

DS 1: 2D Materials and their Heterostructures I: Graphene

Time: Monday 9:30–11:00

Location: SCH A 316

DS 1.1 Mon 9:30 SCH A 316

Atomistic and network models for graphene based macromaterials: role of intercalation, defects and dopants — ●FLORIAN FUCHS^{1,2} and JÖRG SCHUSTER^{1,2} — ¹Fraunhofer Insitute for Electronic Nano Systems (ENAS), Chemnitz, Germany — ²Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, Chemnitz, Germany

The excellent properties of graphene can be utilized in macroscopic conductor materials if the individual flakes are decoupled from each other, for example by misalignment of the lattices or by intercalation. Such materials are promising candidates to replace metals for numerous electrical conductor applications [1].

We show the results of a network model [2,3] which relates the structural arrangement and the properties of the individual graphene flakes to the macroscopically observed electrical conductivity. By this model we assess the properties of the macromaterial as a function of relevant parameters such as flake size, packing density, the graphene flake conductivity, and the interlayer conductance.

On the flake-level, intercalation, doping, and defect healing control the conductivity of the graphene-based macromaterial. We performed density functional theory calculations of these processes. In our presentation we discuss the impact on the material quality by focussing on the in-plane and the out-of-plane conductivity.

[1] J. Schuster et al., *Nano Express* 1, 020035 (2020)

[2] J. Schuster et al., *ACS Appl. Mater. Interfaces* 10, 43008 (2018)

[3] J. Schuster et al., *Comp. Mat. Science* 161, 364 (2019)

DS 1.2 Mon 9:45 SCH A 316

Post-processing on graphene field-effect transistors by critical point drying — ●HAMID REZA RASOULI¹, DAVID KAISER¹, CHRISTOF NEUMANN¹, MARTHA FREY¹, GHAZALEH ESHAGHI¹, THOMAS WEIMANN², and ANDREY TURCHANIN¹ — ¹Institute of Physical Chemistry, Friedrich Schiller University Jena, 07743 Jena, Germany — ²Physikalisch-Technische Bundesanstalt (PTB), 38116 Braunschweig, Germany

We report on a critical point drying (CPD) technique with supercritical carbon dioxide (S-CO₂) as a post-processing step to enhance electrical performance of graphene field-effect transistors (GFETs). This technique is promising for integration into the industrial clean rooms environment and demonstrates high potential not only for GFETs but also for other electronic, photonic and optoelectronic devices based on 2D materials.

DS 1.3 Mon 10:00 SCH A 316

Intercalation of indenene in SiC/graphene interface — ●CEDRIC SCHMITT^{1,2}, JONAS ERHARDT^{1,2}, TIEN-LIN LEE³, TIMUR KIM³, SIMON MOSER^{1,2}, and RALPH CLAESSEN^{1,2} — ¹Physikalisches Institut, Universität Würzburg, D-97074 Würzburg, Germany — ²Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, D-97074 Würzburg, Germany — ³Diamond Light Source, Harwell Science and Innovation Campus, Didcot, UK

In the search for new quantum materials, ultrathin metals are highly interesting as they push bulk properties to the 2D limit and foster novel quantum effects. Unfortunately, unprotected metals are prone to oxidation in air, making them useless for transport devices. Here, we report about a capping method for 2D materials via metal intercalation. In this process an atomic metal monolayer is sandwiched between a SiC substrate and a graphene buffer layer, thus forming freestanding graphene, which protects the intercalated layer against oxidation. Previous intercalation studies focused mainly identifying stable allotropes but lack a detailed investigation of metal coverage and oxidation. Here, we study the intercalation of indenene, a monolayer of indium, which is a novel quantum material [1]. First experiments indicate the indenene layer to remain intact upon air exposure, indeed pointing to an effective protective function of the overlayer graphene. Furthermore, we observe an enlarged In-Si bond distance, which is expected to have a larger non-trivial energy gap.

[1] M. Bauernfeind et al. *Nat. Commun.* 12, 5396 (2021)

DS 1.4 Mon 10:15 SCH A 316

Ultrafast photo-thermoelectric currents in graphene — ●XIAOYI ZHOU, NINA PETTINGER, JOHANNES GRÖBMEYER, PHILIPP ZIMMERMANN, and ALEXANDER HOLLEITNER — Walter Schottky Institut and Physics Department, Technische Universität München, Germany

Graphene as an optoelectronic material has attracted significant attention due to its interesting properties such as fast charge carrier relaxation rates, broadband optical absorption and high carrier mobilities. We apply an ultrafast on-chip pump-probe photocurrent spectroscopy to demonstrate an immediate thermoelectric photocurrent after a femtosecond laser pulse. We demonstrate that gate-tunable graphene junctions can be integrated into THz-circuits, paving the way for graphene-based ultrafast photodetectors and switches.

DS 1.5 Mon 10:30 SCH A 316

Twist angle dependent proximity induced spin-orbit-coupling in graphene/TMDC and graphene/TI heterostructures — ●THOMAS NAIMER¹, KLAUS ZOLLNER¹, MARTIN GMITRA², and JAROSLAV FABIAN¹ — ¹Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — ²Institute of Physics, Pavol Jozef Safarik University in Kosice, 04001 Kosice, Slovakia

We investigate the proximity-induced spin-orbit coupling in twisted heterostructures of graphene/transition-metal dichalcogenides (MoS₂, WS₂, MoSe₂, and WSe₂) as well as graphene/topological insulators (Bi₂Se₃ and Bi₂Te₃) from first principles. We establish that, regardless of the twist angle, the band offsets between the Dirac point and the substrate bands vary linearly with the strain, which is necessary for defining commensurate supercells. This relation allows to identify the apparent zero-strain band offsets and find a compensating transverse electric field correcting for the strain. The resulting corrected band structure is then fitted around the Dirac point to an established spin-orbit Hamiltonian, yielding the twist angle dependencies of the spin-orbit couplings. While for most structures a mix of Rashba and valley-Zeeman spin-orbit coupling is present, we also witness the emergence of Kane-Mele spin-orbit coupling in graphene/topological insulator structures at 30° twist angle. This work was funded by the Elite Network of Bavaria, the Deutsche Forschungsgemeinschaft (DFG), SFB 1277, SPP 2244 and by the European Union Horizon 2020 Research and Innovation Program under contract number 881603 (Graphene Flagship). M.G. acknowledges VEGA 1/0105/20.

DS 1.6 Mon 10:45 SCH A 316

Mobile trions in two-dimensional hybrid perovskites — JONAS DAVID ZIEGLER¹, YEONGSU CHO², ●SOPHIA TERRES¹, MATAN MENAHEM³, OMER YAFFE³, TAKASHI TANIGUCHI⁴, KENJI WATANABE⁴, TIMOTHY C. BERKELBACH², and ALEXEY CHERNIKOV¹ — ¹TU Dresden, Dresden, Deutschland — ²Columbia University, New York, USA — ³Weizmann Institute of Science, Rehovot, Israel — ⁴National Institute for Materials Science, Tsukuba, Japan

Two-dimensional hybrid perovskites represent natural quantum well systems composed of alternating organic and inorganic molecular layers. They combine an efficient coupling of electrons to a soft lattice with strong Coulomb interactions between the charge carriers. The latter leads to the formation of tightly bound excitons that determine the optical response of this class of materials. The interaction between excitons and free charge carriers, however, remains difficult to access in halide perovskites due to persistent challenges to introduce doping.

Here, we report experimental realization of electrically tunable, ultrathin two-dimensional perovskites, by combining them with hBN and multilayer graphene in field-effect transistor geometries. We demonstrate the formation of both negatively and positively charged exciton-electron complexes, known as trions with binding energies up to 46 meV. These values are a direct consequence of strong Coulomb interaction and scale with exciton binding energies, as demonstrated by theoretical calculations. The trions exhibit finite oscillator strength in absorption-like response, are localized at cryogenic temperatures, and exhibit thermally activated diffusion at 50 K.