HL 38: Oxide Semiconductors II

Time: Thursday 9:30–11:30 Location: ER 325

HL 38.1 Thu 9:30 ER 325

Energy and thickness dependent intensity characteristics of simultaneous XEOL-XAS measurements of ZnO — Sergiu Levcenko[1], Konrad Ritter[1], Hans H. Falk[1], Timo Pfeiffelmann[1], Lukas Trefflich[1], Edmund Welter[2], Marius Grundmann[1], and •Claudia S. Schnohr[1] — [1]Felix Bloch Institute for Solid State Physics, Leipzig University, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

X-ray excited optical luminescence (XEOL) is used to study optically active centers in a variety of materials. Combined with spatial and temporal resolution, XEOL is applied for multimodal analysis of hetero- and nanostructures while simultaneous XEOL and X-ray absorption spectroscopy (XAS) experiments can provide element and site selective structural information. However, no comprehensive model for the X-ray fluorescence (XRF) and XEOL intensities has yet been established. Therefore, we performed a systemtatic XEOL-XAS study of ZnO with 1 to 500 μm thicknesses at beamline P65 of PETRA III. The XRF and XEOL near-band-edge (NBE) intensities show a positive edge jump when scanning across the Zn K-edge for all samples. In contrast, the XEOL defect signal exhibits a positive edge jump for thin samples but an inverted intensity profile for thick samples. We demonstrate that all energy and thickness dependent intensity features for XRF, XEOL NBE and XEOL defect signals can be reproduced by a generalized model if the (i) experimental geometry, (ii) creation of excitations, (iii) diffusion and recombination of generated carriers and (iv) re-absorption of XRF and XEOL photons are taken into account.

HL 38.2 Thu 9:45 ER 325

Simulation of multi-component target ablation: a novel combinatorial pulsed laser deposition technique — •Arne Jörns, Holger von Wenckstern, and Marius Grundmann — Leipzig University, Felix Bloch Institute for Solid State Physics

Combinatorial pulsed laser deposition (C-PLD) has become a well-established method in combinatorial material science. With radial and azimuthal target segmentation discrete material libraries with samples of homogeneous composition as well as samples with a continuous composition spread can be obtained from a single target. Thus, target and substrate consumption is significantly reduced. However, powder blending, insufficient hardening or thermic decomposition due to deviating sintering temperatures of the source powders for the respective target segments make the fabrication of such targets technically demanding.

In this work we present two novel deposition approaches for C-PLD which bypass the above mentioned challenges of target preparation. Both techniques allow discrete material libraries covering the entire binary phase diagram. Experimentally, n-type semiconducting zinc-tin-oxide thin films were fabricated with the novel C-PLD approaches, and elemental distributions are well described by simulations made beforehand. Electrical properties are compared to such of zinc-tin-oxide thin films prepared by conventional PLD.

HL 38.3 Thu 10:00 ER 325

Molecular beam epitaxy of ε/κ-Ga_2O_3 using In as a surfactant — •Alexander Karg, Alexander Hinz, Marco Schowalter, Niklas Krantz, Patrick Vogt, Stephan Figge, Andreas Rosenauer, and Martin Eickhoff — Institute of Solid State Physics, University of Bremen, Bremen, Germany

This study is focused on the metastable orthorhombic ε-Ga_2O_3, for which a high spontaneous polarization along the c-axis is predicted, thus making two-dimensional electron gases with high sheet carrier densities at heterointerfaces conceivable [1]. The initiation of the ε-Ga_2O_3 growth by MBE requires the use of additives like Sn, added under Ga metal-rich growth conditions [2].

We present a systematic investigation of the role of In as a surfactant for MBE-growth of ε-Ga_2O_3 [3]. Starting from an ε-Ga_2O_3 buffer layer, realized by initial deposition of an ultrathin SnO_2 layer on the c-Al_2O_3 substrate[4], we deposited ε-$(In,Ga)_2O_3$ layers with varied In flux. The structural properties, the surface morphology and the In concentration in the resulting ε-$(In,Ga)_2O_3$ layers were investigated by X-ray diffraction, atomic force microscopy and scanning transmission electron microscopy. Based on these results we discuss the role of In as a surfactant during growth of ε-Ga_2O_3. Additionally, we demonstrate the use of indium as a surfactant to realize ε-$(In,Al,Ga)_2O_3$ heterostructures with well-defined and sharp interfaces.

[1] Macchioni et al., Appl. Phys. Exp. 9, 041102 (2016). [2] Kracht et al., Phys. Rev. Appl. 8, 054002 (2017). [3] Karg et al., APL Mater. 11, 091114 (2023). [4] Karg et al., J. Appl. Phys. 132, 195304 (2022).

HL 38.4 Thu 10:15 ER 325

Ultrawide Bandgap Semiconductor Cubic Spinel Zn_2GeO_4 Epitaxial Thin Films — •Jingjing Yu, Sijun Luo, and Marius Grundmann — Felix Bloch Institute for Solid State Physics, Faculty of Physics and Earth System Sciences, Universität Leipzig, 04103 Leipzig

It is significant to explore new ultrawide bandgap oxides thin films with a bandgap larger than 4 eV for potential applications in power electronics and deep-UV photodetectors. Cubic spinel Zn_2GeO_4 is a high-temperature and high-pressure metastable phase, to date, only the synthesis and crystal structure are reported. In this work, we report the heteroepitaxial growth of (100)-oriented cubic spinel Zn_2GeO_4 thin films on cubic spinel (100) $MgAl_2O_4$ single crystal substrates using pulsed laser deposition. The 350 nm thick (100) Zn_2GeO_4 epitaxial thin film shows a full width at half maximum of rocking curve of (800) reflex of about 0.35°. The direct optical bandgap is evaluated to be about 5 eV. The resistivity of film decreases gradually from about 4.0 to 0.5 Ω cm as temperature increases from 50 to 350 K. The Hall electron carrier mobility increases from 4.3 to 28.4 $cm^2\ V^{-1}s^{-1}$ while the Hall electron carrier concentration slightly increases from about 3.5 x 10^{17} to about 4.6 x 10^{17} cm^{-3} as the temperature increases from 50 to 350 K. The n-type conductivity probably originates from oxygen vacancies-related defects, as the post annealing at high temperatures in the air could make the thin film become insulating. This work advances the fundamental research on ultrawide bandgap cubic spinel Zn_2GeO_4 semiconductor thin films for potential device application.

15 min. break

HL 38.5 Thu 10:45 ER 325

Growth, faceting and thickness effects of α-Ga_2O_3 and α-$(In_xGa_{1-x})_2O_3$ on m-plane α-Al_2O_3 by molecular beam epitaxy — •Martin S. Williams[1], Manuel Alonso-Orts[1], Marco Schowalter[1], Alexander Karg[1], Sushma Raghuvansy[1], Jon P. McCandless[2], Debdeep Jena[2], Andreas Rosenauer[1], Martin Eickhoff[1], and Patrick Vogt[1] — [1]Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, Bremen, 28359, Germany — [2]School of Electrical and Computer Engineering, Cornell University, 229 Phillip's Hall, 14853, New York, United States of America

Gallium oxide (Ga_2O_3) is a promising ultra-wide band gap semiconductor, especially for high-power electronics which are crucial for reducing loss in power converters [1]. The corundum-structured phase (α-Ga_2O_3) has seen particular interest – owing to its large band gap, of 5.3 eV [2]. Its isostructurality to α-Al_2O_3 allows for band gap engineering of α-$(Al_xGa_{1-x})_2O_3$ over the entire Al compositional range [2]. Achieving single-crystalline α-Ga_2O_3 thin films is therefore important for developing future α-Ga_2O_3-based devices.

In this work, conventional plasma-assisted molecular beam epitaxy (MBE) and metal-oxide-catalysed epitaxy (MOCATAXY) have been employed to grow α-$Ga_2O_3(10\bar{1}0)/\alpha$-$Al_2O_3(10\bar{1}0)$. By varying the O-to-Ga and In-to-Ga flux ratios, a systematic approach was taken to characterise the films and develop a growth diagram.

[1] C. V. Prasad and Z.S. Rim, Materials Today Physics 27 (2022).
[2] R. Jinno et al., Science Advances 7 (2021).

HL 38.6 Thu 11:00 ER 325

Analysis and prediction of thickness distributions for combinatorial pulsed laser deposition — •Clemens Petersen, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Felix-Bloch-Institut, 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. Our combinatorial pulsed laser deposition (c-PLD) method allows for the deposition of entire material libraries on e.g. a single substrate [1]. Accompanied by the usage of high-throughput measurements such as spectroscopic ellipsometry and X-ray diffraction, the characterization of the material systems' physical properties with high chemical resolution and comparably low efforts becomes feasible [2]. By employing the plasma plume expansion model suggested by Anisimov *et al.* [3] and the resulting spatial material-deposition distribution we calculate binary growth rates as function of position on the substrate enabling us to predict film thickness and composition. As a case in point, the deposition of sesquioxide materials can be described exceptionally well over a large range of PLD parameters. Using these results we demonstrate that the binary distributions can be used to predict the thickness- and compositional distributions for ternary alloys grown with c-PLD with high precision. [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 38.7 Thu 11:15 ER 325

Phase-selective growth of κ- vs β-Ga_2O_3 and $(In_xGa_{1-x})_2O_3$ by In-mediated metal exchange catalysis in plasma-assisted molecular beam epitaxy — •Andrea Ardenghi[1], Oliver Bierwagen[1], Jonas Lähnemann[1], Joe Kler[2], Andreas Falkenstein[2], Manfred Martin[2], and Piero Mazzolini[3] — [1]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Hausvogteiplatz 5-7, 10117 Berlin, Germany — [2]Institute of Physical Chemistry, RWTH Aachen University, D-52056 Aachen, Germany — [3]Department of Mathematical, Physical and Computer Sciences, University of Parma, Parco Area delle Scienze 7/A, 43124 Parma, Italy

Monoclinic β-Ga_2O_3 is an ultra-wide bandgap semiconductor (Eg $\approx$ 4.8 eV) that is attracting increasingly attention for power electronics applications. The metastable kappa polymorph (κ-Ga_2O_3), which shares a comparable bandgap, exhibits piezoelectric and potentially ferroelectric properties. In-incorporation into any polymorphs of Ga_2O_3 allows to lower their bandgap. In this work, we provide a guideline to achieve single phase κ-, β-Ga_2O_3 as well as their $(In_xGa_{1-x})_2O_3$ alloys up to x = 0.14 and x = 0.17 respectively, using In-mediated metal exchange catalysis in plasma assisted molecular beam epitaxy (MEXCAT-MBE). The polymorph transition from κ to β is addressed, highlighting the role played by the thermal stability of the κ-Ga_2O_3. Additionally, we demonstrate the growth of (-201) β-Ga_2O_3 on c-Al_2O_3 at temperatures at least 100 °C above those achievable with conventional non-catalyzed MBE.