LEEM is used to monitor the intercalation process at different intercalation temperatures, resulting in either a (1×1) symmetry or in a (10×10) superstructure of the Pb atoms. These findings can be supported by angle-resolved PES and STM. Experiments indicate, in agreement with DFT, different filling of the Pb bands depending on the SiC polytype. Furthermore, XSW was used to determine the interlayer distances, revealing covalent bonding of the intercalant to the substrate and van der Waals bonding to graphene.

O 33.5 Tue 13:30 P3

Liquid metal intercalation of epitaxial graphene Hall bar devices on SiC — •Marc Bothe[1,2], Stefan Wundrack[1,2], Teresa Tschirner[1], Markus Gruschwitz[3], Yefei Yin[1], Klaus Pierz[1], Frank Hohls[1], Rainer Stosch[1], Christoph Tegenkamp[3], Hans Werner Schumacher[1], and Andrey Bakin[2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Halbleitertechnik, TU Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig — [3]Institut für Physik, Technische Universität Chemnitz, Reichenhainer Strasse 70, 09126 Chemnitz, Germany

Epitaxial graphene grown on SiC is a promising platform for metal intercalation, enabling the investigation of proximity effects. Metal intercalation relies on the controlled introduction of lattice defect densities in monolayer graphene, achieved through plasma treatment. This is followed by liquid metal intercalation, during which atoms diffuse through lattice defects and propagate beneath the graphene. However, the use of metal intercalated graphene samples for device fabrication presents two challenges. First, solvents used for lithography often lead to metal deintercalation. Second, lattice defects in graphene compromise the structural and electronic integrity of the graphene device. We use an alternative strategy that combines lithography with metal intercalation through predefined channels. Initial measurements of Hall bar structures intercalated with gallium show superconducting behavior, demonstrating the potential of this approach for advanced device applications.

O 33.6 Tue 13:30 P3

Mesoscopic Lateral Intercalation Dynamics of Tin Between the Epitaxial Buffer Layer of Graphene and SiC — •Benno Harling[1], Zamin Mamiyev[2], Christoph Tegenkamp[2], and Martin Wenderoth[1] — [1]IV. Physical Institute, Georg-August-University Göttingen, Germany — [2]Analysis of Solid Surfaces, Nanostructures and Quantum Materials, TU Chemnitz, Germany

Within the challenges of modern electronics, the dynamics of intercalation in layered structures is key for pushing the boundaries of technological limits. Fine-tuned control and a deeper understanding of the intercalation process is needed. Our study focuses on the lateral dynamics of this intercalation process. Whereas penetration of the

graphene sheet was already often discussed [1], the lateral atom transport processes according to the mesoscopic landscape of the substrate has been less addressed. Kelvin Probe Force Microscopy (KPFM) was used to investigate an epitaxial graphene buffer layer intercalated with tin. A diffusion edge to the pristine buffer layer can be identified with this method down to the mesoscopic scale below 100 nanometers. On a vicinal surface, we find surface steps as a clear barrier for diffusion. Material transfer over the substrate steps is mediated by a local defect, i.e. local pin-holes. Moreover, we do not observe nucleation on the terrace, but the decoration of the next step by tin. Faster diffusion at the step edges leads to directional growth of the intercalated phase.

Financial support by the DFG within research unit FOR5242 is greatly acknowledged.

[1] Wu et al., Prog. Surf. Sci. 96, 100637, 2021

O 33.7 Tue 13:30 P3

Magnetic MnPc molecules adsorbed on epitaxial graphene — •James Oyuga[1], Nhung Nguyen[1], Uwe Gerstmann[2], Eva Rauls[3], Julian Koch[1], and Christoph Tegenkamp[1] — [1]Institut für Physik, TU Chemnitz, Germany — [2]Theoretische Physik, Universität Paderborn, Germany — [3]Department of Mathematics and Physics, University of Stavanger, Norway

Phthalocyanines (Pc) are prototype molecules hosting magnetic ions. When adsorbed on surfaces, the spin state of the molecules is influenced by the substrate. In a combined experimental and theoretical study, we investigated this influence for the case of MnPc molecules adsorbed on monolayer graphene/SiC(0001) using STM, magnetotransport and theoretical DFT modeling. The STM measurements showed that the self-assembly of the MnPc molecules results in an almost defect-free monolayer with a (4×2) unit cell accommodating 8 MnPc molecules. The DFT modeling revealed that the structure and thereby the spin states of the molecules are decisively influenced by the substrate. In the gas phase the MnPc molecules are symmetrically bended with a spin state of $S = 3/2$. However, on an epitaxial graphene monolayer this is changed into an even mixture of flat molecules with an $S = 5/2$ spin state and upward bended molecules with an $S = 3/2$ spin state. This mixture allows for a denser arrangement of the molecules in a (4×2) unit cell, that is commensurable with both the graphene layer and the underlying SiC substrate. The impact of such molecular structures towards transport in epitaxial monolayer graphene is quantified by magneto transport experiments analyzing the weak (anti) localization.

O 33.8 Tue 13:30 P3

Intercalation of a condensed 2D-Ag phase within the epitaxial graphene/SiC interface — •Sawani Datta[1], Vibha Reddy[1], Bharti Matta[1], Arpit Jain[2], Kathrin Küster[1], Joshua A. Robinson[2] und Ulrich Starke[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]Pennsylvania State University, State College, USA

Intercalating 2D materials at the epitaxial graphene (EG)/SiC interface improves their environmental stability, facilitating the use of various ex-situ techniques for their fundamental study and application purposes. In a previous study, we showed that Ag atoms intercalated at the EG/SiC interface form a triangular (1×1) lattice with respect to the SiC and the Ag interlayer is semiconducting [1,2]. Interestingly, intercalating Pb into a previously Ag-intercalated sample results in the complete replacement of Ag by Pb. Subsequently, another round of Ag intercalation can entirely replace Pb, forming a new Ag phase characterized by a 4/3 packing of Ag with respect to the underlying Si layer. Theory suggested the existence of two intercalated 2D material phases also for several other materials [3] and Auger electron spectroscopy mapping indeed shows a higher Ag concentration of the latter Ag phase [4]. In this work, we compare the 2 different Ag phases by low-energy electron diffraction (LEED) and angle-resolved photoemission spectroscopy (ARPES). This ongoing study is supported by DFG through FOR 5242 and by NSF Grant DMR-2011839. [1] Phys. Rev. B 101, 201407(R) (2020). [2] Phys. Rev. B 105, 235428 (2022). [3] arXiv:2011.01914v1 (2020). [4] 2D Materials 8, 41003 (2021).

O 33.9 Tue 13:30 P3

Scanning tunneling potentiometry methods for intercalated graphene systems — •Tim Güldenpfennig[1], Simeon Bode[2], Markus Gruschwitz[1], Martin Wenderoth[2], and Christoph Tegenkamp[1] — [1]Institut für Physik, TU Chemnitz, Germany — [2]IV. Physikalisches Institut, Universität Göttingen, Germany

Graphene and graphene-based (hetero-)systems were subjects in a wide range of studies in the past decades revealing their intriguing electronic properties. Epitaxially grown graphene on SiC plays a vital role as a base for electronic application. By intercalating such grown buffer layer with different elements the electronic properties of the decoupled graphene layer can be precisely manipulated. Recently a great interest in the two dimensional intercalant layers arose as well. The latest advance towards intercalation of heavy elements (Pb, Bi, etc.) comes along with new challenges due to defect-dependent intercalation paths. Macro- and mesoscopic transport experiments on these percolated but multi-scale defective intercalated phases become impractical [1].

For transport investigations at the nanometer scale we utilize scanning tunneling potentiometry (STP). In combination with finite element simulations the conductivity of the intercalated phase and the influence of defects can be separated precisely. Two different setups to investigate the transport properties of intercalated graphene systems on nanoscopic scale are presented. One is implemented in a 4pp-STM/SEM setup with the ability to locally apply transverse voltages. The other setup uses an home-built STM for measurements at 6 K with micro-Volt resolution. [1] Phys. Rev. B 109, 245430 (2024)

O 33.10 Tue 13:30 P3

Electronic and structural properties of a Sn Mott phase proximitized to graphene — C. Ghosal[1], •H.-T. Ngo[1], S. Ryee[2], Z. Mamiyev[1], N. Witt[2,3], T. Wehling[2,3], and C. Tegenkamp[1] — [1]Institut für Physik, TU Chemnitz — [2]Institute of Theoretical Physics, U Hamburg — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg

Graphene, renowned for its exceptional electronic and optical properties as a robust 2D material, traditionally lacks electronic correlation effects. Proximity coupling offers a promising method to endow quantum materials with novel properties. In this study, we achieved such a proximity coupling by intercalating Sn between the buffer layer of graphene on SiC(0001). In the $\sqrt{3}$-areas, the Sn-p_z electrons exhibit robust correlation effects manifest as characteristic Hubbard bands analyzed by STS and EELS. Thereby, the system revealed a spatially modulated hybridization between the Dirac and the correlated electrons depending on the Sn sites with respect to the graphene lattice. The DFT and DMFT calculations show excellent agreement regarding the spectral properties. The analyses revealed further that besides the hybridization and Coulomb interaction also the charge transfer plays an important role for electronic state that emerges in these artificial correlated systems.

O 33.11 Tue 13:30 P3

Twisted Bilayer Graphene by Hydrogen Intercalation — •Hao Yin[1,2], Andrei Matetskii[1], Frank Stefan Tautz[1,2], François C. Bocquet[1], and Christian Kumpf[1,2] — [1]Peter Grünberg Institut (PGI-3), FZ-Jülich, Germany — [2]RWTH Aachen University, Aachen, Germany

Quasi-free-standing twisted bilayer graphene (TBLG) with a 30° twist angle is achieved on a 6H-SiC(0001) surface via hydrogen intercalation of the zeroth-layer graphene (ZLG). Initially, 0°-rotated monolayer graphene is prepared using the surfactant-mediated epitaxial growth method [PRL **125**, 106102 (2020)]. The processes of hydrogen intercalation and deintercalation were investigated using Low Energy Electron Microscopy (LEEM), with intercalation conducted stepwise, while deintercalation was monitored in real time. Our results provide valuable insights into the mechanisms underlying hydrogen intercalation and deintercalation.

A sharp reaction front was observed, aligned parallel to the step edges, suggesting that hydrogen atoms migrate beneath the ZLG from surface discontinuities, such as step edges or defects.

Deintercalation, taking place 200°C above the intercalation temperature, was significantly faster (within one minute) and occurred uniformly, as indicated by the homogeneous brightness changes in deintercalated regions. This implies a much faster diffusion of H under the TBLG at this temperature, or possibly that H atoms are able to penetrate through the graphene layers.

O 33.12 Tue 13:30 P3

Near-Field Optical spectroscopy of few-layer Graphene's interband resonances to study it's gate-tunable band structures — •Dominique Malik, Lina Jäckering, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University

The band structure of few-layer graphene (FLG) defined by the crystallographic stacking order determines its electronic and optical properties. Optical spectroscopy of interband resonances - the excitation of

electron transitions between two electronic bands - allows to directly probe the gate-tunable band structure. Within one flake FLG can exist in different stacking orders. However, conventional far-field spectroscopy is diffraction limited and cannot resolve stacking domains below this limit [1]. Recently, with scanning near-field optical microscopy (s-SNOM) the interband resonances of bilayer graphene (BLG) and 4LG have been retrieved [2]. Due to the stacking specific resonance energy, s-SNOM spectroscopy allowed for the identification of stacking domains on the nanometer scale [2]. The local effect of the application of a gate voltage to FLG has not been studied. Here, we present the theoretical foundation to perform near-field optical spectroscopy of interband resonances of gated trilayer and BLG over the energy range from 0.28 to 0.54 eV to gain insights into gate-tunable modifications of their band structures. We layout the design and fabrication of a suitable sample and show initial results. We expect high-resolution s-SNOM measurements could reveal local variations in band gap opening, which are unachievable with far-field techniques. [1] Lui et al. Nano Lett. 11, 1 (2011) [2] Wirth et al. ACS Photonics 8.2 (2021)

O 33.13 Tue 13:30 P3

non-equilibrium carrier dynamics of a graphene - 2D Mott insulator interface — Maria-Elisabeth Federl[1], •Franziska Bergmeier[1], Zamin Mamiyev[2], Niklas Witt[3], Tim Wehling[3], Christoph Tegenkamp[2], and Isabella Gierz[1] — [1]University of Regensburg — [2]Technical University Chemnitz — [3]University of Hamburg

Hybridization between localized and itinerant electrons is believed to be responsible for the formation of exotic electronic states including heavy-fermion behaviour or unconventional superconductivity. Confinement heteroepitaxy, where novel 2D structures are stabilized at the interface between epitaxial graphene and SiC substrate, provides a pathway to engineer proximity-coupling between the massless carriers in graphene and the carriers in the underlying layer. We intercalated graphene with Sn, where the $(\sqrt{3} \times \sqrt{3})$R30° phase formed on SiC(0001) is believed to be a Mott insulator [1], and used time- and angle-resolved photoemission spectroscopy (trARPES) as well as density functional theory (DFT) to search for indications of interlayer hybridization that might pave the wave towards the realization of exotic electronic phases.

[1] Phys. Rev. Lett. 114, 247602 (2015)

O 33.14 Tue 13:30 P3

Sequential Intercalation of Epitaxial Graphene with Multiple Elements — •Niels Rösch, Mohammad Elkhawaga, Philip Schädlich, Fabian Göhler, and Thomas Seyller — Chemnitz University of Technology, Institute of Physics, 09126 Chemnitz, Germany

The intercalation of epitaxial graphene on SiC(0001) is a field of research that currently attracts attention. On one hand it provides the possibility to fine-tune the properties of the graphene layer. On the other hand it also is a means to fabricate two-dimensional materials in a confined state [1,2].

In this study we test the possibility to synthesize binary compounds by sequential intercalation of two elements. As test cases we have chosen the topological insulator Bi_2Se_3 [3] and the superconductor FeSe [4]. To that end, Bi or Fe is first intercalated using a deposition and annealing approach. This is followed by an exposure to a selenium-rich atmosphere at elevated temperatures. Samples are characterized by photoelectron spectroscopy and electron diffraction.

[1] Z. Y. Al Balushi et al., Nat. Mater (2016) 1166.
[2] N. Briggs et al., Nat. Mater. 19 (2020) 637.
[3] H. Zhang et al., Nat. Phys. 5 (2009) 438.
[4] J.-F. Ge et al., Nat. Mater. 14 (2014) 285.

O 33.15 Tue 13:30 P3

Free-standing graphene films/membranes — •Leon Lasnig, Lukas Kalkhoff, Steffen Franzka, and Marika Schleberger — Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany

Large-area graphene films are usually grown onto a copper sheet via chemical vapor deposition. The transfer of the graphene to another substrate to this date has been done with the help of polymer films, which leads to impurities and residues. These residues can change the properties of graphene. It is therefore necessary to develop new fabrication protocols to prevent or at least minimize contaminations.
Here we present a new technique for fabricating membranes without the requirement of an PMMA layer. The samples were then transferred on hole substrates with a hole diameter of 150 μm. Since a monolayer is not stable enough to cover the hole, samples with multiple layers were prepared. These were characterized using Raman spectroscopy and an optical profilometer. Raman spectroscopy showed that the samples within the holes are very homogeneous in terms of doping and strain. The lack of D mode in the measured Raman spectra indicates a clean sample. The profilometer revealed that the graphene membranes in the holes have an average hight deviation of only 138 nm.

O 33.16 Tue 13:30 P3

Electronic and structural properties of Bi-intercalated epitaxial graphene on SiC(0001) — Niclas Tilgner[1], Susanne Wolff[1], Andres D. Peña Unigarro[1], Philip Schädlich[1], Fabian Göhler[1], Bharti Matta[2], Philipp Rosenzweig[3], Kathrin Küster[2], Mark Hutter[4], Monja Stettner[4], Hao Yin[4], Serguei Soubatch[4], François C. Bocquet[4], Tien-Lin Lee[5], Christian Kumpf[4], Ulrich Starke[2], Sibylle Gemming[1], and •Thomas Seyller[1] — [1]Institut für Physik, TU Chemnitz — [2]Max Planck Institut für Festkörperforschung, Stuttgart — [3]Physikalisches Institut, Universität Stuttgart — [4]Peter Grünberg Institut, Forschungszentrum Jülich — [5]Diamond Light Source, United Kingdom

The intercalation of epitaxial graphene on SiC(0001) is a research area that currently attracts attention. Not only does it provide the possibility to fine-tune the properties of the graphene layer, it also allows fabricating two-dimensional materials in a confined state. Using a variety of experimental (LEED, LEEM, XPS, ARPES, XSW) and theoretical (DFT) approaches we studied the structural and electronic properties of different intercalated Bi phases that are formed depending on the preparation conditions. While a dense phase with a (1×1) periodicity with respect to SiC(0001) shows metallic properties, a diluted $(\sqrt{3} \times \sqrt{3})R30°$ phase appears insulating. Upon annealing in hydrogen, the latter can be transformed into a layer of bismuthene. However, while the bismuthene is arranged with the same periodicity, DFT calculations suggest that the transition is accompanied by a major structural rearrangement.

O 33.17 Tue 13:30 P3

Transport Properties of Epitaxial Graphene on 4H-SiC(0001) and 6H-SiC(0001) on the Local Scale — •Simeon Bode[1], Benno Harling[1], Teresa Tschirner[2], Klaus Pierz[2], and Martin Wenderoth[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

Recent experiments on epitaxial graphene on silicon carbide have shown that transport properties strongly depend on the surface termination of the SiC substrate. Here, we study the impact of the polytype of the substrate SiC on various local properties of Polymer Assisted Sublimation Grown (PASG) graphene. Recently, it has been shown that there are two different surface terminations present at 6H-SiC [1], whereas mainly one surface termination was observed on 4H-SiC. The structural properties are investigated by STM and AFM, whereas electronic properties are extracted from STS data. Local transport measurements using Scanning Tunneling Potentiometry (STP) on 6H-SiC reveal variations in the sheet resistance from terrace to terrace when changing the stacking sequence across a step. On the other hand, the local sheet resistances of neighbouring terraces are very similar if the step height is half of a SiC unit cell, i.e., having the same termination on both sides. PASG graphene on 4H-SiC predominantly exhibits steps of half the unit cell. First data on 4H-SiC indicates that also on this system the sheet resistance is only slightly varying across steps. This work was financially supported by the DFG through the FOR5242. [1] Sinterhauf et al., Nat Commun 11, 555, 2020

O 33.18 Tue 13:30 P3

Growth dynamics of the graphene buffer layer on SiC(0001) grown by polymer-assisted sublimation growth (PASG) — •Julia Guse[1], Teresa Tschirner[1], Stefan Wundrack[1], Kathrin Küster[2], Ulrich Starke[2], Philip Schädlich[3], Thomas Seyller[3], Klaus Pierz[1], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Institut für Physik, TU Chemnitz

Fabrication of two-dimensional (2D) heterostructures using epitaxial graphene on SiC is gaining interest for engineering new electronic material systems. Important for the quality of the epigraphene layer is the 0th graphene layer, the buffer layer, being covalently bonded to

the SiC substrate. However, there is still conflicting theoretical and experimental evidence of the structural properties of the buffer layer and its influence on epigraphene. Further, the quality of this buffer layer is not well defined and systematic studies are still lacking. We use an advanced growth technique preventing step bunching and large terrace step heights to achieve high quality buffer layer on millimeter scale. The buffer layer is grown by thermal sublimation in an argon atmosphere and by applying the polymer-assisted sublimation growth (PASG) method. By pretreatment of the SiC substrate which supplies additional carbon during the initial nucleation process the SiC surface is stabilized by rapid buffer layer formation which prevents step bunching. We investigate the growth parameters for homogeneous buffer layer formation and systematically study its growth dynamics.

O 33.19 Tue 13:30 P3

Modeling the intercalation of epitaxial graphene with main group elements from first-principles — Andres D. Peña Unigarro[1], Niklas Witt[2,3], Maria-Elisabeth Federl[4], •Alexander Korn[1], Isabella Gierz[4], Tim Wehling[2], Florian S. Günther[5], and Sibylle Gemming[1,6] — [1]Inst. Physik, TU Chemnitz — [2]Inst. Theoretische Physik, U Hamburg — [3]Theoretische Physik, JMU Würzburg — [4]Inst. Experimentelle und Angewandte Physik, U Regensburg — [5]UNESP, Rio Claro, Brazil — [6]MAIN Center, TU Chemnitz.

Intercalation of epitaxial graphene on silicon carbide (EG) with metallic interlayers opens up a plethora of fascinating physical phenomena, rooted in both spatial confinement and proximity coupling effects. A rich variety of exotic electronic states is obtained by the simultaneous presence of flat and Dirac-like bands with intricate splittings of the spins and pseudospins in EG and the intercalant.

Here, we present first-principles calculations for supercell models, which capture the essential structural and electronic properties of thin intercalation layers in EG. Ordered structures with different interlayer coverages have been studied, which provide distinctly tailored degrees of proximity coupling. Comparing interlayers from the experimentally well-studied main group elements Sn, Pb, and Bi allows distinguishing between isovalent and heterovalent intercalants as well as studying the influence of relativistic effects, in particular spin-orbit coupling (https://www.epigraphene.de/).

O 33.20 Tue 13:30 P3

Influence of doping on non-equilibrium carrier dynamics in graphene — •Leonard Weigl[1], Johannes Gradl[1], Peter Richter[2], Thomas Seyller[2], Camilla Coletti[3], and Isabella Gierz[1] — [1]University of Regensburg, Germany — [2]Technical University of Chemnitz, Germany — [3]Instituto Italiano di Tecnologia, Pisa, Italy

The understanding of non-equilibrium charge carrier dynamics in the quasi-relativistic dispersion of graphene is a key ingredient for the design of future ultrafast electronic devices. Despite its crucial importance for device operation, the role of the doping level remains controversial. Here, we use time- and angle-resolved photoemission spectroscopy (tr-ARPES) to study the energy-resolved photo-carrier relaxation in epitaxial graphene for different doping levels. In contrast to previous studies on the same material [1], we find the energy-resolved relaxation times to be independent of doping. We attribute this to the fact that - with increasing doping level - the peak electronic temperature is found to decrease, making the phase space for carrier relaxation doping-independent. Therefore, we speculate that the previously observed differences in carrier dynamics between graphene resting on C- and H-terminated SiC substrates, respectively, originate from the different interfaces to the substrate rather than the doping level. [1] J. C. Johannsen et al., Nano Lett. 15, 326-331 (2014)

O 33.21 Tue 13:30 P3

Hexagons on Rectangles: Epitaxial Graphene on Ru$(10\bar{1}0)$ — •Lars Buss[1], Giovanni Zamborlini[2], Cathy Sulaiman[1], Moritz Ewert[1], Mirko Cinchetti[2], Jens Falta[3], and Jan Ingo Flege[1] — [1]Applied Physics and Semiconductor Spectroscopy, BTU Cottbus-Senftenberg, Germany — [2]Department of Physics, TU Dortmund University, Germany — [3]Institute of Solid State Physics, University of Bremen, Germany

The miniaturization of integrated electronics drives the demand for barrierless interconnects, with graphene-ruthenium structures emerging as promising candidates. We present an *in situ* study of the growth and electronic properties of graphene on rectangular Ru$(10\bar{1}0)$ grown by high-temperature carbon segregation. Using low-energy electron microscopy (LEEM), it is shown that graphene grows preferentially along the $[1\bar{2}10]$ direction, forming micrometer-sized rectangular islands. Microspot low-energy electron diffraction (μLEED) reveals two predominant graphene orientations, rotated by 0° (R0) and 30° (R30), with indications for the formation of graphene nanoribbons in bilayer graphene/Ru$(10\bar{1}0)$. Microspot angle-resolved photoemission spectroscopy (μARPES) shows that the Dirac cones remain intact in bilayer graphene with reduced n-type doping compared to graphene/Ru(0001), indicating a weaker interaction with the Ru$(10\bar{1}0)$ surface. These results highlight the influence of substrate symmetry and interactions on graphene properties and provide insights for engineering graphene beyond hexagonal substrates.