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of Materials, Interfaces, and Processing**

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**2017 Fall Meeting
Hudson Mohawk AVS Chapter
October 23, 2017
4:30 – 8:30 PM**

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

Meeting Agenda*:

4:30 PM – 4:55 PM	Reception (NFS Rotunda)
4:55 PM – 5:00 PM	Introductory Comments (NFS Auditorium)
5:00 PM – 6:20 PM	Oral Presentations* (NFS Auditorium)
6:20 PM – 6:30 PM	Break
6:30 PM – 7:45 PM	Poster presentations* and networking with pizza and beverages (NFS Rotunda)
7:45 PM – 8:00 PM	Awards Ceremony (NFS Rotunda)
8:00 PM – 8:30 PM	AVS Hudson Mohawk Chapter Executive Committee Meeting

**Complete presentation schedule is available in the next page.*

***Presentation Schedule:**

(Oral presentations are of 15 minutes with 5 more minutes for Q&A.)

4:55 – 5:00 PM Welcome note by **Dr. Michael Burrell**, Chair 2016, AVS Hudson Mohawk Chapter

Oral Presentations

5:00 – 5:20 PM TOWARDS A MICROGRAVITY-BASED MODEL FOR STUDYING OVARIAN CANCER INVASION
Timothy Masiello, Atul Dhall, L.P. Madhubhani Hemachandra, Logan Butt, Matt Strohmayer, Pujhitha Ramesh, Natalya Tokranova and James Castracane
Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute, Albany NY

5:20 – 5:40 PM TOWARDS SYNAPTIC BEHAVIOR OF NANOSCALE RERAM DEVICES FOR NEUROMORPHIC COMPUTING APPLICATIONS
Karsten Beckmann¹, Wilkie Olin-Ammentorp¹, Joseph Van Nostrand², Nathaniel Cady¹
¹SUNY Polytechnic Institute, Albany, NY 12203, USA
²Air Force Research Laboratory/RITB, Rome, NY, USA

5:40 – 6:00 PM MS2 BACTERIOPHAGE CAPSID AS AN MRI CAPABLE, TARGETED NANOPARTICLE PLATFORM FOR BRAIN DELIVERY
S. M. Curley, J. Castracane, M. Bergkvist, N. Cady
Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute, 257 Fuller Road, Albany, New York 12203

6:00 – 6:20 PM TOPOLOGICAL INSULATOR MATERIALS FOR ULTRA-BROADBAND PHOTODETECTORS
Asish Parbatani, Eui Sang Song, Fan Yang, and Bin Yu
Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute, 257 Fuller Road, Albany, New York 12203

6:20 – 6:30 PM **Break**

6:30 – 7:45 PM **Poster Presentations**

Oral presentation

TOWARDS A MICROGRAVITY-BASED MODEL FOR STUDYING OVARIAN CANCER INVASION

Timothy Masiello, Atul Dhall, L.P. Madhubhani Hemachandra, Logan Butt, Matt Strohmayer, Pujhitha Ramesh, Natalya Tokranova and James Castracane

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Mounting evidence points to gravity's role in evolutionary development, cell mechanics, three-dimensional cell culture and many other essential aspects of biology. Microgravity offers an unprecedented opportunity for the isolation of gravity as an experimental variable to elucidate signaling pathways, behaviors and attributes otherwise inaccessible that might be applied to benefit such areas as drug development, disease studies and tissue engineering. Among the most notable observations, in terms of impact on human health, is that expressions of metastatic markers were reduced in several kinds of cancer cell lines upon exposure to microgravity. However, it is not yet known if the overall metastatic/cancerous potential of these cells *in vivo* has decreased. Understanding the mechanisms/pathways behind such changes could lead to discovery of new therapeutic signaling pathways and their potential targets for delaying or preventing metastasis of cancers.

Ovarian cancer remains one of the deadliest gynecological cancers with both traditional and unique metastatic pathways. Ovarian cancer may be particularly well-suited to microgravity studies due to the intrinsic importance of 3D cell aggregates (spheroids) in the transcoelomic metastatic pathway and the significant impact of microgravity on 3D cell cultures. The overarching goal of this work is to study ovarian cancer in a simulated microgravity system to assess the effects of microgravity on the metastatic behavior of these cells and its potential to define new pathways and targets for therapeutic intervention. The Rotary Cell Culture System (RCCS) is used to generate ovarian cancer spheroids in a simulated microgravity environment and while morphologically they are similar to spheroids produced using liquid overlay and have comparable viability, spheroids from the RCCS exhibit reduced migration along a substrate. Future directions involve further characterizing this change as it pertains to mesothelial clearance and analysis of markers related to this step of invasion. Ultimately, it is hoped that simulated microgravity will provide an accommodating environment for studying altered metastatic pathways in ovarian cancer, perhaps even laying the groundwork for further experimentation in space.

Supported by the Office of the Chief Scientist (Ministry of Economy, Israel) and SUNY Polytechnic Institute.

Oral presentation

TOWARDS SYNAPTIC BEHAVIOR OF NANOSCALE RERAM DEVICES FOR NEUROMORPHIC COMPUTING APPLICATIONS

Karsten Beckmann¹, Wilkie Olin-Ammentorp¹, Joseph Van Nostrand², Nathaniel Cady¹

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Resistive Random Access Memory (ReRAM) has the potential to play a major role in novel circuit architectures. One particular area of interest is neuromorphic hardware in which it could adopt the role as the synaptic device within an artificial neuron. One such architecture is the Memristive Dynamic Adaptive Neural Network Array or short mrDANNA developed to emulate the functionality of a biological synapse/neuron system. This architecture relies on synapses which are capable of changing their resistance in an analog fashion by applying ultra-short pulses. In this contribution we demonstrate HfO₂ based ReRAM devices utilizing a W bottom electrode, a Ti oxygen scavenger layer and a W top electrode. The devices were fabricated based on a 300mm hybrid CMOS/ReRAM process using the IBM65nm 10LPe technology as the base for a custom back-end-of-the-line integration of the ReRAM devices. Fully integrated 1 transistor 1 ReRAM (1T1R) structures were used for the characterization in this effort. We determined the conduction mechanism to be Ohmic in the low resistive state ranging from 3 to 10 k Ω and a Schottky emission process in the high resistive state starting from 15 k Ω and ranging into the M Ω range. Utilizing a microsecond pulsing setup, our devices show endurance exceeding 10¹⁰ switching cycles, with an average R_{off}/R_{on} ratio of 10. Reducing the pulse width to 5 ns FWHM, we achieved incremental resistance changes during the reset operation from 8.8 to 12 k Ω . Variability and resistance ranges could be adjusted by changing the reset voltage and the set current compliance.

Oral presentation

MS2 BACTERIOPHAGE CAPSID AS AN MRI CAPABLE, TARGETED NANOPARTICLE PLATFORM FOR BRAIN DELIVERY

S. M. Curley, J. Castracane, M. Bergkvist, N. Cady

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Delivery of imaging agents and pharmaceutical payloads to the central nervous system (CNS) is essential for efficient diagnosis and treatment of brain diseases. However, therapeutic delivery is often restricted by the blood-brain barrier (BBB), which prevents transport of clinical compounds to their region of interest. For example, MRI contrast agents such as DOTA-Gd³⁺ are unable to enter the brain for imaging purposes unless the BBB has been compromised. Therefore, an innovative approach to facilitate transport of these molecules across the BBB and into the brain is a crucial area of research. A multifunctional nanoparticle system is needed that 1) can be loaded with functional molecules, 2) transport across the BBB, and 3) localize to specific regions in the brain.

In this work, we have developed a nanoparticle delivery system based on the MS2 bacteriophage capsid. MS2 is a 28nm virus that can be functionalized to conjugate targeting moieties to its surface. We have attached Angiopep-2 (AP2), a 3kDa synthetic peptide to the nanoparticle, which provides the ability to transport across the BBB. We have also successfully conjugated an antibody capable of targeting specific brain regions to the nanoparticle surface. The targeting moieties were conjugated to the MS2 surface using the heterobifunctional reagent SMCC, then tested with various biological techniques to confirm conjugation and determine the reaction efficiency. Additional work has focused on loading the nanoparticle with a MRI contrast agent based on a complex formed by psoralen and DOTA-Gd³⁺. The loading efficiency is currently being evaluated using inductively coupled plasma mass spectrometry (ICP-MS).

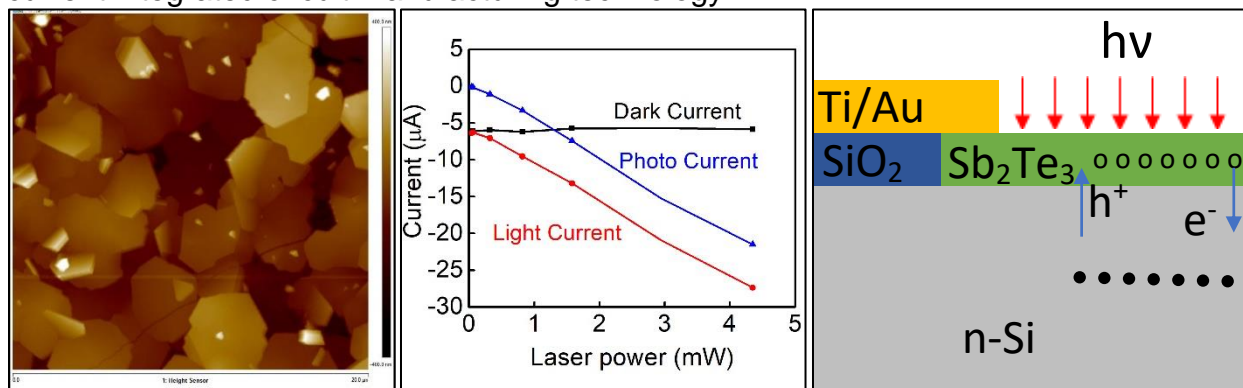
TOPOLOGICAL INSULATOR MATERIALS FOR ULTRA-BROADBAND PHOTODETECTORS

Asish Parbatani, Eui Sang Song, Fan Yang, and Bin Yu

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Narrow band gap (~ 0.3 eV) of a topological insulator (TI) and exotic quantum mechanical metallic surface properties that differ from bulk makes TI material an appealing candidate for the ultra-broadband and novel photodetection applications. Photoemission measurements have revealed that photogenerated carriers recombine within 6 ps, due to which the photoconductivity is hard to observe in field-effect type TI based photodevices. To overcome this challenge, we have introduced a robust Schottky barrier by depositing the Sb_2Te_3 (TI) on Si which increases the overall photogenerated carrier lifetimes. This Sb_2Te_3 on Si heterostructure forms an excellent diode structure with a rectification ratio of 3388. The fabricated photodiode was also self-biased due to the built-in potential at the Sb_2Te_3 -Si interface. The deposited Sb_2Te_3 nanocrystalline film displayed p-type behavior which was confirmed with EDX and XPS analysis. Moreover, the photodiode showed excellent $I_{\text{on}}/I_{\text{off}}$ ratio of 681 an extremely desirable characteristic for high sensitive photodetection applications. The Sb_2Te_3 /Si heterostructure photodiode also demonstrated broadband photodetection from visible to near-infrared wavelengths. The fabrication process involves simple, low-cost physical vapor deposition of Sb_2Te_3 and Si as a substrate which is completely compatible with current integrated circuit manufacturing technology.



SIMULATIONS OF BACKSCATTERED ELECTRONS TO MEASURE SENSITIVITY VERSUS ELECTRON DOSAGE OF BURIED SEMICONDUCTOR FEATURES

Maseeh Mukhtar and Brad Thiel

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Contemporary efforts to improve semiconductor device performance entail size reduction as well as advanced non-planar architecture. In the fabrication of these devices, the demand for greater precision measurement of the end dimensions of contact holes and deep trenches has risen. Furthermore, each layer's overlay alignment precision has similarly become very significant.

Overlay measurements of device patterns have conventionally been performed using optical methods. Beginning with image-based techniques using box-in-box targets that progressed to aerial image (AIM) and multi-level blossom targets to the more recently employed diffraction-based overlay (DBO). Another way to do this measurement is use of SEM overlay, which is now under discussion for use in in-device overlay, because overlay measurements from dedicated kerf structures frequently do not match performance in-circuit, use cases demanding enhanced resolution, as well as a reference metrology. Two main application spaces are measurement features from multiple mask levels on the same surface and buried features [1].

Modern CD-SEMs are adept at measuring overlay for cases where all features are on the surface. In order to measure overlay of buried features, high voltage SEM (HV-SEM) is needed. Gate-to-fin and BEOL overlay are important use cases for this technique. A JMONSEL simulation exercise was performed for these two cases using 10 nm line/space gratings of 5 lines of graduated increase in depth of burial. Backscattered energy loss results of these simulations were used to calculate the sensitivity measurements of buried features versus electron dosage for an array of electron beam voltages.

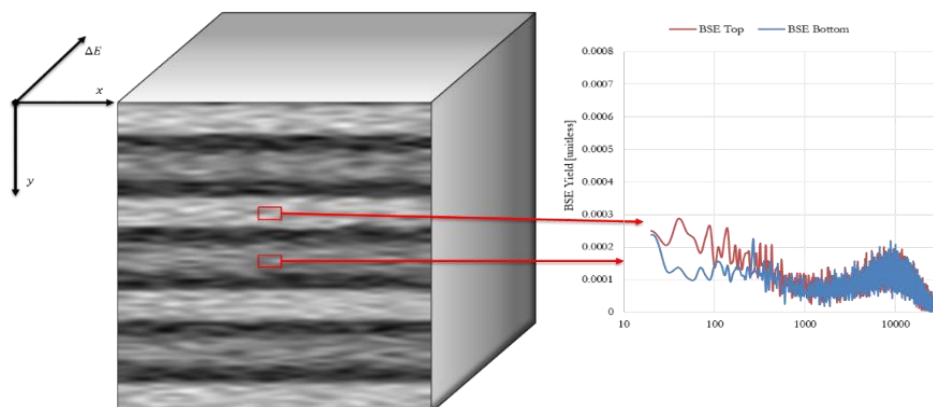


Figure 1. Example simulated energy loss stack profile for buried Cu/SiO₂ grating under SiO₂ overlayer.

[1] B. Bunday *et al.*, *Proc. SPIE* (10145), 101450G (2017)

Poster presentation

**EFFECT OF TOPOGRAPHY ON RETINAL STEM CELL VIABILITY AND
REGROWTH**

Aleksandr Filippov, Yangzi Tian, Yubing Xie

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Age-related macular degeneration is a devastating eye condition that inflicts damage to the retina and leads to irreversible vision loss. The retina is made up of several layers of light-sensing cells, which are supported and nourished by the retinal pigmented epithelial (RPE) layer. The RPE cells sit atop the Bruch's Membrane and form a highly-selective blood-retinal-barrier that is critical for retinal homeostasis. In this project, we attempt to recreate the barrier in vitro using electrospun nanofibers. Human RPE cells were cultured on nanofibers made from natural and synthetic polymers, such as chitosan and polycaprolactone, with Synthemax and gelatin as controls. We found that human RPE cells demonstrated proper morphology and protein expression when cultured on the chitosan substrate.

Poster presentation

Nb₂O₅ BASED RESISTIVE RANDOM ACCESS MEMORY DEVICES

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Resistive Random Access Memory (ReRAM) is a new class of non-volatile memory. It is widely seen as a replacement for Flash memory as well as viable form of non-volatile memory. Advantages of ReRAM compared to other non-volatile memory solutions are the possibility for multi-level resistance states, ultra-high endurance, nanosecond switching and a low voltage operation. These features enable low energy memory designs, neuromorphic computing, and potential computation-in-memory applications. Previous work in our laboratory has focused on the development of hafnium oxide and tantalum oxide devices, for CMOS compatibility and unique switching performance, respectively. Niobium oxide is an alternative ReRAM switching material that is of interest for unique resistive switching applications, primarily due to its ability to form multiple oxidation states. In this work, we developed a process to fabricate Nb₂O₅ based ReRAM devices consisting of a Pt bottom electrode, a Nb₂O₅ switching layer (SL), a Nb oxygen scavenger layer (aka: OSL, which creates an oxygen vacancy gradient within the SL) and a W top electrode. Each layer was deposited via sputtering in a 100 mm wafer-scale fabrication process, and subsequently patterned to gain test structures with sizes ranging from 25x25 μm² to 100x100 μm². Deposition parameters were correlated to the material properties such as thickness and stoichiometry. The best performing devices showed switching voltages below 1.5 V and 100k switching cycles, via a pulse based switching approach with an approximate R_{off}/R_{on} ratio of 4.4. Due to the material system used, and the results obtained thus far, a vacancy change mechanism (VCM) process is likely responsible for resistance changes during switching in these devices.

Poster presentation

HIGHLY POROUS SCAFFOLDS ON TNZT ALLOY FOR BONE IMPLANT APPLICATIONS

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The Ti-35Nb-7Zr-5Ta alloy (TNZT) is more biocompatible than the widely used Ti-6Al-4V since each of its constituent elements is biocompatible. In addition, it has the lowest Young's modulus (50-60 GPa) of all the titanium-based alloys created so far. This property allows for a greater transfer of functional loads, which ultimately leads to bone growth stimulation. TNZT alloys were produced by arc melting pure elements and forging into rods. Oxide nano-scaffolds were grown via hydrothermal treatment onto TNZT samples to investigate the potential of these nanostructured surfaces to improve osseointegration. The alloys with and without nano-scaffolds were characterized using top-view and cross-sectional scanning electron microscopy equipped with an energy dispersive x-ray spectrometer to investigate the structure, morphology and chemistry of the resulting nanostructures. Finally, the formation of hydroxyapatite on the modified surfaces was investigated upon immersion in simulated body fluid (SBF).

Poster presentation

**XPS INVESTIGATION OF THE OXIDATION STATE OF CERIUM PARTICLES IN
CMP SLURRY**

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Ceria nanoparticles are used in CMP slurry for their selective removal of oxides over nitrides. This is the result of a reversible redox reaction at the surface of the particles. A key property that determines the ability of ceria to undergo this reaction is the ratio of Ce^{3+}/Ce^{4+} on the surface of the particles.

In this study, X-ray photoelectron spectroscopy (XPS) was used to measure the ratio as a function of slurry properties such as pH, oxidizing agent and surfactant. The effects of these properties were examined in virgin and aged slurries, and as a function of concentration and type.

It appears that slurry age and pH have little effect on the particles, but much depends on the peak fitting method, which is not yet a settled question in the XPS community. We discuss these findings and their implications for the specific design of future slurries.

Poster presentation

**NANOSCALE VISUALIZATION OF METAL/OXIDE/Si INTERFACE
ELECTROSTATICS WITH BEEM**

Jack Rogers, Dan Pennock, Westly Nolting, Steven Gassner, Vincent LaBella

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Hafnium oxide is widely utilized in MOS gate structures due to the high relative permittivity of hafnium oxide, motivating a need to understand the electrostatics of this interface with nanoscale resolution. The electrostatic barrier of a metal/HfO₂/Si(001) structure was mapped with ballistic electron emission microscopy (BEEM) on p-type silicon substrates. BEEM is an STM technique that measures the transmission of electrons through a metal-semiconductor or MOS interfaces with nanoscale resolution. Electrons are locally injected from the STM tip and electrons which have sufficient energy to pass through the MOS structure are collected as BEEM current. In this way the local barrier height can be mapped and visualized at nanoscale dimensions. Two samples of varying oxide thickness (2 monolayers and 4 monolayers) were measured. The thinner sample yielded more spatially uniform transmission and barrier heights. Nanoscale barrier height maps, histograms, and results from computational modeling of these samples will be presented and discussed.

Poster presentation

DIELECTRIC FILM IMPROVEMENT STUDY BY X-RAY PHOTOELECTRON SPECTROSCOPY

Zeynel Bayindir, Sanjay Mehta

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X-ray photoelectron spectroscopy (XPS) is one of the characterization techniques utilized to investigate materials' compositional and chemical states in semiconductor technology. It has growing importance due to its sensitivity to film thicknesses down to 10 nm and its gentle surface sputtering capability. This poster will review a case study of interlayer dielectric (ILD) voids in a PerHydroPolySilazane (PHPS) film where the XPS technique was used to provide an optimized process solution for advanced node technologies.

PHPS is a spin-on dielectric used to fill high aspect ratio trenches between gates. As coated, the film has long polymeric chains of hydrogen-terminated Si-N bonds. It requires aggressive steam anneal conditions to convert to SiO₂. Due to aggressive gate scaling and high aspect ratio of gap fill dimensions, the steam anneal was not adequate to fully densify the oxide film inside narrow trench features. As a consequence, during the contact etch, the exposed oxide developed voids which would then be filled by CVD-based contact liner and/or contact metal causing shorts. Ultraviolet (UV) curing was proposed to densify the PHPS material in narrow trench features. The XPS technique was used to develop a fundamental understanding of UV interactions with PHPS films. The compositional and chemical changes through the film thickness as a function of UV dose were characterized. XPS analysis helped to optimize the proposed process solution leading to elimination of the defect mode. The poster will also present some electrical results supporting the mechanism that is in agreement with the XPS findings.

Poster presentation

PREPARATION AND OPTICAL PROPERTY OF Mo/Mo-Al₂O₃/Al₂O₃ SOLAR SELECTIVE ABSORBER COATINGS BY A HYBRID MAGNETRON SPUTTERING

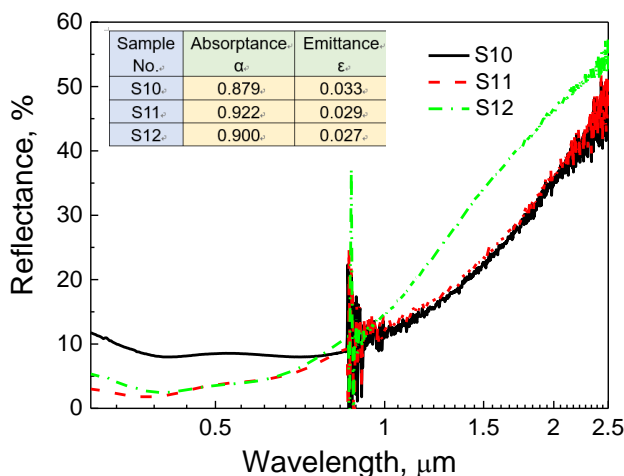
Min Zhang^{1,2}, Wenhui Zhang², Ying Li², Xue Yin², Daniel Gall¹

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This paper selects the metal Mo as the infrared reflective layer, Mo-Al₂O₃ as the absorbing layer and Al₂O₃ as the anti-reflective layer. Mo/Mo-Al₂O₃/Al₂O₃ selective absorbing coatings with double absorption layers were fabricated on polished 316L stainless steel by using a hybrid magnetron sputtering. The influences of the volume fraction of Mo and the thickness of anti-reflective layer and absorbing layer on the selective absorption performance of the obtained Mo/Mo-Al₂O₃/Al₂O₃ selective absorbing coatings were studied. The results show that the thickness of anti-reflective layer exerts an obvious effect on absorption edge and the location of the absorption peak. When the sputtering time for the anti-reflective layer is 10 min, the absorption performance of the coating is the best. With increasing the thickness of high metal absorbing layer, the surge threshold wavelength of the reflectance will red-shift, and the emittance will also increase, however, if the thickness is too high, it will affect the interference effect. With increasing the thickness of high metal absorbing layer, the visible absorption ratio will increase and the surge threshold wavelength of the reflectance will red-shift, but the emittance will gradually increase. With increasing metal content of high metal absorbing layer, its square resistance reduces, resulting that the emittance gradually declines. With increasing metal content of low metal absorbing layer, it will increase the absorption over long wave spectrum and decrease the infrared interference, resulting in a rising emittance.



Poster presentation

ADHESION ANALYSIS OF THIN FILMS

Vijaya Rana, Jay Mody, Brian O' Hara, Jeffrey Riendeau

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As we extend towards lower technology nodes (14nm and below), RC parasitic signal losses between BEOL build levels have become important. To solve RC parasitic problems, we have seen the introduction of new materials including the low-k and the ultralow-k materials. However, these low dielectric materials have inferior mechanical strength and poor adhesion properties. Thus, one of the requirements for these materials is to survive the harsh fabrication flow. To measure the mechanical integrity of low-k thin films, we utilized Nanoindentation to obtain materials properties such as hardness and modulus. To measure the adhesion failure, A Four Point Bend Test (FPBT) was utilized for determining the strain energy release rate.

The Four Point Bend Test is time consuming and requires careful sample preparation. We have observed that the Nanoscratch Test has tremendous potential for reducing the time needed to measure the thin film adhesion properties. Hence, we are employing the Nanoscratch Test to assess the interface properties of these low-k thin films. The sample preparation for the Nanoscratch test is simpler and quicker. A radial probe equipped with a standard transducer was used to perform a controlled load scratch test. To analyze adhesion failure of these low-k thin films, Scanning Probe Microscopy (SPM) images of the scratch and the critical scratch load at the breakthrough event were reported.

Poster presentation

**VISUALIZING THE NANOSCALE ELECTROSTATICS OF META/Si INTERFACES
WITH BEEM**

**W. Nolting, Jack Rogers, Dan Pennock, Steven Gassner, Joshua Goldberg, C.
Durcan,
Vincent P. LaBella**

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Nanoscale fluctuations in the electrostatics of metal semiconductor interfaces impact device performance and are important to understand and measure, which can be accomplished with ballistic electron emission microscopy (BEEM), an STM based technique. In this work, we perform BEEM on Cr/Si and W/Si Schottky contacts to visualize the interface electrostatics to nanoscale dimensions. This is accomplished by acquiring tens of thousands of spectra on a regularly spaced grid and fitting the results to determine the local Schottky barrier height. Computational modeling is utilized to simulate the distributions of barrier heights that includes effects from the interface and transport of the hot electrons as well as indication of a multi-barrier heights interface that are attributed to silicide formation. Thickness dependent studies are also performed to correlate elastic scattering and thickness of the metal deposited. The agreement between the measurements and modeling provides detailed insight into the effects that both elastic scattering and incomplete silicide formation has upon the transport of electrons through these structures, which is difficult to detect with conventional current voltage measurements.

Poster presentation

RESISTIVITY OF EPITAXIAL Ru(0001) THIN FILMS

Erik Milosevic, Daniel Gall

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Ruthenium is a promising candidate for replacing copper as a conductor in confined dimensions due to its small predicted mean free path of 6.7 nm. Epitaxial Ru(0001) layers are sputter deposited onto Al₂O₃(0001) and their resistivity is measured as a function of sample thickness $d = 5-80$ nm both *in situ* and *ex situ* at 295K and 77K for the purpose of quantifying electron scattering at the surfaces and experimentally determining the mean free path without confounding impact from grain boundary scattering. X-ray diffraction analyses show an epitaxial layer-substrate relationship with Ru[0001] || Al₂O₃[0001] and Ru[10 $\bar{1}$ 0] || Al₂O₃[11 $\bar{2}$ 0]. Fitting the resistivity data with the semiclassical model of Fuchs and Sondheimer yields a room temperature mean free path of 6.7 ± 0.3 nm, in excellent agreement with predictions from first principal calculations. Ru interfaces are determined to scatter diffusively, and the Ru surface shows no specular change upon exposure to an oxidative environment. Atomic force microscopy and X-ray reflectivity are used to determine the surface roughness, which is < 1 nm and therefore has a negligible impact on the measured resistivity. Transport measurements at 77K show an unexpected and highly favorable resistivity size effect with a mean free path that is 39% lower than expected based on the temperature dependence of the bulk resistivity. In-plane Boltzmann transport simulations done by integrating over real and reciprocal space of the thin film and the Brillouin zone, respectively, show agreement with experimental results. Transport simulations suggest a reduced resistivity increase for transport perpendicular to the basal plane, with, for example, a $3.59 \mu\Omega\text{cm}$ lower resistivity for a 2 nm thick film. This study confirms Ru as a promising candidate for future back and middle of line applications.

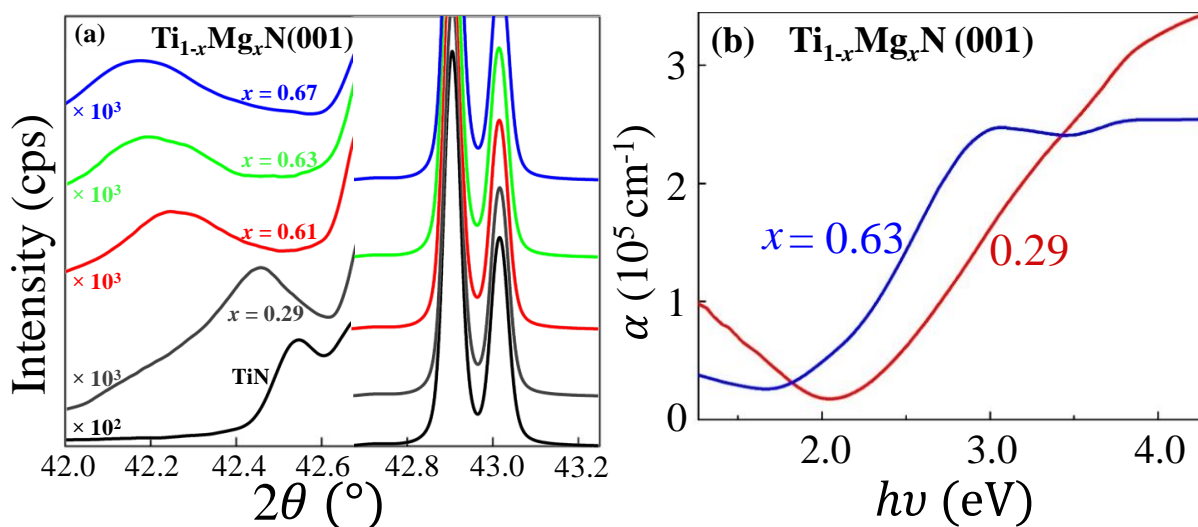
OPTICAL AND ELECTRONIC PROPERTIES OF EXPITAXIAL $\text{Ti}_{1-x}\text{Mg}_x\text{N}$ LAYERS GROWN ON $\text{MgO}(001)$

Baiwei Wang, Sit Kerdsonpanya, Erik Milosevic, Mary McGahay and Daniel Gall

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

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Epitaxial single-crystal $\text{Ti}_{1-x}\text{Mg}_x\text{N}$ (001) ternary alloy layers were deposited on MgO (001) by reactive magnetron co-sputtering from titanium and magnesium targets in 15 mTorr pure N_2 at 600°C . X-ray diffraction (XRD) indicates that the deposited alloy layers exhibit a solid solution rock-salt phase for $x = 0 - 0.67$. Increasing the Mg concentration leads to an increase in the lattice constant from 4.25\AA for TiN to 4.28\AA for $\text{Ti}_{0.33}\text{Mg}_{0.67}\text{N}$, and a decrease in the crystalline quality as quantified by the Full Width of Half Maxima (FWHM) of the ω rocking-curve XRD peak which increases from 0.25° to 0.80° . XRD ϕ -scans verify that all $\text{Ti}_{1-x}\text{Mg}_x\text{N}$ layers are single crystals with a cube-on-cube epitaxial relationship to the substrate: $(001)_{\text{Ti}_{1-x}\text{Mg}_x\text{N}} \parallel (001)_{\text{MgO}}$ and $[100]_{\text{Ti}_{1-x}\text{Mg}_x\text{N}} \parallel [100]_{\text{MgO}}$. The electrical resistivity increases from $14.5 \mu\Omega\cdot\text{cm}$ for $x = 0$ to 554 and $3197 \mu\Omega\cdot\text{cm}$ for $x = 0.29$ and 0.61 , respectively. $\text{Ti}_{1-x}\text{Mg}_x\text{N}$ layers with $x \geq 0.61$ show a negative temperature coefficient of resistivity which is attributed to the decreasing electron density of states at the Fermi level and a weak localization of free carries. Optical transmission measurements indicate the onset of interband transitions at 2.0 and 1.7 eV for $\text{Ti}_{0.71}\text{Mg}_{0.29}\text{N}$ and $\text{Ti}_{0.37}\text{Mg}_{0.63}\text{N}$, respectively.



Poster presentation

EXPLORING THE OPTICAL BEHAVIOR OF ERBIUM IONS IN 20nm SiC:O_x NW PHOTONIC CRYSTAL STRUCTURE FOR QUANTUM APPLICATIONS

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In the emerging field of quantum technology, the controlled placement of color centers with high photoluminescence (PL) yield in solid-state hosts is essential to manipulate isolated quantum systems with high fidelity. Silicon-based nanomaterials may enable the fabrication of nanoarchitectures using current microelectronic fabrication processes, as well as the integration of these nanoarchitectures into more complex photonic circuits, with waveguides and detectors. In that regard, this work presents a novel chemical synthesis route for fabricating self-aligned silicon carbide nanowire (SiC NW) arrays, doped with and without oxygen (SiC:O_x). The width of these chemically synthesized nanowires solely depends on the tailored thermal chemical vapor deposition (TCVD) process, unlike typical top-down lithography pattern transfer processes. Furthermore, this fabrication process has been extended to engineer the placement of color centers (erbium ions, Er³⁺) through controlled doses of implantation. A key enabler of this synthesis route is that NW photonic crystal (PC) nanomaterials are engineered with tailored geometry in precise locations during nanofabrication. The structural and optical behavior of Er-doped 20 nm SiC NW arrays has been studied through Fourier transform infrared spectroscopy (FTIR), ultra violet-visible-spectroscopic ellipsometry (UV-VIS-SE), micro-photoluminescence (uPL), micro-power dependent photoluminescence (uPDPL), and time resolved photoluminescence (TRPL) spectroscopy. About a 60-fold increase in the Er-related PL, ~1540 nm, was observed from the nanomaterial compared to its thin film counterpart. Furthermore, it was observed that the emission efficiency can be modulated with the PC lattice periodicity of the structure. This behavior may allow the utilization of these SiC NWs arrays as a common platform to integrate and investigate novel color centers such as chromium, and vanadium, exhibiting unique quantum properties at room temperature.