Electronic Materials and Photonics Division
Room Oregon Ballroom 203-204 - Session EM-ThP
Electronic Materials and Photonics Poster Session

EM-ThP-1 Phase Transformation and Growth Mechanism of RF Sputtered Ferroelectric Lead Scandium Tantalate ($PbSc_{0.5}Ta_{0.5}O_3$) Films for Thermal Management*, ***Sanju Gupta****,* Penn State University

Lead scandium tantalate ($PbSc_{0.5}Ta_{0.5}O_3$, PST), an order/disorder ferroelectric, is a potential candidate for electrocaloric cooling and pyroelectric IR detector. In this work, we report the phase transformation kinetics from two series of samples containing pure amorphous and mixture of amorphous and pyrochlore to desired perovskite phase using post-deposition rapid thermal processing (RTP) as well as growth mechanism of RF sputtered PST thin films using excess lead target on platinized silicon ($Pt/Ti/SiO_2/Si$) substrates. We find that small changes in the temperature ramp have a large effect on the degree of perovskite conversion (ferroelectric phase), orientation (crystallographic texture), and long-range order parameter ($<S_{111}>$). Through isothermal annealing, we obtained optimal perovskite phase at ≥ 700°C temperature. The phase transformation is characterized by spontaneous formation of center-type in-plane radial rosette-like structures revealed by scanning electron microscopy. The PST perovskite crystallites were found to coexist with pyrochlore in RTP annealed films. The volume fractions for perovskite and pyrochlore phase were obtained from the analysis of "rosettes" and respective x-ray diffraction intensities which helped to determine various parameters associated with phase kinetics (n, k, and activation energy, E_a) and accompanying growth.The effective activation energies of perovskite transition and growth were found to be 332±11 kJ/mol (345±11 kJ/mol) and 114±10 kJ/mol (122±10 kJ/mol), respectively, for pure amorphous only (and mixed amorphous and pyrochlore) phase following nucleation-growth controlled Avrami's equation. A linear growth rate (n~1) for the perovskite phase indicates predominant interface-controlled process anddiffusion-limited phenomena thus inhibiting rosette size owing to reactant depletion and soft impingement at the grain boundary. However, the growth behavior is isotropic in two-dimension parallel to the plane of the substrates for both sample series. Lead loss was severe for in-situ growth and RTP combined with conventional furnace annealing than those of RTP only films, which were closer to stoichiometric *albeit* with excess lead and marginal oxygen vacancies (V_o).[1]

[1]S. Gupta, J. Am. Cer. Soc. **106**, 2209-2224 (2023*)*;*https://doi.org/10.1111/jace.18874.*

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EM-ThP-2 Flexible Phototransistors Array based on Hybrid Channel composed of Tellurium nanowires and tellurium-film with High Optical Responsivity*, ***Uisik Jeong****,* Sungkyunkwan University (SKKU), Republic of Korea*; M. Naqi,* Sungkyunkwan University (SKKU), Pakistan*; S. Kim,* Sungkyunkwan University (SKKU), Republic of Korea

Tellurium (Te) has recently attracted substantial attention as a p-type channel material due to their favorable characteristics such as high transport properties, good photosensitivity, and piezoelectricity. Uniform and stable Te is important for the extensive applicability in terms of electronics and optoelectronics.Here, the novel hybrid channel of Te nanowires and Te-film for flexible p-type phototransistor arrays with highly linear photo-responsivity are reported for the first time. All the processes are conducted at a temperature lower than 100℃ to reduce thermal budget on a flexible substrate. This paper includes optical properties of the TeNWs/Te-based FETs such as threshold voltage shift, photocurrent, responsivity, sensitivity, and time-domain behavior as well as electrical performance of those devices. The array consisting of 50 devices exhibits high mobility of > 5 $cm^2V^{-1}s^{-1}$ and I_{on}/I_{off} of > 10^4on average. More significantly, the stability of the devices is confirmed by the various tests such as positive/negative bias stress, illumination added bias stress, long-term stability response, and even mechanical bending stress, which exhibits stable and uniform characteristics of the devices.

EM-ThP-3 Observation of Gapless Nodal-line States in NdSbTe*, ***Sabin Regmi****,* Idaho National Laboratory; University of Central Florida*; R. Smith, A. Sakhya, M. Sprague, M. Mondal, I. Bin Elius, N. Valadez,* University of Central Florida*; K. Gofryk,* Idaho National Laboratory*; A. Ptok, D. Kaczorowski,* Polish Academy of Sciences, Poland*; M. Neupane,* University of Central Florida

ZrSiS-type Lanthanide (*Ln*) based materials in the *Ln*SbTe family bring the possibility of electronic correlations and magnetic ordering due to the presence of *Ln 4f* electrons in addition to the topology that the ZrSiS-type systems are well known for. Here, we carried out an angle-resolved photoemission spectroscopy (ARPES) study of Neodymium-based NdSbTe, supported by first-principles calculations and thermodynamic measurements. Thermodynamic measurements reveal a magnetic transition into an antiferromagnetic ground state at around 2 K. The paramagnetic phase ARPES results detect the presence of multiple gapless nodal lines, which is also supported by first-principles calculations. Two of such nodal lines reside along the bulk X-R high-symmetry direction and one lies across the Γ-M direction forming a diamond plane centered at the Γ point. Overall, this study reveals the topological electronic structure of NdSbTe and presents a new platform to understand how such electronic structure evolves with spin-orbit coupling tuning across the *Ln*SbTe family.

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EM-ThP-4 Growth of Mn-Doped $Pb(In_{1/2}Nb_{1/2}O_3)$-$Pb(Mg_{1/3}Nb_{2/3}O_3)$-$PbTiO_3$ Thin Films by Pulsed Laser Deposition*, ***Da-Ren Liu****,* Taiwan Instrument Research Institute, National Applied Research Laboratories, Taiwan

Because of their extraordinary large electromechanical coupling coefficient and piezoelectric coefficient, relaxor-based ferroelectric crystals $Pb(In_{1/2}Nb_{1/2})O_3$–$Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ (PIN–PMN–PT) and Mn-Doped $Pb(In_{1/2}Nb_{1/2})O_3$–$Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ (Mn:PIN–PMN–PT) with morphotropic phase boundary (MPB) have attracted extensive attention. The PIN–PMN–PT and Mn:PIN–PMN–PT not only have similar piezoelectric performance to that of the binary PMN–PT but also possesses higher phase transition temperature and coercive field. They also become important materials in the fabrication of high-performance electromechanical devices including transducers, actuators and sensors. In this study, highly textured thin films of the Mn:PIN–PMN–PT were grown on $SrTiO_3$ substrates by Nd:YAG pulsed laser deposition(PLD). According to the results of glancing-angle x-ray powder diffraction (GAXRD), the Mn:PIN–PMN–PT films are polycrystalline. The thickness and roughness of the films were characterized by grazing-incidence x-ray reflectivity (GIXR), and the piezoelectric constant d_{33} was measured by the piezoelectric force microscopy(PFM).The complex refractive indices were measured in the range from 1.5 to 4.0 eV by spectroscopic ellipsometry (SE). The average oscillator strength and its associated wavelength were estimated by using a Sellmeier-type dispersion equation.

EM-ThP-5 Synthesis and Stability of MBE Grown $NbSe_2$*, C. Rogers,* University of Virginia*; A. Hasan,* The University of Virginia*; C. Jezewski, C. Naylor,* Components Research, Intel Corporation, Hillsboro, OR 97124, USA*; N. Shukla, **Stephen McDonnell**,* The University of Virginia

Metallic 2D materials offer a unique pathway to aggressive thickness scaling without sacrificing resistivity. Unlike conventional metals which see significant increases in resistivity, when the thickness is on the order of the electron mean free path, due to increase surface/interface scattering, for 2D materials the conduction is already largely confined to the individual layers with negligible transport across the van der Waals gaps. As such, when scaled into the nm regime, these materials see little or no increase in their resistivity.

Niobium diselenide ($NbSe_2$) is a metal-like transition metal dichalcogenide that has a similar crystal structure to the well-studied 2H-MoS_2. In our work, $NbSe_2$ is grown by molecular beam epitaxy and is shown to naturally deposit with self-intercalated Nb in the van der Waals gap. We demonstrate how the resistivity of $NbSe_2$ varies as a function of deposition temperature and flux ratio and then turn our folks to how the oxidation behavior of the thin films. Specifically, we show that the grown temperature of the thin films impacts their subsequent stability in air, likely due to differing grain sizes. In addition to this we show that some processing steps that are typically nanoelectronic device fabrication can also oxidize the material which suggests that due consideration must be taken if this material is to be integrated into any device architectures.

EM-ThP-6 Hollow-Cathode Plasma-ALD of Titanium Nitride Films Using *In-Situ* Ellipsometry for Conductivity Analysis*, D. Lefcort, S. Bin Hafiz, H. Mohammad, L. Antoine, N. Ibrahimli, S. Ilhom,* University of Connecticut*; A. Okyay,* OkyayTech Inc*; **Necmi Biyikli**,* University of Connecticut

Conducting TiN films are used in various CMOS device layers. As the trend towards highly complex and 3D device architectures continue along with continued scaling in the deep single-digit nanometer level, low-temperature and conformal deposition of precision thickness controlled TiN films are critically needed. Based on our achievements in crystalline III-nitride films using hollow-cathode plasma-assisted atomic layer deposition (HCP-ALD), in this study we have investigated TiN film deposition at 200 ℃ using the very same reactor. We have used *in-situ* ellipsometry to analyze the evolution of film resistivity using various fitting models including Drude-Lorentz and Drude dispersion models. We share our experimental findings on how the TiN film properties were impacted by the HCP-ALD process conditions as well as how the *in-situ* extracted film resistivity values compare with ex-situ measured resistivities.

The TiN films were deposited using metal-alkyl titanium precursor (tetrakis(dimethylamido)titanium) – TDMAT) and various nitrogen/hydrogen plasma mixtures (N_2/H_2 at various flow rates) at 200 °C substrate temperature and 50 – 100 W RF-power range. SiO_2-coated Si(100) wafer and glass slide samples were utilized as substrates for TiN film deposition. Real-time *in-situ* ellipsometry data was recorded using a multiwavelength ellipsometer unit. TiN films grown at lower power values (50 vs 100 W) exhibited lower film resistivity values. The total N_2/H_2 plasma gas flow and chamber pressure showed a significant impact on the film conductivity: Whe compared to 100/100 sccm plasma flow, 20/20 sccm samples grown on SiO_2/Si(100) substrates displayed the lowest resistivity values reaching ~150 micro-ohm.cm. Grazing-incidence XRD (GIXRD) measurements revealed polycrystalline TiN films on SiO_2/Si(100) substrates. The Drude-Lorentz and Drude dispersion model layer fitting results compare reasonably well with the Van der Pauw sample measurements, verifying the effectiveness of *in-situ* ellipsometry for real-time film conductivity analysis.

EM-ThP-7 A Statistical Design of Experiments and Structural Characterization of ITO for Perovskite Solar Cells*, **Firdos Ali**,* Metallurgical and Materials Engineering, The University of Alabama*; D. Li,* Electrical and Computer Engineering, Tne University of Alabama*; S. Gupta,* Metallurgical and Materials Engineering, The University of Alabama

We have optimized the processing and annealing of sputtered indium-tin oxide (ITO) thin films for solar cell applications by DC magnetron sputtering. The effects of process parameters such as deposition power, reactive gas flow percentage, annealing temperature and time, as well as film thickness, on the sheet resistance and transmission of the ITO films was systematically studied, using a Design of Experiments. Additionally, structural characterization of the deposited films was performed using various techniques, including X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM), four-point probe, UV-VIS spectrometry, and atomic force microscopy (AFM). TEM analysis revealed grain boundaries, crystallinity, and d-spacing of ITO thin film. The grain size was calculated with the help of the Scherrer equation. The XRD spectra of the ITO films revealed a polycrystalline structure with preferred (222) orientation of the ITO film. The SEM image of the ITO target gives information about the morphology of the racetrack after sputtering. The topography and surface roughness were evaluated by atomic force microscopy (AFM). A sheet resistance of 10 ohms/sq. and transmission of over 90% over 400-700 nm wavelengths was achieved. Perovskite solar cells fabricated with these optimized ITO electrodes showed promising properties.

EM-ThP-8 Voltage Tunability in Foundry Produced Resonant PZT piezoMEMS*, J. Evans, N. Montross, **Sean Smith**, S. Chapman, M. McDaniel,* Radiant Technologies Inc.

Radiant Technologies recently launched our Thin Film Foundry capable of producing a wide variety of structures. Radiant has been fabricating PZT thin films since 1990 while performing foundry services on a word-of-mouth basis. Over time our process has increased in capability and can now create released MEMS. We have also formalized our design rules and are now offering foundry services to the broader community.

As a part of our process development, we demonstrated a variety of structures such as membranes and beams fixed at one or two ends, with and without tip masses. Released structures can have resonant modes ranging from 100s of Hz to 10s of kHz. These can be plugged into customer's projects or serve as a starting point for a custom design. We collaborate with customers to integrate our PZT capacitors into another stack/process or to deposit their unique sensor material/structure onto a piezoMEMS device.

In this presentation the voltage tunability of our released piezoMEMS structures will be demonstrated along with a brief overview of our foundry process and some examples of what our customers have been able to produce with it.

EM-ThP-9 Enforcing π-π Stacking Using a 1D Perovskite Core*, **Raúl Castañeda**,* New Mexico Highlands University

During the past decade, hybrid organic-inorganic metal halides have attracted the attention of a broad group of institutions due to the many potential applications these materials can have, such as semiconductors, solar cells, and LEDs. More specifically, manganese-halide compounds have been studied for their emission properties and potential applications in X-ray detectors. In this work, four new manganese(II) chloride and manganese(II) bromide 1D coordination polymers were synthesized with 4-ethylpyridine (4-EtP) or 4-phenylpyridine (4PhP) and characterized by single-crystal X-ray diffraction. These materials have a manganese core surrounded by four edge-sharing halide atoms (MnX4) and the ligand coordinating from above and below the MnX4 plane. Interestingly π-π interactions are enforced by the 1D coordination polymer. Further studies on these types of materials can result in new molecular wires as semiconductor materials.

EM-ThP-10 Modular until it's Not – Imaging Fast, Hard X-Rays at NIF*, **Mary Ann Mort**,* University of California at Davis*; A. Carpenter,* Lawrence Livermore National Lab*; C. Hunt,* University of California at Davis

The proposed multi-frame gated x-ray imager (MGXI) is a fast, hard x-ray imaging diagnostic for use in ICF and HED experiments at the National Ignition Facility (NIF), such as Compton radiography and hot spot imaging. MGXI has goals to image 10-100 keV x-rays with 100-1000 ps temporal resolution in 2-8 frames and >5% DQE. Modularity of the versatile testbed for initial MGXI component experimentation starts with testing microchannel plates (MCPs) under vacuum with an electron gun and a simple photodiode (PD) array. Simultaneously, MCPs will be modeled in Computer Simulation Technology (CST) to determine the effects an applied magnetic field has on the electron trajectories.

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