Science and Technology of Materials, Interfaces, and Processing

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2024 Spring Meeting
Hudson Mohawk AVS Chapter
Thursday, April 11, 2024
3:30 – 7:30 PM

University of Albany
ETEC building, Room B011
1220 Washington Avenue, Albany, NY 12226

Meeting Agenda

3:30 - 3:50 Reception (coffee and cookies served)

3:50 - 4:00 Welcoming Remarks

Keynote Presentation

4:00 - 4:30 *Characterization and Metrology of Si/Si$_{(1-x)}$Ge$_x$ Nanoscale Superlattice Film Stacks and Semiconductor Device Structures for Next Generation Transistors and Memory*,
Prof. Alain Diebold (CNSE, UAlbany)

Oral Presentations

4:30 - 4:45 *Correlative Surface Analysis: Combining XPS, Electron Microscopy, and Other Spectroscopies*,
James Lallo (Thermo Fisher Scientific)

4:45 - 5:00 *Surface Activation and Bonding Interface Analysis Technique for Fusion and Hybrid Wafer-to-Wafer Bonding*,
Andrew Tuchman (TEL)

5:00 - 5:15 *Synthesis and Electron Transport in Epitaxial Cubic Co(001)/ MgO(001) Layers as Potential Interconnect Conductor*,
Anshuman Thakral (RPI)

5:15 - 5:30 *Advancing $Cs_3Bi_2I_9$ Perovskite Solar Cells: Insights from Multifaceted Characterization and Machine Learning Analysis*,
Ankit Choudhary (UAlbany)

5:30 - 5:45 *Analysis of Oxide Formation on Ru Thin Films after Device Fabrication Processing Techniques*,
Randall Wheeler (UAlbany)

5:45 - 6:00 *Engineering of Erbium-Implanted Lithium Niobate Films for Integrated Quantum Applications,*
Souryaya Dutta (UAlbany)

6:00 - 7:30 **Poster Presentations** (pizza and refreshments served)

7:30 - 7:40 Awards Ceremony

Poster Presentations

P1. **HARNESSING THERMAL LASER EPITAXY FOR RAPID SYNTHESIS OF TOPOLOGICAL INSULATORS,**
Finley Donachie, Rensselaer Polytechnic Institute (RPI)

P2. **COMPARING OCTANETHIOL GOLD NANOPARTICLE DEPOSITION TECHNIQUES FOR ELECTRONIC NOSE FABRICATION: INKJET PRINTING VS. DROP CASTING,**
Md. Delowar Hossain, University of Connecticut

P3. **DESIGN AND CONSTRUCTION OF A SPUTTER DEPOSITION SYSTEM TO EXPLORE NEW INTERCONNECT MATERIALS,**
Jack Coyle, Rensselaer Polytechnic Institute (RPI)

P4. **TEMPLATE-DIRECTED CRYSTALLIZATION OF AlSb/Sb(A7) PCM FOR LOW ENERGY SWITCHING,**
I.K. Shuvo, University at Albany (UAlbany)

P5. **SECONDARY ELECTRON YIELDS, ELECTRONIC STRUCTURE AND CHEMICAL ENVIRONMENT OF SURFACES,**
Sylvie Rangan, Rutgers, The State University of New Jersey

P6. **SAMPLE STAGE DESIGN FOR SPUTTER DEPOSITION OF NEW INTERCONNECT MATERIALS,**
Emma Sponga, Rensselaer Polytechnic Institute (RPI)

P7. **FABRICATION OF DOPED NbO_2 THRESHOLD SWITCHES FOR NEUROMORPHIC COMPUTING**,
Theodore Wallach, University at Albany (UAlbany)

P8. **ELECTRON SCATTERING AT Ru(0001) SURFACE: IMPACT OF Ti CAPS AND OXYGEN EXPOSURE,**
Sadiq Shahriyar Nishat, Rensselaer Polytechnic Institute (RPI)

Driving Directions

The ETEC building is in the Harriman State Office Complex, which is adjacent to the University at Albany campus. The address of the ETEC building is ETEC, 1220 Washington Avenue, Albany, NY 12226. It is important that you include "ETEC" in your search if you are using a mapping program; otherwise, the search will send you to the state police barracks.

From UAlbany Campus:

There is no direct street access to the ETEC building from the UAlbany campus. You must first drive to either Washington Avenue or Western Avenue and go east towards downtown Albany. Just after passing the UAlbany campus, there will be an entrance to the Harriman State Office Complex (State Office Buildings).

- If entering Campus Access Road from Washington Avenue, you will see the ETEC building on your left. After passing the building, you will take a U-turn to access the side of Campus Access Road that passes in front of the ETEC building. The parking lot is on the north side of the building.
- If entering Campus Access Road from Western Avenue, you will also need to take a U-turn so that you are driving towards the ETEC building, not away from it. Again, the parking lot is on the north side of the ETEC building.

From the North:

Take the Northway (I-87) south to Exit 1E. Merge onto I-90 east (toward Albany/Boston). Then take Exit 3 (State Office Buildings), which will put you on Campus Access Road. After passing the ETEC building, you will take a U-turn to access the side of Campus Access Road that passes in front of the ETEC building.

From the South:

Take the Thruway (I-87) north to Exit 24. Merge onto I-90 east (toward Albany/Boston). Then take Exit 3 (State Office Buildings), which will put you on Campus Access Road. After passing the ETEC building, you will take a U-turn to access the side of Campus Access Road that passes in front of the ETEC building.

From the West:

Take the Thruway (I-87) east to Exit 24. Merge onto I-90 east (toward Albany/Boston). Then take Exit 3 (State Office Buildings), which will put you on Campus Access Road. After passing the ETEC building, you will take a U-turn to access the side of Campus Access Road that passes in front of the ETEC building.

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Print the parking permit and display it on your dashboard when parking in the ETEC lot. Otherwise you will have to pay at a UAlbany meter as a visitor.

HMAVS meeting location is in ETEC Room B011 (Basement level).

Enter ETEC Lot from Campus Access Road (inner ring road, one-way)
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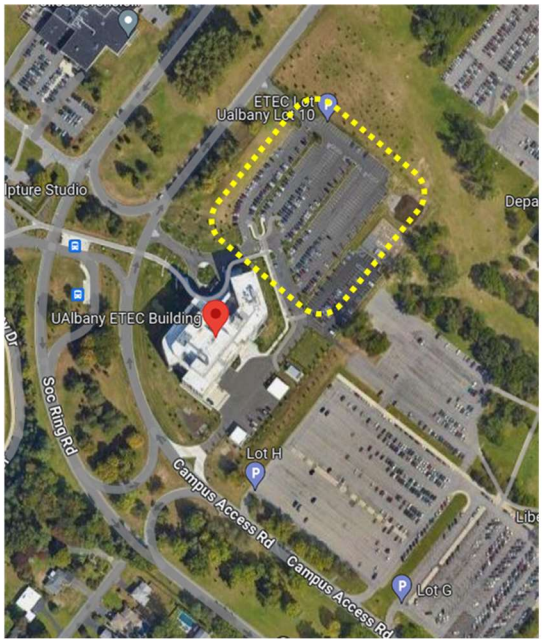
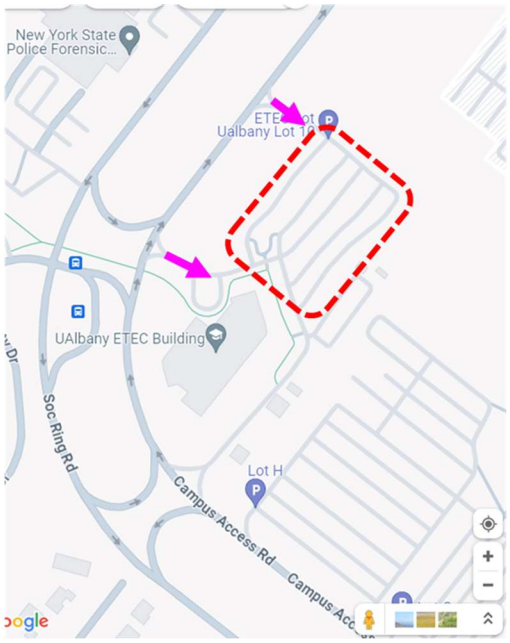
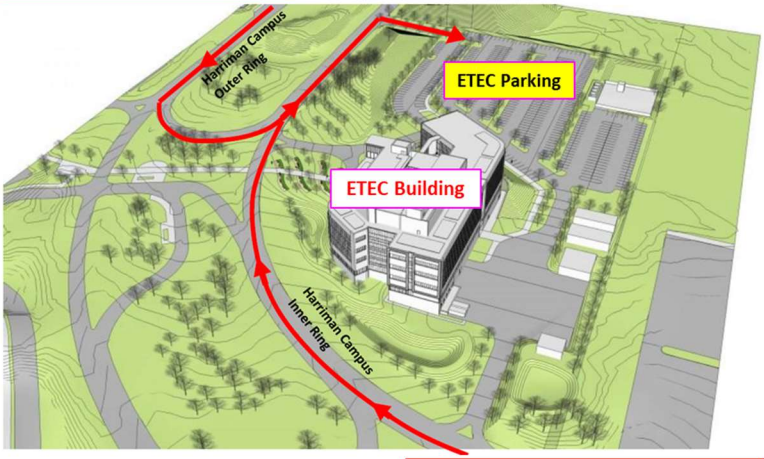




From Washington Ave (North)



From Western Ave (US-20, South)

Keynote Presentation:

CHARACTERIZATION AND METROLOGY OF Si/$Si_{(1-x)}Ge_x$ NANOSCALE SUPERLATTICE FILM STACKS AND SEMICONDUCTOR DEVICE STRUCTURES FOR NEXT GENERATION TRANSISTORS AND MEMORY

Alain C. Diebold

College of Nanotechnology, Science, and Engineering
University at Albany - SUNY
257 Fuller Road, Albany, NY 12203

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As traditional scaling of transistors comes to end, transistor channels and capacitors are being stacked to form new 3D transistor and memory devices. Many of these devices are fabricated using films stacks consisting of multiple Si/$Si_{(1-x)}Ge_x$ layers known as superlattices which must be fabricated with near atomic precision. In this talk, we discuss how Optical, X-Ray, and electron microscopy methods are used to measure the feature shape and dimensions of these structures. The use of X-ray methods such as $\omega - 2\theta$ scans and reciprocal space maps provide layer thickness and stress characterization. We will use simulations to show how a buried layer with a different thickness or Ge concentration alters the data. Recent electron microscopy studies have quantified the stress at the interfaces of these superlattices. We will also discuss how Mueller Matrix spectroscopic ellipsometry (MMSE) based scatterometry is used to measure feature shape and dimension for the nanowire/nanosheet structures used to fabricate nanosheet transistors and eventually 3D DRAM. The starting point for optical scatterometry is determining the optical properties of stressed pseudomorphic $Si_{(1-x)}Ge_x$. MMSE can be extended into the infra-red and into the EUV. In addition, small angle X-ray scattering has been adapted into a method knows as CDSAXS which can be used to characterize these structures. This talk will be an overview of these methods.

Oral Presentation:

CORRELATIVE SURFACE ANALYSIS: COMBINING XPS, ELECTRON MICROSCOPY, AND OTHER SPECTROSCOPIES

James Lallo, Tim S Nunney, Paul Mack, Robin Simpson, and Helen Oppong-Mensah

Thermo Fisher Scientific,
East Grinstead, West Sussex, UK.

Email: James.Lallo@ThermoFisher.com

Comprehensive investigation of the chemistry and structure of surfaces and interfaces is vital to all fields of materials analysis. While an array of analysis exist to examine this region, the most complete understanding is gained from correlating the results of multiple techniques. X-ray photoelectron spectroscopy (XPS) has become established as a one of the key techniques for measuring surface and interface chemistry. XPS can deliver quantified surface chemistry measurements, and by using depth profiling, an understanding of layer and interfacial chemistry. Advances in instrumentation have enabled XPS to keep pace with current investigative requirements, and further developments will allow it to reach even further. An area of particular interest is addressing the fundamental limits on spatial resolution of XPS, which can prevent it from determining how the surface structure is related to the measured chemical properties. For example, how the changing morphology of the surface during a depth profile could influence the measured composition would be challenging to determine using XPS.

Integrating complimentary information from other experimental techniques, while unable to match the surface selectivity of XPS, can overcome these spatial limitations. Electron microscopy can provide high resolution imaging, with elemental composition provided by energy dispersive X-ray microanalysis, but without the same surface selectivity seen with XPS or Auger electron spectroscopy (AES). This technique is an ideal complement to XPS analysis, provided spatial correlation on areas of interest can be achieved. Expanding beyond the electronic structure measurement of XPS is another pathway that can lead to deeper understanding. Molecular spectroscopy, such as FTIR or Raman, can provide such complementary information to XPS, albeit with different sampling depths, which can be extremely useful to validate measurements or confirm particular molecular structures.

In this presentation we will describe such correlative analysis, implemented both by instrumentation and software. The instrumental approach involves measuring samples in a single instrument designed to integrate XPS with reflected electron energy loss spectroscopy (REELS), low energy ion scattering (ISS or LEIS), and Raman spectroscopy. The software approach involves correlating data from SEM analysis with data from separate surface analysis instruments in an automated fashion. With both methodologies will show how the combination of XPS, Raman and SEM can be used to characterize samples. The examples will be focused on 2D nano-materials, geological materials, polymer structures and materials for clean energy, as well as investigate corrosion in critical aeronautical components. These examples highlight the insights gained from a correlative multi-technique, above individual analyses.

Oral Presentation:

SURFACE ACTIVATION AND BONDING INTERFACE ANALYSIS TECHNIQUE FOR FUSION AND HYBRID WAFER-TO-WAFER BONDING

Andrew Tuchman, Joshua Peck, Adam Gildea, Chris Netzband, and Ilseok Son

TEL Technology Center, America, LLC

Email: Andrew.Tuchman@us.tel.com

Wafer-to-wafer bonding using a surface activation plasma is a key enabler for 3D integration. Wafer bonding quality is determined by dual cantilever beam (DCB) testing; however, DCB is influenced by environmental/human factors and prone to large error (>20%). Here, we demonstrate a novel, automated measurement and analysis to remove these factors and deliver industry leading accuracy (<5% error) and throughput (>100x).

In direct wafer-to-wafer bonding, wafers are bonded together using a room temperature surface activation plasma (SAP), followed by a low temperature post-bond anneal (<400 ^{o}C) to form permanent bonds across the bonding interface. There are several methods for characterizing the interface bonding energy, but the DCB method is widely used due to its simplicity and cost-effectiveness. In DCB, a razor blade is inserted between two bonded wafers, and bonding energy is derived from the length of the resulting crack. Due to human and environmental factors, the error in DCB is often too large to make accurate and consistent measurements. The main environmental factor is stress corrosion where ambient water reacts with stressed siloxane bonds in the interface to prematurely break bonds causing the BE to decrease over time. This means the bonding energy over time is proportional to the ambient humidity. Humidity can be removed using a glovebox, but this significantly reduces throughput due to purge times and increases complexity and cost. Here, we automate the crack length measurement in DCB to remove human measurement errors and develop a novel method to remove the impact of stress corrosion without a glovebox. This technique also allows us to detect residual water in the bonding interface. Using our new technique, the bonding energy of fusion and hybrid bonded wafers are measured with <5% error and provide crucial feedback for improving wafer bonding quality.

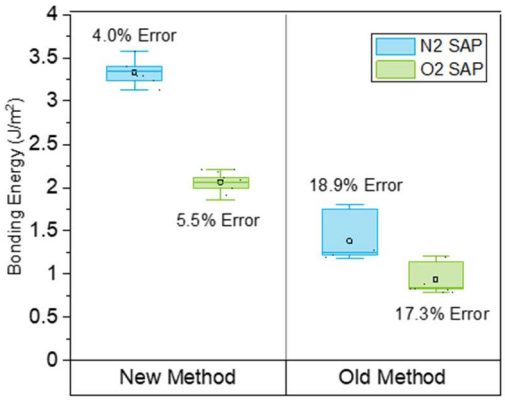


Fig 1. Bonding Energy of Fusion Bonded SiO_2 Wafers Treated by a N_2 or O_2 SAP.

Oral Presentation:

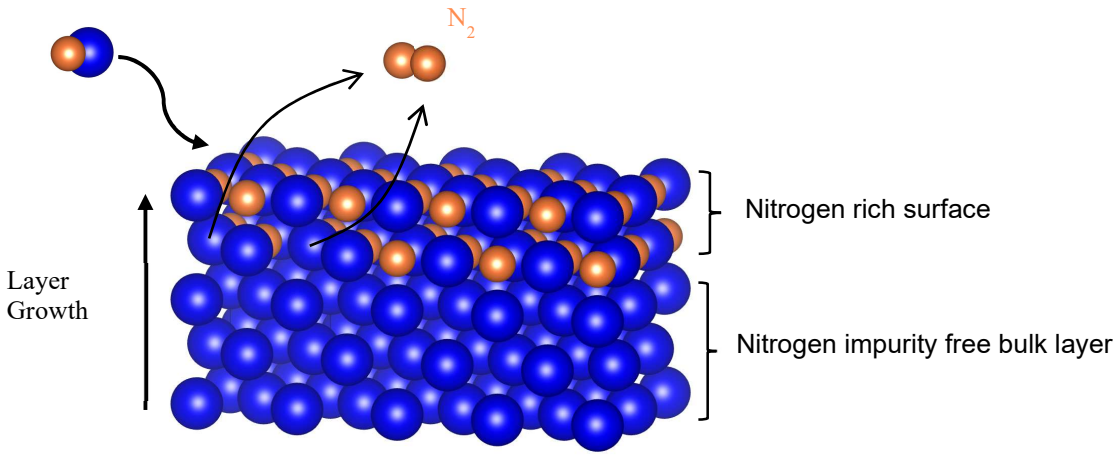
SYNTHESIS AND ELECTRON TRANSPORT IN EPITAXIAL CUBIC Co(001)/MgO(001) LAYERS AS POTENTIAL INTERCONNECT CONDUCTOR

Anshuman Thakral and Daniel Gall

Department of Materials Science and Engineering
Rensselaer Polytechnic Institute, Troy, NY 12180

Email: thakra@rpi.edu

The phase composition of Co layers deposited by magnetron sputtering is studied as a function of processing gas (Ar or N_2), temperature T_s = 100-600 °C, and substrate [Al_2O_3(0001), MgO(001) and SiO_2/Si] in order to determine the energetics for synthesis of metastable fcc cobalt which has been theoretically predicted to be the most conductive metal in the limit of narrow interconnect lines. Nitrogen gas facilitates the growth of the metastable cubic phase particularly at T_s > 200 °C. Cubic MgO(001) substrates suppress nucleation of hcp Co grains, resulting in fcc Co even in an Ar atmosphere. The highest crystalline quality epitaxial fcc Co(001) layers are obtained with deposition on MgO(001) in 5.0 mTorr N_2 using T_s = 400 °C during deposition, followed by vacuum annealing at 500 °C. The resistivity size effect in FCC Co is quantified with transport measurements at 295 and 77 K. Data fitting with the Fuchs-Sondheimer model of the measured resistivity ρ vs thickness d = 5 – 1000 nm for single-crystal Co(001)/MgO(001) layers indicates an effective electron mean free path λ_{eff} = 27± 2 nm at 295 K and a room-temperature bulk resistivity ρ_o = 6.4 ± 0.3 μΩ-cm. At 77 K, the reduced electron-phonon scattering yields a smaller ρ_o = 1.3 ± 0.1 μΩ-cm and a larger λ_{eff} = 79 ± 6 nm. The resulting benchmark quantity $\rho_o\lambda_{eff}$ = 17.4×10 16 and 10.2×10 16 Ω-m^2 at 293 and 77 K, respectively, is 4-6 times larger than the first-principles predictions. The measured ρ_o for fcc Co is identical to that of the stable hcp Co phase. However due to the high effective mean free path and resulting high $\rho_o\lambda_{eff}$ values, cubic Co does not outperform hcp Co for interconnect applications. The developed method for growth of epitaxial fcc Co(001) layers provides opportunities to study this metastable material for potential spintronic applications.



Oral Presentation:

ADVANCING $Cs_3Bi_2I_9$ PEROVSKITE SOLAR CELLS: INSIGHTS FROM MULTIFACETED CHARACTERIZATION AND MACHINE LEARNING ANALYSIS

Ankit Choudhary, Alex Mohan, John Bace, and Dr. Haralabos Efstathiadis

College of Nanotechnology, Science and Engineering;
University at Albany - State University of New York

Email: achoudhary@albany.edu

This study focuses on $Cs_3Bi_2I_9$, a zero-dimensional perovskite absorber material with great potential for photovoltaic applications. We employed Machine Learning (ML) techniques to understand and optimize the performance of $Cs_3Bi_2I_9$ perovskite solar cells. A prepared sub-dataset comprising 26,457 experimentally developed perovskite solar cell device data was utilized for ML calculations. The cleaned dataset contained 29 features and four target variables, including open circuit voltage (Voc), short circuit current density (Jsc), fill factor (FF), and power conversion efficiency (PCE). Among the models, Random Forest Regressor showcased the best performance. Predicted values for Voc, Jsc, FF, and PCE were determined to be 0.562 V, 9.544 mA/cm^2, 0.508, and 5.356%, respectively.

We characterized the different layers of the device using techniques such as X-ray Photoelectron Spectroscopy, Ultraviolet-Visible Spectroscopy, Atomic Force Microscopy, and Ellipsometry to gain insights into the individual layers' properties. The absorber layer bandgap was found to be 1.6-1.9 eV, which indicates that $Cs_3Bi_2I_9$ exhibits favorable characteristics for indoor photovoltaic applications. Preliminary tests on the solution-processed spin-coated complete solar cells have shown a power conversion efficiency of 3.63%. These initial results indicate the potential of $Cs_3Bi_2I_9$ as a viable material for solar cell applications.

Oral Presentation:

ANALYSIS OF OXIDE FORMATION ON RU THIN FILMS AFTER DEVICE FABRICATION PROCESSING TECHNIQUES

Randall Wheeler[1], Anthony Valenti[1], Carl A. Ventrice, Jr[1], Matthew Strohmayer[2], Joleyn Brewer[2], Christopher Nassar[2], and Christopher Keimel[2]

[1]Department of Nanoscale Science and Engineering, University at Albany - SUNY
[2]Menlo Micro, Inc.

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MEMS are micron-scale devices with moving parts. Ru is often used as the electrical contact material in MEMS devices because its native oxide is electrically conductive and has a high hardness. To better understand the effect that processing techniques such as RIE, plasma ashing, and annealing in air have on the stoichiometry, thickness, and geometric structure of the oxide, angle-resolved XPS, TOF-SIMS, and AFM measurements have been performed. The Ru films are deposited on SiO_2/Si(100) substrates. XPS analysis of the as-grown Ru film indicates that the native oxide is less than a nm thick and is in a 2^+ state. Annealing the as-grown film at 350 °C in air results in the formation of a 2.5 nm thick surface oxide, which is primarily composed of RuO_2. In addition, some higher order oxides are present. Performing a RIE or ashing process on the as-deposited Ru film also results in the formation of a thin RuO_2 film with higher order oxides. The oxide thickness after the ashing process depends on the processing parameters but is typically less than 2 nm. The oxide thickness after RIE is about a nm. The AFM data shows rounded clusters of material both before and after the different processing techniques. The roughness of the films is about 2.5 nm for all of the process techniques except RIE, which is about 1.5 nm.

Oral Presentation:

ENGINEERING OF ERBIUM-IMPLANTED LITHIUM NIOBATE FILMS FOR INTEGRATED QUANTUM APPLICATIONS

Souryaya Dutta [*], Alex Kaloyeros[*], and Spyros Gallis

College of Nanotechnology, Science, and Engineering (CNSE),
Department of Nanoscale Science and Engineering,
University at Albany (UAlbany), NY 12222, USA

[*]Indicates equal contributions

Email: sdutta4@albany.edu

Rare-earth-doped materials have garnered significant attention as material platforms in emerging quantum information and integrated photonic technologies. Concurrently, advances in its nanofabrication processes have unleashed thin film lithium niobate (LN), $LiNbO_3$, as a leading force of research in these technologies, encompassing many outstanding properties in a single material. Leveraging the scalability of ion implantation to integrate rare-earth erbium (Er^{3+}), which emits at 1532 nm, into thin film lithium niobate can enable a plethora of exciting photonic and quantum technologies operating in the telecom C-band. Many of these technologies also rely on coupling via polarization-sensitive photonic structures such as waveguides and optical nanocavities, necessitating fundamental material studies.

Toward this goal, we have conducted an extensive study on the role of implantation and post-implantation processing in minimizing implantation-induced defectivity in *x*-cut thin film LN. By leveraging this, we have demonstrated an ensemble optical linewidth of ~140 GHz of the Er emission at 77 K. Our demonstration showcases the effectiveness of our ion implantation engineering in producing cutting-edge Er emission linewidth in thin film LN at higher temperatures compared to values reported for diffusion-doped bulk materials at liquid helium temperatures (~3 K). Furthermore, we show that the Er photoluminescence (PL) is highly polarized perpendicular to the *x*-cut LN *c*-axis through a systematic and combinational PL and high-resolution transmission electron microscopy (HRTEM) study. These results indicate that using Er rare-earth emitters in thin film LN, along with their polarization characteristics and related ion implantation engineering, presents a promising opportunity to produce highly luminescent Er-doped LN integrated photonic devices for nanophotonic and quantum applications at telecom wavelengths.

Poster Presentation:

HARNESSING THERMAL LASER EPITAXY FOR RAPID SYNTHESIS OF TOPOLOGICAL INSULATORS

Finley Donachie and Daniel Gall

Department of Materials Science and Engineering
Rensselaer Polytechnic Institute
110 8th St, Troy, NY 12180

Email: donacf@rpi.edu

This poster presents the plans of Dr. Austin Minnich's laboratory at the California Institute of Technology for the construction of the first thermal laser epitaxy (TLE) system in the United States, a move that stands to revolutionize the synthesis of quantum materials. The Minnich lab intends to leverage TLE to craft topological insulators (TIs) of unparalleled purity, incorporating refractory elements and precipitating an era marked by the discovery of materials with novel properties. This venture is paralleled solely by the prestigious Forschungszentrum Jülich in Germany, the only other facility to boast a TLE system. Through the strategic inclusion of refractory compounds such as TaAs, $NbSe_2$, and WTe_2, TLE is set to broaden the horizons of TIs and catalyze rapid progress in the realms of quantum science and technology.

The developed TLE technology aims to achieve unprecedented deposition rates, up to 1 monolayer per second for tungsten, by employing high-intensity source and substrate lasers. This technique, proficient in attaining substrate and target temperatures in excess of 3000 °C, promotes a uniform thermal gradient across the deposition surface, which is critical for the kinetic processes that govern the growth and quality of the material layers. By forgoing the traditional molecular beam epitaxy requirement for an effusion cell and using the target material itself as a containment vessel, TLE promises a cleaner process environment.

Poster Presentation:

COMPARING OCTANETHIOL GOLD NANOPARTICLE DEPOSITION TECHNIQUES FOR ELECTRONIC NOSE FABRICATION: INKJET PRINTING VS. DROP CASTING

Md. Delowar Hossain, Grasso John, and Brian G. Willis

Department of Chemical and Biomolecular Engineering
University of Connecticut, Storrs, CT

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The main goal of our research is to produce a sensor array with different chemistries to develop an electronic nose that will generate unique responses smelling different vapors. The major challenges to produce unique responses are to choose suitable sensing materials, deposit selected materials on sensor array, minimize moisture interference, extract signal from trace sample concentration, and differentiate responses of different compounds. This study focuses on implementing 1-octanethiol gold nanoparticles (OT-AuNPs) as chemiresistive sensors and comparing inkjet printing process and conventional drop casting process to detect volatile organic compounds (VOCs) and explosives. We discuss, the prospects of inkjet printing technology to achieve our research goal.

Inkjet printing technology potentially offers more controlled deposition and uniform distribution of OT-AuNPs compared to a drop casting process. We find a minimum of 200 layers of 2.4 picoliters droplet with 9 drops per layer and 60 μm drop spacing necessary to reduce device resistance to less than $10^6\Omega$ with low standard error. In contrast, 12 μL OT-AuNPs drop casting declined the device resistances below $\sim 10^7\Omega$. Figure-1a shows, response magnitudes of explosives increase with decreasing device resistances. With inkjet printing, 89 - 92% OT device yield was achieved to detect explosives (hexa-methylene triperoxide diamine (HMTD), penta-erythritol tetra-nitrate (PETN), potassium chlorate (KClO3), tri-acetone tri-peroxide (TATP), royal demolition explosive (RDX), 2,4,6-trinitrotoluene (TNT), urea nitrate (UN), and silica (Blank)), whereas 68-94% of 12μL OT-AuNPs drop casting devices detected these explosive vapors. Experimental findings indicate OT-AuNPs inkjet printed devices are more reproducible and repeatable than drop cast devices. Overall, OT-AuNPs inkjet printed devices are promising to use in sensor arrays to fabricate electronic nose for VOCs and explosives detection. Future work will expand to new chemistries for more diverse chemical sensor arrays.

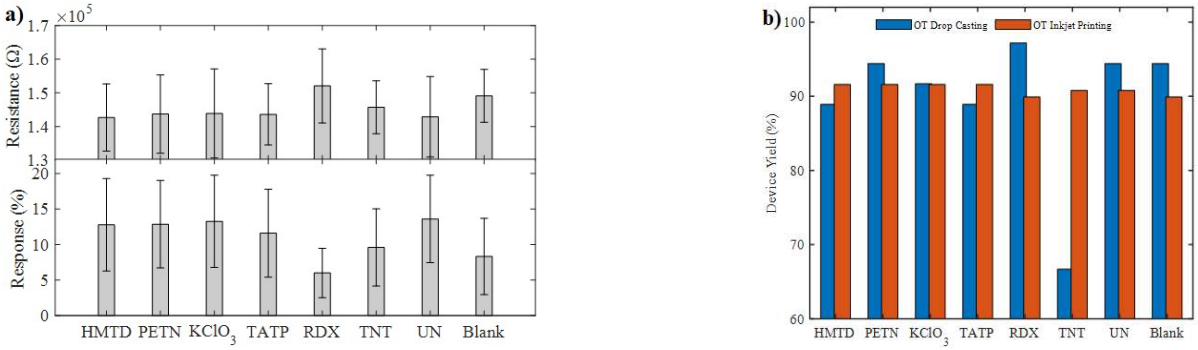

Figure 1: a) OT-AuNPs inkjet printed device responses to explosive vapors b) OT-AuNPs inkjet printed versus drop cast device yields for explosives detection

Poster Presentation:

DESIGN AND CONSTRUCTION OF A SPUTTER DEPOSITION SYSTEM TO EXPLORE NEW INTERCONNECT MATERIALS

Jack Coyle, Emma Sponga, Finley Donachie, Daniel Syracuse, and Daniel Gall

Department of Materials Science and Engineering
Rensselaer Polytechnic Institute
110 8th St, Troy, NY 12180

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This project focuses on the design, construction, and assembly of a new dual chamber ultrahigh vacuum magnetron sputter deposition system. The new system is designed for epitaxial and polycrystalline thin film growth of metals, alloys, nitrides, and borides with its custom-made gas lines and programable mass flow controllers. The dual chamber set up, consisting of a load lock and deposition chamber separated by a gate valve, allows for high throughput of depositions. It also has two sets of power feedthroughs giving the system the capability of sample heating and biasing during deposition. These characteristics render the deposition system highly appropriate for investigating a variety of potential interconnect materials and interfaces, while maintaining control over crystalline quality and surface morphology. Such capabilities enable the quantification of electron interface scattering and the assessment of the back-end-of-line resistivity size effect.

Poster Presentation:

TEMPLATE-DIRECTED CRYSTALLIZATION OF AlSb/Sb(A7) PCM FOR LOW ENERGY SWITCHING

I.K. Shuvo, H. Gong, V. Tokranov, M. Yakimov, and S. Oktyabrsky

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Reduction of the programming current and energy of phase change memory (PCM) is one of the critical needs for further scaling of PCM arrays for big data applications. Recently, Al-Sb binary alloys crystallizing with phase separation into zinc-blende III-Sb and rhombohedral (A7) Sb-rich phase have shown significant progress with improved resistance contrast (>1000), multiple programming states, low switching energy, low drift, and high reliability when compared to the most widely studied Ge-Sb-Te (2-2-5) PCM alloy. Deposition from molecular beams under ultra-high vacuum conditions allowed for the fabrication of the entire PCM stack *in situ* on Si-foundry-prepared templates of ~100 nm diameter. To reduce programming current and energy we used a hetero-structured Sb(4nm)/AlSb(20nm) stack where resistance programming can be controlled by the melting and crystallization of just the Sb-rich layer with low (T_m=631°C) melting temperature while keeping AlSb (T_m=1160°C) crystallized through the PCM cycling. This bilayer PCM cell has shown extremely low pulse energies in amorphization /crystallization (RESET/SET) cycles with programming pulses of 150mA/10ns and 80mA/250ns, respectively. RESET energy of as low as 2.4pJ for 100x resistance swing was demonstrated. Further on, we explored the possibility of using the crystalline AlSb as a template for Sb-rich phase crystallization. The development of MBE growth of oriented layers on an amorphous or polycrystalline substrate provided Sb_2Te_3/AlSb and Sb_2Te_3/Sb pairs with aligned Van der Waals gaps. Finally, the epitaxial crystallization of Sb(012) on AlSb(111) was demonstrated and provides the route for the template-directed operation of the PCM cells with presumably low stochasticity.

Poster Presentation:

SECONDARY ELECTRON YIELDS, ELECTRONIC STRUCTURE AND CHEMICAL ENVIRONMENT OF SURFACES

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Low energy electrons (< 50 eV) are ubiquitous and impact a host of scientific and technological fields. They induce chemical reactions in biological molecules, limit the minimum size of semiconductor devices, initiate cascades in particle detectors, govern the performance of electron microscopes, create and destroy molecules in interstellar space, or even build static charge on orbiting spacecraft. Despite the central role they play in so many areas of science and technology, the intrinsic interaction mechanisms of low energy electrons with solid surfaces is poorly understood and is currently limiting technological breakthroughs.

We have developed a platform able to correlate the yield of secondary electrons generated from incident electrons to the electronic structure and chemical properties of surfaces. Surface properties are assessed using X-ray and UV-photoemission spectroscopies, electron energy loss spectroscopy and work function measurements, and are interpreted in the light of ab-initio calculations of the electronic structure.

Two case-studies are considered. First, discrepancies in secondary electron yields (SEYs) reported in the literature are numerous and are often due to poor surface characterization. Here, we demonstrate the sensitivity of SEYs to the surface properties of two surfaces Al and Ag, measured clean and after exposure to ambient air. In a second example, we characterize the chemical transformation of polymethyl methacrylate films exposed to electrons and correlate the film's alteration to SEY evolution.

Poster Presentation:

SAMPLE STAGE DESIGN FOR SPUTTER DEPOSITION OF NEW INTERCONNECT MATERIALS

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This project focuses on the design, machining, and assembly of a custom sample stage for a dual chamber ultrahigh vacuum magnetron sputter deposition system. The new system is specifically designed for epitaxial and polycrystalline thin film growth of metals, alloys, nitrides, and borides. Custom stage parts have been machined and built in undergraduate machine shops. The sample stage features high-temperature sample heating (1200°C), a sample transfer mechanism, an option for centering the sample to one or two magnetrons, and sample biasing for ion bombardment. These features make the sample stage well suited to explore a variety of potential interconnect materials and interfaces with controlled crystalline quality and surface morphology. This will allow for the quantification of electron interface scattering and the back-end-of-line resistivity size effect.

Poster Presentation:

FABRICATION OF DOPED NbO_2 THRESHOLD SWITCHES FOR NEUROMORPHIC COMPUTING

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Neuromorphic architectures show great potential to reduce power usage through innovative use of resistive devices such as resistive random access memory (ReRAM) or phase change memory (PCM), which are used as artificial synapses. However, the CMOS overhead in implementing artificial neurons (neuristors) is impeding a broader adoption. The volatile switching characteristic of NbO_2 can be harnessed to build neuristors and thus improve neuromorphic architectures by reducing their area and power consumption. The purpose of this project is to stabilize NbO_2 and to improve switching parameters such as threshold and hold voltage, linked to insulator to metal transition (IMT) temperature, and resistance via doping.

We developed a reactive co-sputtering process to dope NbO_2 ($X:NbO_2$) with a transition metal in a range of concentrations. The NY CREATES / UAlbany Memory Test Vehicle was used to build nanoscale devices and integrate a TiN bottom electrode on which $X:NbO_2$ and the Ir top electrode are deposited. A patterning step finishes the device structure. The power applied during sputtering of Nb and X had to be optimized to get the desired composition and thickness of the film. The devices were electrically characterized after an annealing step in N_2 atmosphere. XRD measurements were performed to verify the deposition of the correct phase.

Poster Presentation:

ELECTRON SCATTERING AT Ru(0001) SURFACE: IMPACT OF Ti CAPS AND OXYGEN EXPOSURE

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Electron scattering at the interface between interconnect metals and liners or dielectrics is quantified to determine optimal materials that minimize the interconnect resistance and maximize back-end-of-line energy efficiency. In situ transport measurements are employed to examine the impact of surface chemistry on electron scattering at Ru(0001) surfaces. The sheet resistance R_s of epitaxial 7-nm-thick Ru(0001)/Al_2O_3(0001) films with and without Ti cap layers (0.08-3.0 nm thick) is continuously measured during controlled low-pressure 0.05 mTorr O_2 exposure experiments. Remarkably, pristine Ru(0001) surfaces exhibit a marginal (1%) increase in R_s upon oxygen exposure, highlighting the surface's resilience. The addition of Ti capping layers also causes an initial increase in Rs, attributed to the initiation of partially diffuse surface scattering via electron interactions with localized interface states. Intriguingly, subsequent O_2 exposure attenuates this sheet resistance increase, as the oxidation of Ti mitigates the local interface density of states, thus promoting specular scattering and diminishing Ru resistivity. These findings illustrate the potential of interface density state engineering as a strategic avenue to maximize conductivity in narrow metal interconnect lines, emphasizing the important role of surface chemistry and electron scattering in improving semiconductor technology.