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Presentation Schedule

Breakfast, Sign-in and Registration: 8:00 am – 8:50 am (Martel Hall)

Welcome Remarks: 8:50 am – 9:00am (McMurtry Auditorium)

By Dr. Alberto Pimpinelli, Executive Director, Smalley-Curl Institute, and Organizing Committee Chair and Organizing Committee Chair and Yousif Shamoo, Vice Provost of Research and Professor of BioSciences

Oral Session 1:	**9:00 am – 10:15 am (McMurtry Auditorium)** **Presider: Melia Bonomo**	
9:00 - 9:15 am	Jacob A. Fry, Anna L. Marchant, Melissa C. Revelle, Yi Jin, and Randall G. Hulet, , “Measuring the Speed of Sound in a 1D Fermi Gas” (Paper No. O-1.1)	1
9:15 – 9:30 am	David Renard, Michael McClain, Benjamin Clark, Christopher DeSantis, and Naomi J. Halas, “Solvent-Directed Growth of Aluminum Nanocrystals” (Paper No. O-1.2)	1
9:30 – 9:45 am	Will Hardy, Panpan Zhou, Brandon Isaac, Patrick Marshall, Evgeny Mikheev, Susanne Stemmer, and Douglas Natelson, “Transport studies and potential fluctuations in mesoscopic-scale SmTiO3/SrTiO3/SmTiO3 quantum wells” (Paper No. O-1.3)	1
9:45 – 10:00 am	Steven Demers, Lee Hsieh, Cyna Shirazinejad, James Matthews, and Jason Hafner, “UV Spectrum Analysis of Gold Nanoparticles” (Paper No. O-1.4)	2
10:00 – 10:15 am	Ching-Wei Lin, Sergei M. Bachilo, Michael Vu, Kathleen M. Beckingham, and R. Bruce Weisman, “Spectral Triangulation: a 3D Method for Locating Single-walled Carbon Nanotubes in vivo” ((Paper No. O-1.5)	2
Coffee Break:	**10:15 am - 10:30 am**	
Oral Session 2:	**10:30 am – 11:45 am (McMurtry Auditorium)** **Presider: Josh Hill**	
10:30 - 10:45 am	Yu Zheng, Sergei M. Bachilo, Stephen R. Sanchez, and R. Bruce Weisman, “Displacement Kinetics of Single-Stranded DNA Wrapped around Carbon Nanotubes” (Paper No. O-2.1)	3
10:45 – 11:00 am	Alessandro Alabastri, Pratiksha Dongare, Jinjian Wu, Katherine Zodrow, Akshay Deshmukh, Qilin Li, Menachem Elimelech, Naomi Halas, and Peter Nordlander, “Designs for efficient steam generation and desalination by nanoparticles induced heat confinement” (Paper No. O-2.2)	3
11:00 – 11:15 am	Pratiksha D. Dongare, Alessandro Alabastri, Katherine Zodrow, Jinjian Wu, Seth Pederson, Oara Neumann, Nathaniel J. Hogan, Qilin Li, Peter Nordlander, and Naomi J. Halas, “Nanoparticle Enabled Solar Membrane Distillation” (Paper No. O-2.3)	4
11:15 – 11:30 am	Charlotte Evans, Pavlo Zolotavin, and Douglas Natelson, “Remote heating in bowtie nanoelectrodes by propagating plasmons” (Paper No. O-2.4)	4

11:30 – 11:45 am	Sam Gottheim, Jay Simmons, Michael McClain, Henry O. Everitt, and Naomi J. Halas, "Plasmonic Photodecomposition Probed by Terahertz Rotational Spectroscopy" (Paper No. O-2.5)	
11:45 – 12:00pm	Break (lunch for judges and undergraduate, RET, and RSTEM REU poster presenters	

Lunch and Poster Sessions, *Martel Hall A and B*

Undergraduates and Nakatani RIES Fellowship Students (UG),	5
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3:45 – 4:00 pm	Luiza Gomes Ferreira (Kolomeisky group), "Modeling Molecular Motors Dynamics" (Paper No. O--4.4)	30
4:00 – 4:15 pm	Daniel Vecchiolla and Sibani Lisa Biswal, "Dynamic Crystalline Deformation of Flowing 2-D Foams in Microfluidic Devices" (Paper No. O-4.5)	30

Graduate Students and Post-doctorates Poster (GP) Sessions: 4:15 pm – 7:15 pm (Martel Hall A)

Poster Session A: 4:15 pm – 5:30 pm *(food, wine, and beer will be served)*	31
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Awards Ceremony	**6:45-7:15 pm (McMurtry Auditorium)** *(food, wine, and beer will be served in Martel Hall A)*

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Oral Session 1: 9:00 am – 10:15 am

O-1.1 Measuring the Speed of Sound in a 1D Fermi Gas

Jacob A. Fry,[1] Anna L. Marchant,[1] Melissa C. Revelle,[1] Yi Jin,[1] and Randall G. Hulet[1]
[1]*Department of Physics and Astronomy and Rice Center for Quantum Materials, Rice University, Houston, TX, USA*

Our experiment uses a two-spin component gas of atomic fermions (lithium-6) confined to one-dimension (1D) to study the speed of sound. By cooling these atoms to ultra-low temperatures (100 nK), we can emulate electronic systems such as 1D wires.We create an array of 1D tubes by confining our atoms in a 2D optical trap. When the atoms are limited to move along these tubes, we can examine properties that are not present in a conventional 3D Fermi liquid. In particular, we are interested in how charge and spin excitations propagate in a 1D system. In a 3D electron gas, the electron charge and spin propagate with the same velocity. However, in 1D, theory predicts that the electron charge travels faster than the spin when interactions are present, an effect known as spin-charge separation. Using our gas of atoms trapped in 1D, we study how their charge and spin travel independently when locally perturbed by a laser pulse. Depending on this laser's frequency, the atoms feel either a spin-sensitive or insensitive force (spin or charge excitation respectively). These excitations create notches or bumps in the atom density which can be tracked after the laser pulse is turned off. From this, velocities for spin and charge can be extracted for a wide range of interaction strengths. This work will improve our understanding of strongly correlated Fermi systems.

O-1.2 Solvent-Directed Growth of Aluminum Nanocrystals

David Renard,[1] Michael McClain,[1] Benjamin Clark,[1] Christopher DeSantis,[1] and Naomi J. Halas[1]
[1]*Department of Chemistry, Rice University, Houston, Texas, U.S.*

Plasmonic nanoparticles have recently garnered much interest for their applications in catalysis, sensing, photovoltaics, and solar energy harvesting due to their unique ability to capture and direct light at the nanometer scale. Unlike conventional plasmonic materials (i.e. gold and silver), aluminum nanochemistry is limited to air/moisture-free conditions. This poses a significant challenge in rational design of synthesis schemes for size and shape control of the resulting nanoparticles. The precise control of particle morphology is an ongoing and pertinent goal of the current research. Tactics employed for the directed growth of gold and silver nanoparticles often include weakly interacting ligands in aqueous environments. In this light, weakly coordinating solvents, such as phosphines, amines, and ethers, are being synergistically combined for the controlled growth of aluminum nanocrystals. Previously unobtainable morphologies have been realized through the systematic combination of these weak surface active agents. The precise morphological control of aluminum nanocrystals is critical for their implementation as superior plasmonic materials

O-1.3 Transport studies and potential fluctuations in mesoscopic-scale $SmTiO_3/SrTiO_3/SmTiO_3$ quantum wells

Will Hardy,[1] Panpan Zhou[2], Brandon Isaac[3], Patrick Marshall,[3] Evgeny Mikheev,[3] Susanne Stemmer,[3] and Douglas Natelson[2]
[1]*Applied Physics Graduate Program, Smalley-Curl Institute, Rice University, Houston, Texas, USA*
[2]*Department of Physics and Astronomy, Rice University, Houston, Texas, USA*
[3]*Materials Department, University of California, Santa Barbara, California, USA*

Heterointerfaces of rare earth titanates of the form $RTiO_3$ (R = rare earth) display a bounty of coexisting and competing physical orders. For example, the $LaAlO_3/SrTiO_3$ interface can support high carrier density quantum wells whose dynamics can be tuned by a combination of lattice distortions, spin-orbit coupling, defects, and various regimes of magnetic and charge ordering. An improved understanding of these model systems, especially their quantum coherent properties, may lead to new insights into the nature of high-temperature superconductivity. Here, we have studied electronic transport in mesoscale devices (~ few hundred nanometer spacing between voltage probe electrodes) made with heterostructures of $SmTiO_3$ and $SrTiO_3$, uncovering extremely large potential fluctuations that grow with decreasing temperature, but remain relatively unaffected by changes in drive current or device length. Fluctuations are also observed as a correction to the low-temperature magnetoresistance, superimposed on the overall curve shapes observed for larger samples, but are inconsistent with the well-understood universal conductance fluctuations. Additional measurements are ongoing to better understand whether the accumulated body of evidence suggests the presence of both mesoscopic quantum coherence effects and time-dependent relaxation processes, which may be modeled as ensembles of two-level fluctuators.

O-1.4 UV Spectrum Analysis of Gold Nanoparticles

Steven Demers,[1] Lee Hsieh,[1] Cyna Shirazinejad,[1] James Matthews,[1] and Jason Hafner[1,2]
[1]*Physics & Astronomy Department, Rice University, Houston, TX*
[2] *Chemistry Department, Rice University, Houston, TX*

The ultraviolet (UV) absorption spectrum of gold nanoparticle solutions was studied to see what information it contains related to the nanoparticle dimensions and surfactant molecules in solution. A strong UV absorbance in gold nanorod solutions at wavelengths below 225 nm was identified to be the charge transfer to solvent (c.t.t.s.) excitation of bromide ions in solution. Once this contribution was removed, the UV absorbance of gold nanoparticles was studied. At wavelengths between 200 and 300 nm the dielectric function of gold follows a Drude model, as it does at long visible and infrared wavelengths, so the absorption spectrum should be affected by nanoparticle size. Gold nanosphere spectra between 200 and 900 nm were found to closely match the Mie solution to Maxwell's equations for 20, 30, 60, and 80 nm diameter particles. The UV spectral shape was strongly dependent on nanoparticle size and could possibly be used as a characterization tool. The gold nanorod UV absorption spectrum was compared to finite element method calculations of nanorod extinction. The UV spectrum was found to have size-dependent contributions from the longitudinal and transverse excitations that were similar to the nanospheres. These results may be of interest in studies of the gold dielectric function, as well as measuring nanoparticle size and shape with simple optical measurements.

O-1.5 Spectral Triangulation: a 3D Method for Locating Single-walled Carbon Nanotubes *in vivo*

Ching-Wei Lin,[1] Sergei M. Bachilo,[1] Michael Vu,[2] Kathleen M. Beckingham,[2] and R. Bruce Weisman[1,3]
[1]*Department of Chemistry, Rice University, Houston, TX*
[2]*Department of Biosciences, Rice University, Houston, TX*
[3]*Department of Materials Science and NanoEngineering, Rice University, Houston, TX*

Nanomaterials with luminescence in the short-wave infrared (SWIR) region are of special interest for biological research and medical diagnostics because of favorable tissue transparency and low autofluorescence backgrounds in that region. Single-walled carbon nanotubes (SWCNTs) show well-known sharp SWIR spectral signatures and therefore have potential for noninvasive detection and imaging of cancer tumors, when linked to selective targeting agents such as antibodies. However, such applications face the challenge of sensitively detecting and localizing the source of SWIR emission from inside tissues. A new method, called spectral triangulation, is presented for three dimensional (3D) localization using sparse optical measurements made at the specimen surface. Structurally unsorted SWCNT samples emitting over a range of wavelengths are excited inside tissue phantoms by an LED matrix. The resulting SWIR emission is sampled at points on the surface by a scanning fiber optic probe leading to an InGaAs spectrometer or a spectrally filtered InGaAs avalanche photodiode detector. Because of water absorption, attenuation of the SWCNT fluorescence in tissues is strongly wavelength-dependent. We therefore gauge the SWCNT–probe distance by analyzing differential changes in the measured SWCNT emission spectra. SWCNT fluorescence can be clearly detected through at least 20 mm of tissue phantom, and the 3D locations of embedded SWCNT test samples are found with sub-millimeter accuracy at depths up to 10 mm. Our method can also distinguish and locate two embedded SWCNT sources at distinct positions. Finally, recent results will be presented showing sensitive detection of SWCNTs inside live mice.

Reference:

(1) Lin, C.-W.; Bachilo, S. M.; Vu, M.; Beckingham, K. M.; Weisman, R. B., Spectral triangulation: a 3D method for locating single-walled carbon nanotubes *in vivo*. *Nanoscale* **2016**, *8*, 10348-10357.

Oral Session 2: 10:30am – 11:45 am

O-2.1 Displacement Kinetics of Single-Stranded DNA Wrapped around Carbon Nanotubes

Yu Zheng,[1] Sergei M. Bachilo,[1] Stephen R. Sanchez, [1] and R. Bruce Weisman[1, 2]

[1]*Department of Chemistry and the Smalley-Curl Institute and* [2]*Department of Materials Science and NanoEngineering, Rice University, Houston, TX, 77025*

Surface coatings on single-walled carbon nanotubes (SWCNTs) play key roles in their properties and applications. One of the most intriguing coatings is single-stranded DNA, which is known to helically wrap individual nanotubes with affinities that depend on oligonucleotide sequence and SWCNT structure. To better understand such selective interactions, we use fluorescence spectroscopy to monitor the kinetics of ssDNA displacement by sodium deoxycholate (SDC), a common surfactant. This displacement causes distinct changes in the wavelength and intensity of structure-specific SWCNT near-IR emission peaks. By quantifying the kinetics of these changes as a function of oligonucleotide sequence, oligonucleotide length, SWCNT structure, sample temperature, and SDC concentration, we have extracted sets of values for the activation enthalpy $\Delta H^{\neq}$, activation entropy $\Delta S^{\neq}$, and activation Gibbs free energy $\Delta G^{\neq}$ for displacement of $d(GT)_n$, with n ranging from 10 to 30. We find that rates of displacement decrease for longer oligonucleotides and drop sharply as nanotube diameter increases from 0.75 to 0.97 nm. These increases in $\Delta G^{\neq}$ are attributed to increases in $-T\Delta S^{\neq}$ that exceed the decreases in $\Delta H^{\neq}$ over this range. Remarkably, the kinetics also reveal a strong power-law dependence (up to 6th order) in SDC concentration, indicating a highly cooperative process for ssDNA displacement. We will present experimental results and a proposed mechanistic interpretation.

O-2.2 Designs for efficient steam generation and desalination by nanoparticles induced heat confinement

Alessandro Alabastri,[1] Pratiksha Dongare[1], Jinjian Wu[2], Katherine Zodrow[2], Akshay Deshmukh[2], Qilin Li[2], Menachem Elimelech[3], Naomi Halas[1] and Peter Nordlander[1]
[1]*Department of Physics, Rice University, Houston, Texas, USA*
[2]*Department of Civil and Environmental Engineering Rice University, Houston, Texas, USA*
[2]*Department of Chemical and Environmental Engineering Yale University, New Haven, Connecticut, USA*

Recent research from Rice has demonstrated that broad-band light absorbing nanoparticles dispersed in water can greatly enhance the evaporation rate and provide an efficient means of steam production using sun light. Dispersed particles close to the water surface, by a combined effect of photons absorption and scattering, are capable to convert light into localized heat within a thin region close to the liquid/air interface. We are now applying these concepts to enhance evaporation process for sun-powered water treatment and steam generation devices. Here we present both 2D and 3D numerical models which integrate all the relevant physical phenomena involved in water evaporation mediated by the heating of nanoparticles. Results from calculation could be matched with actual experiments and the models are now being used to design high-efficient novel devices for water evaporation at low solar intensity. In facts, the possibility to avoid the use of bulky and expensive sun-focusing equipment would is crucial for the scaling of water treatment systems and for limiting costs. It will be shown what the ingredients for maximizing steam production are and how these can be integrated in actual devices.

O-2.3 Nanoparticle Enabled Solar Membrane Distillation

Pratiksha D. Dongare,[1,2,6] Alessandro Alabastri,[2,3] Katherine Zodrow,[4] Jinjian Wu,[4] Seth Pederson,[4] Oara Neumann,[1,2] Nathaniel J. Hogan,[1,2,6] Qilin Li,[4] Peter Nordlander,[1,2,3,6] and Naomi J. Halas[1,2,3,5,6]
[1]*Department of Electrical and Computer Engineering,* [2]*Laboratory for Nanophotonics,* [3]*Department of Physics and Astronomy,* [4]*Department of Civil and Environmental Engineering,* [5]*Department of Chemistry,* [6]*Smalley-Curl Institute, Rice University, Houston, Texas, USA*

Membrane distillation is being used for water desalination for more than 30 years. In conventional membrane distillation system, vapor pressure difference on the two sides of a porous hydrophobic membrane drives water vapor across the membrane, thus separating salts from water. This vapor pressure difference is either created by flowing water with difference in temperature on two sides of the membrane or using vacuum pumps. This process is energy intensive as it heats up bulk water to maintain temperature difference across the membrane. This results in significant increase in the size of the system and limits the scalability of the membrane distillation module, making it difficult to be used in remote areas. In this project we have created a sustainable and scalable nanoparticle enabled solar membrane distillation (NES-MD) system, which uses conventional polyvinylidene fluoride (PVDF) membranes electrospun with broad band absorbing carbon black nanoparticles that absorb more than 90% of the incident solar radiation. In sunlight this locally heats up the water on one side of the membrane creating vapor pressure difference driving water through it even when there is no difference in the temperature of the bulk water on the two sides of the membrane. Diffuse reflectance measurements and Monte Carlo simulations are used to obtain the optical properties of the electrospun membrane. Through outside solar experiments we have confirmed the effectiveness of the lab scale NES-MD prototype. This system is scalable as the temperature difference is created locally on the membrane and the membrane performance does not drop with increasing area.

O-2.4 Remote heating in bowtie nanoelectrodes by propagating plasmons

Charlotte Evans,[1] Pavlo Zolotavin,[1] and Douglas Natelson[1,2,3]
[1]*Department of Physics and Astronomy, Rice University, Houston, Texas, United States*
[2]*Department of Electrical and Computer Engineering, Rice University, Houston, Texas, United States*
[3]*Department of Materials Science and NanoEngineering, Rice University, Houston, Texas, United States*

Electronic transport and simultaneous optical measurements on molecule-containing junctions can provide critical information about the dissipation of energy through inelastic processes. Gold bowtie nanostructures have been used for electronic transport and as plasmonically active substrates for surface-enhanced Raman scattering (SERS), conventionally with exciting light incident directly on the molecular junction. Electromigrating these devices created interelectrode nanogaps with single-molecule sensitivity in which the Raman scattering rate is dominated by plasmonically enhanced electromagnetic fields due to the presence of the metal nanojunction near the molecules of interest. Direct optical excitation of the junction region, however, can cause heating of the metal, molecular instability via conformational and chemical changes, and breakdown over time. Adding metallic gratings to the electrode design enables the excitation of propagating plasmon modes that can couple into the junction region without direct excitation by far-field radiation. We will present data on remote heating of bowtie nanostructures by excitation of propagating plasmons. Efficiency of propagating plasmon excitation is assessed by measuring the temperature increase of the nanowire using the bolometric detection method. We discuss potential future applications for true low-temperature, simultaneous single-molecule SERS and electrical measurements. This research was funded by NSF GRFP DGE-1450681 and ARO award W911 NF-13-1-0476.

O-2.5 Plasmonic Photodecomposition Probed by Terahertz Rotational Spectroscopy

Sam Gottheim,[1,2] Jay Simmons,[3] Michael McClain,[1,2] Henry O. Everitt[3,4] and Naomi J. Halas[1,2,4,5]
[1]*Chemistry Department, Rice University, Houston, Texas*
[2]*Laboratory for Nanophotonics, Rice University, Houston, Texas*
[3]*Army Aviation and Missile RD&E Center, Redstone Arsenal, Alabama, United States*
[4]*Department of Electrical and Computer Engineering, Rice University, Houston, Texas* [5]*United States Department of Physics and Astronomy, Rice University, Houston, Texas*

Plasmon induced chemistry has become an exciting area of research over the past several years. We have developed frequency modulated THz spectroscopy as a novel technique for the sensitive monitoring of plasmon induced photocatalytic processes. THz spectroscopy has never before been used to study catalysis or photocatalysis. We report a limit of detection down to picomolar quantities for our technique. An internal calibration method was developed such that only a single rotational transition of a molecular species needs to be calibrated in order to quantitatively determine concentrations of any detectable species. This is due to the fact that relative rotational transition strengths can be calculated and are well known in the literature. We show that there is good agreement between the calculated relative rotational transition line strengths and our measurements. One application of this technique is the detection and decomposition of toxic industrial chemicals (TICs). Wet chemically synthesized aluminum nanocrystals (Al NCs) are utilized to demonstrate the photocatyltic decomposition of carbonyl sulfide (OCS) through hot electron injection monitored by our technique. It is shown that OCS can be efficiently decomposed into CO and S by raster scanning 80 mW of a 488 nm laser over a glass substrate. Most importantly, frequency modulated THz rotational spectroscopy is a novel tool that can be used for detailed examination of plasmon induced chemistry.

Poster Session – Undergraduate Researchers 12:00 pm – 1:30 pm

UG-1 - Ion Infused Hydrogels in Soft Robotics

Christine Chao,[1,2] Linlin Cao,[2] and Professor Jun Lou[2]
[1]*Smalley-Curl Institute NSF REU Program, Rice University, Houston, Texas, USA*
[2]*Department of Mechanical Engineering and Materials Science, Rice University, Houston, Texas, USA*

Soft robots are able to deform change its shape in dynamic environments, making it an optimal candidate for many biomedical applications. With an optimized and specific design, soft robots can be used to assist humans in movement, deliver drugs within the body, and act as sensors. However, since research on the subject is still in its initial stages, few types of soft materials have been experimented on. Hydrogels are soft and flexible materials that have the capability to swell and deswell based on external stimuli, such as temperature, light, and pH. Furthermore, ion infused hydrogels can change its shape based on changes in an electric field. They can also be altered by changing their thicknesses so that they can bend and morph in a more targeted manner. These characteristics can be particularly useful in soft robotics because they can easily be manipulated in order to create a moving robot. In order to have an accurate prediction on the movement of the hydrogels, we carefully took into account the effect of thickness on its flexibility by making certain areas of the robot thick or thin. Furthermore, we made the shape of the hydrogel to have sinusoidally shaped surfaces. This changes the degree of thickness within a single gel, and gives the user more control over the flexibility of the material. By incorporating these measures, we can build a robot that can potentially move and grab an item in a more precise manner.

UG-01 **Determining the IECs of Polyvinyl Alcohol membranes crosslinked with Sulfosuccinic Acid (PVA+SSA) for use in MCDI experiments**

Tensae Assefa[1], Amit Jain[2], Rafael Verduzco[2]
[1]Department of Bioengineering, Rice University, Houston, Texas, USA
[2]Department of Chemical and Biomolecular Engineering, Rice University, Houston, Texas, USA

Membrane Capacitive Deionization (MCDI) is a potentially low-cost method for water desalination. In MCDI, an electronic potential difference is applied across an aqueous solution that flows in between two porous electrodes that have been coated with ion exchange membranes. Ions are adsorbed onto the porous electrodes, resulting in a water stream with reduced ion and salt concentration.

In this project, we are aiming to use MCDI to selectively remove divalent counterions from brackish water. We have so far experimented with several PVA+SSA membranes and determined their Ion Exchange Capacities (IEC). The IEC values were measured via titration of the amount of H+ ions released following the immersion of the membranes in 1M HCl for 24 hours. The higher the Ion Exchange Capacities of the membranes, the stronger they will attract their respective ions and the purer the solution exiting the cell will become. Our membranes were made via dip coating onto glass slides. The next step is to coat these membranes onto our electrodes for use in MCDI experiments. For future experiments, we will determine the IECs of membranes such as PVA+SSA+GA using a flow coater device in order to achieve better uniformity in our samples.

UG-02 **Phase Behavior of Carbon Nanotube Liquid Crystalline Solutions**

Evan Biggers, Vida Jamali, Francesca Mirri, and Matteo Pasquali
Department of Chemical and Biomolecular Engineering, Rice University, Houston, Texas United States

Carbon nanotubes (CNTs) are 100 times stronger than steel, as conductive as copper, and have a thermal conductivity 3 times that of diamond, all while being extremely lightweight. All of these spectacular properties make CNTs the perfect material for numerous applications, ranging from wearable electronics to protective clothing. In order to reach the point of real-world applications, however, we must first understand the fundamental behavior of the CNT solutions that will be processed into macroscopic materials. CNTs can be individually dissolved in chlorosulfonic acid, making them pliable for application. CNTs, being very long, rod-like molecules, make the solution behave differently from simple fluids. At a certain critical concentration, the solution transitions from an isotropic phase with randomly oriented molecules to form a liquid crystalline phase, which has some properties of a solid crystal, yet in a liquid solution. We used polarized light microscopy to detect CNT alignment, since the aligned molecules will interact with the polarized light and make the solution birefringent. Similarly, the polymer-like nature of CNTs will make them align under extensional stresses, which in turn alters the extensional viscosity of the solution. This alteration can be measured through extensional rheology, which can be used to find the average aspect ratio of the individual CNTs. Finally, Raman spectroscopy determines the uniformity and purity of the CNTs, as well as gives insight into semi-conducting or metallic nature of the CNTs. The understanding of the CNT solution morphology is fundamental for fluid-phase processing of macroscopic CNT-based materials.

UG-03 **Multicolor Electrochromic Devices with Molecular Plasmonics**

Grant J. Stec,[1,7] Adam Lauchner,[2,7] Yao Cui,[1,7] Alejandro Manjavacas,[3,7] F. Javier García de Abajo,[5,6] Peter Nordlander,[2,4,7] and Naomi J. Halas [1,2,4,7]
[1]*Department of Chemistry, Rice University, Houston, TX*
[2]*Department of Electrical and Computer Engineering, Rice University, Houston, TX*
[3]*Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM*
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[6]*ICREA-InstitucióCatalana de Recerca i Estudis Avancats, Barcelona, Spain*
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We demonstrate the use of molecular plasmon resonances in charged PAHs as a method to electrically control optical transmittance in the visible regime. Analogous to the geometric and electrical tunability of spatially-confined graphene plasmons in the mid- to far-infrared regions, the tunability of PAH plasmons in the visible regime as predicted theoretically and supported experimentally are exploited herein to produce electrochromic devices with properties presently unattainable by conventional methods. Reversible multicolor switching in the reported devices is achieved through electrochemical reduction and oxidation in a supporting ion gel by selectively and reversibly adding or removing a single electron to produce PAH anions or cations, respectively. By changing the polarity of the applied potential, the formation of either the PAH anion or cation can be selected. Because the molecular plasmon resonance and resulting color are dependent on the charge of the molecule, the ability to electrically select a specific charged state allows for multicolor switching in a device using a single PAH species. Also reported is a device combining the distinct optical resonances of multiple PAH species in a single device layer capable of switching between colorless and black optical states. These two device capabilities demonstrate the novel electrochromic properties of PAH molecular plasmons and the advantages they provide over existing technologies.

UG-04 **One-photon photoluminescence of gold nanorods**

Eric Sung,[1] Yiyu Cai[1], Anneli Hoggard[1], Stephan Link[1,2]
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[2]*Dept. of Electrical and Computer Engineering and Laboratory for Nanophotonics, Rice University, Houston, Texas, USA*

We investigated the one-photon photoluminescence of gold nanorods. The nanorods were first characterized using dark field scattering spectroscopy. Then, the one-photon photoluminescence spectra of the nanorods were measured under 405 and 785 nm continuous-wave excitation. The spectral line-shape and quantum yield of the nanorods were investigated as a function of aspect ratio and excitation power.

UG-05 **Three-Dimensional SiO2 as Fire-Retardant Material**

Irene Hwang,[1] Peter Owuor,[1] and Pulickel Ajayan[1]
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The fire-resisting ability of materials used in buildings plays a critical role in the safety of the buildings. In this study, we explore the mechanical and fire-retardant properties of 3-dimensional SiO2 foams. Using vacuum filtration, we synthesized SiO2/water foam, SiO2/silane foam, and SiO2/silane/graphene oxide(GO) foam. The SiO2/silane and SiO2/silane/GO foams were

found to have superior mechanical properties and fire retardant properties than SiO2/water foam. From visual characterization, it was concluded that the properties of the SiO2 foams fabricated with silane arose from an interconnected nanostructure between the SiO2 nanoparticles. The functionalization of SiO2 by the silanol groups in diethyltriamine silane resulted in covalent bonds between the particles. Thus, we were able to produce a three-dimensional structure composed entirely of a one-dimensional component. This method of synthesis provides a blueprint for future endeavors for bottom-up three-dimensional nanostructure synthesis.

UG-06 Three-Dimensional SiO2 as Fire-Retardant Material

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The fire-resisting ability of materials used in buildings plays a critical role in the safety of the buildings. In this study, we explore the mechanical and fire-retardant properties of 3-dimensional SiO2 foams. Using vacuum filtration, we synthesized SiO2/water foam, SiO2/silane foam, and SiO2/silane/graphene oxide(GO) foam. The SiO2/silane and SiO2/silane/GO foams were found to have superior mechanical properties and fire retardant properties than SiO2/water foam. From visual characterization, it was concluded that the properties of the SiO2 foams fabricated with silane arose from an interconnected nanostructure between the SiO2 nanoparticles. The functionalization of SiO2 by the silanol groups in diethyltriamine silane resulted in covalent bonds between the particles. Thus, we were able to produce a three-dimensional structure composed entirely of a one-dimensional component. This method of synthesis provides a blueprint for future endeavors for bottom-up three-dimensional nanostructure synthesis.

UG-07 Teslaphoresis of Carbon Nanotubes

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Teslaphoresis is the directed motion and self-assembly of matter by radiofrequency energy transmitted from a Tesla coil. Conventional electric field directed self-assembly of matter has been restricted to small scale structures, but with Teslaphoresis, we exceed this limitation by using the Tesla coil's antenna to create a gradient high-voltage force field that projects into free space. Carbon nanotubes placed within the Teslaphoretic field polarize and rapidly self-assemble into wires (< 5 s) that span from the nanoscale to the macroscale, the longest thus far being 15 cm. We also show the self-assembly of long nanotube wires at remote distances (> 30 cm away from the antenna) and that the Teslaphoretic transmitter wirelessly powers nanotube-based LED circuits that harvest energy directly from the Teslaphoretic field. Furthermore, we found that individualized carbon nanotubes in suspension self-organize into large-scale, parallel arrays on a substrate with high fidelity alignment to the direction of the transmitted electric field. Thus, the Teslaphoretic system may be an effective tool for scalable manufacturing of carbon nanotube transistors and conductive fibers.

UG-08 Optimization of Surface Planarization of Si/SiGe Virtual Substrates for Use in Quantum Computational Devices

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The creation of highly coherent qubits is crucial to the realization of large-scale quantum computers, which have been proven theoretically to significantly speed up the solution of difficult problems in computing.[1,2] This project aims to contribute to ongoing efforts in fabricating gate-confined, single-electron spin qubits in a strained, isotopically enriched[3] Si/SiGe heterostructure.[4] To strain the Si layer and enhance electron confinement, the device structure contains a graded buffer of Si and Ge referred to as the virtual substrate (VS). However, due to the relaxation of the lattice after VS growth, a crosshatch pattern develops at the surface of the virtual substrate. The surface roughness caused by the crosshatch pattern presumably traps additional electrons, which decrease the coherence time of the qubit spin state. In order to increase the likelihood of successful qubit formation, we employ a process called chemical mechanical planarization (CMP) to obtain an atomically flat surface in the VS plane. To characterize the roughness of the material surface before and after CMP, we use atomic force microscopy and laser scanning microscopy, which we also use to measure change in material thickness. Excessive removal of material during CMP can lead to a breakdown of the VS structure, which causes device failure. Consequently, we aim to determine the optimal parameters for achieving an atomically flat surface at the VS/Si interface while removing as little material possible from the VS to fabricate viable spin qubits.

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UG-09

Lithography-Free Fabrication of Transparent Conductive Single-Walled Carbon Nanotube Films

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Single-walled carbon nanotubes (SWNTs) have excellent electrical conductivity, flexibility, and mechanical strength. Consequently, they are a promising candidate material for transparent conductive films (TCFs) [1]. However, maximal performance of transparency and conductivity is hindered by the trade-off relationship between both characteristics in regard to SWNT film density. One method of improving this balance is patterned growth of SWNT films into low-density regions favorable to transparency and other high-density regions favorable to conductivity, which has proven feasible through previous researches [2, 3]. However, these previous methods involve lithography or complex treatments that arrange the SWNTs into TCFs after growth. We present a method to fabricate as-grown SWNT TCFs using self-assembled metal masks that is easier and more efficient than methods described in previous studies. The metal masks for selective catalyst deposition are created by annealing thin films of metal to realize an “island” morphology of patterned metal clumps and exposed substrate. This is followed by catalyst deposition and SWNT growth using alcohol catalytic chemical vapor deposition (ACCVD) [4]. We demonstrate SWNT patterned TCFs with higher transparency and comparable conductivity to continuous thin-films. Furthermore, the efficacy of our SWNT TCFs is demonstrated by utilizing them in CNT-Si solar cells.

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UG-10 Characterization of Carbon Nanotubes by Parallel Plate Waveguide Terahertz Spectroscopy

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Single-wall carbon nanotubes (SWCNTs) are a unique 1-d material with many exciting properties that show promise for various applications. In particular, SWCNTs demonstrate an ultrahigh electron mobility which shows great potential for application in electronic and photonic devices. However, their properties in the terahertz (THz) frequency range are largely unexplored. THz time-domain spectroscopy (THz-TDS) is typically used to characterize electromagnetic properties of materials. However, it is very challenging to use conventional THz-TDS on ultrathin materials such as SWCNT films due to the very short interaction length, typically in the order of nanometers. In this experiment, we use a parallel plate waveguide (PPWG) with the sample layer located halfway between the plates to achieve an increased interaction length that is limited only by the length of the waveguide. We use this setup to measure the THz response and calculate the conductivity of both aligned and unaligned SWCNT films on substrates of both magnesium oxide (MgO) and silicon. Based on other recent research on SWCNT conductivity, we expect very high conductivity from nanotubes aligned parallel to the transverse THz electrical field, lesser conductivity in unaligned nanotubes, and virtually zero conductivity in aligned nanotubes perpendicular to the THz film. The results of this study will provide new insight into the properties of SWCNT films and give us a better understanding of how these films are affected by nanotube alignment and choice of substrate.

UG-11 **3D Microfabrication of Boron Nitride Nanotube/Polymer Composites by Two-Photon Polymerization Lithography**

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We report the fabrication of arbitrary three-dimensional microstructures with boron nitride nanotube (BNNT)/polymer composites using two-photon polymerization lithography. Potential applications include micro/nano actuators, sensors, photonics devices and nanoelectromechanical systems based on BNNTs. Our preferred method using two-photon polymerization (TPP) allows fabrication of three-dimensional microstructures with sub-diffraction limit resolution. Along with mechanical properties comparable to carbon nanotubes', BNNTs possess distinguishable electronic properties independent of chiralities, higher thermal stability (900°C) and transparency in the visible region, most advantageous for TPP. BNNTs could not be dissolved in MMA, the standard monomer for TPP fabrication, even with inclusion of various surfactants. An acrylate monomer (R712) proved to be utmost suitable for dispersion. Raman imaging presented unclear spectra and was inefficient for verifying the presence of BNNTs. Distribution of BNNTs in the sample was ensured by dark field imaging. The stable range is 0.01-0.1-wt% BNNT. Optimization of the protocol for increased ratio of the nanotubes based on dispersion results occurred concurrently with fabrication of BNNT-R712 composite 3D structures. We anticipate this can demonstrate BNNTs can enhance properties of microstructures fabricated by two-photon polymerization.

UG-12 **Evaluation of Porphyrus Envelope as a Novel Drug Delivery System for Photodynamic Therapy of Prostate Cancer**

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Prostate cancer is the second-leading cause of cancer-related death in men. Side effects from traditional therapies as well as increased treatment resistance have led to a search for more effective treatment modalities. Photodynamic therapy (PDT) has the potential to fulfill this need. PDT uses photosensitizers, light-sensitive drugs/dyes, which selectively accumulate in tumor cells. Light stimulation of the photosensitizers causes the formation of reactive oxygen species (i.e.: $^1O_2$) only in tumor cells, sparing normal, healthy cells. This study evaluated porphyrus envelope as a novel therapeutic agent for PDT. Porphyrus envelope is created by incorporating the protoporphyrin IX lipid (PpIX lipid), a photosensitizer, into the hemagglutinating virus of Japan envelope (HVJ-E). HVJ-E was used because it leads to immune cell recruitment and activation of anti-tumor immunity, and thus a higher therapeutic effect in deeper tissue. Additionally, HVJ-E's fragmented RNA induces apoptosis in cells via the RIG-I pathway. Direct cytotoxicity assays performed in this study found that HVJ-E alone and porphyrus envelope showed statistically similar decreases in cell survival rate in the absence of light stimulation/PDT. However, porphyrus envelope led to significantly lower tumor cell survival rate in the presence of light stimulation/PDT when compared to HVJ-E alone. The ideal irradiation wavelength (450 nm) was established using PpIX lipid's absorption spectrum. Thus, porphyrus envelope represents a novel drug delivery system that can be used to more effectively treat prostate cancer as well as enhance the treatment options of other types of cancers conducive to PDT treatment, including brain and skin cancers.

UG-13

Hidden Symmetries in One-Dimensional Photonic Crystals

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One-dimensional photonic crystals (PCs) are systems with N layers of dielectric media varying in only one direction. They allow us to control the propagation of light, which has useful applications in creating optoelectronic devices. In this study, we investigate the optical properties of PCs in which each layer is one of two dielectric media, with thickness one-quarter the wavelength of light corresponding to a central frequency in that medium. Tavakoli and Jalili[1] found that certain self-similar PCs can produce desirable optical properties, such as a very sharp peak in the transmission spectrum or a high electric field enhancement. However, these are only very specific sequences out of all possible 2^N. Using the transfer matrix method, the transmission probability T is calculated for all possible 2^N sequences for small N. Unexpectedly, it was found that instead of 2^N different values of T at the central frequency, there is only a small number of discrete values. For example, with $N = 8$, there are $2^8 = 256$ possible sequences, but only 5 distinct T values. In physics, high degeneracy generally implies the existence of hidden symmetry operations. We found such symmetries and proved that they do not change T. Additionally, analytical formulae were derived for the T values and degeneracy at each as functions of N and a sequence's total "charge", which we shall define. By understanding the origin of these hidden symmetries and patterns, we can create more efficient algorithms for finding and designing optimal sequences of PCs for large N.

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UG-14

The effects of Ag on the thermoelectric properties of higher manganese silicide

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Higher manganese silicide (HMS) possesses electron transport properties suitable for thermoelectric generators and Peltier coolers, but its slightly large lattice thermal conductivity prevented us from utilizing it in practical applications. HMS containing a 5 at % heavy elements such as Ta, W and Re shows reduced lattice thermal conductivity, despite the materials being metastable and decomposing at high temperatures. It is preferable to make bulk samples of these materials without the formation of precipitate. We found that small amounts of Ag works as "glue" to help obtain bulk samples with lower sintering temperature. Therefore, in this study, the addition of Ag to n-type and p-type HMS on the thermoelectric properties of HMS-based materials are being intensively investigated. This process to create the materials consists of (1) measuring out the elements, (2) mixing them into homogenous powders, (3) arc melting the pressed powders together to create an ingot consisting of several phases, (4) making single phased ribbons using a liquid quenching or melt spinning machine, (5) mixing the obtained ribbons with different amounts of Ag, and (6) creating bulk samples using spark plasma sintering. The thermoelectric properties, Seebeck coefficient, electrical resistivity, and

thermal conductivity were measured in a wide temperature range from 300 K to 900 K. This allows us to figure out the best Ag concentrations that lead to the best thermoelectric, non-toxic and cheap HMS materials.

UG-15 **Applications of MoS_2 Transistors to Nonvolatile Memory**

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Thermally-assisted memories are a growing area of study in nanotechnology, where heat is used to ease the switching between nonvolatile memory states [1]. Thermally-assisted switching provides high scalability, thermal stability, and low-power programming. Molybdenum disulfide (MoS_2), a transition metal dichalcogenide (TMDC), is a wide bandgap semiconductor with a direct band structure when isolated in monolayer form [2]. While previous studies have examined how the two-dimensional (2D) semiconductor MoS_2 displays a transfer curve with a pronounced hysteresis at high temperatures, there is little research which examines the temperature-dependent characteristics of MoS_2 field-effect transistors (MOSFET) [3]. Our interest is on data obtained at temperatures above 400 K, where our group has recently reported a novel form of hysteresis, behavior that has not been reported previously. The essential property that allows this memory behavior to be achieved is the hysteresis that appears in the transfer curve of the transistor when the temperature is increased [4]. At the highest temperatures studied (~500 K), the hysteresis exhibits a step-like change in drain current, induced when sweeping the gate voltage upwards from an initial negative value [4,5]. By using scanning probe microscopy, our study will explore the connection of this phenomenon to charge injection/release in the gate insulator, and will also investigate how the memory effect can be maintained by decreasing the temperature from 500 K to room temperature. The nonvolatile nature of this memory effect makes it potentially useful for memory technology.

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UG-16 **Enhancing the Detection Sensitivity of Terahertz Spectroscopy for Biomolecules using Metasurfaces**

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Terahertz Time-Domain Spectroscopy (THz-TDS) has been recognized as an emerging optical biosensing technique, based on the observation that the intermolecular vibration frequencies of major biomolecules have resonances in the Terahertz (THz) region. THz-TDS emits low-energy, non-ionizing radiation and can be performed non-invasively, giving it extensive applicability in the biomedical field. That being said, it is often limited by a weak and broad detection, characterized by a low Q-factor. THz metasurfaces serve as a promising solution to this issue by interacting with the THz wave at a sub-wavelength scale. This ultimately allows us to achieve high local electric field enhancement and increase the molecular absorption cross section. In our experiment, we fabricated three different gold metasurfaces by photolithography to use in conjunction with the THz system. By using metasurfaces, we anticipate heightening the system's ability to discern a spectral shift correlated with modifications to the refractive index of creatinine solutions. Serum and urine creatinine levels are widely used to evaluate renal health and abnormally high concentrations tend to indicate kidney disease. A multitude of creatinine measurement techniques currently exist, of which isotope dilution mass-spectrometry (IDMS) is regarded as the primary reference method. IDMS and other creatinine assays, however, involve tedious and expensive preparation steps. Comparatively, THz-TDS has much higher throughput and eliminates the need for expensive reagents. As such, the THz-TDS/metasurface combination has the potential to become a valuable addition to the existing landscape of diagnostic practices available for analyzing creatinine and many other biomolecules.

UG-17 **Amplifying Brain Waves to Control a Robot by Using Flexible Organic Transistor Circuits**

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We demonstrate how the use of organic thin film transistors in a Pseudo-CMOS integrated circuit can effectively amplify alpha waves in the range of 8-12 Hz emitted by a brain to wirelessly control a robot. Modern electronics such as computer displays, smartphones, and sensors are rigid and made of inorganic materials. Using an organic semiconducting material instead allows the realization of flexible and stretchable electronics. Furthermore, organic materials can be solvent-based, leading to large surface area and low-cost inkjet printing to allow manufacturing scalability. Taking advantage of these properties, we integrated a flexible Pseudo-CMOS amplification circuit on a stretchable and flexible silver electrode to reduce noise and cross talk characteristic of crystalline based devices, attain large gain, and reduce cost by two orders of magnitude from industry standards. To demonstrate functionality, the electrode and amplification circuit was integrated with a custom wireless EEG (electroencephalogram) device to amplify alpha waves. Successful control of the robot paves the path for the development of other bio-signal detection devices. Sleep health can be monitored to optimize health and fitness, which is of increasing interest due to the 2020 Olympic Games in Tokyo. Alzheimer’s and heart irregularities can be monitored at all times to provide urgent care and immediate response. A seamless internet infrastructure then emerges, allowing data to be collected from the physical world, sent to the cloud, processed, acted upon, instantly. Realizing this cyber-physical system is the intention of our work.

UG-18

Terahertz Emission and Detection in Graphene Based Heterostructures

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Electromagnetic waves with frequencies in the terahertz (THz) range have potential uses in imaging and ultrafast communication that would be safer, faster, and more accurate than current imaging and wireless communication technology. However, while many devices can operate in frequencies both smaller and larger than THz, it is currently difficult to achieve high power THz emission or sensitive THz detection. Therefore, we study the use of graphene as a THz emitter and detector. Specifically, we use two types of graphene samples: a distributed-feedback dual-gate graphene-channel field-effect transistor (DFB-DG-GFET) for emission and an asymmetrical dual-grated-gate graphene field-effect transistor (ADGG-GFET) for detection. For emission, we use Fourier transform infrared (FT-IR) spectroscopy, which consists of a cryostat containing the graphene sample, and a bolometer to detect the THz radiation. The graphene sample is first excited using current injection, and the carriers in population-inverted graphene can then recombine to emit THz photons. Previously observed single mode emission at 5.2 THz from a DFB-DG-FET suggests that this structure can be viably used as a THz laser. We try to reproduce these results and achieve better operation at higher temperatures. For the detection experiment, we use a uni-traveling carrier photodiode (UTC-PD) as a THz source and place the ADGG-GFET under THz radiation. Using a lock-in amplifier, we look for an increase in the sample’s current as a signal of carrier excitation caused by THz radiation. We expect to see a strong photocurrent response, moving us closer to finding a graphene structure with optimal THz detection capabilities.

UG-19 **Terahertz Detection at Room Temperature Using Highly Aligned Single-Wall Carbon Nanotube Films**

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Terahertz (THz) radiation has a broad range of potential applications in the medical, security, industrial, and agricultural fields. However, current technology for generating, modulating, and detecting THz radiation is unsuitable for commercial applications because of its limited performance, high cost, and cryogenic temperature requirements. Single-wall carbon nanotubes (SWCNTs) are a candidate for developing high-temperature-operating THz detectors due to their wide range of absorption at room temperature, high charge carrier mobility, flexibility, and strength. Additionally, SWCNTs come in various species, called chiralities, including metallic and semiconducting types, which have differing band gaps, conductivities, and Seebeck coefficients allowing for different responses to THz radiation. In this study, we set out to characterize the effects of back gate control on THz absorption of highly aligned single-chirality and metal/semiconductor mixture SWCNT films [1]. Each of our devices consisted of a SWCNT film on a Si/SiO_2 substrate with four Cr/Au electrodes deposited by electron beam evaporation and an Al back gate deposited by thermal evaporation. Because aligned SWCNT films exhibit different values of absorption and conductivity depending on the direction of polarization/current flow with respect to the films' alignment, we characterized the current-voltage relationship for each orientation with and without a back gate bias voltage and with and without THz irradiation.

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UG-20 **$MoSe_2$ Thin-Film Growth by Molecular Beam Epitaxy and Electrical Double Layer Transistor Implementation**

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Atomically layered semiconducting transition metal dichalcogenides (TMDs) have attracted recent attention in the field of 2D materials due to their thickness-dependent band gaps, which become direct in the monolayer limit, ideally suited for optoelectronic device applications. However, mechanical exfoliation, a widely-used method for thin-film fabrication, is unsuitable for industrial application. An alternative method, molecular beam epitaxy (MBE), can produce high-quality and large-area (mm-range) films with controllable thickness. Here, we strive to demonstrate the viability of MBE as a means of TMD thin-film fabrication by presenting an electrical double layer transistor (EDLT) that utilizes MBE-grown $MoSe_2$ and its resulting transport measurements. EDLTs are specialized field effect transistors that rely on an electrochemical phenomenon and have been able to achieve ambipolar operation in similar TMDs.[1] We selected MSe_2 (M = W, Mo) as the materials of focus due to their semiconducting properties that make them appropriate for EDLT integration. $MoSe_2$ and WSe_2 are also notable TMD materials because of their promising optical properties and previously observed electroluminescence.[2,3] We grew $MoSe_2$ films by MBE and characterized them by atomic force microscopy and x-ray diffraction to confirm their quality. We then fabricated an EDLT that incorporates $MoSe_2$ and measured its transport characteristics using a Physical Property Measurement System (PPMS®). The optimization of TMD thin-film growth by MBE can greatly improve the efficiency of 2D TMD research efforts and introduce scalability in device fabrication.

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UG-21 **Hydration Analysis of Carbon Nanotubes/Polyamide Nanocomposite Thin Films**

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With the ever growing population and scarcity of clean, drinkable water, filtration and desalination have become essential in daily life. Polyamide (PA) reverses osmosis (RO) membranes have become the industry standard for water desalination because of their high salt rejection, high water flux and robustness, but they have limited lifespans due to low oxidant tolerance and high fouling rate. Carbon nanotube/PA nanocomposite RO membranes have shown improved flow rate, oxidant tolerance, and lower fouling rates without compromising salt rejection [1]. Computational and theoretical findings [2] have suggested that the carbon nanotubes act as a support structure for the PA membrane, increasing the density of the active layer. This suggests there are fewer water pockets within the membrane, which act as ion transport channels, resulting in a higher salt rejection. However, this proposed mechanism has yet to be confirmed due to a lack of experimental measurements. In this work, we examine the changes in hydration of PA membranes prepared with the addition of carbon nanotubes. Our measurements indicate the membranes containing carbon nanotubes have a lower relative water absorption, suggesting an increase in membrane density. These results are in agreement with the numerical simulations, and provide additional insight into the much needed advancements in water filtration technologies.

[1] S. Inukai, R. Cruz-Silva, J. Ortiz-Medina, A. Morelos-Gomez, K. Takeuchi, T. Hayashi, A. Tanioka, T. Araki, S. Tejima, T. Noguchi, M. Terrones & M. Endo. High-performance multi-functional reverse osmosis membranes obtained by carbon nanotube/polyamide nanocomposite Scientific Reports 5, Article number: 13562 (2015) DOI:10.1038/srep13562

[2] T. Araki, R. Cruz–Silva, S. Tejima, K. Takeuchi, T. Hayashi, S. Inukai, T. Noguchi, A. Tanioka, T. Kawaguchi, M. Terrones, and M. Endo. Molecular Dynamics Study of Carbon Nanotubes/Polyamide Reverse Osmosis Membranes: Polymerization, Structure, and Hydration *ACS Applied Materials & Interfaces* 2015, *7* (44), 24566-24575 DOI:10.1021/acsami.5b06248

UG-22 **Modeling a New Type of Gamma-Ray Detector for Nuclear Photonics**

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This study simulates the response of a new type of gamma-ray detector called scintillation attenuation spectrometer (SAS) using GEANT4, the CERN Monte Carlo code for radiation and high-energy physics. The scintillator consists of a lead collimator and a large 2D matrix of fully-coated LYSO crystal pixels (1.5mm x 1.5mm x 1cm) with 100% reflectivity at the pixel boundaries. Monoenergetic gamma-rays are injected from the side each time, and the energy deposition at each pixel is acquired, representing local scintillation optical photon output (approximately 30000 blue photons per MeV of energy absorbed). The 2D light pattern is then recorded using a CCD camera. Each image represents the detector response at that particular gamma-ray energy. Using a large collection of scintillation light patterns of gamma-rays spanning a broad range of energies (e.g. 0.1 to 50 MeV), we can construct the detector response matrix. We will then use the matrix to deconvolve the observed optical images from real experiments into gamma-ray spectra, and compare our simulation results with experimental data from calibration radioisotope sources.

Poster Session – STEM Research Experience for Undergraduates (REU) 12:00 pm – 1:30 pm

UG-HS-01 Difference of Morphological Traits and Their Association with Mating Behaviors Among Host-Associated Populations of Gall Wasp *Belonocnema treatae*

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Multiple factors, such as habitat and behavior, acting as natural selection could result in reproductive isolation, which sparks the process of ecological speciation and the formation of new species. A major significant factor that can contribute to reproductive isolation is sexual selection, which can be triggered as a byproduct of divergent selection on morphological traits. For instance, the preference of males with a larger body size by females can be observed in many animals systems. *Belonocnema treatae* is a host specific gall wasp species that feed and induce galls on species of live oak. Previous research has shown evidence of divergent selection from different host species on *B. treatae* gall morphology and host preference. Therefore, it is an ideal organism to study not only the divergent selection from host species on morphological traits but also how the difference in morphological traits could influence courtship/mating behavior. Firstly, we measured the morphological traits of *B. treatae* from different host species to identify morphological differences due to host species. Then, we conducted observations of the courtship/mating behaviors of the *B. treatae* from different host plants and measured 15 different morphological traits to identify those that could predict mating success. We found significant differences in morphological traits among females and males that indicate that host plants are acting as a form of selection on the morphology of *B. treatae*. Our results indicate that males from host plant *Quercus geminata* prefer to mate with females from the same host plant of similar or smaller size.

UG-R-01 Removing methylene blue from water using hydrogen peroxide and metal oxide catalyst.

Arreyndip Arung Etah, [1] Camilah D. Powell, [2] and Prof. Michael S. Wong[2]
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[2]*Department of Chemical &Biomolecular Engineering, Rice University, Houston, Texas, U.S.A*

This study evaluated the generation of hydroxyl radicals from hydrogen peroxide (H_2O_2) by several different heterogeneous catalysts and compared their relative efficiencies. The catalysts chosen for this study include Fe_3O_4, Co_3O_4, MnO_2, Fe_2O_3, NiO, CuO, ZrO_2, TiO_2, CeO_2, ZnO, UiO-66 and C-on-Fe. These studies could find useful application in environmental remediation and the treatment of textile industrial waste water. These particles are active towards the decomposition of hydrogen peroxide at room temperature and the production of hydroxyl radicals was quantified by using the UV-vis spectrophotometer. The results obtained show that all the tested metal oxide catalysts decomposed H_2O_2 and the rate of the reaction was determined to be first order. The rate of decolorization of the model pollutant, methylene blue by each metal oxide in the presence of hydrogen peroxide was also investigated using the UV-vis spectrophotometer. These metal oxides are expected to enhance the decolonization of methylene blue in the presence of hydrogen peroxide.

UG-R-02 Molecular Structure of Triiron Dodecacarbonyl

Toul T. DeGuia-Cranmer[1], *Andrew Leitner*[2], *and Kenton Whitmire*[2]
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[2]*Department of Chemistry, Rice University, Houston, Texas, United states*

A metal-organic framework (MOF) is proposed to elucidate the molecular structure of triiron dodecacarbonyl, $Fe_3(CO)_{12}$. The *crystalline sponge,* $\{[(ZnI_2)_3(2,4,6\text{-tri (4-pyridyl)-1,3,5-triazine})_2]\cdot(C_6H_5NO_2)\}$, is determined to be a suitable MOF because of the pore size. Synthesis by layering uses two solvents of different densities to form a reaction boundary and facilitate slow introduction of ZnI_2 solution to 2,4,6-tri (4-pyridyl)-1,3,5-triazine (TPT) solution. A slow reaction rate is necessary for producing large single crystals (30-300 μm). After crystals have grown they are collected and consolidated into a single test tube containing cyclohexane (10ml). By exchanging nitrobenzene with cyclohexane the pores are prepared to accept guest molecules. The pores are activated if no nitrobenzene peak is observed (1344 cm^{-1}) in the solid-state infrared (IR) spectrum. Once the pores are activated, large single crystals are selected and are submerged into a vial containing $Fe_3(CO)_{12}$ dissolved in cyclohexane (10 ml). When encapsulation of $Fe_3(CO)_{12}$ is

complete, the crystals will become green and solid-state IR of $\{[(ZnI_2)_3(TPT)_2]\cdot(Fe_3(CO)_{12})\}$ will show a peak at 1750-2120 cm^{-1}. Single-crystal x-ray diffraction will elucidate the molecular structure of $Fe_3(CO)_{12}$.
So far, crystalline sponges have been synthesized and the pores have been activated. Crystals have been characterized at each step, by solid IR, powder x-ray diffraction, single-crystal x-ray diffraction to ensure purity.
During the manufacturing of the crystalline sponge it was determined that glass test tubes are better than plastic test tubes for growing crystals and that cubic block crystals are ideal because they do not decompose during the solvent exchange process.

UG-R-03 **Nano-particle Synthesis and Applications**

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Shape-specific growth methods for gold and palladium nanoparticles were developed based on aqueous and non-aqueous reactions. In particular, seed-mediated syntheses produced gold decahedra with exposed {111} facets of approximately 80nm edge length. Production of single-crystalline palladium cubes with exposed {100} facets of greater than 80nm edge length has been so far elusive, with research ongoing. Shape control of the seed particles was accomplished with of high concentrations of poly-vinylpyrrolidone(PVP), an effective capping agent for the production of nanoparticles. Then, larger particles were grown from these seeds to maintain the homogeneity of shape distribution and also achieve a larger size. PVP concentration alone was found to be less effective than seed-mediated approaches for controlling shape as particles; citric acid and bromide ions were used to modify the surface energies of seed particles to promote growth of the {111} and {100} facets of gold and palladium respectively. The syntheses have yielded promising results, and the particles will be further characterized for research into catalysis and bio-sensing applications.

UG-R-04 **Study of Asphaltene Deposition from Destabilized Oils with Water Emulsions Using Porous Microfluidics Chip**

Hunter Ducharme,[1] Peng He[2], Yu-Jiun “Nate” Lin[2], Sibani Lisa Biswal[2]
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Asphaltene deposition is commonly known to restrict the flow of oil in pipelines and the near wellbore region of oil reservoirs, which can lead to a plethora of problems. Understanding the mechanism by which asphaltenes deposit is highly desirable in order to maintain flow assurance in the recovery of oil. This research serves as an attempt to develop a deeper understanding of the behavior of asphaltene deposition under dynamic flow conditions. In particular, the existence of water in oil further complicates the process of asphaltene deposition. To reproduce the typical flow conditions found in this region, our team utilized a microfluidics device with a porous-media section consisting of circular micron-sized posts. Crude oil containing water-in-oil emulsions was flowed through the microfluidic porous-media in the presence of a precipitant. Trapping of water emulsions within the asphaltenes deposits on the porous media was observed. Experiments that varied the salt concentration and salinity of water were carried out to understand how salinity affected emulsion trapping. For each concentration and salinity of water, the deposition of asphaltenes was visually recorded using high speed optical microscopy and quantified using imaging processing. By understanding this cause and effect process, it is possible that our team can develop strategies to minimize the asphaltene deposition in the presence of water emulsions and as a result maximize flow assurance in the oil recovery operations.

UG-R-05 **Multi-functional Polymer Binder for V_2O_5 Cathode in Li-ion Battery**

Abigail Gonzalez[1], Xiaoyi Li[2], Andrea L. Miranda[2], and Rafael Verduzco[2]
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Lithium-ion batteries are used globally for computers, cameras, electric automobiles, and other portable devices. An essential, but oftentimes overlooked, component of the battery electrode is a binder material for maintaining mechanical integrity and electrical contact with current collectors. While the most popular binders are based on non-conductive and non-redox active polymers, we propose that the use of multifunctional, conductive and redox-active, polymers can be used to improve battery performance. Our objective is to understand the properties of conjugated polymer binders, and how they can improve the electrochemical properties of lithium-ion batteries, including the capacity and the lifecycle. As a model system, we investigated the use of self-doped conjugated polymers as binders for vanadium pentoxide (V_2O_5) cathodes. A series of poly(fluorene-co- phenylene) (PFP) polymers with ionic side-chains were synthesized through a Suzuki polycondensation. We varied our synthesis approaches by modifying the temperature, alternating between solvents, and changing reaction instruments. The counterion was exchanged through dialysis, and the resulting materials were characterized through UV-VIS absorbance measurements. These polymers were incorporated into V_2O_5 binders, and preliminary results demonstrate enhanced capacity performance with incorporation of 5 % PFP-Na binders. In future work we will look at the impact of similar annealing on PFP self-doped copolymers in cathodes of lithium-ion batteries.

UG-R-06 Engineering Adeno-Associated Virus (AAV) for Protease Targeted Gene Therapy and Immunogenicity

Natasha Hede, Tawana Robinson, Junghae Suh
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Adeno-associated viruses (AAVs), area type of non pathogenic virus that can be modified for gene therapy due to their small DNA base pair length. Clinical research has proven promising regarding the safety and efficacy of AAVs as a gene therapy tool. However, AAVs can illicit an immune response despite their safe nature. To address this issue, the capsid may be modified through peptide insertion, vector choice, and masking immunogenicity epitopes. Through molecular cloning techniques and conducting genetic modification, a type of AAV capsid will be engineered with optimally conformed peptide and linkers. These linkers will be placed at different locations and in different sizes and numbers to test the decrease of phagocytic susceptibility and help with immunogenicity while not interfering with gene therapy. Three different types of AAV viruses will also be created with self peptide inserts so that they will not susceptible to macrophages. Finally, these viruses will be characterized through a variety of assays and PCRs to help understand viability. This is vital to AAV gene therapy as it could further our understanding how to modify viruses, but also help create a method of gene therapy which could be used as a drug to combat pathological diseases.

UG-R-07 Model of Hepatitis C Viral Dynamics through Deterministic and Stochastic Methods

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In most people infection by Hepatitis C Virus (HCV) leads to liver failure. However, rare patients show the ability of spontaneous recovery. The reasons of such phenomenon are still not well understood, but it has been found that in chronically infected individuals there is a high level of HCV diversity due to high mutation rate in the virus. Furthermore, different mutants have diverse properties, and thus how they are hazardous for human immune system varies. The infected organism responds efficiently until a fit enough mutant arises that escapes the immune pressure. Here we present the theoretical analysis of virus dynamics with incorporation of mutations and immune response that may shed the light on the disease progression and spontaneous recovery. We roughly estimate the time for the appearance of escape mutant for different conditions. Our method consists of the solution of the kinetic model and stochastic Monte-Carlo simulations based on Gillespie algorithm. Preliminary results show that in the stochastic simulations some of the virus mutants completely disappear while it is not observed in the kinetic model. Moreover, kinetic model always demonstrates the immediate growth of escape mutant due to self-reproducing, but it appears in the organism mainly because of the mutations which is proved by stochastic simulations. Obtained results are utilized to analyze clinical data.

UG-R-08 Optimizing Film Measurements of Gold Nanorods

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With advances in nanomaterials over the past two decades, there has been a large interest in the physical properties of metallic nanoparticles, which are utilized in optical sensing, catalysis, and nanoscale electronics. For detailed optics, thin films of gold nanoparticles need to be deposited on a substrate. Currently, glass substrates are used to obtain the optical measurements of the nanorods; however, there is a need to find an alternative method of creating films that are flexible, uniform, reproducible, cost-efficient, and time-efficient. Optimally, rods need to be uniform on the films and at high densities to be optically suitable for measurements.This investigation primarily explores a method that involves passing nanorods through filters such as 0.03μm track-etched nuclepore and anodized alumina anodisc filters. Preliminary results show that when passing 1 mL of nanorods suspended in 10mM CTAB, results in about half of the nanorods pass through the filter and about a tenth are left on the filter, which suggests that some nanorods are getting stuck inside the filter that is part of the setup, or the absorbance from the filter needs to be scaled. Also, the width of the absorption spectrum of the nanorods on the filter suggest that they are clumping together. Filtering gold nanorods modified with polyethylene glycol (and without CTAB) resulted in 21% of the rods stuck to the filter and 4% was recovered from the remaining liquid. Further examination and experimentation is required to explain the missing rods.

UG-R-09 **Role of Fibroblast Growth Factor in Human Embryonic Stem Cells Pluripotency and Communication**

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The fibroblast growth factor (FGF) signaling pathway is stimulated by different FGF ligands which leads to various functional outputs during early development. While it is established that in human embryonic stem cells (hESCs) the FGF2 ligand drives the FGF pathway to maintain an undifferentiated state, the underlying molecular mechanisms are unclear. Current work in the laboratory also shows that FGF may be involved in the regulation of community effect (enforcement of common fate in a group of cells). Specifically, common pluripotent fate in groups of cells may be enforced via cell-cell communication where FGF functions to suppress differentiation. This work aims to clarify the role of FGF in maintaining pluripotency and community effect.

We will examine the effects of FGF inhibition at multiple levels of this signaling cascade and at various time points, using the FGF signaling activity (phosphorylated ERK) and pluripotency markers as read-outs. We will also look at differentiation markers that are upregulated upon FGF inhibition at later time points to identify its targets. Lastly, we will look at the cross-talk between FGF and Nodal, a major pluripotency pathway in hESCs.

Disruption of the FGF signaling cascade (FGF2-MEK kinase-pERK-gene expression) at the level of MEK lead to decrease of pERK levels to near background after 6 hours which remained low at 42 hours. MEK inhibition also affected activity of PI3K pathway (essential for stem cell proliferation and pluripotent state) through reducing PI3K signal transducer, phosphorylated Akt. This suggests that FGF could regulate the pluripotent state indirectly through PI3K.

UG-R-10 **Characterization of Carbon Nanotubes**

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Carbon nanotubes (CNTs) are an allotrope of carbon with outstanding properties. These properties make CNTs ideal for a variety of applications including electronics, optics, and biomedical engineering. CNTs are synthesized using multiple techniques like arc discharge, chemical vapor deposition, and laser ablation. Their diameter is on the scale of nanometers and their length is on the scale of micrometers. They are unique because of their extraordinary mechanical strength, high electrical and thermal conductivities, and their low density. They come in two forms: single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs). Our work aims to determine conductivity, defect density, and length of SWNTs and MWNTs provided by NASA. We use Raman spectroscopy, polarizing optical microscopy, and extensional rheology to characterize the CNTs. To analyze the CNT samples by polarized optical microscopy and extensional rheology, it is necessary to individually dissolve the CNTs into a solvent. Chlorosulfonic acid (CSA) is a true solvent for CNTs. At high concentrations, CNT-CSA solutions form an aligned liquid crystalline phase that is particularly advantageous when these solutions are used to produce highly aligned fibers and films. Our work is fundamental in determining the level of purity in the sample, the crystallinity, and length of the CNTs, which are all factors that dramatically affect the properties of CNT-based materials.

UG-R-11 **Interplay of Superconductivity and Magnetism in $Yb_3Rh_4Sn_{13}$**

Andrea Revelo[1], Macy Stavinoha[2], Emilia Morosan[2,3]

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The focus of the study is to synthesize doped crystals of $Yb_3Rh_4(Sn_{1-x}M_x)_{13}$, where M = Ge, Pb, Si. Doping will be used to drive the system from one ground state (superconductivity for x = 0) to another (magnetic, heavy fermion). The competition between the different states will also be analyzed, which may lead to quantum phase transitions (or transitions at absolute zero temperature). Single crystals of the studied compounds were synthesized using the flux growth method with elemental metals under partial pressure of an inert gas that were typically heated to a temperature of 900°C and then slowly cooled down to 600°C. Precipitated crystals were obtained by centrifugation. Powder X-ray diffraction was used to determine the type of crystal and purity, and to obtain the lattice parameters and determine if doping was successful. Magnetization measurements M(T,H) were performed, to determine the compounds ground state (e.g. superconducting or magnetic). The results showed 3-4-13 crystals with signs of doping. Further experiments will be performed such as doping 3-4-13 crystals to a greater extent to drive the state of the crystal from one to another.

Poster Session – Research Experience for Teachers (RET) 12:00 pm – 1:30 pm

RET-01 **Synthesizing, Purifying, and Characterizing Dirhodium triacetate monotrifluoroacetate [$Rh_2(OAc)_3(tfa)_1$] and *cis*-dirhodium diacetatebistrifluoroacetate [*cis*-$Rh_2(OAc)_2(tfa)_2$].**

Ibironke T. Ajayi, [1] Zachary T. Ball, [2] Claire Coogan, [2] Cody Martin, [2] Carolyn Nichol [3]
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[3]Rice Office of STEM Engagement, Rice University, Houston, United States

Dirhodium tetracetate [$Rh_2(OAc)_4$] was reacted to form dirhodium triacetate monotrifluoroacetate [$Rh_2(OAc)_3(tfa)_1$] and *cis*-dirhodium diacetatebistrifluoroacetate [*cis*-$Rh_2(OAc)_2(tfa)_2$]. These products can be used to form metallopeptides and metallo-inhibitors that bind to proteins in order to identify and specify their binding sites. $Rh_2(OAc)_4$ was reacted with trifluoroacetic acid to form the crude products [$Rh_2(OAc)_3(tfa)_1$] and [*cis*-$Rh_2(OAc)_2(tfa)_2$]. These crude products were then purified using column chromatography and analyzed for the desired results through Thin Layer Chromatography (TLC), High Performance Liquid Chromatography (HPLC), and ^{1}H Nuclear Magnetic Resonance (^{1}H NMR) spectroscopy. The purified products can be combined with peptides by other scientists to form metallopeptides that bind to specific sites on proteins thus causing the proteins to be inhibited or activated. Due to the different functions of these products, [$Rh_2(OAc)_3(tfa)_1$] and [*cis*-$Rh_2(OAc)_2(tfa)_2$], biologist can use the newly formed products to better understand the various biological systems they treat. Medical researchers can use them to better understand and identify active sites of various proteins. [$Rh_2(OAc)_3(tfa)_1$] and [*cis*-$Rh_2(OAc)_2(tfa)_2$] can create tools that can be used to study, improve, and cure diseases like leukemia. As of today, researchers are currently using these products to widen their research and test the limits and capacities to which [$Rh_2(OAc)_3(tfa)_1$] and [*cis*-$Rh_2(OAc)_2(tfa)_2$]can be used.

RET-02 **Bubble Coalescence in Low Viscosity Fluid.**

1Najma Bano, 2Sofia Avendano, 3Dr. Helge Gonnermann
1NSF Research Experience for Teachers, Rice University, Houston, Texas
2Department of Earth Sciences, Rice University, Houston, TX, USA

Abstract: During volcanic activity, decompression causes bubbles to form and grow within magma. These bubbles then affect the buoyancy of the magma. The growth of bubbles within the magma depends on several parameters, one of which is bubble coalescence. In this study, analog materials (silicon oils with viscosities of 10 Pas and 100 Pas, within range of basaltic magmas) are used in order to observe coalescence. For all conditions studied herein, small bubbles coalesce with a large bubble known as a slug or Taylor bubble. The coalescence of a small bubble with a slug in silicon oil was observed through camera and subsequent image analysis. A series of experiments was conducted focusing on the coalescence of a single spherical bubble with the gas slug. Acrylic columns of diameters of 0.25”, 0.5” and 1.0” were filled with silicon oil with headspace left at the top. The small bubble would then be injected at the bottom of the tube, and then the column would be inverted and coalescence would be recorded if it occurred. The small bubble's diameter, slug's length and speed were calculated to compare the data before and after the coalescence in order to better understand what parameters control bubble coalescence.

RET-03 **Nanotechnology Enabled Water Treatment (NEWT) Through the Use of Hybridized Materials**

Cole Cairl

NEWT, Arizona State University, Tempe, Arizona, USA

The Nanotechnology Enabled Water Treatment Research Experience for Teachers (RET) provided lab time on the ASU Polytechnic Campus under the supervision of Dr. Kiril Hristovski (Faculty Host) and Jasmina Markovski (Postdoctoral Mentor). Work done in the laboratory was focused on the use of Granulated Activated Carbon (GAC) as a base for nanoparticles in order to create hybrid filtration materials. The focal point of the work conducted during the course of the program was done by adhering Aluminum Dioxide to the surface of the GAC thereby forming a hybridized media. The purpose of the Aluminum Dioxide was to remove targeted toxins from the water; in this particular lab case the targeted toxin was Fluorine. Elsewhere in the lab both Aluminum Dioxide and Titanium Dioxide were used to remove Nitrates, Fluorine, and Arsenic from contaminated water. While the compounds added to the GAC aid the extraction of additional toxins the presence of these compounds cause pores within the surface of the GAC to be filled. The more pores that are in use the less effective the GAC is at its primary function of filtration. The goal of the work being done is to find the optimal saturation of Aluminum Dioxide onto the GAC so that both the targeted toxin can be removed while also not reducing the efficacy of the GAC's filtration capabilities below safe levels.

RET-04 **Laser Induced Graphene (LIG) for Capacitive Deionization (CDI)**

Sharon Carswell,[1] Yilun Li,[2] Jun Kim,[3] Qilin Li,[3] and James M. Tour[2]

[1]*NEWT Research Experience for Teachers,* [2]*Department of Chemistry,* [3]*Department of Civil Engineering, Rice University, Houston, Texas*

Laser induced graphene (LIG) is a porous graphene structure produced from commercial polymer films through a one-step laser scribing process. The as-prepared LIG material shows high surface area and good electrical conductivity, thus suitable to be used as the electrode material for capacitive deionization (CDI) systems. By adjusting the laser conditions, LIG samples with a variety of densities and thicknesses were prepared, and were then fabricated into electrodes and tested in a CDI system by monitoring the conductivity of the feed water, which correspond to the amount of ions absorbed by the LIG porous electrodes. Various designs of the electrodes have also been explored to find the optimal configuration of the testing systems. This potential application of LIG towards CDI systems should be an important part of the Nanotechnology Enabled Water Treatment (NEWT) project.

RET-05 **Polyvalent Phages Conjugated To Magnetic Nanospheres For Mixed Biofilm Treatment**

Carlton C. Colmenares[1, 3], Pingfeng Yu[1], Lingli Li[2], Pedro J. J. Alvarez[1]

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Wastewater has traditionally been a repository for serious pathogenic and enterobacteria; its treatment is intrinsically associated with public health. The presence of antibiotic resistant bacteria is not uncommon in waste water treatment plants, especially within biofilms' extracellular polymeric substances that are produced by a complex community of organisms. Bacteria found within biofilms are challenging to control. Non-conventional solutions may exploit nanotechnology and genetic resources, including bacteriophages (phages), as phages may be utilized to control pathogenic bacteria (*Pseudomonas* and *Enterobacteriaceae*) in unconventional situations. Our methodologies included a novel conjugation technique for three substances—magnetic nanospheres, polyvalent phages and the biofilm treatment. Previous attempts to apply phages via aqueous media to control bacteria have met resistance, but by our sequential process of isolating phages for polyvalency and then conjugating the phages to specific magnetic nanoparticles, we and our colleagues have overcome the biofilm barrier and increased the infectibility of our polyvalent phages to our target *E. coli* 15597 and *P. aeruginosa* (PAO-1). Conjugated *in vitro* polyvalent phages successfully demonstrated plaque forming units (PFU) of $6*10^6$ applied to a medium containing a 1:1 ratio of PAO-1 to *E. coli*.

RET-06 **The Breaker of Molecules: Ti02, Water, Blue Methylene**

Claire Cook

Ira A Fulton School of Engineering, *Arizona State University, Tempe, AZ, USA*

This lab and experiment focused on the understanding of nanotechnology and use of a nanomaterial, Ti02. The lab consisted of using Food Grade Ti02, Blue Methylene or a food dye, and drinking water. The experiment was to determine whether or not Ti02 would break apart and destroy the molecules found in Blue Methylene/ dye when added to water and exposed to sunlight. The blue methylene would act as a pollutant in water, an area of study my students have been learning about. Since Food Grade Ti02 is a photo- catalyst, a few different types of bottles were used for the experiment to show how well the Food Grade Ti02 would break down molecules. Four 16.9 FL OZ bottles were used, each containing something different ingredients.

The **first** had water, blue methylene/dye, Ti02 and was placed in the sun but was wrapped entirely in aluminum foil. The **second** had water, blue methylene/dye without Ti02 and was placed in the sun and wrapped entirely in aluminum foil. The **third** had water, blue methylene/dye with Ti02 and was placed in the sun. The **fourth** had water, blue methylene/dye, with Ti02 but remained in doors, out of the sun. 50grams of Ti02 were added to each bottle as well as 2mg of blue methylene or one drop of dye. Pictures of each of the bottles roughly every two hours, however, within five minutes the **third** bottle's color had completely disappeared. The Ti02 acted incredibly fast obliterating the blue methylene when exposed to the sun. Although not completely clear and somewhat foggy, there was no blue visible. The aluminum covered bottles showed no difference thus proving that the sun enhanced the Ti02's ability to break the molecules of the blue methylene.

RET-07 **Using Light to Reveal Depth Information**

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Light has a broad array of information coded into its behavior. The way the light is decoded determines the usable data that will reveal properties of the object(s) in the image. Three methods were used to create depth images during this study. They were holography using lasers and holographic film, lenticular printing using computers to interlace/overlay the images and lenticular lenses, and stereophotography which uses a prism and color processing of the objects along with colored lenses for viewing. The hologram traps the interference patterns from the reflected and reference laser light and it can then be reconstructed by shining the reference beam back onto the recorded pattern. The image is of the reflected surfaces and the interference pattern conveys depth. The lenticular printing adds depth by overlaying different portions of a larger image to give references to establish relative position and then uses special lens overlay to create the depth. The stereophotography image uses a prism to refract the light and captures two slightly shifted images. The images are over-laid using red and blue/green filters which can be separated by the viewer using special bicolor 3D glasses to create depth. The information from light that gives us depth enriches the image to provide more information to the viewer. Perspective, size and contours contribute to the viewers knowledge of, or reaction to the image. The methods are explored and evaluated in terms of ease of use in creating as well as in viewing the images.

RET-08 **Bubble Nucleation in hydrated silicates**

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Volcanic eruption style is controlled by magma degassing. Magma degassing is the exsolution of volatiles, mostly water, from magma during eruption and consists of many steps including bubble nucleation, bubble growth, and bubble coalescence. To better understand the nucleation process during magma eruptions, decompression experiments were conducted on samples of hydrated volcanic glass. By exposing the glass to a range of high temperatures and pressures the conditions and ranges in which the degassing of magma occurs can be quantified. Once the samples become heated and pressurized, the samples are decompressed in order to model the changes experienced by magma as it rises to the Earth's surface. This decompression nucleates micron size gas bubbles inside of the melt. A quick quenching traps the gas bubbles in place. A count and analysis of the nucleated bubbles provides a method for comparison between computer model results and experiments. By comparing different parameters such as starting pressures, rates of decompression, final pressures, and the amount and size of the bubbles, a better insight is gained into magma degassing and consequently we can better understand why volcanoes behave differently.

RET-09 **Anaerobic bioremediation of 1,4-dioxane by sludge enriched with nitrogen reducing microorganisms**

Robert Harding

RET-10 **The Impact of Particle Size on Field Capacity and Biochar Soil Amendment**

Natalie Johnson, [1] Dr. Xiaodong Gao, [2] Dr. Caroline Masiello [2]

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Biochar is charcoal intentionally amended to soil to sequester carbon and improve soil performance. Biochar's ability to mitigate physical deficiencies in soil not only improves soil performance, but also has implications in combating climate change through carbon sequestration. The application of biomass to create charcoal for soil amendment is one of only two rapidly implementable carbon sequestration techniques (Kinney et al., 2012). This study explores the hydrologic changes in soils that were amended with biochar. The specific property explored was field capacity. Soil water holding capacity or field capacity is the measure of a soil's ability to retain water after saturation and free drainage for 30 minutes. Results show that sample particle size is strongly correlated with field capacity, and that biochar soil amendment can increase the field capacity of coarse soils.

RET-11 **Air Pollution: Ozone and Particulate Matter 2.5 Trends in Texas**

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Texas is often scrutinized for air pollution, especially in its major cities. This study investigates the particulate matter (PM) and ozone trends according to Texas air pollution monitors. The objective is to analyze whether the levels over time for particulate matter and ozone ground level pollution have decreased. Furthermore, since ozone air quality standard is based on its fourth highest peak value, the objective is also to compare trends in ozone average values and the fourth highest peak value. In addition, analysis of wind back trajectories for the most polluted days will be carried out to find out the origin of pollution. Using data compiled from the Environmental Protection Agency, the evidence supports that the most polluted monitors experienced the sharpest reductions in ozone and PM. The results also showed correlation between ozone and PM trends as the monitors with the greatest reduction in ozone shared significant reductions in PM. Overall analysis of the monitors reveals that Texas air quality is improving, especially in its major cities.

RET-12 **Adeno-associated Virus Serotype 2 VLP Characterization Assay**

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Many diseases, including most cancers and several cardiovascular diseases, involve increased expression of extracellular proteases in the diseased tissue. In particular, matrix metalloproteinases (MMPs) play a significant role in the pathophysiology of several cancers, coronary heart disease and neurological diseases. Targeting these elevated MMP areas and delivering virus that contains the DNA sequences that will encode for therapeutic solutions is a research goal. A protease-activatable virus (PAV) has previously been developed based on Adeno-associated virus, AAV, that delivers genetic material into target cells only when MMPs can proteolyze and activate the PAV. This PAV has been partially characterized but the rate of proteolysis and the kinetic behavior of the MMPs as they proteolyze the PAV locks has yet to be determined. An additional research goal is to create a simplified virus-like particle (VLP) that is easier to characterize than the original PAV while still maintaining the main MMP-cleavable behavior. The first step in characterizing the PAV is to ablate the start codon from the VP1 and VP2 protein subunits. In order to ablate the start codon site-directed mutagenesis is used to make point mutations, rendering the start sequences of the VP1 and VP2 subunits inactive. The simplified VLP model will generate only two protein fragments after proteolysis, whereas the original PAV would generate up to nine fragments. These two fragments will be easier to resolve on an SGS-PAGE gel for future kinetic assays.

RET-13 **Using Silver Nanoparticles to Reduce the Effects of Biofouling On Water Filtration Membranes**

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The potential effects of the application of silver nanoparticles to increase the efficiency of water filtration membranes are being investigated. Currently, membranes suffer from biofouling, a buildup of bacteria on the surface of the membrane which slows down the rate of water filtration. The silver solution (mix of Silver Nitrate and Sodium Borohydrate) is an antimicrobial agent that can reduce the effects of biofouling and increase the efficiency of the filter. Three different silver concentrations (1mM, 3mM, 6mM) are tested on three different membranes types (nylon, cellulose based UF, RO) in the presence of both nano-pure water and tap water. Measurements of the water output in a two-hour period for each scenario with the use of a computer fixed balance, nitrous oxide gas and a membrane house apparatus are taken to determine the most efficient conditions. Once the most efficient conditions are determined, the corresponding membrane and silver concentration will be used in a mobile water filtration unit through embedded piping. This truck will travel around to serve as an educational tool and on site water filtration system to provide immediate clean drinking water to the community.

In my classroom, students will conduct this same experiment to investigate various mechanisms of water filtration, explore the concept of biofouling, understand the importance of a mobile filtration unit and include visit a local water filtration facility to see their small membranes on a larger scale. The lesson will blend lab science with the environmental and societal issue of the need for clean drinking water.

RET-14 **Influence of Engineered Surface Pattern on Bacterial Attachment**

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Objective: In this study, the influence of designed surface patterns on bacterial attachment was investigated. Bacterial attachment is affected by surface roughness as well as topography. **Method:** Patterns containing orthogonal arrays of cuboidal pillars with systematically varied pillar size or spacing were fabricated on silicon wafers with photolithography (P-PHO) and E-beam (P-EBeam). The micropatterned silicon wafers were incubated statically with bacteria suspension in PBS with 1% LB media for 1 hr at 37 ºC. *Pseudomonas aeruginosa* 700829 was used as a model bacterium with initial cell concentration of 5×10^6 CFU/mL. The bacteria attached on the surface of the silicon wafers were stained with diamidinol-2-phenylindole (DAPI), and examined under an inverted Fluorescence Microscope. Bacterial attachment images were taken and analyzed using CellSens software. **Results:** On P-EBeam, the attached bacteria decreased with increased spacing when pillar size was the same in static conditions, but the reduction was less under sheared conditions. On P-PHO, the impact of patterns on bacterial attachment was not significant. **Conclusion:** Shallow patterns with pillar sizes more comparable to bacteria cell dimensions showed more impact on cell attachment. It is still unclear how the surface topography affect bacterial attachment. Further research is needed to understand the impact of topography on fluid dynamics as well as the biological process during attachment.

RET-15 **PROCESSING OF POLYANILINE AND CARBON NANOTUBES COMPOSITES**

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In this study we seek to use carbon nanotubes with Polyaniline (PANI) and Chlorosulfonic Acid (CSA) to create supercapacitors. The first aspect of this research is to explore if by using sulfonated PANI we can create a solution that yields better properties than the current method of using PANI. The goal of sulfonating PANI is to allow the acid in the solution to remain as acidic as possible and consequently helping the carbon nanotubes remain well dispersed in the solution. Sulfonated PANI was synthesized by leaving PANI in CSA for 72 hours. The solution was then quenched in water. Once quenched, we add acetone to the solution in order to precipitate our PANI, thus resulting in sulfonated PANI. The solutions were then sheared to create films. Using these films, the alignment, tensile strength, conductivity and transparency are tested to compare the properties. Future research will involve working with the resulting material to determine the electrochemical properties for use in supercapacitors

RET-16 **Method for Optimizing the Signal to Noise Ratio of smFRET Measurements for the Conformational States of Calcium-proton Antiporters**

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Single-molecule Förster Resonance Electron Transfer (smFRET) is a technique that can be used to understand the conformational changes that occur in proteins, such as a calcium-proton antiporter, due to their interactions with different molecules. FRET is commonly used as a spectroscopic ruler to measure distances less than 10 nm through the use of donor and acceptor FRET pairs. Unlike ensemble, smFRET is able to resolve the heterogeneity intrinsic to the conformational states of proteins due to short-lived intermediate states that would otherwise be lost in ensemble measurements. Confocal microscopy is used to acquire smFRET signals to understand the conformational states of proteins, specifically in calcium-proton antiporter channels. Because single-molecule experiments are extremely sensitive to fluorescent contamination, the early preparation steps reduce the contamination that would result in undesirable background noise that decreases the signal to noise ratio. To immobilize the YfkE trimer, we use biotin-avidin chemistry. After immobilization, we are able to acquire data on two spectrally resolved detectors (donor and acceptor), allowing for the determination of the FRET efficiencies that have a direct relationship to the distance between the donor and acceptor dyes. After data is collected, created algorithms are used to determine the distribution of the conformational states. It was found that following these specific methods allows for the testing of the effect of different ligands on the conformational states of our protein of interest: the YfkE trimer.

RET-17 **Characterization of a Self-Healing Polydimethylsiloxane Elastomer with Albumen**

Preetcharan Singh[1], Peter Samora Owour[2], Jun Lou[2], and Carolyn Nichol[3]

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Polydimethylsiloxane (PDMS) is commonly used in a wide array of products from cosmetics, as a skin moisturizer, surfactants in detergents, to children's toys like silly putty. More recently PDMS has been used in formulating self-healing materials. Self-healing materials have the ability to completely or partially repair damage inflicted on them, meaning, if there is a crack, it is anticipated that the original functionality can be restored. This study concentrates on synthesizing different PDMS (Sylgard® 184) elastomer systems with varying concentrations of albumen, with a focus on mechanical characterization of each system after curing. Pure PDMS was formulated, to act as a control, and tested with the addition of 1, 3 or 5% concentrated albumen. PDMS is cured with a platinum based cross-linker with a ratio of 1 part to 10 parts PDMS, and then the albumen is mixed in at the different concentrations. Once formulated, the sample is left to cure in an oven at 70°C for one hour and left to cool for a further hour. Dynamic Mechanical Analysis (Q800) and Thermogravimetric Analysis (Q600) were the instruments used for characterizing the samples by measuring the material properties in relation to how they perform under stress and temperature. Under conditions of stress, 3% PDMS performed the best, with a noticeable drop in performance with 5% PDMS, meaning absorption and dissipation of energy is optimal at 3% albumen. All four systems performed comparably in temperature characterization. Further research will need to be conducted in order to test the efficacy of how well the polymer systems self-heal.

Oral Session 3: 1:30 pm – 2:45 pm

O-3.1 Single Particle Chiroptical Spectroscopy

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Chirality has been a fascinating subject within optics for centuries. The conversion between and differential interactions of light polarizations with chiral matter, broadly classified as chiroptical activity, is a useful tool for molecular enantiomer determination and protein structure characterization, but these effects are always of remarkably small magnitude. More recently, chiral plasmonic nanomaterials have been intensely investigated due to their dramatically larger sensitivity to light polarization with chiroptical effects being demonstrated to be potentially orders of magnitude greater than their molecular counterparts. This is both interesting from a fundamental optics view and has potential applications for polarization sensitive optoelectronics, chiral metasurfaces for flat optics, and ultrasensitive detectors of molecular handedness or protein structure.

The Link lab has recently developed a method to characterize the chiroptical activity of individual nanostructures in a way that may be correlated with electron microscopy imaging. This enables a highly detailed correlation of the geometry of the chiral structure with its spectral response, which is critical for the advancement and development of these materials for different application. To date, we have characterized micron length twisted chiral nanoribbons composed of CdSe, twisted gold nanorod dimers, and polymer-captured gold dumbbell nanoparticle dimers, with many exciting chiral samples on the horizon. This technique cuts through the noise of sample heterogeneity in nanoparticle samples and yields unique insights into the field nanoscale chiroptical activity.

O-3.2 4D Compressive Imaging for Hyperspectral Video Microscopy

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Hyperspectral video imaging remains a challenging task given the high dimensionality of the datasets. Yet, it has great potential in studying dynamic optical phenomena with complicated spectral information, both in microscopic and macroscopic systems. Combining a new compressive imaging algorithm that is able to exploit the inherent redundancy in the temporal-spatio-spectral datacube with a unique optical system based on a single light modulator and a single detector, we are able to demonstrate a hyperspectral video imaging camera that compresses nearly 1000 to 1. With this system, it is possible to image molecular fluorescence and plasmon resonances in a dynamic environment from the ultraviolet to the mid-infrared spectrum.

O-3.3 Bottom-up Fabrication and Testing of a High-Resolution Retinal Prothesis for Macular Degeneration

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Many visual disabling diseases involve degeneration of the photoreceptor layer of the retina while preserving the neuronal retinal processing and ganglion cell layers. Electrical stimulation of the remaining live neurons in the retina is a potential way to restore vision for people with macular degeneration and genetically induced blindness. Current devices that stimulate the retina to restore vision are built via *top-down* processes and only provide a visual acuity of 20/1000 – 20/4000. The Argus II, Alpha IMS, and Stanford Subretinal have between 60-1000 fabricated electrodes of 50 to 200 microns in diameter. The size of these electrodes only allow them to stimulate the retina on a tissue level. To stimulate the retina on a cellular level, our device is built via a *bottom-up* process. When laser induced graphene is grown on silicon, a Schottky photodiode is generated. Carbon nanotubes grown seamlessly from the graphene surface conduct the charge generated at the photodiode to individual cells in the retina, changing the rate at which they fire. Because every cell in the retina can be individually addressed by this device, it has the potential to allow for megapixel-level vision, restoring people's ability to read and recognize faces. This retinal prosthesis can change the rate of retinal neuron firing in an *ex vivo* mouse retina, but further work needs to be done to determine the visual resolution that this device can provide.

O-3.4 **Super Temporal-Resolved Microscopy (STReM)**

Wenxiao Wang,[1] Hao Shen,[2] Bo Shuang,[2] Benjamin S Hoener,[2] Lawrence J Tauzin,[2] Nicholas A. Moringo,[2] Kevin F Kelly,[1] and Christy F. Landes[1,2,3]
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[3]*Smalley-Curl Institute, Rice University, Houston, Texas, United States*

Super-resolution microscopy typically achieves high spatial resolution but the temporal resolution remains low. We report Super Temporal-Resolved Microscopy (STReM) to improve the temporal resolution of 2D super-resolution microscopy by a factor of 20 compared to the camera frame rate, which is achieved by rotating a phase mask in the Fourier plane. STReM is verified with both simulated and experimental 2D adsorption/desorption and 2D transport.

O-3.5 **Absorption-Enhanced Imaging through Scattering Media**

Mehbuba Tanzid,[1, 2] Nathaniel J. Hogan,[1, 2] Ali Sobhani,[1, 2] Hossein Robatjazi,[1, 2] Adithya K. Pediredla,[1] Adam Samaniego,[1] Ashok Veeraraghavan[1] and Naomi J. Halas[1, 2]
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Highly scattering media pose significant challenges for many optical imaging and communications applications due to the inherent loss of information caused by the scattering process. Absorption can also result in significant degradation of image quality even in diffuse systems where it is commonly ignored. In this work, we show both experimentally and computationally that absorption can actually improve the quality of images transmitted through a scattering medium in certain regions of parameter space. The image improvement varies significantly depending on the absorption and scattering coefficients and the anisotropy factor of the scattering medium. Using broadband absorbing and scattering nanoparticles, while keeping the anisotropy factor constant, we show that a sufficiently high scattering coefficient is necessary for the improvement in image quality and resolution. Moreover, we show that the addition of absorbers to a forward-scattering medium (e.g. biological tissue) has a negligible effect on image quality as compared to an isotropic scattering medium. For analyzing the image quality and resolution quantitatively, we use structural similarity index (SSIM) and cut-off spatial frequency from modulation transfer function (MTF) of a resolution target, respectively. This work has consequences for applications in imaging through media that exhibits both scattering and absorption, such as biological tissue, as well as for engineering media for optimal imaging and image transmission, or communication.

Oral Session 4: 3:00 pm – 4:15 pm

O-4.1 **Plasmon-induced selective CO_2 hydrogenation on earth-abundant aluminum-copper oxide antenna-reactor complex**

Hossein Robatjazi[1,5], Hangqi Zhao[1,5], Dayne F. Swearer[2,5], Linan Zhou[2,5], Peter Nordlander[1,3,4,5], Naomi J. Halas[1,2,3,4,5]
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Recent advancements in the field of plasmonic photocatalysis have brought to the forefront the potential of plasmonic metal nanostructures for enhancing the efficiency of photocatalysis. Until very recently, light-driven chemical transformation on plasmonic photocatalysts nanostructures has primary relied on Au and Ag. However, practical future applications of those plasmonic noble metals for photocatalysis are largely hindered by their significant cost and low abundance.

As the most earth-abundant metal, Al nanoparticles have been recently demonstrated as novel plasmonic photocatalysts, being able to drive H_2 dissociation, a benchmark reaction for photocatalysis. Here we report Al-Cu_2O antenna-reactor complex for

plasmon-induced selective CO_2 hydrogenation under ambient condition. This is a unique plasmonic heterostructure because of combining Al, the cheapest plasmonic material, with Cu-based catalyst that is also relatively cheap, earth-abundance and has low toxicity. We find that under laser illumination in ambient pressure and temperature, Al-Cu_2O complex in which the Cu_2O shell is separated from Al core by a few-nanometer native aluminum oxide layer can selectivity hydrogenate CO_2 into CO. Catalytic CO_2 hydrogenation at elevated temperatures without external irradiation generates CO and CH_4 as reaction products, thereby offering lower selectivity. Our studies indicate that in Al-Cu_2O antenna-reactor complex, the role of the Al core is to supply energetic carriers to initiate CO_2–CO conversion either through feeding hot electrons (from non-radiative plasmon decay) into the conduction band of the copper oxide shell and through near-field enhancement, that induces an interband transition in the copper oxide shell, generating carriers for subsequent chemical reactions.

O-4.2 Millisecond Multiple Particle Spectroscopy for Real-time Detection of Irreversible Plasmonic and Electrochemical Processes

Silke R. Kirchner[1], Kyle Smith[1], Wenxiao Wang[1], Wei-Shun Chang[1], Calum Kinnear[3], Paul Mulvaney[3], Christy F. Landes[1,2] and Stephan Link[1,2]

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Plasmonic metallic nanostructures characterized by their strong interaction with resonant light and their high surface to volume ratio constitute a novel and pivotal generation of catalysts[1,2]. Understanding the fundamentals and kinetics of plasmon-mediated catalytic processes on the nanoscale expedites their accuracy and efficiency and facilitates the usage in various interdisciplinary scientific areas reaching from chemistry, nanomedicine, nanophysics to nanotechnology.

However, in case irreversible plasmon-mediated experiments are performed in colloidal many particle systems and detected by UV/VIS-NIR spectroscopy statistical average phenomena disguise a detailed analysis of the impact of individual photophysical effects as hot electron generation, local field enhancement or plasmonic heating on the processes[3]. Fast single particle spectroscopy is limited to the spectral measurement of a single nanostructure at a time and does not allow a simultaneous measurement of multiple individual irreversible plasmon-mediated processes. The lack of high-throughput measurement techniques that can detect those processes represents an important problem since the impact of photophysical effects on irreversible and fast plasmonic processes is not yet understood.We present a novel and pivotal experimental approach that allows an exact insight into the fast kinetics of and photophysical effects behind individual irreversible plasmonic and electrochemical processes in a multiple particle system. The high-resolution (0.21nm/pixel) spectral detection of 200-300 individual plasmonic nanostructures with a exposure time ~ 1 ms enables a real-time detection of multiple simultaneous processes and paves the way for the extraction of quantitative information on the fast kinetics of irreversible plasmonic and electrochemical processes.

[1] Nano Lett. 2013, 13, 240−247
[2] Angew. Chem. Int. Ed. 2013, 52, 13910 – 13940
[3] Science 2001, 294, 1901-1904

O-4.3 Ultrafast electron diffraction study of photo-carrier dynamics and carrier-phonon coupling in transition metal dichalcogenides

Vidya Kochat,[1] Ming-Fu Lin,[2] Clemens Weninger,[2] Xiang Zhang,[1] Amey Apte,[1] Robert Vajtai,[1] Priya Vashishta,[3] Xijie Wang,[2] David Fritz,[2] Uwe Bergmann,[2] and P. M. Ajayan[1]
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[3]*Dept. of Physics and Astronomy, University of Southern California, Los Angeles, California, US*

Recent years have seen an increased activity of synthesizing and exploring properties of atomically thin monolayers of layered solids starting with the discovery of graphene. Another interesting class of 2D layered materials is the semiconducting transition metal dichalcogenides (TMDCs) that exhibit a transition from indirect to direct bandgaps as layer thickness decreases from multilayers to monolayers, with a variety of applications envisioned in the field of photodetectors, field effect transistors, sensors and catalysts. Many of the interesting opto-electronic properties of the TMDCs depend strongly on the electron-phonon coupling and their long-lived excitonic effects. In this experiment, we have used ultrafast electron diffraction (UED) technique to probe the non-thermal transitions in $MoSe_2$ monolayers, bilayers and multilayers induced by femtosecond laser excitation. This photo-excitation drives the electrons and lattice far out of equilibrium leading to lattice distortions due to the modification of the interatomic potential as a result of the excitation of a large fraction of valence band electrons into the conduction band. The photo-excited carriers relax mainly by carrier-carrier scattering and carrier-phonon scattering processes, the dynamics of which are entirely different for the monolayer and bi/multilayer $MoSe_2$ due to the direct to indirect gap transition. These have been studied from the Debye-Waller response of the diffraction pattern obtained at various pump-probe delay times and pump fluences. In this talk, I will give a brief overview of the pump-probe techniques of UED and the results of the UED experiments on $MoSe_2$ as a function of layer number to understand the photo-carrier dynamics.

O-4.4 **Modeling Molecular Motors Dynamics**

Luiza Gomes Ferreira,[1] (Kolomeisky group)
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Molecular motors are biological molecules that play important role in functioning of living systems. They support processes including muscle contractions, cellular transport and cell division. Over the past two decades there were many advances in describing molecular motors, both on experimental and theoretical sides. We understand now single motors quite well. But to understand and simulate systems of multiple motors is currently a challenge. Multiple motor proteins behavior deviates from what one may expect. The efficiency and the cooperation of these systems are intriguing. The purpose of this work is to study models of multiple motors. We intend to analyze the asymmetric simple exclusion model as a way of describing many motors through analytical methods. We will utilize mean-field calculations, and modified mean-field approximation where we take explicitly into account the energy of forming and breaking cluster in the lattice. Our calculations are compared with large-scale computer simulations and the results show that we have a good agreement for the limiting cases, where energy tends to zero and in the case of strong repulsions. For high attractions, our model has to be further developed, our next approach will be using four lattice clusters instead of two, since we know that for high energy the long-distance correlations are important. Another aspect of multiple molecular motor interactions that we want to understand is how the system reaches the steady state We plan to study this trough the domain wall theory, and show more precisely when systems like this reach the steady state.

O-4.5 **Dynamic Crystalline Deformation of Flowing 2-D Foams in Microfluidic Devices**

Daniel Vecchiolla[1] and Sibani Lisa Biswal[1]
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The groundbreaking work of Bragg and Nye in the 1940s on soap bubble rafts as 2-D analogs of metal crystals and the formation of 3-D crystalline structures from multiple bubble layers has received renewed interest over the last decade. Foam crystals have already found applications in tunable 2-D diffraction gratings and the 3-D formation of highly structured porous solids. Utilization of a flow-focusing microfluidic device enables the rapid generation of stable, ordered monodisperse foams with the simple tuning parameters of the fluid flow rates and the geometrical dimensions of the device. Here, I will present work focusing on the dynamic crystalline deformation of these flowing foams in the wet foam limit in a wide (1400-1800 µm) collection channel with regions of expansion and contraction. The influence of the flow parameters on plastic deformation via changes in bubble morphology and packing density can be readily visualized and analyzed. Insights into the mechanisms of dislocation nucleation, glide, reflection, and dipole interactions will be discussed.

Graduate Student and Post-doctorates Poster Session A: 4:15 pm – 5:30 pm

GP-A-01 Stable Electrochromic Devices with Molecular Plasmonics

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We present absorbance-stability and cycling-endurance results for electrochromic devices based on Polycyclic Aromatic Hydrocarbon (PAH) molecular plasmon resonances. We have previously demonstrated that PAHs exhibit a molecular plasmon resonance highly sensitive to the molecule's charge state. PAHs can be regarded as molecular versions of graphene, possessing the same hexagonal C_6 unit cell. Theoretical studies have shown that the visible-regime charge-sensitive resonances in PAHs are directly analogous to graphene's infrared plasmon resonances. Recent device designs and fabrication methods permit these devices to maintain their optical switching over many hours even when tested in air. The latest device improvements significantly enhance the prospect for additional physical characterization such as plasmon lifetime measurements and signal the promise of such devices for commercial applications.

GP-A-02 Amplifying Plasmonic Hot Electron Photocurrent in the Near Infrared with a Silicon-based Device

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When an incident electromagnetic wave at optical frequencies couples to a metallic nanostructure, it creates coherent resonances of free carriers in the metal known as plasmons. Plasmons can decay and generate carriers (hot electrons) that have higher energies than the Fermi level of the metal. Plasmon-induced hot electrons are important since they carry the energy signature of the absorbed incident photons. When a metallic nanostructure is patterned on a silicon substrate, hot electrons can be transported over the junction between the metal and the semiconductor, to be collected as a photocurrent. Plasmonic absorbers that generate hot electrons are tunable over much broader spectral regimes than semiconductor absorbers. However, the poor responsivity (~ 1mA/W) is the major drawback with these devices. Thus, increasing the photocurrent response is crucial for hot electron devices. In my research, we increase the current flow of hot electrons over a Schottky junction by modulating the Schottky barrier in reverse bias and we acquire a signal that is much greater than the original hot electron flow of the nanostructures. With this method we amplify the photocurrent signal using a CMOS compatible fabrication process on silicon substrates. Our approach to amplify the hot electron-based photocurrent opens up the possibility of making cheap plasmonic sensors with direct electrical readout, such as an on-chip plasmonic detector with tunable wavelength sensitivity that can operate beyond the conventional semiconductor photodetectors.

GP-A-03 Unraveling Fundamental Electrochemical Properties on the Nanoscale

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As the field of nanoscience is growing, it is important to distinguish nanoscale methods and properties from similar methods used on bulk materials. Commonly used standard reduction potential tables – providing useful information about electrochemical properties – are an example of standard data collected on bulk electrochemical systems. Because electrochemical techniques are often applied on nanoscale systems and because the electrostatic potential is a function of the size of the solution-metal interface, it is important to understand how electrochemical properties are different on the nanoscale. **In this study, electrochemical techniques are applied on the nanoscale to unravel fundamental nanoelectrochemical properties.** A proof-of-concept Cu deposition on Au nanoparticles demonstrates the viability of this technique. Single particle studies are conducted by correlating dark field (DF) optical microscopy with scanning electron microscopy (SEM). DF optical scattering is used as the primary technique to monitor Cu deposition in real time. Further characterization of Cu deposition is conducted using X-ray photoelectron spectroscopy (XPS) and energy dispersive X-ray spectroscopy (EDS). Experimental findings are supported by discrete dipole approximation (DDA) simulation results. **This study provides a foundation for the development of a new set of electrochemical properties that are relevant on the nanoscale.**

GP-A-04 The Catalyst Matters Most: Shape-Controlled Synthesis of Aluminum Nanocrystals

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In many ways, the synthesis of aluminum nanocrystals (Al NCs) by thermal decomposition of amine alane adducts is analogous to the synthesis of quantum dots and polyol-mediated noble metal nanoparticle (NP) syntheses. For example, the size of Al NCs (and their localized surface plasmon resonance) can be controlled simply by changing the reaction temperature. Since the solvent molecules serve as the nanocrystal's ligands, the Lewis basicity of the solvent (e.g. OR_2, NR_3, PR_3) presents another handle for synthetic control of Al NC morphology. However, unlike the solvothermal reduction of metal ions to synthesize NPs or quantum dots, the thermal decomposition of alane to produce Al NCs is *catalyzed* by a selection of hard Lewis acids. We demonstrate that by using different catalysts, namely, titanium isopropoxide, titanium dioxide NPs, or direct solvothermal decomposition, Al NCs with distinct morphologies are synthesized in the same solvent at a fixed temperature. In the case of direct solvothermal decomposition, octahedral and truncated trigonal bipyramidal Al NCs with sizes on the order of ~250 nm are produced. Introducing a catalytic amount of titanium isopropoxide decreases the size of Al NCs to ~50 nm. Most remarkably, introducing titanium dioxide NPs facilitates the synthesis of aluminum nanorods with dimensions of ~300 x 1500 nm. Elucidating the mechanisms of alane decomposition induced by different catalysts is anticipated to afford greater synthetic control of Al NC morphology and is the subject of ongoing research.

GP-A-05 Plasmonic Nanoparticle Shape Dependent Sensitivity to Electrochemical Charging and Oxidation

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Active control of plasmonic nanoparticle spectra is required for applications in tunable displays. Previously chemical processes have been used to dramatically alter plasmonic scattering spectra, but spectral tuning by physical processes such as capacitive charging is more ideal for reversibility and preserving the nanoparticle structure over time. However, the magnitude of spectral tuning by charging must be increased to be viable for application. To date, the reported change in resonance wavelength of gold nanorods due only to charge density tuning has been only a few nm. In this work we optimize gold nanoparticle size and shape to determine which structures are more sensitive to capacitive charging from -0.3 V to +0.1 V. We demonstrate that change in resonance wavelength due to capacitive charging is increased as initial resonance wavelength is redshifted by comparing gold spheres and gold nanorods of different aspect ratios. We also show that sensitivity to capacitive charging is increased as surface area to volume is increased by comparing large and small volume gold nanorods of the same aspect ratio. Since aqueous electrolyte solution is used, gold nanorod oxidation occurs at more positive potentials (-0.3 V to 0.2-0.7 V). At negative potentials, the reduction of the oxide causes a sharp decrease in the resonance wavelength. Taking the differential of the resonance wavelength with respect to potential results in a peak at the reduction potential, reproducing the bulk CV peak on a single nanoparticle microelectrode.

GP-A-06 Lithographically Defined Al-Pd Heterodimers for photocatalysis: an Antenna-Reactor Effect

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Photocatalysis is a process that harvests energy from light to drive chemical reactions. An ideal photocatalyst should interact strongly with both light and molecules to conduct the energy flow between them. Conventional industrial catalysts made of transition metal nanoparticles suffer from weak optical absorption. Meanwhile, plasmonic metals, e.g., Au, Ag, and Al, support surface plasmon resonance with much larger optical cross sections and electromagnetic field enhancement, but lack the capability of molecular activation on their surfaces. Combining plasmonic and catalytic metals in one heterogeneous entity takes advantage of the beneficial properties of both metals simultaneously: the plasmonic antenna can focus light onto the catalytic reactor to enhance its optical absorption hence chemical reactivity. Experimental demonstrations of this antenna-reactor concept on chemically synthesized heterostructures, however, are subject to averaging effects which blur the detailed role of the light. Here, we demonstrate lithographically defined Al-Pd heterodimers as an antenna-reactor platform, which is scalable, highly uniform, and self-aligned, offering clear spectral features to rationalize the photocatalytic activities at different wavelengths and polarizations. Using the hydrogen-deuterium exchange reaction on Al-Pd antenna-reactors as a mechanistic probe, we show that the reaction rate closely follows the optical absorption in the Pd reactor, which is modulated by the surface plasmon resonance of the Al antenna.

GP-A-07 Utilizing smFRET to determine the effect of calcium on the distribution of conformational states of the trimeric calcium-proton antiporter

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Calcium is the most prevalent and versatile of the signaling ions that regulate processes in eukaryotic organisms and has been studied extensively; however, the role of calcium in regulating physiological functions in prokaryotic organisms is not well-understood. In the signaling pathways in both eukaryotes and prokaryotes, transmembrane transport proteins facilitate the transport of ions across the cellular membrane. The calcium-proton antiporter (the YfkE trimer) from *Bacillus subtilis* exchanges protons for calcium ions using the proton gradient as a driving force, but the mechanism behind the changes between the conformational states of the antiporter, including the short-lived intermediate states, is not well-understood. Single-molecule Förster Resonance Energy Transfer (smFRET) is a technique that can be used to probe the structural changes of proteins, while resolving the heterogeneity stemming from these short-lived intermediate states. After immobilizing the donor/acceptor labeled antiporters using biotin-avidin chemistry, we use a homebuilt fluorescence confocal microscope to acquire spectrally resolved single-molecule fluorescence signals and then derive the FRET efficiencies mathematically, which are directly related to the distance between the donor and acceptor dyes. Using smFRET, we are able to determine the distributions and the most probable conformational states of the antiporter in the absence and presence of calcium ions, leading to a better understanding of the mechanism behind the co-transport of calcium ions and protons across the cellular membrane in prokaryotes.

GP-A-08 Structure-Dependent Mechanical Properties of Coupled Metallic Nanostructures Studied using Transient Extinction Microscopy

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Metallic nanostructure behave as nanomechanical oscillators with extremely high frequencies, in the range of tens to hundreds of GHz or even THz, and many efforts have been devoted to vibrational frequency detection and phonon manipulation to design a next generation frequency modulator based on nanostructures. However, the mechanical properties especially the acoustic properties of coupled metal nanostructures are still open questions. Here we used ultrafast laser pulses to impulsively launch acoustic phonons in well-designed coupled gold nanodisk which was fabricated by using electron-beam lithography. The breathing mode of gold nanodisk was optically probed by using femtosecond time-resolved transient extinction microscopy. Strong experimental evidence of dynamic mechanical coupling between two isolated nanostructure though substrate was obtained. Our results show that the acoustic vibration frequency of gold nanodisk could be manipulated by presence of another gold nanodisk which is strongly coupled for both plasmonic and phonon mode. This modulation of acoustic frequency is strongly dependent on the gap distance and size mismatch between nanodisks and materials of substrate. The parametric resonance between the coherent vibrational phonons in coupled metallic nanostructure was firstly observed.

GP-A-09 **Structural Characterization of Anisotropic Aluminum Nanocrystals**

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The facile ability to modify size, shape, and composition of metal nanocrystals has allowed for platforms that have interesting tunable properties. For example, the synthesis of anisotropic nanostructures has opened the door to materials with easily modifiable localized surface plasmon resonances (LSPRs). In turn, these materials can be used in applications using their optical features such as biological sensing and efficient photocatalysis. Currently, gold nanorods are of wide interest for optical study, as their extinction maxima can be tuned within the visible spectrum by adjusting aspect ratio. Other anisotropic structures, such as branched nanocrystals, have features that can also have extinction maxima tunable by aspect ratio. However, gold is a very expensive material. Here, we present characterization of anisotropic Al nanocrystals. Such structures include branched nanocrystals and elongated nanorods. We found that the crystallinity of these structures can vary from single crystalline branched structures to pentagonally twinned nanorods. A consistency in these structures, however, is {111} faceting. These results allow for insight into the growth of aluminum nanostructures, allowing for a route to cheap, highly modifiable plasmonic nanomaterials.

GP-A-10 **A near-infrared gas sensor system based on tunable laser absorption spectroscopy and its application in CH_4/C_2H_2 detection**

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A near-infrared (NIR) dual-channel differential gas sensor system was experimentally demonstrated based on tunable laser absorption spectroscopy (TLAS) and wavelength modulation spectroscopy (WMS). The sensor consists of four modules, including distributed feedback (DFBs) lasers for the detection of targeted gases, a custom portable DFB driver compatible for butterfly-packaged DFB lasers, a 20cm-long open-reflective gas-sensing probe and a custom cost-effective lock-in amplifier for harmonic signal extraction. The optical and electrical modules were integrated to a standalone sensor system, which possesses advantages of easy operation, good stability, small volume and low cost. With different DFB lasers, the sensor system can be used to detect different gases. As an application, a DFB laser with an emission wavelength of 1.65 µm and another one with an emission wavelength of 1.53 µm were used to detect CH_4 and C_2H_2, respectively. Standard CH_4 and C_2H_2 samples were prepared and experiments were carried out to determine detection performance of these two gas species. The relation between the second harmonic amplitudes (2*f*) and gas concentration was obtained for the two gases by means of calibration. The limit of detection on CH_4 was determined to be 29.52 ppm based on the Allan deviation with an averaging time of 1 s, and the relative detection error on C_2H_2 is < 5% within the concentration range of 200-10,000 ppm. The sensor system will be useful in industrial trace gas monitoring due to the use of low-loss optical fiber and the open-reflective gas-sensing probe.

GP-A-11 **Heterometallic Antenna-Reactor Nanostructures for Photocatalysis**

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Metallic nanoparticles with strong optically resonant properties behave as nanoscale optical antennas, and have recently shown extraordinary promise as light-driven catalysts. Traditionally, however, heterogeneous catalysis has relied upon weakly light-absorbing metals such as Pd, Pt, Ru, or Rh to lower the activation energy for chemical reactions. Here we show that coupling a plasmonic nanoantenna directly to catalytic nanoparticles enables the light-induced generation of hot carriers within the catalyst nanoparticles, transforming the entire complex into an efficient light-controlled reactive catalyst. In Pd-decorated Al nanocrystals, photocatalytic hydrogen desorption closely follows the antenna-induced local absorption cross section of the Pd islands, and a supralinear power dependence strongly suggests that hot-carrier-induced desorption occurs at the Pd island surface. When acetylene is present along with hydrogen, the selectivity for photocatalytic ethylene production relative to ethane is strongly enhanced, approaching 40:1. Designer antenna-reactor photocatalysts based on the principle of plasmon-assisted absorption enhancements leads to precise control of plasmon resonance energies with flexible surface chemistry. This combination infuses an increase in control over the modulation of chemical reactivity and selectivity in the next generation of heterometallic plasmonic photocatalysts.

GP-A-12 **Formation of bright matter-wave soliton trains**

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Solitons are non-dispersive waves that are ubiquitous in nature. They appear in water waves, light in a nonlinear medium, and matter-waves. Previously, the formation of a train of matter-wave solitons was observed, and an alternating phase structure was inferred from the dynamics of the soliton train[1]. In this experiment, we form a Bose-Einstein condensate (BEC) of ^{7}Li in a cigar-shaped confinement and quench the interaction from repulsive to attractive. We study the creation of a soliton train from the BEC, and the formation of the alternating phase structure. We demonstrate that the train arise as a consequence of modulational instability[2], in which the density and phase fluctuation of the BEC grows exponentially under the attractive nonlinearity. The data can also resolve the controversy over how the alternating phase structure arises.

1. K. E. Strecker et al. Nature 417, 150 (2002).
2. L. D. Carr and J. Brand, Phys. Rev. Lett. 92. 040401 (2004).

GP-A-13 **Analysis of Microchannel Particle Diffusion on the International Space Station**

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Understanding diffusion of particles through micro and nanochannels is critical in the development of drug formulations and delivery systems. The International Space Station (ISS) offers a unique environment to study this phenomenon due to microgravity. The nanometric size of drug molecules is a limitation for particle tracking using fluorescent microscopes. To overcome this, we used specially designed microfluidic chips with microchannels (4.5, 5, 6, 7 μm and 2.5, 3, 3.5, 4 μm) into which fluorescent polystyrene microspheres (4 μm and 1 μm) were injected; this system replicates the particle-channel size ratio of the nanometric system. The experiment was launched on board Space X-8 and the particle movement captured by microscope images on the ISS were collected, processed, and analyzed by a custom-made algorithm. Here we present the algorithm structure and the data analysis performed on the images. The results highlight the necessity of different approaches due to the noise influence for different size particles images. A brief comparison between the ISS experiments and the ones performed on Earth is presented.

GP-A-14 **Enhancing Lithium-Sulfur Batteries with Hybrid Carbon Nanomaterials**

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Lithium-ion (Li-ion) batteries are nearing their energy storage limit, which is still insufficient for the future society demands and the switch to renewable energies. Therefore, the next-generation of energy storage requires new chemistries beyond Li-ion, such as lithium-sulfur, which possesses high energy density (~5 times greater than Li-ion) and is environmentally friendly. However, there are some major challenges that need to be addressed for its commercialization, these include: the insulating nature of sulfur, the volume expansion and lost of active materials during the discharging/charging process; resulting in low Columbic efficiency and poor cycle life. Reported approaches to address these problems include the use of conductive host materials, the use of additives in the electrolyte and coated separators. Nonetheless, these approaches present cathodes with low specific capacities, limited cycle life, low sulfur loading and hardly scalable fabrication processes. We report here a scalable three dimensional hybrid graphene carbon nanotube structure (GCNT) as a host sulfur material. Its high surface area, excellent electron transfer network, mechanically stability and covalent bond with the current collector provide a binder-free/high sulfur loading cathode (60 to 90 wt%), with specific capacities up to 1200 mA h g^{-1} (72% of the theoretical specific capacity). In addition, we improved the capacity retention (60% after 100 cycles) with the use of graphene nanoribbons-coated separators. The capabilities of Sulfur-GCNT cathode makes it a promising electrode candidate for the high energy density Li-S batteries that the world needs.

GP-A-15 **Synthesis of large-scale atomic layer SnS_2 through chemical vapor deposition method**

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Abstract: Two-dimensional layers of metal dichalcogenides have attracted much attention because of their ultrathin thickness and potential applications in electronics and optoelectronics. Monolayer SnS_2, with a band gap of ~ 2.6 eV, has an octahedral lattice made of two atomic layers of sulfur and one atomic layer of tin. So far, there are limited reports on the growth of large scale and high quality SnS_2 atomic layers and study of their properties as semiconductor. Here, we report a chemical vapor deposition (CVD) growth of atomic layer SnS_2 with large crystal size and uniformity. In addition, layer number can be controlled from monolayer to few layers and to bulk by changing the growth time. Scanning transmission electron microscopy (STEM) was used to analyze the atomic structure and demonstrate the 2H stacking poly-type of different layers. The resultant SnS_2 film is used as a photodetector with external quantum efficiency as high as 150%, suggesting promise for optoelectronic applications.

GP-A-16 **Single-Molecule Kinetics of Protein Adsorption onto Polymer Films**

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Understanding the protein polymer interaction is critical in designing diagnostic tools, biosensors and biocompatible implants. However, the current mechanistic understanding of the protein polymer interaction is inadequate. The major obstacles to a cohesive understanding include the ubiquitous heterogeneity in analyte transport and adsorption, which stems from a variety of sources such as steric accessibility and irregularities in polymer surfaces. Single-molecule fluorescence spectroscopy is a powerful tool to interrogate the protein polymer interactions because of its in-situ, real-time observations. In this work, we used this technique to study the protein adsorption onto two types of polymers, nylon 6,6 representing the hydrophilic surfaces and polystyrene representing the hydrophobic surfaces. Two structurally similar protein molecules, α-lactalbumin and lysozyme were used in this study, and we observed that the protein molecules were immobilized at the nonspecific adsorption sites on the hydrophilic polymer surface, while they hopped between adjacent sites on the hydrophobic surface. The α-lactalbumin adsorption onto nylon 6,6 surfaces exhibited clear time-dependent behavior, which can be described with a monolayer Langmuir model. Detailed kinetic analyses revealed that a rough surface might increase the number of adsorption sites, but was energetically less favorable. On the contrary, the lysozyme molecule hopped on polystyrene surfaces, which can be readily quantified by single-particle tracking. It was found that with longer polystyrene chains, the average hopping distance decreased, possibly due to the increased density of adsorption sites. We envision that such single-molecule approach can be widely applied for the observation of protein polymer interactions.

GP-A-17 Weak Fermi level pinning in 2D lateral junctions

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In traditional 3D metal-semiconductor junctions, the Schottky barrier height is generally determined by the phenomenon called "Fermi level pinning". Due to the interfacial states caused by chemical disruptions, the barrier height can become insensitive to the metal workfunciton, leading to deviation from the Schottky-Mott rule, or even full Fermi level pinning[1]. However, this is not the case in 2D lateral junctions, as we will show in this talk. According to our analysis, due to weak electronic screening in 2D systems, the interfacial states have very minute influence to the Schottky barrier height. This shows that, unlike 3D junctions, the barrier height for 2D junction can be easily tuned by the choice of material, resulting in better control of device characteristics. Similar results are expected for 2D heterojunctions in general.

1. Tung, R. T. The physics and chemistry of the Schottky barrier height. *Appl. Phys. Rev.* **1,** 011304 (2014).

GP-A-18 How to tell a plasmon: a comprehensive study on its origin from few-electron nanoclusters to carrier-dense noble metals

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The concept of plasmon, in the past few years, has raised much interest due to its unique optical properties to confine light within nano-metric sized nanoparticles through a collective and coherent oscillation of electrons, allowing large absorption efficiencies as well as field enhancements. By further decreasing system size, single electron transitions make a great contribution to the total optical response, resulting that the plasmon concept enters the quantum picture. However, it is still poorly understood whether it is possible to define a plasmon when the system is very small. It is, in fact, troublesome to distinguish plasmons from single electron transitions within few-electron systems. In this work, by employing the Random Phase Approximation method we calculated the evolution of plasmon resonances and single electron transitions by observing absorption spectra for a jellium nanosphere. The induced charge density as well as field enhancement are also calculated, offering a visualization method to distinguish a plasmon from single electron transitions. Besides, we propose a metric, the generalized plasmonicity index, to measure how the total Coulomb energy deviates from zero, providing a semi-classical approach to tell a plasmon from single electron transitions. The Generalized plasmonicity index can also distinguish the plasmon mode and photonic mode, and quantify how good a plasmon is. Finally, we apply the scaling procedure onto the Coulomb potential between induced charges, offering an alternative way to tell a plasmon analogy to quantum calculations.

GP-A-19 Interpreting Gold Nanorod Surfactant Layer Orientation from Surface Enhanced Raman Scattering

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The natural alignment of the electromagnetic field and of surfactant molecules at gold nanorod surfaces opens the possibility to use SERS as a tool to characterize interfacial chemical structure. SERS measurements on CTAB supported gold nanorods suspended in solution have been analyzed with input from density functional theory (DFT) and electromagnetic simulations by the finite element method (FEM). The peak heights in the SERS spectra depend on molecular orientation relative to the electric field, and can be predicted by the (unenhanced) Raman tensor available from DFT. The spectra also depend on the magnitude of the field, which can be calculated by FEM and also depends on the distance from the gold surface. We have calculated peak height ratios at various orientations and compared to the measured spectra. The best fit indicates a CTAB layer orientation in agreement with the accepted model. Results on intercalants in the CTAB bilayer and on lipid bilayers will also be discussed.

GP-A-20 Classification of Circulating Malaria Infected Red Blood Cells Versus Phagocytes Using *In Vivo* Microscopy of Hemozoin

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Clinical diagnosis of malaria suffers from poor specificity, leading to overtreatment with antimalarial drugs and the potential for drug resistance. Current commercial malaria diagnostic tests rely on a fingerprick blood sample, requiring single-use consumables and increasing per-test costs. We recently developed a needle-free method to optically detect circulating infected red blood cells *in vivo* by targeting the malaria byproduct, hemozoin. Hemozoin is an endogenous chromophore with a strong absorbance peak in the visible range, serving as an ideal optical biomarker for non-invasive detection; however, hemozoin may be phagocytized by the host's white blood cells, which persist after infection has cleared presenting the potential for false positive diagnosis. Here, we present a method to classify hemozoin signal by cell type using two features of the hemozoin absorbance signal, area and intensity, assessed *in vitro* in two strains of *Plasmodium*, *P. yoelii* and *P. falciparum*. The classification performance of this algorithm was evaluated *in vivo* in an animal model, showing an area under the receiver operating characteristic curve of 0.90. Additionally, an automated image analysis algorithm using local adaptive thresholding and peak trace analysis was employed for the rapid identification and quantification of hemozoin signal *in vivo*. These results suggests that these features may be used to discriminate hemozoin signal by cell type in vivo, addressing the potential for false positive diagnosis.

GP-A-21 Aluminum Plasmonics for Sensing and Nonlinear Optics

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Aluminum has attracted tremendous attention for plasmonic applications due to its ability to cover the whole visible range, high abundance in nature, low cost and compatibility with semiconductor industry. Here we 'borrow' the idea from noble metal plasmonics and apply them to aluminum nanostructures. Chemically synthesized nanocubes are potential for environment sensing because of their sharp resonance, and aluminum disk dimers can achieve large local field enhancement for nonlinear optical effects, but at much shorter wavelength than gold.

GP-A-22 Ultrafast Optical Spectroscopy of (6,5) Single-Wall Carbon Nanotubes

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A semiconducting single-wall carbon nanotube (SWCNT) provides a unique system to explore optical phenomena at the boundary of solids and molecules, due to the coexistence of exciton and continuum states. The optical studies in a semiconducting SWCNT are promising to reveal many interesting physical phenomena, such as exciton-exciton annihilation, optical stark effect, superradiance, etc. Here, we will talk about how we can address some of the open questions in this field by using macroscopic ensembles of single-chirality (6,5) SWCNTs, both in the form of an aqueous suspension and an aligned film, through ultrafast non-degenerate pump-probe spectroscopy. Preliminary results will be presented, showing both ultrafast relaxation dynamics of photo-generated carriers/excitons and coherent nonlinear optical effects that occur within the pulse-width of the pump.

GP-A-23 Filling Carbon Nanotube Cores with Hydrocarbons to Enhance their Near-IR Fluorescence

Kyle W. Bayliff, Stephen R. Sanchez, Sergei M. Bachilo, and R. Bruce Weisman

Department of Chemistry, Rice University, Houston, TX

In this study, several experimental treatments are presented, all aimed at enhancing the spectral sharpness of near-infrared fluorescence from single-walled carbon nanotubes in aqueous surfactant suspension. These treatments involve introducing long-chain hydrocarbons — decane, tetradecane, or octadecane — into the interior space of carbon nanotubes for the purpose of excluding water, which is known to quench the NIR fluorescence. Other sample processing parameters, such as sonication time and power, washing and filtering steps, heating time and temperature, and the addition of micellar space-filling compounds, are also varied experimentally in an attempt to optimize the hydrocarbon treatment effect. However, results to date show that the treatment with hydrocarbons without the addition of other compounds causes spectral broadening at a statistically significant 99% confidence level for all three hydrocarbon species under all experimental conditions, rather than a sharpening. Post-processing addition of hexanol, a micellar space-filling agent, does yield a significant sharpening of the NIR fluorescence features for the hydrocarbon-treated samples compared to the same samples without hexanol, as it also does for untreated nanotube samples. However, addition of hexanol to the hydrocarbon-treated samples does not give any significant sharpening in comparison to the untreated nanotubes. We will also present further results for samples that have undergone an additional annealing step intended to desorb species that might block the openings at nanotube ends.

GP-A-24 **Transient Absorption Measurements of Molecular Plasmons**

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Graphene has been shown to be an exceptional material for supporting plasmons, with a tunability ranging from the mid-infrared to terahertz frequencies. By limiting the system to only a few dozen carbon atoms it becomes possible to access the visible regime, which has many promising applications including sensing and photocatalysis. Polycyclic Aromatic Hydrocarbons (PAH), which are available in high purity, defect-free forms commercially, can be regarded as molecular versions of graphene. This is especially exciting as other traditional methods of fabricating plasmonic materials (lithography and colloids) are limited by spatial resolution and time for the former or defects and intensive chemical synthesis for the latter. Recent theoretical work implies that molecular-scale systems are capable of supporting collective excitation modes indicative of plasmonic behavior, rather than just single electron transitions (SET). In particular, for PAHs, the addition/removal of an electron changes the electronic structure of the molecule such that low-energy collective excitations may arise. However, there is still much we don't know about the collective behavior of this special class of electronic resonances, and beginning to understand their ultrafast dynamics is an important component of their characterization. We have now further analyzed the dynamics and lifetime of both the neutral and radical ionic perylene systems using same wavelength transient absorption spectroscopy. These measurements help elucidate the behavior of plasmons on a molecular scale to more conclusively demonstrate the shorter-lived collective behavior of the molecular plasmon resonance in the charged states in contrast with the longer-lived SET of the neutral system.

GP-A-25 **Bowtie-Shaped Gold Antenna with sub-5nm Nanogaps for Surface-Enhanced Infrared Absorption (SEIRA)**

Liangliang Dong,[1] Xiao Yang,[2] Ben Cerjan,[2] Chao Zhang,[3] Linan Zhou,[1] Peter Nordlander,[2,3,4] and Naomi J. Halas[1,2,3,4]
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Plasmonic nanoantennas takes advantage of the strong coupling of light to electron oscillations in metals enabling light concentration into subwavelength dimensions. Here, I report a new nanoantenna design for surface-enhanced infrared absorption (SEIRA) detection consisting of a bowtie-shaped structure with a sub-5nm gap positioned on top of a Au mirror substrate with a SiO_2 spacer layer. A mixed self-assembled monolayer of n-nitrothiophenol (NTP) and n-methoxybenzenethiol (MOBT) is functionalized onto antenna surface through Au-S bond. We optimized the various geometrical parameters of the structure and predict a theoretical field enhancement factor of over 10^7 in the gap region using finite-difference time-domain (FDTD) calculations. Such a high enhancement factor corresponding to the ability to measure hundreds of NTP and MOBT molecules with a standard commercial FTIR spectrometer has been confirmed in my experiment.

GP-A-26 Copper Nanoparticles for Plasmonic Photocatalysis: Carbon Dioxide Fixation and Reduction

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Abstract: Reverse water gas shift (RWGS) reaction ($CO_2 + H_2 \rightarrow H_2O + CO$) could, in principle, be a promising way to convert the CO_2 into value-added chemical and mitigate the Greenhouse effect, but requires high temperature to achieve high conversion with thermal catalysis as it is an endothermic reaction with ΔG = +41 kJ/mol. In this context, plasmonic photocatalyst, which photocatalyzes chemical reactions by transferring hot carriers derived from the decay of localized surface plasmon resonance (LSPR) to adsorbed molecules and activating their dissociation, might provide a preferable solution. Here we report a plasmonic photocatalyst using copper nanoparticle as the active component achieves high conversion (~ 80%) at room temperature with medium light intensity (~ 8 W/cm^2). Besides, this photocatalyst exhibits high external quantum efficiency (EQE) ~ 60% and selectivity higher than 99.999% towards CO, with little degradation over 8 hours. Even more interesting is that the power dependence of external quantum efficiency shows "S" shape and reaches saturation after a critical light intensity. Combining the experiments of power dependence at different wavelengths and theoretical simulation, we proposed a mechanism of hot electron multiplication to explain the power dependence and the high external quantum efficiency, which could possibly be applied to other weak interaction systems as well.

GP-A-27 Carbon Nanomaterials and Corresponding Small Molecule Analogs for Biomedical Applications

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Carbon nanomaterials are a useful platform for applications in medical research, and have been applied as drug delivery vehicles, biosensors, imaging agents, tissue scaffolds, and therapeutics. This work covers the use of highly oxidized carbon nanomaterials called PEG-HCCs (PEGylated hydrophilic carbon clusters) as drug delivery vehicles and as antioxidants. PEG-HCCs catalytically convert superoxide to oxygen and hydrogen peroxide at a rate faster than most single-active-site enzymes, and they also quench hydroxyl radicals, making them potent antioxidants. PEG-HCCs have been shown to carry out therapeutic functions that have been unattainable from enzymes or small molecule antioxidant treatments; they have been studied *in vitro* and *in vivo* and were successfully applied to treat models of traumatic brain injury, stroke, cancer, rheumatoid arthritis, and multiple sclerosis. This work covers the synthesis, characterization, and antioxidant mechanisms of PEG-HCCs as well as their recent use to image cancer cells and treat glioblastoma in mice.

In order to study the exact mechanism of action of our antioxidant carbon nanomaterials, small molecule analogs can be synthesized and studied to precisely determine the structural features involved in superoxide quenching. This work also covers the synthesis, characterization, and analysis of antioxidant activity of various small molecules that serve as model systems for PEG-HCCs and other carbon-based nanomaterial antioxidants.

GP-A-28 MRI-Active Au Nanomatryoskhas

Luke Henderson,[1] Oara Neumann,[3] Valeria Marangoni,[1,5] Caterina Kaffes,[6] Hui Zhang,[2,4] Valtencir Zucolotto,[5] James Bankson,[6] Peter Norlander,[2,4] and Naomi Halas[1,2,3,4]

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Multifunctional plasmonic nanoparticles have shown extraordinary potential for near-IR photothermal and triggered-therapeutic release treatments of solid tumors. However, the critical ability to efficiently track these particles *in vivo* remains difficult. To address this challenge, we have created MRI-active Au nanomatryoshkas. These are Au core-silica layer-Au shell nanoparticles with Gd(III) ions encapsulated within the silica layer between the inner core and outer Au layer of the nanoparticle (Gd-NM). This multifunctional nanoparticle retains its strong near-IR Fano-resonant optical absorption properties essential for photothermal or other near-IR light-triggered cancer therapy, while simultaneously providing increased T_1 contrast in magnetic resonance imaging by concentrating Gd(III) within the nanoparticle. By design, this system secures chelated Gd(III) within the NM, reducing toxicity but still enabling interaction with neighboring water molecules for MR enhancement. Measurements of Gd-NM revealed a substantially enhanced T_1 relaxivity ($r_1 \sim 17$ mM^{-1} s^{-1}) even at 4.7 T as compared to conventional Gd(III)-DOTA chelating agents ($r_1 \sim 4$ mM^{-1} s^{-1}) currently in clinical use. The observed relaxivities are consistent with Solomon-Bloembergen-Morgan (SBM) theory, describing the longer-range interactions between the Gd(III) and protons outside the nanoparticle. This novel system has the potential to enable tracking of therapeutic nanoparticles *in vivo*, an essential step for optimizing light-induced, nanoparticle based therapies. Furthermore, our system has shown great promise in loading a variety of metal ions to enhance MRI contrast and decrease toxicity.

Graduate Student and Post-doctorates Poster Session B:5:30 pm – 6:45 pm

GP-B-01 Ultrafast Optical Study on the Acoustic Vibrations of Lithographically Fabricated Au and Al Nanostructures

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Ultrafast pump-probe optical measurements provide a non-invasive way to study the mechanical properties of metallic nanostructures, which possess unique optical properties due to surface plasmon resonances. Au nanostructures are particularly interesting due to their spectral response in the visible and near-IR region and their resistance to oxidation. To fabricate robust metallic nanostructures with top-down patterning methods such as electron-beam lithography, an initial nanometer-scale layer of a second metal is deposited to promote adhesion of the metal of interest. However, how this nanoscale layer affects the mechanical properties of the nanostructure and how adhesion layer thickness controls the binding strength to the substrate are still open questions. Here we use ultrafast laser pulses to impulsively launch acoustic phonons in single gold nanodisks with variable titanium layer thicknesses, and observe an increase in phonon frequencies as a thicker adhesion layer facilitates stronger binding to the glass substrate. In addition to an all-optical interrogation of nanoscale mechanical properties, our results show that the adhesion layer can be used to controllably modify the acoustic phonon modes of a Au nanodisk. We further investigate the acoustic motions of Al nanostructures, which are emerging plasmonic materials due to their lower price, higher abundance and wider wavelength tunability. These results show that Al nanodisks are intrinsically bound to the substrate moderately despite no adhesion layer and that the vibration frequencies are highly affected by native oxide at the top rather than at the side wall of the structures.

GP-B-02 How conformational dynamic influences the protein search on DNA

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Protein search and association to specific sequences on DNA is crucial for all fundamental biological processes. The detailed qualitative and quantitative mechanism of fast target finding is still unknown in spite of numerous experimental and theoretical efforts. Particularly, the role of protein conformational fluctuations in the search dynamics remains not well understood. We extend developed earlier theoretical method to analyze how the conformational dynamic affects the process of finding the specific targets on DNA. Our approach is based on discrete-state stochastic calculations that take into account main physical-chemical processes. This allows us to describe analytically the protein search for the targets on DNA at different conditions. Our calculations suggest that conformational fluctuations might strongly affect the protein search dynamics. We discuss how and why the shift in the conformational equilibrium influences the target search kinetics. Theoretical predictions are validated with extensive Monte Carlo

computer simulations.

GP-B-03 Study of Hot Electron Distribution in Plasmonic Nanoparticles Using Two-Photon Photoemission

Michael Semmlinger,[1,6] Bob Zheng,[2,6] Nathaniel J. Hogan,[1,6] Ming-Lun Tseng[2,6], Kyle D. Chapkin[1,6], and Naomi J. Halas[2,3,4,5,6]
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Recently, our lab used hot electrons generated by plasmonic nanoparticles for applications like photocatalysis. However, the hot electron energy distribution in these systems is not well understood yet. Therefore, we are proposing to directly measure this distribution through a pump-probe study utilizing an electron energy analyzer. Initially, a pump pulse excites a plasmon resonance in a nanostructure. A UV probe pulse will then be focused on the excited plasmonic nanoparticle, photoemitting hot electrons. The energy of the emitted electrons and the momentum parallel to the surface of the nanoparticle can then directly be analyzed in a hemispherical analyzer. In this way, the hot electron distribution for any compatible nano structure can be mapped out. The 200nm probe pulse will be generated by fourth harmonic generation of 800nm light via two frequency doubling crystals. In addition, we are proposing a method to generate shorter probe pulses using aluminum Fano structures. We intend to achieve a wavelength of 133nm by third harmonic generation of 400nm light. If successful, these aluminum structures could function as a simple and compact source for vacuum ultra violet light. The understanding gained through these experiments will help us to better engineer nanostructures for the utilization of hot electrons.

GP-B-04 Size control of aluminum nanocrystals via bidentate coordinating solvents for UV Plasmonics

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Aluminum is the most abundant metal in the earth's crust and can support a UV plasmon resonance. The UV region is of great interest for many applications including ultrasensitive detection of organic molecules, photocatalysis, sterilization and remediation. Previously, our group achieved size control of aluminum nanocrystals from 70 nm to 220nm, tuning the plasmon resonance from 300 to 700 nm. In order to achieve higher energy localized surface plasmons, we need to understand the mechanism of growth of aluminum nanocrystals from *N,N*-dimethylethylamine alane. Using FT-IR spectroscopy, we show the aluminum hydride-adduct exchanges ligands with coordinating solvents in solution. We found that bidentate coordinating solvents lead to polymeric aluminum hydride structures which in turn lead to 35 nm nanoparticles. This work provides the basis for rational design of air-sensitive metal nanocrystals and allows for a facile route to control the size of aluminum nanostructures.
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GP-B-05 Active Dielectric Metasurface Based on Phase-Change Medium

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A novel reconfigurable all-dielectric metasurface based on phase-change material $Ge_2Sb_2Te_5$ alloy will be reported. Phase-change material $Ge_2Sb_2Te_5$ exhibits dramatic differences in optical and electrical characteristics between its crystalline and amorphous states, and it has been widely used in the optical data storage and electronic phase-change memories. Nanoantenna made of phase change material is used as the basic building block in this paper. The functionalities of the metasurface can be tailored by selectively controlling the phase transitions on the composing GST elements. Metamaterials with tunable optical Fano resonances are achieved by selectively change the phase state of the constituent GST nanoantenna. Gradient optical metasurfaces with tunable anomalous Re flection can be achieved with variable supercell period consisting of different patterns of the GST nanoantenna in their amorphous and crystalline states. This work opens up new exciting space in developing metamaterial devices with much broader applications that cannot be achieved in their passive counterparts with permanent properties once fabricated.

GP-B-06 A Comparative Study of the Condensing Effects of Ergosterol and Cholesterol

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Cholesterol, due to its condensing effect, is considered an important regulator of membrane thickness. Other sterols, due to their structural similarities to cholesterol, are often assumed to have a universal effect on membrane properties similar to the condensing effect of cholesterol, albeit possibly to different degrees. We used x-ray diffraction to investigate this assumption. By the combination of lamellar diffraction and grazing-angle scattering, we measured the membrane thickness and the tilt-angle distribution of the lipid's hydrocarbon chains. This method is sensitive to phase separation, which is important for examining the miscibility of sterols and phospholipids. Mixtures of ergosterol or cholesterol with dimyristoylphosphatidylcholine, palmitoyloleoylphosphatidylcholine, and dioleoylphosphatidylcholine were systematically studied. We found that mixing ergosterol with phospholipids into a single phase became increasingly difficult with higher sterol concentrations and also with higher concentrations of unsaturated lipid chains. The only condensing effect of ergosterol was found in dimyristoylphosphatidylcholine, although the effect was less than one-third of the effect of cholesterol. Unlike cholesterol, ergosterol could not maintain a fixed electron density profile of the surrounding lipids independent of hydration. In dioleoylphosphatidylcholine and palmitoyloleoylphosphatidylcholine, ergosterol made the membranes thinner, opposite to the effect of cholesterol. In all cases, the tilt-angle variation of the chain diffraction was consistent with the membrane thickness changes measured by lamellar diffraction, i.e., a thickening was always associated with a reduction of chain tilt angles. Our findings do not support the notion that different sterols have a universal behavior that differs only in degree.

GP-B-07 Unified spin Model for magnetic excitations in iron chalcogenides

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Recent inelastic neutron scattering (INS) measurements on FeSe and FeTeSe, have sparked intense debate over the nature of the ground state in these materials. Here we propose an effective bilinear-biquadratic spin model which is shown to consistently describe the evolution of low-energy spin excitations in FeSe, both under applied pressure and upon Se/Te substitution.

The phase diagram, studied using a combination of variational mean-field, flavor-wave calculations, and density-matrix renormalization group (DMRG), exhibits a sequence of transitions between the columnar antiferromagnet common to the iron pnictides, the non-magnetic ferroquadrupolar phase attributed to FeSe, and the double-stripe antiferromagnetic order known to exist in $Fe_{1+y}Te$. The calculated spin structure factor in these phases mimics closely that observed with INS in the FeTeSe, series. In addition to the experimentally established phases, the possibility of incommensurate magnetic order is also predicted.

GP-B-08 Differential Structured Illumination Microendoscopy for Improving In Vivo Detection of Cervical Cancer

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Cervical Cancer causes the death of 266,000 women every year with 87% occurring in low-income regions making it the second most common and third most deadly cancer in developing countries for women. The standard of care in high resource settings for diagnosis is biopsies and histology which is too expensive for low-resource settings. Fiber optic microendoscopy has shown promise for visualizing cervical tissue and identifying nuclear morphometry associated with neoplasia. However, fiber optic microendoscopy image contrast can be limited by out-of-focus light generated in highly scattering tissue. Current optical sectioning methods for microendoscopes to remove out-of-focus light reduce imaging speed or require bulky optical components on the distal end of the fiber probe which can hinder *in vivo* imaging. Here we present differential structured illumination microendoscopy (DSIMe) which is capable of performing optical sectioning using structured illumination in real-time without requiring opto-mechanical components on the distal end of the fiber optic probe. Images acquired with DSIMe show improved axial sectioning and contrast enhancement of nuclear morphometry in highly scattering tissue *ex vivo*. Results of a preclinical pilot study on patients diagnosed with cervical adenocarcinoma *in situ* also demonstrates contrast enhancement and the ability to identify cellular atypia associated with neoplasia *in*

vivo.

GP-B-09 Characterization and fitting of complex fluorescence point spread functions

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Super-resolution fluorescence microscopy is a robust method of sub-diffraction limited optical microscopy. However, it has been demonstrated that fluorophores close to metallic nanowires generate non-standard point spread functions and cannot be localized by traditional Gaussian fitting methods. Complex point spread function shape is based on location and orientation relative to nanowires, but there has not yet been a method proposed to accurately localize these fluorophores. I have generated point spread functions for fluorophores near silver nanowires using finite-difference time-domain simulations, and developed a fitting model based on weighted linear combinations of Hermite-Gaussian beam modes.

The method of steepest descent algorithm for the Hermite-Gaussian model with LASSO (least absolute shrinkage and selection operator) regularization recovers sparse weight functions for test images. Decomposition of finite-difference time-domain PSFs for fluorophore rotation about the optical axis also recovers sparse weight functions, and displays variation based on fluorophore orientation. In the future this method can be further developed to determine the location and position of fluorophores close to metallic nanowires, providing useful insights into the minute surface dynamics taking place.

GP-B-10 Li dendrite suppression using graphene-carbon nanotubes electrodes

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Li metal presents the highest gravimetric capacity compared to any other materials used for anodes in lithium ion batteries. Problematically, Li metal forms dendrites and related unstable structures during battery operation. This results in low coulombic efficiency and cycle life and poses serious safety concerns as the dendrites can cause short circuits. Reported approaches to address the dendrite problem include specially designed electrolytes or the deposition of a shell encapsulating the Li foil. The approaches reported to date either limited Li storage capacity per unit electrode area and cycle life, or they restricted the current density since dendrite formation is more rapid and severe at higher current density. We report here a seamless graphene-carbon nanotube (GCNT) electrode that is capable of reversibly storing large amounts of Li metal with complete suppression of dendrite formation. The GCNT serves as a support material in which Li metal is infused as a thin coating over its high surface area (~2600 m^2 g^{-1}). With a Li storage capacity up to 4 mAh cm^{-2} (823 mAh cm^{-3}) and 25.3 Ah $g^{-1}{}_{G\text{-}CNT}$, the GCNT stores 6.6 times its weight in Li, 68 times greater than does graphite (372 mAh $g^{-1}{}_{C}$), 6.6 times greater than does Si (3859 mAh $g^{-1}{}_{Si}$), and far exceeds other Li storage materials. High energy density full batteries are obtained when these GCNT-Li anodes are combined with cathodes materials such as $LiCoO_2$ or sulfur.

GP-B-11 Progress towards isotope-dependent optical trapping of strontium

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Independently controllable trapping potentials for different atomic elements, isotopes, and states are useful for forming quantum degenerate gases through sympathetic cooling, for quantum computing architectures[1] , and for fundamental studies in many-body physics[2].

In strontium, the large isotope shifts (~100 MHz) relative to the narrow ${}^1S_0$-${}^3P_1$ intercombination line (7.5 kHz) offers the possibility of creating multi-isotope optical traps in which the potentials are optimized for each individual species, such as ^{86}Sr with ^{87}Sr or ^{86}Sr with ^{88}Sr, allowing for efficient evaporative cooling. We will present results for confinement of ^{84}Sr when a dimple is created using far-detuned 689 nm light ($\Gamma/\Delta \sim 10^{-5}$) within a large-volume 1064 nm dipole trap ($\Gamma/\Delta \sim 10^{-7}$). The 689 nm dimple will be used to develop a trap for efficient creation of ^{88}Sr Bose-Einstein condensates, overcoming the slow evaporation currently required.

Research supported by the AFOSR, the NSF, and the Robert A. Welch Foundation.

[1] Anderlini et al., Nature 448, 452-456 (2007)
[2] Mandel et al., Phys. Rev. Lett. 91, 010407 (2003)

GP-B-12 Quantum Plasmonics: Doped Silicon Nanocrystals

Runmin Zhang,[1] Hui Zhang,[2] Katelyn Schramke,[3] Jihua Yang,[3] Nicholas M. Bedford,[4] Katharine Hunter,[3] Alejandro Manjavacas,[5]
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Doped semiconductor nanocrystals represent an exciting new type of tunable plasmonic material with optical resonances in the infrared. The plasmon resonance can be tuned by altering the doping density using either phosphorous or boron impurities. Due to the band structure of silicon, the doping process results in two kinds of carriers with different effective masses and one would expect two distinct plasmon branches. Here we develop a classical hybridization theory and a full quantum mechanical TDLDA approach for two-component carrier plasmas and show that the interaction between the two plasmon branches results in strongly hybridized plasmon modes. The theoretical results are in excellent agreement with experimental data.

GP-B-13 Surface Enhanced Raman Spectroscopy (SERS) on Active Aluminum Nanocrystal Aggregates

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Surface-enhanced Raman Scattering (SERS) is a well-developed analytical technique since the 1970s, and is now a powerful method to detect chemicals and biomolecules down to single molecule level. SERS detection requires metallic nanostructured surfaces or nanoparticles to provide a surface plasmon for near-field enhancement. Commonly used plasmonic metals are Au and Ag. Recently, Aluminum nanostructures are also found to have surface plasmon with the tunability through UV to near-IR. As the most abundant metal on earth and with the low cost, Al is a promising substrate for SERS application. Furthermore, as a chemically active metal, Al nanocrystals form a thin layer of Al_2O_3 immediately after exposed to air or water. Comparing to Au and Ag, this alumina layer on Al gives rise to possibilities to detect chemicals that bond weakly on metal surfaces. In this poster, we present a wet-chemically synthesized Aluminum nanocrystals which shows potential in serving as a SERS substrate. Molecules with functional groups such as carboxylate, silane, and phosphate were detected under 514nm and 785nm laser excitation. The performance of Al substrate was compared to that of Au. These functional groups are essential in bio-molecule detection, and we have demonstrated that Al is a sensitive substrate for SERS detection of single-stranded DNA and hemoglobin.

GP-B-14 Probing the Dynamics of Nanoparticle–Protein Interaction under Physiological Relevant Environment

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Our research is to study nanoparticle-protein binding dynamics in physiologically relevant environments and to determine the connection between protein corona structure and their in vivo physiological destination. Our goals are to characterize in situ interaction of nanoparticle and protein, to determine the protein corona binding dynamics as well as protein competitive binding, and finally to identify the relationship between protein coronas and their physiological outcome. Those goal will be achieved using a combination of techniques including fluctuation correlation spectroscopy, super-localization microscopy, 3D particle. The outcomes of our research are expected to provide a better understanding of corona evolution dynamics and further help to drive safety design of nanomaterials for biomedical applications.

GP-B-15 Using Variance Spectroscopy to Measure Single-Walled Carbon Nanotube Absorption Cross Sections

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This project achieves a novel experimental solution to a long-standing challenge in single-walled carbon nanotube (SWCNT) studies: quantifying the concentrations of specific (*n*,*m*) structural species in bulk samples. Optical absorption spectroscopy is the apparent method of choice, but unfortunately the required molar absorptivity values have not been available for SWCNTs, despite their obvious importance. Here we report absolute molar absorptivities for the first electronic transitions of a set of 12 (*n*,*m*) species.[1] To measure these reference absorptivities, we used the new method of variance spectroscopy. This analyzes statistical variations among fluorescence spectra from different small regions of a dilute sample to deduce the concentrations of specific (*n*,*m*) components. Comparison of these concentrations to the sample's short-wave IR optical absorptions then gives the desired (*n*,*m*)-specific absorption cross sections (absorptivities). Our findings confirm and extend the smaller set of values measured earlier at Rice by a direct counting method.[2] We combine the current and prior findings into a table of measured and estimated absorptivities that will serve as a valuable standard reference, enabling SWCNT researchers to quantitatively characterize their samples through simple absorption spectroscopy.

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GP-B-16 Understanding activation-deactivation mechanism of NMDA receptors using single molecule FRET

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Ionotropic glutamate receptors serve as ion channels in neuronal membrane and are responsible for fast excitatory neurotransmission across neuronal synapses in our central nervous system. N-methyl-D-aspartate receptor (NMDAR) is a unique class of glutamate receptors owing to its structural diversity and availability of a number of binding sites on different domains. Ligands binding at specific domains not only activate/deactivate the ion channel, but also can potentially modulate the activated /deactivated state of the channel, in an allosteric fashion. We present experimental strategies to investigate such activation mechanism of NMDAR ion channels. Single molecule Förster resonance energy transfer (smFRET) has been used as a spectroscopic technique to probe extent of activation or deactivation of the ion channel in presence of ligands, binding at different domains of the NMDAR protein. These binding sites on the receptor protein can serve as potential drug targets for controlling aberrant activation of the ion channel that leads to a number of neurological disorders. The results from this study are expected to elucidate potential drug target sites on glutamate receptors and therefore contribute to the ever expanding research of targeted neuro-therapy.

GP-B-17 Circular Differential Scattering Studies of Bovine Serum Albumin Coated Nanorod Aggregates

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The biological fate of plasmonic nanoparticles in living systems is largely dependent on the interaction between the particle and the proteins in the system. A protein corona is formed, which alters the recognition of the particle by the cell and ultimately determines the fate of the particle. The chiral structures of proteins interact preferentially with circularly polarized light of the same handedness. When circularly polarized light is incident on a plasmonic structure that is chiral, the helical pitch of the light is reduced in size from the wavelength of the light to a scale which is more comparable with the size of tertiary and quaternary chiral structures in proteins. This size match up greatly increases the chiral signal from the chiral protein structure. When gold nanorods are placed in a low concentration solution of bovine serum albumin (BSA), the rods will aggregate. The unperturbed aggregates in solution give both the expected circular dichroism (CD) signal from BSA in the UV, and another very strong plasmon coupled signal in the visible region. In order to determine whether the aggregates themselves are chiral and contributing to the CD signal, which is likely, it is proposed that single particle circular dichroism scattering (CDS) measurements be correlated with 3D TEM tomography. In this way, the contribution to the CDS signal from the chiral plasmonic aggregate structure can be determined, and theoretically the signal from the protein can be separated and the structure, native or otherwise, determined.

GP-B-18 Investigating Nanoparticle Catalysis Using Electo-Generated Chemiluminescence

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The desire to develop clean and efficient ways to generate power has led to interest in researching better catalytic supports and reactions. Nanomaterials have been researched thoroughly as a catalysts due to their high surface area to volume. Additionally plasmonic nanomaterials have offered better catalytic activity due to surface plasmons generating high e-field hot spots and high energy hot carriers. However, the individual contributions of e-field hot spots, molecular affinity, and hot carriers have not been thoroughly studied. One method for separating catalytic activity generated through molecular affinity from catalytic activity generated due to the surface plasmon is the use of electro-generated chemiluminescence (ECL) microscopy. This method entails electrochemically generating light through a redox/reaction of $Ru(bpy)_3^{2+}$ with coreactant tripropylamine (TPA). Without the need of external light to detect the reaction occurring on the surface of the nanomaterial, the contributions of molecular affinity alone can be investigated. In this work, the method for investigating these contributions will be explained and preliminary ECL data will be shown.

GP-B-19 **A compact mid-infrared dual-gas CH_4/C_2H_6 sensor using a single interband cascade laser and custom electronics**

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A compact mid-infrared (MIR) dual-gas sensor system was demonstrated for simultaneous detection of methane (CH_4) and ethane (C_2H_6) using a single continuous-wave (CW) interband cascade laser (ICL) based on tunable laser absorption spectroscopy (TDLAS) and wavelength modulation spectroscopy (WMS). Custom electronics with ultra-compact size and ultra-low noise were developed, including a laser current driver, a temperature controller and a lock-in amplifier. These custom electronics reduces the size and weight of the sensor system as compared with a previous version based on commercial electronics. A multi-pass gas cell with an effective optical length of 54.6 m was adopted to enhance the absorption. The 3337 nm ICL was capable of targeting a C_2H_6 absorption line at 2996.88 cm^{-1} and a CH_4 line at 2999.06 cm^{-1}. Dual-gas detection was realized by scanning both the CH_4 and C_2H_6 absorption lines. Based on an Allan deviation analysis, the 1 σ detection limit was < 10 parts per billion by volume (ppbv) for CH_4 and < 2 ppbv for C_2H_6. Sensor measurements for both indoor and outdoor concentration changes of CH_4 and C_2H_6 were conducted. The reported single ICL based dual-gas sensor system has the advantages of reduced size and cost compared to two separate sensor systems and a dual-sensor system based on currently available large sized, high-cost commercial electronics.

GP-B-20 **Probing the Near-fields of Plasmonic Nanostructures with Photo-induced Force Imaging**

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The ability to image the optical near-field of nanoscale structures, map their morphology and concurrently obtain spectroscopic information with high spatiotemporal resolution, is a highly sought after technique in nanophotonics. As a step towards this goal, we demonstrate the mapping of optical forces between a nanoscale tip and an optically excited sample consisting of plasmonic nanostructures, in a setup akin to atomic force microscopy. We observe that the enhancement in near-field optical forces mimic the expected electric field enhancements in gold nanorods and disk dimers, with strong polarization sensitivity. Through numerical simulations, we evaluate the optical forces in the tip-sample vicinity by considering realistic tip dimensions and compare them with experimentally measured force intensity profiles.

GP-B-21 CW DFB-QCL and EC-QCL based sensor for simultaneous NO and NO_2 measurements via frequency modulation multiplexing using multi-pass absorption spectroscopy

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Nitrogen oxides (NO_x), including nitric oxide (NO) and nitrogen dioxide (NO_2), play important roles in determining the photochemistry of the ambient atmosphere, controlling the production of tropospheric ozone, affecting the concentration levels of the hydroxyl radical, and forming acid precipitation. In order to enable fast-response NO_x detection, we developed a sensor system capable of simultaneous measurements of NO and NO_2 by using a commercial 76-m astigmatic multi-pass gas cell (MPGC). A continuous wave (CW) distributed-feedback (DFB) quantum cascade laser (QCL) and a CW external-cavity (EC) QCL were employed for targeting a NO absorption doublet at 1900.075 cm^{-1} and a NO_2 transition at 1630.33 cm^{-1}, respectively. Both laser beams were combined and transmitted through the MPGC in an identical optical path and subsequently detected by a single mid-infrared detector. A frequency modulation multiplexing scheme was implemented by modulating the DFB-QCL and EC-QCL at different frequencies and demodulating the detector signal with two Labview software based lock-in amplifiers to extract the corresponding second-harmonic (2f) components. Continuous monitoring of NO and NO_2 concentration levels was achieved by locking the laser frequencies to the selected absorption lines utilizing a reference cell filled with high concentrations of NO and NO_2. The experimental results indicate minor performance degradation associated with frequency modulation multiplexing and no cross talk between the two multiplexed detection channels. The performance of the reported sensor system was evaluated for real time, sensitive and precise detection of NO and NO_2 simultaneously.

GP-B-22 Advance Spectral Analysis for Single-Walled Carbon Nanotubes Samples Characterization

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Single-walled carbon nanotubes (SWCNTs) have promised wide range of novel applications for containing a mixture of many structures with different properties. However, accurate sample composition analysis still challenging with simple characterization methods: absorption and emission spectra. Such spectra of heterogeneous samples are complex and difficult to analyze due to the overlapping features from various (*n*,*m*) species. Here we report progress in determining the relative and the absolute sample composition by carefully analyzing the florescence and absorption spectra simultaneously.

The first step is to deduce the relative abundances from florescence spectra measured with fixed-wavelength lasers. For this we have conducted emission spectra studies of bulk and single-nanotube. Emission profile parameters determined as a function of nanotube structure to construct a robust emission model. Furthermore, the fluorescence excitation spectra for enriched sample is determined and analyzed to construct a fluorescence excitation model that can predict that ones for (*n*,*m*) species beyond those that were directly measured. A combination of emission and excitation models allows an accurate analyzes of the fluorescence spectra of nanotubes mixture as a sum of contributions from multiple (*n*,*m*) species.

The second step is to deduce the absolute (*n*,*m*) concentrations from absorption spectra. For this purpose, the absorption spectrum of a mixed sample is simulated as a background function plus components determined from the fluorescence emission and excitation profiles for the (*n*,*m*) species that were found to be present. Then the separate E_{11} (*n*,*m*) absorbance components are divided by their structure-specific absorption cross sections to find absolute species concentrations.

GP-B-23 Detection of antiferromagnetic order[1] and characterizing spin-charge separation[2] with ultracold ^6Li in a compensated optical lattice

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Using ^6Li atoms in a three-dimensional (3D) optical lattice, we can explore the fermion physics in both 1D and 3D. We have realized the 3D Fermi-Hubbard model and detected short-range antiferromagnetic (AFM) spin correlations via Bragg scattering of light[3]. To further explore the long-range ordering, we must cool the system further. We are designing an optical setup with spatial light modulator to create arbitrary-potential profile. With this device, we can engineer the entropy distribution of the system. It will improve evaporative cooling and allowing us to possibly achieve long-range ordering.

In addition, we are also studying 1D systems by turning off one of the lattice beams. Predicted by Luttinger liquid theory, fermions have a different speed of sound for spin and charge excitations, called spin-charge separation. Evidence of spin-charge separation has been seen in quantum wire tunneling experiments[4,5]. However, spin and charge dispersion were not able to be measured directly. With ultracold atoms, a highly tunable system, we may directly observe this phenomenon using Bragg spectroscopy[6].

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GP-B-24 **Computational Design of Metal-Organic Frameworks with High Methane Deliverable Capacity**

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Metal–organic frameworks (MOFs) are a rapidly emerging class of nanoporous materials with largely tunable chemistry and diverse applications in gas storage, gas purification, catalysis, etc. Intensive efforts are being made to develop new MOFs with desirable properties both experimentally and computationally in the past decades. To guide experimental synthesis with limited throughput, we develop a computational methodology to design new MOFs with high methane deliverable capacity. This *de novo* design procedure applies known chemical reactions, considers synthesizability and geometric requirements of organic linkers, and evolves a population of MOFs with desirable property efficiently. We identify about 500 MOFs with higher deliverable capacity than MOF-5 in 10 networks. We also investigate the relationship between deliverable capacity and internal surface area of MOFs. This methodology can be extended to MOFs with multiple types of linkers and multiple SBUs.

GP-B-25 **1D to 3D Crossover of a Spin-Imbalanced Fermi Gas**

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We study the one to three-dimensional (1D to 3D) crossover of an ultracold spin-imbalanced Fermi gas [1]. In our experiment, we create a two-spin component gas of atomic fermions (lithium-6) in a 2D optical lattice. The lattice confines the atoms in an array of 1D tubes with a variable maximum lattice depth.

Phase separation has been observed to occur in spin-imbalanced atomic Fermi gases in both 1D and 3D geometries [2,3]. The phases are inverted in 1D compared to 3D. In 1D, the atomic cloud has a partially-polarized core and either fully-polarized or fully-paired superfluid wings. In 3D, the atomic cloud has a balanced superfluid core surrounded by a partially-polarized shell, enclosed by a fully-polarized outer shell.

By changing the interactions between atoms and tunneling rates in the lattice, we probe the crossover regime between 1D and 3D using phase separation as a guide. We find that our data collapses to a single curve indicating a universal value of the crossover. Locating the crossover region is vital for our future work on the direct detection of the exotic superfluid state, FFLO [4].

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GP-B-26 **Mechanism study of photoluminescence in gold nanorods**

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In this research, we provide a mechanistic understanding of photoluminescence (PL) in gold nanorods (AuNRs). We tested the theory of Purcell effect enhanced radiative relaxation of plasmon-induced hot carriers for PL in AuNRs. The theory is applied in explaining the excitation wavelength dependent and power dependent experimental results about Stokes PL as well as the anti-Stokes PL of AuNRs. The influence of hot carrier energy distribution and local density of photonic states on PL is also discussed within this research. The results can pave a way for using PL as a tool for indicating the hot carrier energy distribution, charge and energy transfer processes happening on plasmonic nanostructures.

GP-B-27 **Recent developments in plasmonics: Tunable charge transfer plasmons and tunable acoustic vibrations of nanoparticles**

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Wire-bridged plasmonic dimer structures exhibit a Charge Transfer Plasmon (CTP) resonance involving an AC current through the bridging wire. The unique feature of the CTP is that its energy can be tuned over a broad spectral region simply by changing the conductance of the wire. This can be achieved either by changing the cross section, length, or material of the wire. We will present experimental and theoretical results demonstrating the extraordinary tunability of this system across the visible down into the infrared.[1] Another recent result from our group is a demonstration that the acoustic vibrations in a substrate-supported nanoparticle can be tuned by modifying the thickness of its adhesion layer. Using ultrafast laser excitation and ultrafast probing, we show that the acoustic vibration frequencies of the nanoparticle blueshift with increasing thickness of the adhesion layer. The experimental results agree very well with theoretical predictions.[2] This direct coupling between optically excited plasmon modes and phonon modes provide a non-invasive way to study optomechanical phenomena.

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GP-B-28 **Optoelectronic Properties of Conjugated Block Copolymer with Flexible Linking Group**

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While organic photovoltaics (OPVs) showed promising performance in the past few years, the basic understanding for their charge separation and recombination is still lacking. Charge separation and recombination occurs at donor/acceptor interface, and is significant for further improvement in the performance of OPV devices. Here, we synthesize a donor-acceptor block copolymer poly(3-hexyl thiophene)-block- poly((9,9-dioctylfluorene)-2,7-diyl-alt-[4,7-bis(thiophen-5-yl)-2,1,3-benzothiadiazole]-2′,2″-diyl) (P3HT-PFTBT), and demonstrate a chemical modification method at its donor and acceptor interface. This is done by inserting flexible poly ethylene (PEG) linking group in between the polymer blocks. Photoluminescence data show that linking group is possible in breaking up the conjugation of donor and acceptor blocks, and may therefore increase photovoltaic efficiency by impeding charge recombination of electron and hole carriers.