HL 9: Oxide Semiconductors I

Time: Monday 15:00–16:30 Location: H17

HL 9.1 Mon 15:00 H17

Nitrogen Doping of Sputtered BiVO_4 Thin Films — •Hannah Sassenfeld[1,2], Tsedenia Zewdie[1,2], Ian D. Sharp[1,2], and Verena Streibel[1,2] — [1]Walter Schottky Institute, Technical University of Munich, D-85748 Garching, Germany — [2]Physics Department, TUM School of Natural Sciences, Technical University of Munich, D-85748 Garching, Germany

Bismuth vanadate (BiVO_4) is a promising photoanode material for photoelectrochemical (PEC) water splitting, given its suitable band gap (≈2.5 eV) and valence band maximum position relative to the water oxidation potential. Reducing the band gap of BiVO_4 can lead to a more effective utilization of the solar spectrum. One strategy towards band gap reduction is nitrogen incorporation, as previously reported by Irani et al. [1] and Kim et al. [2]. While both studies observe reduced band gaps, they do not agree on how nitrogen is incorporated into BiVO_4 and whether it improves or deteriorates PEC performance. To shed light onto the nature and effects of nitrogen incorporation, we use well-controlled reactive co-sputter deposition of BiVO_4 in nitrogen-containing environments (N:BiVO_4). Adjusting the amount of nitrogen in the reactive gas mixture and post-annealing treatments allow us to control the amount of incorporated nitrogen. Using this systematic sample library of N:BiVO_4, we interrogate the optical and structural properties of N:BiVO_4, its composition and electronic structure, and evaluate the impact of nitrogen incorporation on PEC performance.

[1] Irani et al. Solar RRL 4.1 (2020): 1900290. [2] Kim et al. Nature communications 6.1 (2015): 8769.

HL 9.2 Mon 15:15 H17

Plasma Plume Deflection and Target Surface Roughness During Pulsed Laser Deposition of Functional Oxides — •Jonas Elz, Holger von Wenckstern, and Marius Grundmann — Leipzig University, Felix Bloch Institute for Solid State Physics, Semiconductor Physics Group, Leipzig, Germany

Pulsed laser deposition (PLD) is a highly flexible, fast and reproducible physical vapor deposition technique that uses a pulsed laser to evaporate a target material, producing an excited laser-induced plasma. Although simple in set-up, modeling the ablation process is difficult because of its non-equilibrium nature due to the high pulse energy incident on a short time scale (20 ns laser pulse width). Ablation of any target material requires optimization of the process parameters. Some targets used in PLD develop a rough surface structure upon longer use that causes the plasma plume to deflect toward the incoming laser beam during the ablation process. Typically, the plume deflection increases until a stable surface morphology is reached. In this work, we present a comparison of the plasma plume deflection with surface roughness and morphology of different PLD targets as measured by laser scanning microscopy. A Python script is used to evaluate plume images to determine the deflection angle.

HL 9.3 Mon 15:30 H17

Analysis of film thickness distributions for combinatorial pulsed laser deposition — •Clemens Petersen, Marius Grundmann, and Holger von Wenckstern — Universität Leipzig Felix-Bloch-Institut für Festkörperphysik, Leipzig, Deutschland

Recently combinatorial deposition methods have increasingly gained scientists* attention, due to the high experimental throughput and resource-wise efficiency they offer in materials discovery. They enable fast screening of material properties of multinary material systems using just a single sample. By employing pulsed laser deposition with our segmented target approach [1] we realized the deposition of α-$(Al_xGa_{1-x})_2O_3$ with continuous composition spread over the whole composition range on a single 2-inch sapphire wafer [2]. Accompanied by the usage of high-throughput measurements such as spectroscopic ellipsometry and X-ray diffraction, the characterization of physical properties with high chemical resolution and comparably low efforts becomes feasible.

Here we utilize a predictive numerical model, based on the corrected plasma expansion description of Anisimov *et al.* [3], for the calculation of binary growth rates of group-IIII and transition metal sesquioxides. Further the model can be applied to predict and model elemental composition and thickness distributions of ternary alloys for these materials. [1] H. von Wenckstern *et al.*, pss(b), Vol. 257, 1900626 [2] A. Hassa *et al.*, pss(b), Vol. 258, 2000394 [3] S. I. Anisimov *et al.*, Phys. rev. B, Vol 48, 12076.

HL 9.4 Mon 15:45 H17

Influence of different gate metals on α-Ga_2O_3 MESFET device performance — •Sebastian Köpp, Clemens Petersen, Sofie Vogt, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix Bloch Institute for Solid State Physics, Semiconductor Physics Group, Leipzig, Germany

We present metal-semiconductor field effect transistors (MESFET) on α-Ga_2O_3 grown by pulsed laser deposition in a two-step process on Al_2O_3 [5]. The MESFETs exhibit high on/off ratios above 9 orders of magnitude and subthreshold swings as low as 100 mV/dec. We evaluate different gate materials in an effort to optimize device switching and breakdown behaviour.

With its ultra-wide bandgap of 5.3 eV to 5.6 eV [1,2] and a high predicted breakdown field of 10 MV/cm [3], α-Ga_2O_3 is a promising material for high-power devices, as well as deep-UV photodetectors. α-Ga_2O_3, being isostructural to aluminium oxide, allows for heteroepitaxial growth on cost-efficient sapphire substrates, and also opens up the option of α-$(Al_xGa_{1\text{-}x})_2O_3$ alloys [4], potentially pushing device performance even further.

[1] A. Segura *et al.*, Phys. Rev. Materials 1, 024604 (2017)
[2] E. Ahmadi *et al.*, J. Appl. Phys. 126, 160901 (2019)
[3] M. Biswas and H. Nishinaka, APL Mater. 10, 060701 (2022)
[4] J. Steele *et al.*, APL Mater. 12, 041113 (2024)
[5] S. Vogt *et al.*, Phys. Status Solidi A, 220 2200721 (2023)

HL 9.5 Mon 16:00 H17

Adsorption-controlled growth of κ-Ga2O3 — •Alexander Karg[1], Niklas Krantz[1], Manuel Alonso-Orts[1,2], Marco Schowalter[1,2], Patrick Vogt[1,3], Andreas Rosenauer[1,2], and Martin Eickhoff[1,2] — [1]Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany — [2]MAPEX Center for Materials and Processes, University of Bremen, Bibliotheksstraße 1, 28359 Bremen, Germany — [3]Max Planck Institute for solid state research, Heisenbergstraße 1, 70569 Stuttgart, Germany

The ultra-wide band gap semiconductor Ga2O3 can crystallize in at least 5 different polymorphs. For one of these, the metastable κ-Ga2O3, a spontaneous polarization along the c-axis is predicted [1]. Utilizing this property in heterostructure devices requires the formation of sharp, distinct interfaces between different alloyed layers to achieve high sheet carrier densities.

The recent development of suboxide MBE (S-MBE) has enabled the adsorption-controlled growth of Ga2O3 thin films [2]. In this contribution, S-MBE is specifically applied to the growth of metastable, orthorhombic κ-Ga2O3. The growth process, phase stabilization, and their impact on layer properties are analyzed in detail. This is combined with the use of indium as surfactant. Additionally, the study is complemented by the realization of κ-Ga2O3-based heterostructures using suboxide MBE [3].

[1] Maccioni et al., Appl. Phys. Express 9, 041102 (2016);[2] Vogt et al., U.S. Patent No. 11,462,402 (2022);[3] Karg et al., APL Mater. 11, 091114 (2023)

HL 9.6 Mon 16:15 H17

Realization of highly rectifying pn-heterojunctions on pulsed laser deposited α-Ga_2O_3 thin films — •Paul Bokemeyer, Sofie Vogt, Clemens Petersen, Holger von Wenckstern, and Marius Grundmann — University Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnestr. 5, Leipzig, Germany

The wide band gap of about 5.3 eV[1], the possibility for adjusting the band gap energy by alloying with isostructural aluminum oxide or indium oxide[1] and a high expected breakdown field of up to 10 MV/cm[2], renders the corundum α-phase of Ga_2O_3 interesting for high power applications. We present lateral p^+n-heterojunction diodes on α-Ga_2O_3:Sn grown by pulsed laser deposition(PLD) using a two step approach[3]. Room temperature deposited ZnCoO(ZCO) (PLD), NiO (PLD) and CuI (PLD and sputtering) were used as p^+-type materials. We further investigated the influence of a remote oxygen plasma treatment prior to the deposition of the p-type layers on the device performance. High current rectification ratios of of 8.2 (ZCO), 7.8 (NiO), and 5.1 (CuI) orders of magnitude at ± 3V were achieved. Additionally, α-Ga_2O_3:Zr junction-field-effect-transistors(JFETs) with ZCO and NiO as gate materials were fabricated, yielding on/off ratios of more than 9 orders of magnitude and sub-threshold-swings down to 119 mV/dec.

[1] A. Hassa et.al., J.Phys. D: Appl. Phys. **54**, 223001 (2021)
[2] M. Biswas et al., APL Mater. **10**, 060701 (2022)
[3] S. Vogt et al., Phys. Status Solidi A, **220** 2200721 (2023)