Thin Films
Room Ballroom BC - Session TF-ThP
Thin Film Poster Session

TF-ThP-1 Thickness and Elemental Quantification of (Ultra)Thin Films Revisited, ***Markus Sauer***, *Jakob Rath, Annette Foelske,* TU Wien / AIC, Austria; *Dieter Ingerle,* TU Wien / XRC, Austria

Many approaches have been taken towards precise determination of overlayer thickness and (elemental) quantification of thin/ultrathin films (0.5-100nm). X-ray reflectivity (XRR) and X-ray photoelectron spectroscopy (XPS) as well as spectroscopic ellipsometry are commonly used to provide information about sample composition and layer depth (1-3). However, each of these methods has its limitations and specific techniques/sample geometries etc. might require extensive preparation and or do not allow for the use of ultra-high vacuum instrumentation. In addition, some of these methods as well as alternatives like Rutherford Backscattering/Elastic Recoil Detection Analysis (RBS/ERDS) require expensive equipment and/or access to large-scale facilities which is not always an alternative in every day-use cases.

Herein we report a broad comparison of different techniques including most of the above-mentioned ones (XPS, SEM-EDX, XRR, Ellipsometry) as well as Auger-Meitner Electron Spectroscopy (AMES), X-ray fluorescence (WXRF and GIXRF) and Raman spectroscopy for two sets of reference materials: HfO_2 on SiO_2/Si (4) and Fe/Ni thin films with different relative compositions.

We provide an approach for choosing different methods and method combinations depending on the requirements/sample surface size/roughness etc. for laboratory scale application beyond the reference material case. In addition, limitations of each method in terms of precision and applicability are discussed.

A roadmap is laid out for finding the most useful way of reaching the desired precision for quantification and thickness determination trying to use methods that are available to a large number of researchers in academia and industry.

(1)J. R. Shallenberger *et al.*, "Oxide thickness determination by XPS, AES, SIMS, RBS and TEM," *1998 International Conference on Ion Implantation Technology. Proceedings (Cat. No.98EX144)*, Kyoto, Japan, 1999, pp. 79-82 vol.1, doi: 10.1109/IIT.1999.812056.

(2)Donald R Baer, Yung-Cheng Wang, David G Castner, Use of XPS to Quantify Thickness of Coatings on Nanoparticles, *Microscopy Today*, Volume 24, Issue 2, 1 March 2016, Pages 40–45, doi: 10.1017/S1551929516000109
[https://doi.org/10.1017/S1551929516000109]

(3)S. Terada, H. Murakami and K. Nishihagi, "Thickness and density measurement for new materials with combined X-ray technique," *2001 IEEE/SEMI Advanced Semiconductor Manufacturing Conference (IEEE Cat. No.01CH37160)*, Munich, Germany, 2001, pp. 125-130, doi: 10.1109/ASMC.2001.925630.

(4)https://www.bipm.org/documents/20126/46087117/CCQM-P190.pdf/5eaf9732-659b-fc91-c1b9-7d14f25112d1

TF-ThP-3 Electrical and Mechanical Stability of Flexible Low-Dielectric Constant Carbon-Doped Oxide (SiCOH) Thin Films Under Repeated Mechanical Stress, ***Rajib Chowdhury***[1], *SeonHee Jang,* University of Louisiana at Lafayette

The microelectronics industry continuously advances materials science to enhance integrated circuit (IC) performance. Interconnect structures are becoming critical as the transistor density increases. It also limits the chip speed due to increased resistance-capacitance (RC) delay. Traditionally, aluminum (Al) and silicon oxide (SiO_2) were utilized as metal and dielectric materials, which were replaced with copper (Cu) and low dielectric constant carbon-doped silicon oxide (low-*k* SiCOH, $k < 4$) to improve the RC delay and power consumption. Simultaneously, flexible electronics have gained attention, utilizing polymer substrates for applications like wearable devices and displays. However, integrating low-*k* flexible dielectric films with polymer-based substrates remains challenging due to the low glass transition temperatures of the substrates. Besides, it is essential to study the mechanical stability of materials for the integration of flexible electronic devices. This study explores the applicability of the low-*k* SiCOH thin films for flexible electronics by observing the effects of repeated mechanical bending tests.

Flexible low-*k* SiCOH films were produced onto flexible indium tin oxide-coated polyethylene naphthalate (ITO/PEN) substrates by plasma-enhanced chemical vapor deposition (PECVD) of a tetrakis (trimethylsilyloxy)silane precursor. The films were deposited at room temperature with the RF plasma power varied from 20 to 100 W. The films were subjected to bending tests with up to 10000 bending cycles. Mechanical characterization was performed by nanoindentation testing for the elastic modulus and hardness. Chemical bonds were characterized by Fourier transform infrared (FTIR) spectroscopy, and the atomic concentration was measured by X-ray photoelectron spectroscopy (XPS). The dielectric constant was measured from capacitance-voltage measurements.

The pristine SiCOH films had a mechanical strength of up to 9.1 GPa and a low *k*-value down to 2.00. The films were optically transparent, smooth, and hydrophobic. The prominent chemical peaks of CH_x, Si-CH_3, Si-O-Si, and Si-$(CH_3)_x$ were identified for pristine films from the analysis of FTIR spectra. Upon repeated mechanical bending tests with bending cycles up to 10,000, the flexible SiCOH films maintained their transparency, smoothness, and hydrophobicity and showed a stable *k*-value below 4.0. No significant changes in the FTIR spectra were observed, and no cracks or delamination were observed in the films. The SiCOH films showed stable physical, chemical, and electrical properties under repeated mechanical bending.

TF-ThP-4 The Impact of Copolymer Molecular Sequence on Electronic Transport, ***Mahya Mehregan***, *Jack Schultz,* University of Missouri-Columbia; *Matthew Maschman, Matthias Young,* University of Missouri, Columbia

This work demonstrates the successful formation of EDOT-co-Py copolymer thin films using oxidative molecular layer deposition (oMLD), with electrical conductivity values intermediate between those of PEDOT and PPy. By controlling the molecular sequence during copolymerization via the sequential surface reactions afforded by oMLD, we investigate the influence of monomer arrangement on electronic conductivity. Our findings reveal that the electrical conductivity of the copolymer thin films is not determined by the composition ratio of EDOT and Py but is instead strongly influenced by the block length of each monomer chain. These block lengths modulate the electron energy well depths for electron transport along the copolymer chains, which in turn affects conductivity. Our analysis reveals that the energy well depth in Boltzmann transport modeling exhibits a sigmoidal relationship with the separation distance between conductive domains, rather than the previously assumed linear dependence. We identified a critical domain size of >3 monomer units (corresponding to 1.4 nm) that significantly alters electronic conductivity, consistent with electron hopping distances observed in biomolecules. This suggests a universal length scale for electronic interactions in polymers.

TF-ThP-5 Synthesis of Bismuth-based EUV Photoresists using Molecular Layer Deposition, ***Jane Keth***[2], *Duncan Reece, David Bergsman,* University of Washington

Extreme ultraviolet (EUV) photolithography has seen substantial interest from the semiconductor industry as a tool to create sub-10 nm features, which are necessary to improve device performance. To use this process, EUV-compatible photoresists are needed that are highly absorbing of EUV light, can be deposited as a thin film, and have high etch resistance. Many photoresist materials have been explored to meet this need, including polymer films exposed to vapor-phase infiltrants, polymer films combined with metal additives, and hafnia-based nanoparticle thin films. However, these resists tend to be limited to low viscosity resist formulations or use deposition methods like spin coating that struggle to form conformal coatings. One promising strategy for creating these resists involves using molecular layer deposition (MLD) to synthesize hybrid inorganic-organic films directly on the surface of interest. MLD is a vapor-phase layer-by-layer thin film deposition process that can deposit films with subnanometer thickness and compositional control. While MLD has been used to make aluminum, hafnium, and tin-based EUV photoresists, films based on other elements may be beneficial. In this work, we will present on using a Bismuth-based MLD process to grow hybrid organic-inorganic EUV photoresists. Using a specialized parallelizing reactor unique to the Bergsman research group, we explore the growth of Bi-based photoresists with different organic linkers, characterizing their composition and testing their ambient stability and chemical stability. After studying the as-deposited resists, we treat the resists to UV light and measure their

[1] **TFD James Harper Award Finalist**

[2] **JVST Highlighted Poster**

subsequent chemical structure and stability. This data is used to derive the understanding of how Bi-based EUV photoresists can be further optimized for EUV photolithography.

TF-ThP-6 Hollow-Cathode Plasma-Assisted ALD of CuO Thin Films: Evaluating Self-Limiting Growth Conditions and Material Properties, *Fatih Bayansal, Steven Allaby, Habeeb Mousa, Helena Silva,* ***Necmi Biyikli,*** University of Connecticut

Copper oxide (CuO) is a promising p-type semiconductor material with potential applications for energy and optoelectronic devices. In this study, we conducted a comprehensive saturation study within the scope of our initial attempts to grow CuO films by hollow-cathode plasma-assisted atomic layer deposition (HCP-ALD) followed by material characterization study to evaluate the structural, optical, and electrical properties of grown samples.

During CuO growth experiments, copper(II) hexafluoroacetylacetonate hydrate [$Cu(hfac)_2 \cdot xH_2O$] and O_2 plasma were used as the metal precursor and oxidizing agent, respectively. Saturation experiments performed on Si(100) substrates at 150 °C showed that the growth rate reached the saturation regime when the precursor pulse duration increased above a certain threshold. This demonstrated that surface-controlled self-limiting ALD behavior is achieved under appropriate plasma conditions. On the other hand, CuO formation was suppressed in the growths performed using only Ar plasma or O_2/Ar mixture, and metallic or non-stoichiometric structures were observed in some samples. These results confirmed the critical role of reactive oxygen species for CuO growth.

After determining the self-limiting growth window, the synthesis temperature was gradually increased to 250°C and film deposition studies were carried out on n-Si, sapphire, and quartz substrates. Initial transmittance measurements showed that as the temperature increased, the films exhibited higher transmittance in the visible region, thus increasing the film smoothness and quality.

X-ray diffraction (XRD) analyses revealed that the films grown in optimized O_2 plasma conditions contained polycrystalline CuO phases with (110), (002) and (111) planes. In Ar-oriented plasma environments, Cu_3N phases were observed, suggesting that oxidation was incomplete, or nitrogen doping occurred. These findings indicate that the HCP-ALD process is extremely sensitive to plasma composition and precursor-plasma interactions.

Hall effect, XPS, and TEM analyses are ongoing to determine the electrical, chemical, and structural properties. This research provides the basis for reliable CuO film growth at low temperature, and future process optimizations are aimed at the production of phase-pure, stoichiometric, and electrically active p-type CuO films.

TF-ThP-7 Low-Temperature Atomic Layer Deposition of ZnO Thin Films on Cotton for Flexible Electronics, *Habeeb Mousa,* ***Steven Allaby,*** *Fatih Bayansal,* University of Connecticut*; Md Sazid Bin Sadeque, Tamer Uyar,* Cornell University*; Helena Silva, Necmi Biyikli,* University of Connecticut

The development of flexible electronics has advanced rapidly, with applications from sensors and energy storage to wearables. Among these, photodetectors (PDs) are of growing interest due to their potential roles in health monitoring, security, and optical communication. Zinc Oxide (ZnO), with its wide bandgap, stability under long-term light exposure, and high sensitivity to UV/visible radiation is an ideal material for such devices. However, fabricating thin film-based devices on textiles often affects their mechanical properties such as flexibility, durability, and washability. This work presents an approach that leverages low-temperature atomic layer deposition (ALD) of ZnO on cotton to achieve flexible PDs while preserving the inherent properties of cotton.

ZnO was deposited on cotton (woven bleached, 98 gsm) substrates using diethylzinc (DEZ) and H2O as Zn precursor and co-reactant respectively in a thermal ALD reactor at 120 °C. The unit ALD cycle in which 20 sccm N2 is used as the carrier gas consists of 0.5s DEZ pulse, 30s purge, 0.5s H2O pulse, 30s purge steps. Following the deposition of ZnO layers on cotton, interdigitated electrodes consisting of 200 nm Cr was evaporated by e-beam deposition to create the metal-semiconductor-metal (MSM) structures.

The resulting ZnO films on cotton are characterized in terms of their structural, morphological, compositional, and photo-response properties. X-ray diffraction analysis revealed the polycrystalline nature of the as-grown ZnO layer on cotton. The photo-response characteristics of the fabricated MSM-PD device structures were placed under a solar simulator (Newport 94022A) at a distance of ~20 cm. The bias voltage was scanned from –10 to 10V in a 100-mV step under dark and illuminated conditions. The resulting photo-current at 10V bias showed ~160-fold increase when compared to dark current (from 5.5 nA to 888 nA). Moreover, our study displays an effective ZnO-based photodetector on cotton at low bias voltage of 1V where the photocurrent increased from 0.58 nA to 74 nA (~128 fold increase) highlighting the potential for low-power wearable sensing applications. In order to investigate the sensitivity and stability of the device, the photocurrent—time measurements were conducted by applying five 'ON/OFF' pulses at a bias voltages 10 V. The 'ON' state and 'OFF' state lasted for 5 mins each. The sensitivity was calculated and found to be 271. Future studies could focus on further characterizing the spectral photo-response under various environmental conditions and optimizing the device architecture by exploring different doping strategies, or composite structures that can enhance light absorption.

TF-ThP-8 The Impact of Bismuth Surfactants on MBE-Grown Insb Thin Films for Applications in Mid-Infrared Devices, ***T. Pan Menasuta,*** *John H. McElearney, Thomas E. Vandervelde,* Tufts University

Indium antimonide (InSb), an important narrow direct bandgap semiconductor (0.17 eV at 300K), is highly optically sensitive in the mid-wave infrared (MWIR, 2-5 μm) spectrum. InSb-based devices are crucial for thermal imaging, spectroscopy, and astronomy as a result of atmospheric transmission and thermal emission characteristics. [1–5]. Its broad sensitivity (1.5-7 μm) also enables gas detection. However, reproducible growth of high-quality InSb epitaxial layers via molecular beam epitaxy (MBE) is challenging due to its low melting point. The epitaxial process requires lower growth temperatures and is prone to crystalline and surface defects. Optimal InSb growth occurs at 385°C with a V: III ratio of 1.2. Accurate temperature control is challenging at these lower temperatures, which further complicates the narrow optimal growth range and can negatively impact the film properties. Controlling surface morphology during growth is critical for advanced optoelectronic devices.

Bismuth surfactancy in MBE has been shown to improve surface morphologies in many III-V materials [6, 7]. A very low bismuth flux can modify the adlayer surface before desorption, and has been shown to improve the morphology of the surface in multiple materials [6–8].To our knowledge, no systematic studies have been reported on the effects of Bi surfactancy on MBE growth of InSb thin films [6, 7, 9]. This study investigates the effects of Bi surfactancy on InSb MBE growth over a wide range of growth temperatures (280-410°C). Two series of homoepitaxial InSb(100) films were grown by MBE: a control set and a set grown with Bi surfactancy, with identical parameters otherwise. The temperature was calibrated using the RHEED pattern transition c(4x4) to a(1x3), which is reported to occur at 370°C [10, 11]. The surface morphology and elemental distribution were analyzed using AFM and SEM-EDS, while XPS confirmed the absence of Bi incorporation. Finally, TEM was performed to analyze the film's lattice structure.

TF-ThP-9 Strategically Introducing Interfaces into Refractory Concentrated Alloys to Increase Tolerance in Extreme Environments, ***Benjamin Derby,*** *Yao Li,* Los Alamos National Laboratory

This work introduces three-dimensional interfaces into refractory concentrated alloys to increase mechanical and conductivity performance in extreme environments. Physical vapor co-deposition at elevated temperature kinetically forces the system to phase separate into alloy architectures with unique 3D interface structures. The increase in dynamic strength and deformability of these structures are tested using a novel high-strain-rate nanoindenter. These materials provide a rapid prototyping framework for developing bulk materials with optimized performance in complex, extreme environments.

TF-ThP-10 Raman Scattering as a Probe for Tuning Magnetic Quasiparticles in NiO Thin Films Through Ion Beam Irradiation, ***Simranjeet Kaur,*** Indian Institute of Technology Delhi, India

NiO is a wide-band transparent insulator, exhibiting a bandgap of 3.6 eV-4.0 eV [1]. It is an antiferromagnetic material with a Néel temperature of 523 K. NiO crystallizes in a NaCl-type face-centered cubic structure with a lattice parameter of 0.417 nm. The antiferromagnetic order in NiO is due to the antiferromagnetic alignment of ferromagnetic (111) planes along the [111] crystallographic direction[2].Below T_N,magnetic ordering induces a rhombohedral distortion.This study presents the growth of (111)-oriented NiO thin films on (0001)-sapphire substrate using pulsed laser deposition (PLD). DC magnetic susceptibility measurements of the films confirm that they maintain antiferromagnetic ordering at room temperature. Additionally, this finding is supported by the observation of two-magnon(2M) Raman scattering.The relative intensity of this 2M mode

compared to a neighboring phonon mode further highlights the bulk-like antiferromagnetic state in the thin films. NiO thin films were irradiated utilizing an Au ion beam at varying fluences.X-ray diffraction (XRD) analysis indicated a broadening and a shift towards a higher 2θ value in the NiO(111) peak with increased fluence, which suggests a reduction in the out-of-plane lattice parameters.Atomic force microscopy (AFM) results demonstrated increased surface roughness of the films post-irradiation.DC magnetic susceptibility measurements showed a decrease in the magnetic moment and Néel temperature at the higher fluence of $5x10^{12}$ ions/cm^2, attributable to defects induced by the ion beam irradiation. Raman spectroscopy further supported these findings, with significant changes observed in the two magnon peaks,which experienced a redshift and broadening in the irradiated samples. This shift and broadening signify a reduced antiferromagnetic coupling due to high-energy ion beam irradiation.Additionally,the 1P peak at 575 cm^{-1} exhibited a redshift and broadening in the irradiated samples. The ratio of I_{1P}/I_{2P} increased significantly upon irradiation and even surpassed one at the higher fluence value, indicating a higher degree of disorder induced by the ion beams. Overall, this study demonstrates the successful deposition of (111)-oriented NiO thin films via PLD, exhibiting magnetic properties similar to bulk NiO, and the tuning of the 2M peak by ion beam irradiation.These findings highlight the potential of NiO thin films for exploring fundamental magnetic interactions and developing optoelectronic applications.

[1]H. Ohta et al., Thin Solid Films 445, 317(2003)

[2]S. M. Rezende et al., J. Appl. Phys. 126, 151101(2019)

TF-ThP-11 Mesoporous Metal Fluoride Films with Ultra-low Tunable Refractive Index for Broadband Antireflection, ***Choon-Gi Choi,*** Thin Film Materials Research Center, Korea Research Institute of Chemical Technology (KRICT), Republic of Korea*; Dong In Kim, Soonmin Yim, Saewon Kang, Sun Sook Lee,* Korea Research Institute of Chemical Technology (KRICT), Republic of Korea*; Ki-Seok An,* Thin Film Materials Research Center, Korea Research Institute of Chemical Technology (KRICT), Republic of Korea

Porous materials are of great interest in various fields such as optics, biology, energy, and catalysis. While energy and catalysis applications focus on achieving high porosity, optical applications demand not only low-refractive-index (RI) materials that overcome the limitations of naturally occurring substances but also the formation of a smooth RI gradient from the substrate to air. This requires both high porosity and precise control over it. Conventional methods for fabricating porous structures, including templating, self-assembly, and zeolitic synthesis, typically rely on sacrificial templates, which must be removed through chemical etching or thermal treatment, potentially damaging the host material and limiting scalability.

In this study, we present mesoporous metal fluoride films composed of MgF_2 and LaF_3, fabricated using a simple, template-free, one-step precursor-derived method. Pores spontaneously form during solidification due to the inherent instability of $La(CF_3OO)_3$. Electrostatic interactions between $Mg(CF_3OO)_2$ and $La(CF_3OO)_3$ precursors enable the controlled formation of mesoporous structures with finely tunable RI values ranging from 1.37 to 1.16. By stacking layers of $MgF_2(1–x)–LaF_3(x)$ with different compositions, a graded refractive index (GRIN) antireflection coating (ARC) is achieved, delivering excellent broadband performance with an average transmittance of ~98.03% in the 400–1100 nm range. Despite these advances, a refractive index gap still remains between the fluoride composite and air, primarily due to the inherently high RI of LaF_3.

To address this, we propose an innovative approach that enables precise tuning of porosity using micelle-assisted MgF_2 precursor intermediates. As micellization increases the size of the MgF_2 precursor clusters, the resulting solidified MgF_2 grains and the intergranular voids between them also increase, allowing for the fabrication of MgF_2 structures with ultra-low RI (~1.04) and fine RI control increments. When applied as a GRIN ARC on quartz substrates, this strategy achieves an average transmittance of ~97.96% across the 250–1100 nm spectral range.

This research was supported by Nano-Material Technology Development Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (grant no. 2021M3H4A3A01055854).

TF-ThP-12 A New Approach to Control Metal Deposition on Dielectrics Selectively Using an Aldehyde Inhibitor, ***Chi Thang Nguyen****, Kailey E. Jones, Jacob Bohreer, Bratin Sengupta, Jeffrey W. Elam,* Argonne National Laboratory, USA

Selective metal deposition on dielectric surfaces (MoD) is essential for advanced microelectronics applications, particularly in the context of the ongoing transition from 2D to 3D device architectures. However, achieving this selectivity remains challenging due to the similar surface chemistries of many dielectrics. In this work, we introduce a new approach for selectively controlling metal deposition on dielectric substrates by area-selective atomic layer deposition (AS-ALD) using an aldehyde inhibitor. Butyraldehyde was employed as an inhibitor to selectively adsorb on and passivate Al_2O_3 surfaces while leaving SiO_2 surfaces unaffected. As a result, the adsorption of the ruthenium precursor, $[Ru(TMM)(CO)_3]$, was prevented on the aldehyde-inhibited Al_2O_3 surface in subsequent Ru ALD cycles and the Ru grew selectively on the SiO_2 surface. The inhibitor adsorption behavior, surface blocking properties, and film selectivity were investigated using water contact angle, ellipsometry, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS) measurements. We believe that AS-ALD using aldehyde inhibitors offers a promising pathway for area-selective MoD in general, and for the integration of Ru into complex interconnects and 3D nanoarchitectures in particular, for next-generation microelectronic devices.

TF-ThP-13 Al_2O_3 ALD Mechanism of Li_6PS_5Cl: Toward Interface Engineering in Sulfide-Based Solid-State Electrolytes, ***Kyobin Park****, Donghyeon Kang, Vepa Rozyyev, Anil Mane, Francisco Lagunas, Hacksung Kim, Fulya Dogan, Zachary Hood, Peter Zapol, Justin Connell, Jeffrey Elam,* Argonne National Laboratory

Sulfide-based all-solid-state batteries (ASSBs) have emerged as a compelling alternative to conventional Li-ion batteries owing to their superior gravimetric and volumetric energy densities and enhanced safety characteristics. However, sulfide electrolytes such as Li_6PS_5Cl (LPSCl) are prone to chemical and electrochemical degradation upon contact with cathode and anode materials during cycling, giving rise to significant chemo-mechanical instability. Additionally, LPSCl exhibits extreme sensitivity to moisture and air exposure, leading to the release of toxic H_2S gas and the formation of resistive, electrochemically inactive interphases.Atomic layer deposition (ALD) offers a promising strategy to mitigate LPSCl degradation by depositing an ultrathin, conformal buffer layer on the LPSCl that is chemically and electrochemically stable. When properly engineered, this coating not only suppresses interfacial decomposition but can also improve ionic conductivity and mechanical integrity while minimizing electronic conductivity. Despite its potential, the interfacial reaction mechanisms between ALD precursors and LPSCl remain poorly understood.

In this study, we elucidate the reaction mechanism of Al_2O_3 ALD using trimethylaluminum (TMA) and H_2O on LPSCl through a combination of in situ and ex situ characterizations supported by density functional theory (DFT) calculations. In situ Fourier transform infrared (FTIR) spectroscopy and ex situ nuclear magnetic resonance (NMR) measurements revealed the surface functional groups involved in TMA chemisorption and subsequent H_2O reactions during the initial ALD cycle. Continued ALD cycling demonstrated steady Al_2O_3 growth, as observed by FTIR. Ex situ X-ray photoelectron spectroscopy (XPS) confirmed the formation of new interfacial bonds, while ex situ Raman spectroscopy verified the structural preservation of bulk LPSCl after ALD. Complementary DFT calculations enabled identification of the most thermodynamically favorable reaction pathways for precursor adsorption and film growth.Together, these results provide mechanistic insight into the ALD process on sulfide electrolytes and offer design principles for optimizing interfacial coatings in ASSBs, with implications for broader applications across sulfide-based solid electrolyte systems.

TF-ThP-14 Controlling the Structural and Electrocatalytic Properties of Pulsed Laser Deposited Ruthenium Oxide thin films for Oxygen Evolution Reactions, ***Jonathan McNair,*** STEM Early College at North Carolina A&T State University*; Russell Boone,* Grimsley High School*; Ikenna Chris-Okoro, Sheilah Cherono, Mengxin Liu, Ghanashyam Gyawali, Veluchamy Palaniappagounder, Shyam Aravamudhan, Dhananjay Kumar,* North Carolina A&T State University

Globally there has been a push for renewable energy sources that can serve in the future as an alternative to the conventional energy sources in existence today that continually lead to environmental degradation. In line with this, research efforts have been geared towards studying the sustainability and reliability of these possible alternatives. In this light, hydrogen generation through the splitting of water is proposed.

This study investigates the electrochemical and structural properties of single crystal ruthenium dioxide (RuO_2), focusing on the effect of varying

oxidation state (sub-stoichiometric-RuO2-x, stoichiometric RuO2, and hyper-stoichiometric RuO2+x) and lattice strain on electrochemical water splitting particularly in the oxygen evolution reactions (OER) in 0.1M KOH. Electrochemical Impedance Spectroscopy (EIS) and Cyclic Voltammetry (CV) were used to characterize RuO_2's behavior in alkaline environments, extracting key parameters such as solution resistance (R_s), charge transfer resistance (R_{ct}), and double-layer capacitance (C_{dl}). RuO_2 thin films were grown through the Pulsed Laser Deposition (PLD) on single-crystal sapphire (Al_2O_3) substrates at varying oxygen pressures (25–75 mTorr) at substrate temperatures 600°C at 4800 pulses. Structural characterization was performed using X-ray diffraction (XRD), X-ray Photoelectron spectroscopy (XPS), X-ray absorption spectroscopy (XAS), Non-Rutherford Backscattering Spectrometry (NRBS), Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM). Atomic modelling was carried out using Vesta to understand the epitaxial growth and relationship between the film and substrate. The films' electrochemical performance was evaluated via CV and Linear Sweep Voltammetry (LSV), with emphasis on the effect of crystal structure and oxidation state on OER activity. These results, validate RuO_2 as a promising material for water splitting applicationswell as illustrates the importance of deposition ambient control in tailoring the properties of RuO_2 film, which is a fundamental part of the design and optimization of an efficient electrode material.

This work was supported by the NSF-PREM on the Collaborative Research and Education in Advanced Materials Center (via grant # DMR-2425119) and the DOE EFRC on the Center for Electrochemical Dynamics and Reactions on Surfaces (CEDARS) via grant # DE-SC0023415.

TF-ThP-15 Pulsed Laser Deposition and Characterization of Titanium Oxynitride Thin films for Renewable Energy Applications, ***Russell Boone***, Grimsley High School; *Jonathan McNair, Sheilah Cherono, Ikenna Chris-Okoro, Mengxin Liu, Ghanashyam Gyawali, Veluchamy Palaniappagounder, Shyam Aravamudhan, Dhananjay Kumar,* North Carolina A&T State University

In our world today, despite the efforts of various governments and institutions, fossil fuel unfortunately remains the main source of electricity in the United States and globally. These energy sources create toxic emissions, pollute the atmosphere while promoting climate change. In line with the global shift towards developing sustainable fuels, efforts are needed to develop material systems and processes that can convert molecules in the air (e.g., water, carbon dioxide, and nitrogen) into renewable energy products. In response to preventing a continued dependence on fossil fuels, the splitting of water to produce hydrogen fuel and oxygen is proposed.

In this study Pulsed laser deposition (PLD) technique has been used to grow titanium oxynitride (TiNO) thin films on sapphire (Al_2O_3) for renewable energy applications. A pulsed Krypton Fluoride (KrF) excimer laser (Wavelength=248nm, pulse duration=30ns) was used, with a laser repetition rate of 10 Hz, 6000 pulses, and a deposition temperature of 600°C.

Structural properties of the films were investigated using X-ray Diffraction and Reflection (XRD, XRR), X-ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM) and Scanning Electron Microscopy. Structural modelling was performed using Vesta to understand the epitaxial growth and relationship between the film and substrate.

Electrochemical Impedance Spectroscopy (EIS) and Cyclic Voltammetry (CV) were used to characterize titanium oxynitride (TiNO) behavior in alkaline environments, extracting key parameters such as solution resistance (Rs), charge transfer resistance (Rct), and double-layer capacitance (Cdl).EIS data, analyzed with Nyquist plots and Randles circuit modeling, these results confirmed the presence of both resistive and capacitive elements, validating as a promising material for water splitting applications.

This work was supported by the NSF-PREM on the Collaborative Research and Education in Advanced Materials Center (via grant # DMR-2425119) and the DOE EFRC on the Center for Electrochemical Dynamics and Reactions on Surfaces (CEDARS) via grant # DE-SC0023415.

TF-ThP-16 Understanding the Electrocatalytic Reaction Kinetics of Ruthenium Dioxide Thin Films using Tafel Equations, ***Jonathan Roop***, *Ghanashyam Gyawali, Mengxin Liu, Sheilah Cherona, Ikenna Chris-Okoro, Wisdom Akande, Brianna Barbee, Veluchamy Palaniappagounder, Shyam Arvamudhan, Dhananjay Kumar,* North Carolina A&T State University

This research focuses on the study of hydrogen and oxygen evolution reaction kinetics of ruthenium dioxide (RuO_2) thin films in alkaline and acidic media using Tafel slope analysis. The study has given insights into the rate-determining step, kinetics, and mechanisms that govern electrochemical reactions at the RuO_2 electrode and electrolyte interface. The Butler-Volmer equation was also combined with the Tafel equation at higher overpotentials, which has allowed us to establish a connection between the magnitude of the Tafel Slope and the mechanism of the rate-determining step of the reaction. RuO_2 is an ideal candidate as an electrocatalyst because it is intrinsically stable, corrosion-resistant, and has low resistivity, making it viable for water splitting applications. The RuO_2 films were grown on (0001) plane Al_2O_3 under different deposition conditions, using a pulsed laser deposition method. A three-electrode cell and KOH and $HClO_4$ electrolytes with different concentrations were used for Linear Sweep Voltammetry testing. The OER and HER overpotential (h) was plotted as a function of log(j), for which the Tafel slope is calculated using the Tafel equation, h = a + blog(j). For example, Tafel Slope results in 1.0M KOH provide b_{OER} = 115 $mVdec^{-1}$ for the 4800-pulse sample and, b_{OER} = 150 $mVdec^{-1}$ for the 2100-pulse sample. While Tafel Slope results in 0.1M $HClO_4$ provide b_{HER} = 115 $mVdec^{-1}$ for the 4800-pulse sample and, b_{HER} = 160 $mVdec^{-1}$ for the 2100-pulse sample. This data suggests a thicker RuO_2 film will result in more kinetic activity on the surface in alkaline and acidic media. Future work will consist of different characterization methods to verify these results and compare our experimental data to theoretical data for further understanding the mechanisms and steps limiting the reactions of RuO_2 thin films as a working electrode.

TF-ThP-17 Crystallinity's Contribution Toward Electrocatalysis of Ruthenium Dioxide Thin Films, ***Salil Pai***, *Ghanashyam Gyawali, Mengxin Liu, Sheilah Cherona, Ikenna Chris-Okoro, Wisdom Akande, Brianna Barbee, Veluchamy Palaniappagounder, Shyam Arvamudhan, Dhananjay Kumar,* North Carolina A&T State University

In this study, high-quality ruthenium dioxide (RuO_2) thin films were developed as electrocatalysts, synthesized on sapphire (Al_2O_3) substrates via pulsed laser deposition (PLD)—both materials selected for their financial and logistical accessibility. The investigation centered on the relationship between film crystallinity and electrocatalytic performance, comparing two sets of samples: a more crystalline, thicker set deposited with 4800 pulses, and a less crystalline, thinner set deposited with 2100 pulses. Deposition parameters were held constant at a growth rate of 10 pulses per second, a substrate temperature of 600 °C, and a (100) film orientation. Epitaxial growth and crystallinity were assessed through X-ray diffraction/reflectivity, atomic force microscopy, and Hall effect measurements. Electrochemical analysis via the three-probe method revealed a broad potential window with reversible redox behavior, indicating robust electrochemical activity. Charge transfer dynamics were further examined via electrochemical impedance spectroscopy across varying applied potentials and potassium hydroxide concentrations. The thicker, more crystalline films exhibited enhanced performance and long-term stability compared to their thinner, less crystalline counterparts, reinforcing the conclusion that higher crystallinity is critical for electrocatalytic efficiency. These findings underscore the promise of RuO_2 thin films as durable, high-performance electrocatalysts for energy conversion and storage, while also motivating future studies to systematically explore how deposition parameters—thickness, temperature, orientation, and growth rate—govern crystallinity and, by extension, catalytic performance.

TF-ThP-18 Power-Modulated Thermally Assisted Oxygen Plasma for Enhanced Reliability in Tio_2/TiO_{2-x} Memristors, ***Beom Gu Lee***, Chungdaro 1, Republic of Korea; *Jae-Yun Lee,* 409, Chungdaero 1 E8-1, Republic of Korea; *Sung-Jin Kim,* Chungdaro 1, Republic of Korea

The advancement of TiO_2-based memristors is critical for next-generation neuromorphic systems and non-volatile memory devices due to their simple structure, scalability, and stable resistive switching properties. However, achieving high endurance and uniform switching remains a major challenge. Precise control of oxygen vacancy distribution is essential to improve device reliability and performance.

In this work, we propose a thermally assisted oxygen plasma process with RF power modulation for the fabrication of glass/ITO/TiO_2/TiO_{2-x}/Ag memristors. The plasma treatment was conducted at various RF powers (0–80 W) under optimized thermal conditions to investigate its influence on resistive switching endurance, retention stability, and conduction mechanisms. Device performance was evaluated through I–V measurements, endurance cycling, and retention tests.

Acknowledgements: This work was supported by Innovative Human Resource Development for Local Intellectualization program through the Institute of Information & Communications Technology Planning &

Evaluation (IITP) grant funded by the Korea government (MSIT) IITP-2025-RS-2020-II201462 (50%), in part by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by Ministry of Education under Grant RS-2020-NR049604 (50%)

TF-ThP-19 Pholuminescence on Room-temperature Germanium-Tin (GeSn), ***Lia Guo***, *Vijay Gregory, Jay Mathews,* University of North Carolina at Charlotte

The use of silicon (Si) in the optics and photonics industry is very popular due to its electronic properties and compatibility with CMOS technology, as well as other semiconductor devices. Germanium (Ge) is an alternative material that can be grown on Si substrates and is now used in photonic devices. However, both Ge and Si suffer from non-radiative processes due to being indirect band-gap materials. Unlike Si, Ge is a quasi-direct bandgap semiconductor and can be band engineered through strain or Sn alloying. Similar to Ge, germanium-tin (GeSn) has shown potential in the photonics industry with a greater focus on light sources. Photoluminescence spectroscopy was carried out using a NIR 980nm laser to probe the optical properties of the GeSn/Ge/Si samples. These measurements were analyzed with reference to Rutherford backscattering and cross-sectional TEM.

Author Index

Bold page numbers indicate presenter