O 16: Mini-Symposium: Free-standing functional molecular 2D materials II

Time: Monday 13:30–15:30 Location: R2

Invited Talk O 16.1 Mon 13:30 R2

Combining 2D materials and optical metasurfaces — •Isabelle Staude — Institute of Solid State Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, 07743 Jena, Germany

Optical metasurfaces, two-dimensional arrangements of designed nanoresonators, offer unique opportunities for controlling light fields and for tailoring the interaction of light with nanoscale matter. Due to their flat nature, their integration with two-dimensional materials consisting of only a single molecular layer is particularly interesting [1]. This talk reviews our recent and ongoing activities in hybridizing optical metasurfaces composed of resonant metallic or dielectric building blocks with different types of two-dimensional materials, including monolayer transition metal dichalcogenides (2D-TMDs) and carbon nanomembranes (CNMs). On the one hand, we will show that CNMs can serve as mechanically stable substrates for free-standing metasurface architectures of nanoscale thickness [2]. On the other hand, we will demonstrate that the ability of the nanoresonators to concentrate light into nanoscale volumes can be utilized to carefully control the properties, such as pattern and polarization, of light emitted by 2D-TMDs via photoluminescence or nonlinear processes [3,4]. [1] R. Mupparapu et al., Advances in Physics: X 5, 1734083 (2020). [2] Y. D. Sirmaci et al., ACS Photonics 7, 1060 (2020). [3] T. Bucher et al., ACS Photonics 6, 1002 (2019). [4] F. J.F. Löchner et al., ACS Photonics, https://doi.org/10.1021/acsphotonics.0c01375 (2020).

O 16.2 Mon 14:00 R2

Towards atomic-resolution HRTEM imaging of organic 2D materials — •Haoyuan Qi, Baokun Liang, David Mücke, and Ute Kaiser — Electron Microscopy Group of Materials Science, Universität Ulm, 89081 Ulm, Germany

Organic two-dimensional materials (O2DMs), such as 2D polymers, 2D covalent-organic frameworks (COFs), and 2D metal-organic frameworks (MOFs), open up the exciting possibility of crystal engineering tailored for next-generation applications. However, structural characterization of O2DMs via transmission electron microscopy (TEM) remains a formidable task. The main challenge arises from the strong interaction between incident electrons and the bonded hydrogen atoms. During TEM imaging, the incident electrons transfer kinetic energy to the atoms (i.e., knock-on damage) and may trigger bond dissociation and various chemical reactions degrading the structural integrity of O2DMs.

Here, we will present a comprehensive illustration of experimental techniques that are dedicated to enhancing achievable image resolution. For instance, through low-dose HRTEM imaging, a near-atomic resolution has been achieved on 2D polyimine under 300 kV. We further demonstrate that, by applying a mid-range acceleration voltage, i.e., 120 kV, the useful structural information per unit damage can be enhanced in several COFs, resulting in higher S/N ratio in the experimental images as compared to 300 kV. Besides, through a hydrogen-free structural design, MOFs' intrinsic stability can be significantly increased, allowing direct observation down to atomic scale.

O 16.3 Mon 14:15 R2

Mechanics of free-standing inorganic and molecular 2D materials — •Xianghui Zhang, André Beyer, Florian Paneff, and Armin Gölzhäuser — Faculty of Physics, Bielefeld University, 33615 Bielefeld, Germany

The discovery of graphene has triggered a great interest in inorganic as well as molecular two-dimensional (2D) materials. In this contribution, we summarize recent progress in the mechanical characterization of free-standing 2D materials, such as graphene, hexagonal boron nitride (hBN), transition metal-dichalcogenides, MXenes, black phosphor, carbon nanomembranes (CNMs), 2D polymers, 2D metal-organic frameworks (MOFs) and covalent organic frameworks (COFs). Elastic, fracture, bending and interfacial properties of these materials have been determined using a variety of experimental techniques including AFM-based nanoindentation, in situ tensile/fracture testing, bulge testing, Raman spectroscopy, Brillouin light scattering, and buckling-based metrology. Additionally, we address recent advances of 2D materials in mechanical applications, including resonators, microphones, and nanoelectromechanical sensors.

Invited Talk O 16.4 Mon 14:30 R2

Electronic properties of freestanding ultra-thin small-molecular and multilayer graphene films — •Thomas Weitz — I. Physics Institute, Faculty of Physics, Georg-August-University Göttingen, Germany — AG Physics of Nanosystems, Faculty of Physics, LMU Munich, Germany

Suspension of thin functional films allows to investigate their electronic properties in vacuum - a low-dielectric (low-k) environment free from contaminants. Two examples of our recent work in this direction will be discussed: 1.) Highly-crystalline, two molecule thin organic semiconducting films composed of an electron-conductive perylene-diimide have been investigated by temperature-dependent charge transport and have shown a small density of charge traps due to the inert surrounding. [1] 2.) Enabled by the low-k surrounding, dually-gated, suspended bi- and trilayer graphene films show exchange-driven quantum phases such as the quantum anomalous Hall effect. [2-4]

[1] L.S. Schaffroth, J. Lenz, V. Geigold, M. Kögl, A. Hartschuh, R.T. Weitz, Adv. Mat. 31, 1808309 (2019) [2] R.T. Weitz, M.T. Allen, B.E. Feldman, J. Martin, and A. Yacoby, Science 330, 812 (2010) [3] F.R. Geisenhof, R.T. Weitz et al. In preparation (2021) [4] F. Winterer, R.T. Weitz et al. In preparation (2021)

O 16.5 Mon 15:00 R2

Sensitive detection of biomarkers in clinical samples based on van der Waals heterostructures of carbon nanomembrane and graphene — •David Kaiser[1], Nikolaus Meyerbroeker[2], Werner Purschke[3], Simone Sell[3], Christof Neumann[1], Andreas Winter[1], Zian Tang[1], Daniel Hüger[1], Gerben Ferwerda[4], Thomas Weimann[5], Marien de Jonge[4], Albert Schnieders[2], Axel Vater[3], and Andrey Turchanin[1] — [1]Friedrich Schiller University Jena, Germany — [2]CNM Technologies GmbH, Germany — [3]APTARION biotech AG, Germany — [4]Radboud University, The Netherlands — [5]Physikalisch-Technische Bundesanstalt, Germany

Due to their low surface charge in aqueous electrolytes, almost direct contact with the analyte and special electronic properties, graphene field-effect transistors (GFETs) are promising for ultrasensitive biodetection. However, challenges with their reliable biochemical functionalization have hindered their use with real clinical samples so far. Here, we employ 1 nm thick carbon nanomembranes (CNMs) to functionalize GFETs via van der Waals assembly of the CNM/graphene heterostructures. The aptamers grafted on the CNMs result in specific adsorption of the relevant biomarkes on the GFET surface. Using clinical samples, we demonstrate the detection of the biomarker CXCL8 with a very low concentration (5 pg/ml). We support our experimental findings by a detailed modelling of the device performance.

Final discussion with all speakers