TT 68: Graphene: Electronic structure, excitations, etc. – Poster (joint session O/TT)

Time: Wednesday 18:00–20:00 Location: P2

TT 68.1 Wed 18:00 P2

Strong-Field Bloch Electron Interferometry for Band-Structure Retrieval — •Tamara Pröbster, Tobias Weitz, Christian Heide, and Peter Hommelhoff — Friedrich-Alexander-Universität Erlangen-Nürnberg, Department Physik, Staudtstr. 1, 91058 Erlangen

Strong optical fields drive electrons in solids far from equilibrium, enabling access to ultrafast quantum dynamics that directly reflect the underlying band structure. When Bloch electrons in graphene are exposed to an intense few-cycle laser field, they undergo coherent intraband motion during which they accumulate a quantum phase determined by the local band curvature. If this laser-driven trajectory encounters an avoided crossing between the valence and conduction bands, the electron wave packet can coherently split via a Landau-Zener transition. In our work, we exploit pairs of such transitions to realize strong-field Bloch electron interferometry, forming an interferometric sequence fully embedded in the electronic band structure. The resulting interference encodes band information in the phase-dependent photocurrent. We retrieve the Fermi velocity of graphene near the K points as 1.07 ± 0.04 nm·fs^{-1}, in excellent agreement with theoretical expectations. Our results establish strong-field Bloch electron interferometry as a general and versatile approach for band-structure reconstruction under ambient conditions. Because the method relies solely on ultrafast optical driving and detection, it is naturally suited for tracking light-induced modifications of electronic structure with femtosecond temporal resolution.

TT 68.2 Wed 18:00 P2

Folding the electronic band structure of graphene-Bi and graphene-Pb heterobilayers — •Johanna Schurr, Alexander Korn, Andres Unigarro, Sibylle Gemming, and Nebahat Bulut — Institute of Physics, TU Chemnitz, Germany

Translational and rotational degrees of freedom in 2D material stacks open up a wealth of tunable materials properties, such as electrical conductivity, magnetism, or optical properties, in particular if heavy intercalant atoms are present. In this study, the band structure of the two hexagonal hetero-bilayer systems bismuthene-graphene and plumbene-graphene were investigated, because experiment gives evidence for a large number of structural varieties especially for plumbene.

The aim was to identify and characterise the influence of bismuthene and plumbene layers on the band structure of graphene. For this purpose a code was generated to correlate the k-path of the band structures calculated for supercells and primitive cells within their respective Brillouin zones. Subsequent folding back of the bands into the first Brillouin zone of the supercell, while maintaining the information of the original k-path in the primitive cell, provided an overview of all existing bands and the origin of their Brillouin zone.

TT 68.3 Wed 18:00 P2

A tool for folding and unfolding of electronic band structures applying it to graphene and the gold(111)-surface — •Alexander Korn, Nebahat Bulut, and Sibylle Gemming — Institute of Physics, TU Chemnitz, Germany

The electronic band structure is an important property of materials. For comparison with experiments and other studies, as well as for better readability, it is useful to display and analyse the band structure of the primitive cell rather than a supercell. Studying more complex materials with dopants or adatoms is only possible using a supercell instead. Therefore, one must unfold the band structure of the supercell into the primitive cell.

For this purpose, we offer a tool for abinit (www.abinit.org) that can be used to unfold all possible supercells. The unit vectors of the supercell can be stretched and also rotated relative to the unit vectors of the primitive cell. We also offer an additional qualitative tool for band folding that also tracks the origin of the Brillouin zone of each band at each k-point. We provide a practical example of folding and unfolding using the gold(111) surface with sulfur as an adatom.

TT 68.4 Wed 18:00 P2

Enhanced Screening in Indium Intercalated Graphene Enabled by 2D Nearly Free Electron States — •Lukas Gehrig[1,2], Cedric Schmitt[1,2], Kilian Strauss[1,2], Jonas Erhardt[1,2], Stefan Enzner[2,3], Martin Kamp[1,4], Timur Kim[5], Giorgio Sangiovanni[2,3], Jörg Schäfer[1,2], Simon Moser[6], and Ralph Claessen[1,2] — [1]Physikalisches Institut, Universität Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Germany — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany — [4]Röntgen Center for Complex Material Systems, Würzburg, Germany — [5]Diamond Light Source, Harwell Science and Innovation Campus, Didcot, United Kingdom — [6]Experimentalphysik IV - AG Oberflächen, Ruhr-Universität Bochum, Germany

Intercalation of epitaxial graphene on SiC has been intensively explored to modify graphene's electronic properties, but previous intercalants provide only weak screening, leading to pronounced electron-plasmon coupling and the appearance of plasmaron bands in ARPES [1]. Here, we demonstrate that intercalated bilayer indium exhibits strongly Rashba-split bands, which acquire nearly free-electron-like character at the Fermi level. This induces exceptionally strong screening in graphene, significantly reducing many-body renormalization effects in the graphene bands, which arise from plasmaron coupling. This approach opens new opportunities to explore and control many-body interactions in graphene-based heterostructures.

[1] Bostwick A et al., Nat. Phys. 3, 36-40 (2007)

TT 68.5 Wed 18:00 P2

Terbium intercalation as a route to n-doping of graphene past the van Hove singularity — •Bharti Matta[1], Philipp Rosenzweig[1], Craig Polley[2], Kathrin Küster[1], and Ulrich Starke[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]MAX IV Laboratory, Lund, Sweden

Exotic ground states driven by many-body interactions, such as unconventional chiral superconductivity and spin-density waves, were theoretically predicted more than a decade ago for heavily n-doped graphene near the van Hove singularity (VHS). In recent years, achieving such high doping levels in epitaxial graphene on SiC via intercalation has attracted considerable interest. Intercalation of rare-earth elements such as Gd, Yb, and Er has already proven promising in reaching these regimes. Here, we demonstrate that intercalation of Tb atoms at the graphene/SiC interface provides access to extreme n-doping levels beyond the π^* VHS, without requiring any adsorbates on the graphene surface. The extended VHS is shifted by 0.07 eV below the Fermi level (E_F) as seen in angle-resolved photoemission spectroscopy. From the area enclosed by the giant hole pocket around Γ, we extract an electron density of $\approx 5 \times 10^{14}$ cm^{-2}. Strong renormalization of the graphene bands leads to a Dirac point about 1.55 eV below E_F, indicating that the doping cannot be described by a rigid single-particle band shift. Based on these experimental parameters, theoretical calculations predict the emergence of topological superconductivity with a critical temperature up to 600 mK (S. A. Herrera *et al.*, *ACS Nano 18* (51), 34842–34857 (2024)).

TT 68.6 Wed 18:00 P2

Vanishing Fermi velocity in Periodically Strained Graphene — •Leo-Malik Benneka[1], Taher Rhouma[2], Guy Trambly de Laissardière[2], Clemens Winkelmann[1], Mark Zelsmann[3], and Vincent Renard[1] — [1]Université Grenoble Alpes, CEA-IRIG-PHELIQS, 38000 Grenoble, France — [2]CNRS-LPTM, CY Cergy Paris Université, 95302 Cergy-Pontoise, France — [3]CNRS-LTM, 38000 Grenoble, France

Intense research has been made in engineering flat bands in twisted bilayer graphene, leading to various correlated phases [1]. An alternative route to realizing similar flat bands involves a monolayer graphene strained by a periodic triangular superlattice induced by a corrugated substrate. The height modulation h and the superlattice periodicity L serve as tuning parameters for controlling band flattening and the Fermi velocity v_F near the Dirac cones [2, 3]. Tight-binding calculations were performed by explicitly accounting for relative rotations between the graphene lattice and the superlattice, as would occur in an experimental device. These calculations not only reproduce the known decrease of the Fermi velocity with increasing h [4], but also reveal a renormalization of v_F that depends on the specific ratio $\sqrt{a_C C}\, L/h$ and on the relative lattice orientation. Remarkably, this behavior is universal for any superlattice size L. These predictions may assist in

the design of experimental devices aimed at engineering flat bands. [1] Cao et al., Nature, 556 (2018) 43-50 ; [2] Mao et al., Nature, 7820 (2020) 215-220 ; [3] Yuan et al., Phys. Rev. B, 24 (2024) 245408 ; [4] S. P. Milovanović et al., Phys. Rev. B, 24 (2020) 245427.

TT 68.7 Wed 18:00 P2

Optimizing the excitation cross section for graphene phonons in inelastic electron tunnelling via intercalation. — Karl Rothe[1], •Nicolas Néel[1], Mads Brandbyge[2], and Jörg Kröger[1] — [1]Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany — [2]Center of Nanostructured Graphene, Department of Physics, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

Platinum-intercalated graphene on a (111)-oriented iridium surface gives rise to a variety of rotational domains, which exhibit characteristic moiré patterns. Independent of the twist angle subtended by the graphene and substrate lattice, inelastic electron tunnelling spectroscopy reveals elevated graphene phonon excitation only on the intercalated phases. Combining spatially resolved spectroscopy of the electronic structure with non-equilibrium Green's function simulations highlights the relevance for effective phonon creation of the balance between elastic and inelastic electron transport. The intercalation-induced shift of electron density of states from the Brillouin zone centre to its boundary enhances the inelastic channel at the expense of the elastic channel and thereby increases the phonon excitation cross section. Financial support by the Deutsche Forschungsgemeinschaft through KR 2912/18-1 is acknowledged.

TT 68.8 Wed 18:00 P2

Se-intercalation of graphene on SiC(0001) — •Susanne Wolff[1,2] and Thomas Seyller[1,2] — [1]Institut für Physik, Technische Universität Chemnitz — [2]Research Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Technische Universität Chemnitz

The epitaxial growth of graphene on SiC in an argon atmosphere is a well-established method to produce homogeneous, high quality carbon layers. The first-grown carbon layer exhibits a $\left(6\sqrt{3}\times 6\sqrt{3}\right) R30°$ periodicity and is partially covalently bound to the SiC substrate. Therefore, this so-called buffer layer lacks the typical electronic properties of graphene. One pathway to decouple the buffer layer from the substrate and obtain graphene-like electronic properties is intercalation, which involves introducing a certain element at the buffer layer/SiC interface. Furthermore, the choice of intercalant influences the electronic properties of the decoupled graphene.

In this study, we investigated the intercalation of a buffer layer with selenium (Se). This process was carried out in a two-zone tube furnace, with the selenium precursor $SnSe_2$ and the buffer layer positioned in different temperature zones. The samples were characterized using X-ray photoelectron spectroscopy (XPS) and angle-resolved photoelectron spectroscopy (ARPES). XPS revealed successful decoupling of the buffer layer with intercalated Se at the interface and not-intercalated Se on the surface. ARPES measurements in the vicinity of the Dirac point of graphene showed a p-type doping of the decoupled carbon layer.

TT 68.9 Wed 18:00 P2

Mesoscopic Lateral Intercalation Dynamics of Indium Between the Epitaxial Zero-Layer of Graphene and SiC — •Benno Harling[1], Zamin Mamiyev[2], Narmina Balayeva[2], Dietrich R.T. Zahn[2], Christoph Tegenkamp[2], and Martin Wenderoth[1] — [1]IV. Physikalisches Institut, Georg-August-Universität, Friedrich-Hund-Platz 1, 37077, Göttingen, Germany — [2]Institut für Physik, Technische Universität Chemnitz, Reichenhainer Str. 70, 09126, Chemnitz, Germany

Intercalation, the process of diffusing a material species in-between layered materials, can be utilized for both bulk and 2D systems to achieve tailored electronic properties. [1] For the 2D limit, this work investigates the lateral diffusion dynamics of indium intercalation into the epitaxial zero-layer of graphene on SiC using Kelvin Probe Force Microscopy (KPFM). For tin, material transfer across surface substrate steps is observed at local sites at the mesoscopic scale. [2] With the used experimental parameters, we find that this is not the case for indium intercalation. Instead, only terrace transport is observed. The KPFM measurements were complemented by micro-Raman spectroscopy, assessing the extent and uniformity of In intercalation. Remarkably, intercalation through the carbon layer seems to be dependent on the graphene or substrate properties that still need to be further resolved. This leads to a situation where just some of the terraces are observed to be intercalated. Financial support by the DFG within Research Unit FOR5242 is acknowledged. [1] Stark et al., Adv. Mater. 2019, 31, 1808213 [2] Harling et al., Carbon 244 (2025) 120711