DS 14: 2D Materials and their Heterostructures I (joint session DS/O/HL)

Time: Tuesday 9:30–11:30 Location: CHE 89

DS 14.1 Tue 9:30 CHE 89

Plasma-enhanced atomic layer deposition of AlN at 40°C for encapsulation and dielectric integration of 2D materials — •Michele Bissolo, Alex Henning, Theresa Grünleitner, and Ian D. Sharp — Walter Schottky Institute, 85748 Garching, Germany

To date, hexagonal boron nitride (h-BN) is the material of choice for the dielectric integration of 2D materials since it preserves the intrinsic photoluminescence yield, charge carrier mobility, and band gap of 2D semiconductors by reducing strain, effects of interfacial defects, and remote phonons. However, h-BN must be either mechanically transferred with a polymer stamp onto a bulk substrate, which introduces contamination, or grown by MBE at temperatures above 800°C, which is incompatible with BEOL, microlithography, and temperature-sensitive materials. Here, we demonstrate atomically flat aluminum nitride (AlN), grown by plasma-enhanced atomic layer deposition (PEALD) at 40°C, as a scalable alternative to h-BN. AlN has a similar band gap (E_g = ∼6 eV) and a larger dielectric constant (ϵ = ∼9) in comparison to h-BN. Because ALD is conformal, it enables the full enclosure of the 2D material. In this work, we test PEALD AlN as a substrate and encapsulation layer for mono- and few-layer MoS_2. Raman spectroscopy suggests a strain-free integration of MoS_2 with AlN and photoluminescence shows a relatively stronger emission from the A and B excitons without emission from defects. We demonstrate the improved field-effect mobility with MoS_2 field-effect transistors enclosed by an AlN dielectric layer. This work provides a scalable route to the dielectric integration of 2D materials critical for future optoelectronics.

DS 14.2 Tue 9:45 CHE 89

Spin-Sensitive Readout of Two-Dimensional Wigner Crystals in Transition-Metal Dichalcogenides — •Johannes Knörzer[1,2], Martin Schuetz[3], Geza Giedke[4,5], Dominik Wild[3], Kristiaan de Greve[3], Richard Schmidt[1,2], Mikhail Lukin[3], and Ignacio Cirac[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Physics Department, Harvard University, Cambridge, USA — [4]Donostia International Physics Center, San Sebastián, Spain — [5]Ikerbasque Foundation for Science, Bilbao, Spain

Wigner crystals are prime candidates for the realization of regular electron lattices under minimal requirements on external control and electronics. However, technical challenges have prevented their detailed experimental investigation to date. Here we propose an implementation of two-dimensional electron lattices for quantum simulation based on self-assembled Wigner crystals in transition-metal dichalcogenides. We show that these semiconductors allow for minimally invasive all-optical detection schemes of charge ordering and total spin. For incident light with optimally chosen beam parameters and polarization, we predict a strong dependence of the transmitted and reflected signals on the underlying lattice periodicity, thus revealing the charge order inherent in Wigner crystals. At the same time, the selection rules in transition-metal dichalcogenides provide direct access to the spin degree of freedom via Faraday rotation measurements.

DS 14.3 Tue 10:00 CHE 89

Growth of ultra-thin large sized 2D WS_2 flakes in at air-liquid interface — •Talha Nisar[1], Torsten Balster[1], Ali Haider[2], and Veit Wagner[1] — [1]Department of Physics and Earth Science, Jacobs University Bremen, Campus Ring 1, 28759, Bremen, Germany — [2]Department of Life Sciences and Chemistry, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

2D tungsten disulfide (WS_2) flakes were obtained at the air-liquid interface by a technique recently developed [1]. For this purpose, aqueous solution of ammonium tetrathiotungstate (ATTW) is used as precursor. The process exhibit a clear temperature dependence. At the room temperature, no flakes are observed. When the aqueous solution of ATTW is kept at 80°C, formation of flakes is observed. These flakes can be transferred from the air-liquid interface to a silicon substrate by a controlled dip-coating process. Large flakes with lateral size of up to 100μm were obtained. Thicknesses ranging from bilayer WS_2 to 5 MLs as measured by atomic force microscopy. Various spectroscopic techniques (FTIR, Raman, UV-Vis and XPS) are applied to investigate the chemical reaction mechanism for the formation of the flakes. These results show that the initial flakes are made of WO_3. The obtained flakes are converted to WS_2 by a post annealing step at 500-900 °C with an additional sulfur source in Ar/H_2 environment. The successful conversion to WS_2 after annealing is confirmed by Raman and XPS. This non-expensive growth technique can be used to produce large WS_2 flakes for various applications. [1] X. Zeng, et al, Nanoscale, 2017, 9, 6575-6580

DS 14.4 Tue 10:15 CHE 89

Electrical Properties and Doping effects of Chemical Vapor Deposition Growth Layered MoS2 Transistor on Different Back gate oxide Substrates — •Ying-Chun Shen and Yu-Lun Chueh — Department of Materials Science and Engineering National Tsing-Hua University 101, Sec. 2, Kuang-Fu Road, Hsinchu 30013, Taiwan, R. O. C

Recently, there have been many research evolvements in the transition-metal dichalcogenides (TMDCs) materials, which are featured by exotic properties of single or a few layers derivative in terms of direct or indirect bandgap, mechanical or electrochemical behavior. In addition to the pristine properties, the chemical and physical features of TMDCs can be controllably tuned by either nano-structure or dopants. Due to the nature of the TMDCs, they have been the promising candidates of the next-generation semiconductor devices. In our study, we have demonstrated the chemical vapor deposition growth layered MoS2 transistors on different back gate oxide substrates, such as SiO2, HfO*2 and Al2O3. Among these three substrates, HfO2 based MoS2 transistor exhibits the best performance, e.g., higher drain current up to 10 mA, on-off ratio about 106, stable mobility around 20 cm2/ V* s. Furthermore, we performed the doping effect by adding metal ions, and investigate the ion influence on the MoS2 transistor. Moreover, we also compared the electrical performance of distinct metal ions and the number of ions. Here, we provide not only the properties of back gate oxide selection but also a roadmap of ion doping effect to boost the electrical characteristics of the MoS2 transistors.

DS 14.5 Tue 10:30 CHE 89

Optical properties of TMDC monolayers interfaced with 2D metals — •Katharina Nisi[1], Shruti Subramanian[2,3], Florian Sigger[1], Margaux Lassaunière[4], David O. Tiede[4], Hendrik Lambers[4], Alexander Holleitner[1], Joshua Robinson[2,3], and Ursula Wurstbauer[4] — [1]Walter Schottky Institute and Physics Department, Technical University of Munich, Garching, Germany — [2]Department of Materials Science and Engineering, The Pennsylvania State University, USA — [3]Center for 2-Dimensional and Layered Materials, The Pennsylvania State University, USA — [4]Institute of Physics, University of Münster, Münster, Germany

Two-dimensional metals such as 2D-Ga or 2D-In prepared by confinement epitaxy are an emerging class of materials with peculiar properties including superconductivity and strong plasmonic response [1]. The plasmon resonance of those 2D metals spectrally overlaps with the excitonic transition energies of semiconducting transition metal dichalcogenides. Hybrid structures of 2D metals with TMDCs are promising for enhancing the light matter interaction. We investigate the optical response of 2D metal-TMDC hybrid structure by a combination of spectroscopic imaging ellipsometry, photoluminescence and Raman spectroscopy.

[1] B. Bersch et al. arXiv:1905.09938 (2019).

DS 14.6 Tue 10:45 CHE 89

Rigid Band Shifts in Two-Dimensional Semiconductors through External Dielectric Screening — •Malte Rösner[1], Lutz Waldecker[2,3], Archana Raja[4,5], Christina Steinke[6], Aaron Bostwick[4], Roland J. Koch[4], Chris Jozwiak[4], Takashi Taniguchi[7], Kenji Watanabe[7], Eli Rotenberg[4], Tim O. Wehling[6], and Tony F. Heinz[2,3] — [1]Institute for Molecules and Materials, Radboud University, Netherlands — [2]Department of Applied Physics, Stanford University, USA — [3]SLAC National Accelerator Laboratory, USA — [4]Lawrence Berkeley National Laboratory, USA — [5]Kavli Energy NanoScience Institute, University of California Berkeley, USA — [6]Institute for Theoretical Physics, University of Bremen, Germany — [7]National Institute for Materials Science, Japan

We investigate the effects of external dielectric screening on the elec-

tronic dispersion and the band gap in the atomically thin, quasi-two-dimensional (2D) semiconductor WS2 using angle-resolved photoemission and optical spectroscopies, along with first-principles calculations. We find the main effect of increased external dielectric screening to be a reduction of the quasiparticle band gap, with rigid shifts to the bands themselves. Specifically, the band gap of monolayer WS2 is decreased by about 140 meV on a graphite substrate as compared to a hexagonal boron nitride substrate, while the electronic dispersion of WS2 remains unchanged within our experimental precision of 17 meV. These essentially rigid shifts of the valence and conduction bands result from the special spatial structure of the changes in the Coulomb potential induced by the dielectric environment of the monolayer.

DS 14.7 Tue 11:00 CHE 89

Unveiling valley lifetimes of free charge carriers in monolayer WSe_2 — •Manfred Ersfeld[1], Frank Volmer[1], Lars Rathmann[1], Luca Kotewitz[1], Maximilian Heithoff[1], Mark Lohmann[2], Bowen Yang[3], Kenji Watanabe[4], Takashi Taniguchi[4], Ludwig Bartels[3], Jing Shi[2], Christoph Stampfer[1,5], and Bernd Beschoten[1] — [1]2nd Institute of Physics and JARA-FIT, RWTH Aachen University, 52074 Aachen, Germany — [2]Department of Physics and Astronomy, University of California, Riverside, California 92521, USA — [3]Department of Chemistry and Materials Science & Engineering Program, University of California, Riverside, California 92521, USA — [4]National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan — [5]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany

We report on nanosecond long, gate-dependent valley lifetimes of free charge carriers in WSe_2, unambiguously identified by the combination of time-resolved Kerr rotation (TRKR) and electrical transport measurements. While the valley polarization increases when tuning the Fermi level into the conduction or valence band, there is a strong decrease of the respective valley lifetime consistent with both electron-phonon and spin-orbit scattering. The longest lifetimes are seen for spin-polarized bound excitons in the band gap region. We explain our findings via two distinct, Fermi level-dependent scattering channels of optically excited, valley polarized bright trions either via dark or bound states.

DS 14.8 Tue 11:15 CHE 89

Superconducting Properties of MXene Monolayers — •Cem Sevik[1], Jonas Bekaert[2], and Milorad Milosevic[2] — [1]Department of Mechanical Engineering, Eskisehir Technical University, Ankara, Turkey — [2]Department of Physics, University of Antwerp, Antwerpen, Belgium

MXenes are a new class of two-dimensional materials, consisting of a carbon or nitrogen layer sandwiched in between two transition metal layers. Various experimental studies have demonstrated that these crystals have broad and growing areas of application, such as Li-ion batteries, super-capacitors, fuel-cells, and hydrogen storage. Since most of the MXene monolayers are metals, they could also host superconductivity, depending on their electronic and vibrational properties. Therefore, we have systematically investigated the superconducting properties of monolayer MXenes of stoichiometry M2X (M being the transition metal and X either C or N), with a first-principles approach to Eliashberg theory. Due to the presence of the transition metal, we found the choice of the type of exchange-correlation and inclusion of spin-orbit interactions to be crucial to describe the vibrational and superconducting properties of these monolayers. Cautiously considering these, we have identified five new superconducting monolayer MXenes, out of which three carbides (Mo2C, W2C, and Sc2C) and two nitrides (Mo2N and Ta2N). The highest predicted critical temperature (Tc) of 17 K is found for Mo2N. Our first principle-based systematic analysis clearly has opened up a whole new class of superconductors with sizeable Tc in the monolayer limit.