THIRTY-FIRST ANNUAL SYMPOSIUM

of the

LABORATORY FOR SURFACE MODIFICATION

and

INSTITUTE FOR ADVANCED MATERIALS, DEVICES

AND NANOTECHNOLOGY

Tuesday, March 7, 2017

8:30 a.m. to 5:00 p.m.

Rutgers, the State University of New Jersey

PROGRAM

Life Science Center
Busch Campus
Piscataway, New Jersey
THIRTY-FIRST ANNUAL SYMPOSIUM
LABORATORY FOR SURFACE MODIFICATION

8:30  Registration, coffee
9:00  Introductory Remarks
      Professor Torgny Gustafsson,
      Director, Laboratory for Surface Modification

SESSION I:

HIGHLY CORRELATED MATERIALS

Chair:

9:05  Visualizing Local Electronic Properties of Defects in Magnetic Topological Insulators
      Wenhan Zhang\textsuperscript{1}\textsuperscript{*}, Y. Qiu\textsuperscript{2}, Y. S. Hor\textsuperscript{2} and Weida Wu\textsuperscript{1}
      \textsuperscript{1}Physics and Astronomy \textsuperscript{and} \textsuperscript{2}Physics, Missouri University of Science and Technology

9:20  Revealing Electron Correlation Effects through Crystal Field Excitations in 4f-Electron Systems
      Mai Ye\textsuperscript{1}\textsuperscript{*}, Alexander Lee\textsuperscript{1}, Hsiang-Hsi Kung\textsuperscript{1}, Priscila F. S. Rosa\textsuperscript{2}, Eric D. Bauer\textsuperscript{2}, Zachary Fisk\textsuperscript{3} and Girsh Blumberg\textsuperscript{1}
      \textsuperscript{1}Physics and Astronomy, \textsuperscript{2}Los Alamos National Laboratory \textsuperscript{and} \textsuperscript{3}Physics and Astronomy, University of California

9:35  Surface Phases of the Transition Metal Dichalcogenide IrTe\textsubscript{2}
      Chen Chen\textsuperscript{1}\textsuperscript{*}, Jisun Kim\textsuperscript{2}, Yifan Yang\textsuperscript{2}, Guixin Cao\textsuperscript{2}, Rongying Jin\textsuperscript{2} and E. W. Plummer\textsuperscript{2}
      \textsuperscript{1}Physics and Astronomy \textsuperscript{and} \textsuperscript{2}Physics and Astronomy, Louisiana State University

9:50  Resonant Electronic Raman Excitations with A\textsubscript{2g} Symmetry in Bi\textsubscript{2}Se\textsubscript{3}
      Hsiang-Hsi Kung\textsuperscript{1}\textsuperscript{*}, X. Wang\textsuperscript{1}\textsuperscript{2}, A.C. Lee\textsuperscript{1}, Sang-Wook Cheong\textsuperscript{1}\textsuperscript{2} and Girsh Blumberg\textsuperscript{1}
      \textsuperscript{1}Physics and Astronomy \textsuperscript{and} \textsuperscript{2}Rutgers Center for Emergent Materials

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10:05 – 10:30 Coffee Break and Poster Session

\* = Student Presenter
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SESSION II:

MICROSCOPY AND APPLICATIONS

Chair:

10:30 WELCOMING REMARKS

10:45 **HIGHLIGHT PRESENTATION**

Helium Ion-Milled Solid-State Nanopores and Their Applications in Biological Sensing
Adam R. Hall
Virginia Tech-Wake Forest School of Biomedical Engineering and Sciences, Wake Forest University School of Medicine

11:30 Helium Ion Microscopy Characterization and Analysis of Biological Structures
Viacheslav Manichev\textsuperscript{1,3*}, Eric Garfunkel\textsuperscript{1,3}, Leonard C. Feldman\textsuperscript{2,3} and Torgny Gustafsson\textsuperscript{2,3}
\textsuperscript{1}Chemistry and Chemical Biology, \textsuperscript{2}Physics and Astronomy and Laboratory for Surface Modification and \textsuperscript{3}Institute for Advanced Materials Devices and Nanotechnology

11:45 The Rutgers UltraSTEM: A Characterization Tool for Nanomaterials
Maureen J. Lagos\textsuperscript{1,2,3*} and Philip. E. Batson\textsuperscript{1,2,3}
\textsuperscript{1}Institute for Advanced Materials, Devices and Nanotechnology, \textsuperscript{2}Materials Science and Engineering and \textsuperscript{3}Physics and Astronomy

12:00 The Vacuum-Liquid Interface of Functionalized Ionic Liquids
Aleksandra B. Biedron\textsuperscript{1}, Sylvie Rangan\textsuperscript{2}, Eric L. Garfunkel\textsuperscript{1} and Edward W. Castner, Jr.\textsuperscript{1}
\textsuperscript{1}Chemistry and Chemical Biology and \textsuperscript{2}Physics and Astronomy and Laboratory for Surface Modification

\$\$ 12:15 – 1:30 Lunch and Poster Session  \$\$

* = Student Presenter
1) **Visualizing Ferromagnetic Domains in Undoped and Fe-doped Sr$_4$Ru$_3$O$_{10}$**  
Paul Sass$^{1,*}$, Weida Wu$^1$, Zhiqiang Mao$^2$ and Peigang Li$^2$  
$^1$Physics and Astronomy and $^2$Physics and Engineering Physics, Tulane University

2) **A Novel Frequency Tuning Device Built on Semiconducting-Piezoelectric ZnO**  
Guangyuan Li$^{1,*}$, Rui Li$^1$, Ke Tang$^2$, Pavel I. Reyes$^1$, Keyang Yang$^1$, Szu-Ying Wang$^1$, Hongfei Ye$^1$, Yuxuan Li$^1$, Wen-Chiang Hong$^1$, Jian Huang$^2$ and Yicheng Lu$^1$  
$^1$Electrical and Computer Engineering and $^2$School of Material Science and Engineering, Shanghai University

3) **Critical Evaluation of the Relationship between Raman Peak Shift and Stress in Semiconductor Materials**  
Shawn Ward$^*$ and Adrian B. Mann  
Materials Science and Engineering

4) **The Rutgers UltraSTEM: A Characterization Tool for Nanomaterials**  
Maureen J. Lagos$^{1,2,3,*}$ and Philip. E. Batson$^{1,2,3}$  
$^1$Institute for Advanced Materials, Devices and Nanotechnology, $^2$Materials Science and Engineering and $^3$Physics and Astronomy

5) **ZnTPP Nonequilibrium Growth Phenomenon on Ag(100) Surface**  
Peter Kim$^{1,*}$, Sylvie Rangan$^1$, Robert Bartynski$^1$, Charles Ruggieri$^1$, Deyu Lu$^2$ and Stephen Whitelam$^3$  
$^1$Physics and Astronomy and Laboratory for Surface Modification, $^2$Center for Functional Nanomaterials, Brookhaven National Laboratory and $^3$Molecular Foundry, Lawrence Berkeley National Laboratory

6) **Characterization of n-BuSnOOH: Solution Precursors Identify and Film Quality**  
Mengjun Li$^{1,*}$, Jenn Amador$^2$, Ryan T. Frederick$^3$, Sumit Saha$^2$, Trey Dilius$^3$, Douglas A. Keszler$^2$, Gregory S. Herman$^3$ and Eric L. Garfunkel$^1$  
$^1$Chemistry and Chemical Biology, $^2$Chemistry, Oregon State University and $^3$School of Chemical, Biological and Environmental Engineering, Oregon State University

7) **Photoemission Studies of a Biased Graphene-Insulator-Semiconductor Structure**  
Malathi Kalyanakar$^{1,*}$, Sylvie Rangan$^2$, Junxi Duan$^2$, Gang Liu$^3$, Robert A. Bartynski$^2$, Eva Y. Andrei$^2$, Leonard Feldman$^3$ and Eric Garfunkel$^1$  
$^1$Chemistry and Chemical Biology, $^2$Physics and Astronomy and $^3$Institute for Advanced Materials, Devices and Nanotechnology

* = Student Presenter
8) **Investigation of Cyclooctatetraene on Copper (001)**
   John L. Wieczorek*, Erkan Z. Ciftlikli, Sylvie Rangan, Robert A. Bartynski and B. J. Hinch
   1Chemistry and Chemical Biology and 2Physics and Astronomy and Laboratory for Surface Modification

9) **Copper Phosphide as a CO\textsubscript{2} Reduction Catalyst**
   Timothy A. Goetjen, Karin U.D. Calvinho, Anders B. Laursen and G. Charles Dismukes
   1Chemistry and Chemical Biology and 2Institute for Advanced Materials, Devices and Nanotechnology

10) **Direct Electrochemical Reduction of Carbon Dioxide by Nickel Phosphide**
    Karin U. D. Calvinho, Anders B. Laursen, Timothy A. Goetjen, Alexander Lubarsky, Martha Greenblatt and G. Charles Dismukes
    1Chemistry and Chemical Biology and 2Institute for Advanced Materials, Devices and Nanotechnology

11) **Novel Catalysts for Electrochemical Ammonia Synthesis under Ambient Conditions**
    Chris R. Dziedziak, A. B. Laursen and G. Charles Dismukes
    1School of Engineering, 2Chemistry and Chemical Biology, 3Institute for Advanced Materials, Devices and Nanotechnology and 4Waksman Institute

12) **Excellent Catalytic Activity and Stability of NiP\textsubscript{2} Thin Film Hydrogen Evolution Reaction Catalysts on Silicon Photocathode with Titanium Nitride Passivation Layer**
    Shinjae Hwang, Spencer H. Porter, Anders B. Laursen, Voshadhi Amarasinghe, Mengjun Li, Martha Greenblatt, Eric Garfunkel and G. Charles Dismukes
    1Institute for Advanced Materials, Devices and Nanotechnology, 2Chemistry and Chemical Biology and 3Physics and Astronomy

13) **Composition Analysis of Ground, Sieved, and Calcined Degussa P25 TiO\textsubscript{2} via Differential Diffuse Reflectance and Differential Kubelka Munk Spectral Analysis**
    Ashley M. Pennington, Amanda I. Okonmah, Daryll T. Munoz, Carolina S. Radecki, George Tsilomelekis and Fuat E. Celik
    Chemical and Biochemical Engineering

14) **Continuous-Flow Heterogeneous Alkane Transfer Dehydrogenation Effected by Immobilized Pincer-Ligated Iridium Catalysts**
    Boris Sheludko, Ashley M. Pennington, Molly T. Cunningham, Marisa E. Gliege, Bo Li, Longfei Chao, Akshai Kumar, Alan S. Goldman and Fuat E. Celik
    1Chemistry and Chemical Biology, 2Chemical and Biochemical Engineering and 3Chemical Engineering and Bioengineering, Washington State University

* = Student Presenter
15) Scalable Micro/Nanomanufacturing of Complex Architectures through Hybrid Lithography
Tianxing Ma*, Lin Lei, Valeria Saro-Cortes, Arielle Gamboa, Imrhankhan Shajahan, Michael Nitzsche and Jonathan Singer
Mechanical and Aerospace Engineering

* = Student Presenter
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SESSION III:
CHEMISTRY AT SURFACES AND INTERFACES

Chair:

1:30  **HIGHLIGHT PRESENTATION**
Shape and Surface Engineering of Monodisperse Nanocrystals for
Photocatalysis and Electrocatalysis
Christopher B. Murray
Chemistry and Materials Science and Engineering, University of Pennsylvania

2:10  Solution-Processed MoS$_2$/Organolead Trihalide Perovskite Photodetectors
Yan Wang*, Raymond Fullon, Jieun Yang and Manish Chhowalla
Materials Science and Engineering

2:25  Electrodeposited Films of Cadmium Selenide for Silicon-based Tandem Solar
Devices
W. Ross Rucker*, Janki Patel, Daniel Um and Dunbar Birnie
Materials Science and Engineering

2:40  Photoluminescence Stability of Blue Organic Phosphorescent Materials on
Silver Metasurface Electrodes
Catrice M. Carter¹*, Zeqing Shen², Kun Zhu¹, Kelsey Gwynne³ and Deirdre M. O’Carroll¹,²,⁴
¹Materials Science and Engineering, ²Chemistry and Chemical Biology, ³Wagner
College, Staten Island and ⁴Institute for Advanced Materials, Devices and
Nanotechnology

2:55  Electrochemical Hydrogen Evolution on Ni$_3$P
Anders B. Laursen¹,², M. J. Whitaker¹, R. B. Wexler¹, A. M. Rappe³, Martha Greenblatt¹
and G. Charles Dismukes¹,²
¹Chemistry and Chemical Biology, ²Institute for Advanced Materials, Devices and
Nanotechnology and ³University of Pennsylvania

3:10 – 3:35 Afternoon Break
SESSION IV:

NOVEL MATERIALS

Chair:

3:35  Understanding Interfaces in Gold Nanospheres-Hybrid Silica Gel Systems
     Stamantia Kallontzi1*, Lisa C. Klein1, Laura Fabris1,2 and Andrei Jitianu3
     1Materials Science & Engineering, 2Biomedical Engineering and 3Chemistry, Lehman
     College-City University of New York

3:50  Hole Doping Problem in Bi2Se3 Thin Films and its Solution: Role of
     Interfacial vs Bulk Defects
     Jisoo Moon1*, Nikesh Koirala1, Maryam Salehi2, Wenhan Zhang1, Weida Wu1 and
     Seongshik Oh1
     1Physics and Astronomy and 2Materials Science & Engineering

4:05  Nanostars: Where Localized and Propagating Plasmons Meet
     Ted V. Tsoulos*, Supriya Atta and Laura Fabris
     Materials Science and Engineering

4:20  Thermal Decomposition of SiO2 on 4H-SiC(0001)
     Xiuyan Li1,3, Sylvie Rangan2, Mengjun Li1, Viacheslav Manichev1,2,3, Voshadhi
     Amarasinghe3, Torgny Gustafsson2,3, Eric Garfunkel1,3 and Leonard C Feldman2,3
     1Chemistry and Chemical Biology, 2Physics and Astronomy and 3Institute for Advanced
     Materials, Devices and Nanotechnology

4:35  Presentation of Theodore E. Madey Student Award:
     Best Oral Presentation

Presentation of Leszek Wielunski Student Award:
     Best Poster Presentation

* = Student Presenter
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**ABSTRACTS FOR TALKS**

**9:05** Visualizing Local Electronic Properties of Defects in Magnetic Topological Insulators  
Wenhan Zhang\textsuperscript{1*}, Y. Qiu\textsuperscript{2}, Y. S. Hor\textsuperscript{2} and Weida Wu\textsuperscript{1}  
\textsuperscript{1}Physics and Astronomy and \textsuperscript{2}Physics, Missouri University of Science and Technology

Quantum anomalous Hall effect (QAHE) manifests as a quantized dissipationless Hall conduction due to chiral edge state circulating along the edge of 2D electron systems without external magnetic field. This effect relies on strong spin-orbit coupling and ferromagnetism. QAHE has been experimentally realized in both Cr-doped and V-doped (Sb\textsubscript{1-x}Bi\textsubscript{x})\textsubscript{2}Te\textsubscript{3}, which are magnetic topological insulators (TIs). V-doped (Sb\textsubscript{1-x}Bi\textsubscript{x})\textsubscript{2}Te\textsubscript{3} exhibits higher Curie temperature and much less zero-field longitudinal resistance. It is still unclear why V is better than Cr for QAH effect. Here we present scanning tunneling microscopy and spectroscopy (STM/STS) studies on the local electronic properties in both Cr\textsubscript{1-x}Sb\textsubscript{x}Te\textsubscript{3} and V\textsubscript{1-x}Sb\textsubscript{x}Te\textsubscript{3} single crystals. Preliminary STM/STS results indicate the local properties of defects strongly influence the magnetic ordering in doped TIs, which is crucial for robust QAHE at elevated temperature.

**9:20** Revealing Electron Correlation Effects through Crystal Field Excitations in 4f-Electron Systems  
Mai Ye\textsuperscript{1*}, Alexander Lee\textsuperscript{1}, Hsiang-Hsi Kung\textsuperscript{1}, Priscila F. S. Rosa\textsuperscript{2}, Eric D. Bauer\textsuperscript{2}, Zachary Fisk\textsuperscript{3} and Girsh Blumberg\textsuperscript{1}  
\textsuperscript{1}Physics and Astronomy, \textsuperscript{2}Los Alamos National Laboratory and \textsuperscript{3}Physics and Astronomy, University of California

Crystal-field (CF) potential plays an important role in determining the ground state and low-temperature phase diagram for 4f-electron systems\textsuperscript{[1]}. Measurement of CF excitations often serves to establish a CF level scheme; in this talk, we demonstrate that studying CF excitations also allows for a systematic investigation of electron correlation effects. We report Raman-scattering results of CeB\textsubscript{6} to explore the CF excitations, which are influenced by the many-body correlation effects in this system. One intra-multiplet\textsuperscript{[2]} and three inter-multiplet CF excitations are observed, which determine the CF level scheme for the upper multiplet. From 302 K to 15 K, the energy of three excitations increases due to lattice contraction and hybridization (the interaction between localized 4f-electrons and itinerant electrons) effect. The FWHM, which corresponds to relaxation rate, of two excitations decreases on cooling above T*\textsubscript{\textminus}70 K, but starts to increase on cooling below T*\textsuperscript{[1]}. Above T*, lattice vibration and hybridization effects contribute to the FWHM; below T*, the increasing FWHM results from the formation of the 4f-band.

\textsuperscript{[1]} P. Santini, et. al., Rev. Mod. Phys. 81, 807 (2009)  
9:35 **Surface Phases of the Transition Metal Dichalcogenide IrTe₂**
Chen Chen¹*, Jisun Kim², Yifan Yang², Guixin Cao², Rongying Jin² and E. W. Plummer²
¹Physics and Astronomy and ²Physics and Astronomy, Louisiana State University

Transition metal dichalcogenides have received great attention because of their fertile properties. The bulk of IrTe₂ exhibits first-order structural transitions from the expected trigonal structure at room temperature to unusual quasi-one-dimensional striped structure at low temperature. We have investigated, using low energy electron diffraction (LEED) and scanning tunneling microscopy (STM), the surface structural properties of IrTe₂. We observe complex striped lattice modulations as a function of temperature via cooling and warming processes, including 5x1 and 8x1 phases seen in the bulk. The ground state at the surface is 6x1 phase, not seen in the bulk, and the surface transition temperatures are distinct from the bulk. The broken symmetry at the surface creates a quite different phase diagram, with the coexistence of several periodicities resembling a devil’s staircase phenomena.

9:50 **Resonant Electronic Raman Excitations with A₂g Symmetry in Bi₂Se₃**
Hsiang-Hsi Kung¹*, X. Wang¹,², A.C. Lee¹, Sang-Wook Cheong¹,² and Girsh Blumberg¹
¹Physics and Astronomy and ²Rutgers Center for Emergent Materials

Here, we report the observation of a sharp collective mode with energy of 150 meV, below the edge of a gapped continuum, in bulk topological insulator Bi₂Se₃. Both features appear in the pseudovector-like symmetry of the A₂g representation of the D₃d group. The gapped continuum can be understood as the electron-hole excitations between the Dirac cones, whereas the slightly below gap edge collective mode is the corresponding exciton bound state. Such inter-Dirac-cone excitation flips the in-plane electron spin, but preserves the out-of-plane angular momentum, resulting in singlet exciton states. This is a demonstration of novel collective excitation from the surface states of 3D topological insulators.

* = Student Presenter
**HIGHLIGHT PRESENTATION**

**Helium Ion-Milled Solid-State Nanopores and Their Applications in Biological Sensing**

Adam R. Hall  
*Virginia Tech-Wake Forest School of Biomedical Engineering and Sciences, Wake Forest University School of Medicine*

Solid-state (SS-) nanopores are nanoscale apertures in thin membranes that can be used to probe individual biomolecules in solution and report on their structure. However, conventional methods of fabrication have been either slow or imprecise, frustrating efforts to push the platform forward. In our lab, we have used the emerging technology of Helium ion microscopy (HIM) to develop multiple capabilities that address these challenges and add functionality to the devices. I will focus on the effects of three specific ion dose regimes and describe a specific application for each: high dose, at which nanopores or nanopore arrays can be formed with nanometer precision; medium dose, at which local membrane thickness can be modified in situ; and low dose, at which intrinsic optical properties of the membrane material can be engineered.

**Helium Ion Microscopy Characterization and Analysis of Biological Structures**

Viacheslav Manichev, Eric Garfunkel, Leonard C. Feldman and Torgny Gustafsson  
*Chemistry and Chemical Biology, Physics and Astronomy and Laboratory for Surface Modification and Institute for Advanced Materials Devices and Nanotechnology*

Helium Ion Microscopy (HIM) is one of the latest technologies in the imaging toolbox. The HIM utilizes ~ 35 KeV He ions focused on a small spot (a few ångströms in diameter). The main advantage of HIM for imaging is the much deeper field of view and the unique capability to image non-conducting samples without a deposited metal overlayer. Using HIM we are pursuing collaborative projects in both the biological and biomedical fields. We have imaged “aged” rat kidney glomeruli, the biological structure responsible for the blood filtration. A series of images clearly reveals the structural and morphological changes associated with the aging process. We have also investigated the effect of ocean acidification on coral survivability. We have imaged calcification centers in corals and observed significant morphological changes as absorbed calcium forms.

We are developing a time of flight (ToF) energy analysis system which allows elemental identification on the nanometer scale in combination with the quantitative advantages of ion scattering technologies. The facility brings new capabilities for both characterization and metrology for a nano-electronics.

*Work done with A. Schulz et al, Ionwerks, Houston, TX.*

*This work was supported by Rutgers Institute for Advanced Materials, Devices and Nanotechnology, NSF grant DMR-1126468, and DOE grant DE-FG02-93ER14331.*
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11:45 The Rutgers UltraSTEM: A Characterization Tool for Nanomaterials
Maureen J. Lagos1,2,3* and Philip. E. Batson1,2,3
1Institute for Advanced Materials, Devices and Nanotechnology, 2Materials Science and Engineering and 3Physics and Astronomy

Rutgers University has become the house of one of the most advanced scanning transmission electron microscope (STEM) in the world. The RUTGERS UltraSTEM instrument is equipped with both aberration corrector and energy monochromator, which allows the physical exploration of phenomena over a wide energy range with both high spatial and energy resolution. Currently, our instrument has achieved angstrom resolution (~1 Å) and 8 meV of energy resolution at 60 KV. With this outstanding performance, users can perform routinely structural characterization using STEM imaging techniques of nanomaterials. In addition, this type of instrumentation is allowing Rutgers users to perform studies of vibrational, plasmonic, interband transition and core-shell spectroscopy. The remarkable capabilities of the new RUTGERS UltraSTEM are illustrated through a large variety of experimental results from ongoing collaborations with both internal and external researchers.

12:00 The Vacuum-Liquid Interface of Functionalized Ionic Liquids
Aleksandra B. Biedron1, Sylvie Rangan2, Eric L. Garfunkel1 and Edward W. Castner, Jr.1
1Chemistry and Chemical Biology and 2Physics and Astronomy and Laboratory for Surface Modification

Ionic Liquids (ILs) have novel physiochemical properties with many potential applications. In order to design ILs for superior performance in sensor, tribological, electrochemical, and catalytic processes, a fundamental understanding of structural ordering at the vacuum-liquid interface is necessary. This work examines how the ionic structure, cation ring, cation tail, tail functionalization, and anion size, modulates the interfacial structural properties of IL thin films. Angle-resolved X-ray photoelectron spectroscopy was used to compare bulk and interfacial composition. Results suggest that all ILs have interfacial ordering: typically, less the polar cation tails point up into vacuum. The extent of this structural ordering is related to both cation and anion functional groups.

Figure 1: Model of vacuum-Ionic Liquid interface

* = Student Presenter
Shape and Surface Engineering of Monodisperse Nanocrystals for Photocatalysis and Electrocatalysis
Christopher B. Murray
Chemistry and Materials Science and Engineering, University of Pennsylvania

The synthesis of colloidal semiconductor nanocrystals (NCs) has advanced dramatically in the past 10 years. The chemical reactivity of these “artificial atoms” can now be programmed precisely by the control of nanocrystal size, shape, and surface treatments, and doping. In this talk, I will highlight some of our efforts to advance the understanding of shape/facet dependent photocatalytic properties of TiO$_2$. [1] We will report on the facet dependent reactivity of anatase TiO$_2$ NCs surface treated with fluorine [2] to control the shape and in brookite TiO$_2$ nanorods [3] in which the average nanorod aspect ratio is adjusted to optimize the photocatalytic activity [4]. Progress in the doping of the brookite nanorods will also be discussed as a method to extend their activity further into the visible. Designing core/shell architectures has emerged as one of the most promising design strategies in catalysis research to compliment shape control. I will describe advances in combining shape-selective synthesis with core/shell overcoating strategies to improve the performance and cost of electrocatalysts. Specific examples will be drawn from studies of CoP$_2$/Pt core/shell nanorods [5] and Pt/Ni core/shell NCs [6] and new studies in biomass conversion [7]. If time permits I will extend the discussion of shape-controlled assembly to the design of electronic and optoelectronic materials [8].

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2:10 Solution-Processed MoS2/Organolead Trihalide Perovskite Photodetectors
Yan Wang*, Raymond Fullon, Jieun Yang and Manish Chhowalla
Materials Science and Engineering

Integration of organic/inorganic hybrid perovskites with metallic or semiconducting phases of 2D MoS2 nanosheets via solution processing is demonstrated. The results show that the collection of charge carriers is strongly dependent on the electronic properties of the 2D MoS2 with metallic MoS2 showing high responsivity and the semiconducting phase exhibiting high on/off ratios.

2:25 Electrodeposited Films of Cadmium Selenide for Silicon-based Tandem Solar Devices
W. Ross Rucker*, Janki Patel, Daniel Um and Dunbar Birnie
Materials Science and Engineering

Cadmium selenide (CdSe), electrodeposited on a transparent conductive oxide substrate can be used as the top layer of a stack-structure tandem solar device. The conditions of the bath affect the morphology and quality of the films. They have been produced to have a bandgap of 2.0 eV (the optimal match for silicon in a tandem device), high absorbance of short wavelengths of light, and high transmission of long wavelengths of light. The aim is to make them suitable for integration into a stack structure tandem solar device with silicon as the bottom absorber layer.

2:40 Photoluminescence Stability of Blue Organic Phosphorescent Materials on Silver Metasurface Electrodes
Catrice M. Carter1*, Zeqing Shen2, Kun Zhu1, Kelsey Gwynne3 and Deirdre M. O’Carroll1,2,4
1Materials Science and Engineering, 2Chemistry and Chemical Biology, 3Wagner College, Staten Island and 4Institute for Advanced Materials, Devices and Nanotechnology

Emerging lighting and display technologies use phosphorescent organic light-emitting diodes (Ph-OLEDs) because they are thinner, more flexible, and less pixelated than their inorganic counterparts. However, blue Ph-OLEDs are unstable relative to red and green Ph-OLEDs due to triplet-exciton quenching processes. This study aims to experimentally investigate the use of plasmonic silver metasurface electrodes to increase the radiative decay rate of blue organic phosphorescence and, therefore, minimize triplet quenching processes and increase stability. Our preliminary data has shown a correlation between enhanced photoluminescence stability and lifetime of blue organic phosphors on a variety of silver metasurface electrodes relative to planar silver surfaces.

* = Student Presenter
Electrochemical Hydrogen Evolution on Ni$_3$P

Anders B. Laursen$^{1,2}$, M. J. Whitaker$^1$, R. B. Wexler$^1$, A. M. Rappe$^3$, Martha Greenblatt$^1$ and G. Charles Dismukes$^{1,2}$

$^1$Chemistry and Chemical Biology, $^2$ Institute for Advanced Materials, Devices and Nanotechnology and $^3$University of Pennsylvania

Electrochemical water splitting promises to be essential for the development and application of renewable energy sources, like solar and wind and an environmentally friendly source for sustainable fertilizer production. Since 2013, many transition-metal phosphides have been reported as potential replacements for Pt - the archetypical electrocatalyst for H$_2$ evolution. Recently, we reported Ni$_3$P$_4$ with electrical efficiency comparable to Pt and excellent corrosion resistance. Here, we present the synthesis and benchmarking of Ni$_3$P, another member of the extensive nickel phosphide family of stoichiometric crystalline compounds. Here we show that this nickel-rich electrocatalysts is stable in acidic electrolyte as opposed to pure nickel metal. Use a chemical bonding model we can understand this difference in stability. A DFT structural analysis, offers insights into electrochemical reaction mechanism and shows surface reconstructions formed prior to catalysis giving rise to the high activity. Supported by a joint DOE-EERE/NSF-CBET grant, NATCO, DOE-BES, DOE, NSF, NERSC, & Rutgers.

Understanding Interfaces in Gold Nanospheres-Hybrid Silica Gel Systems

Stamatia Kallontzi$^{1,*}$, Lisa C. Klein$^1$, Laura Fabris$^{1,2}$ and Andrei Jitianu$^3$

$^1$Materials Science & Engineering, $^2$Biomedical Engineering and $^3$Chemistry, Lehman College-City University of New York

Hybrid silica gels prepared through the sol gel process, using mono-substituted and di-substituted siloxanes, have been doped with citrate-capped gold nanospheres. When heated at temperatures greater than 150°C, the gels become rigid, forming a glass-like material. Using UV-Vis spectrophotometry we confirmed that gold citrate nanoparticles were incorporated and dispersed in the hybrid gel. We carried out Raman and FTIR spectroscopy analyses to investigate the properties of the interface between the gel and the gold nanoparticles. With this study we are able, for the first time, to investigate the physico-chemical properties of nanoparticle-silica gel hybrids, with the goal to design innovative applications using these unique glasses.
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3:50  Hole Doping Problem in Bi$_2$Se$_3$ Thin Films and its Solution: Role of Interfacial vs Bulk Defects

Jisoo Moon$^1$*, Nikesh Koirala$^1$, Maryam Salehi$^2$, Wenhan Zhang$^1$, Weida Wu$^1$ and Seongshik Oh$^1$
$^1$Physics and Astronomy and $^2$Materials Science & Engineering

Abstract: Bi$_2$Se$_3$, one of the most widely studied topological insulators, is naturally electron (n-type) doped. In bulk crystals and thick films, n-type Bi$_2$Se$_3$ can be converted into p-type through compensation doping. However, such a compensation doping scheme has so far failed to achieve p-type Bi$_2$Se$_3$ thin films. Here, we show that there exists a thickness-dependent p-doping problem in Bi$_2$Se$_3$ thin films, which originates from the high density of interfacial defects compared with that of the bulk, and provide a solution to this long-standing puzzle. Reducing the interfacial defects by employing an effective buffer layer on the bottom and a capping layer on the top, we facilitate the compensation doping scheme and achieved dominant p-type carriers in Bi$_2$Se$_3$ thin films down to the thinnest topological regime. Availability of p-type Bi$_2$Se$_3$ thin films will open new opportunities in this active field of topological materials.

4:05  Nanostars: Where Localized and Propagating Plasmons Meet

Ted V. Tsoulos*, Supriya Atta and Laura Fabris
Materials Science and Engineering

Plasmonic modes of gold nanostars reveal a novel view of electron cloud oscillations as the localized plasmon resonances coexist with coherent delocalized interface waves, i.e. surface plasmons. Hot spots on nanostar tips are the meeting point of propagating interface waves and localized plasmon excitations as shown by numerical solutions for the scattered electric field on nanostars suspended in water. Experimental studies of the same system validate this hypothesis. Various plasmonic resonances of nanostars of different shapes and sizes are successfully predicted. Transverse plane plots indicate the coexistence of bulk plasmons and surface plasmons on the spherical core and the spikes of gold nanostars.
4:20  **Thermal Decomposition of SiO$_2$ on 4H-SiC(0001)**

Xiuyan Li$^{1,3}$, Sylvie Rangan$^2$, Mengjun Li$^1$, Viacheslav Manichev$^{1,2,3}$, Voshadhi Amarasinghe$^3$, Torgny Gustafsson$^{2,3}$, Eric Garfunkel$^{1,3}$ and Leonard C Feldman$^{2,3}$

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SiC based field effect transistors (MOSFETs) operate under conditions (i.e. elevated temperature) where conventional Si devices fail. The performance of SiC MOSFETs (reliability and mobility) are significantly correlated with the quality of the SiO$_2$/SiC interface formed by high temperature oxidation of SiC. The thermal stability of SiO$_2$ on SiC is central to improve the SiO$_2$/SiC interface quality. We present a kinetic study of high-temperature SiO$_2$ decomposition on the 4H-SiC(0001) substrate using several x-ray photoelectron spectroscopic methods. Ultrathin SiO$_2$ films grown on SiC are found to decompose at high temperature in ultra-high vacuum via pinhole formation and growth. We discuss the effects of this phenomenon on SiO$_2$/SiC interface quality in real SiC processes.
ABSTRACTS FOR POSTERS

1) Visualizing Ferromagnetic Domains in Undoped and Fe-doped Sr$_4$Ru$_3$O$_{10}$

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Transition-metal oxides have proven to be a great source of interesting phenomena and new quantum phases of matter with high potential for developing exciting technologies. Specifically, the triple-layered oxide Sr$_4$Ru$_3$O$_{10}$ exhibits coexistence of ferro- ($T_C < 105$ K) and meta- ($T_M < 50$ K) magnetism with strong anisotropy. Despite many studies on bulk magnetic properties of this material, the microscopic nature of the magnetic phase is still unclear. We report our variable field and temperature magnetic force microscopy studies on floating-zone grown undoped and Fe-doped Sr$_4$Ru$_3$O$_{10}$ single crystals. Various stripe and branch-like domain patterns were observed below $T_C \approx 105$ K.

2) A Novel Frequency Tuning Device Built on Semiconducting-Piezoelectric ZnO

*Guangyuan Li$^1$, Rui Li$^1$, Ke Tang$^2$, Pavel I. Reyes$^1$, Keyang Yang$^1$, Szu-Ying Wang$^1$, Hongfei Ye$^1$, Yuxuan Li$^1$, Wen-Chiang Hong$^2$ and Yicheng Lu$^1$

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A tunable surface acoustic wave (SAW) device consisting of a Cr/SiO$_2$/n-ZnO/Piezoelectric ZnO multilayer structure is built on a bendable glass substrate. The hybrid growth technique was used to deposit the ZnO dual layers: MOCVD for a n-ZnO film and RF sputtering for a piezoelectric Ni:ZnO (NZO) film. The acousto-electric interaction between the n-ZnO layer and the piezoelectric NZO layer enables SAW frequency tuning. Frequency tunability of ~0.5% is achieved at operation frequency of 310 MHz. This tunable SAW on glass technology shows a promising potential for programmable RFID and adaptive sensing systems.

Figure: A schematic layer structure of a tunable SAW device
3) **Critical Evaluation of the Relationship between Raman Peak Shift and Stress in Semiconductor Materials**  
Shawn Ward* and Adrian B. Mann  
*Materials Science and Engineering*  

An in-situ, method for rapid determination of the stress/strain to Raman peak shift in semiconductor has been developed and verified with Si-I. The measured shift of the Si-I peak in single crystal, undoped silicon was compared to theoretical work and found to be in the range of the expected values. Applying the method to polished, N-type 4H-SiC it was found that there is a strong correlation between stress and the 796 cm⁻¹ TO peak position. This allowed direct evaluation of the accuracy of existing models for peak shifts that all use 3C-SiC as their theoretical basis.

4) **The Rutgers UltraSTEM: A Characterization Tool for Nanomaterials**  
Maureen J. Lagos¹,²,³* and Philip. E. Batson¹,²,³  
¹Institute for Advanced Materials, Devices and Nanotechnology, ²Materials Science and Engineering and ³Physics and Astronomy  

Rutgers University has become the house of one of the most advanced scanning transmission electron microscope (STEM) in the world. The RUTGERS UltraSTEM instrument is equipped with both aberration corrector and energy monochromator, which allows the physical exploration of phenomena over a wide energy range with both high spatial and energy resolution. Currently, our instrument has achieved angstrom resolution (~ 1 Å) and 8 meV of energy resolution at 60 KV. With this outstanding performance, users can perform routinely structural characterization using STEM imaging techniques of nanomaterials. In addition, this type of instrumentation is allowing Rutgers users to perform studies of vibrational, plasmonic, interband transition and core-shell spectroscopy. The remarkable capabilities of the new RUTGERS UltraSTEM are illustrated through a large variety of experimental results from ongoing collaborations with both internal and external researchers.

5) **ZnTPP Nonequilibrium Growth Phenomenon on Ag(100) Surface**  
Peter Kim¹*, Sylvie Rangan¹, Robert Bartynski¹, Charles Ruggieri¹, Deyu Lu² and Stephen Whitelam³  
¹Physics and Astronomy and Laboratory for Surface Modification, ²Center for Functional Nanomaterials, Brookhaven National Laboratory and ³Molecular Foundry, Lawrence Berkeley National Laboratory  

Scanning tunneling microscopy was used as a local probe to determine the molecular adsorption configurations of zinc(II) tetraphenylporphyrin (ZnTPP) molecules deposited onto Ag(100) surfaces. Nonequilibrium growth modes of ZnTPP on Ag(100) surfaces were observed to have a kinetically trapped configuration that relaxes to a thermodynamically stable square configuration upon annealing. DFT calculations are used using parameters obtained from STM analysis to determine the electronic structures and energetics of the system. From these calculations, a strain in the Ag(100) substrate induced by the ZnTPP overlayer is observed, and may be a key component in the underlying mechanism behind the nonequilibrium adsorption geometry. Kinetic Monte Carlo simulations are being implemented to model the underlying kinetics and proposed adsorption mechanisms, demonstrating a regime of nonequilibrium growth modes that arise due to kinetic trapping.

* = Student Presenter
6) Characterization of n-BuSnOOH: Solution Precursors Identify and Film Quality
Mengjun Li1*, Jenn Amador2, Ryan T. Frederick3, Sumit Saha2, Trey Dilius3, Douglas A. Keszler2, Gregory S. Herman3 and Eric L. Garfunkel1
1Chemistry and Chemical Biology, 2Chemistry, Oregon State University and 3School of Chemical, Biological and Environmental Engineering, Oregon State University

Extreme ultraviolet (EUV) lithography is expected to replace current photolithographic methods because of its improved resolution. A series of organo-tin oxo compounds are studied for this application. Researchers do not yet fully understand how the film changes chemically as photons and electrons travelling through it.

We have been using a range of energies with different sources to study the sensitivity of these films. AFM (Atomic-force microscopy), RBS (Rutherford Backscattering Spectrometry) and XPS (X-ray Photoelectron Spectroscopy) are used to examine as-deposited, exposed, and developed films. Results point to the strong possibility that ligand chemistry is critical in determining post-exposure solubility.

7) Photoemission Studies of a Biased Graphene-Insulator-Semiconductor Structure
Malathi Kalyanikar1*, Sylvie Rangan2, Junxi Duan2, Gang Liu3, Robert A. Bartynski2, Eva Y. Andrei2, Leonard Feldman3 and Eric Garfunkel1
1Chemistry and Chemical Biology, 2Physics and Astronomy and 3Institute for Advanced Materials, Devices and Nanotechnology

Electrostatic potential changes across ultrathin films are of great importance for understanding the properties of multilayered structures and devices. A general approach to the direct measurement of nanoscale internal fields is pursued in this work through x-ray photoemission studies on a biased graphene/SiO2(6nm)/Si structure. The core-levels of the different elements provide a measure of the local potential and are used to reconstruct the potential profile as a function of the probing depth across the stack. A simple linear potential profile across the oxide along with two offsets at each interface is able to describe the experimental data. The offset at the SiO2-Si interface relates to the band bending developed in the Si substrate under the different biasing conditions. The graphene-SiO2 interface potential offset, in the studied bias range, is proposed as a polarization effect of trapped water and other polar species at the interface.
8) **Investigation of Cyclooctatetraene on Copper (001)**
John L. Wieczorek*, Erkan Z. Ciftlikli, Sylvie Rangan, Robert A. Bartynski and B. J. Hinch

\[ ^1 \text{Chemistry and Chemical Biology and} ^2 \text{Physics and Astronomy and Laboratory for Surface Modification} \]

Cyclooctatetraene (C\(_8\)H\(_8\), COT) is non-planar in the gas phase. On the basis of limited TPD and EELS studies\[1,2\] it has been suggested that COT can adsorb on noble metal faces in another configuration, i.e. as an ionically-bound planar and aromatic adsorbate, COT\(^2\). The fundamentals of adsorption of stable cyclic hydrocarbons on noble metal surfaces are key to metal organic interfaces for molecular electronics applications. The configurations of charged adsorbate hydrocarbons can be significant also in understanding ionic liquid-metal interfaces.

This poster reports on helium atom scattering(HAS) and STM studies of saturated COT overlayers on Cu(001). HAS is used to study COT uptake as well as temperature induced desorption of COT. He reflectivity changes are consistent with molecular desorption at temperatures as high as 340\(^\circ\)C. A HAS “pseudo TPD” curve is peaked at 285\(^\circ\)C, supportive of a chemisorbed COT species as seen on Cu(111)[1].

He diffraction indicates rotated quasi-hexagonal incommensurate phases at room temperature which are stable after annealing to 100 \(^\circ\)C. A higher order commensurate (HOC) quasi hexagonal (6, 1; 1, 3) phase has been identified. RT scanning tunneling microscopy (STM) has also shown short range ordering of this type, although long range ordering is not as persistent.


\[ ^2 \text{Merrill, P.B.; Madix, R.J.; Surface Science, 1996, 365, 701-728} \]

9) **Copper Phosphe as a CO\(_2\) Reduction Catalyst**
Timothy A. Goetjen*, Karin U. Calvinho, Anders B. Laursen and G. Charles Dismukes

\[ ^1 \text{Chemistry and Chemical Biology and} ^2 \text{Institute for Advanced Materials, Devices and Nanotechnology} \]

Electrochemical carbon dioxide reduction not only diminishes atmospheric CO\(_2\) concentration, but also stores energy as fuel. Copper is the state-of-the-art catalyst for producing hydrocarbons from CO\(_2\), but requires high overpotentials and exhibits low selectivity towards single products. The overpotential for hydrocarbon production can be lowered by (1) modifying the catalyst to include moderately oxophilic elements, which bind reaction intermediates in favorable conformations, and (2) the presence of a partial positive charge on transition metals. Phosphorous is a good candidate due to its abundance and stabilizing effect on the positive metal charge. The most stable copper phosphide, Cu\(_3\)P, was successfully synthesized as a phase pure film on a copper foil substrate and tested for electrochemical CO\(_2\) reduction. Quantification done via GC, NMR, and HPLC with Faradaic efficiency calculations.
Copper and noble-metal alloys have been shown to catalyze the electrochemical reduction of CO\(_2\) to hydrocarbons such as methane and ethylene, the building blocks for chemical synthesis of most industrial product. However, the production of hydrocarbons in this manner is heavily energy-consuming because of the high overpotential needed and efficiency losses due to concomitant H\(_2\) production. We have developed a transition metal phosphide catalyst that is able to reduce carbon dioxide to hydrocarbons at lower overpotentials than copper, as well as produce an aldehyde-carbonate co-polymer. We show structural and electrochemical characterization of the catalyst and product quantification.

Room temperature electrochemical ammonia synthesis (EAS) uses the favorable thermodynamics at low temperature while using renewable energy to produce the most important industrial chemical. Presently, ammonia synthesis is limited by low-activity catalysts. Here, we shall benchmark RuO\(_x\) on carbon (industrial ammonia catalyst) for EAS compared to a phase-pure nano-sized molybdenum phosphide (MoP) renewable catalyst. MoP is an active hydrogen evolution catalyst but is untested for ammonia production. We shall investigate the synthesis and characterization of the renewable MoP catalysts and evaluate EAS activity in alkaline electrolyte and ambient conditions. Activity will be measured using the colorimetric Indigophenol Berthelot assay, with a detection limit of 1.80 \times 10^{-5}\text{ mol }\%\text{ ammonia.}
12) Excellent Catalytic Activity and Stability of NiP\textsubscript{2} Thin Film Hydrogen Evolution Reaction Catalysts on Silicon Photocathode with Titanium Nitride Passivation Layer

Shinjae Hwang\textsuperscript{1,2*}, Spencer H. Porter\textsuperscript{1,2}, Anders B. Laursen\textsuperscript{1,2}, Voshadhi Amarasinghe\textsuperscript{1,3}, Mengjun Li\textsuperscript{1,2}, Martha Greenblatt\textsuperscript{1,2}, Eric Garfunkel\textsuperscript{1,2} and G. Charles Dismukes\textsuperscript{1,2}

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Hydrogen is a preferred energy carrier because it can be conveniently generated from water using electricity, which if derived from solar electricity, produces renewable hydrogen. Therefore, the development of highly efficient photoelectrochemical cells that can produce clean hydrogen is a great challenge for the field of renewable energy.

Here, we developed a thin film of crystalline NiP\textsubscript{2} using thermal evaporation of Ni followed by chemical vapor phosphidation on silicon photoabsorber. We introduced TiN passivation layer between the catalyst and silicon photoabsorber to create a conducting interface that stabilize the elements against diffusion. Our study demonstrated that TiN not only blocks the diffusion of Si, but also maintains a clean interface that does not corrode during catalysis of the hydrogen evolution reaction for over 25 hours without failure. Supported by the NSF-CBET/DOE-EERE.

13) Composition Analysis of Ground, Sieved, and Calcined Degussa P25 TiO\textsubscript{2} via Differential Diffuse Reflectance and Differential Kubelka Munk Spectral Analysis

Ashley M. Pennington*, Amanda I. Okonmah, Daryll T. Munoz, Carolina S. Radecki, George Tsilomelekis and Fuat E. Celik

Chemical and Biochemical Engineering

The ability to alter polymorph composition and analyze the compositional variations of P25 TiO\textsubscript{2}, a common semiconductor catalyst, thoroughly and quickly is important to catalyst manufacturers and users alike. P25 samples were ground, sieved, and calcined and then characterized by UV-Visible Spectroscopy Differential Diffuse Reflectance, Differential Kubelka Munk, X-ray Diffraction, and Raman Spectroscopy to determine the band gap energies, ratios of anatase to rutile, and percent rutilization. G-S50-C500, ground and sieved sample with an agglomerate size between 53 \(\mu\)m and 45 \(\mu\)m had a ten-fold increase in rutilization compared to as purchased P25 calcined at 773 K.
Continuous-Flow Heterogeneous Alkane Transfer Dehydrogenation Effected by Immobilized Pincer-Ligated Iridium Catalysts

Boris Sheludko\(^1,2\)*, Ashley M. Pennington\(^2\), Molly T. Cunningham\(^1\), Marisa E. Gliege\(^3\), Bo Li\(^1\), Longfei Chao\(^2\), Akshai Kumar\(^1\), Alan S. Goldman\(^1\) and Fuat E. Celik\(^2\)

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The recent boom in unconventional oil recovery has led to an increase in hydrocarbon sources of energy, among which are included the lighter C\(_6\)-compounds which currently find only limited commercial use. Being able to convert these compounds to longer chain compounds would allow them to be included in transportation fuels. One way to effect this transformation is via tandem alkane transfer dehydrogenation (AXD) - olefin metathesis, with the dehydrogenation step being performed by a pincer-ligated iridium catalyst and the metathesis by a zeolite. Prior work has demonstrated that AXD can be performed with a number of such iridium catalysts in batch homogeneous and heterogeneous reactions[1]; However, in order for this process to find expanded use in industrial-scale applications, a continuous-flow system is preferred.

In this work, we use such a system to investigate the activity of immobilized pincer-ligated iridium catalysts for AXD. The catalysts are immobilized on a solid support (γ-alumina, mesoporous silica, silicon carbide and others), and investigated using either an air-free plug-flow reactor or an air-free \textit{in situ} FT-IR reactor. The former allows for the assessment of reaction kinetics, while the latter allows for the characterization of the state of the catalyst over the course of the reaction. Turnover frequencies (TOFs) for AXD are found to be low, presumably due to inhibition by solid support[2]. However, it is found that co-feeding a small amount of water stabilizes the catalyst and leads to increased acetone production when catalyst is supported on alumina, likely by an iridium/alumina co-catalyzed mechanism.


Scalable Micro/Nanomanufacturing of Complex Architectures through Hybrid Lithography

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Mechanical and Aerospace Engineering

The ultimate goal of nanofabrication is to achieve total control over the static and dynamic properties of deliberately patterned architectures. The impetus for this undertaking is the extraordinary effective properties displayed by both naturally-occurring biological nanostructures and lab-scale metamaterials inherent in their complex structures. We have thus made it the mission of our lab, the Hybrid Micro/Nanomanufacturing Laboratory (HMNL), to develop techniques for incorporating designer nanostructures into high-throughput manufacturing. Our objective is the successful integration of nanostructured features into processes such as roll-to-roll (R2R) printing, thermoplastic forming, or spray coating that would enable industrial and consumer products that possess the benefits of nanostructured surfaces. To accomplish this, the HMNL leverages combinations of top-down and bottom-up approaches to optimize key fabrication metrics: control, rate, resolution, and materials flexibility. The three thrusts of this research have been: (i) sacrificial template paradigms to stretch the limits of nanoimprint lithography (NIL); (ii) extreme thermal gradients to accomplish nanoscale photolithography with free-space optics; and (iii) electrospray deposition of hierarchical ceramic nanostructures. In pursuing these investigations, we seek to generate methods to deliberately-nanostructured, mass-produced architectures including: (i) nanocomposite flexible photovoltaics, high-performance nanofiltration membranes, and biocompatible medical implants; (ii) plasmonic metasurfaces for advanced optics and transparent electrodes for photovoltaics; and (iii) spray-on, self-cleaning anticorrosion surfaces to increase the longevity of metal components in biological or aquatic environments.