DS 11: Layer Deposition

Time: Wednesday 9:30–11:45 Location: REC/B214

DS 11.1 Wed 9:30 REC/B214

Photo-Assisted Atomic Layer Deposition — •Paul Butler[1,2], Simon Wörle[1,2], Pengyu Hu[1,3], Manfred Stemplinger[1,2], and Ian D. Sharp[1,2] — [1]Walter Schottky Institut, Technische Universität München, 85748, Garching, Germany — [2]Physics Department, TUM School of Natural Science, Technische Universität München, 85748, Garching, Germany — [3]Department of Electrical Engineering, TUM School of Computation, Information and Technology, Technische Universität München, 85748, Garching bei München, Germany

Atomic layer deposition (ALD) is a powerful technique for uniformly coating complex surfaces with thin films, though achieving lateral control remains one of its main challenges. This work demonstrates the implementation of visible-wavelength excitation to assist in the ALD process, thereby providing an opportunity for selective-area deposition using beam-shaping. We demonstrate that optical laser excitation can be used to assist in several ALD processes. An optical laser was used to selectively photo-assist the deposition of TiO_2 on gold as well as monolayer MoS_2 at low temperatures. The molecular precursors, titanium isopropoxide (TTIP) and ozone were used for the low-temperature deposition of TiO_2 on gold, while tetrakis(dimethylamido)titanium (TDMAT) and water were used for the deposition of TiO_2 on MoS_2. Photoexcitation is also shown to reduce the nucleation delay when $MeCpPtMe_3$ and ozone are used to deposit platinum films on Si and SiO_2 surfaces, using. Samples are characterized with spectroscopic ellipsometry and AFM before and after depositions, with in-situ ellipsometry during ALD procedures.

DS 11.2 Wed 9:45 REC/B214

Epitaxial growth of wurtzite $Al_{1-x}Hf_xN$ thin films by reactive magnetron sputtering — •Valentin Walbrunn[1,2], Laura I. Wagner[1,2], Verena Streibel[1,2], Mingyun Yuan[3], and Ian D. Sharp[1,2] — [1]Walter Schottky Institute, Technical University of Munich, Germany — [2]Physics Department, TUM School of Natural Sciences, Germany — [3]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Germany

Ternary nitrides such as transition metal (TM) wurtzite $Al_{1-x}TM_xN$ compounds offer great potential for future electromechanical and ferroelectric devices. While this class of materials is exemplified by $Al_{1-x}Sc_xN$, alternative TM elements such as Hf, Zr, and Ti remain largely underexplored, despite predictions of increased piezoelectric responses and the benefit of reduced reliance on rare earth elements. In this work, we explore reactive magnetron co-sputtering of wurtzite aluminum hafnium nitride ($Al_{1-x}Hf_xN$) to achieve epitaxial thin films suitable for high-frequency surface acoustic wave (SAW) applications. We tune the Hf content by scaling the power applied to the metallic Hf and Al targets in an Ar/N_2 atmosphere and determine optimized conditions with Hf cation fractions up to 40 %. X-ray diffraction confirms the formation of a wurtzite phase with strong c-axis orientation, and rocking curve measurements indicate improved crystalline quality, comparable to sputtered $Al_{1-x}Sc_xN$. These films demonstrate epitaxial wurtzite $Al_{1-x}Hf_xN$ as a promising material platform for high-frequency SAW applications.

DS 11.3 Wed 10:00 REC/B214

Epitaxial growth of hexagonal boron nitride (h-BN) by thermal laser epitaxy (TLE) — •Markus A. Blonski[1], Gideok Kim[2], João Marcelo Lopes[1], Audrey Gilbert[1], Lutz Geelhaar[1], Jochen Mannhart[2], Darrell G. Schlom[3], and Patrick Vogt[1,2] — [1]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Cornell University, Ithaca, USA

Thermal laser epitaxy (TLE) is a novel thin film synthesis technique in which the substrate and sources are heated by high-power infrared lasers. Without heating elements, TLE achieves unprecedentedly high growth temperatures and pressures, exceeding those of traditional methods like standard chemical vapor deposition (CVD) or molecular beam epitaxy (MBE). TLE enables thermal in situ substrate termination, accelerating surface treatment and avoiding pre-growth contamination. Using TLE, we map an unrivaled growth pressure and temperature (*P-T*) parameter space for h-BN growth on $Al_2O_3(0001)$ substrates. To optimize substrate termination, the Al_2O_3 surface is nitridized to form an AlN adlayer at $T \sim 1800\,^{\circ}C$ under an NH_3 atmosphere with a pressure of $P = 10^{-3}$ mbar. This termination process is followed by h-BN growth at 1600 °C to 2000 °C with NH_3 pressures ranging from 10^{-6} mbar to 10^{-1} mbar. We demonstrate epitaxial h-BN growth under unprecedented *P-T* conditions, characterized by Reflection high-energy electron diffraction, Fourier transform infrared spectroscopy, Raman spectroscopy and atomic force microscopy.

DS 11.4 Wed 10:15 REC/B214

Local growth of GaAs on Si(001) and Si(001)4.5° by Laser-assisted MOVPE — •Christian Bruckmann, Jürgen Bläsing, Armin Dadgar, and André Strittmatter — Institute of Physics, Otto-von-Guericke-University Magdeburg, Germany

The demand for increasingly performant, energy-efficient semiconductor devices is driving the research on how to combine III/V- with Si-based components in the most efficient way possible. While the monolithic integration on the Si substrate offers advantages compared to hybrid integration schemes, the heteroepitaxy of III/V-compound semiconductors is challenging due to different material properties. The Laser-assisted MOVPE enables an additive fabrication of semiconductor devices allowing cost-efficient low-volume production of special device structures. Key part is a high-power laser diode used for local heating of the substrate surface leading to local growth. GaAs islands were grown on Si(100) as well as Si(100) 4.5 ° substrates using a two-step growth approach which consists of a low-temperature nucleation layer followed by a high-temperature buffer layer. Optimization of the growth parameters and characterization with AFM and XRD shows qualitative trends similar to conventional MOVPE. For an island with a diameter of 260 nm and a height of 230 nm a XRD FWHM of 0.47 ° (ω-Scan, GaAs(004)) was obtained. Increasing the layer thickness to 3 μm yields a FWHM of 0.26 ° at optimum. Roughness measurements in the island center lead to RMS values of 4.0 nm (5 x 5 μm^2).

15 min. break

DS 11.5 Wed 10:45 REC/B214

Interface formation in ALD-based SnO_2/CeO_x heterostructures — •Dominic Guttmann[1], Rudi Tschammer[1], Carlos Morales[1], Malgorzata Kot[2], Michal Mazur[2], Damian Wojcieszak[2], Paulina Kapuscik[2], Wiktoria Kolodzinska[2], Jarosław Domaradzki[2], and Jan Ingo Flege[1] — [1]Applied Physics and Semiconductor Spectroscopy, BTU Cottbus-Senftenberg, Cottbus 03046, Germany — [2]Faculty of Electronics, Photonics and Microsystems, WUST, 50-372 Wroclaw, Poland

The electrical resistance of SnO_2 ultrathin films (< 20 nm) made by atomic layer deposition (ALD) strongly depends on thickness, due to intrinsic film defects at interfaces arising from changes in the ALD reaction mechanism during the first cycles and from the film/substrate interaction. Modifying interface properties in SnO_2/CeO_x heterostructures can enhance H_2 sensing performance. We studied the initial growth of SnO_2 by ALD on CeO_x substrates prepared by either electron beam evaporation (EBE) or ALD. Employing the commercial precursor tetrakis(dimethylamino)tin (TDMASn) and ozone (O_3) as well as in vacuo and near-ambient-pressure X-ray photoelectron spectroscopy, we examined how substrate preparation affects the SnO_2 nucleation behavior in the first cycles. SnO_2 growth on EBE-CeO_x indeed starts with the first precursor cycle, whereas ALD-CeO_x requires an additional conditioning step. Connecting these findings to surface chemistry, distinct C1s and N1s signatures attributed to TDMASn adsorption indicate a slow C/N buildup, consistent with previous reports on ALD-grown SnO_2 on Si, SiO_2, and Al_2O_3.

DS 11.6 Wed 11:00 REC/B214

Enhancing the antiferroelectric response of $AgNbO_3$ thin films — •Sreelakshmi Prasanna, Juliette Cardoletti, Philipp Komissinskiy, Thorsten Schneider, and Lambert Alff — Institute of Materials Science, TU Darmstadt, Darmstadt, Germany

Dielectric capacitors are widely utilized in numerous advanced high power electronic systems due to their distinctive features of high-power density, ultrafast charge/discharge capability, long storage lifetime, etc. Among them, antiferroelectrics have attracted extensive attention for energy storage applications because of their double hysteresis

loop and zero remnant polarization. Within this class of materials $AgNbO_3$-based lead-free perovskites are promising candidates due to their environmentally friendly nature and strong intrinsic antiferroelectric response. In this work, we have grown $AgNbO_3$ thin films using pulsed laser deposition and examined their structural properties using X-ray diffraction and SEM. The presence of metallic Ag particles on the $AgNbO_3$ surface with a size ranging from nanometres to micrometres indicates excessive Ag creating conductive pathways and severely compromise the electrical performance, suppressing the antiferroelectric behaviour. We demonstrate a post-annealing and post-deposition treatment to remove excessive Ag in grain boundaries and as well as on the surface, while preserving the $AgNbO_3$ phase.This procedure reduces the leakage current significantly and enables the access to the antiferroelectric properties of $AgNbO_3$. This simple and effective way to enhance the performance of $AgNbO_3$ thin films opens the way to their application in eco-friendly energy storage devices.

DS 11.7 Wed 11:15 REC/B214

Low-Temperature Atomic Layer Deposition of Rutile Titanium Dioxide Buffer Layers for Thermochromic Windows — •Jan Leithäuser, Waafa Al Nachwati, Philip Klement, Sangam Chatterjee, and Martin Becker — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

Vanadium dioxide (VO_2) exhibits a reversible semiconductor-metal transition (SMT) at approx. 68°C and enables thermochromic smart windows that modulate solar heat gain. To achieve high solar modulation (T_{sol}) at industrially compatible temperatures, a smooth, chemically stable rutile TiO_2 buffer layer is required. Here, we demonstrate that atomic layer deposition (ALD) of TiO_2 at 200 °C, followed by low-temperature annealing, results in dominant rutile at 220 °C, provided the TiO_2 thickness is at leat 30 nm; thinner layers (10 nm) crystallize as anatase. Integrating such ALD-grown rutile buffers into VO_2 || TiO_2 || Glass structures allow for optimal VO_2 growth windows at 400 - 450 °C and yields a T_{sol} comparable to that of high-temperature sputtered rutile buffers. The ALD approach maintains nanometer-scale roughness. This low-temperature route to rutile TiO_2 represents an advancement for scalable, energy-efficient thermochromic coatings compatible with temperature-sensitive substrates.

DS 11.8 Wed 11:30 REC/B214

Interface induced ferromagnetism and Superconductivity in epitaxially engineered thin films — •Mostafa Marzouk[1,2], Anupam Singh[2], Igor Mazinchenko[2], Malli Tangi[2], Sergey Ostanin[2], Younghyuk Kim[2], Ilya Kostanovski[2], Arthur Ernst[2], Mathew Gilbert[2], and Stuart Parkin[2] — [1]Current Address: Institute for Topological Insulators, University of Wuerzburg, 97074 Würzburg, Germany — [2]Max-Planck institute of Microstructure Physics, 06120 Halle (Saale), Germany

Two-dimensional electron gases (2DEGs) at oxide interfaces offer several advantages that are not typically found in semiconductor-based 2DEGs. One key advantage is their high sheet carrier density, which is essential for achieving the high current densities required in power and memory applications.

In this talk, I will present the emergent phenomena at oxide interfaces we grew using state-of-the-art molecular beam epitaxy (MBE), with a primary focus on the two-dimensional electron gases formed at KTaO-based interfaces. We observe the development of ferromagnetism in the KTaO3(110)/LaTiO3 and KTaO3(111)/LaTiO3 2DEGs. Remarkably, these ferromagnetic 2DEGs retain high electron mobilities, reaching approximately 250 cm2/V.s at 2 K and 20 cm2/V.s at 300 K. The presence of ferromagnetism is confirmed through anomalous Hall effect hysteresis loops, butterfly-shaped magnetoresistance hysteresis loops (down to 1.7 K), out-of-plane magnetization hysteresis loops, and x-ray magnetic circular dichroism (XMCD) measurements at 2 K.