HL 8: 2D Semiconductors and van der Waals Heterostructures II

The session covers the physics of emerging 2D materials.

Time: Monday 15:00–16:15 Location: H15

HL 8.1 Mon 15:00 H15

atomic and electronic structures of colloidal ultrathin PbSe nanoplatelets — •Huu Thoai Ngo[1,2], Leon Biesterfeld[3], Ahmed Addad[1], Bruno Grandidier[1], Christophe Deere[1], Jannika Lauth[3], and Louis Biadala[1] — [1]Université de Lille, CNRS, Centrale Lille, Université Polytechnique Hauts-de-France, Junia-ISEN, UMR 8520-IEMN, INRAE, UMR-8207, UMET- Unité Matériaux et Transformations, F-59000 Lille, France. — [2]Solid Surface Analysis, Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany. — [3]Institute of Physical Chemistry and Electrochemistry, Leibniz University Hannover, Callinstr. 3A, D-30167 Hannover, Germany

Two-dimensional (2D) PbSe nanoplatelets (NPLs) are promising materials for lighting technologies due to their efficient and tunable photoluminescence (PL), such as narrow PL emission reaching telecom bands. However, the electronic properties of single NPLs remain underexplored, limiting insights into quantum confinement effects. Here, we investigate the structural and electronic properties of ultrathin PbSe NPLs using low-temperature scanning tunneling microscopy (LT-STM). STM images confirm flat 2D morphologies at various thicknesses while tunneling spectra reveal pronounced quantum confinement along the thickness, resulting in bandgap shifts. High-angle annular dark-field scanning transmission electron microscopy confirms the rock-salt crystal structure, providing atomic-level insights. Additionally, tight-binding calculations demonstrate lateral quantum confinement effects, showing that in-plane dimensions influence electronic properties.

HL 8.2 Mon 15:15 H15

Modifying properties of 2D transition metal dichalcogenides by confined-space annealing — •Christian Tessarek, Christian Petersen, Tim Grieb, Florian F. Krause, Alexander Karg, Christian Habben, Andreas Rosenauer, and Martin Eickhoff — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

2D transition metal dichalcogenides (TMDs) can be grown by different methods, e.g. chemical vapor or atomic layer deposition (ALD) [1]. Subsequent annealing is often applied to improve the properties of the as-grown 2D layers. Decomposition of TMD layers due to desorption of chalcogenides usually limits the temperature range. Higher annealing temperatures are possible in a chalcogene containing atmosphere but require special safety requirements of the annealing equipment.

In this study, a confined-space annealing (CSA) approach is demonstrated and realized by a close contact face-to-face sample arrangement of TMD layers on SiO_2/Si or graphene substrates. CSA is performed in vacuum or in an inert gas atmosphere without using additional chalcogene containing precursors. Such sample arrangement strongly reduces chalcogene outdiffusion from the confined space and allows annealing at higher temperatures and longer durations. The influence of CSA parameters is investigated with respect to structural and optical properties of the TMDs and compared to a standard annealing process of uncovered layers. It will also be shown that CSA can be used for conversion of MoS_2 to ternary $Mo(S,Se)_2$ and binary $MoSe_2$.

[1] C. Tessarek et al., 2D Mater. **11**, 025031 (2024).

HL 8.3 Mon 15:30 H15

Mapping the lateral homogeneity of semiconducting monolayer 2D polar Ag using spectroscopic imaging ellipsometry — •Ulrich Limberg[1], Jakob Henz[1], Siavash Rajabpour[2], Alexander Vera[2], Joshua Robinson[2], and Ursula Wurstbauer[1] — [1]Institute of Physics, University of Muenster, Germany — [2]MatSE; Center for 2DLM; Atomic; 2D Crystal Consort, PennState University, USA

2D polar metals are a novel family of atomically thin plasmonic quantum materials, which are synthesized by confinement heteroepitaxial growth (CHet)[1]. Hereby, metal atoms such as silver or gallium are intercalated between bilayer graphene and a silicon carbide substrate. In the case of 2D polar silver, a stable monolayer structure forms which has been shown to be an indirect bandgap semiconductor[2]. However, Raman imaging seems to indicate the existence of a second, possibly metallic, phase[3].

We investigated 2D polar silver samples of varying growth conditions via spectroscopic imaging ellipsometry, in order to access lateral inhomogeneities by modifications in the dielectric functions sensitive to different phases.

1 N. Briggs, et al. Nature materials 19.6 (2020): 637-643.
2 W. Lee, et al., Nano letters, 22(19) (2022): 7841-7847.
3 M. Wetherington et al., 2D Materials, 8.4 (2021): 041003.

HL 8.4 Mon 15:45 H15

Biaxial Compressive Strain Tuning of Quantum Properties in 2D Materials — •Eudomar Rafael Henriquez Guerra[1,3], Lisa Almonte[1,3], Hao Li[4], Daniel Elvira[3], Reyes Calvo[1,2,3], and Andres Castellanos Gomez[4] — [1]BCMaterials, Basque Center for Materials, Applications and Nanostructures — [2]Ikerbasque, Basque Foundation for Science — [3]Depto. de Física Aplicada, Instituto Universitario de Materiales, Universidad de Alicante — [4]2D Foundry Group, Instituto de Ciencia de Materiales de Madrid, CSIC

This study investigates the impact of biaxial compressive strain on 2D materials at cryogenic temperatures, focusing on single-layer transition metal dichalcogenides (TMDs) and multilayered NbSe2. While tensile strain has been widely explored, compressive strain at low temperatures remains underexplored, despite its potential to significantly alter quantum properties such as magnetic and superconducting phase transitions. We show that biaxial compressive strain, induced by the thermal expansion mismatch between the polymer substrates and TMDs, leads to dramatic shifts in exciton energy and gauge factors, surpassing previous compressive strain effects. Moreover, we observe a consistent reduction in the superconducting critical temperature of NbSe2 flakes, with the most pronounced changes in thinner samples. Remarkably, this effect is still noticeable even for NbSe2 flakes as thick as 86 nm. These results highlight a powerful and cost-effective method for tuning phase transitions and other quantum phenomena in 2D materials at low temperatures.

HL 8.5 Mon 16:00 H15

Two-dimensional semiconductor with tunable bandgap close to the full visible spectrum: a MOCVD study — •Nils Langlotz, Robin Günkel, Tigmanshu Sundiyal, Oliver Massmeyer, Jürgen Belz, and Kerstin Volz — Department of Physics and Material Sciences Center, Philipps-University Marburg, Germany

Two-dimensional (2D) semiconductors have attracted considerable attention due to their extraordinary thickness-dependent properties. III-VI compounds such as GaSe or GaS exhibit a unique Mexican hat band structure with a van Hove singularity near the valence band maxima (VBM) at the Γ point. Furthermore, 2D GaSe and GaS as bulk material have a direct band gap of 2.0 eV and 2.5 eV, respectively, making a dilute $GaSe_xS_{1-x}$ system a tunable LED in the visible regime. Tuning the band gap in the few layer regime is also possible, but the indirect band gap has to be overcome, which is suggested by doping. Metal organic chemical vapour deposition (MOCVD) is used for the growth of bulk GaSe, GaS and $GaSe_xS_{1-x}$ on sapphire (0001). Growth for all materials was performed in an AIX200GFR at 50 mbar at 500°C in a flow modulated growth mode where the first pulse is 30 s of the gallium species and the second pulse is 30 s of selenium or sulphur, repeated for 150 cycles for the pure crystals. For the diluted crystal the second pulse is replaced by $(30-x)$ s of selenium followed by x seconds of sulphur. The organometallic precursors used were tri-tertiarybutyl-gallium (TTBGa), di-iso-propyl-selenide (DiPSe) and tertiarybutyl-sulphide (TBS). Raman spectroscopy is used to verify the selenium/sulphur incorporation.