Undergraduate Poster Session
Room Ballroom A - Session UN-ThP

Undergraduate Poster Session

UN-ThP-1 Deposition and Annealing of RF-Sputtered, Thin Film Gallium Oxide*, Aria Lindberg, Jackson Anderson,* University of Vermont

Gallium oxide (Ga_2O_3) is a polymorphic semiconductor material whose β phase demonstrates potential for applications in power electronics due to high Johnson and Baliga figures of merit. When compared to other materials commonly used in piezoelectric MEMS, metastable ε-Ga_2O_3 demonstrates a promising electromechanical coupling coefficient (k^2) — highlighted in Table 1. Despite this, ε-Ga_2O_3 remains less studied than β-Ga_2O_3, which has been grown using melt, MOCVD, and PVD techniques.

This study presents initial results of the effects of different RF sputtering and annealing conditions on the crystal characteristics of thin-film Ga_2O_3 on <111> silicon substrates towards the goal of determining ideal temperature, gas type and flow ratio, and RF power values contributing to ε-phase stabilization. The study follows the process shown in Fig. 1.

Films were sputtered from a Ga_2O_3 target in 32 sccm of Ar at 3 mTorr with 50W RF power for 2 hours (Fig. 2) and subsequently annealed in an air-ambient tube furnace at 500 to 900°C in 100°C steps for 30 minutes at temperature. These temperatures were chosen based on literature showing the transition of ε- to β-Ga_2O_3 around 800°C. Samples were characterized before and after annealing with spectroscopic ellipsometry shown in Fig. 3 and XRR shown in Fig. 4.

Ellipsometry results indicate a slight decrease in film thickness at sub-600°C anneals with rapid expansion at higher temperatures (Fig. 3); XRR fringe spacing (Fig. 4), in contrast, indicates thickness expansion across all anneal temperatures, while critical angle right shift indicates densification and increasing slope indicates increasing roughness. This is supported by AFM (Fig. 5), which demonstrates a change in surface roughness from 66.59pm RMS (unannealed) to 1.858nm RMS (900°C) while also revealing the polycrystalline nature of the annealed films. XRD measurement did not yield clean spectra, likely due to the disoriented polycrystalline nature of the films.

Following literature on successful deposition of ε-Ga_2O_3, future work will explore deposition at elevated temperatures, while also varying O_2/Ar gas mixture, substrate bias, and deposition rate to enhance ε-phase stability and crystallinity.

UN-ThP-2 Temperature-Dependent Behavior of TaN Thin Film Resistors*, Joshua Dykas, Alex Zaccardi, Alexander C. Kozen,* University of Vermont

Tantalum Nitride (TaN) is a thin-film resistive material that is widely used in the semiconductor industry for its temperature stability and CMOS compatibility. However, stoichiometry and deposition process conditions can heavily influence resistive properties. Additionally, cross-wafer nonuniformities in materials composition or thickness can vary the electrical behavior of devices from the center to the edge of a wafer. We developed an automated temperature-dependent electrical characterization system to perform thin-film resistivity measurements of TaN films as a function of temperature from 50°C to 130°C. A custom-built Python program automates data collection, analysis, and real-time data plotting. 200 mm oxidized silicon wafers, subsequently coated in sputtered TaN were provided by GlobalFoundries (GF). These wafers were cleaved into 3 cm squares selected from the center, middle, and edge of each wafer for TCR measurements. The average TCR for 48 nm TaN is -371.4 ± 10.8 ppm/°C, meanwhile the TCR for 15 nm High-Nitrogen TaN is -1066 ± 52 ppm/°C. Our data indicates that higher concentrations of nitrogen and thinner films cause the resistive properties of TaN to be less stable with temperature. Notably, the center of both wafers exhibits lower TCR values than the middle or edges of the wafer, indicating radial nonuniformities related to TaN deposition conditions.

UN-ThP-3 Analyzing Hardness of Poly (Methyl Methacrylate) (PMMA) Infiltrated with Trimethyl Aluminum (TMA) Through Vapor Phase Infiltration (VPI)*, Annie Powell, Mark Losego, Ronan Neill,* Georgia Institute of Technology

This research seeks to understand how the hardness of poly (methyl methacrylate) (PMMA), a thermoplastic polymer, can be altered when it is infiltrated with an inorganic via vapor phase infiltration (VPI). In VPI, the polymer sorbs inorganic vapors into the bulk of the polymeric material, transforming it into an organic-inorganic hybrid material. The resultant hybrid materials are known to have properties that differ from their parent polymer. In this work, we examine the VPI of PMMA blocks with trimethylaluminum (TMA) vapors and water to form PMMA-AlOx hybrid materials. We study the effects of infiltration temperature, time, and number of cycles on the hardness of the material using a microhardness tester. Additionally, chemical changes to the composition and chemical structure of the material are studied with SEM-EDX analysis and FTIR spectroscopy.

The results of this experiment in Figure 1 show that when PMMA is infiltrated at 120 °C, hardness initially decreases and then steadily increases. We observe a decrease in Vickers' hardness from about 23.1 ± 0.6 to 10.9 ± 0.5 between the pure polymer and 3 hours of infiltration. The hardness then rises to 16.1 ± 0.2 after 10 hours of infiltration, which is still lower than the pure polymer. These results are surprising to us, given we nominally infiltrate the softer polymer material with a harder ceramic-like material. This phenomenon may be explained by chemical bond disruption in the hybrid that is softening the polymer upon infiltration. Additionally, there is visible chemical change in the sample, as they increase in amber color with longer hold times as shown in Figure 2. These chemical changes will be discussed more fully at my poster presentation.

UN-ThP-4 Exploring Feasibility of Raman Spectroscopy for Identification of Nb Oxides on NASA Devices*, Dorian Davis, Femi Akinrinola, Mikel Holcomb,* West Virginia University

Niobium thin films are widely used for superconducting applications due to their low-temperature superconductivity and corrosion resistance. This makes them well suited for NASA detectors for astrophysics, and quantum computing. However, NASA believes that the formation of oxide phases on the thin films tends to cause variability in device performance. To better understand the origin of this variability, we aimed to characterize the oxide phases forming on the device surface. To this end, we sought to determine whether Raman spectroscopy is a reliable identification method, in comparison of other methods — such as XAS — are not as accessible as Raman can be. We suspected our signal was going to be small, so we chose to compare it to samples which had been annealed to promote oxide growth. We were able to identify Nb_2O_5 oxides on an annealed sample and had difficulty finding any oxides on the devices, using Raman. Our findings suggest that Raman is best used when a thin film has a greater concentration of surface oxides, and is not the optimal identification method for devices that tend to have low oxide content.

UN-ThP-5 Spectroscopic Ellipsometry of High-K Dielectrics*, Alexander Zaccardi, Joshua Dykas, Alexander Kozen,* University of Vermont

Spectroscopic ellipsometry is a characterization technique used for analyzing the optical characteristics of high-k dielectric films in advanced semiconductor devices. Using the J.A. Woollam M-2000D spectroscopic ellipsometer, we characterized monolithic and nanolaminate dielectric layers composed of hafnium oxide, aluminum oxide, and silicon dioxide to investigate the relationship between film composition, structure, and dielectric performance. Through the utilization of Cauchy and B-spline fitting models, we extracted the refractive index and the extinction coefficient across ultraviolet to near-infrared wavelengths. We compared monolithic and nanolaminate dielectric film stacks to determine which configuration yielded the highest dielectric constant. Wafer mapping was used to reveal nonidealities and nonuniformities in the varying layer stacks across a 200 mm substrate. Results demonstrate that hafnium oxide and aluminum oxide nanolaminate structures exhibit the highest dielectric constants, and increased concentrations of aluminum oxide may further improve the dielectric constant. Our results provide crucial insight into thin-film dielectrics suitable for next-generation semiconductor devices.

UN-ThP-6 An Electrodeposited Iridium Oxide pH Sensor for Ingestible Capsule Localization*, Micheal York, College of Southern Maryland; Justin Stine,* University of Maryland, College Park

Gastrointestinal (GI) disorders, such as inflammatory bowel disease (IBD), are commonly diagnosed using invasive endoscopy and biopsy. Ingestible capsules have emerged as a minimally invasive alternative for GI monitoring, sampling, and targeted drug delivery. As these pill-sized devices traverse different GI regions, localization becomes essential for interpreting measurements within the appropriate physiological context. Therefore, scalable and low-cost pH sensing solutions are desired to complement existing capsule size and electronics. This work presents the integration of an iridium oxide (IrO2) pH sensor into an ingestible capsule prototype for measuring dynamic pH gradients in GI environments to classify sensor readouts (Fig. S1).

The pH sensor consists of screen-printed electrode (SPE) with platinum (Pt) working and counter electrodes and a silver (Ag) reference electrode. An electrodeposition solution was prepared following existing protocols. Briefly, iridium chloride was dissolved in DI water (5.5 mM) and stirred for 30 minutes, followed by addition of 0.5 mL hydrogen peroxide and stirring for 10 minutes before adding 0.25 g oxalic acid. The solution was adjusted to pH 10.5 with potassium carbonate, heated under a water bath for 5h, then stored at 4 °C until use. Electrodeposition was performed using an Interface 1010E benchtop potentiostat (Fig. S2). The SPE was submerged in solution, within an ice-water bath, and the Pt working electrode was modified using either (1) chronopotentiometry (CP) at 0.2 mA/cm2 for 100 s or (2) cyclic voltammetry (CV) from 0 V to +0.7 V at 50 mV/sec for 90 cycles (Fig. S2b).

IrO2 film formation was characterized using open circuit potential (OCP) measurements in pH 4.00, 6.86, and 9.81 buffer solutions for 60 s (Fig. S3a). Calibration curves were generated for each electrodeposition method (Fig. S3a,b). Linear fitting yielded sensitivities of 71.25 mV/pH (R2 = 0.9861) for the CV-pH sensor and 65.07 mV/pH (R2 = 0.959) for the CP-pH sensor (Fig. S3b). Solution pH was verified using a commercial pH meter (Nanbei Instrument) prior to testing. Sensor drift was evaluated in pH 4.00 buffer solution for 30 minutes, yielding 2.36 and 28.80 mV/hr, respectively. This showed that the CV-pH sensors showed superior film formation and performance compared to the CP-pH sensor. This work further demonstrates the integration of the IrO2 sensor with a high-impedance voltage follower (LTC6078) and analog front-end (AD5940) into an existing ingestible capsule prototype (Fig. S3c), while implementing embedded on-chip calibration to improve signal fidelity, and evaluating performance in simulated gastric and intestinal fluids.

UN-ThP-7 A Hybrid Energy-Harvesting Ingestible Capsule: Piezoelectric Harvester, ***Kristin Wiens***, *Izabella Tucker, Ian Jackson, Jenna Pratt, Anika Prasanna, Daniel Hutman, Abinezer Abate, Sydney Overton, Justin Stine, Reza Ghodssi,* University of Maryland, College Park

Advances in microelectromechanical (MEMS) research has enabled the development of non-invasive ingestible capsule devices for medical interventions in the gastrointestinal (GI) tract. Further ingestible device miniaturization is limited by the necessity for batteries to power them. Onboard energy harvesters present an alternative power method, reducing the footprint of the ingestible device. Gastric battery and chemical energy harvesters have shown promising results integrating into ingestible devices, but operation is limited to the stomach and prone to energy leakage. To overcome these limitations, we propose a hybrid energy harvesting system that enables chemical harvesting in the stomach and piezoelectric harvesting in the intestines, thereby extending the overall region of operation (Fig. S1).

Here, we report a piezoelectric energy harvester to convert mechanical, peristaltic motion within the intestines to electrical energy. The harvester utilizes polyvinylidene fluoride (PVDF) thin films, known for their excellent biocompatibility, flexibility, and piezoelectric properties. Multiple thin film configurations under controlled mechanical excitation were evaluated to maximize voltage output and prevent back charging between the PVDFs. Two thin films with isolated H-bridges had the highest voltage output of 85 mV (Fig. S2). Integration with an integrated circuit (IC) improved energy collection efficiency from the PVDFs by preventing premature voltage dissipation. Our findings support the feasibility of piezoelectric energy harvesting for microscale biomedical applications.

To facilitate testing, we are developing a simulated small intestinal model consisting of a silicone sleeve and actuators that apply a realistic pressure wave via an external pump to move the capsule prototype through the model (Fig. S3). Testing the piezoelectric harvester in the simulated model will enable characterization of voltage outputs from peristaltic forces in the microscale (18–62 mmHg). We anticipate the supplemental energy collection supplied from the piezoelectric harvester will counteract capacitor leakage and allow for a decrease in overall capsule size once scaled appropriately. Integrating the piezoelectric harvester with a chemical harvester will enable an ingestible self-powered system capable of sustained operation in the GI tract.

UN-ThP-8 A Hybrid Energy-Harvesting Ingestible Capsule: Electrochemical Harvester, ***Ian Jackson***, *Abinezer Abate, Daniel Hutman, Kristin Wiens, Izabella Tucker, Anika Prasanna, Jenna Pratt, Sydney Overton, Justin Stine, Reza Ghodssi,* University of Maryland, College Park

Advances in microelectromechanical (MEMS) research has enabled the development of non-invasive ingestible capsule devices for medical interventions in the gastrointestinal (GI) tract. Further ingestible device miniaturization is limited by the necessity for batteries to power them. Onboard energy harvesters present an alternative power method, reducing the footprint of the ingestible device. Gastric battery and chemical energy harvesters have shown promising results integrating into ingestible devices, but operation is limited to the stomach and prone to energy leakage. To overcome these limitations, we propose a hybrid energy harvesting system that enables chemical harvesting in the stomach and piezoelectric harvesting in the intestines, thereby extending the overall region of operation (Fig. S1). This work investigates the design trade-offs of electrochemical harvester electrodes for current generation within ingestible capsule form factors.

Previously reported chemical energy harvesters have been demonstrated, utilizing stomach acid to induce oxidation-reduction reactions, producing electric current that can be used to power an ingestible device. While these systems can generate electrical current, maintaining sufficient power output over the capsule's residence time in the stomach remains a challenge. To address this limitation, this work integrates both piezoelectric and chemical energy harvesters; each system can be independently optimized for maximum power output within its respective operating region and duration. Thus, the chemical harvester seeks to maximize power for the amount of time the capsule will spend in the stomach.

Optimizing the power generation of the chemical harvester entailed material selection and evaluation of electrode dimensions and size. Anode and cathode materials were examined using galvanostatic discharge across a 1kΩ load with a benchtop potentiostat. Based on the average power density, the electrochemical cell comprises a magnesium (Mg) anode and molybdenum (Mo) cathode and was assembled on a thin polyimide film with 4 mm spacing (Fig. S2). Characterization of the Mg-Mo harvester at varied surface area (i.e., 8, 16, 24 and 32 mm2) in simulated gastric fluid revealed that power density increased with increasing electrode size (Table S3); however plateau at the 4 mm x 4 mm size anode/cathode, which produces 0.219 mW/mm. Integrating the chemical harvester with a piezoelectric harvester will enable an ingestible self-powered system capable of sustained operation in the GI tract.

UN-ThP-9 Exploring Novel CVD Synthesis Routes for Enhanced Optoelectronic Properties of VS_2, ***Amari Gayle***, *M. K. Indika Senevirathna,* Clark Atlanta University

Vanadium disulfide (VS_2), a member of the transition metal dichalcogenides (TMDs) family, has gained considerable attention from researchers owing to its remarkable properties. These include metal-insulator transition behavior, room-temperature ferromagnetism, a unique layered structure, and metallic conductivity. Additionally, VS_2 can form highly crystalline materials. With advances in achieving a more precise structure of this semiconducting material, VS_2 nanomaterials have the potential to be the most efficient TMDs for various photonic and optoelectronic applications. Chemical vapor deposition (CVD) has proven to be an effective method for synthesizing two-dimensional materials. Its simple process, compatibility with industry standards, and capacity to produce high-quality crystals make it an excellent choice for both researchers and industrial producers. This study will investigate the optoelectronic behavior of VS_2 thin films synthesized on different substrates using CVD, building on and extending conventional growth techniques. It will determine the optimal growth conditions, with particular attention to substrate type, growth temperature, and carrier gas flow rate. The properties of the resulting samples, including surface morphology, crystalline quality, Raman phonon modes, and bandgap characteristics, will be systematically studied as a function of substrate type, growth temperature, and carrier gas flow rate using Raman spectroscopy, photoluminescence (PL), and confocal laser scanning microscopy.

UN-ThP-10 Electrochemical Protonation of ALD Oxide Thin Films, ***Kaydence Delgado***, *Daniel MacAyeal, Alexander Kozen,* University of Vermont

Electrochemical Protonation of ALD Oxide Thin Films

Kaydence Delgado, Daniel J. MacAyeal, Alexander C. Kozen

University of Vermont, Department of Physics

Hydrogen incorporation in ultra-thin atomic layer deposited (ALD) oxide films is important for understanding macroscale properties such as water diffusion barrier performance, dielectric behavior, chemical reactivity, and electrical breakdown strength, and, critically, suitability as a barrier material in fusion reactors. However, accurately measuring hydrogen content in films thinner than 10 nm remains difficult using conventional surface science techniques. An alternative approach is to use electrochemical ion

insertion/extraction to quantify exchangeable protons in ALD-grown oxide films using an aqueous system. We investigate the protonation behavior of ALD oxide films (Al2O3, ZnO, and Nb2O5) growth with TMA, NbEtOH, and DEZ as metalorganic precursors and H2O, t-BuOH, and O3 as oxidation precursors, and discuss how differences in oxidation precursor selection impact protonation behavior in these oxide films. We examine electrochemical reactions with cyclic voltammetry and discuss how ALD film thickness and oxidation precursor selection affects electrochemical response, proton insertion behavior, and ion-transport kinetics using cyclic voltammetry. Lastly, we will use Dunn–Trasatti analysis to extract protonation redox kinetics, giving us insight into the relationship between ALD film thickness, transport behavior, and ion insertion/deinsertion kinetics.

UN-ThP-11 ALD Silica for Surface Passivation of Porous Stainless Steel, ***Alexander Randall***, *Richard Vanfleet, Robert Davis,* Brigham Young University

Atomic layer deposition (ALD) could allow surface passivation of porous metals which could enable their use in molecular separation or purification processes, including liquid chromatography. We explored ALD passivation of porous stainless steel metal monoliths (“metalliths”) formed by powder sintering with the goal of passivating all exposed stainless steel surfaces including interior surfaces. In the ALD process, tris(dimethylamino)silane (3DMAS) and ozone precursors were used to coat the metallith pores with a thin film of silica. For comparison, trimethylaluminum and H_2O ALD was also performed on the metalliths. The resulting passivated metalliths were characterized with energy dispersive x-ray spectroscopy and scanning electron microscopy to determine the penetration uniformity, conformality, and thickness of the silica film.

UN-ThP-12 Fourier Denoising of the C Auger XPS Signal for Subsequent D-Parameter Calculation, ***Jonathan C. Nelson***, *Alvaro J. Lizarbe, B. Maxwell Clark, Matthew R. Linford,* Brigham Young University

X-ray Photoelectron Spectroscopy (XPS) of carbon-containing compounds requires peak and derivative analysis to find the percent hybridization (sp^2 versus sp^3 ratio) via the so-called D-parameter, which is the separation between the minimum and maximum of the first derivative of the carbon Auger spectrum. However, taking the derivative of raw spectral data can yield incorrect minima and maxima, distorting the D-parameter, because of high-frequency background noise. Accordingly, the C Auger peak is usually smoothed prior to D-parameter calculation. We have developed a tool based on denoising via Fourier analysis that allows D-parameter calculation. Results from this tool are consistent with other known procedures for determining the D-parameter.

UN-ThP-13 The Effect of Aluminum Precursor on the Electrical, Optical, and Structural Properties of Atomic Layer Deposited Aluminum-Doped Zinc Oxide Thin Films, ***Addison McLean***, *Nicholas Strandwitz,* Lehigh University

Aluminum-doped zinc oxide (AZO) is a promising material characterized by high transparency and conductivity, emerging as a inexpensive transparent conductive oxide alternative to indium tin oxide. Atomic layer deposition (ALD) is a technique well suited for depositing AZO films with precise control over dopant composition and film thickness. While the effect of aluminum composition and growth temperature on electrical properties is well studied, understanding the role of aluminum precursors in the ALD process is essential for further optimizing optoelectronic properties. In this study, the effect of aluminum precursor size and reactivity on the electrical, optical, and structural characteristics of ALD AZO thin films was investigated. AZO films were grown via the ALD supercycle method, in which matrix (ZnO) film layers are periodically interrupted by single dopant (Al) layers. The fraction of aluminum atoms contributing to carrier donation (doping efficiency) is dependent on the distribution of dopant atoms in the doping layer. Four aluminum precursors were investigated, including trimethyl aluminum, aluminum tri-sec-butoxide, tributyl aluminum, and tris(dimethylamino)aluminum. It was found that larger, less reactive precursors resulted in a lower Al concentration while maintaining a similar carrier concentration to smaller precursors by limiting the clustering of Al in the ZnO film, suggesting higher doping efficiencies. Additionally, mobility and conductivity both increased with precursor size, while refractive index, absorption coefficient, and transmittance remained largely unchanged.

UN-ThP-14 Plasma Diagnostics for the Modification of Plant-Based Biopolymers, ***Morgan Schnell***, *Joshua Blechle,* Wilkes University

Seed biopolymers, such as chickpeas, are commonly utilized in kitchens and are grown worldwide. Known for their great yield, health benefits, and versatility – agriculture and everyday suburbia depend on chickpeas. However, due to their thick outer cuticle structure, germination varies from seed to seed and results in a slow growth rate. As such, there is a desire to develop procedures that produce more consistent and faster germination processes. One potential method is the utilization of plasma-enhanced modification techniques. It has been suggested by surface analysis that the use of cold air plasma treatments will etch at the outer layer of the seed coat, inducing hydrophilicity. If this translates onto the chickpea biopolymer, germination should consequently be enhanced.

In order to achieve more reproducible etching processes, the mechanism driving the etching of the seed coat must be explored. Here, optical emission spectroscopy (OES) is used to monitor gas-phase species during chickpea treatment. A low-temperature, inductively-coupled plasma system formed from a mixture of breathing air and argon (90% and 10%, respectively, by pressure) is used for all treatment conditions, with the Ar serving as an actinometric addition. Various treatment times (30 - 120 s), pressures (50 - 250 mTorr), and applied powers (50 – 100 W) were assessed. Densities (measured via OES) were determined for plasma systems, with and without the chickpeas present, to help identify key reactive species and etch products. Notably, the presence of chickpeas increased the density of CO* gas while simultaneously reducing the density of NO*. These relationships help verify the predicted etching and break down of the hydrophobic cuticles. This is further explored by increasing the number of chickpeas present in the reactor, as well as further comparison with other conditions previously described. Etching into the hydrophilic cuticle as planned will allow for easier water access into the seed and higher consistency in the germination process.

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