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of Materials, Interfaces, and Processing*

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**2013 FALL MEETING of the
HUDSON MOHAWK AVS CHAPTER**

2:30 – 8:00 PM, Monday, October 14, 2013

**College of Nanoscale Science & Engineering
CESTM Rotunda and Auditorium
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Albany, NY 12203**

Chair:

Carl A. Ventrice, Jr.
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Secretary:

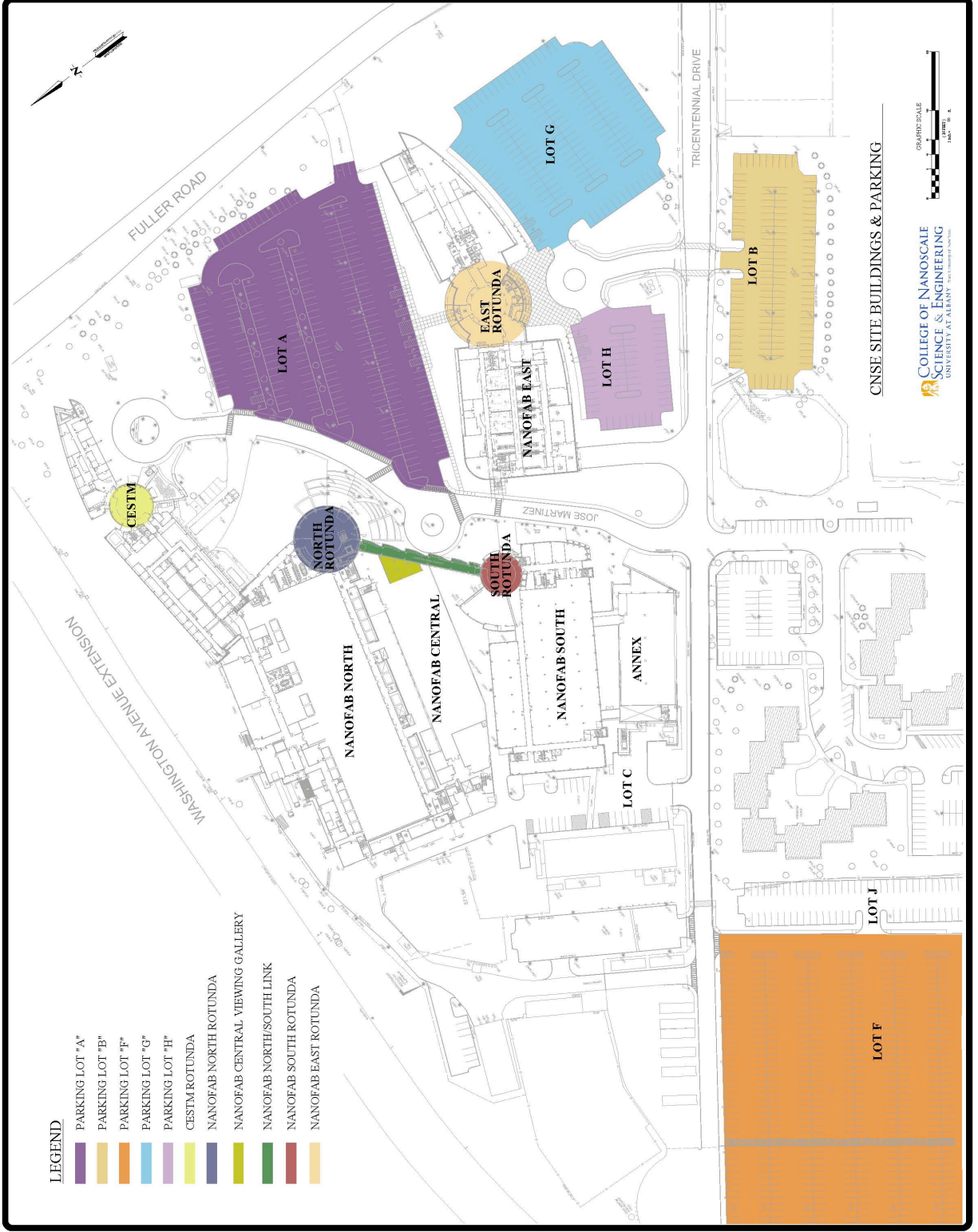
Eric Bersch
SEMATECH International
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Agenda:

2:30 – 3:00	Reception and Refreshments
3:00 – 4:00	Tour of Research Facilities
4:00 – 6:00	Oral Presentations
6:00 – 7:30	Poster Presentations and Pizza Dinner
7:30 – 8:00	Award Ceremony

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Oral Presentations:

A COMPREHENSIVE STUDY OF Cu ATOMIC LAYER DEPOSITION OF $\text{Cu}(\text{thd})_2/\text{H}_2$ PROCESS ON PALLADIUM SURFACES

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The author studied the Cu atomic layer deposition of Copper bis (2,2,6,6-tetramethyl-3,5-heptanedionate) ($\text{Cu}(\text{thd})_2$)/ H_2 reaction on palladium and dielectric films with real-time spectroscopic ellipsometer (SE) by in-situ. Surface optical parameter delta and psi were measured to study thickness change as well as the surface adsorption, desorption and reaction from cycle to cycle. Saturation curves of Cu ALD were plotted and the growth rate was controlled under different conditions. It is found that copper ALD can grow at relatively low temperature around 135-160°C. Cu ALD occurs at the step edges and kink sites on the Cu-Pd surface. The ALD growth rate temperature window shows a different trend verse the Cu growth on platinum studied by previous research, which indicates a different growth mechanism on palladium substrate. A comprehensive study of SE, x-ray photoelectron spectroscopy (XPS) and x-ray diffraction (XRD) interprets that the diffusion of palladium into Cu layer is dependent on both the temperature and helium purge time. More pure Cu film with less palladium mixing can be fabricated under a lower substrate temperature. Cu ALD also has very good selectivity on Pd over SiO_2 and Si_3N_4 substrates. A mechanism of Cu ALD reaction on Pd with chemisorbed hydrogen reaction with $\text{Cu}(\text{thd})_2$ during purge step is proposed. For the purpose of application of Cu ALD on nanofabricated devices, well controlled growth rate and high quality Cu film can be achieved.

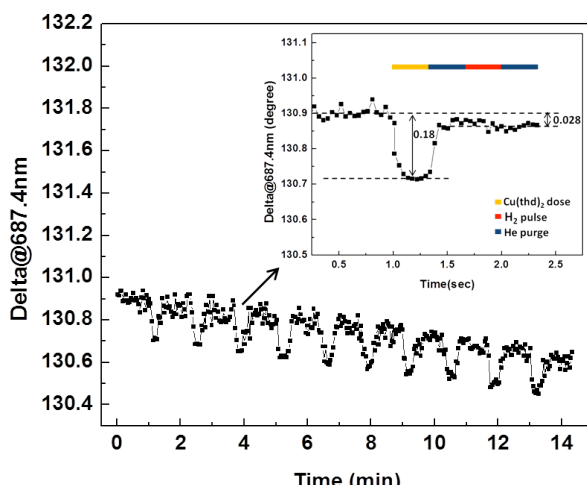


Figure-1. Ellipsometry spectroscopy result of 10 cycle copper ALD and the inserted figure is one cycle copper ALD

ANALYSIS OF Si AND Si_(1-x)Ge_x NANOSTRUCTURED FIN ARRAYS USING HIGH RESOLUTION X-RAY DIFFRACTION

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Over the past decade, an exponential increase in the transistor count per chip has accompanied scaling from 180nm to 22nm nodes. Now, the semiconductor industry is moving on to achieve 14nm and beyond using increasingly novel techniques. A switch from planar to 3D transistors resulted in high speed transistors with lower power consumption. The miniaturization of CMOS transistors and introducing strain in the materials resulted in the reduction of node size and spacing between the fins and increased the mobility of the carriers. To provide unique insight into these structures, we need highly accurate methods of measurement. High resolution x-ray diffraction offers a collection of application techniques for a quick and non destructive analysis for characterizing these structures. With the advantage of acquiring data over a large area and able to probe the nano dimensions, HR XRD offers advanced measuring techniques that characterize many essential features in the fin arrays. Here, we present different measurement techniques to analyze the essential parameters in the Si, Si_(1-x)Ge_x (x=25) and SiGe (x=50) fin array samples using Bede Metrix L, QC3 and APS equipment. We show how to identify pitch walking along with the pitch measurement introduced due to an error in lithography patterning using additional peaks in the symmetric 004 Omega rocking curves based on the Kinematic theory of x-ray diffraction. Qualitative estimation of strain and relaxation along the fin length and perpendicular to the fin length is shown using asymmetric 224 reciprocal space maps. Omega-2Theta coupled scans are utilized to detect the non-rectangularity of the fin shape. The non-rectangular fins have a sidewall slope and the sidewall angle calculation is shown using a peak split in the longitudinal scans of higher order fin peaks. High resolution x-ray diffraction can always be a complimentary method to assist other critical dimension measuring techniques and can be utilized in providing preliminary data for OCD modeling of fin structures.

ULTRAHIGH THERMAL CONDUCTIVITY NANOWIRE-FILLED POLYMER COMPOSITES AND INTERFACES

Indira Seshadri^{1,2}, Nikhil Balachander¹, Rutvik Mehta¹, Gibran Esquenazi¹, Linda Schadler¹, Theodorian Borca-Tasciuc², Pawel Keblinski¹, Ganpati Ramanath¹

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Realizing high thermal conductivity nanocomposites is a major challenge because of difficulties in incorporating high fractions of uniformly dispersed nanofillers and countering low filler-matrix interfacial conductance. Here, we demonstrate that these issues are obviated by using < 4 volume% ultrathin sub-10-nm gold nanowire fillers to obtain an unprecedented 30-fold increase in polydimethylsiloxane [1] thermal conductivity to $\sim 5 \text{ Wm}^{-1}\text{K}^{-1}$ that is 6-fold higher than any previously reported nanocomposite filler including graphene, carbon nanotubes at comparable filler loadings, and exceeds theoretical predictions. The nanowire diameter and aspect ratio are key to obtaining cold-welded networks that enhance thermal conductivity, while fostering low modulus and electrical conductivity. The nanocomposites exhibit high compliance with a low elastic modulus of $\sim 5 \text{ MPa}$ conducive for conformal formation of interface thermal contacts. However, the interfacial thermal contact conductance of the nanocomposites interfaced with copper is low, e.g., $\sim 1.5 \text{ kWm}^{-2}\text{K}^{-1}$. Rheology measurements reveal that the low conductance is due to a liquid-solid transition that is sensitive to the nanowire loading fraction [2]. In particular, the filler loading corresponding to the formation of a percolation network and maximizing the nanocomposite thermal conductivity also causes pre-cure gelation of the polydimethylsiloxane matrix inhibiting the formation of conformal void free interfaces. Based on these findings, we propose a controllable welding induced network formation approach to counter pre-cure gelation. Our results provide several insights to increase the thermal contact conductance at interfaces where efficient heat transport is of importance, e.g., in device packaging applications.

¹N. Balachander, I. Seshadri, R.J. Mehta, L.S. Schadler, T. Borca-Tasciuc, P. Keblinski, and G. Ramanath, "Nanowire-filled polymer composites with ultrahigh thermal conductivity," *Applied Physics Letters*, vol. 102, 2013, pp 093117 – 093117-3.

²I. Seshadri, T. Borca-Tasciuc, P. Keblinski, and G. Ramanath, "Interface thermal conductance and rheology nexus in metal contacted nanocomposites," *Applied Physics Letters*, 2013, in press.

NOVEL $\text{Al}_{1-x}\text{Sc}_x\text{N}$ ALLOY: A STUDY ON STRUCTURE AND BANDGAP

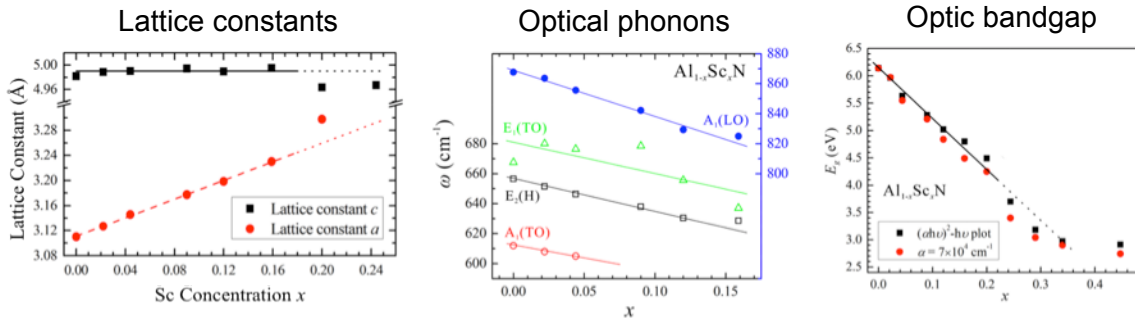
Ruopeng Deng and Daniel Gall

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Aluminum Scandium Nitride ($\text{Al}_{1-x}\text{Sc}_x\text{N}$) alloy has been recently discovered with significantly enhanced piezoelectric response compared to pure AlN. The fundamental mechanism is unclear, but proposed in simulation to be related with structural softening effect caused by meta-stable hexagonal ScN bonding.

In the present study, epitaxial $\text{Al}_{1-x}\text{Sc}_x\text{N}$ alloy thin films with varied Sc concentration are deposited on sapphire 0001 substrate, and maintain single crystal until phase separation happens near $x = 0.2$. The alloy crystal structure investigated by XRD exhibits anisotropic expansion with lattice constant c unchanged while lattice constant a increasing linearly with Sc concentration. Optical phonon modes $A_1(\text{LO})$, $A_1(\text{TO})$, $E_2(\text{H})$, and $E_1(\text{TO})$ measured by Raman and specular IR reflectance all shift to lower frequency with x indicating structural softening. And it can be understood by Valence-Coulomb-Force-Field model as combined effects from increased ionicity and reduced bond strength. The optic bandgap of $\text{Al}_{1-x}\text{Sc}_x\text{N}$ measured by UV-Vis R/T is linearly decreasing with Sc concentration with adjustable range of 6.2-4.4 eV, which could also have implication in bandgap engineering in fabricating LEDs.



SCHOTTKY BARRIER HEIGHT MEASUREMENTS OF Cu/Si(001), Ag/Si(001) and Au/Si(001) INTERFACES UTILIZING BALLISTIC ELECTRON EMISSION MICROSCOPY AND BALLISTIC HOLE EMISSION MICROSCOPY

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The Schottky barrier heights of both n and p doped Cu/Si(001), Ag/Si(001), and Au/Si(001) diodes were measured under ultra high vacuum (UHV) using ballistic electron emission microscopy (BEEM) and ballistic hole emission microscopy (BHEM), respectively. Measurements using both forward and reverse BEEM and BHEM injection conditions were performed. The Schottky barrier heights were found by fitting to a linearization of the power law form of the Bell-Kaiser BEEM model. The sum of the *n*-type and *p*-type barrier heights is in good agreement with the band gap of silicon and independent of the metal utilized. The Schottky barrier heights are found to be below the region of best fit for the power law form of the BK model, demonstrating its region of validity.

TEMPERATURE DEPENDENT RESISTIVITY OF COPPER THIN FILMS

Grant Boruchowitz, Y. Timalisina, X. Shen, Z. Fu, G. Qian, M. Yamaguchi,
G.-C. Wang, K. Lewis, and T.-M. Lu

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When the dimensions of a copper film approach the intrinsic electron mean free path (~ 40 nm), the size of the film plays a significant role on the resistivity due to electron scattering. Electron scattering significantly contributes to the resistivity, such that the resistivity increases with decreasing film thickness. Thus, understanding and controlling the resistivity of materials is important when developing electrical devices such as sensors and conductors as these materials can be used to insulate components. To this extent exploring electron scattering in copper films is critical.

For this project four point probes are used to determine the resistivity of copper thin films of thickness 10 nm and 300 nm which were grown epitaxially. The resistivity of the films as a function of temperature is measured in the temperature range from 77 K to 300 K. The four point probe measurement technique employing van der Pauw geometry allows one to estimate the resistivity of copper thin films.

The effect of electron-phonon interaction in these samples is quantified using the Debye temperature. This temperature is extracted from the Bloch-Grüneisen (B-G) equation. We found that in contrast to the thick film, there was a deviation from the B-G equation for the thin film. We observed that as the film thickness increased, the Debye temperature increased. This differs from the resistivity of wires, where an increase in diameter does not always correspond to an increase in Debye temperature. Future work will involve measuring the resistivity and verifying the validity of the electron-phonon interaction constant for thin films at temperatures below 77 K.

Poster Presentations:

STUDY OF POLYMETHYL METAACRYLATE (PMMA) and HYDROGEN SILESQUIOXANE (HSQ) RESIST SURFACE INTERFACE

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Two common electron beam resists are Polymethyl Metaacrylate (PMMA) and Hydrogen Silesquioxane (HSQ). The PMMA is a positive tone material whereas HSQ is negative tone. While attempting to pattern HSQ over previously exposed PMMA interfacial effects were observed that warranted further investigation.

The electron beam lithography patterning was performed on spin coated PMMA resist residing on a three inch silicon wafer. For the two level lithography applications; the HSQ resist was spin coated on the developed PMMA patterns. Figure 1 shows the micrograph of the HSQ deposited on PMMA patterns.

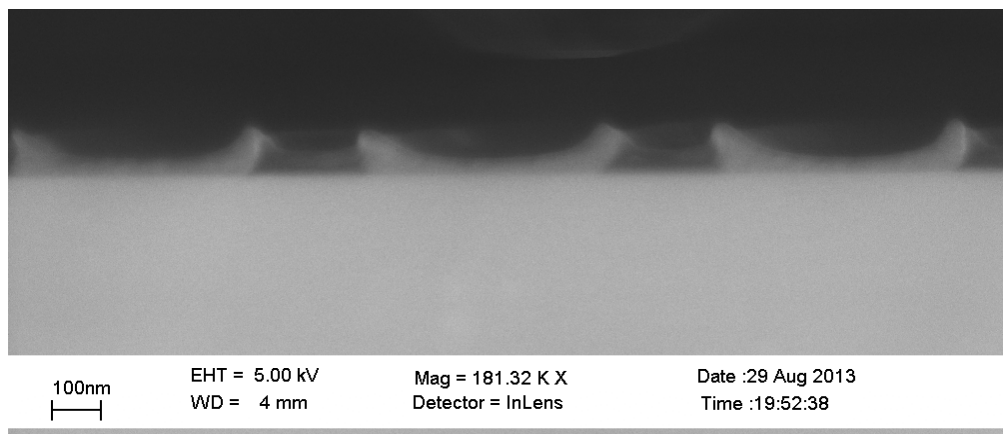


Figure-1: HSQ deposited on PMMA pattern

In Figure-1, the reduction in the resist thickness was observed along with buckling of patterned profile. As a result of that, authors initiated a detailed study of the resist surface interface. To examine the interface 120 nm of PMMA resist was spin coated on the wafer. The unexposed sample was then dipped in the PMMA developer, (1:3 MIBK to IPA) followed by an additional step to spin coated with 40 nm of HSQ.

In order to understand the surface interface, X-ray photoelectron spectroscopy (XPS) and SEM cross sectional imaging was performed on the sample having HSQ/PMMA resist layers.

A FACILE APPROACH FOR THE SYNTHESIS OF MONOLITHIC HIERARCHICAL POROUS CARBONS

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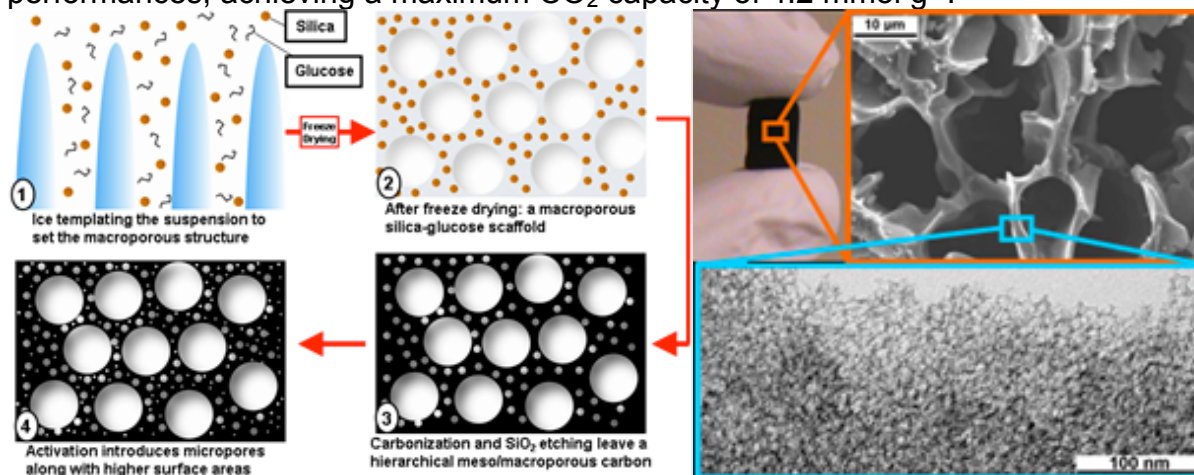
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The move from a fossil fuel based energy economy to a renewable energy based economy is currently underway. In order to realize this goal, it is vital to mitigate the environmental effects of the current fossil fuel infrastructure, while advancing the effectiveness of renewable energy alternatives. In this work, we show how hierarchical porous carbon (HPC) materials with high surface area and pore volume can address both goals. By providing a scaffold support for amine impregnation, HPCs can be used to fabricate effective CO₂ capture materials providing the means to mitigate the environmental effects of a fossil fuel energy economy. Furthermore, the open, vascular structure of HPCs can be used to produce effective EDLC supercapacitors for energy storage and high power output, important when considering the intermittent nature of many renewable energy sources (prominently wind and solar).

In this work we demonstrate a facile and scalable synthesis technique for producing a family of highly tunable monolithic HPC materials. Using Ice templating, hard templating and physical activation, the porosity of the materials can be modified for all three length scales (macro- meso- and microporosity respectively). Initial results reveal the HPCs to be an excellent candidate to be used as effective EDLC electrodes with a maximum charge storage capability of 6 W h kg⁻¹ and a maximum power density of 14 kW kg⁻¹. When used as scaffolds for amine based CO₂ capture, the HPCs show exceptional performances, achieving a maximum CO₂ capacity of 4.2 mmol g⁻¹.



GROWTH OF β -TUNGSTEN FILMS TOWARDS A GIANT SPIN HALL EFFECT LOGIC DEVICE

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Spin orbit interaction in a semiconductor^[1] and metal^[2] result in spin current transverse to a charge current, this is spin Hall effect. It was theoretically predicted by Dyakonov. et. al^[1] and J.E.Hirsch^[2], but not until it was experimentally confirmed in 2004 by Kato, Y.K. et al.^[3] did it attract the much attention. Recent spin Hall effect studies in metals like β -Ta, β -W produce spin currents strong enough to switch an adjacent magnetic layer^[4]

α and β phases of Tungsten are strongly governed by film resistance^[5], thickness^[6], base pressure^[7] and oxygen availability^{[8][9]}. The metastable β -W is known to exhibit giant spin Hall effect^[10]. Deposition conditions selective to β phase should be used to fabricate these devices.

A step wise process flow for a fully functioning device that combines the giant spin Hall effect and magnetic tunnel junction needs to be explored. This poster will present our work on fabricating and characterizing thicker tungsten films, dominated with β -phase, towards a giant spin Hall Effect structures utilizing the 300 mm wafer processing facilities at CNSE.

References:

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- [2] J.E. Hirsch, arXiv:cond-mat/9906160
- [3] Kato, Y.k., Myers, R.C., Gossand, A.C. Awschalom, D.D.: Science 306, 1910 (2004)
- [4] Luaiao Liu et al. Science 336, 555 (2012)
- [5] P.Petroff et. al. J.Apply, 44, 2545 (1973)
- [6] D. Choi, et al. J. Vac Sci. Technol.A 29, 051512 9 (2011)
- [7] S.M. Rossnagel et al. J.Vac. Sci. Technol. B20, 2047 (2002)
- [8] S.Basavaiah Appl. Phys. Lett. 12, 259 (1968)
- [9] T. Karabacak et al. Thin Solid Films 493 (2005) 293-293
- [10] C.F.Pai et al. arXiv:1208.1711

OXIDE GROWTH AND CHARACTERIZATION AND SPIN PRECESSION MEASUREMENTS IN CVD GRAPHENE

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Utilizing the spin of electron as well as its charge has a potential to create devices which are more energy efficient with faster operating speeds. The all spin logic device was proposed as one such example in 2010^[1]. In order to realize such a device, channel materials with two important metrics are needed; long spin relaxation times and efficient spin injection. Graphene is an ideal channel material because it has intrinsically low spin-orbit coupling and minimal hyperfine interaction with carbon nuclei give it a long spin lifetime at room temperature^[2]. Our previous work has demonstrated that introducing a tunnel barrier between the ferromagnetic metal and an epitaxial graphene channel improves the measured lifetime and spin injection efficiency^[3]. In this presentation, we are presenting our recent systematic work on growing aluminum oxide under ultra-high vacuum conditions for the use of tunnel barriers on graphene grown by chemical vapor deposition (CVD). The chemical and structural composition of the oxide both with and without the use of a Ti seed layer is investigated using atomic force microscopy and X-ray photoelectron spectroscopy. The Ti seed layer is shown to significantly reduce the surface roughness of the dielectric film and if kept thin enough remain completely oxidized^[4]. The electrical measurement results will be also presented showing the successful spin injection into CVD graphene.

References:

- [1] B. Behin-Aein *et al.*, *Nat. Nanotechnol.*, **5**, 266 (2010)
- [2] N. Tombros *et al.*, *Nature*, **448**, 571 (2007)
- [3] J. Abel *et al.*, *J. Vac. Sci. Technol. B*, **30**, 04E109 (2012)
- [4] A. Matsubayashi *et al.*, *J. Vac. Sci. Technol. A*, **31**, 021506 (2013)

RAPID MICROWAVE-SOLVOTHERMAL SYNTHESIS OF CONNECTED SILVER NANOSTRUCTURES FOR THERMAL APPLICATIONS

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Large scale rapid synthesis of connected metallic nanostructures is of interest for several thermal and electrical applications. Specifically, it has been demonstrated that metal nanowire networks with high connectivity can yield upto 35x enhancement in thermal conductivity when incorporated in polymers at < 4 vol. %. filler loading. Here, we report rapid, scalable microwave-solvothermal routes to manipulate aspect ratio and connectivity of polyvinylpyrrolidone (PVP) functionalized silver nanostructures. By controlling microwave dose, precursor concentrations and PVP polymerization we selectively synthesize silver nanowires and nanocubes in high yield. We demonstrate branching of silver nanowires through intermittent microwave exposure. We also irradiate silver nanowires with microwaves to induce in solution welding creating high-connectivity networks. Our results open up multiple pathways for the facile synthesis of connected metallic nanostructures.

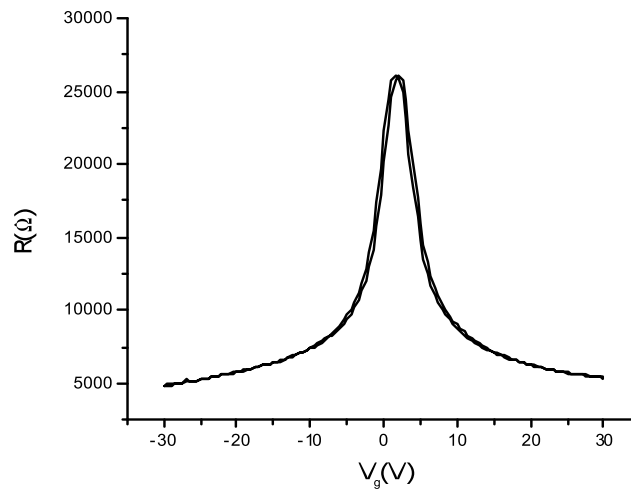
MEASUREMENT OF THE ENHANCED TRANSFER CURVES OF GRAPHENE FET DEVICES

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The electrical properties of graphene make it a prime candidate for post-CMOS electronic devices. By using the resistance at the Dirac point, switching between the on and off state can be achieved. However, due to the lack of a band gap and graphene-substrate interface effects, this ratio tends to be low and the electron mobility is poor. We show our enhanced transfer curve measurements on CVD grown graphene based FET devices. These devices were created using a standard photolithography process. ON/OFF ratios and electron mobilities for two-terminal measurements will be shown for devices measured in a standard microprobe station. Our results will include these measurements for graphene FETs fabricated where graphene was transferred onto pristine and non-pristine substrates.



*Example of transfer curve for Graphene FET device
showing low hysteresis and a zero dirac point*

MODIFYING ELECTRICAL PROPERTIES OF METAL-THERMOELECTRIC INTERFACE USING A MOLECULAR NANOLAYER

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Thermoelectric materials are attractive for realizing ecofriendly solid-state refrigeration, and waste heat recovery and harvesting. Besides obtaining high thermoelectric figure of merit ZT materials, tailoring the electrical properties of interfaces of these materials with metals is crucial for high performance device applications. It is understood that molecular nanolayers can modify interfacial properties such as thermal conductance and mechanical strength. Here, we describe the impact that molecular nanolayers of 1-octanethiol and 1,8-octanedithiol have on the electrical conductance of n-Bi₂Te₃ contacted with Cu. X-ray photoelectron spectroscopy analysis reveals molecular bilayers self-assembling on the n-Bi₂Te₃ surfaces. Interfacial contact resistance measurements via a modified Cox & Strack model show the modification of the Cu/n-Bi₂Te₃ electrical contact resistance by the molecular nanolayers. Based upon these findings, we describe a phenomenological model revealing the connection between interface chemistry and the electrical transport properties. Our results will be important for designing metal contacts to thermoelectric devices.

ENHANCING SUPERCAPACITOR PERFORMANCE USING GRAPHENE LAYER ELECTRODES

Don DeRosa, Kathleen Horvath, John Fite, Ben Grisafe, Gopal Ganesan, Manisha V.
Rane-Fondacaro, Ji Ung Lee, and Pradeep Haldar

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Supercapacitors electrostatically store energy through the accumulation of ions on conductive high surface area materials, resulting in a rapidly charging energy storage system with a significantly longer lifetime than conventional electrochemical batteries. The adoption of this technology in hybrid vehicles and smart grid systems has been hindered by its relatively low energy density (ca. 54 kJ/kg). Graphene has theoretically the highest surface 2600 m²/g area among carbon materials enabling high energy density (65-115 kJ/kg, using ionic liquid electrolytes). Through a chemical vapor deposition process (CVD), high quality single layer graphene sheets were grown on copper substrates and transferred on to stainless steel current collectors for fabricating lab scale supercapacitor devices, with the intention of dramatically increasing the energy density of these devices. Supercapacitors with graphene electrodes containing 1, 2, 3, 4, and 10 layers were fabricated and paired with a proprietary ionic liquid electrolyte of high conductivity and electrochemical stability window. The supercapacitor device was cycled at increasing potential ranging from $\Delta 1V$ to $\Delta 8.5V$. The energy density of the graphene supercapacitor was observed to triple at the operating voltage of 8.5V, which was maintained upon subsequent cycling at lower potential. Currently this is hypothesized to be a direct consequence of ion intercalation between the graphene layers leading to an expanded interlayer separation, thereby enabling easy accessibility of surface area during charge-discharge. This additional accessible surface results in a higher capacitance for the device which translates to a higher energy density. The underlying mechanism for capacitance enhancement is currently being investigated.

MODELING THERMOELECTRIC TRANSPORT PROPERTIES OF NANO-BULK Bi_2Te_3

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Theodorian Borca-Tasciuc

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Designing thermoelectric materials with a high figure of merit (ZT) is difficult because it requires retaining a high Seebeck coefficient and electrical conductivity while suppressing thermal conductivity. Recent advances in microwave-stimulated wet-chemical synthesis have allowed the production of nanostructured bulk Bi_2Te_3 , which exhibit $\text{ZT} > 1$. In order to understand the physics behind these results and be able to adjust sample synthesis for optimum ZT, the thermoelectric properties of Bi_2Te_3 were modeled using the Boltzmann Transport Equations under the Relaxation Time Approximation. By adding scattering mechanisms due to nanostructuring and doping to a model which successfully reproduces single crystal Bi_2Te_3 transport properties, the nanostructured Bi_2Te_3 transport properties are explained.

ATOMIC LAYER DEPOSITION (ALD) OF MIXED METAL FUEL CELL CATALYSIS

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The major road block to the commercialization of fuel cells is the high cost associated with the Pt necessary for the catalyst. The Pt is necessary in the cathode of the fuel cell to overcome the slow kinetics of the oxygen reduction reaction (ORR).

ALD is a method utilizing half reactions minimizing the amount of material deposited at a time. This allows the possibility of depositing ultralow quantities of Pt on a material to maximize its surface to bulk atom ratio. An additional method of decreasing the Pt content is through bimetallic catalysis. Studies in this approach found that CoPt_3 and NiPt_3 are able to catalyze the oxygen reduction reaction more efficiently and have been shown to have a higher lifetime.

This research combines both these techniques to make an enhanced catalyst with ultralow amounts of Pt. CoPt and RuPt mixed metal catalysts were made on substoichiometric titanium dioxide thin films also prepared through atomic layer deposition as well as traditional Vulcan carbon supports. Electrochemical results are shown for Pt as a metal on its own compared to results with CoPt and RuPt . Enhancement was shown with Ru which would not dissolve in an acidic media. Unfortunately CoPt films showed a dissolution of the Co from the catalyst resulting in poor working catalysts.

Characterization was performed with scanning electron microscopy (SEM), Auger electron spectroscopy (AES), x-ray photoelectron spectroscopy (XPS), Rutherford backscattering spectrometry (RBS), four point probe analysis, and cyclic voltammetry (CV).

COMPARISON BETWEEN CYCLOPENTADIENYL-BASED SrO and MgO ALD: AN *IN-SITU* SPECTROSCOPIC ELLIPSOMETRY INVESTIGATION

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SrO ALD is used for the ALD of the ternary strontium titanate (STO), which is of major interest for use with high-density metal-insulator-metal (MIM) capacitors. SrO is also of interest for the growth of epitaxial perovskite oxides on semiconductors where it acts as a buffer layer between the reactive semiconductor and metal oxide layers. MgO is also of scientific and technological importance. With a band gap of 7.8 eV, for example, MgO is widely used as the intervening tunnel barrier to enable efficient spin injection in the magnetic tunnel junctions (MTJs). Due to the basicity, SrO and MgO are chemically unstable once exposed to the air, and *ex-situ* chemical and structural analysis tools may not reveal the true properties of SrO and MgO films. Thus, in order to better understand and control ALD processes, *in-situ* thin film analysis techniques are highly desirable. Spectroscopic ellipsometry is an all-optical, non-destructive method, and *in-situ* real time spectroscopic ellipsometry (RTSE) provides a fast and simple way to acquire thickness and optical property data during ALD growth. The objective of this work is to provide insight into the mechanisms of SrO and MgO ALD by using RTSE to study ALD half-cycles, and to learn about nucleation surface chemistry for Sr precursor reactions with oxide and hydroxide surfaces. We present results of experiments performed for both SrO hetero- and homo-ALD processes using $\text{Sr}(\text{C}_5\text{Pr}_3\text{H}_2)_2$ and H_2O chemistry and MgO homo-ALD process using $\text{Mg}(\text{C}_5\text{H}_5)_2$ and H_2O with emphasis on the unique structural characteristics of Sr and Mg films and their impact on growth characteristics, especially GPC variation with deposition temperature. We emphasize the importance of substrate effects in metal oxide ALD processes and establish correlations between the composition and crystallinity of substrates and thin film material properties.

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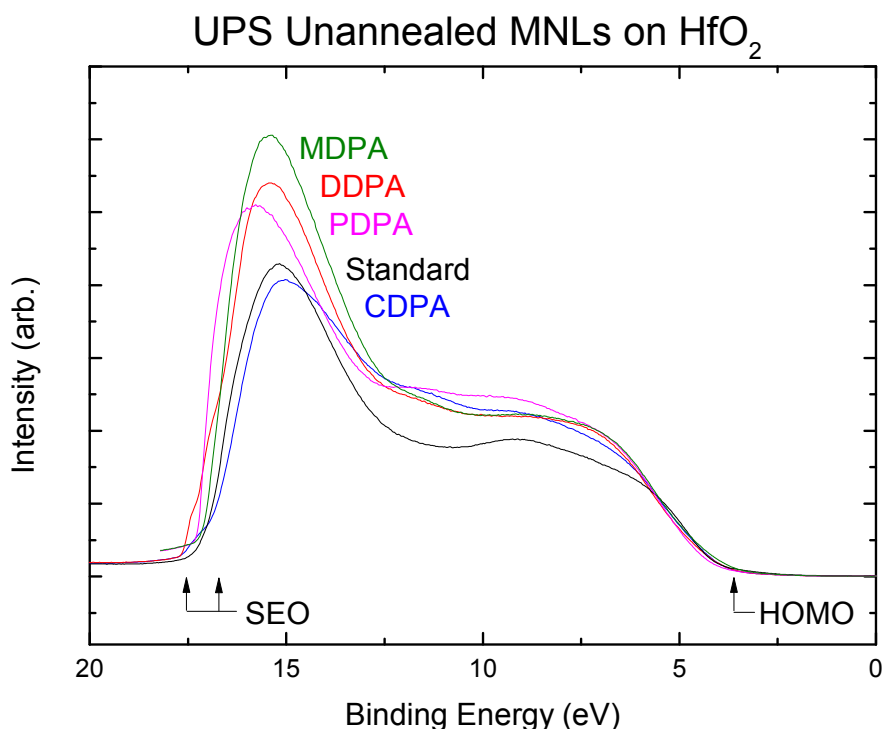
METAL OXIDE VALANCE BAND TUNING WITH PHOSPHONIC ACID MOLECULAR NANOLAYERS

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Our work shows that the ionization energy of hafnium oxide surfaces can be modified by the addition of phosphonic acid molecular nanolayers (MNLs). Ultraviolet photoelectron spectroscopy (UPS) is used to measure the valence structure of hafnia, and reveals that the surface ionization energy increases or decreases depending on the MNL moieties. In addition a larger increase in ionization energy is achieved upon annealing samples at 140 °C. Examination of the UPS data reveals that changing the MNL moieties shifts the secondary electron onset (SEO) energy, whereas annealing shifts the highest occupied molecular orbital (HOMO) energy. These results show that the valence band of hafnia can be tuned by both chemical and process modification of MNLs.



SECONDARY ELECTRONS IN EUV LITHOGRAPHY AND ELECTRON ENERGY LOSS SPECTROSCOPY

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In the rapidly growing semi-conductor industry, the quest of getting finer IC (Integrated Circuit) design and to accommodate more and more thin FET's in a chip has been an astonishing challenge. Even advanced techniques such as X-Ray Lithography, UV Lithography have failed to get thinner FET's that are finer than today's standards. The ability of the semiconductor industry to continue developing higher density, higher performance integrated circuits has been enabled by the evolution of lithography, pattern transfer and process technology. Hence, researchers all over the world are working on a new form of lithography called EUVL (Extreme Ultra Violet Lithography), a next generation lithography which uses EUV light that has a wavelength of 13.5nm. EUVL is in its initial phase and is developing rapidly; however, a key barrier is to develop highly efficient chemically amplified resists called Photoresists for EUVL. Such resists consists of PAG (Photo-Acid Generators) that generate secondary electrons on interacting with EUV photons. To make better resists, it is important to understand the energy losses of these secondary electrons. Electron Energy Loss Spectroscopy (EELS) is the technique selected to study the energy losses of the secondary electrons due to its high resolution characteristics, and a customized retarding field analyzer is being built for this experiment.

CLEANING OF SAMPLES PRIOR TO XPS AND TOF-SIMS ANALYSIS VIA *IN-SITU* AMBIENT AIR PLASMAS

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In an industrial setting many of the samples analyzed, as received, by X-ray Photoelectron Spectroscopy (XPS) and/or Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS) reveal a hydrocarbon signature that results from processing, handling, and/or ambient exposure. With the high surface specificity of XPS and especially ToF-SIMS the contamination (hydrocarbon, and/or silicones) signal can attenuate and/or mask the signals of species of interest. To counteract this issue, an *in-situ* ion beam is often used to remove the outer layer of a sample surface via sputtering and thus remove contaminants. However this erosion process is inherently destructive and can alter the surface of interest and/or change the topography/microstructure of the surface. Herein we report use of a plasma-chemical method to prepare samples for analysis.

**UNDERSTANDING EUV RESISTS
(SECONDARY ELECTRONS INTERACTIONS AND BEYOND)**

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Extreme Ultra Violet (EUV) Lithography is currently being developed for 450mm High Volume Manufacturing (HVM) of Semiconductor devices beyond 14nm technology node. One of the issues related to EUV lithography is the line edge roughness (LER) that occurs in laying high density lines of narrow dimensions. In order to solve the appearance of LER, it is very important to develop an efficiency characterization technique to identify the same as a means of quality control.

In this poster, we present a novel characterization system ERIC (Electron Resist Interaction Chamber). This technique measures secondary electrons generated during EUV exposure of resists including their number, energies, diffusion lengths and their reactivity with photo acid generators (PAG). Ellipsometry results indicate that the depth of penetration is a function of dose and energy of the incident electron beam.

CONSTRUCTION OF A SPIN LAB MEASUREMENT SYSTEM TO ENABLE MEASUREMENT OF SPIN CARRIER TRANSPORT IN MATERIALS

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Measuring electron spin transport metrics of materials and devices is becoming increasingly important as there is a great desire to fabricate devices that utilize the spin of the electron as well as its charge. This creates a need to measure ultra-low current without creating an increase in the signal-to-noise ratio with variable temperature and magnetic fields. In this poster we will present our custom built spin transport measurement system called the “Spin Lab Measurement System” (SLMS). This system can perform spin relaxation time measurements using non-local spin detection with spin precession (i.e. Hanle technique), along with other standard measurements such as Hall Effect, spin Hall Effect, Kondo Effect and other transport measurements. We will also describe how to measure spin Hall effect (SHE) using the SLMS as well as characterizing a spin transport material. Two Primary measurements are able to be carried out, the spin Hall effect and non-local spin detection with spin precession.

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