HL 42: 2D Materials 6 (joint session HL/CPP/DS)

Time: Friday 9:30–12:00 Location: H36

HL 42.1 Fri 9:30 H36

THz conductivity of nanograined Bi2Te3 pellets with varying Te doping — •Ahana Bhattacharya[1], JeongWoo Han[1], Sepideh Izadi[2], Sarah Salloum[3], Stephan Schulz[3], Gabi Schierning[2], and Martin Mittendorff[1] — [1]Universität Duisburg-Essen, Fakultät für Physik, 47057 Duisburg, Germany — [2]Universität Bielefeld, Fakultät für Physik, 33615 Bielefeld, Germany — [3]Universität Duisburg-Essen, Fakultät für Chemie, 45141 Essen, Germany

The topological insulator Bi2Te3 hosts surface states with a high carrier mobility as back scattering of charge carriers is suppressed due to the spin-momentum locking. While in large crystals the electronic properties are dominated by the bulk states, hot-pressed pellets of nanograined Bi2Te3 offer a high surface-to-volume ratio, which provides a platform to exploit the surface carriers even in extended samples. Here we employ THz time-domain spectroscopy to disentangle the contribution of surface and bulk carriers to the transport properties. Even at room temperature the THz reflection is determined by characteristic features of the high-mobility surface carriers, i.e. Drude conductivity but also plasmonic contributions. The latter are caused by confinement of the surface carriers due to the mechanical structure of the sample. Variations of the Te content allows to shift the Fermi energy and thus strongly influences the resulting THz spectra.

HL 42.2 Fri 9:45 H36

Direct growth of monolayer MoS2 on nanostructured silicon waveguides — •A Kuppadakkath[1], E Najafidehaghani[2], Z Gan[2], A Tuniz[3], G Ngo[1], H Knopf[1], F Löchner[1], F Abtahi[1], T Bucher[1,5], S Shradha[1], T Käsebier[1], S Palomba[3], N Felde[4], P Paul[1], T Ullsperger[1], S Schröder[4], A Szeghalmi[1,4], T Pertsch[1,4], I Staude[1,5], U Zeitner[1,4], A George[2], A Turchanin[2], and F Eilenberger[1] — [1]Institute of Applied Physics (FSU), Jena, Germany — [2]Institute of Physical Chemistry (FSU), Jena, Germany — [3]Sydney Nano, Camperdown, Australia — [4]Fraunhofer IOF, Jena, Germany — [5]Institute of Solid State Physics (FSU), Jena, Germany

We report for the first time the direct growth of Molybdenum disulfide (MoS2) monolayers on nanostructured silicon-on-insulator waveguides. Our results indicate the possibility of utilizing the Chemical Vapour Deposition (CVD) on nanostructured photonic devices in a scalable process. Direct growth of 2D material on nanostructures rectifies many drawbacks of the transfer-based approaches. We show that the van der Waals materials grow conformally across the curves, edges, and the silicon-SiO2 interface of the waveguide structure. Here, the waveguide structure used as a growth substrate is complex not just in terms of its geometry but also due to the two materials (Si and SiO2) involved. A transfer-free method like this yields a novel approach for functionalizing nanostructured, integrated optical architectures with an optically active direct semiconductor.

HL 42.3 Fri 10:00 H36

Atomic layer deposition of ternary $MoWS_2$ — •Christian Tessarek, Tim Grieb, Andreas Rosenauer, and Martin Eickhoff — Institut für Festkörperphysik, Universität Bremen

Two-dimensional (2D) monolayers of binary molybdenum disulfide (MoS_2) and tungsten disulfide (WS_2) belong to the transition metal dichalcogenide (TMDC) material family and are direct band gap semiconductors. The optical band gap of monolayer MoS_2 and WS_2 is ∼1.9 and 2.0 eV, respectively. Ternary $Mo_xW_{1-x}S_2$ enables tuning of excitonic transition energy dependent on the concentration x.

Atomic layer deposition (ALD) is used to deposit $MoWS_2$ in the whole composition range between pure MoS_2 and WS_2. The concentration x is determined by the frequency position of the A_{1g} Raman mode. The distribution of W and Mo atoms in the crystal lattice of $MoWS_2$ is studied by high resolution scanning transmission electron microscopy. Additional annealing is performed to improve structural and optical properties. Photoluminescence spectroscopy measurements show concentration dependent spectral position of A and B excitonic emission.

HL 42.4 Fri 10:15 H36

Epitaxial growth of post transition metal chalcogenides: From standard approaches to new capabilities — •Eugenio Zallo[1,2], Michele Bissolo[1], Marco Dembecki[1], Gregor Koblmüller[1], and Jonathan J. Finley[1] — [1]Walter-Schottky-Institut and Physik Department, Technische Universität München, Am Coulombwall 4, 85748, Garching, Germany — [2]Paul-Drude-Institut für Festkoerperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Hausvogteiplatz 5-7, 10117, Berlin, Germany

Van der Waals (vdW) materials grown epitaxially are an urgent challenge for the development of scalable and high-crystalline-quality semiconductor films that can be exploited for novel device technologies. 2D materials "beyond graphene" have sparked immense interest in recent years, due to their excellent physical properties. Among them, post transition metal chalcogenides (PTMC, M={In,Ga} and C={S,Se,Te}) are vdW semiconductor materials with extraordinary photoresponsivity, a quasi-direct gap with a Mexican hat valence band and promising thermoelectric properties but they suffer from fast layer oxidation. In this presentation, the molecular beam epitaxy (MBE) growth of large-area PTMC is demonstrated on 3D and 2D bonded substrates by means of encapsulation strategies and careful microscopic and spectroscopic characterizations supported by density functional theory calculations. In order to study the pristine information of air sensitive materials, we present a cutting edge UHV cluster tool for the synthesis of ultrapure 2D-PTMCs and their heterostructures. The potential directions will be described.

HL 42.5 Fri 10:30 H36

Fabrication of Dielectric Mirrors and Microcavity Configurations for Light-Matter Coupling with Transition-Metal Dichalcogenides Heterostructures — •Chirag Palekar[1], Manan Shah[2], Fynn Kunze[2], Peter Klar[2], Stephan Reitzenstein[1], and Arash Rahimi-Iman[2] — [1]Institute of Solid State Physics, Technische Universität Berlin, D-10623, Germany. — [2]I. Physikalisches Institut und Zentrum für Materialwissenschaften, Justus-Liebig Universität Gießen, D-35392, Germany

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15 min. break

HL 42.6 Fri 11:00 H36

Selective area growth of MoS_2 via CVD on patterned GaN-AlO_x substrates — •Simon Wörle, Theresa Grünleitner, Alex Henning, and Ian Sharp — Walter Schottky Institute and Physics Department, Technical University of Munich, Garching, Germany

Two-dimensional (2D) transition metal dichalcogenides have attracted considerable attention due to their unique optoelectronic properties. For the application of 2D materials in semiconductor devices, the controlled and scalable synthesis of high-quality 2D materials is critical.

Here, we demonstrate the selective area growth of MoS_2 by chemical vapor deposition (CVD) on GaN substrates that were patterned with ultrathin aluminum oxide coatings created by low-temperature atomic layer deposition. Optical and scanning electron microscopy images show that mono- and few-layer MoS_2 flakes preferentially nucleate and grow directly on the (uncoated) GaN. Atomic force microscopy and Raman measurements further reveal the formation of triangular and star-like shaped multilayer MoS_2 crystals at the interfaces between GaN and AlO_x. Moreover, the observed fixed orientation of the triangular MoS_2 flakes with respect to the GaN substrate lattice indicates van der Waals epitaxy. By altering the CVD growth conditions, the density of deposited MoS_2 flakes can be tuned, resulting in the growth of either isolated MoS_2 nanosheets or continuous films, in the latter of which the individual flakes have coalesced.

The presented results mark an important step towards integrated MoS_2 based heterostructures for semiconductor device applications.

HL 42.7 Fri 11:15 H36

Patterned growth of transition metal dichalcogenides monolayers and multilayers for electronic and optoelectronic device application — •Seung Heon Han[1], Ziyang Gan[1], Emad Najafidehaghani[1], Fatemeh Abtahi[2], Christof Neumann[1], Julian Picker[1], Tobias Vogel[2], Uwe Hübner[3], Falk Eilenberger[2], Antony George[1], and Andrey Turchanin[1] — [1]Institute of Physical Chemistry, Friedrich Schiller University Jena,

Jena, Germany — [2]Institute of Applied Physics, Friedrich Schiller University Jena, Jena, Germany — [3]Leibniz Institute of Photonic Technology (IPHT), Jena, Germany

We present a simple, large area, cost effective soft lithographic method for growth of high-quality two-dimensional transition metal dichalcogenides (TMDs). Initially, a liquid precursor (Na2MoO4 in aqueous solution) is patterned on the growth substrate using micro-molding in capillaries (MIMIC) technique. Subsequently, a chemical vapor deposition (CVD) step is employed to convert the precursor patterns to monolayer, few layers, or bulk TMDs, depending on the precursor concentration. The grown patterns were characterized using optical microscopy, atomic force microscopy, Raman spectroscopy, X-ray photoelectron spectroscopy, scanning electron microscopy, and photoluminescence spectroscopy to reveal their morphological, chemical, and optical characteristics. The applicability of the grown patterned TMDs were tested for application such as field effect transistors, photodetectors, and memtransistor devices.

HL 42.8 Fri 11:30 H36

Conductive 2D MOFs in van-der-Waals heterostructures — •Jonas Pöhls[1], Zhiyong Wang[2], Renhao Dong[2], and Thomas Weitz[1] — [1]I. Physical Institute University of Göttingen, Göttingen, Germany — [2]Technical University of Dresden, Dresden, Germany

In conventional three-dimentional (3D) Metal-Organic Frameworks (MOFs) the electric conductivity is limited by the large separation of the metal centers by the organic ligands. Recent advantages in the synthesis of layered two-dimensional conjugated MOFs (2D c-MOFs) lead to a large improvement of the electronic properties, these materials allow a charge transfer along both interlayer (π-π-stacking) and intralayer (basal plane) directions [1]. In order to elucidate the underlying charge transport mechanisms in the 2D c-MOFs, we perform electronic characterizations of the films implemented in field-effect transistors under varying conditions. In addition to the improved properties of the 2D c-MOFs themselves, their 2D nature make them also a promising candidate for the fabrication of van-der-Waals heterostructures with other 2D materials like graphene, which could give access to a variety of interaction-driven effects. We present first results on the charge transport of 2D c-MOFs down to the size of single crystals as well as implemented in van-der-Waals heterostructures.

[1] Z. Wang et al. "Interfacial Synthesis of Layer-Oriented 2D Conjugated Metal*Organic Framework Films toward Directional Charge Transport", J. Am. Chem. Soc. (2021)

HL 42.9 Fri 11:45 H36

Controlled Encapsulation of Monolayer MoS2 with Ultrathin Aluminium Oxide for Tunnel Contacts — •Sergej Levashov, Chenjiang Qian, Theresa Grünleitner, Jon J. Finley, Alex Henning, and Ian D. Sharp — Walter Shottky Institut, TUM, München, Deutschland

Two-dimensional (2D) semiconductors have unique optoelectronic properties that provide the opportunity to overcome current scaling and performance limits of semiconductor devices. To harness the full of potential of 2D materials, requires their seamless integration with bulk materials. In particular, contacting mono- and few-layer 2D semiconductors with metals is challenging since the deposition process may introduce defects impeding interfacial charge transport. Here we use low-temperature atomic layer deposition to encapsulate monolayer MoS_2 with a van der Waals bonded and ultrathin aluminium oxide (AlO_x) layer. The 18 Å thin AlO_x coating introduces additional charge carriers ($\sim 5 \cdot 10^{12}$ cm^{-2}), while it also protects monolayer MoS_2 from defect creation during metallization. Microscratching of the AlO_x adlayer by contact mode atomic force microscopy and subsequent spectroscopic analysis demonstrate the reversibility of the charge transfer doping effect, indicating weak interaction. Importantly, current voltage measurements yielded a two-fold reduction in the contact resistance for MoS_2 field-effect transistors contacted with AlO_x interlayer. Overall, this work demonstrates the beneficial effect of the AlO_x adlayer for improving 2D device contacts and provides a scalable route to the damage-free integration of 2D semiconductors.