HL 9: Oxide Semiconductors: Growth and Fabrication

Time: Monday 15:00–16:30 Location: POT/0051

HL 9.1 Mon 15:00 POT/0051

Growth of rutile GeO_2 by plasma-assisted suboxide molecular beam epitaxy — Alexander Karg[1], •Satjawoot Phiwondee[1], Manuel Alonso-Orts[1,2], Marco Schowalter[1], Andreas Rosenauer[1,2], Martin Eickhoff[1,2], and Patrick Vogt[3] — [1]Institute of Solid State Physics, University of Bremen, Bremen, Germany — [2]MAPEX Center for Materials and Processes, University of Bremen, Germany — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany

The interest in ultra-wide bandgap (UWBG) semiconductors for high-power electronic applications is rapidly increasing, for which rutile germanium dioxide (r-GeO_2) is a promising material. It possesses excellent properties: a bandgap of 4.6 eV [1], thermal conductivity of 51 W/mK [1], and a breakdown electric field of 7 MV/cm [1] and theoretical bipolar dopability [2].
This work reports on the growth of r-GeO_2 on m-plane Al_2O_3 substrates using plasma-assisted suboxide molecular beam epitaxy, using a SnO_2 buffer, followed by a r-$Ge_xSn_{(1-x)}O_2$ buffer to stabilize the r-GeO_2 phase. The growth of r-GeO_2 on those buffer layers is demonstrated and the responsible nucleation mechanism is investigated in detail. Characterization was performed by atomic force microscopy (AFM) and high resolution X-ray diffraction (HRXRD). Selected r-GeO_2 layers were analyzed by scanning transmission electron microscopy (STEM).
[1]: M. Labed et al., Materials Today 83, 513-537 (2025)
[2]: S. Chae et al., Appl. Phys. Lett. 114, 102104 (2019)

HL 9.2 Mon 15:15 POT/0051

Wafer-scale transfer and integration of tungsten-doped vanadium dioxide films — •Guanyi Li[1,2], He Ma[2], and Peter J. Klar[1] — [1]University of Giessen Institute of Physic, Giessen, 35392, Germany — [2]Beijing University of Technology, Institute of Information Photonics Technology, Beijing 100124, People's Republic of China

The trend in modern optoelectronic devices is towards greater flexibility, wearability, and multifunctionality. This demands more flexible fabrication methods of functional layers. Vanadium dioxide (VO_2), with its metal-insulator transition (MIT) at 68 °C, is of interest for many optoelectronic devices. However, high-quality VO_2 usually needs to be grown at T >450 °C in an oxygen-containing atmosphere implying a low compatibility with many optoelectronic device concepts, e.g., on flexible substrates. Here, we use a layer-by-layer transfer method of wafer-scale tungsten-doped VO_2 films, which enables sequential integration of VO_2 films with different MIT temperatures (down to 40 °C) onto arbitrary substrates. By stacking multiple VO_2 films with different doping levels of W, a quasi-gradient-doped VO_2 architecture can be achieved, effectively broadening the MIT temperature window and reducing the hysteresis of VO_2. Such integrated VO_2 films find a wide scope of applications, e.g., flexible temperature indicator strips, infrared camouflage devices, nonreciprocal ultrafast light modulators, or smart photo actuators. Our work promotes the development of more flexible and tunable optoelectronic devices integrated with VO_2.

HL 9.3 Mon 15:30 POT/0051

Growth and characterization of ultra-wide bandgap oxide semiconductor $LiGa_5O_8$ — •Nazar Masiuta, Sofie Vogt, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix Bloch Institute for Solid State Physics, Semiconductor Physics Group, Leipzig, Germany

Lithium gallium oxide ($LiGa_5O_8$) has been recently grown as an ultra-wide bandgap oxide semiconductor with robust p-type conductivity using mist chemical vapor deposition[1]. This discovery suggests application of the material in high-power electronics by forming p-n junctions with n-type α-Ga_2O_3, β-Ga_2O_3, and isostructural γ-Ga_2O_3. However, establishing the origin of p-type conductivity of lithium gallium oxide remains an experimental challenge[2], while a theoretical prediction argues that neither native nor dopant defects in $LiGa_5O_8$ could be responsible for it[3]. We analyze the influence of pulsed laser deposition growth parameters on the quality of lithium gallium oxide films on different substrates. The structural, optical, and electrical characterization of $LiGa_5O_8$ is performed to determine the type of conductivity and its origin in the fabricated samples.
[1] K. Zhang *et al.*, Adv. Electron. Mater. **11**, 2300550 (2025).
[2] K. Zhang *et al.*, APL Mater. **13**(4), 041104 (2025).
[3] J. L. Lyons, J. Appl. Phys. **135**(16), 165705 (2024).

HL 9.4 Mon 15:45 POT/0051

(N:)CuBi2O4 photocathode thin films for photoelectrochemical water splitting — •Miriam J. Fehrenbach[1,2], Dominic Rapf[1,2], Katarina S. Flashar[1,2], Ian D. Sharp[1,2], and Verena Streibel[1,2] — [1]Walter Schottky Institute, Technical University of Munich, Garching, Germany — [2]Physics Department, TUM School of Natural Sciences, Technical University of Munich, Garching, Germany

Photoelectrochemical (PEC) water splitting is a promising pathway to carbon-neutral solar fuels. While metal oxides are well explored as photoanodes, complementary photocathodes remain scarce. Potential candidates are Cu-based oxides, which naturally exhibit p-type conductivity. Among them, copper bismuthate (CuBi*O*) is a promising material [1], combining a visible-light bandgap with high photocurrent onset potentials [2], but suffering from poor charge transport [1]. To address this limitation, we developed a reactive co-sputtering and annealing process to synthesize high-quality, nitrogen-modified CuBi*O* thin films. We systematically examine structural and optical effects of nitrogen incorporation and find a significant improvement in PEC activity. To understand this enhanced performance, we investigate the charge carrier transport properties with (photo)conductivity measurements. [1] J. K. Cooper et al., Chem. Mater., 2021, 33, 3, 934*945. [2] N. T. Hahn et al., J. Phys. Chem. C, 2012, 116, 10, 6459*6466.

HL 9.5 Mon 16:00 POT/0051

High-throughput combinatorial synthesis of perovskite-type materials for solar applications — •Clemens Petersen, Andreas Rosnes, and Holger von Wenckstern — Centre for Materials Science and Nanotechnology, University of Oslo, Norwa

Recently, combinatorial deposition methods have increasingly gained attention due to the high experimental throughput and resource-wise efficiency they offer in materials discovery. Our combinatorial pulsed laser deposition (c-PLD) approach enables the fabrication of material libraries on a single substrate, spanning wide compositional spaces with precise spatial control. Combined with high-throughput characterization techniques (HTC) such as spatially resolved UV-VIS spectroscopy and X-ray diffraction, the properties of complex materials can be rapidly mapped with high chemical resolution and minimal effort. We demonstrate the potential of c-PLD for accelerating the discovery of perovskite oxides for solar-energy-related applications. Using the $SrTiO_3$*$BaTiO_3$ (STO-BTO) system as an example, we showcase rapid screening of structural and optical properties on small area spatially addressable material libraries (SAML) covering the full composition range. In addition, STO-BTO SAMLs enable systematic strain engineering of functional perovskite materials. The tunable band structures and suitability for catalytic processes such as photoelectrolysis and proton-coupled electron transfer render titanate perovskites promising candidates for solar fuel production. Our results underline the capability of c-PLD and HTC workflows to efficiently identify and optimize oxide perovskites for sustainable energy technologies.

HL 9.6 Mon 16:15 POT/0051

Pulsed laser deposition of rutile GeO_2 thin films — •Hannah Dichelle, Sofie Vogt, Marius Grundmann, and Holger von Wenckstern — Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Germany

Rutile germanium-oxide has recently come into focus as an ultrawide bandgap material which is predicted to offer the possibility of ambipolar doping. [1,2] The stabilization of rutile phase GeO_2 is challenging due to the similar formation energies of the amorphous phase and α-Quarz phase.[2] We present GeO_2 thin films fabricated by pulsed laser deposition at heater temperatures >450°C. To facilitate the crystallization in the rutile phase (Sn, Ge)O_2 buffer layers are grown on sapphire and TiO_2 substrates at heater temperatures >600°C. Both ternary $Sn_xGe_{1-x}O_2$ buffer layers and vertically composition graded buffer layers are used to stabilize the rutile phase. The structural properties of rutile phase GeO2 thin films are investigated as a function of the growth temperature and oxygen pressure.

[1] Chae *et al.*, Appl. Phys. Lett. 114, 102104 (2019)

[2] Shimazoe *et al.*, Jpn. J. Appl. Phys. 64, 050903 (2025)