HL 14: 2D Materials III (joint session HL/CPP)

Time: Tuesday 9:30–12:15 Location: POT 81

HL 14.1 Tue 9:30 POT 81

Sub-THz detection in two dimensional systems and CVD graphene heterostructures — Franziska Linss[1], Vincent Strenzke[1], Pai Zhao[1], Chithra S. Sharma[1], Lars Tiemann[1], •Qin Hua[2], and Robert H. Blick[1] — [1]Center for Hybrid Nanostructures, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Suzhou Institute of Nanotech and Nanobionics (SINANO) of the Chinese Academy of Sciences (CAS), China

Electromagnetic radiation in the THz range can induce surface plasmons, i.e., a collective motion of electrons, in graphene-based devices. We fabricated a field-effect-transistor with asymmetric dual-grating gates (ADGG) to detect sub-THz radiation using large-scale graphene that was synthesized by chemical vapor deposition (CVD). The CVD graphene sheet is encapsulated between two flakes of hBN and placed on a highly doped Si wafer that acts as a back gate. The ADGG was structured on the top hBN flake. The control of the carrier concentration via electrostatic gates is crucial to match the resonance condition of the plasmons. The sample was characterized by sweeping the top gate voltage from -1 V to 2 V and the charge neutrality point was reached at a top gate voltage of 0.87 V at 4.2 Kelvin. Furthermore, we used a high electron mobility transistor (HEMT) to detect THz radiation, where the detection mechanism is based on a mixing with a reference radiation in a nonlinear medium. In this device, we can demonstrate sub-THz radiation at room temperature.

HL 14.2 Tue 9:45 POT 81

Theory of non-local Andreev reflection through Andreev molecular states in graphene Josephson junctions — •Andor Kormányos[1], Eduárd Zsurka[1], Noel Plaszkó[1], and Péter Rakyta[1,2] — [1]Department of Physics of Complex Systems, Eotvos Lorand University, Budapest, Hungary — [2]Wigner Research Center for Physics, 29-33 Konkoly-Thege Miklos Str., H-1121 Budapest, Hungary

We propose that a device composed of two vertically stacked monolayer graphene Josephson junctions can be used for Cooper pair splitting. The hybridization of the Andreev bound states of the two Josephson junction can facilitate non-local transport in this normal-superconductor hybrid structure, which we study by calculating the non-local differential conductance. Assuming that one of the graphene layers is electron and the other is hole doped, we find that the non-local Andreev reflection can dominate the differential conductance of the system. Our setup does not require the precise control of junction length, doping, or superconducting phase difference, which could be an important advantage for experimental realization.

HL 14.3 Tue 10:00 POT 81

Quantum Hall measurements near electric field controlled Lifshitz transitions in trigonally warped bilayer graphene — •Martin Statz, Anna Seiler, Jonas Pöhls, Moritz Knaak, Francesca Farlorsi, and Thomas Weitz — 1st Physical Institute, Faculty of Physics, University of Göttingen, Friedrich-Hund-Platz 1, Göttingen 37077, Germany

Various spontaneous symmetry broken phases such as Stoner ferromagnetism, spin-polarized superconductivity, a quantum anomalous Hall octet and a topologically non-trivial Wigner-Hall crystal phase have recently been reported in bilayer graphene (BLG) [1]. Since these interaction-driven phenomena are dictated by the ratio of the Coulomb and kinetic energy of carriers, they can be promoted by the formation of flat bands and a divergent density of states (DoS) near Lifshitz transitions (LT). Trigonally warped BLG at low vertical displacement fields (D-field) and carrier densities ($\sim 10^{11}$ cm^{-2}) displays one centre and three off-centre Dirac cones in each valley, and therefore offers a rich playground for correlated phases (CP) and changes in the Fermi surface topology by inducing charge density and D-field driven LT. Here, we report on quantum Hall measurements near charge density and D-field driven LT in trigonally warped BLG encapsulated in hexagonal boron-nitride in a dual-gated architecture with graphite contacts and graphite gates at 10 mK. We further outline our status on the temperature dependence of several CP in the aforementioned regimes.

[1] Seiler, A.M. et al. Nature 608, 298-302 (2022)

HL 14.4 Tue 10:15 POT 81

Tuning electronic properties of graphene with a transferred ultrathin Ga_2O_3 encapsulation — Matthew Gebert[1], •Semonti Bhattacharyya[2], Christopher Bounds[1], Nitu Syed[3,4], Torben Daeneke[4], and Michael S. Fuhrer[1] — [1]School of Physics and Astronomy, Monash University, Melbourne — [2]Leiden Institute of Physics, Leiden University, Leiden — [3]School of Physics, The University of Melbourne, Parkville, Melbourne — [4]School of Engineering, RMIT University, Melbourne

Although graphene holds immense potential for future electronics and spintronics, it is tricky to find a suitable large-area encapsulation layer for graphene that enhances its properties. In this talk, I will demonstrate a large-area passivation layer for graphene by mechanical transfer of ultrathin Ga_2O_3 synthesized on the surface of liquid Ga metal.[1]

Electrical measurements of millimetre-scale passivated and bare CVD graphene on SiO_2 substrate indicate that the passivated graphene maintains its high field effect mobility, desirable for applications. Surprisingly, the temperature-dependent resistivity is reduced in our passivated graphene over a range of temperatures below 230 K, due to the interplay of screening of the remote optical phonon modes of the SiO_2 by the high dielectric constant of Ga_2O_3, and the relatively high characteristic phonon frequencies of Ga_2O_3. Raman spectroscopy and electrical measurements indicate that Ga_2O_3 passivation also protects graphene from further processing such as plasma-enhanced atomic layer deposition of Al_2O_3.

1. Gebert, Bhattacharyya et al, Nano Lett, https://doi.org/10.1021/acs.nano

HL 14.5 Tue 10:30 POT 81

Hopping transport in ultraclean dual graphite gated bilayer graphene — •David Alexander Darek Emmerich[1], Eike Thomas Icking[1,2], Philipp Schmidt[1,2], Frank Volmer[1,3], Kenji Watanabe[4], Takashi Taniguchi[5], Bernd Beschoten[1], and Christoph Stampfer[1,2] — [1]RWTH Aachen University, Germany — [2]Forschungszentrum Jülich, Germany — [3]AMO GmbH, Advanced Microelectronic Center Aachen (AMICA), Germany — [4]Research Center for Functional Material, Japan — [5]International Center for Materials Nanoarchitectonics, Japan

Bernal-stacked bilayer graphene (BLG) is a material that has a unique property: BLG is intrinsically a semimetal, but becomes a semiconductor under the applicaton of an out-of-plane displacement field. This controlled opening of a gate-tunable band gap makes it a promising material for realizing highly-tunable transistors and photodetectors. The limiting factor of BLG-based devices is disorder. Only by using graphitic bottom gates a true band insulating state was achieved in BLG, which exhibits a clean gap opening with faint signs of residual disorder. Using finite bias spectroscopy, we show that BLG devices with graphitic top and bottom gate electrodes exhibit extremely low disorder. We perform transport measurements down to the sub-Kelvin regime and analyse the temperature-dependent transport behaviour. For small displacement fields, where gap and disorder are expected to be of the same order of magnitude, the low-temperature hopping transport data are investigated concerning the dominant hopping mechanism.

15 min. break

HL 14.6 Tue 11:00 POT 81

high responsivity monolayer MoS_2 photodetectors on cyclic olefin copolymer-passivated SiO_2 gate dielectric — •Emad Najafidehaghani[1], Sirri Batuhan Kalkan[2], Ziyang Gan[1], Jan Drewniok[2], Michael F Lichtenegger[2], Uwe Hübner[3], Alexander S Urban[2], Antony George[1], Bert Nickel[2], and Andrey Turchanin[1] — [1]Friedrich Schiller University Jena, Institute of Physical Chemistry, Jena — [2]Ludwig Maximilian University of Munich, Faculty of Physics, Munich — [3]Leibniz Institute of Photonic Technology (IPHT), Jena

2D material-based photodetectors attracted significant research interest due to their high responsivity, flexibility and transparency. However, the trap states present at the surface of SiO_2 gate dielectrics diminishes the performance of 2D material-based photodetectors. To reduce the detrimental effect of SiO_2 surface traps, an ultrathin film (5 nm) of cyclic olefin copolymer (COC) layer is employed as a surface passivator. Due to the reduction of the interface trap density, the photoresponsivity of the MoS_2 devices on passivated SiO_2 is enhanced by four orders of magnitude compared to non-passivated MoS_2 devices. Under optimized conditions a record photoresponsivity of 3×10^7 A/W in combination with a short response time is observed. Our findings show that the ultrathin COC passivation of the gate dielectric enables to probe exciting properties of the atomically thin 2D semiconductors.

HL 14.7 Tue 11:15 POT 81

Atomic layer deposition of horizontal and vertical MoS_2/WS_2 heterostructures — •Christian Tessarek, Tim Grieb, Andreas Rosenauer, and Martin Eickhoff — Institut für Festkörperphysik, Universität Bremen

Beyond the properties of single two-dimensional (2D) layers, heterostructures made of 2D transition metal dichalcogenides promise new properties based on moiré physics and interlayer excitons.

Vertical and horizontal MoS_2 and WS_2 heterostructures were grown by atomic layer deposition (ALD) and analyzed by Raman and photoluminescence spectroscopy. The influence of the the ALD growth sequence, i.e. MoS_2/WS_2 vs. WS_2/MoS_2, was investigated. Elemental distribution of Mo and W in a horizontal heterostructure was studied by high resolution transmission electron microscopy and energy-dispersive X-ray spectroscopy. Additional high temperature annealing was performed to improve the structural and optical properties of the layers.

HL 14.8 Tue 11:30 POT 81

Fully automated platform for 2D material flake detection using real-time machine learning techniques — •Jan-Lucas Uslu, Taoufiq Ouaj, Bernd Beschoten, Lutz Waldecker, and Christoph Stampfer — JARA-FIT and 2nd Institute of Physics A, RWTH Aachen University, Aachen, Germany

As of today, most of fundamental experimental 2D material research is based on mechanically exfoliated flakes, finding suitable flakes for the fabrication of van der Waal heterostructures is time-consuming and time-critical part requiring expert knowledge and manpower.

In order to mitigate this problem, we demonstrate a simple and robust real time-capable algorithm based on Gaussian mixture models, a machine learning technique, to allow for a fast automated search of exfoliated flakes of different 2D materials in a single run with an automated microscope setup to analyze batches of exfoliated material.

The algorithm solves the task of automatically detecting various flakes on Si++/SiO2 wafer dices, allows to index the location and segmentation of each flake and provides metrices such as size, thickness and shape.

The algorithm is evaluated on more than 500.000 images of different 2D materials including graphene and multilayer graphene, hexagonal boron nitride, transition metal dichalcogenides and 2D magnets.

HL 14.9 Tue 11:45 POT 81

CVD Growth of Hexagonal Boron Nitride on CMOS-compatible Substrates — •Max Franck[1], Jarek Dabrowski[1], Markus Andreas Schubert[1], Walter Batista Pessoa[2], Dominique Vignaud[2], Luc Henrard[3], Christian Wenger[1,4], and Mindaugas Lukosius[1] — [1]IHP - Leibniz-Institut für innovative Mikroelektronik, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]University Lille, CNRS, Centrale Lille, JUNIA ISEN, University Polytechnique Hauts de France, UMR 8520-IEMN F-59000 Lille, France — [3]Department of Physics, Namur Institute of Structured Materials, University of Namur, Rue de Bruxelles 61, 5000 Namur, Belgium — [4]Semiconductor Materials, BTU Cottbus-Senftenberg, Platz der Deutschen Einheit 1, 03046 Cottbus, Germany

Hexagonal boron nitride (hBN) is a two-dimensional insulator with a range of promising applications, including DUV optoelectronics and protection layers for high-mobility graphene. Most commonly, high-quality hBN is grown via CVD on catalytic transistion metal substrates. However, the hBN films require transfer to CMOS-compatible substrates, which leaves residual metal contaminations at concentrations unacceptable for Si technology integration.[1] Therefore, growth of hBN thin films directly on CMOS-compatible substrates, such as Si, Ge or dielectrics, is desirable. We present recent results regarding CVD synthesis of well-oriented, few-layer hBN films on such substrates using borazine as a single-source precursor. Morphology and crystallline quality were characterized using XPS, AFM, Raman spectroscopy and TEM. [1] G. Lupina, J. Kitzmann, et al. ACS Nano 2015, 9, 4776-4785.

HL 14.10 Tue 12:00 POT 81

Microwave plasma driven 2H-1T phase modulation of WSe2 for improving NO2 gas sensing performance — •Yu Duan[1,2], Sam Zhang[2], Huaping Zhao[1], and Yong Lei[1] — [1]Fachgebiet Angewandte Nanophysik, Institut für Physik & IMN MacroNano, Technische Universität Ilmenau, 98693 Ilmenau, Germany — [2]Center for Advanced Thin Films and Devices, School of Materials and Energy, Southwest University, Chongqing, 400715, China

Transition metal dichalcogenides (TMDs) have been widely used in recent years for gas sensors. Herein, we constructed a simple microwave plasma device by modifying a home microwave oven for surface treatment of WSe2. A 1T/2H hybrid phase structure was constructed by phase modulation and Se vacancies were introduced to effectively enhance its gas sensing performance. The sample after 60 s of treatment exhibited high response (52.24%), fast response rate (49.8 s), short recovery time (14.9 mins), and outstanding stability and selectivity for 1 ppm NO2 at room temperature. In addition, molecular model of the microwave plasma-treated sample is proposed, leading to the intrinsic mechanism of its performance enhancement. It is demonstrated that microwave plasma treatment is a promising method to enhance the gas sensing performance of TMDs.