HL 30: Focus Session: Young Semiconductor Forum

The young semiconductor forum gives a platform for post-docs at all career stages to present themselves and their scientific ideas. It consists of an oral session with invited talks and immediately afterwards, a poster session, where further participants present a poster about their work and/or scientific vita. With this format, we hope to attract both postdocs and senior researchers and decision makers to join this forum: for postdocs, to give them a platform to present themselves, and for professors, to meet the next generation of scientists.

Organized by Alexander Holleitner and the AGyouLeaP (Susanne Liese, Alexander Schlaich, and Christoph Kastl)

Time: Wednesday 9:30–12:15 Location: H13

Invited Talk HL 30.1 Wed 9:30 H13

Exploring semiconducting epigraphene grown by polymer-assisted sublimation growth — •Teresa Tschirner, Julia Guse, Stefan Wundrack, Frank Hohls, Klaus Pierz, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Epitaxial graphene on SiC is a potential candidate in a variety of applications, such as the fabrication of 2D heterostructures and the intercalation of graphene layers with other materials for engineering new electronic material systems. Important for the quality of the graphene is the 0th layer, or buffer layer, which is covalently bonded to the SiC substrate. The buffer layer itself can be functionalized by intercalation. In a recent study it was shown that an electronic bandgap can be opened in the otherwise gapless buffer layer. The semiconducting epigraphene (SEG) on SiC has a bandgap of 0.6 eV and high room temperature mobilities (5000 cm^2/Vs), much larger than silicon and other 2D-semiconductors [1]. In this study we grow high-quality buffer layers not only across single terraces as in the aforementioned study but on millimeter scale, due to an advanced growth technique preventing step bunching and large terrace step heights. We use a polymer-assisted sublimation growth (PASG) method, where pretreatment of the SiC substrate supplies additional carbon and stabilizes the SiC surface by rapid buffer layer-formation preventing step-bunching. We investigate the growth parameters for homogeneous buffer layer formation with our PASG method and systematically study its structural properties and characteristics. [1] J. Zhao et al., Nature 625, 60 (2024).

Invited Talk HL 30.2 Wed 10:00 H13

Huge Enhancement of the Giant Negative Magnetoresistance with Decreasing Electron Density — •Lina Bockhorn[1], Christian Reichl[2], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland

Ultra-high mobility two-dimensional electron gases often show a remarkably robust negative magnetoresistance at zero magnetic field. Below 800 mK, this phenomenon divides into two distinct parts [1-4]: a temperature-independent narrow peak around $B = 0\,\mathrm{T}$, arising from the interplay of smooth disorder and elastic scattering at macroscopic defects [2, 3], and a temperature-dependent giant negative magnetoresistance (GNMR) at higher magnetic fields. The theoretical understanding of the GNMR remains an open question, as it involves several independent parameters in addition to electron-electron interaction possibly leading to hydrodynamic transport effects. To gain insights into the nature of the GNMR, we investigate this effect as a function of electron density at various temperatures and currents. Our results show a significant dependence of GNMR on electron density [4], indicating that variations in scattering potentials [5] are not considered appropriately in theoretical models. [1] L. Bockhorn et al., Phys. Rev. B 83, 113301 (2011). [2] L. Bockhorn et al., Phys. Rev. B 90, 165434 (2014). [3] L. Bockhorn et al., Appl. Phys. Lett. 108, 092103 (2016). [4] L. Bockhorn et al., Phys. Rev. B 109, 205416 (2024). [5] Y. Huang et al., Phys. Rev. Materials 6, L061001 (2022).

Invited Talk HL 30.3 Wed 10:30 H13

Ultrafast quantum optics with single-photon emitters in 2D materials — •Steffen Michaelis de Vasconcellos — Physikalisches Intitut, Universität Münster, Germany

Single-photon sources are essential components for building quantum networks, though achieving optimal control remains a significant challenge in advancing quantum technologies. Recently, 2D van der Waals materials, such as transition metal dichalcogenides (TMDs) and hexagonal boron nitride (hBN), have emerged as promising platforms for solid-state quantum light emitters, enabling new possibilities for creating, tuning, and integrating quantum emitters into photonic devices [1].

In my talk, I will review the development of single-photon emitters in 2D materials, focussing particularly on the robust emitters in hBN, which efficiently emit single photons even at room temperature. We demonstrate the efficient collection of single-photons by 3D-printed microlenses [2] and explore ultrafast coherent control of individual hBN quantum emitters [3]. Understanding the underlying dephasing mechanisms is key to designing devices that meet the requirements for future quantum technologies. Our work paves the way towards controlled hybrid quantum systems integrating electronic and phononic excitations.

[1] S. Michaelis de Vasconcellos, et al., Single-Photon Emitters in Layered Van der Waals Materials, phys. status solidi (b) 259, 2100566 (2022) [2] J. A. Preuß, et al., Nano Lett. 23, 407 (2023) [3] J. A. Preuß, et al., Optica 9, 522 (2022)

15 min. break

Invited Talk HL 30.4 Wed 11:15 H13

Realistic simulation of quantum emitter dynamics made easy — •Moritz Cygorek — TU Dortmund, Germany

Few-level quantum emitters such as quantum dots are a main workhorse for cutting edge research in quantum science, e.g., for non-classical light generation. A practical challenge is the strong interaction with the physical environment such as phonons, which gives rise to a plethora of effects such as decoherence, phonon-assisted transitions, and renormalization. The intricacy of environment effects and computational challenges have in the past rendered the theoretical analysis an expert topic requiring an in-depth understanding of various theoretical methods.

Here, I demonstrate how the concept of process tensor matrix product operators (PT-MPOs) enables quick-and-easy, yet numerically exact simulations of very general open quantum systems. A computational framework is presented that can be used as a black box by the practitioner, which (i) requires no expert knowledge, (ii) leverages path integrals and tensor networks for exceptional speed and accuracy, (iii) is based on C++ for computational and memory efficiency, (iv) yet can be controlled by parameter files and requires no explicit programming, (iv) while also providing Python bindings for easy postprocessing.

Moreover, I demonstrate applications to solid-state cavity-QED relating to concrete experiments: single- and entangled photon generation, multitime correlation functions and dynamically dressed Mollow spectra, as well as phonon effects on cooperative emission and superradiance.

Invited Talk HL 30.5 Wed 11:45 H13

Data-driven Design of Next Generation 2D Materials and Their Heterostructures — •Rico Friedrich — TU Dresden — Helmholtz-Zentrum Dresden-Rossendorf — Duke University, USA

Two-dimensional (2D) materials and their heterostructures provide an extensive platform for realizing advanced electronic and magnetic functionalities at the nanoscale. While individual 2D systems are traditionally obtained from bulk layered compounds bonded by weak van der Waals (vdW) forces, the recent surprising experimental realization of semiconducting non-vdW 2D materials derived from non-layered crystals [1] opens up a new direction.

As outlined by our recent data-driven investigations employing autonomous *ab initio* calculations [2, 3], several dozens of new candidates showcase a wide range of appealing electronic, optical, and in particular magnetic properties owing to the (magnetic) cations at the active surfaces of the sheets. Further generalizing the data-driven modelling approach to all inorganic compounds provides fundamental insights into the exfoliation and cleavage of crystals. At the same time, chemical tuning by surface passivation provides a valuable handle to further control the electronic and magnetic properties of these next generation 2D compounds [4]. These features thus make non-vdW 2D materials an attractive platform for fundamental as well as applied nanoscience.

[1] A. Puthirath Balan *et al.*, Nat. Nanotechnol. **13**, 602 (2018).
[2] R. Friedrich *et al.*, Nano Lett. **22**, 989 (2022).
[3] T. Barnowsky *et al.*, Adv. Electron. Mater. **9**, 2201112 (2023).
[4] T. Barnowsky *et al.*, Nano Lett. **24**, 3974 (2024).