

O 22: Poster Session - 2D Materials Beyond Graphene: Growth, Structure and Substrate Interaction

Time: Monday 18:15–20:00

Location: P1A

O 22.1 Mon 18:15 P1A

Structural and electronic investigations of Blue Phosphorene on Au(111) — ●JULIAN PICKER, MAXIMILIAN SCHAAL, MARCO GRUENEWALD, FELIX OTTO, ROMAN FORKER, and TORSTEN FRITZ — Institute of Solid State Physics, Friedrich Schiller University Jena, Helmholtzweg 5, 07743 Jena, Germany

In the last decades a wealth of two dimensional (2D) materials have obtained profound interest in fundamental research and practical applications because of their unique physical properties. A relatively new representative of these kind of materials is semiconducting Blue Phosphorene (BlueP), an allotrope of phosphorus. Theoretically, a buckled honeycomb structure and fascinating properties for optoelectronic applications such as a tuneable band gap size and a high carrier mobility were predicted [1,2]. In our study we observed the growth of BlueP on Au(111) by using molecular beam epitaxy (MBE) as well as the physical properties of this 2D material. The layer deposition was monitored *in-situ* via reflection high-energy electron diffraction (RHEED). Furthermore, we investigated the structural properties in reciprocal space by low-energy electron diffraction (LEED) and in real space by scanning tunneling microscopy with and without a hydrogen functionalised tip (STHM, STM). The electronic structure of the valence and conduction band were investigated by angle-resolved ultra violet photoelectron spectroscopy (ARUPS) and scanning tunneling spectroscopy (STS).

[1] J. L. Zhang *et al.*: Nano Lett. **16**, 4903-4908 (2016).[2] J. Zhuang *et al.*: ACS Nano **12**, 5059-5065 (2018).

O 22.2 Mon 18:15 P1A

Selective Oxygen Functionalization of the h-BN/Rh(111) Nanomesh — ●MARIE FREIBERGER, FLORIAN SPÄTH, FABIAN DÜLL, PHILIPP BACHMANN, JOHANN STEINHÄUER, HANS-PETER STEINRÜCK, and CHRISTIAN PAPP — FAU, Erlangen, Germany

2D materials such as hexagonal boron nitride (h-BN) and graphene are interesting due to their electronic properties, as inert template structures or as possible hydrogen storage materials. As a structural graphene analogue, h-BN features a honeycomb structure. The morphology of a supported h-BN layer strongly depends on the underlying crystal surface. In the case of Rh(111), a Moiré pattern evolves, also known as nanomesh, showing pore and wire regions. This strong corrugation makes h-BN/Rh(111), for example, a suitable template for confined metal nanocluster growth. Further modification of h-BN can be achieved via oxygenation or hydrogenation. In the case of the h-BN nanomesh on Rh(111), this is interesting since the pores and wires may show different reactivity towards functionalization.

Herein, we present detailed studies on the adsorption of molecular oxygen on the h-BN nanomesh on Rh(111). The system is investigated in a model approach under ultra-high vacuum conditions. Using synchrotron radiation-based *in situ* high-resolution X-ray photoelectron spectroscopy (HR-XPS) we are able to provide a deep insight in this system regarding the adsorption behaviour and thermal stability. Oxygenation is performed via a supersonic molecular beam and is found to occur selectively in the pores of h-BN. The adsorbed oxygen species is stable up to 600 K.

O 22.3 Mon 18:15 P1A

Gating monolayer MoS₂ by charging its substrate — ●CAMIEL VAN EFFEREN, CLIFFORD MURRAY, JEISON FISHER, JOSHUA HALL, and THOMAS MICHELY — II. Physikalisches Institut, Universität zu Köln, Zùlpicher Straße 77, 50937 Köln, Germany

We gate quasi-freestanding monolayer MoS₂, grown by molecular beam epitaxy (MBE) on graphene (Gr) on Ir(111) [1], by introducing intercalants between Gr and Ir(111). Using intercalants like Eu and O, we control the position of the Gr Dirac point, allowing us to n- or p-gate the Gr and in turn also the MoS₂. Applying a combination of scanning tunneling microscopy and spectroscopy we measure the effects of the gating on the band structure of monolayer MoS₂, which has previously been studied using comprehensive scanning tunneling spectroscopy [2]. In ungated MoS₂/Gr/Ir(111) a 1D hole gas is found around the 4|4E mirror twin boundaries of MBE-grown MoS₂, a consequence of band bending around the charged boundary. We investigate how the band bending and the 1D hole gas are affected by the gating,

due to changes in the screening environment and the charge transfer from the substrate. Moreover, as a consequence of gating, we observe also a shift in the periodicity of the confined states in the mirror twin boundaries.

[1] Joshua Hall *et al.*, 2D Materials **5**, 025005 (2018)[2] Clifford Murray *et al.*, Phys. Rev. B **99**, 115434 (2019)

O 22.4 Mon 18:15 P1A

When halogene atoms do not guide the selfassembly of GNR precursor molecules — ●CHRISTOPH DOBNER¹, JACOB TEETER², PAULO COSTA³, ALEXANDER SINITSKII², and AXEL ENDERS^{1,3} — ¹Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth — ²Department of Chemistry, University of Nebraska - Lincoln, Lincoln NE 98588, USA — ³Department of Physics and Astronomy, University of Nebraska - Lincoln, Lincoln NE 98588, USA

The on-surface selfassembly of the prototypical precursor molecule for graphene nanoribbon synthesis, 6,11-dibromo-1,2,3,4-tetraphenyltriphenylene (C₄₂Br₂H₂₆), and its non-brominated analog hexaphenylbenzene (C₄₂H₃₀), was investigated as a function of thermal treatment using scanning tunneling microscopy. The "herringbone" reconstructed surface of Au(111) was used for all growth studies, and all experiments have been carried out under ultrahigh vacuum conditions. It is found that for sufficiently high substrate temperatures, there is no halogene-guided selfassembly of the brominated molecules, in stark contrast to the well-known formation of chevron-shaped GNRs from these precursors. Instead, both species, the brominated and non brominated ones, form identical one-dimensional structures consisting of fully planarized and cyclized molecules on the surface. For hexaphenylbenzene, which form non-covalent two-dimensional networks at room temperature, a thermally induced transition of the network structure could be achieved by moderate annealing, which is likely driven by π -bond formation.

O 22.5 Mon 18:15 P1A

Classical molecular dynamics investigation of carbon nanomembranes — ●JULIAN EHRENS and JÜRGEN SCHNACK — Universität Bielefeld, PF 100131, D-33615 Bielefeld

Nanometer thin carbon nanomembranes (CNMs) that are made by electron-induced crosslinking of aromatic self-assembled monolayers (SAMs) [1] can not be adequately investigated with regard to their internal structure by experimental means such as X-ray diffraction. Computer simulation is thus a viable method to further investigate the membranes on an atomic level.

We present the extension and continuation of our previous theoretical research with the focus on possible internal structures of carbon nanomembranes. We compare our theoretical estimates of the Young's modulus to the experimental results. For our calculations classical molecular dynamics as implemented in LAMMPS is employed and various ways of obtaining the modulus are presented for different models of membrane formation.

[1] Turchanin *et al.*, Progress in Surface Science, Volume 87, Issues 5-8, May-August 2012, Pages 108-162

O 22.6 Mon 18:15 P1A

Growth and characterization of WS₂ on epitaxial graphene on SiC(0001) — ●ADRIAN SCHÜTZE, PHILIP SCHÄDLICH, CONSTANCE SCHMIDT, FLORIAN SPECK, DIETRICH R. T. ZAHN, and THOMAS SEYLLER — Institute of Physics, TU Chemnitz, Chemnitz, Germany

2D materials such as, for example, graphene, hexagonal boron nitride or transition metal dichalcogenides have recently received much interest as building blocks for electronic devices. For a successful integration of these materials, scalable growth methods are essential. Here we investigate the growth of WS₂ by metal organic molecular beam epitaxy (MOMBE) [1] on epitaxial graphene on SiC(0001). In that process W(CO)₆ is used as a precursor in conjunction with sulfur vapor produced by decomposition of FeS₂ in a thermal evaporator. Using MOMBE we were able to grow ultra-thin films of WS₂ on epitaxial graphene which were characterized by a combination of X-ray photoelectron spectroscopy (XPS), angle resolved photoemission spectroscopy (ARPES), low-energy electron diffraction and microscopy (LEED, LEEM), atomic force microscopy (AFM) and Raman spec-

troscopy. The ultra-thin films, which had thicknesses between one and two monolayers, were observed to consist of triangular domains. We discuss the influence of the growth parameters on the structural and electronic properties of the layers.

[1] S. Tiefenbacher et al., Surf. Sci. 318 (1994) L1161.

O 22.7 Mon 18:15 P1A

Growth and characterization of monolayer MnSe₂ on Au(111)

— •SEBASTIEN HADJADJ, EVANGELOS GOLIAS, SANGEETA THAKUR, IVAR KUMBERG, and WOLFGANG KUCH — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

During the last couple of years, there is a rising interest in novel two-dimensional magnetic materials. Most recently, several groups have shown that magnetic order in two-dimensional materials can be stable [1, 2]. The case of MnSe₂ is interesting, since it has shown magnetic properties at room temperature, making it an ideal candidate for actual applications. However, magnetic order has been reported for MnSe₂ grown on GaSe or SnSe₂, and the role of the interface in the stabilization of magnetic order is not yet clear. It needs to be ascertained if the magnetic ordering of monolayer MnSe₂ is an intrinsic effect of the material or an interface-induced phenomenon. Here we use molecular beam epitaxy to co-deposit Se and Mn on Au(111). Selenium is mounted in an effusion cell and is heated up to evaporate, while manganese is evaporated by electron bombardement. We characterize the films chemically by x-ray and Auger electron spectroscopy as well as structurally by low-energy electron diffraction.

[1] B. Huang et al. "Electrical control of 2D magnetism in bilayer CrI₃", Nature Nanotechnology 13, 544 (2018).

[2] D. J. O'Hara et al. "Room Temperature Intrinsic Ferro-

magnetism in Epitaxial Manganese Selenide Films in the Monolayer Limit", Nano Letters 18, 3125 (2018).

O 22.8 Mon 18:15 P1A

Growth of transition metal dichalcogenides on hBN —

•ZIYANG GAN¹, EMAD NAJAFIDEHAGHANI¹, ZIAN TANG¹, JOHANNES HOLLER², ANTONY GEORGE¹, KENJI WATANABE³, TAKASHI TANIGUCHI³, CHRISTIAN SCHÜLLER², TOBIAS KORN⁴, and ANDREY TURCHANIN¹ — ¹Friedrich Schiller University Jena, Institute of Physical Chemistry, D-07743 Jena, Germany — ²Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — ³National Institute for Materials Science, Tsukuba, Ibaraki 305-0044, Japan — ⁴Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

Monolayer transition metal dichalcogenides (TMD) have emerged as versatile materials with the potential to be applied in next-generation electronics and optoelectronics devices owing to their attractive physical properties such as direct bandgap, spin-coupled valley degrees of freedom, etc. High quality TMDs can be synthesized by chemical vapor deposition (CVD) on Si substrates. However, the as grown monolayers show poor optical quality due to the detrimental interaction with the dielectric environment of the substrate. It has been shown recently that encapsulation in hexagonal boron nitride (hBN) is crucial to access the intrinsic optical quality of CVD grown monolayer TMDs. This motivates us to develop growth procedures for direct growth of monolayer TMDs on exfoliated and CVD grown hBN layers. The grown TMDs on hBN were characterized using optical microscopy, atomic force microscopy, Raman spectroscopy and photoluminescence spectroscopy to reveal their morphological, structural and optical properties.