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2018 Fall Meeting
Hudson Mohawk AVS Chapter
Tuesday, October 16, 2018
3:30 – 7:50 PM

CESTM Auditorium and Rotunda
Colleges of Nanoscale Science and Engineering
SUNY Polytechnic Institute
257 Fuller Road
Albany, New York 12203

Meeting Agenda*:

3:30 PM – 4:00 PM	Reception and registration
4:00 PM – 4:05 PM	Introductory Comments
4:05 PM – 5:45 PM	Oral Presentations
5:45 PM – 7:15 PM	Poster presentations and networking with pizza and beverages
7:15 PM – 7:20 PM	Awards Ceremony
7:20 PM – 7:50 PM	AVS Hudson Mohawk Chapter Executive Committee Meeting

Complete presentation schedule is available in the next page.

*Presentation Schedule:
(Talks are of 15 minutes with 5 more minutes for Q&A.)

3:30 – 4:00 PM	Reception and registration (coffee and cookies served)
4:00 – 4:05 PM	Introductory Remarks
4:05 – 4:25 PM	Xin Sun - METALORGANIC VAPOR PHASE EPITAXY OF CdTe THIN FILMS ON GRAPHENE AND MICA THROUGH CHEMICAL AND VAN DER WAALS MIXED INTERACTIONS
4:25 – 4:45 PM	Tuo Gao - RAPID AND SCALABLE CHEMICAL SPECTROMETER FOR ORGANIC VAPOR DETECTION WITH LARGE CHEMIRESISTOR ARRAY
4:45 – 5:05 PM	Natasha Tabassum - MODULATION OF ERBIUM EMISSION AT 1540 NM WITH DETERMINISTICALLY POSITIONED ULTRATHIN NANOWIRE-BASED SIC PHOTONIC CRYSTAL STRUCTURES FOR APPLICATIONS IN QUANTUM INFORMATION TECHNOLOGY
5:05 – 5:25 PM	Matthew Strohmayer - DEVELOPMENT OF FOCUSED ELECTROHYDRODYNAMIC PRINTING TECHNOLOGY
5:25 – 5:45 PM	Chengwu Zhang - SELECTIVE ALD FOR PLASMONIC METALLIC NANOARRAYS
5:45 – 7:15 PM	Poster Presentations (pizza and refreshments served)

Oral Presentations

METALORGANIC VAPOR PHASE EPITAXY OF CdTe THIN FILMS ON GRAPHENE AND MICA THROUGH CHEMICAL AND VAN DER WAALS MIXED INTERACTIONS

Xin Sun[1*], Dibyajyoti Mohanty[1,2], Zonghuan Lu[1], Yu Xiang[1,3], Yiping Wang[4], Lihua Zhang[5], Kim Kisslinger[5], Jian Shi[1,4], Lei Gao[6], Morris Washington[1,3], Gwo-Ching Wang[1,3], Toh-Ming Lu[1,3] and Ishwara Bhat[1,2]

[1]Center for Materials, Devices, and Integrated Systems, [2]Electrical, Computer and Systems Engineering Department, [3]Physics, Applied Physics and Astronomy Department, [4]Material Science and Engineering Department, Rensselaer Polytechnic Institute, Troy, NY 12180, USA
[5]Center for Functional Nanomaterials, Brookhaven National Laboratory, P.O. Box 5000, Upton, NY, 11973, USA
[6]Corrosion and Protection Center, Key Laboratory for Environmental Fracture (MOE), University of Science and Technology Beijing, Beijing 100083, China

*sunx12@rpi.edu

High quality heteroepitaxy of CdTe is challenging due to lattice mismatches of CdTe with many substrates. In this talk, we demonstrate the epitaxial growth of single crystalline CdTe films on graphene and mica using metalorganic chemical vapor deposition, regardless of large in-plane lattice mismatches between CdTe(111) and graphene and between CdTe(111) and mica(001). X-ray diffraction, reflection high-energy electron diffraction, electron backscatter diffraction (EBSD), and transmission electron microscopy coherently suggest that CdTe is epitaxially aligned with graphene and mica: out-of-plane CdTe(111)//graphene base plane, CdTe(111)//mica(001); in-plane CdTe [-12-1]//graphene [10], CdTe [-12-1]//mica [010]. Grain size in excess of 250 μm is observed by EBSD in CdTe films on mica, larger than most observations reported in the literature. The interface interactions between CdTe and graphene and between CdTe and mica are examined by density functional theory. Calculations indicate that the former case is van der Waals interaction dominating. In the latter case, however, chemical interaction contributes ~80% of the total interfacial energy. We conclude that the nature of interface interactions dictates crystal quality of CdTe films. The demonstrated epitaxy of semiconductors on van der Waals substrates implies potential for flexible optoelectronic devices.

RAPID AND SCALABLE CHEMICAL SPECTROMETER FOR ORGANIC VAPOR DETECTION WITH LARGE CHEMIRESISTOR ARRAY

Tuo Gao[1], Chengwu Zhang[1], Yongchen Wang[2], Zachariah Pittman[1], Alexandra Oliveira[1], Jing Zhao[2], Brian G Willis[1]

[1]Department of Chemical and Biomolecular Engineering, [2]Department of Chemistry,
University of Connecticut, Storrs, Connecticut, USA 06269

High-speed, miniaturized, portable chemical sensors have a wide range of application in environmental monitoring, homeland security, food safety, and health screening. Specifically, metal nanoparticles with self-assembled organic-functional monolayers (SAM) have provided the ability to detect volatile organic compounds with fast responses. As rapid-developing sensing elements, organo-functionalized metal-nanoparticles (NP's) transduce vapor sorption in SAM layers into measurable electrical signals. To achieve good selectivity and sensitivity toward various analytes, diverse metal-ligand pairs are essential to construct high-order chemiresistive sensor arrays that give broad resolution against many different types of molecules. It is important to incorporate different ligand functionality into single chip sensors to understand the affinity of sensing materials toward different analytes. This work presents a detailed study on vapor sensing performance with 4 types of amine-functionalized gold nanoparticles along with chemical pattern recognition.

Castellated microelectrodes with 2-µm gap size and nanostructure with 50-nm gap size were fabricated by lithography processes on silicon wafer with 300-nm thermal oxide. Thin films of 10-nm titanium and 200-nm gold were deposited by electron-beam evaporation to create electrical contacts. The final features were obtained through metal lift-off. For electrical property measurement, a custom-made probe card was designed to fit on the contact pads around the chip. A maximum of 48 sensors from the same chip can be monitored simultaneously.

In this study, we present a robust and accurate sensor platform by integration of metal-nanoparticle sensing elements into a dense array of chemiresistor to detect and differentiate 20 organic vapor analytes, which cover a wide range of chemicals. These chemiresistive sensors were assembled by direct drop-casting method with micropipette using 4 types of amine-functionalized gold nanoparticles with different carbon-chain length. Simultaneous monitoring of real-time sensing performance ($\Delta R/R$) of 48 sensors were recorded using a switch matrix and multimeter. Saturated vapor of each chemical was delivered by a syringe pump and mixed with nitrogen stream at headspace of the sensor chip. Working sensors with a $\Delta R/R$ of 10-100% were achieved with baseline resistances (R_0) of 10^4-10^7 Ω. Pattern recognition is evaluated by principal component analysis (PCA) and linear discriminant analysis (LDA). The results show 80% accuracy for single-type gold nanoparticle assembly. These results provide useful insights for scaling up nanoparticle integration with many different metal-ligand pairs to further improve the low-cost, miniaturized, high-speed chemical detection and monitoring process.

Oral Presentations

MODULATION OF ERBIUM EMISSION AT 1540 NM WITH DETERMINISTICALLY POSITIONED ULTRATHIN NANOWIRE-BASED SIC PHOTONIC CRYSTAL STRUCTURES FOR APPLICATIONS IN QUANTUM INFORMATION TECHNOLOGY

Natasha Tabassum[1], Mounika Kotha[1], Edward Crawford[2], Vidya Kaushik[1], Vasileios Nikas[1] and Spyros Gallis[1]

[1]Colleges of Nanoscale Science & Engineering, SUNY Polytechnic Institute, Albany, New York 12203, USA
[2]GLOBALFOUNDRIES Corp., East Fishkill, New York 12533, USA

Recent research attempts to realize quantum devices, such as quantum memories, and single photon sources, for long-distance quantum information and communication technologies at low-loss telecom C-band wavelength ~1540 nm are limited by their unsuitable emission wavelength, random placement of emitters, in addition to their stringent fabrication and operation temperature requirements. Rare-earth-ions, particularly erbium ions, are one of the most promising candidates as quantum emitters in solid hosts because of their intra-*4f* transitions at the technologically significant wavelength of ~1540 nm. We have fabricated a new class of silicon carbide (SiC) nanowire-array-based photonic crystal (NW-PC) structures, grown in a self-aligned manner at predetermined positions through an innovative chemical synthesis route, where the width of each NW (< 20 nm) does not depend on lithographic-transfer techniques. These nanostructures not only facilitate the deterministic placement of erbium ions in the nanowires but are also pivotal in engineering the erbium-induced 1550 nm emission. To this end, this report focuses on a comparitive study of the modified spontaneous emission properties of Er^{3+} ions in NW-PC structures, exhibiting high pumping efficiency, high room-temperature photoluminescence (PL) yield, and excellent photostability. The structural characterizations by means of Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible spectroscopic ellipsometry (UV-VIS-SE), X-ray diffractometry (XRD), transmission electron microscopy (TEM), and atomic force microscopy (AFM) confirmed the high quality polycrystalline 3C phase of SiC host material. Through a combinational and systematic study of power-dependence PL (PDPL), time-resolved PL (TRPL), temperature-dependence PL (TDPL), and finite-difference time-domain (FDTD) calculations, the effects of the photonic bandgap and the bulk-defect density on erbium PL yield in the near-infrared range (~1540 nm) were explored. By engineering the geometry of 20 nm SiC NW-PC structures, both experimental results and numerical calculations showed the modulation of the 1540 nm emission as a function of the periodicity of the structures. Approximately 60-fold enhancement of the room-temperature 1540 nm PL was observed coupled with a 30-fold increase of the lifetime in SiC NW-PC structures compared to its thin-film counterpart. The fundamental understanding of erbium emission in these photonic nanostructures can expedite the incubation of pathways towards ubiquitous advances in silicon-based nanophotonics, defect-based biological imaging and sensing, quantum storage of single-photons and long-distance quantum signal processing.

SELECTIVE ALD FOR PLASMONIC METALLIC NANOARRAYS

Chengwu Zhang*, Jie Qi, Tuo Gao and Brian Willis

Chemical & Biomolecular Engineering,
University of Connecticut, Storrs, CT, 06269, USA.
*chengwu.zhang@uconn.edu

Plasmonic metallic nanostructures can be designed to concentrate and manipulate light at nanoscale by their interactions with resonant photons through exciting surface plasmons. Arrays of metallic nanostructures have applications in the field of chemical and biological sensing, photon-driven chemical conversion, optical information processing and surface enhanced spectroscopy. The electric field between nanoantennas can be greatly enhanced by decreasing the gap. Atomic layer deposition (ALD) is characterized by producing conformal thin films with precisely controlled thickness and composition at atomic level. In this work, we use selective ALD to investigate deposition behavior in metallic nanoarrays.

We present a case study of Cu selective ALD on Pd-Au antenna nanoarrays. The SEM images show different grey contrast: left nanostructures (Au) and right nanostructures (Pd). After Cu deposition, right nanostructures (Pd) become bigger and rounded, while left nanostructures (Au) and substrate almost stay as before. It indicates Cu selectively deposits on Pd, not Au or the substrate. Quantitively surface area of Pd nanostructures has increased by 68.9%, while that of Au nanostructures has increased by 13.9%.

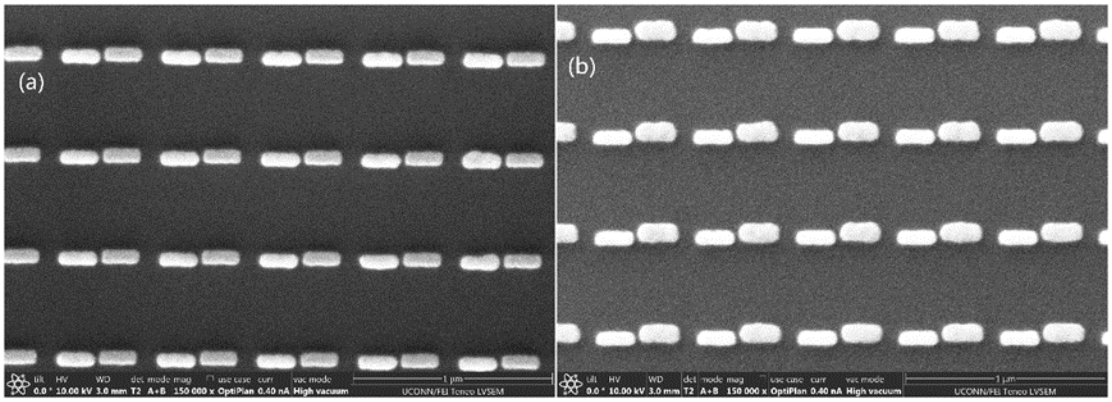


Figure 1. SEM images of pre- (a) and post-ALD (b) of Pd-Au nanoarrays.

DEVELOPMENT OF FOCUSED ELECTROHYDRODYNAMIC PRINTING TECHNOLOGY

Matthew Strohmayer[1*], Atul Dhall[1], Pujhitha Ramesh[1], Amir Rastegar[2],
Natalya Tokranova[1], and Carl A. Ventrice, Jr.[1]

[1]Colleges of Nanoscale Science & Engineering, SUNY Polytechnic Institute, Albany NY
[2]Department of Biomedical Engineering, Stony Brook University, Stony Brook, NY

*mstrohmayer@sunypoly.edu

Additive manufacturing, also referred to as 3-D printing, shows great promise for both research and industrial applications. The main advantages of 3D printing include limited waste and the ability to build complicated structures. In addition, for rapid prototyping this is typically the fastest technique for producing parts. The most common techniques for 3-D printing are fused deposition manufacturing (FDM), digital light printing (DLP), and ink jetting (termed 3DP). All of these techniques suffer from resolution and material limitations. On the other hand, two-photon polymerization (2PP) 3D printing can reach nanoscale resolution (hundreds of nanometers) but is prohibitive in cost. Recently, a cost-effective, versatile method of high-resolution printing called electrohydrodynamic (EHD) printing has been introduced. This method allows for spatial resolution in the hundreds of nanometers (and possibly lower). This method works similarly to a typical ink jetting system, except instead of the ink/polymer being pushed out of a tip, it is pulled out by an applied electric field. This allows for the resultant droplet to be smaller than the needle diameter, which is in part responsible for the high resolution achieved. Coulomb's law, leading to the space charge effect, limits the ultimate resolution of this technique. To overcome this resolution limitation, a method for focusing the droplets is being developed. This should significantly increase the resolution of the printed features by helping the droplets overcome the repulsive force from Coulomb's law, thus limiting the space charge effect and leading to better spatial resolution. This approach will, in addition, allow an EHD system to run in an electrospray mode, which will greatly increase patterning throughput.

Poster presentation

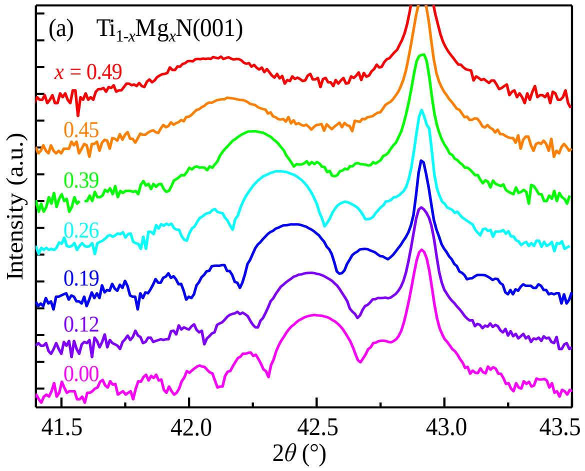
FULLY STRAINED EPITAXIAL $Ti_{1-x}Mg_xN$/MgO(001) LAYERS GROWN BY REACTIVE MAGNETRON SPUTTER DEPOSITION

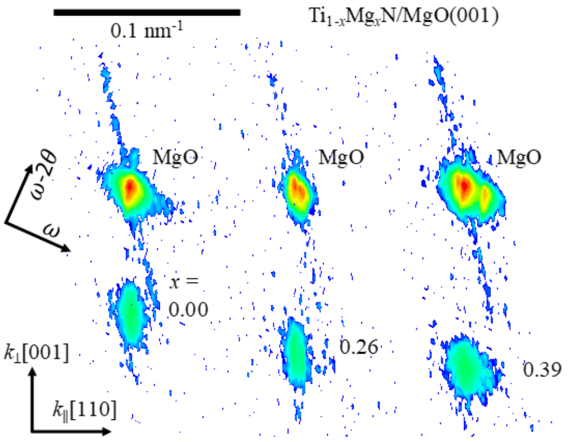
Baiwei Wang* and Daniel Gall

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

*wangb12@rpi.edu

The goal of this research is to investigate the interdependence of strain relaxation with thickness and composition for $Ti_{1-x}Mg_xN$ layers, which is a promising new material system for semiconducting (x = 0.5), thermoelectric and plasmonic devices, without compromising its refractory and CMOS-compatible properties. Single crystal $Ti_{1-x}Mg_xN$(001) layers ($0.00 \leq x \leq 0.49$) were deposited on MgO(001) by reactive magnetron co-sputtering from titanium and magnesium targets in 5 mTorr pure N_2 at 600 °C. X-ray diffraction ω-2θ scans, ω-rocking curves, φ-scans, and high resolution reciprocal space maps show that rock-salt $Ti_{1-x}Mg_xN$ layers are epitaxial single crystals with a cube-on-cube epitaxial relationship with the substrate: $(001)_{TiMgN} \| (001)_{MgO}$ and $[100]_{TiMgN} \| [100]_{MgO}$. $Ti_{1-x}Mg_xN$(001) layers, with thickness $36\text{ nm} \leq d \leq 57\text{ nm}$, are fully strained after deposition, yielding an in-plane lattice parameter $a_{\|} = 4.212 \pm 0.001$ Å and out-of-plane lattice parameters $a_{\perp}$ that increase from 4.259 Å ($x = 0.00$) to 4.289 Å ($x = 0.49$), following a bowing expression $a_{\perp} = (1-x)a_{TiN} + xa_{MgN} - bx(1-x)$, where a_{TiN}, a_{MgN}, and b are fitting parameters determined as 4.255, 4.432, and 0.199 Å, respectively. The in-plane x-ray coherence length $\xi_{\|}$ is large, 156-381 nm, for $0.00 \leq x \leq 0.45$, but drops to 25 nm for $x = 0.49$, indicating local strain variations and a considerable reduction of the distance between threading and/or misfit dislocations when the alloy approaches phase separation. The out-of-plane x-ray coherence length $\xi_{\perp}$ matches the layer thickness. $Ti_{1-x}Mg_xN$(001) layers with a larger thickness ($110\text{ nm} \leq d \leq 275\text{ nm}$) exhibit a mild compressive strain (-0.34% for pure TiN) or are fully relaxed (for alloys), indicating a thickness-induced strain relaxation.





Graduate student presenter

Poster presentation

VISUALIZATION OF METAL/OXIDE/Si INTERFACE ELECTROSTATICS WITH BEEM

Jack Rogers*, Westly Nolting, Vincent LaBella

Colleges of Nanoscale Science and Engineering,
SUNY Polytechnic Institute, Albany, New York 12203, USA
*jrogers@sunypoly.edu

Nanometer thick HfO2/Si is utilized as an MOS gate layer substrate due to the high relative permittivity of hafnium oxide, motivating a need to understand the electrostatic uniformity at these length scales. Nanoscale visualization of the interface electrostatics can be accomplished with ballistic electron emission microscopy (BEEM) and computational modeling. BEEM measures the transmission of electrons through a metal-semiconductor or MOS interface using an STM. Electrons with sufficient energy to pass through the electrostatic barrier contribute to a BEEM current. In this study, the electrostatic barrier for Au/HfO2/Si(001) was visualized at nanometer spatial resolution over a square micron on p-type silicon substrates. Two samples of different oxide thickness (2 monolayers and 4 monolayers) were mapped over a square micron. Both samples showed regions of a high-energy dielectric barrier and a lower-energy, Au/Si Schottky barrier. Computational modeling corroborates the existence of discrete energy peaks associated with the Schottky interface and dielectric. Additionally, XPS measurements were performed to determine the structural composition of the dielectric. These results provide information on the relationship between the structural and electrostatic uniformity of nanometer-thick dielectric films.

Graduate student presenter

Poster presentation

EPITAXIAL GROWTH OF $WC_{1\text{-}x}$(001) THIN FILMS

Peijiao Fang*, Baiwei Wang, Daniel Gall

Department of Materials Science and Engineering, Rensselaer Polytechnic Institute

*fangp@rpi.edu

Epitaxial $WC_{1\text{-}x}$(001) layers were deposited on MgO(001) by reactive magnetron sputtering in a 5 mTorr CH_4 - Ar mixture at 400 °C. A series of ω-2θ scans, ω rocking curves of the $WC_{1\text{-}x}$ 001 reflection, and reciprocal space maps of $WC_{1\text{-}x}$ 113 and MgO 113 indicate an epitaxial cube on cube relationship: $(001)_{WC_{1\text{-}x}} \parallel (001)_{MgO}$ and $[100]_{WC_{1\text{-}x}} \parallel [100]_{MgO}$. The full-width at half-maximum of the rocking curves are < 0.08° for all layers, suggesting an excellent crystalline quality. Increasing the CH_4 partial pressure from 0.05 to 1 mTorr leads to an increase in the measured relaxed lattice constant from 4.225 to 4.262 Å, indicating an increasing carbon concentration in the deposited layers. However, simultaneously, the vertical x-ray coherence length decreases from 19 to 4 nm, suggesting that surface segregated excess carbon may nucleate crystalline defects and/or misoriented grains.

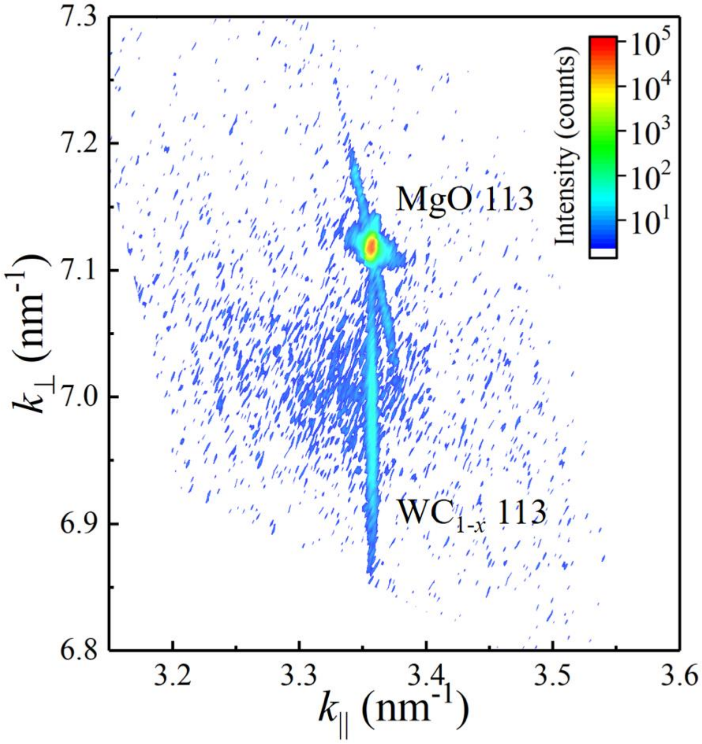


Figure 1: X-ray diffraction reciprocal space map from an epitaxial $WC_{1\text{-}x}$(001)/MgO(001) layer. The vertically aligned $WC_{1\text{-}x}$ and MgO 113 reflections indicate a fully strained layer.

Graduate student presenter

Poster presentation

CONDUCTIVE SURFACE OXIDE IN CrN(001) FILMS

Mary E. McGahay* and Daniel Gall

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

*mcgahm@rpi.edu

Epitaxial CrN(001) layers were deposited on MgO(001) by reactive DC magnetron sputtering in 3 mTorr pure N_2 at 750 °C. Subsequently, they were exposed to a 90% Ar - 10% O_2 mixture with a continuously increasing pressure dp/dt = 0.05 Pa/s to a maximum pressure p = 240 Pa, while simultaneously measuring the sheet conductance G_s at 22 °C. As-deposited layers with thickness d = 10 and 300 nm have an *in situ* measured G_s = 1.8×10^{-5} and 4.3×10^{-4} $[\Omega/\square]^{-1}$, respectively. These values increase during the Ar-O_2 exposure by $\Delta G_s = 5\times10^{-5}$ $[\Omega/\square]^{-1}$ which is independent of d but is negligible for a 300-nm-thick CrN(001) control sample that was capped with an insulating AlN layer prior to oxygen exposure. These results suggest the formation of a conductive surface oxide with a sheet conductance of 5×10^{-5} $[\Omega/\square]^{-1}$ and a thickness that is considerably smaller than 10 nm. The conductive layer is attributed to substitutional replacement of N with O atoms, leading to n-type doping in semiconducting CrN. Subsequent exposure to air has no further effect on the measured conductance, but G_s at 77 K is 48-89% lower than at room temperature, indicating that the conduction electrons from the O dopants are not fully delocalized. The overall results suggest that the large variation in previously reported transport properties of CrN may be attributed to differences in oxygen exposure.

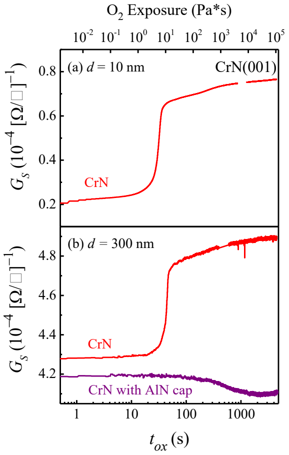


Figure 1: Measured sheet conductance G_S vs oxidation time t_{ox} and O_2 exposure of epitaxial CrN(001) layers with (a) thickness d = 10 nm and (b) d = 300 nm with and without AlN cap layer.

Graduate student presenter

Poster presentation

XPS INVESTIGATION OF THE OXIDATION STATE OF DIFFERENT CERIA POWDERS FOR CMP SLURRY

Christopher Netzband* and Kathleen Dunn

SUNY Polytechnic Institute, Albany, New York, USA

*cnetzband@sunypoly.edu

Ceria nanoparticles are used in chemical mechanical planarization (CMP) slurry for their selective removal of oxides over nitrides. This removal depends on the ratio of Ce^{3+}/Ce^{4+} ions on the surface of the particles. As this ratio increases, so does the interaction with the oxide surface, resulting in an increased removal rate. Most studies to date focus on how synthesis and particle size affect these ratios but ignore the changes that could arise when using the particles in an aqueous slurry environment. In this study, X-ray photoelectron spectroscopy (XPS) was used to measure the surface Ce^{3+} concentration of three different sources of ceria nanoparticles.

Table 1: Parameters for three different sources of ceria nanoparticles

Ceria Source	**Condition**	**Nominal Particle Size (nm)**	**Ceria Sample Conc. (%)**
Sigma	Dry Powder	<50	1.0
Sky Spring	Dry Powder	20	1.0
Sigma	Dispersion	5	1.0

The change in surface Ce^{3+} concentration due to changing chemical environment was measured as a function of pH and oxidizing agent concentration in the slurry. The effects of these properties were examined using three different sources for the ceria nanoparticles. Three sources of ceria nanoparticles for this study were chosen to determine if any trends found in response to changing pH or oxidizing agent concentration were observed across different particles and consistent with established trends

Graduate student presenter

Poster presentation

INFRARED REFLECTING/TRSMITTING SMART GLASS FOR ENERGY EFFICIENT WINDOWS

Mark Altwerger[1], Iulian Gherasoiu[2] and Harry Efstathiadis[1]

[1]SUNY Poly – CNSE, Albany
[2]SUNY Poly – COE, Utica

The development of a versatile and robust, metamaterial that can reflect near infrared heat radiation (NIR), while transmitting more than 70% of the visible light intensity. The ability to reflect NIR and transmit a particular wavelength range is obtained through highly doped metal oxide thin films. In this particular case we use a silicon doped zinc oxide film (ZnO:Si), which is deposited by magnetron sputtering. The proposed structure could regulate the bandwidth of the NIR and in turn the amount of heat reflected. This is achieved through control of the electron concentration in a thin film region below the dielectric/ZnO:Si interface. The structure is applicable for reduction of heating on solar cells, building windows, car windows and materials which are sensitive to heat/NIR. Overall this technology would reduce the cooling costs of large buildings. Another application includes, photonics; photonic band gaps can be opened and closed due to its optical tunability and active modulation of its effective electromagnetic parameters.

Graduate student presenter

Poster presentation

CARBON FILMS FOR CORROSION RESISTANT PHOTOELECTROCHEMICAL CELLS

Philip Schneider[1*], Iulian Gherasoiu[2] and Harry Efstathiadis[1]

[1]State University of New York Polytechnic Institute Colleges of Nanoscale Science and Engineering, Albany, NY, 12203, USA
[2]State University of New York Polytechnic Institute College Engineering, Utica, NY, 13502, USA

*PSchneider@sunypoly.edu

Hydrogen stands as an ideal source of clean energy, as it's able to be used in back-up power sources and in automobiles. While there are many production methods available to produce hydrogen, all of them use fossil fuels, detracting from any benefits this renewable energy source could provide. The purpose of this work is to fabricate a photoelectrochemical (PEC) cell that can use the energy of sunlight to power electrolysis to generate and capture hydrogen from water for use as fuel for applications such as mobile or stationary fuel cells. Most electrodes in modern PEC cells corrode very rapidly, in less than a week, preventing the system's large-scale implementation. The research focuses on solving this issue by synthesizing Diamond-Like Carbon (DLC) through Plasma-enhanced Chemical Vapor Deposition (PECVD) for use as an anti-corrosion layer and co-doping the film with either Boron and Phosphorous atoms. The anticipated outcome of this is to optimize the synthesis of DLC through PECVD and therefore to increase the lifespan of PEC cells to a range that is acceptable for industrial applications, without interfering in the electric current flow of the cell. We have shown that DLC can be synthesized at low temperature (~100°C) and the annealing enables the formation of diamond on the substrate. Moreover, the film experiences an increase in conductivity post phosphorous implantation and annealing, demonstrating the effectiveness of the ion implantation method for the control of the conductivity of DLC films. The film characteristics were investigated by 4-point probe, Auger Electron spectroscopy, and Raman spectroscopy.

Student presenter

Poster presentation

FABRICATION PROCESS VALIDATION AND INVESTIGATIONS OF LITHIUM-IONIC CONDUCTORS FOR SOLID ELECTROLYTE LI-ION BATTERIES

Spencer Flottman[1], Hunter J. Frost[1*], Seiichiro Higashiya[1], Devendra Sadana[2], and
Harry Efstathiadis[1]

[1]College of Nanoscale Engineering, State University of New York Polytechnic Institute,
Albany, NY 12203, USA
[2]International Business Machines (IBM), Albany NY, 12203, USA

The rapid adoption of Li-ion batteries with liquid organic electrolytes created many safety issues, due to gas production and leakage of the flammable liquid organic electrolytes when operating at high voltages of ~6V and/or elevated temperatures of ~150°C. A possible solution to this problem is to use solid state electrolytes instead of liquid electrolytes. It has been demonstrated that some solid electrolytes can perform as well as their liquid electrolyte counterparts during battery operation. One such promising solid state electrolyte is Lithium Aluminum Titanium Phosphate (LATP). Thick LATP films (several micrometers) have shown ionic conductivity of ~3x10^{-3} S cm-1 which is similar to that of a liquid electrolyte conductivity. It has excellent long-term stability in contact with the lithium anode, and has been evaluated as a solid electrolyte for Li-ion batteries as well as for electrochromics and deep neural networks. This study is therefore aimed at in-depth exploration of the LATP electrolyte for both the lithium ion battery and neuromorphic devices applications. Our work is focused on studying the influence of sputtering deposition parameters on the composition and the ionic conductivity of LATP that is not well understood. A systematic study to optimize sputtering target power, substrate heating, sputtering vacuum pressure, annealing temperature, atmospheric composition during annealing, and sputtering atmospheric composition was performed. Compositional uniformity of LATP films were analyzed via dynamic secondary ion mass spectroscopy (D-SIMS), time-of-flight SIMS (TOF-SIMS), nuclear reaction analysis (NRA), Rutherford backscattered electron spectroscopy (RBS) and x-ray photoelectron spectroscopy (XPS). Results from the aforementioned techniques have shown that deposition of compositionally uniform LATP films can be achieved by co-sputtering of Ti, Al and Li3PO4 on a Si or Si/SiO_2 substrate. However, annealing of these films at > 400°C is required to enhance their ionic conductivity. Microscale batteries (~ 100 µm x 100 µm) created with the annealed LATP films show promising electrolyte behavior. Charging of the batteries with a constant current of 200pA at 4.2 V displayed charging and discharging characteristics of a typical battery with no measurable leakage.

Student presenter

Poster presentation

CHARACTERIZATION OF MAGNETIC THIN FILMS FOR ACTUATING ORIGAMI DEVICES

Sierra Russell[1*], Tanner Pearson[2], Paul McEuen[2]

[1]SUNY Polytechnic Institute, [2]Cornell University
*SRussell@sunypoly.edu

Fabrication inspired by origami offers a novel method for the development of micron-scale machines, which have a wide range of potential applications. The use of magnetic thin films in tandem with ultra-thin atomic layer deposition (ALD) films allows for the creation of actuatable devices that can be controlled with external magnetic torques. We characterized cobalt, nickel, and iron films to compare their viability for these devices. We deposited our films via electron-beam evaporation at thicknesses of 25 μm and 50 μm and deposition rates of 0.3 Å/s and 0.6 Å/s, on top of a 10 nm thick titanium adhesion layer. We performed stress measurements of each film pre- and post-deposition, as well as thickness measurements to verify the deposited film thickness. We obtained the hysteresis curve of each film by using a vibrating sample magnetometer (VSM). We see that Fe and Co have significantly higher magnetizations than Ni, whereas Ni benefits from having the lowest stress of all three films. We also showed that the addition of a low stress polymer (SU-8) spun on top of the magnetic films may help to reduce the stress in the composite film. We discuss the implications of these results for our origami-inspired devices.

Undergraduate student presenter

Poster presentation

STUDY OF ANISOTROPY IN NOVEL-PASSIVATED LAYERED GATE THROUGH RAMAN AND PHOTOLUMINESCENCE SPECTROSCOPIES

Daniel Santos*, Mounika Kotha, Spyros Gallis
Colleges of Nanoscale Sciences and Engineering, SUNY Polytechnic Institute, Albany, New York 12203, USA

*dsantos@sunypoly.edu

Recently there has been a surge in interest for 2D layered semiconductors, such as rhenium disulfide (ReS_2), zirconium trisulphide (ZrS_3), and gallium telluride (GaTe), due to their unique properties such as thickness- and polarization-dependent optical properties. Characterization and study of their anisotropic light-matter interactions can open up new opportunities towards flexible polarized photodetector, optoelectronic, near-field imaging, and optical communication applications. We have developed a novel chemical passivation that results in complete encapsulation of the mechanically-exfoliated monoclinic GaTe flakes in ultrathin hydrogen-silsesquioxane (HSQ) film. These flakes range from a few layers to about 100 nm in thickness. The effective HSQ-encapsulation of layered GaTe has allowed its anisotropic properties to be studied using angle-resolved Raman and photoluminescence (PL) spectroscopies as probes. Polarization-dependent measurements of layered GaTe reveal that the A_g-Raman peak around 115 cm^{-1}, which has a high cross-section under 633 nm excitation, exhibits a lemniscate-like behavior in Raman intensity polar plots. Furthermore, the GaTe-induced 164 cm^{-1} Raman peak has a more unique anisotropy displaying a sinusoidal spiral with maximum intensities at 45°, 135°, 225° and 315°. PL studies revealed a possible thickness-dependent polarization behavior in layered GaTe, as PL anisotropy becomes more evident in thicker flakes, with a PL polarization dependence similar to that observed in the 115 cm^{-1} Raman peak. GaTe has two-thirds of the Ga-Ga bonds normal to the layer and one-third almost in the plane of the layer unlike other gallium chalcogenides. The Ga-Ga atomic arrangement along the *b*-axis direction results in structural in-plane anisotropy and may be responsible for the optical anisotropy seen in GaTe. Our investigation into the anisotropic properties of layered GaTe can open new venues for polarization-dependent optical and optoelectronic applications.

Undergraduate student presenter

Poster presentation

DEVELOPMENT OF SUBSTRATE PREPARATION TECHNIQUES FOR GRAPHENE SYNTHESIS

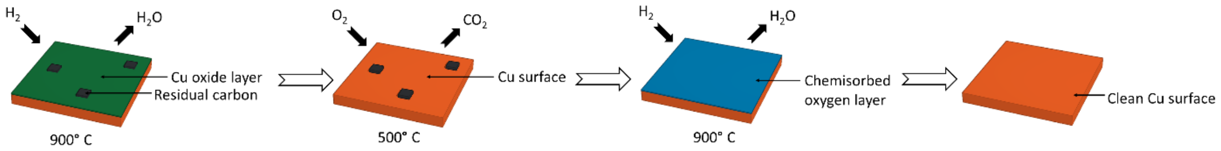
Siddarth Laveti[1*], Thomas Manna[1], Jodi Hotalen[2], and Carl A. Ventrice, Jr.[1,2]

[1]Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute
[2]College of Nanoscale Science & Engineering, University at Albany-SUNY

*SLaveti@sunypoly.edu

The most common technique for producing large area graphene films is by chemical vapor deposition (CVD) on Cu foil substrates. Cu is used as a substrate because it has a very low solubility for carbon at the temperature at which the CVD is performed. This ensures a surface-mediated growth that is self-limited at a single monolayer of graphene. Before performing CVD, the surface oxide and residual carbon need to be removed from the surface. In addition, the surface roughness needs to be reduced by annealing. This should result in fewer defects in the graphene film. The goal of this research project is to determine the optimal procedure for preparation of the Cu foil substrate to produce high quality graphene. Cu foils with 99.8% and 99.999% purity were used for the experiment. The Cu foils were heated by passing a current through the films, and the temperature was monitored using a disappearing filament optimal pyrometer.

The Cu substrate preparation procedure involved annealing in 1 x 10^{-5} Torr of H_2 at 900 °C to remove the native oxide, followed by an anneal in 1 x 10^{-6} Torr of O_2 at 500 °C to remove residual carbon from the surface. This is followed by annealing in 1 x 10^{-5} Torr of H_2 at 900 °C to remove chemisorbed oxygen from the surface from the previous anneal in O_2. The anneal durations were varied to determine the optimal technique. The mechanism of annealing is illustrated in the figure below.



The samples were characterized using X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and optical microscopy. The XPS data showed that the longer initial H_2 anneals yielded higher purity Cu. The SEM data showed that the H_2 anneals resulted in a change in surface morphology. It was also observed that the 99.8% Cu substrates had smaller Cu grains than the 99.999% Cu substrates.

Undergraduate student presenter

Poster presentation

MODELING OF ERBIUM EMISSION IN NOVEL SILICON CARBIDE PHOTONIC CRYSTAL NANOSTRUCTURES

Benjamin Harrington*, Natasha Tabassum, Spyros Galis

SUNY Polytechnic Institute CNSE

*bharrington@sunypoly.edu

Research attempts to realize optical quantum devices for long-distance quantum information technologies at low-loss telecom 1540 nm wavelength are currently hindered by their unsuitable emission wavelength, and also stringent fabrication and operation temperature requirements. Rare-earth-doped materials, and particularly erbium (Er)-doped materials, are the only systems that can potentially meet the current requirements to realize a quantum memory device at 1540 nm wavelength. We have introduced new artificial optical nanostructures composed of arrays of deterministically-tailored ultrathin silicon carbide (SiC) nanowires (NWs). Our nanosynthesis route enables the fabrication of nanowire-based photonic crystal (NW-PC) nanostructures and the deterministic placement of Er ions in the nanowires. This report focuses on the study of the modified spontaneous 1540nm-emission properties of Er^{3+} ions in NW-PC. The extraction efficiency and the spatial distribution of the spontaneous emission from a dipole in NW-PC and from a uniform slab without a PC structure are explored using 3D finite-difference time-domain (FDTD) calculations. Furthermore, through a combinational and systematic study of micro-photoluminescence (PL) spectroscopy, and FDTD calculations, the effects of the periodicity, nanowire-width and -height of the NW-PC structures on the Er-induced PL emission are investigated. The simulated 1540 nm-dipole emission in the vertical direction from NW-PC structures is enhanced by approximately an order of magnitude compared to their thin-film counterparts, where emission is mostly confined in the horizontal direction. The extraction efficiency enhancement of the dipole's spontaneous emission in NW-PC can be explained considering the suppression of optical modes in the in-plane direction and the presence of a photonic bandgap. Furthermore, FDTD calculations reveal that the Er-induced emission extraction efficiency can be enhanced by engineeringly controlling the NW-PC structure. We have experimentally observed modulation of the Er^{3+} PL with the NW-PC periodicity, presenting a qualitative match to the FDTD-modeled extraction efficiency. Moreover, the NW-PC exhibits a substantial (~60-fold) room-temperature 1540-nm-emission enhancement compared to its thin-film counterpart. Our studies of large-scale Er-doped SiC NW-PC may incubate an alternative pathway towards advancements in quantum information technologies that can be benefited by the deterministic placement of rare-earth ions and the modification of their emission in such new photonic nanostructures.

Undergraduate student presenter