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The Smalley-Curl Institute
1st Annual Summer Research Colloquium Sponsors
## 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

**Oral Session 1:**  
9:00 am – 10:15 am (McMurtry Auditorium)  
**Presider:** Josh Hill

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<td>“Electrochemical control of surface plasmons – from individual core-shell structures to plasmonic drawbridges” (Paper No. O-1.1)</td>
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<td>Pelham Keahey, Tomasz Tkaczyk, Kathleen Schmeler, and Rebecca Richards-Kortum,</td>
<td>“Improving High Resolution Microendoscopy for the Early Detection of Cervical Cancer” (Paper No. O-1.3)</td>
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**Coffee Break:** 10:15 am - 10:30 am

**Oral Session 2:**  
10:30 am – 11:45 am (McMurtry Auditorium)  
**Presider:** Daniel Gonzales

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<td>11:45 – 12:00 pm</td>
<td>Break (lunch for judges and undergraduate, RET, and RSTEM REU poster presenters)</td>
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| Lunch and Poster Sessions: 12:00 pm – 1:30 pm | Undergraduate Poster (UG) – *Martel Hall A*  
Research Experience for Teachers Poster Session (RET) - *Martel Hall B*  
RSTEM Research Experience for Undergraduates (REU) Poster Session (UG-R) - *Martell Hall B* |
| Oral Session 3: | 1:30 – 2:45 pm (McMurtry Auditorium)  
**Presider:** Jesse Adams |
| 1:45 – 2:00 pm | Jingqiang Li, Eric W. Frey, Sithara S. Wijeratne, and Ching-Hwa Kiang, “Reconstructing Multiple Free Energy Pathways of DNA stretching from Single Molecule Experiments” (*Paper No. O-3.2*) |
| 2:00 – 2:15 pm | James Matthews, Courtney Payne, and Jason Hafner, “Gold Nanorod Supported Phospholipid Bilayer Structures and Phases Detected by Surface Enhanced Raman Scattering” (*Paper No. O-3.3*) |
| 2:15 – 2:30 pm | Binod K Rai and E. Morosan, “Intermediate valence to heavy fermion through a quantum phase transition in Yb3(Rh1-xTx)4Ge13 (T = Co and Ir)” (*Paper No. O-3.4*) |
| 2:30 – 2:45 pm | Ali Sobhani, Alejandro Manjavacas, Yang Cao, Michael McClain, F. Javier García de Abajo, Peter Nordlander, Naomi J. Halas, “Narrowing the plasmon resonance with coupled aluminum nanoparticle-film systems” (*Paper No. O-3.5*) |
| Coffee Break | 2:45 pm – 3:00 pm |
| Oral Session 4: | 3:00 pm – 4:15 pm (McMurtry Auditorium)  
**Presider:** Pelham Keahey |
| 3:00 – 3:15 pm | Hui Zhang, Runmin Zhang, Alejandro Manjavacas, Peter Nordlander, “Plasmon Hybridization in Doped Silicon Nanocrystals with Two-Component Carriers” (*Paper No. O-4.1*) |
| 3:15 – 3:30 pm | Thomas Langin, Patrick McQuillen, Trevor Strickler, Thomas Pohl, and Thomas Killian, |
“Universality in the Equilibration of Quenched Yukawa One Component Plasmas” (Paper No. O-4.2)

3:30 – 3:45 pm  Bob Zheng, Hangqi Zhao, Alejandro Manjavacas, Michael McClain, Peter Nordlander, and Naomi J. Halas, “Shining Light on Carrier Generation in Metallic Nanostructures” (Paper No. O-4.3)

3:45 – 4:00 pm  Henry Yu, Alex Kutana, and Boris Yakobson, “Theoretical Modeling of 2D Lateral Semiconductor Hetero-junction” (Paper No. O-4.4)

4:00 – 4:15 pm  Pavlo Zolotavin, and Doug Natelson, “Low temperature study of plasmonic heating in Au nanowire” (Paper No. O-4.5)

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

Posters Session A: 4:15 pm – 5:30 pm (food, wine, and beer will be served)

Posters Session B: 5:30 pm – 6:45 pm (food, wine, and beer will be served)

Awards Ceremony 6:45-7:15 pm (McMurtry Auditorium)
(food, wine, and beer will be served in Martel Hall A)

Event Catered by:
Oral Session 1: 9:00 am – 10:15 am

**O-1.1 - Electrochemical control of surface plasmons – from individual core-shell structures to plasmonic drawbridges**

Chad P. Byers,1,2 Hui Zhang,3 Dayne F. Swearer,2 Mustafa Yorulmaz,2 Benjamin S. Hoener,2 Da Huang,2 Añneli Hoggard,2 Wei-Shun Chang,2 Paul Mulvaney,3 Emilie Ringe,2,5 Naomi J. Halas,1,2,4,5,6 Peter Nordlander,1,4,5,6 Stephan Link,1,2,6 Christy F. Landes1,2,6

1 Applied Physics Graduate Program, Rice University, Houston, Texas, USA
2 Department of Chemistry, Rice University, Houston, Texas, USA
3 School of Chemistry and Bio21 Institute, University of Melbourne, Parkville, Victoria, AUS
4 Department of Physics and Astronomy, Rice University, Houston, Texas, USA
5 Materials Science and NanoEngineering, Rice University, Houston, Texas, USA
6 Department of Electrical and Computer Engineering, Rice University, Houston, Texas, USA

The optical properties of metallic nanoparticles are tunable via size, shape, composition, and dielectric environment. Neighboring nanoparticles in particular are also extremely sensitive to interparticle separation. In this work, we control the optical properties of individual and strongly coupled nanoparticles through reversible redox electrochemistry, allowing us to control the composition, size, and gap width of strongly coupled nanoparticles. The electrochemical conversion of Ag/AgCl shells of varying thickness between redox states results in strong reversible control the optical response of Au@Ag core-shell nanoparticles. In the case of strongly coupled nanoparticles, we first demonstrate the fine control of single-dimer scattering spectra by tuning the interparticle gap width. By bridging the gap with an electrochemically switchable shell, we then show the dramatic yet reversible changes to line shape resulting from actively controlling the coupling mechanism between nanoparticles.

**O-1.2 - Formation and Lifetime Measurements of Ultralong-Range Molecular Rydberg States of Strontium**

F. Camargo,1 J. D. Whalen,1 R. Ding,1,2 G. W. Junior,1 F. B. Dunning,1 T. C. Killian1

1 Physics & Astronomy, Rice University, Houston, TX, USA
2 Applied Physics Program, Rice University, Houston, TX, USA

Atoms of very high principal quantum number, so called Rydberg atoms, exhibit ultralong-range interactions which can give rise to unusual quantum phenomena. One example is the formation of ultralong-range $Sr_2$ molecules comprised of a ground state atom and a highly excited Rydberg atom. For attractive interactions between the Rydberg valence electron and a ground state atom bound states can be supported featuring an internuclear separation of thousands of Bohr-radii. Through two-photon excitation, we observe various molecular bound states including the vibrational ground and excited states of $5s^2 1S_0-38s^2 3S_1$ dimers. We show the dependence of each molecular state’s lifetime on the density of the ground state atoms which controls the rate of dissociation due to collisions between the molecule and a ground state atom.

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

**O-1.3 - Improving High Resolution Microendoscopy for the Early Detection of Cervical Cancer**

Pelham Keahey,1,2 Tomasz Tkaczyk,2 Kathleen Schmeler,3 and Rebecca Richards-Kortum2

1 Applied Physics Graduate Program, Rice University, Houston, TX, USA
2 Department of Bioengineering, Rice University, Houston, Texas, United States
3 Department of Gynecologic Oncology and Reproductive Medicine, The University of Texas MD Anderson Cancer Center, Houston, United States

Cervical cancer causes the death of 266,000 women worldwide each year and 87% of these deaths occur in low and middle income regions. Cervical cancer is the second most common cancer and third most deadly for women in low-income regions. The standard of care for diagnosing cancer is collecting biopsies for histology, however, this requires extensive laboratory infrastructure and expertise that does not exist in many low-income areas. There is a need for an imaging device which can be used in vivo to provide histological information without the need for biopsy. Fiber-optic microendoscopes have shown promise at identifying the nuclear changes associated with cancerous growth in squamous epithelium such as in the oral mucosa and cervix in vivo. However, fiber-optic
microendoscopy image contrast is reduced by out-of-focus light generated by scattering within tissue. The scattering-coefficient of cervical columnar epithelium is greater than squamous epithelium and hinders successful imaging in the cervix. To address this challenge, we present a small and portable microendoscope system capable of performing optical sectioning using structured illumination (SI) in real-time. Several optical phantoms were developed and used to quantify the sectioning capabilities of the system. Columnar epithelium from cervical tissue specimens was then imaged ex vivo, and we demonstrate that the addition of SI achieves higher image contrast, enabling visualization of nuclear morphology.

O-1.4 - Synthesis of Laser Induced Graphene Nanoribbons from Polyimide Sheets

Luong Xuan Duy,1,2 Zhiwei Peng,2 Jibo Zhang,2 Yilun Li,2 James M. Tour2,3

1Applied Physics Program, Rice University, Houston, Texas, USA
2Department of Chemistry, Rice University, Houston, Texas, US,
3Department of Material Science and NanoEngineering, Rice University, Houston, TX, USA

Graphene nanoribbons (GNRs) have potential application in numerous devices including supercapacitors and lithium ion batteries due to their higher surface area and active edge sites. However, commercial use of GNRs has been limited due to the lack of scalable synthetic methodologies. Recently, we developed a simple yet effective method to make porous graphene structures from commercially available polyimide (PI) sheets using laser induction to produce laser induced graphene (LIG) with high electrical conductivity, high thermal stability and outstanding electrochemical performance. In this study, we show that by controlling the pulse rate of the laser we can now quickly fabricate laser induced graphene nanoribbons (LIGNRs) on PI sheets. The power applied during laser induction is critical for the formation of LIGNRs and the work presented here may open a new direction for the synthesis and large-scale production of GNRs which will further facilitate their use in future applications.

O-1.5 - Molecular Plasmonics: Graphene Plasmons in the Picoscale Domain

Adam Lauchner,1,2 Andrea E. Schlather,3,7 Alejandro Manjavacas,4,7 Yao Cui,3,7 Michael J. McClain,3,7 Grant Stec,3,7 F. Javier Garcia de Abajo,5,6 Peter Nordlander,2,4,7 and Naomi J. Halas2,3,4,7

1Applied Physics Graduate Program, Rice University, Houston, TX, USA
2Department of Electrical and Computer Engineering, Rice University, Houston, TX, USA
3Department of Chemistry, Rice University, Houston, TX, USA
4Department of Physics and Astronomy, Rice University, Houston, TX, USA
5ICFO-Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain
6ICREA-Institució Catalana de Recerca i Estudis Avancats, Passeig Lluís Companys, 23, 08010 Barcelona, Spain
7Laboratory for Nanophotonics, Rice University Houston, TX, USA

Graphene supports surface plasmons that have been observed to be both electrically and geometrically tunable in the mid- to far-infrared spectral regions. In particular, it has been demonstrated that graphene plasmons can be tuned across the infrared by spatial and electronic confinement. The identification of a general class of plasmonic excitations in picoscale graphene systems containing only a few dozen atoms permits us to extend this versatility into the visible and ultraviolet. Thus, graphene emerges as a robust, novel platform for light modulation and photonic devices over a remarkably broad spectrum, from the infrared to the ultraviolet. As appealing as this extension might be for active nanoscale manipulation of visible light, its realization constitutes a formidable technical challenge. We experimentally demonstrate the existence of molecular plasmon resonances in the visible for ionized PAHs, which we reversibly switch by adding, then removing, a single electron from the molecule. The charged PAHs display intense absorption in the visible regime with geometrical tunability analogous to the plasmonic resonances of much larger nanographene systems. Finally, we also use the switchable molecular plasmon in anthracene to demonstrate a functional proof-of-concept electrochromic device.
**O-2.1 - Aluminum Antennas for Internally Calibrated Surface Enhanced Infrared Absorption Spectroscopy**

Benjamin Cerjan,¹ Xiao Yang,¹ Peter Nordlander¹,³,⁴, and Naomi J. Halas¹,²,³,⁴

¹Department of Physics and Astronomy, Rice University, Houston, TX, USA
²Department of Chemistry, Rice University, Houston, TX, USA
³Department of Electrical and Computer Engineering, Rice University, Houston, TX, USA
⁴Laboratory for Nanophotonics, Rice University, Houston, TX, USA

There has been a great deal of recent progress on Surface-Enhanced Infrared Absorption (SEIRA) spectroscopy, achieved by using tunable gold nanoantennas that enhance the incident electromagnetic field in the mid-infrared region of the spectrum. This approach enhances the sensitivity of a standard, commercially available Fourier Transform Infrared (FTIR) spectrophotometer by many orders of magnitude. Here we examine aluminum, a highly abundant and low cost metal, as the constituent material for SEIRA antennas. Unlike gold, the more highly reactive aluminum antenna is coated with a 2-4 nm self-terminating oxide layer, whose presence we exploit in our antenna design. We have chosen an asymmetric cross-shaped design, which possesses two primary modes: one tuned to the Al-O stretching mode of the intrinsic Al₂O₃ coating layer (950 cm⁻¹), and the other to characteristic modes of an analyte of interest (C-H modes at ~2900 cm⁻¹). The asymmetry of this antenna structure enables the simultaneous detection of multiple infrared (IR) vibrational resonances. By depositing octadecanoic acid on our antennas, we were able to clearly detect the C-H stretching modes of these molecules, and also directly identify the binding modes of the COOH terminal group to the Al₂O₃ antenna surface. By exploiting the presence of the native oxide layer on the aluminum structures, an internal standard is demonstrated to quantify the number of molecules on the surface of the antenna. We explored the use of this standard by demonstrating increasing molecular coverage along a Langmuir isotherm, proving that high-quality SEIRA spectroscopy is feasible with aluminum.

**O-2.2 - Protein Search for multiple targets on DNA**

Maria Kochugaeva¹, Martin Lange¹,², and Anatoly B. Kolomeisky¹,³

¹Department of Chemistry, Rice University, Houston, Texas, USA
²Johannes Gutenberg University, Mainz, Germany
³Center for Theoretical Biological Physics, Rice University, Houston, Texas, USA

Protein-DNA interactions are essential for all biological processes. One of the most important fundamental aspects of these interactions is the protein binding to the specific sites on DNA. A large number of experimental and theoretical investigations have been devoted to explanation of molecular mechanisms of fast and precise protein search and recognition, but the detailed description of this phenomenon is still not well understood. One of the most intriguing and uncovered problems is the role of multiple targets in the protein search dynamics. Using a recently developed theoretical framework based on a discrete-state stochastic approach, we derived full analytical description of all dynamic properties of protein-DNA system. Specifically, systems with two and three targets have been explicitly investigated. It was found that multiple targets in most cases accelerate the search in comparison with a single target situation. However, the acceleration is not always proportional to the number of targets. Furthermore, there are even situations when to find one of the multiple targets is longer than the properly positioned single target! The critical parameters for such systems are spatial position of the targets, distances between them, and ratio of the total DNA lengths and average scanning lengths of protein molecules on DNA. Our results were compared with experimental observations as well as with results from a continuum theory for the protein search. Also, extensive Monte Carlo computer simulations fully support our theoretical calculations.
**O-2.3 - Compressive Hyperspectral Microscopy**

Liyang Lu\(^1\), Lindsey Anderson\(^2\), Jason Hafner\(^2\), and Kevin Kelly\(^1\)

\(^1\)Department of Electrical and Computer Engineering, Rice University, Houston, TX  
\(^2\)Department of Physics and Astronomy, Rice University, Houston, TX  

Compressive sensing (CS) is a novel imaging technology based on the inherent redundancy within most images including those in optical microscopy. By applying CS in the 3-dimensional hyperspectral data acquisition processes, we demonstrate a hyperspectral microscope system, which achieves much higher sensitivity while requiring less imaging time compared to single particle or pushbroom-based counterparts. As an example, its effectiveness in analyzing plasmon resonances of gold nanobelts by compressive dark-field microscopy will be discussed. As such, it takes five to twenty times fewer measurements to acquire an image than the raster-scan approach while also receiving much more light per measurement. Lastly, we will discuss how to perform compressive video acquisition with this system.

**O-2.4 - Novel Short-Wave Infrared In Vivo Imaging using Single-walled Carbon Nanotubes**

Ching-Wei Lin\(^1\), Sergei Bachilo, \(^1\) Michael Vu, \(^2\) Kathleen M. Beckingham, \(^2\) and R. Bruce Weisman\(^1\)

\(^1\)Department of Chemistry, Rice University, Houston, Texas, United States  
\(^2\)BioSciences, Rice University, Houston, Texas, United States  

Single-walled carbon nanotubes (SWCNTs) are good candidates for non-invasive in vivo detection because they emit at short-wave infrared (SWIR) wavelengths, minimizing scattering and autofluorescence. Our goal is detecting anti-cancer antibodies tagged with SWCNTs for ovarian cancer diagnosis. However, fluorescence detection and imaging in deep tissues is challenging because of strong photon diffusion. We report here a novel optical device and methods to localize weak SWCNT emission from tumors in laboratory mice.

A highly sensitive lens-free SWCNT fluorescence scanner has been built from a 3D printer and SWIR spectrometer. Excitation is provided by a stationary large-area LED array rather than a laser to limit optical power densities. SWIR fluorescence from SWCNTs is transmitted to a multichannel SWIR spectrometer from an optical fiber tip placed very close to the mouse’s skin. The collector position is computer-controlled using the 3D printer mechanism. At each measured position, we capture a full emission spectrum to distinguish SWCNT fluorescence from background emission. Initial studies have used a tissue phantom shaped like a mouse. We find base-10 penetration depths of ~10 mm for excitation (630 nm) and 2 to 9.8 mm for emission (850 to 1400 nm). Horizontal spatial resolution degrades systematically with increased tissue depth between source and probe.

We also describe a new method for triangulating SWCNT positions inside tissues. Because water absorption is strongly wavelength-dependent, ratios of detected SWCNT intensities at different wavelengths reveal the measurement path length. This allows the source to be located in three dimensions from a small number of measurements.

**O-2.5 - Spectroelectrochemistry of Halide Anion Adsorption and Dissolution of Single Gold Nanorods**

Benjamin S. Hoener, \(^1\) Chad P. Byers, \(^1,3\) Swarnapali Indrasekara\(^1\), and Christy F. Landes\(^1,2\)

\(^1\)Department of Chemistry, Rice University, Houston, Texas, United States  
\(^2\)Department of Electrical and Computer Engineering, Rice University, Houston, Texas, United States  
\(^3\)Applied Physics Graduate Program, Rice University, Houston, Texas, United States  

A spectroelectrochemical flow cell was used to probe the plasmon resonance of the same single gold nanorods in sodium fluoride, sodium chloride, and sodium bromide electrolytes using dark-field scattering. The change in resonance energy, full-width half-max (FWHM), and peak intensity of a Lorentzian fit to the single rod scattering spectra as the rods are charged are compared between the halide electrolytes to determine the role of anion adsorption energy. We demonstrate that up to +0.25 V, the change in the plasmon resonance as a nanorod is charged is independent of halide anion. Adsorption of the more reactive halide anions, bromide and chloride, at higher potentials (+0.3 V to +0.35 V) damps the nanorod plasmon, causing an increase in the FWHM of the scattering spectra. Anion adsorption and plasmon damping occurs at lower potential for bromide since the least amount of energy is required for gold to adsorb bromide compared to chloride and fluoride. Nanorod scattering intensity decreases at +0.35 V in bromide electrolyte, indicating dissolution. The kinetics of the dissolution can be controlled by electrolyte concentration and show that the rate of dissolution increases with each cycle from negative to positive potential.
**UG-1 - Ion Infused Hydrogels in Soft Robotics**

Christine Chao,1,2 Linlin Cao,2 and Professor Jun Lou2

1Smalley-Curl Institute NSF REU Program, Rice University, Houston, Texas, USA
2Department 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-2 - Spin Transport in Ultracold Rydberg Atoms**

J. Hollingsworth,1,2 R. Mukherjee,2,3 and K. R. A. Hazzard2,3

1Smalley-Curl Institute NSF REU Program, Rice University, Houston, TX, USA
2Department of Physics and Astronomy, Rice University, Houston, Texas, USA
3Rice Center for Quantum Matter, Rice University, Houston, Texas, USA

Transport of mass, heat, charge, and information has long played a crucial role in science and engineering. Interest in quantum transport has grown due to the breadth of its applications: novel materials, collision of high energy nuclei, quantum computing, and even models of biological systems are but a few examples. Atoms at ultracold – nanoKelvin – temperatures are an exciting arena in which to engineer quantum phenomena because these atoms can be manipulated and controlled in unique, powerful ways. We devise a scheme to use ultracold highly-excited (Rydberg) atoms to study models of transport. In contrast to previous schemes, which allow for couplings between atoms separated by a distance $r$ that scale as $1/r^3$, ours allows for couplings that scale as $1/r^6$, opening up new regimes that are important for real materials. Disorder also plays a crucial role in real materials’ transport, and we show that one can engineer disorder in a controllable way using ultracold atoms. We theoretically demonstrate that current experiments can observe the transport, and derive the experimental parameters for Strontium atoms that are necessary to reach this regime. We explore the dynamics, looking for signatures of ballistic, diffusive, and localized behavior as a function of the types and strength of disorder applied.

**UG-3 - Molecular Dynamics Simulations of Ion Equilibration in Ultracold Neutral Plasmas**

Nikola Maksimovic,2 Thomas Langin,2 Trevor Strickler,2 and Thomas Killian2

1Smalley-Curl Institute NSF REU Program, Rice University, Houston, Texas 77251, USA
2Department of Physics and Astronomy, Rice University, Houston, Texas 77251, USA

Understanding transport and equilibration in strongly coupled plasmas is important for modeling plasmas found in extreme environments like inertial confinement fusion plasmas and interiors of gas-giant planets. We use molecular dynamics simulations of Yukawa one component plasmas under periodic boundary conditions to study the evolution of strongly coupled ultracold neutral plasmas (UNPs) at early times. Simulations provide access to observable quantities in strongly coupled plasmas, namely correlation functions. Experimentally, the average velocity of an ion subset with a skewed velocity profile has been used to measure velocity autocorrelation functions and provide access to diffusion coefficients and other transport processes in UNPs. Using the simulation, we verify the experimental measurements of average velocities of ion subsets in UNPs and confirm their agreement with the velocity autocorrelation function. Finally, we examine the collective mode behavior of the ions during their equilibration phase by calculating the longitudinal current correlation function at various times during equilibration. This allows us to study the collective mode coupling behavior of the equilibration of ions in UNPs and its dependence on screening parameter.
UG-4 - Competition of magnetic ground states in Fe$_{0.33}$(Nb$_{1-x}$Ta$_x$)S$_2$

Emily Maxwell, Chih Wei Chen, and Emilia Morosan

1 Smalley-Curl Institute NSF REU Program, Rice University, Houston, Texas, United States
2 Department of Physics, Rice University, Houston, Texas, United States

Over the past several years, interest has arisen in the properties of a class of layer-type solid structures called the transition metal dichalcogenides (TMDs). These two-dimensional compounds have been vastly studied due to increasingly important roles as metals, semiconductors, and superconductors. The fundamental characteristics of TMDs are able to be modified by intercalating them with various elements which may lead to a change in magnetic and transport properties. One way to study the competition of different ground states of these intercalated compounds is doping. Because Fe$_{1/3}$TaS$_2$ and Fe$_{1/3}$NbS$_2$ have ferromagnetic and antiferromagnetic ground states respectively, the Ta-doped Fe$_{1/3}$NbS$_2$ provides a system to study the competition between these two ground states. We have synthesized Fe$_{0.33}$(Nb$_{1-x}$Ta$_x$)S$_2$ single crystals with different values of x and have characterized our samples using both X-Ray diffraction and magnetization measurements. Our results suggest that at the Nb-rich side, the magnetic properties are close to antiferromagnetic ground state as non-doped Fe$_{1/3}$NbS$_2$, but have ferromagnetic coupling involved. This also shows that the complexity is raised by the competition between ground states in the Fe$_{1/3}$(Nb$_{1-x}$Ta$_x$)S$_2$ system.


UG-5 - Paving the Way for Sustainable Cement

Siddharth S Raju, Dr. Vahid Hejazi, and Dr. Rouzbeh Shahsavari

1,3 Smalley-Curl Institute NSF REU Program, Rice University, Houston, TX, United States
2 Research Division, C-Crete Technologies, Houston, TX, United States
3 Department of Civil Engineering, Rice University, Houston, TX, United States

In 2014, 4.3 billion tonnes of cement were produced globally, and demand is expected to grow as developing countries industrialize. Cement manufacture accounts for about 5% of anthropogenic global carbon emissions per year, and about a quarter of emissions from the manufacturing sector alone; given the stark predictions for the planet’s future if we do not take steps to address such emissions, and the sheer volume of cement demanded per year, there exists a significant incentive to efficiently produce a greener material that can replace such a ubiquitous and polluting material. In order to do so, we consider the crystal Calcium-Silicate-Hydrate (C-S-H), the basic component of cement. The structure of C-S-H crystals varies considerably from even small changes in the Ca/Si ratio, and these small differences at the nano scale manifest in the macro scale in yielding significantly different mechanical properties. We have synthesized a polycrystalline C-S-H composite of a “spherical” morphology. Production of our composite pollutes negligibly, and the composite significantly outperforms standard cement on some mechanical property tests, such as compressive strength. Once we have optimized our production costs, we will have created a stronger, greener material that may reasonably compete in a market that has stood unchallenged for centuries.

UG-6 - Measuring Nanotoxicity of nAg and SiO$_2$ in Caenorhabditis elegans Using High Throughput Assays

Vinyou Tamprateep and Weiwei Zhong

1 Smalley-Curl Institute NSF REU Program, Rice University, Houston, Texas, United States
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With the widespread application of nanotechnology, nanoparticles have occupied a global presence in society and are exposed to humans on a daily basis in products such as food, paint, computers, and cosmetics. However, despite the ubiquity of nanoparticles in every day technology and products, there is a lack of comprehensive information regarding the toxic effects of exposure to these nanoparticles over extended periods of time as well as the potential of genetic susceptibility. In this study, we use the model organism Caenorhabditis elegans to investigate the effects of human disease genes on the toxicity of the nanoparticles nAg and SiO$_2$. There are over 1,500 orthologs of human disease genes in C. elegans. The conservation of function between nematode and human molecular pathways makes this model organism a valuable tool for studying genetic resistance or predisposition to nanotoxicity in humans. Knowledge of how the inactivation of specific genes adversely affects the organism may help elucidate which molecular pathways these nanoparticles disrupt. We induce genetic silencing through the application of RNA interference (RNAi), which utilizes double
stranded RNA to decompose complementary messenger RNA, to inhibit the expression of a gene. The relative fitness of the worms are then quantified by measuring and comparing the rate of bacterial consumption of worms exposed to nanoparticles to worms that were not exposed. These findings may give insight to the harmful effects these nanoparticles may have on humans as well as the role human disease genes may play in nanotoxicity.

**UG-7 - Extracting and Analyzing Electron and Positron Signals from High Noise Backgrounds in Laser Pair Creation Experiments**

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Using lasers to create dense pair-dominated plasmas has many applications to astrophysics, fundamental physics and medical technologies. This laboratory has gotten results confirming the feasibility of creating pair-dominated plasmas using a high-intensity, short pulse laser called the Texas Petawatt Laser to irradiate gold and platinum targets. These e\(^+\)/e\(^-\) pairs are observed through analyzing image plate x-ray images of electron, positron, and proton spectra recorded using magnetic spectrometers. Measurements contain both the wanted signal and unwanted x-ray noise, which detracts from the signal and makes it more difficult to view and analyze. This project examines the different ways to extract and analyze the electron and positron signals from high noise backgrounds using ImageJ and MatLab processing. A limitation to one single successful image-processing result is that every shot is different and thus the method must be adjusted slightly every time. However, a commonality between all data sets, which this project shows, is that effects of noise can be minimized using moving averaging and polynomial background modeling and subtraction. This approach can be used in future trials for de-noising positron and electron spectrometer signals in any high background environment. This approach has also made the analyzing of multiple datasets possible.

**UG-8 - An Anti-Trapping Beam for Time-Of-Flight Expansion in 1D Spin-Imbalanced Fermi Gas**

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Our experiment studies spin-imbalanced Lithium-6 fermions confined in an array of 1D tubes created by a 2D optical lattice. We aim to study the exotic superfluid phase FFLO (Fulde-Ferrell-Larkin-Ovchinnikov). FFLO differs from the BCS (Bardeen-Cooper-Schrieffer) superfluid phase in that Cooper pairs in FFLO have non-zero center of mass momenta. A proposed method of observing FFLO is time-of-flight expansion imaging, which requires canceling the trapping potential within the tubes with a beam that is blue-detuned from the atomic resonance. We realize this method by directing a 532 nm laser beam onto the atoms to exactly cancel the axial harmonic confinement while maintaining the 2D optical lattice, allowing the atoms to expand in 1D. This constrains the beam spot size and power incident on the atoms. An optical simulation program, OSLO, was used to design the lens system, while a CAD program, SolidWorks, was used to design the physical layout of the apparatus. As a result of this work, we hope to conclusively detect FFLO, an observation that could yield insights into magnetism and superconductivity.

**UG-9 - Mid-Infrared-Pump Terahertz-Probe Spectroscopy Using a Single-Shot Terahertz Spectrometer**

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We have developed a single-shot terahertz time-domain spectrometer to perform optical pump/terahertz probe experiments. These experiments are of interest in condensed matter physics because they allow us to probe non-equilibrium dynamics of many-body systems through determination of characteristic time scales for scattering, relaxation, and recombination. They can also provide
insight into the nature of electron-electron interactions by extracting the frequency and temperature dependence of dynamic conductivities. The mid-infrared optical pump beam is generated using an optical parametric amplifier (OPA) with an output wavelength range of 0.5-11 µm. Efficient, phase-matched terahertz generation is achieved using the tilted-pulse-front excitation method in LiNbO3. The single-shot detection of the terahertz waveform incorporates a reflective echelon to create time-delayed beamlets across the intensity profile of the probe beam before spatially and temporally overlapping with the terahertz radiation in a ZnTe detection crystal. After imaging the probe beam onto a CCD camera, the terahertz time-domain waveform can be recorded. As a demonstration, we have observed carrier lifetimes in InSb at a temperature of 77K.

**UG-10 - Modeling Protein Macrostates Using Transition Probabilities**

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NMDA receptors are a type of ion channel found in the central nervous system that contribute to excitatory neurotransmission. Fluorescence resonance energy transfer (FRET) experiments have yielded some information about distances between a residue pair on this protein, but the structures of various macrostates are still unknown. Distance distributions from FRET experiments have previously been used in our group to solve for an ideal set of simulation model parameters and gain structural information about the macrostates of the protein. A drawback to FRET distance fitting is that it lacks time information. In this study, fitting was performed on a transition matrix, which shows the probability of the protein transitioning from one state to another in a given lag time. Transition matrices calculated from C-alpha model trajectories were fit to an experimental transition matrix. Results from different transition lag times and starting model parameters are presented.

**UG-11 - Cancer cell elasticity in response to in vitro mechanical microenvironment**

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The mechanical properties of a cell’s microenvironment affect the cellular property and response. In particular, the rigidity of the local microenvironment has been shown to impact the cytoskeletal structure of cells and influence cell morphology and motility. Currently, in vitro cancer cell studies are primarily performed on monolayer culture grown on two-dimensional rigid polystyrene surfaces, but in vivo cancer microenvironment usually involves much softer substrates. We applied single cell manipulation using the atomic force microscope to probe cancer cell behavior on soft-substrate culture platforms that mimics tissues with stiffness within the physiological range (0.2–1000 kPa) to emulate the essential features in the in vivo microenvironment. We observed that the substrate stiffness has a significant effect on morphology and membrane tension. The results from our data may have implications regarding cancer metastasis and motility.

**UG-12 - Branching Out: Exploring CαCβ-Model of NMDA**

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NMDA is a neurotransmitter that has been linked to memory elasticity through its highly active role in synaptic transmissions. By increasing understanding of NMDA’s dynamics, particularly its ligand binding domain, understanding in how to approach the protein as a target for treatment in illnesses such as Alzheimer’s may increase as well. Incorporating experimental FRET data, a coarse-grained C-α model has not yet suitably matched what the FRET data shows. As such, improvements must be made. Addition of the C-β side-chain atoms branching off the C-α backbone nearly doubles the parameters for the simulation, but also adds a significant amount of new physical features that may better capture the complex’s true dynamics. In addition to presenting tests of a new model, statistical analysis on the data output by the current fitting procedure will also be presented to determine the accuracy of the simulations.
**UG-13 - Single Molecule Force Studies of Factor H**

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Factor H (FH) proteins regulate the alternative pathway of the complement system, a critical >30-protein-component of the immune system, to ensure that pathogens do not damage host tissue. It was recently discovered that recombinant FH (RFH), as opposed to purified FH (PFH), reduces the disulfide bonds that link von Willebrand Factor (VWF) monomers of various chain lengths into larger VWF multimers (without shear stress). However, PFH can reduce VWF only in the presence of EDTA and urea. Thus, we used AFM to investigate activated (RFH, PFH + EDTA, PFH + urea) and non-activated (PFH) forms of factor H. Our data indicate that activated FH has different conformations when compared with non-activated FH. Because factor H is a reductase for large-soluble VWF multimers, the knowledge gained from this study may provide insight into the mechanism of VWF reduction for therapeutic strategies.

**UG-14 - Broadband Photothermopiles Based on Carbon Nanotube Sheets**

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Carbon nanotubes (CNTs) have laid a novel platform for many novel applications in the diverse areas, including supercapacitors, hydrogen storage, solar cells, THz polarizers, photodetectors, and optical modulators. Here, we explore optoelectronic properties of CNT sheets manufactured from a solution of CNTs in chlorosulfonic acid (CSA) using a dip coating method. These CNT sheets are approximately 20 μm thick and become heavily p-doped during the manufacturing process. We characterized the transmittance spectra of these CNT sheets in a wide range using a UV-VIS-NIR spectrophotometer, a Fourier transform infrared spectrometer, and a time-domain terahertz (THz) spectroscopy system. We found that they have very high absorption in the entire spectral range from the UV to the THz. To take advantage of this strong broadband absorption, we fabricated a photothermoelectric (PTE) photodetector, or a photothermopile, using CNT sheets. Based on our previous work on PTE effect based detectors using different types of CNTs, we engineered and optimized the spatial profile of the Seebeck coefficient in the device by current annealing to create a p⁺-p⁻ junction. Position, power and wavelength dependent photothermal response was measured. The measured responsivity for the UV, visible, and MIR ranges using 405, 660, and 4530 nm lasers were ~ 0.29, 0.29, and 0.15 V/W, respectively, which are comparable to or better than previously reported values for CNT-based photothermopiles.

**UG-15 - Aqueous Two Phase Extraction for Structural Sorting of Single-Walled Carbon Nanotubes**

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One of the main challenges in basic and applied research on single-walled carbon nanotubes (SWCNTs) is sorting as-produced mixed samples into fractions with specific structural forms. One of the most promising new nanotube sorting methods is aqueous two phase extraction (ATPE). This relies on cheap, accessible polymers and surfactants to separate various biomolecules via a thermodynamically driven two phase process. ATPE with controlled surfactant conditions has recently been shown to selectively sort SWCNTs by exploiting the unique structural characteristics of individual nanotube species. These structural characteristics include the nanotube diameter, chirality, and metallicity (metallic vs semiconducting).¹ Furthermore, it has been determined changes in SWCNT oxidation state can be used to fine-tune the partitioning between the two phases.² Here we report a multi-step process for separating various SWCNT chiralities utilizing trichloroisocyanuric acid (TCCA), a common industrial organic oxidizing agent, along with surfactants sodium cholate (SC), sodium deoxycholate (DOC), and sodium dodecylsulfate (SDS) in select concentrations. By using absorption and fluorescence spectroscopies, we are able to observe the partitioning of specific nanotube species. As a preliminary step, oxidative ATPE by TCCA was used to selectively remove metallic SWCNTs from an unsorted sample. This sample, enriched in semiconducting SWCNT species, was then sorted using ATPE tuned by surfactant concentrations into fractions containing a narrow range of structures. A general mechanism for sequential separation of the SWCNTs has been devised and will be further elaborated.

**UG-16 - Arbitrary Laser Shaping for a Generalized Compensated Lattice**

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The compensated optical lattice has proven to be an essential scheme to adjust the local chemical potential and provide evaporative cooling for ultracold fermions. To employ such a scheme, an optical design was developed to generate a laser beam with adjustable shape via a digital mirror device (DMD). Simulations using a frequency domain method in Finesse2.0 were calculated to determine the performance of our optical system under an arbitrary predetermined shape, including both diffraction and aberration effects. Particularly, a generalized compensated lattice potential was generated and calculated in the simulation, which was predicted to further cool fermions to lower temperatures compared with our previous regular Gaussian compensated beam. Preliminary tests were done and further measurements regarding the generalized compensated lattice will be conducted and compared with the simulations.

**UG-17 - A UV laser system by using Second Harmonic Generation for cooling Lithium 7 atoms**

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Laser is one of the main tools for cold atoms experiments used to cool and to trap atoms at very low temperature (few nanokelvins). We present the design and construction of a UV laser system that will be used to cool 7Li atoms using the 2s-3p transition at 323 nm, where the narrower linewidth ($\Gamma = 2\pi \times 764$ kHz) results in an initially colder sample (as compared to the 2s-2p transition at 671 nm). There are three primary aspects of our apparatus that we will address. First, we will describe the Pound Drever Hall technique we use to narrow the linewidth of an external cavity diode laser (ECDL) by locking it to a Fabry-Perot cavity. Secondly, we stabilize the frequency of the laser against long term drifts using saturated absorption with an iodine cell, and finally, we will discuss the generation of UV light using a non linear BBO crystal within a build-up cavity.

**UG-18 - Coherence Measurements in Gold Nanojunctions at Room Temperature**

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An experimental setup for measuring the room temperature electron coherence time has been developed and tested. A gold bowtie device is electromigrated and mechanically strained to bring it close to the conductance quantum. Mechanical strain is controlled by applying a force at the center of the device while keeping the edges fixed, allowing stable control of the conductance down to the single channel limit. The non-linearity of universal conductance fluctuations contributes to $dI^2/dV^2$. We apply an ac modulation at frequency $\omega$ and measure the rms current response at $2\omega$. The second harmonic signal can be used to infer the value of $(dI^2/dV^2)_{\text{rms}}$. If successful, a suppression of $(dI^2/dV^2)_{\text{rms}}$ at conductance values near the conductance quantum will show that the UCF contribution from quantum coherence is readily detectable even at room temperature. From the development of $(dI^2/dV^2)_{\text{rms}}$ with bias the coherence time can be found, a quantity previously not measured at room temperature.

**UG-19 - Molecular Plasmonics for Electrochromic Devices**

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The use of molecular plasmons in electrochromic devices holds potential advantages over traditional electrochromics such as faster switching speeds, greater color availability, and longer device lifetime. Here we demonstrate the use of molecular plasmon resonances in charged Polycyclic Aromatic Hydrocarbons (PAHs) as a method to electrically control optical transmittance in the visible regime. Reversible color switching in the reported devices is achieved through electrochemical reduction and oxidation in an electrolyte gel by selectively adding an electron to the PAH and then removing it. Since the charged PAHs exhibit highly reactive free radical behavior, molecular plasmons present an imposing but surmountable challenge when developing devices for commercialization. Because the composition of the PAH-containing gel electrolyte has great influence on the optical and electrical behavior of the devices, an electrolyte material meeting the criteria of sufficient ionic conductivity, adequate PAH solubility, high optical transparency, and minimal oxygen and water content was developed. Analogous to the geometric and electrical tunability of spatially-confined graphene in the mid- to far-infrared regions, the variety of PAH geometries and influence of ionization state on plasmon frequency provide exceptional tunability across the visible spectrum as predicted theoretically and supported experimentally. These novel properties of molecular plasmons open the door to new optoelectronic devices with visible light modulation operating on a faster timescale than traditional devices.

UG-20 - Advanced Apparatus for Tracking and Controlling the Reaction Kinetics of Single-Walled Carbon Nanotubes during the Functionalization Process

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Unique electronic properties of single-walled carbon nanotubes (SWCNTs) have led to active research in pursuit of highly conductive nanotube wires. Metallic SWCNTs spun into a wire are proposed to possess conductivity that is an order of magnitude higher than the industry standard, copper wire. Therefore, developing a suitable technique to separate metallic SWCNTs from the bulk sample containing a mixture of metallic and semiconducting SWCNTs is advantageous. Many separation methods have previously been published (e.g. separation by SWCNT growth process, chromatography, and formation of SWCNT anions), but our research seeks to utilize highly soluble functionalized SWCNTs due to their diameter dependent defunctionalization temperature. We have developed a robust and controlled method in a state-of-the-art apparatus to functionalize nanotubes in a scalable manner. Liquid ammonia-based chemistry enables the tunable functionalization of single-walled carbon nanotubes to achieve solubility in many solvents including water. Prior to functionalization, the raw nanotube samples undergo gas-phase chlorine treatment to remove most of the residual metal catalyst without significant damage to the nanotubes. The custom-designed reactor apparatus provides a convenient route to produce highly functionalized nanotubes in large quantities and allows for enhanced separation of chiral types by selective defunctionalization.

UG-21 - Field-Effect Characterization of Polymorphic Molybdenum Disulfide using Scanning Probe Techniques


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Molybdenum disulfide (MoS2) is a two-dimensional polymorphic material known to exist in at least two different structures, 2H and 1T. In monolayer 2H form it is characteristic of an n-type direct gap semiconductor, while 1T exhibits metallic properties. A thorough understanding of each form and how to convert from one to the other allows for the creation of efficient field effect transistors based on this material. Single-crystal MoS2 flakes are grown by chemical vapor deposition and analyzed by scanning
with SNOM) similar polarization dependence exists. We have deposited gold electrodes onto the sample and completed fabricating the detector. We are measuring the photothermoelectric response of the device in response to polarization, temperature, and magnetic field induced through electron beam (EB) irradiation, crystals were partially exposed to EB irradiation. Electrical contacts are deposited on some samples, while others lack Cr/Au composites. Observation of EFM and SGM responses reveals distinct regions dependent upon EB exposure and consistent with the presence of separate metallic and semiconducting areas. These results confirm the capacity of EB exposure to control the electrical properties of MoS2, important for the development of transistor technology from this material.

3 Y. Zhan et al., Small 8, 966-971 (2012).

**UG-22 - Terahertz Detection at Room Temperature with Wafer-Scale Films of Highly-Aligned Single-Wall Carbon Nanotubes**

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Terahertz (THz) imaging and spectroscopy could be used for the detection of cancer cells, various drugs, and even bacterial infections [1]. Carbon nanotubes (CNTs) promise to eliminate the bulkiness and low-temperature restrictions of previous THz detectors. CNTs exhibit ultra-broadband absorption [2] and aligned CNT films have shown high sensitivity to polarization changes of radiation even at room temperature [3]. However, current CNT-based detectors utilize a chemical vapor deposition and wet transfer fabrication process [4] that is unsuitable for application integration. We aim to develop a wafer-scale THz detector, with arc-discharge-grown aligned CNTs, that functions at room temperature, is polarization-sensitive, and is compatible for device integration.

We characterized the THz response of a highly dense film of aligned single walled CNTs (SWNTs) using THz-time domain spectroscopy (THz-TDS) and near-field scanning optical microscopy (SNOM). When radiation (0.1 to 7 THz) polarization was parallel to CNT alignment, absorption was 10 times higher than in the perpendicular case. It was also found that absorption peaked around 4.1 THz, where the CNTs exhibit a phonon resonance effect. We also discovered that on a nanometer spatial scale (analyzed with SNOM) similar polarization dependence exists. We have deposited gold electrodes onto the sample and completed fabricating the detector. We are measuring the photothermoelectric response of the device in response to polarization, temperature, and magnetic field dependence. The ultimate goal of this research is to develop a high-resolution array of THz detectors from such a wafer-scale SWNT film to create a THz camera capable of macro-scale real-time imaging.


**UG-23 - 3D Simulations of Interacting Gliding Dislocation in 3C-SiC(001)**

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3C-SiC has been identified as a leading semiconducting material for use in high, voltage, temperature, and frequency devices. In contrast to the other SiC polytypes, 3C-SiC has shown great potential through its high saturated electron drift velocity. The material also shows a very low density of states at the 3C-SiC/ SiO2 interface making it an attractive option for use in power-switching MOSFETs. However, stacking faults form due to the 19.7% lattice mismatch at the 3C-SiC/ SiO2 interface, and then expand throughout epitaxial growth, eventually terminating with other stacking faults, creating electrically active defects that lead to the electrical degradation of the material. After the epitaxial growth process has finished, the gliding of the partial dislocations at the edges of the stacking faults, instigated by the intrinsic shear stress of the system, begin to generate forest dislocations. The forest
dislocations are created by the intersection of the counter pair of carbon-terminated stacking faults along the (-111) and (1-11) planes and the silicon-terminated stacking faults along the (111) and (-1-11) planes. By employing Monte Carlo simulations to model the generation of the dislocations we are able to analyze the density of forest dislocations throughout the system as a function of the shear stress, as well as a function of the temperature, material thickness, and stacking fault density. The results will allow for greater insight into the mechanisms by which leakage current density increases and how the generation of electrically active defects can be reduced through more sophisticated fabrication processes of 3C-SiC.

**UG-24 - Nonlinear Terahertz Responses of Single-Wall Carbon Nanotube Films**

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Single-wall carbon nanotubes (SWCNT) have a versatile, chirality-dependent electronic character and unique one-dimensional (1D) properties that are ideal for optoelectronic applications. Metallic SWCNTs have a gapless and massless electronic dispersion akin to parent material graphene while semiconducting SWCNTs have diameter-dependent direct band gaps. Although their linear optical properties have been extensively studied over the past decade, their nonlinear optical properties remain largely unexplored, particularly in the terahertz (THz) range. Here, we investigate the nonlinear THz response of aligned and unaligned SWCNT films of various chirality compositions. Specifically, we focused on third harmonic generation (THG) arising from the third-order conductivity of 1D massless carriers. We first utilized Fourier-transform infrared spectroscopy and time-domain THz spectroscopy (TDTD) to characterize the film’s linear low-energy dynamics and provide initial insights. For nonlinear spectroscopy, we employed an alternate TDTS setup producing large THz electric field pulses using the tilted-pulse-front technique. Drawing on recently published predictions of third-order quantum behavior in the intraband dynamics of massless carriers in graphene, we expect strongly anisotropic nonlinear responses of 1D carriers in metallic SWCNT films due to their similar, massless band structure. Conversely, we do not expect to observe THG in semiconducting SWCNTs, which lack free carriers. This study presents a unique contribution to the field by offering new insights in fundamental 1D solid-state physics while also giving rise to a new class of efficient, high-frequency THz emitters based on prototypical low-dimensional materials systems.

**UG-25 - Fabrication of ZnO Thin Film Transistors Using Pulsed Laser Deposition**

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High electron mobility makes ZnO thin film transistors (TFTs) a possible alternative to silicon-based TFTs for driving liquid crystal displays and organic light emitting diode displays. Moreover, optical transparency in the visible light region and low deposition temperature make ZnO TFTs a suitable component of flexible and transparent future LED displays. We report the fabrication and characterization of low temperature processed ZnO-based TFTs on glass substrates. ZnO channels were grown by pulsed laser deposition method (PLD) without heating. In addition to the conventional ZnO TFTs composed of metal electrodes, Al-doped ZnO films were evaluated as ohmic and gate electrodes for realizing fully transparent TFTs. High dielectric constant HfO2 was used for the gate insulator layer in order to improve the transfer characteristics. This presentation investigates the effects that changing the deposition method and the growth conditions of HfO2 gate insulator has on the electrical characteristics of TFT. The former is a comparison of the electron beam evaporation and PLD, the latter is a comparison of the atmosphere with or without oxygen gas. We examine the transfer characteristics, transconductance and on/off ratio of ZnO TFTs with these different types of HfO2 gate insulators in order to determine the optimal deposition conditions.

**UG-26 - Conductance Fluctuations in Fabricated h-BN/graphene/h-BN Devices at Low Temperatures**

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Improved understanding of graphene device characteristics is needed for the development of nanoelectronics. Inherent scattering and impurities in graphene/SiO$_2$ devices cause the majority of characterization to be carried out in the diffusive transport regime. Better-quality characterization can now take place because there has been advancement in fabricated graphene/hexagonal boron nitride (h-BN) devices. Hexagonal boron nitride has an atomically smooth surface with no dangling bonds and a small lattice mismatch with graphene, making it a promising substrate for graphene-based nanoelectronics. Quasi-ballistic and ballistic transport regimes can now be explored, and this project focuses specifically on the conductance fluctuations that take place in fabricated h-BN/graphene/h-BN devices in the quasi-ballistic regime. Conductance fluctuations can be used to evaluate device quality because they have distinct characteristics that can be used to infer information about the transport properties of their respective samples. While prior work has investigated the nature of the conductance fluctuations in disordered graphene, exfoliated on SiO$_2$ substrates, there have been no systematic reports of this phenomenon in higher-quality graphene isolated on BN. We have fabricated such devices and have studied their conductance fluctuations by applying a magnetic field perpendicular to the device. Conductance fluctuations generated by varying both magnetic field and gate voltage are investigated at low temperatures (≥0.3 K). In our presentation we discuss the differences exhibited by the quantum fluctuations in these samples, and those exhibited by lower-quality graphene. Our efforts contribute to the need for increased knowledge about graphene’s unique transport properties and the invention of new nanodevices.


**UG-27 - Electroporation-introduced Gold Nanoparticles for Surface Enhanced Raman Spectroscopy of Biomolecules in Cells**

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Surface Enhanced Raman Spectroscopy (SERS) is a rapidly growing area of research which offers many applications in biomedical sciences. For example, this technique can be used to study molecular details of cellular processes or in disease diagnosis. SERS of biomolecules in cells relies on the introduction of metallic nanoparticles (NPs) which act as SERS probes. This is typically accomplished with passive cellular uptake through endocytosis. Endocytosis has several drawbacks, including a long incubation time for particle uptake and severe limitations on molecular information because particles are encased in lipid endosomes and are therefore not free in the cytoplasm. An alternative method for particle delivery, the creation of transient membrane pores through electroporation, was introduced recently and offers potential to solve these issues. Particle introduction with this method is faster than endocytosis, and NPs are expected to be free in the cytoplasm of the cell. We focus on the introduction of gold nanoparticles (AuNPs) into HeLa cells. Various parameters for electroporation were tested, and their effectiveness was ascertained by taking photoluminescence (PL) images with a 532 nm laser which causes strong PL of gold. PL method was chosen to allow for the location of AuNPs within cells to be determined despite the high lipid content of HeLa cells. We then performed SERS analysis, directly following PL imaging, with a slit-scanning Raman microscope (excitation wavelength 590 nm) on cells with particles introduced through electroporation and endocytosis to compare the spectral differences and similarities between the two methods of NP delivery.

**UG-28 - Transferring Carbon Nanotubes and Graphene onto Antireflective Surfaces for High-efficiency Solar Cells**

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Solar cells and flexible electronics are important topics today as the energy and technology industries are two of the fastest growing ones. By texturing a silicon surface, it develops antireflective properties for use specifically in CNT film and graphene solar cells, where we will also be able to test the limits of flexibility of those two materials across a rough surface. Based on a recipe from literature, for substrate preparation we etched pyramids out of the silicon substrate along the 111 plane by using sodium hydroxide after cleaning the native oxide from its surface and then etched it using a solution of Metasilicate-nonahydrate, potassium hydroxide, and isopropyl alcohol. By varying the concentrations, we constructed relationships between the variables and pyramid size and
optimized the surface to have the most uniform, smallest pyramids possible. We investigated the contact between the etched surfaces and graphene and carbon nanotube films by SEM imaging and Raman mapping. While similar substrates have been previously studied; our research brings more detail to the subject as we investigate specifically the substrates covered with CNT films and graphene beyond fine tuning the etching process. We compared the efficiency of CNT and graphene solar cells and quality of contact between CNT films and graphene using substrates with variously rough silicon surfaces. Finding the limits on the flexibility and relative solar cell efficiencies of CNT film and graphene on these surfaces leads to improving CNT and graphene solar cells as well as sets new opportunities into flexible electronics.

**UG-29 - Protection of the Optical Properties of Few Layer 2D Phosphane**

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Over the past year, the discovery and development of 2D black phosphorus (2D Phosphane) has generated much excitement due to its high carrier mobility, strong anisotropy, and direct bandgap. 2D phosphane’s bandgap exhibits a significant layer dependency allowing for tunability from 0.3 eV (bulk) to 2 eV (monolayer), making it a versatile material for optical applications. The primary issue preventing the integration and development of 2D phosphane is the material’s ambient degradation. In the presence of light, water, and oxygen, black phosphorous undergoes a rapid photoassisted oxidation reaction resulting in the destruction of its electronic and optical properties. This project characterizes this ambient degradation by photoluminescence and goes on to demonstrate an effective method of protecting the crystal’s optical properties with the use of thin layered hexagonal boron-nitride (h-BN). This project paves the way for the future use of 2D phosphane in a variety of different optical applications and devices.

**UG-30 - Study of Electromagnetic Wave Absorption in Graphene**

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We consider the possibility of theoretically achieving 100% absorbance in single layer and bi-layer transparent graphene systems. Transparent graphene is useful for optical devices, such as liquid-crystal displays (LCDs) and light-emitting diodes (LEDs). However, in order to develop other optical devices, such as photodetectors, optical antennas, and solar cells, high optical absorption in graphene is required to generate a sufficiently large photocurrent. Current methods are much more complicated and expensive, thus making them less viable and accessible. Our objective is to use incident electromagnetic waves in the terahertz region to enhance the optical absorption of the graphene systems. We will place the single layer graphene in between two separate dielectric media to construct a total internal reflection geometry, and we will add a second graphene layer and a third dielectric medium to construct the bi-layer graphene’s total internal reflection geometry. The total internal reflection geometry is desired because it produces the highest absorbance values. This work is very similar to M. S. Ukhtary, E. H. Hasdeo, A. R. T. Nugraha and R. Saito’s paper “Fermi energy-dependence of electromagnetic wave absorption in graphene” where they theorize 100% optical absorption of graphene with microwaves. With terahertz waves, we have theorized nearly 100% absorption with both single-layer and bi-layer graphene systems and these results can allow for the development of the other optical devices listed earlier. This talk will demonstrate how changing parameters that affect graphene’s conductivity and optical absorbance can create a graphene system with an optical absorbance of 100%.
**UG-31 - Eliminating Gate-Voltage Hysteresis in Suspended Single-Wall Carbon Nanotube Field-Effect Transistors**

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Single-Wall Carbon Nanotubes (SWCNTs) have an immense potential to revolutionized modern day electronics and optoelectronics due to their unique optical and electronic properties. Particularly, semiconducting SWCNTs have a direct band-gap, allowing one to take advantage of both optical and electronic properties in a device. One such device is the SWCNT field-effect transistor (FET). However, SWCNT FETs exhibit gate-voltage induced hysteresis and time-dependent behavior. This hysteresis, likely caused by atmospheric and environmental effects, prevents one from truly ascertaining the gate-dependence on multiple properties of the device. In this study, we fabricated suspended SWCNT FET devices, performed photoluminescence excitation (PLE) spectroscopy, as well as creating a vacuum box (through modification of an optical microscopy cryostat) in order to measure the pressure-dependence of hysteresis of chirality-assigned SWCNTs. We observed an elimination of hysteresis in both current vs. gate-voltage and PL vs gate-voltage in low-pressure environment. Finally, we also observed a gradual recovery of hysteresis after exposing the low-pressure samples to air. By developing an easy to use and reproducible method of eliminating gate-induced hysteresis, we anticipate that these results can help us better explore crucial optoelectronic properties of SWCNT devices.

**UG-32 - Searching for Two Higgs Modes in Superconducting MgB₂ Using Terahertz Pump – Terahertz Probe Spectroscopy**

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MgB₂, a metallic superconductor, is known to exhibit a two-superconducting-gap structure associated with two bands, termed \( \pi \) and \( \sigma \) bands, at the Fermi level. This two-band structure serves as the perfect platform to study some interesting physical phenomena. Here, we utilize this two-band structure to detect and study the two distinct Higgs modes in MgB₂ and their interactions. Using terahertz pump – terahertz probe spectroscopy, we examined the ultrafast reactions of the order parameter of our 60-nm-thick MgB₂-film sample to nonadiabatic excitation in the \( \pi \)-band caused by a monocycle THz pulse. In our initial test for the Higgs mode, we generated and detected forced oscillations of the order parameter in the \( \pi \)-band and high-frequency forced oscillations in the larger \( \sigma \)-band. Whereas the \( \pi \)-band Higgs mode is considered to be excited through the nonadiabatic excitation by the incident THz pulse, the \( \sigma \)-band Higgs mode excitation suggests coupling between the two Higgs modes since the incident pulse was not in the nonadiabatic excitation regime of the \( \sigma \)-band. With this, we believe that there is a distinct connection between the two Higgs modes, and through further tests of MgB₂, we hope to detect the relaxed oscillations and interactions of the two Higgs modes. This ongoing study can lead to a fundamental understanding of how multiple Higgs modes interact and, at the same time, provided us with a powerful tool to study more complex multiband superconductors such as iron-based superconductors.

**UG-33 - Terahertz Emission and Detection in Graphene-Based van der Waals Heterostructures**

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The terahertz (THz) frequency band of the electromagnetic spectrum, located between radio waves and light waves, offers many applications within non-invasive screening technologies and ultra-broadband communications. Some devices are capable of operating within this band, but due to limitations, there are no commercially viable devices that can operate across the THz range. Here, we investigate the gated double graphene layer heterostructure (G-DGL) for emission and detection of THz radiation by photon-assisted quantum mechanical resonant tunneling. To examine the phenomena, we use two different experimental setups. In our photo-detection setup, we use a uni-traveling-carrier photodiode (UTC-PD)-type photomixer to generate continuous THz waves at 0.3, 0.5,
and 1.0 THz. The generated THz radiation is directed to the sample by an adjustable Indium Tin Oxide (ITO) mirror. By adjusting the angle of the ITO mirror, we alter the photonic and plasmonic responses in the G-DGL, and then measure the tunneling current. For the stimulated emission setup, we considered electro-optic sampling (EOS) of time-domain spectroscopy to optically pump G-DGL. To calibrate the EOS system, we first observed the stimulated THz emission in monolayer graphene using a CdTe crystal. A 1.55-μm, 80-fs pulsed laser pumps the graphene sample and CdTe crystal. The optically rectified CdTe generates a THz probe pulse along the Cherenkov angle and is reflected at the top surface of the CdTe back to the graphene sample. These results characterize the in-plane spatial distribution of the polarization-sensitive regions where the graphene plasmons are strongly excited for future G-DGL samples.

**UG-34 - Characterizing MoS2-Si p-n Heterojunction Using Laser Terahertz Emission Spectroscopy**

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Atomically thin two-dimensional (2D) materials demonstrate markedly different properties from their bulk (3D) counterparts, which could lead to interesting applications for optoelectronic and electronic devices. Advancements in the creation of these 2D semiconductor materials have expedited the fabrication of a variety of 2D-2D and 2D-3D van der Waals heterojunctions with novel properties compared to those of typical covalently bonded semiconductor junctions. However, the characteristics of 2D-3D semiconductor junctions have not yet been extensively studied and are therefore not well understood. In this study, we examined the emission of terahertz radiation from a heterojunction created with n-type monolayer MoS2 and p-type bulk Si using laser terahertz emission spectroscopy. The results of this study will provide new insight into the nature of the MoS2-Si p-n junction energy states (e.g., band alignment and bending) as well as allow us to better understand how the properties of 2D-3D junctions differ from those of conventional 3D-3D junctions.

**UG-35 - Fabrication of ZnO Thin Film Transistors Using Pulsed Laser Deposition**

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High electron mobility makes ZnO thin film transistors (TFTs) a possible alternative to silicon-based TFTs for driving liquid crystal displays and organic light emitting diode displays. Moreover, optical transparency in the visible light region and low deposition temperature make ZnO TFTs a suitable component of flexible and transparent future LED displays. We report the fabrication and characterization of low temperature processed ZnO-based TFTs on glass substrates. ZnO channels were grown by pulsed laser deposition method (PLD) without heating. In addition to the conventional ZnO TFTs composed of metal electrodes, Al-doped ZnO films were evaluated as ohmic and gate electrodes for realizing fully transparent TFTs. High dielectric constant HfO2 was used for the gate insulator layer in order to improve the transfer characteristics. This presentation investigates the effects that changing the deposition method and the growth conditions of HfO2 gate insulator has on the electrical characteristics of TFT. The former is a comparison of the electron beam evaporation and PLD, the latter is a comparison of the atmosphere with or without oxygen gas. We examine the transfer characteristics, transconductance and on/off ratio of ZnO TFTs with these different types of HfO2 gate insulators in order to determine the optimal deposition conditions.
**RET-1 - Solar Steam Generation by Heat Localization using Broadband Light-Absorbing Nanoparticles**

**Greg Adragna**

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Conventional generation of steam requires much energy due to the physical characteristics of water and the requirement that the bulk liquid must be heated to the boiling temperature. Steam has long been used for many important processes, such as, the production of work and sterilization. Research in the areas of photonics and plasmonics has produced a new method for producing non-equilibrium steam using the light-absorbing properties of tuned metallic nanoshells and conductive carbon nanoparticles. These nanoshells and particles react almost immediately with sunlight and, on sustained illumination, a vapor envelope develops and grows around the nanoparticle eventually resulting in buoyancy. When the nanoparticle-bubble reaches the surface of the liquid the steam vapor is released and the nanoparticle returns to the liquid without being degraded. This process also heats the bulk liquid and a combination of the processes result in steam production with less energy and lower water temperature.

**RET-2 - Inexpensive Nanoparticles for Direct Solar Membrane Distillation**

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The demand for fresh water will continue to increase as a result of population growth and limited resources to accommodate needs in underdeveloped countries. Current methods to desalinate water have proven to be energy consuming and environmentally harmful which lead to unmanageable costs. Membrane distillation is widely used but methods to make the process more cost effective and sustainable are greatly needed. Solar desalination coupled with carbon black nanoparticles is a low maintenance, cost effective method that can enhance membrane distillation and the production of fresh water. When coupled with solar energy, carbon black nanoparticles have been shown to increase heat production causing the distillation process to yield a higher flux and operate with greater efficiency. Through the use of a renewable energy source and nanophotonics fresh water demands can be accommodated in an energy efficient, environmentally safer, and cost effective manner.

**RET-3 - Density and Porosity of Biochar - Density and Porosity Changes**

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Biochar is the solid, carbon rich product of heating biomass with the exclusion of air. If added to soil at a large scale biochar has the potential to benefit global agriculture and mitigate climate change. Biochar locks up rapidly decomposing carbon in plants and carbon emissions in the air by storing it in small nm size pores. These storage chambers can hold carbon anywhere from hundreds of years to thousands of years. Biochar through intentional human amendment to sequester C can provide other agronomic benefits. Density and porosity are fundamental characteristics that control how biochar moves through the landscape, how it interacts with water to alter the soil hydrologic cycles. We sampled slow pyrolysis biochars from various biomass charred from 450-700°C. Skeletal density was measured using an Accupyc 1340, which measures the skeletal volume by volume displacement of helium, to measure envelope density we used the Geopyc 1360 which measure by displacement of a dry granular suspension under a controlled pressure, and is calculated as a function of skeletal and envelope densities. The chart represents average envelope density from biomass charred from Australia and the graph represents skeletal and envelope density of miscanthus and mesquite biochars as a function of pyrolysis temperature. Biochar skeletal density consistently increases with pyrolysis temperature, whereas envelope density decreases from 300 to ~450°C and remains constant beyond 450 °C.
**RET-4 - Developing a Model to Demonstrate the Use of Polymeric Self-Assembled Microspheres in the Removal of Contaminants from Groundwater**

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This study seeks to use the “physical, chemical, and engineering properties that go beyond the component building block molecules or structures” to construct a visual model that combines Prof. Michael S. Wong’s polyamine-salt aggregate synthesis, with a lab demonstration emulating the encapsulation of model environmental contaminants using food coloring. This secondary school hands-on lab is expanded to allow students to test, compare and contrast the electrostatic interaction of poly(allylamine hydrochloride) (PAH), a weak cationic polyelectrolyte that to different degrees cross links with model dye compounds in solution such as indocyanin green (ICG), Rhodium B and Fluorescein sodium salt. The adsorption of each dye is also tested against activated carbon (Darco G-60), Mineral Oil, and Iron Oxide (Fe₃O₄). If any of the fluorescent dyes remain in solution or are not adsorbed, these can be readily observed via eye. The degree to which adsorption has or has not occurred can be measured and compared using the spectral absorption analysis with a range between 300-900 nm. Visual verification of adsorption that corroborates spectral absorbance analysis will complete testing using a microscope with an oil immersion resolution of 1000x to obtain digital images that support spectral analysis.

**RET-5 - Synthesis and Characterization of Metamagnetic TbPtIn**

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In this work, single and polycrystalline samples of TbPtIn were characterized by comparing their magnetic properties. Single crystals of TbPtIn were synthesized using the liquid flux method. The polycrystalline form was synthesized using arc-melting and then annealing. The crystal structure of both samples was identified as hexagonal P62m TbPtIn using powdered x-ray diffraction. Temperature dependent magnetization under an applied field of 1000 Oersted indicated antiferromagnetic order with the Néel temperature higher for the poly crystal as compared to the single crystal. An analysis using the Curie-Weiss law indicated that a magnetic moment similar to that of Tb. Fielddependent magnetization measurements at 2 K revealed metamagnetic in the single crystal while the singular transition in the poly crystals was less pronounced. In temperature-dependent resistivity measurements, polycrystalline sample exhibited higher residual resistivity. Moreover, the feature corresponding to the ordering temperature was less pronounced than that observed in the single crystal data. In conclusion, by analyzing the metamagnetic TbPtIn, we demonstrates the importance of synthesizing samples in the single rather than polycrystalline form.

**RET-6 - Analysis of axial ligation of N-methylimidazole to dirhodium tetraacetate complex**

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Efforts have been made to use protein metalloinhibitors containing dirhodium tetraacetate, Rh₂(OAc)₄. Steric hindrance of the axial positions could decrease the binding activity while increasing complex stability. This work was designed to determine the dissociation constant at the axial positions and to determine how bulky substituents on the rhodium affect binding constants. A solution of dirhodium tetraacetate was titrated with N-methylimidazole (ligand) and monitored by UV-visible spectroscopy (UV-vis). As the ligand is titrated into the rhodium complex, the maximum of the UV spectrum is shifted to a lower wavelength. The solution turned from a pale blue to pink, indicating displacement of oxygen by coordination of nitrogen to the rhodium core.
**RET-7 - Low-Cost Disposable Cartridge for Performing a White Blood Cell Count at the Point-Of-Care**

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According to Buchegger et al (2014) neonatal sepsis is still the leading cause of death among newborns. There is a need to design a low-cost disposable cartridge for performing white blood cell count at the point-of-care to determine sepsis. We tested and designed a cartridge that would be able to determine sepsis by counting white blood cells in neonates. The cartridge is composed of a glass slide, a layer of transfer tape, and a glass cover slip which contains acridine orange for staining cells. The design for the slide was an important part of the mixing process of acridine orange and the blood for staining. We can view the cells under a microscope that is designed to be cost effective as well. This allows for quick diagnosis of sepsis in neonatal patients. White blood cells are crucial in determining infection in human patients and can assist in protecting tissues against toxic agents. Being able to count the cells is critical in diagnosing many diseases. This device can be used in low to medium income areas.


**RET-8 - Evaluating the Significance of Cholesterol Oxidation Products in Aging**

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The demand for lengthened life expectancies continue to increase as our population ages and healthcare is improved around the world. Current research in aging looks at cholesterol oxidation products and their influence on the aging process of cells on an individual level. When cholesterol, a normal and healthy component of a cell, is oxidized by conditions in the cell, cholesterol oxidation products occur. These products disrupt the lipid raft of the lysosomal membrane resulting in reduced efficiency in clearing out the cell’s waste products. This is particularly problematic when paired with the presence of lipofuscin, a recalcitrant heterogeneous protein complex that accumulates in our lysosomes as we age and is very difficult for the lysosomes to break down. Through the use of cyclodextrin, a compound known to bind to cholesterol oxidation products, we are able to see promising results in reducing lipofuscin in the cell by up to a third. This mechanism is proposed to result in the slowed aging of the cell and potentially could be used in various drugs to slow down the aging process.

**RET-9 - Characterization of Nonionic and Ionic Surfactants in Aqueous Solutions with Polyethylene-block-Polyethylene Glycol**

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Worldwide energy consumption is expected to increase approximately 50% by the year 2030. As renewable energy sources are still under development, we must also develop more efficient methods for oil recovery to meet this growing demand. Primary and secondary oil recovery techniques typically produce less than 40% of the oil in a reservoir; Enhanced Oil Recovery (EOC) methods can be used to extract large amounts of the remaining hydrocarbons. In porous media, aqueous solutions of surfactants and polymers have been shown to greatly reduce viscosity and recover up to 89% of remaining oil. In this study we characterize the properties of multiple surfactants with the polymer Polymer Polyethylene-block-Polyethylene Glycol (PE-PEG). The critical micelle concentration of these Surfactants and the PE-PEG polymer were measured using surface tension data obtained from the KRUSS K100 Tensiometer. The phase behavior of ternary systems that included water, surfactant, and octane were studied at various salinities with and without the addition of polymer. Interfacial tension (IFT) between the two densest phases was measured once each system reached equilibrium. Interfacial tensions were measured using a KRUSS DSA100 Drop Shape Analyzer and SITE100 Spinning Drop Tensiometer. To significantly increase the mobility of oil in a reservoir interfacial tensions below 10^{-2} \text{mN/m} are required. The addition of 0.1% by weight of PE-PEG polymer decreased the IFT for some surfactants by a factor of 10 while others were unaffected.
The Alfoterra surfactant S23-71SM yielded the lowest IFT at $6.5 \times 10^{-4}$ mN/m when at 6% salinity. Future research seeks to find surfactant-polymer blends which are nontoxic, low cost, and effective at the high temperatures and salinities found in many reservoirs.


**RET-10 - Mass Transfer at the Nanoscale**

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In this study we seek to explore correlations between electrolyte concentration and mass transfer at the nanoscale in order to say with certainty that a certain amount of mass transfer was done. The procedure begins with running full wavelength scan of a known concentration using the Ultraviolet–visible spectroscopy (UV-Vis). The results will allow us to determine the concentration of that sample using Beer’s Law. Once we electroplate decahedral particles of Gold with Copper we take a UV-Vis absorbance reading of the solution used in electroplating to ascertain the new concentration of the solution. Once that concentration has been attained we can correlate that with the electrolyte charge and have a formula to calculate the exact transfer of mass to the nanoparticle. Future research will involve Anjli working with the results of my analysis of absorbance readings and putting it together with the readings of electrolyte concentration and work to produce those calculations that will allow us to know the mass transferred unto the nanoparticle.


**RET-11 - Effects of cellular uptake of TiO₂ nanoparticles on autophagic vesicle accumulation**

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Autophagy is a biochemical pathway by which cellular components or foreign materials are engulfed in a vesicle called an autophagosome and subsequently digested by lysosomal enzymes. Autophagy occurs at basal levels in healthy cells and may be activated in cells under stress. The autophagosome assembles after autophagy activation, which becomes apparent with the conversion of the protein LC3-I to LC3-II. Since LC3-II is found only in autophagosomal membranes, cellular levels of LC3-II are a reliable indicator of autophagy activation; however, LC3-II accumulation can also indicate a failure of autophagosome clearance. When the lysosome fails to fuse with the autophagosome, there will be a blockage in autophagic flux, resulting in an accumulation of LC3-II. It is hypothesized that at certain sizes and concentrations, TiO₂ NPs may induce autophagy and may also block autophagic flux by impairing lysosomal function. To test this, we drugged HeLa cell samples with three TiO₂ nanoparticle sizes (15, 50, and 100nm) at two concentrations (10 and 100µg/mL), either with or without the drug bafilomycin, a known autophagic flux inhibitor, and performed western blots to detect LC3-II in the different samples. Our results indicate that 50nm TiO₂ nanoparticles activate autophagy significantly at both concentrations, though the effect is more pronounced at 100µg/mL. 15nm and 100nm TiO₂ nanoparticles activate autophagy significantly at only 100µg/mL. Additionally, autophagy appears to be blocked in the 100nm TiO₂ nanoparticle size and 100µg/mL concentration samples. Our results are consistent with previous western blots as well as data from TFEB nuclear localization experiments.
One of the large-scale natural hazards that affect human life are explosive volcanic eruptions, whose intensity is intimately linked to the manner in which dissolved volatiles, mainly consisting of water, escape from the erupting magma during its ascent to the Earth’s surface. This degassing process begins with bubble nucleation, which therefore is, if not the, critical process during volcanic eruptions. Currently, numerical modeling of nucleation experiments of water bubbles in magma suggests that Classical Nucleation Theory, on which predictive models of bubble nucleation are based, is not completely sufficient to predict bubble nucleation rates in silicate melts. This suggests that the nucleation work, the key parameter within the Classical Nucleation Theory, has a non-constant surface energy term. Here we seek to determine the dependency of this surface energy term on other parameters, such as the degree of supersaturation of dissolved water or decompression rate of magma, to more accurately model bubble nucleation and therefore magma degassing. For this purpose, experiments wherein variably water-saturated rhyolite melt was decompressed at variable rates, before being quenched to glass, provided samples of rhyolitic glass containing large numbers of micron-size vesicles, which formed by nucleation of vapor bubbles during sample decompression. These glass samples were then analyzed for the number density and size distribution of vesicles. These, in turn, provide essential constraints on planned numerical models of the bubble nucleation and growth during each experiment, from which a more accurate description of surface energy will be obtained.

In this work, we used Texas Commission on Environmental Quality (TCEQ) data from 2004 to 2014 to determine ozone, PM2.5 and NOx trends for individual monitors for the 5th, 25th, 50th, 75th, and 95th percentiles and mean of MDA8 ozone values and aggregated the results by season. We determined significance of multiyear trends using the regression data analysis tool in Microsoft Excel which we considered significant for p-values less than 0.05. We find that decreasing ozone trends generally occur in the warm season (May to September) and at the upper end of the ozone distribution (the 95th percentile). Ozone concentrations in the cold season (October to April) showed a mixed trend. Ozone concentrations are both increasing and decreasing. Further, the p-value for monitors C8, C15 and C45 indicate a decreasing trend and are statistically significant. Similar analysis of NOx and PM2.5 show decreasing trends in warm seasons for both NOx and PM2.5 respectively. However, trends are mixed in cold seasons at monitors C8, C78 and C572 (Aldine, Conroe and Clear Lake). These areas are characterized by less anthropogenic NOx emissions and more biogenic activity (emission of hydrocarbons by plant life). Further, decreasing trends in ozone concentrations at the 95th percentile would capture the 4th highest 8-hour maximum by decreasing the average maximum ozone daily concentrations. The Environmental Protection Agency (EPA) set a standard of 0.075 ppm (8-hour averaging, fourth highest daily maximum averaged over three years). This work also agrees with the assertion of H. Simon and A. Reff that decreasing trends in ozone demonstrates the large scale success of U.S control strategies targeted at decreasing peak ozone concentrations.
**UG-R-1 - Modification of the Microvasculature Microscopy (MVM) Device using a Digital Light Processor (DLP) for a More Efficient Needle-free Diagnosis of Malaria at the Point-of-Care (POC)**

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Globally, a high infant mortality rate in malaria-endemic regions has emphasized the need for a more efficient tool for the diagnosis of malaria. The Microvasculature Microscopy (MVM) is an optical diagnostic tool designed for *in vivo* microscopy to detect and quantify the presence of hemozoin, a byproduct of the malaria parasite, in the blood based on absorption properties of blood vessels in the green spectrum, and hemozoin in the red spectrum. MVM currently comprises a white LED illumination passing through a green filter ($\lambda$550nm) and red filter of ($\lambda$640). This research evaluates the modification of the MVM by using a Digital Light Processor (DLP) as the single illuminating component of the device. Given the ability of the DLP to project various patterns and wavelengths, we aim to achieve simplicity by creating both green and red illumination modes using the DLP eliminating the need for multiple filters. Optical modifications were made, including the addition of a liquid lens. The resulting green light from the DLP provided sufficient power required to identify superficial blood vessels in the human oral mucosa. We employed dark-field illumination technique to reduce light reflections from the tissue and improve image quality. Further research will focus on synchronizing the DLP projector and CMOS camera to allow for optical sectioning, examining image quality in red illumination, and developing an auto-focus algorithm.

**UG-R-2 - Engineering Adeno-Associated Virus to Decrease Phagocytic Clearance**

Chioma Okorie, Tawana Robinson, and Junghae Suh

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Adeno-Associated Virus (AAV) shows promise as a vector for gene delivery because it is non-pathogenic, has simple genome, and low Immunogenicity. A significant progress in AAV is the development of an AAV gene delivery vector, known as glybera, which is used to treat lipoprotein lipase deficiency. However, one of the limitations of using AAV as a gene therapy vector is that majority of the population already has pre-existing anti-AAV antibodies. Although strategies such as immunosuppression decreases the neutralizing effects of an antibody response, this may adversely affect the ability of the immune system to effectively fight disease. As such, there is need for a better way to address this problem. Our solution is to design AAV with a minimal peptide inserted at the distal amino acid of the VP1 capsid protein for effective receptor-receptor interactions. The peptide mimics a stealth molecule in the human body to evade phagocytosis. Using both site-directed mutagenesis and ligation procedures, our aim is to mutate the unwanted cleavable site and insert the stealth peptide at the distal position. This research has the potential to improve the widespread clinical use of AAV as a vehicle for gene delivery.

**UG-R-3 - Nitrogen and carbon partitioning between Fe-rich alloy melt and silicate melt**

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Nitrogen and carbon are essential ingredients for a habitable Earth. However, the origin and distribution of both nitrogen and carbon in Earth’s different reservoirs remains poorly understood, although it is known that the main component of our atmosphere is nitrogen gas. During the accretion of our Earth, due to radiogenic heating and extraterrestrial impacts, early Earth may have been partially or completely molten, forming a so-called “magma ocean”. At this point, Iron-rich metal separated deep into the Earth forming the core. So far, the potential impact of core-formation on the Earth’s nitrogen and carbon cycle has rarely been investigated.
An understanding of nitrogen and carbon chemistry in the “magma ocean” is the first step to understanding their origin and distribution in Earth. We therefore designed experiments to attempt to measure how much nitrogen and carbon could partition into the core, how much nitrogen and carbon would be retained in the silicate mantle just after complete core-mantle separation, and which possible carbon and nitrogen species are in the “magma ocean”. Our experiments were performed at a fixed pressure of 2 GPa and temperatures of 1500-1800 °C to measure the partition coefficients of nitrogen and carbon between coexisting iron-rich metal and basaltic melt (2 GPa = 2 × 10^9 Pa). We used a high-pressure apparatus called a “piston cylinder”, which can generate pressures up to 4 GPa and temperatures up to 1800 °C. Preliminary results indicate preference of metals by Nitrogen gas.

UG-R-4 - Observations of the Growth of Gold Nanobelts

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Improved methods for synthesizing nanoparticles and structures have been essential to developing nanotechnology. Directly observing nanoparticles while they grow may yield important insight into improving their synthesis, which has been difficult due to the unsuitability of typical optical and electron microscopy. Gold nanobelts have nanoscale cross section and microscale length, which makes them suitable for observation in an optical microscope. Time-lapse photography was used to capture the formation of these 1-D nanostructures in solution. Gold nanobelt synthesis involves the reduction of tetrachloroauric acid (HAuCl₄) with L-ascorbic acid in a solution of two common surfactants (SDS and CTAB). For this experiment, a Zeiss Axiovert microscope with an attached Nikon D5000 camera and an intervalometer was used to capture images of a gold nanobelt synthesis taking place in a capillary tube. The gold nanobelts appear to elongate quickly from gold nanoparticles near the beginning of the reaction and then thicken slowly as the reaction continues. By understanding how nanobelts grow, we can improve the quality and yield of the reaction, possibly leading to improved gold waveguides and atomic force microscopy probes, as well as other nanostructures suitable for biomedical applications.

UG-R-5 - Systematic Studies on Synthesis of Gold Nanodecahedra Particles

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Gold Nanoparticles (AuNPs) have many physical and optical properties which can be used for high end technologies, such as in devising different sensors or probes and in the medical field. AuNPs can have different sizes and shapes, and their interaction with light and with other materials is mainly dependent on both their size and shape. For this reason it is important to optimally synthesize the AuNPs to achieve homogeneity in the desired shape and size. In this study, we performed systematic studies on decahedra AuNPs to determine how temperature, stirring speed, concentration of auric chloride and other variables affect the size and homogeneity of AuNPs. Different synthesis methods were performed to determine what temperature, stirring speed and concentration of Auric Chloride is needed to get certain sizes of decahedra nanoparticles. The synthesized AuNPs were characterized using Scanning Electron Microscopy (SEM) for size and shape distribution of the particles. A strong correlation between particle size and optical response was also noticed by using a UV-VIS-NIR spectrometer. It was examined that the average size of decahedra AuNPs decreased as the stirring rate was increased. Lowest stirring speed which was 200 RPM yielded nanoparticles which were 30 nm bigger than the particles synthesized using 900 RPM. Low stirring speed also yielded more homogenous nanoparticles. It was also determined that high concentration of Auric Chloride yielded bigger and more homogenous nanoparticles while low concentration yielded smaller and less homogenous particles.

UG-R-6 - Carbon Nanotubes for use in Lithium-ion Battery Cathodes and Other Electrical Applications

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The need to enhance existing technology for uses in various electronic, textile and pharmaceutical applications is paramount. However, the search to find alternate materials as advanced as our current devices has been a challenge. The lithium ion battery (LIB)
is predominantly used to power devices because it has a higher energy and power density than other batteries. The cathodes that are typically used in these batteries have low conductivity and use inactive materials such as binders and current collectors. Therefore, these commercial cathodes have significant weight of inactive material. The goal of this study is to eliminate inactive material and improve the portability and cyclability of the cell as well as reduce the thickness. The active material LiFePO₄ (LFP) was used and processed with carbon nanotubes (CNT). The mixture is combined, forming a conducting network of CNTs and are dispersed among the active material. CNTs are flexible, thin and conductive, and as a result, so is the cathode material. Our methodology shows the unique fabrication and use of the LFP composites that decreases the amount of inactive materials and eliminates the use of high temperature processing and the formation of volatile organic compounds.

**UG-R-7 - Stimulus Responsive Wing-Flap with Shape Memory Effect**

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Technology has developed surprising advances in smart materials such as shape memory materials (SMMs) and stimulus responsive materials (SRMs). SRMs are a type of SMM that responds to a particular stimulus by altering their physical properties. Alteration of the physical properties allows some SRMs to undergo a temporary change in shape that can be stimulated to return to its original form. The purpose of this research was to design and create an efficient stimulus responsive wing-flap with shape memory effect that can be controlled by increasing or decreasing the turbulence or control of air with the smart-flap when stimulated. The smart-flap was created by using preset shape memory nitinol (NiTi) strips embedded into a carbon nanotube treated thermoplastic elastomer (TPE) matrix. Morphing movements of the smart-flap were controlled with a solid, fixed base embedded through the middle of the matrix, allowing contact with the NiTi strips. The base allowed delivery of the appropriate stimulus to the NiTi strips inducing the shape memory effect to take place, producing the desired and controlled morphing movements of the smart-flap. When devices such as vanes are made of TPEs, the motor that controls the device consumes less electrical energy. The resulting smart-flap is an energy efficient device that delivers effective flexibility in morphing shapes that allow control of air similar to flight. It can also be adapted to different systems such as in aerodynamics, fans, or agitators.

**UG-R-8 - Synthesis of Graphene Quantum Dots from Biochar**

*Oanh Hoang1, Andrew Metzger2, Macy Stavinoha2, Zonghao Zheng2, James M. Tour2*

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Photoluminescent graphene quantum dots (GQDs) have been recently synthesized from coal by reaction in concentrated sulfuric acid and nitric acid. This is a significant improvement to the synthesis of GQDs compared to previous syntheses using fullerene, glucose, graphite, graphene oxide, carbon nanotubes and carbon fibers. Here we report an exciting further improvement of synthesis of GQDs from coal by using nitric acid only. By removing sulfuric acid, this method becomes less dangerous, faster, and produces better GQDs with narrower polydispersity. In this study, we used biochar to obtain GQDs around 10 nm in diameter, and these GQDs emitted blue light under 365 nm excitation UV lamp. Photoluminescence quantum yield can be improved via hydrothermal reduction followed by borohydride reduction.
Using a bottom up approach, chemical synthesis of silver nanoparticles was obtained by the combination of silver nitrate with copper nanoparticles in a galvanic replacement reaction. The copper nanoparticles were synthesized from copper sulfate, coated with gum acacia, and hydrazine as reducing agent. In an attempt to identify ideal reagents to control for uniformity in size and morphology of nanoparticles, varying concentrations of precursors, surfactants, capping agents, and solvents were used. Capped-bottle reactions were implemented to limit environmental exposure to avoid surface oxidation during the initial phase of building the copper nanoparticles, which are highly reactive in open air. Both cetyltrimethylammonium bromide (CTAB) and gum acacia were used as capping agents with the latter preferred due to shorter reaction time and ability to produce stable nanoparticles for storage. Varying concentrations of reagents yielded different quantities, sizes and shapes of copper nanoparticles ranging from 50-200 nm in diameter. SEM, EDS, TEM and XPS were used to characterize the size and shape of particles.

Gadolinium oxide nanoparticles have been well-known for their function as a T1 magnetic resonance imaging (MRI) contrast agent. Gd$_2$O$_3$ nanoparticles are often immobilized in polar structures such as carbon nanotubes and mesoporous silica nanoparticles. To enable the immobilization, the synthesized Gadolinium oxide nanoparticles in organic phase must be transferred to water phase to be able to interact with the biological environment. The synthesis of Gd$_2$O$_3$ nanoparticles will be presented using the thermal decomposition method. Particles were collected and purified in a mixture of acetone and hexane by centrifuge. Gd$_2$O$_3$ nanoparticles were water transferred by using CTAB (hexadecyltrimethylammonium) with different concentrations. The stability of these particles was then measured by DLS (Dynamic Light Scattering) over two weeks. The results of this Gd$_2$O$_3$ nanostructure showed a contrast agent of high stability and good performance.
Oral Session 3: 1:30 pm – 2:45 pm

O-3.1 - Single-Particle Absorption Spectroscopy by Photothermal Contrast

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Plasmonic nanoparticles exhibit interesting radiative and non-radiative properties upon their interaction with light. These properties have been widely exploited for a variety of intriguing applications in fields ranging from chemistry to biology and photonics. For example, gold nanoparticles can be used for optical probing and sensing, waveguiding, local heating, and optical data storage. Single-particle methods have been utilized to understand the interesting properties nanoparticles. The obtained information is very helpful in order to make rational designs using nanostructures for specific applications. Moreover, these methods make the distribution of variables accessible which otherwise is averaged out in an ensemble of particles. While the radiative properties are well-characterized using fluorescence and scattering spectroscopy tools, studying the non-radiative properties still keeps challenging. Photothermal microscopy is a very sensitive technique that can be used to detect a single nano-object by the heat it generates. Even detection of a single chromophore by its absorption using the photothermal contrast has been shown in literature. However, all these measurements have been performed using a single excitation wavelength limiting the knowledge of pure absorption as a function of wavelength for an individual nano-object. Here, we introduce the evolution of photothermal imaging toward absorption spectroscopy. In order to achieve that, we incorporate photothermal microscopy with a supercontinuum laser source and a correction procedure which accounts for the effects of chromatic aberration and wavelength dependent excitation efficiency on the measured absorption spectrum. The single-particle absorption spectroscopy we develop can benefit applications of individual plasmonic nanostructures in photonics and optoelectronic devices.

O-3.2 - Reconstructing Multiple Free Energy Pathways of DNA stretching from Single Molecule Experiments

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Free energy landscapes provide information on the dynamics of proteins and nucleic acid folding. Single molecule force spectroscopy has been demonstrated to be able to reconstruct such landscape using Jarzynski's equality, which requires only stretching data. When the process is reversible, the Crooks fluctuation theorem provides rapid convergence of free energy estimates of different states by combining both stretch and relaxation force data. In this study, we demonstrate that the Crooks fluctuation theorem can be used to reconstruct the full free energy landscape. In addition, when the free energy landscapes exhibit multiple folding pathways, Jarzynski's equality can be used to reconstruct individual pathways if their work distributions obtained from experiment are distinct. We applied the method to reconstruct the free energy pathways of stretching poly(dA) to demonstrate that the nonequilibrium work theorem combined with single molecule force measurements provides a clear picture of the free energy landscapes.

O-3.3 - Gold Nanorod Supported Phospholipid Bilayer Structures and Phases Detected by Surface Enhanced Raman Scattering

James Matthews,1 Courtney Payne,2 and Jason Hafner1,2

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2Department of Chemistry, Rice University, Houston, Texas

Surface enhanced Raman scattering (SERS) and localized surface plasmon resonance sensing (LSPR) have been applied for a detailed analysis of lipid bilayers at the surface of gold nanorods. The spatial dependence of surface enhancement and the optical effects of the lipid phase transition confirm the presence of a bilayer membrane structure. Deuterated lipids exchanged rapidly between the nanorod surface and lipid vesicles in solution, suggesting a loosely bound, natural membrane structure. However, at a low solution concentration of lipid vesicles, the lipids on the gold nanorod surface convert to a non-bilayer structure, which could have a significant impact on biological applications of these nanomaterials.
O-3.4 - Intermediate valence to heavy fermion through a quantum phase transition in Yb₃(Rh₁₋ₓTx)₄Ge₁₃ (T = Co and Ir)

Binod K Rai and E. Morosan

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The A₃T₄Ge₁₃ compounds (3-4-13), where A is a rare earth or alkaline earth, T is a transition metal and M is a group 14 element, exhibit a diverse set of properties such as magnetism and superconductivity,[1,2] structural phase transitions,[3] intermediate valence and heavy fermion behavior.[4,5] The compounds with unstable 4f shell rare earths like Ce and Yb can change their ground state from magnetic to non-magnetic, with tuning of the rare earth 4f energy with respect to Fermi energy, upon the application of external parameters such as pressure, doping or magnetic field. This can also lead to intermediate valence, Kondo lattice and heavy fermion behavior.[4,6,7] In addition, quantum phase transitions (QPTs) driven by quantum fluctuations can be reached in magnetically ordered heavy fermions.[8,9] Very few Ce based 3-4-13 compounds have been reported as heavy fermions [10,11] and no Yb based 3-4-13 heavy fermions have been discovered yet. In this talk, I will present the first Yb-based 3-4-13 antiferromagnetic heavy fermion Yb₃Ir₄Ge₁₃, and the intermediate valence compounds Yb₃T₄Ge₁₃ (T = Co or Rh). I will show how the QPT and intermediate valence transition in the heavy fermion compound can be tuned through chemical doping I will also discuss a full characterization and the related science of these single crystals, obtained from various, measurement techniques.

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O-3.5 - Narrowing the plasmon resonance with coupled aluminum nanoparticle-film systems

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Aluminum nanostructures are emerging as a very promising platform for plasmonics. Their ability to support resonances in the visible and UV parts of the spectrum, together with their dramatically reduced cost, make them an ideal alternative to noble metal nanostructures for developing plasmonic applications. In this work, we experimentally demonstrate that the coupling of an aluminum nanoparticle with an aluminum film results in a dipolar plasmon resonance with a surprisingly narrow linewidth and enhanced intensity, relative a gold nanoparticle and films in the same geometry. We interpret this effect as a consequence of the hybridization of the dipolar and quadrupolar plasmons of the nanoparticle allowed by the coupling with the film, which reduces the radiative losses of the dipolar plasmon, and therefore narrows the corresponding resonance. This behavior is in contradiction with the general assumption that closely coupled metallic nanostructures produce more damped plasmons due to the increase in the loss caused by a larger penetration of the local electric field into the metal. Our results point to a new strategy for obtaining narrow plasmonic resonances in aluminum nanostructures, expanding the potential of this material for real-world plasmonic applications.
O-4.1 - Plasmon Hybridization in Doped Silicon Nanocrystals with Two-Component Carriers

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Unlike noble metals, doped semiconductor nanocrystals represent a new type of plasmonic material with optical resonances in the infrared, and have recently gained much interest. The plasmon resonance can here be tuned by altering the doping density. Currently, most studies are on II-VI nanocrystals which are both complicated to fabricate and dope to high carrier density. Very recently it has been shown that Silicon nanocrystals can be doped using Phosphorous and Boron resulting in highly tunable infrared plasmon resonances. Due to the band structure of Silicon, the doping results in two carriers with different effective mass. Here we develop a hybridization theory for two-component carriers both within the quantum TDDFT and the classical regime, which account for the experimental data. Most importantly, as observed in the experiments, the theory predicated one dominant plasmon resonance rather than two branches as would be expected from a simple classical approach.

O-4.2 - Universality in the Equilibration of Quenched Yukawa One Component Plasmas

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A Yukawa one-component plasma (OCP) is an idealized model in which particles interact through a 1/r potential with an additional exponential falloff with length scale inversely proportional to the “screening parameter” κ. The screening parameter depends on both the temperature of the electron component (T_e) and the plasma density (n). This model is used in approximate descriptions of a wide range of physical systems, most notably strongly coupled plasmas. Plasmas in the strongly coupled regime are those which have Γ≥1, where Γ is the ratio of the Coulomb interaction energy between neighboring particles to the kinetic energy per particle.

All dynamics and physical properties in Yukawa OCPs are expected to be universal in κ when expressed in appropriate scaled units, meaning that two plasmas with vastly different n and T_e should nevertheless behave similarly if they have identical κ values. We test this theory by studying the behavior of ultracold neutral plasmas (UNPs), which are created by photoionization of an ultracold atomic gas. This method gives us control over n and T_e, and therefore κ. By comparing experimental data to molecular dynamics (MD) simulations, we show that the dynamics immediately following the rapid quench from a non-interacting gas to a UNP with Yukawa interactions is identical in UNPs with densities that differ by two orders of magnitude, as long as their κ values are the same. This work provides a non-trivial demonstration of the validity of universality as a tool to describe the dynamics of strongly coupled plasmas.

O-4.3 - Shining Light on Carrier Generation in Metallic Nanostructures

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Efficiently converting solar light into useful energy is an important scientific and technological challenge. One method of circumventing conventional thermodynamic efficiencies of light-harvesting devices involves the use of metallic nanostructures to generate energetic, or "hot" carriers for direct photocurrent production or photocatalysis. However, previous experimental realizations of hot carrier devices have shown low photo-conversion efficiencies. Consequently, recent theoretical work has sought to understand the fundamental processes behind hot carrier generation in the hopes of providing a path toward higher efficiencies. In this work, we experimentally show that plasmon-induced hot carrier generation occurs independently of inherent material absorption. We accomplish this using a nanowire device geometry that can discriminate between hot carrier generation from interband transitions and surface plasmons by comparing the generated photocurrents in the presence or absence of an energy barrier. With this approach, we discriminate between plasmonic hot carrier generation, which results in high energy hot carriers, and carrier generation from interband
transitions, resulting in low energy carriers. This study also clearly shows that plasmonic hot carrier generation depends on the field intensity enhancement, which can be largely decoupled from a material’s inherent absorptive properties. Our work sheds light on the fundamental mechanisms behind carrier generation in metallic nanostructures, paving a path towards more efficient plasmon-based photovoltaic and photocatalytic devices.

**O-4.4 - Theoretical Modeling of 2D Lateral Semiconductor Hetero-junction**

Henry Yu\(^1\), Alex Kutana\(^2\), and Boris Yakobson\(^3\)

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\(^2\)Material Science & Nanoengineering, Rice University, Houston, Texas, USA
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Two-dimensional (2D) materials have shown remarkable electronic [1][2][3] properties since their emergence. In order to harness these properties in a workable device one has to form a heterojunction. While vertically stacked junction of 2D materials have been widely explored, lateral junctions have been made only recently [4][5]. Heterojunctions in low dimensions present an intriguing theoretical problem: 2D semiconductors have drastically different behavior near band edges [6], and poor electrical screening results in longer screening length and deeper impurity levels [7][6]. Thus it is obvious that traditional notions of heterojunctions such as space charge, interfacial dipole, and Fermi level pinning will require reconsideration and a new physical picture in lower dimensions. In this work we investigate theoretically the properties of a 2D lateral junction. A general form of charge distribution for 2D heterojunction is uniquely obtained, and the redefinition and the scaling law of the depletion region given. The effect of interfacial dipole in a 2D heterojunction is discussed. Finally, we point to potential applications in solar cells, terahertz devices, and quantum capacitors.


**O-4.5 - Low temperature study of plasmonic heating in Au nanowire**

Pavlo Zolotavin, Douglas Natelson

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We report heating of individual Au nanowire in a cryogenic environment (substrate temperatures down to 4 K) under laser illumination. Unlike previous experiments at room temperature and 80 K, we report a substantially larger light-driven temperature increase of 80-120K. We differentiate between plasmon and direct gold absorption by investigating the polarization dependence of the observed temperature change. The effect is quantified by measuring optically induced change in the resistance of metal nanowire and by change in the magnitude of simultaneously measured Johnson-Nyquist noise. A combination of these techniques provides independent measurements of effective lattice and electronic temperatures. The implications of the observed behavior for electronic transport in single molecular junctions with plasmonically active nanowire leads will be discussed.
GP-A-1 - Plasmon Hybridization in Symmetrically Branched Nanocrystals

Sam Gottheim,1,6 Thawda Aung,1,6 Christopher DeSantis,1,6 Peter Nordlander,2,3,4,6 and Naomi Halas1,2,3,5,6

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Over the past decade there has been intense study into the optical properties of noble metal nanoparticles. The optical properties of metal nanoparticles are a function of their size, shape, material composition, and dielectric environment. By placing two metal nanoparticles close to one another, new hybridized modes are created, analogous to the formation of molecular orbitals from hybridized atomic orbitals. This current work focuses on one and two particle systems, studying the hybridization of octopod particles. These single particles have octahedral symmetry, which allows us to further our understanding of nanoparticle coupling by varying their orientation (changing the point group symmetry) as well as inter-particle spacing. The plasmonic response is measured via dark field spectroscopy and the local modes are visualized through cathodoluminescence spectroscopy (CL). To further investigate the underlying principles governing the hybridization modes, theoretical modeling of the nanoparticle systems is performed using the finite-difference time-domain (FDTD) method. Hybridized systems have improved molecular sensing due to the intense electric fields confined to gap regions. Our study will increase our knowledge of hybridized modes in coupled metallic nanoparticles, allowing us to design better hybridized systems.

GP-A-2 - Magnetoelectric materials for neural modulation

Amanda Wickens1,2, Rena Chen3, Pulickel Ajayan3,4,5, and Jacob Robinson1,6,7

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Methods currently used for neural modulation involve invasive procedures implanting electrodes into tissue. The resulting signal is attenuated by surrounding tissue and lacks specificity. Magnetic fields can pass through tissue without attenuation. Using the magnetoelectric coupling between a magnetostrictive and piezoelectric material we propose several geometries of magnetoelectric materials that will allow for specific, non-invasive neural modulation by the application of an external magnetic field.

We first propose to use a two-layer film composed of Metglas (magnetostrictive) and polyvinylidene fluoride (piezoelectric) layers. Cells expressing voltage gated sodium channels will be grown on these films and an external alternating magnetic field will be magnetoelectrically converted into a voltage across the piezoelectric layer. At resonant frequencies, this voltage is expected to be up to 5 V, which is sufficient to capacitively stimulate voltage gated ion channels. To create a magnetoelectric mechanism compatible with in vivo preparations we will also investigate multiferroic nanoparticles with a magnetostrictive core (cobalt ferrite) and a piezoelectric shell (barium titanate). These magnetoelectric nanoparticles will then be directly tethered to the NaChBac channel. Under an applied magnetic field, the core and the shell will interact to create an electric field sufficient to trigger gating of the channel.

Equivalent circuit modeling of both of these geometries has shown magnetoelectric materials to be capable generating action potentials in neurons under the application of an external magnetic field. This technology has future applications in many areas of neurological research.
**GP-A-3 - Transmission Window Generation through Selective Photothermal Reshaping of Au Nanorods**

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We developed a facile, generalizable approach toward constructing an optical transparency window by selectively reshaping Au nanorods through monochromatic laser irradiation. The two-step process begins with synthesizing and mixing nanorods of various sizes in a solution to produce a spectral plateau. Then this solution is irradiated with a monochromatic laser such that nanorods with longitudinal localized surface plasmon resonances (LSPRs) on resonance with the laser will reshape while nanorods sufficiently off resonance will not. To achieve partial reshaping necessary for an optical transparency window, the laser power to irradiate the nanorods must be sufficiently low so as not to induce full melting. Notably, the transparency window dip minima is not on resonance with the laser but consistently shifts to the red, which we have determined through theoretical calculations and single-particle measurements is due to partial reshaping conditions. The window dip minima position, depth, and width can be modified by altering the laser conditions as well as the time of irradiation, demonstrating the versatility of this process.

**GP-A-4 - Extraordinary Local Angular Momentum near Plasmonic Nanoparticles**

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The intense local field induced near metallic nanostructures that provides strong enhancements for surface enhanced spectroscopies has been a major focus of plasmonics research over the past decade. However, plasmonic nanoparticles can also induce remarkably large electromagnetic field gradients near their surfaces. Sizeable field gradients can excite dipole-forbidden transitions in nearby atoms or molecules and provide unique spectroscopic fingerprinting for chemical and bimolecular sensing. Here we investigate how the local field gradients near metallic nanostructures depend on geometry, composition and wavelength. We introduce a novel concept, the Local Angular Momentum (LAM) vector, as a useful figure of merit for the design of nanostructures that provide large field gradients. This quantity, based on integrated fields rather than field gradients, is particularly well suited for optimization using numerical grid-based full wave electromagnetic simulations. The LAM vector has a more compact structure than the gradient matrix, is directly related to the rotational content of $\Delta J>0$ transitions, and can be straightforwardly associated with the angular momentum of electromagnetic fields incident on the plasmonic structures.

**GP-A-5 - Understanding the influence of crystallinity on the photoluminescence of Au nanostructures**

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Photoluminescence has been widely applied in imaging and sensing, molecular fluorescence being the most commonly used because of its high sensitivity and selectivity. However, one main drawback of molecular fluorescence is stability, as it suffers from photobleaching and photobleaching. Gold nanostructures are an ideal option to overcome these disadvantages based on their strong interaction with light, highly tunable spectrum and biocompatibility. However, the mechanism of their photoluminescence remains unclear. Our group has proposed that gold nanoparticle photoluminescence occurs through direct plasmon emission. In order to further clarify the mechanism we want to study the influence of crystallinity on photoluminescence of these structures. We expect that a decrease in crystallinity could introduce more defects and therefore increase plasmon damping and lower the quantum yield. To confirm this expectation, we will examine samples of different of crystallinity: chemically synthesized and e-beam lithography fabricated gold nanorods. We measured single particle dark-field scattering and photoluminescence spectra, which give information about the degree of crystallinity. We have prepared chemically synthesized gold nanorods using the improved bisurfactant seed-mediated growth method, and fabricated similarly sized lithography nanorods. Preliminary characterization confirms the expected polycrystallinity of the lithography nanorods. We also studied the photoluminescence spectrum of chemical synthesized gold nanorods with different laser excitation power. We observed that with higher excitation power the peak wavelength of the photoluminescence spectrum has blueshift and the linewidth increased. These experiments will provide additional insight into the mechanism of gold nanoparticle photoluminescence, and help to direct their design for future applications.
Investigating the optical behavior of carbon black (CB) is interesting both fundamentally and due to its promising potential to be used as an absorber material for solar thermal applications. Physical and chemical properties of CB nanoparticles, synthesized by various chemical processes, have been extensively studied using techniques like Raman spectroscopy, NMR spectroscopy, FTIR spectroscopy, X-ray photoelectron spectroscopy and high resolution transmission electron microscopy, providing detailed information up to the single particle level. However, ensemble measurement techniques like UV-vis-NIR spectroscopy and spectrofluorometry have been the main techniques used to probe the optical properties of CB nanoparticles. These techniques are not capable of investigating the absorptive properties of single carbon nanoparticles. Macroscopic properties like shape, size and agglomeration state play an important role in the absorption of CB nanoparticles; therefore, it is important to investigate the optical properties of individual carbon nanoparticles in detail to completely understand their optical response. Single particle absorption spectroscopy has been used to study individual nanoparticles using the nano-lensing effect of the surrounding medium due to a single particle’s absorption and a temperature sensitive index of refraction. In this work, we compare the response of commercially obtained CB particles under common ensemble techniques with single particle scattering and absorption measurements. This work suggests that single particle techniques may provide more useful information about the optical response of CB, helping engineer solutions that have the optimum ensemble response for the desired application.

**GP-A-7 - Frequency Shift in Lattice Vibration of Strongly Coupled Plasmonic Structures**

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Strong electric field enhancement occurs in the gap of coupled plasmonic nanostructures, which amplify spectroscopic signal such as fluorescence, SERS, absorption and high order harmonic generation. Coupled nanostructures with modulated gap distance could gate the spectroscopic signal in the GHz due to the acoustic frequencies of plasmonic nanostructures leading to potential applications to GHz devices. In this work, we used single particle transient extinction spectroscopy to study mechanical couplings in Fano structures. Fano structures are strongly coupled plasmon structures due to an interaction between superradiant and subradiant modes. The Fano structures we studied in this work are consisted of a central gold nanodisk and nine satellite gold nanodisks. By probing laser-induced acoustic vibrations in these structures, we observed vibration frequency shift of Fano structure compared to those of its constituted counterparts. Similar frequency shifts were observed in the Fano structures with and without titanium adhesion layer, which promotes the mechanical coupling between the nanostructures and the substrates Therefore, the results indicate that the mechanical coupling is through space rather than through substrates.

**GP-A-8 - Single-molecule Kinetics of α-lactalbumin Adsorption on Thin Nylon 6,6 Films**

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Protein-polymer interaction is of great importance for biomedical devices, the food and beverage industries, and environmental remediation; however, studying protein-polymer interactions is difficult, especially when kinetic information is needed. In this work we use single molecule spectroscopy to investigate the in-situ dynamics of protein-polymer interactions and extract time dependent adsorption rates for the adsorption of Alexa 555 labeled α-Lactalbumin to porous and nonporous nylon 6,6 thin films. By spin coating the nylon 6,6 solution on glass substrates, we synthesized a model polymer film with controllable thickness. Protein adsorption events at the polymer solution interface were recorded as spatially resolved movies, allowing the precise quantification of the adsorption rate and adsorption site distribution. We find that the adsorption rate is time dependent: with increasing experiment time, the rate decayed eventually reaching equilibrium. This time dependent adsorption rate was modeled with a simple monolayer adsorption algorithm, which is related to the protein concentration in bulk solution and the available adsorption sites at the interface. We further studied the morphology affected adsorption kinetics by comparing the flat and porous nylon 6,6 films and found significantly slower desorption on porous nylon films.
**GP-A-9 - Photocatalytic Hydrogen Dissociation using Aluminum Nanoparticles**

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Hydrogen dissociation is a critical elementary step in numerous catalytic hydrogenation reactions. Conventionally, noble and precious metals have been used as catalysts due to their favorable electronic structure for hydrogen adsorption and dissociation. Recently, plasmonic nanoparticles have emerged as a new breed of photocatalyst for similar reactions. Characterized by their strong interaction with electromagnetic fields through the localized surface plasmon resonance (LSPR), plasmonic nanoparticles can photocatalyze chemical reactions by transferring hot carriers, derived from LSPR decay, to adsorbed molecules and activating their dissociation. Recently Aluminum, being the most abundant metallic element in the Earth’s crust and tens of thousands of times cheaper than precious metals, has been shown to possess highly promising plasmonic properties. In this work, we demonstrate that chemically synthesized Aluminum nanocrystals (Al NCs) are capable of photocatalyzing hydrogen dissociation under laser illumination, where the H\(_2\) excited state formed results in molecular dissociation. 100 nm Al NPs supported on γ-Al\(_2\)O\(_3\) were prepared as the photo catalyst and the isotopic exchange reaction H\(_2\) + D\(_2\) \(\rightarrow\) 2HD was used to monitor hydrogen dissociation. Hot carriers generated from both LSPR decay and direct interband transition absorption were found to contribute to this reaction.

**GP-A-10 - Mesoscopic Magnetotransport in Hydrogenated Vanadium Dioxide Nanobeams**

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Vanadium dioxide (VO\(_2\)) is a strongly correlated material famous for its first-order, hysteretic insulator-to-metal transition at 67°C that spans several orders of magnitude. Recent work has shown that this transition can be (reversibly) suppressed by doping hydrogen into the VO\(_2\) lattice, either via catalytic spillover or by direct treatment with atomic hydrogen, resulting in the stabilization of a “bad metal” state (resistivity exceeding the Mott-Ioffe-Regel limit, but well below that of the insulating phase) that persists to cryogenic temperatures. This relatively low-resistivity phase enables measurement of low-temperature magnetotransport properties that are not readily accessible in the case of pristine VO\(_2\). Here, we discuss results of variable-temperature magnetoresistance measurements on single-crystal VO\(_2\) nanobeams, where signatures of weak (anti)localization physics and mesoscopic conductance fluctuations are observed. Strain is considered as an important factor that contributes to determination of the transport properties, including the observed opposite signs of magnetoresistance in devices fabricated with different lengths and by different methods.

**GP-A-11 - Dynamics of colloidal droplets in rotating magnetic fields**

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Applying external magnetic fields to paramagnetic particles allows for tunable interaction potentials. In this work, we use rotational magnetic fields to generate induced dipole interactions that are strong enough to allow for the assembly of particles into ordered structures, yet weak enough to allow for rearrangement into a configuration that leads to minimization of free energy. This drives the formation of circular two-dimensional colloidal clusters, which rotate similar to hard disks, yet grow and coalesce similar to that of liquid droplets. We explore the dynamics of the system such as the rate of growth and coalescence of the colloidal droplets as they try to reach equilibrium. These dispersions of “colloidal droplets” are characterized by calculating their interfacial tension using surface excess energy. The bond orientation order parameter was also measured as a function of distance away from the center of mass. The system provides insight into the dynamics of droplet migration and coalescence on the molecular level.
Heart disease is the leading cause of death worldwide; heart failure, ischemic heart disease, and acute myocardial infarction are the three most common causes of death. Heart transplants save many patients from heart disease, but limited numbers of donor organs and risk of immune rejection mean that there remains an urgent need for new therapies for heart disease. To better understand the processes involved in heart development and failure, and develop regenerative treatments, there is a need for large quantities of cardiac cells. Cell reprogramming technologies have advanced rapidly in recent years, making it possible to induce pluripotency in terminally differentiated cells and direct the differentiation of pluripotent cells towards specific lineages. This has enabled the culturing of historically unobtainable numbers of human cardiac-differentiated cells. While initial studies on stem-cell derived cardiomyocytes show great promise, electrical activity is the most important functional assay for determining their ability to provide accurate models for adult cardiomyocytes and their suitability for use in cell therapy. It is therefore crucial to determine the relationship between electrical phenotype and genotype within the heterogeneous population of differentiated cardiac cells. We are developing a microfluidic device for sorting cells based on electrophysiological phenotype. Our device is comprised of flow channels containing cell traps which house a horizontally suspended nanoelectrode. This electrode can help determine the cell’s phenotype by recording electrical activity in the cell as it responds to electrical stimulation.

Imaging through plasmonic nanoparticles can provide unique information regarding what it would be like to visualize and resolve objects through nanoparticle-constituent materials, information that is not obtainable from their extinction spectra alone. The tunable optical properties of plasmonic nanoparticles distinguish them from broadband, nonresonant absorptive or scattering media, and enable them to be used in applications where specific regions of the spectrum, or specific spectral lineshapes, may be desirable. We constructed an optical setup and obtained images through solutions of plasmonic nanoparticles and nanoparticle mixtures, to analyze the effects of optical density, relative absorption and scattering cross sections, and engineered spectral windows, on a transmitted image. To evaluate the transmitted image we used two approaches. We evaluated the transmitted image using the Structural Similarity Index (SSIM), a perceptual distortion metric compatible with human-visual-system, originally developed to assess the quality of images reconstructed after image compression. From SSIM analysis, we found that at equal optical densities, scattering causes more image distortion than absorption. Furthermore, the SSIM showed a threshold behavior while optical density of nanoparticle solutions was varied.

We also analyzed the modulation transfer function (MTF) of nanoparticle solutions, which resolves the transmitted information content as a function of spatial frequency: evaluating the nanoparticle solution as if it were an additional component in an optical imaging system. From this analysis, we found that the maximum resolvable spatial frequency through different plasmonic nanoparticles was dependent on the scattering and absorption cross-sections of the individual nanoparticle constituents of a mixture, as well as the optical density of the plasmonic nanoparticle solution.

The near-resonant dressing of ultracold strontium gases and BECs contained in an optical dipole trap (ODT) with the \( n = 30^3S_1 \) Rydberg state is investigated as a function of the effective two-photon Rabi frequency, detuning, and dressing time. The measurements demonstrate that, even when well detuned from resonance, such dressing can lead to a rapid decrease in the ground-state atom population in the ODT. This decrease is attributed to Rydberg atom excitation which can lead to direct escape from the trap and/or population of very long-lived metastable states. The large Rydberg atom production rates are explained using a reaction model.
in which the initial excitation of a Rydberg atom triggers the excitation of neighboring atoms leading to rapid avalanche-like growth in
the Rydberg population. The implications of the present measurements as regards use of Rydberg dressing to control the interactions
between “ground-state” atoms are discussed.

**GP-A-15 - Photoluminescence of a Plasmonic Molecule**

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Photoluminescence describes the process of light emission from any kind of matter after interacting with an electromagnetic field, which is an important property of Au nanostructures. With no photobleaching and photoblinking and comparable emission intensity as molecular fluorophores, Au nanostructures have gained popularity in a variety of applications in bio-sensing and bio-imaging. However, a central question on the detailed mechanism of PL from Au nanostructures, which have a bulk-like density of states, remains controversial: whether PL is direct plasmon emission or plasmon enhanced emission. Several one-photon PL mechanisms have been proposed based on investigations on isolated gold nanoparticles, including interband transition, intraband transition, and radiative decay of surface plasmon. In order to address this question, it is valuable to investigate capacitively coupled plasmonic Au nanosheres, where we can probe the influence of local electric field enhancement on PL emission. AuNS dimers, also referred as the simplest plasmonic molecule, are the most fundamental model structures of plasmon coupling and are therefore ideal for PL study. Here, we report PL quantum yield study of strongly coupled AuNS dimers. Single particle technique enabled selective measurement of PL quantum yields from individual AuNS monomers and dimers. We found the quantum yields of monomers and dimers are nearly identical even with 2-3 orders of magnitude difference in their local electric field enhancement. As such, we propose direct plasmon emission as the major PL emission pathway.

**GP-A-16 - Characterizing the antiferromagnetic ordering of fermions in a compensated optical lattice**

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The Hubbard model of interacting fermions on a cubic lattice is the simplest model containing strong correlations. It has been proposed as a model to explain high-temperature superconductors, as physicists are still uncertain how these novel materials work. To better understand these materials, we realize the Hubbard model using fermionic $^6$Li atoms in a three-dimensional optical lattice formed from three pairs of standing waves of light. The lattice is compensated by the addition of three blue-detuned Gaussian beams which overlap each of the lattice laser beams, but are not themselves retro-reflected. We have developed this method to cool atoms in a lattice to unprecedented low temperatures. Using the compensated lattice potential, we have reached temperatures low enough to produce antiferromagnetic (AF) spin correlations, which we detect via Bragg scattering of light. The variation of the measured AF correlations as a function of the Hubbard interaction strength, $U/t$, provides a way to determine the temperature of the atoms in the lattice by comparison with quantum Monte Carlo calculations. This method shows our temperature to be 1.4 times the AF (Néel) ordering temperature. At this temperature, we observe short-range AF correlations [1]. We also explore negative $U/t$ where charge density (CD) correlations are expected to form. We also use Bragg scattering to search for CD ordering. High-temperature superconductors are known to exhibit CD ordering in the form of a checkerboard-like pattern or in stripes.

GP-A-17 - An Isotope–Dependent ODT for Producing Quantum Degenerate Gases of Strontium

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Independently controllable trapping potentials for different atomic elements, isotopes, or states are useful for forming quantum degenerate gases through sympathetic cooling, quantum computing architectures, and fundamental studies in many-body physics. We investigate a method for creating isotope-dependent optical potentials in atomic strontium, taking advantage of the narrow linewidth and isotope shift of the 1S0→3P1 transition. Because of favorable inter-isotope scattering lengths, this is a promising route to producing mixtures of quantum degenerate gases.

GP-A-18 - Plasmon-induced Hot Carriers in Metallic Nanoparticles

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Plasmon-induced hot carrier formation is attracting an increasing research interest due to its potential for applications in photocatalysis, photodetection and solar energy harvesting. Here we develop a theoretical model for both generation and decay of plasmon-induced hot carriers and apply it to spherical nanoparticles. We show that the inclusion of many-body interactions has only a minor influence on the results. Using the model we calculate the rate of hot carrier generation, finding that it closely follows the spectral profile of the plasmon. Our analysis reveals that particle size and hot carrier lifetime play a central role in determining both the production rate and the energy distribution of the hot carriers. For the decay of the hot carrier, we parameterize the e-e scattering as a function of energy and use master equations to show the time evolution of the hot carrier distribution, photoluminescence, and discuss the effect of metal band structure.

GP-A-19 - Transition Metal Decorated Aluminum Nanocrystals

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Aluminum nanocrystals (AlNCs) decorated with crystalline islands of various transition metals have been synthesized. The size of nanoislands decorating the surface of the AlNCs ranges between 2-20nm and can be controlled by varying reaction conditions. Morphological and elemental characterization of these particles using HRTEM, STEM-HAADF, and EDX will be presented. We have found separation of metals by the naturally occurring 4nm oxide layer on AlNC surfaces. This oxide acts as a dielectric barrier between the decorating transition metal nanoislands and the subsurface aluminum crystal. The natural separation of metals should yield unique optical properties in these structures. Single particle dark-field measurements of nanoparticle optical properties will be performed and discussed. Additionally, transition metal nanoparticles are well-known heterogeneous catalysts. The potential for combining unique optical properties and highly active catalytic surfaces for plasmon-induced photochemistry will be addressed.
GP-A-20 - Measuring the Hydrodynamic Size of Colloidal Nanoparticles using Fluctuation Correlation Spectroscopy

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FCS is a well-established analytical technique in biological sciences, and it is starting to be used as a characterization tool for size determination of fluorescent and non-fluorescent nanoparticles in colloidal solution as well. In this poster, I will provide the reader with the underlying physical principles of FCS, its calibration methods as well as its advantages and limitations when applied to colloidal nanoparticles that are typically much larger than fluorescent dye molecules. Overall, we believe that FCS will continue to provide important information about nanoparticle size, diffusion, and transport, relevant to different areas within physical chemistry as well as many possible applications of nanoparticles.

GP-A-21 - 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 Al2O3 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 chemistry synthesized Aluminum nanocrystals which shows potential in serving as a SERS substrate. Two analytes, para-aminobenzoic acid (PABA) and stearic acid (SA), were detected using 514 nm and 785 nm lasers as the excitation source. Under low concentration and low laser power, we demonstrated enhanced detection of both analytes, proving that Al is a sensitive substrate for Raman down to monolayer detection.
**GP-B-1 - Superfluidity and Spin-Charge Separation in a Spin-Imbalanced Fermi Gas**

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Our experiment studies superfluidity in a dual-spin component gas of fermionic Lithium-6. By cooling these atoms to ultra-low temperatures, we can emulate electronic systems such as superconductors or Luttinger liquids, which are fermionic liquids confined to move in a single dimension.

The atoms are confined in an optical trap, and by changing the trap characteristics the atoms can move in either 3D or 1D. With a 3D system we examine how normal superfluid pairing changes when we vary the spin-imbalance and the interaction strength between the atoms.

When limited to 1D motion, we can examine properties that are not present in a conventional Fermi liquid. In an electronic system, the charge and the spin propagate with the same velocity. This allows us to envision an electron traveling through a conductor carrying both its charge and spin information. In 1D, this Fermi liquid model breaks down and we must instead use Luttinger liquid theory. Within this regime, the charge travels faster than the spin, and we can no longer use the model of an electron moving through a conductor. Using our gas of atoms trapped in 1D, we can study how their charge and spin travel.

As a result of this work, we hope to better understand superfluidity which would allow for applications such as high critical temperature superconductors to be more easily realized. Also, we will be able to shed light on the fundamental differences between conventional Fermi liquids and Luttinger liquids.

**GP-B-2 - 3D Superresolution Microscopy by Phase Modulation**

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Fourier plane imaging using double-helix (DH) point spread functions (PSFs) is a cutting-edge technique for imaging three dimensional biological samples that distorts the diffraction limited spot in a predictable manner directly correlated to the difference in z-height between the molecule and the focal plane. The rotating property of DH PSFs can be explained by decomposing the transfer function in Gaussian- Laguerre modes domain. Similarly, we design another depth dependent PSFs by engineering the transfer function in Hermite- Gaussian modes domain: The PSFs stretch towards two directions when moving through planes of different depth. The stretching rate would change if different modes were chosen in Hermite- Gaussian domain, which means that the depth detection range and the localization precision of the microscopy can be well tuned by applying different PSFs. We showed two PSFs that are optimized to have a similar response with 3D microscopy using cylindrical lenses. Depth localization precision and detection range of the two PSFs are different by the optimizing the PSFs in Hermite- Gaussian modes domain.

**GP-B-3 - Super-resolution algorithm for 3D single-molecule microscopy imaging**

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We introduce a general 3D super-resolution recovery algorithm that works for all kinds of phase mask generated 3D point spread functions. This algorithm uses advanced fast deconvolution algorithm to generate initial guess and further refines the positions by least square fitting. Our algorithm fills the gap of the 3D recovery algorithm for arbitrary point spread functions. We have tested the performance of our algorithm over different designs of 3D point spread functions in simulation. Due to heavy computation in 3D, we further accelerate the algorithm using parallel computing techniques. By using graphics processing unit arrays, real time analysis is possible. This algorithm will also serve as a standard criterion for future phase mask design.
**GP-B-4 - Detection and Quantification of Hemozoin Using In Vivo Microscopy**

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Clinical diagnosis of malaria suffers from poor specificity, leading to overtreatment with antimalarial drugs and the potential for drug resistance. Alternatives, such as blood smear microscopy, require a blood sample. Alternatively, we employ standard microscopy techniques to optically detect infected red blood cells circulating in the superficial microvasculature. To evaluate this method we developed the Microvascular Microscope (MVM), an inexpensive, hand-held, battery-powered microscope amenable for use at the point-of-care. The MVM was designed for imaging blood flow in the oral mucosa, targeting the parasite by-product hemozoin as an endogenous optical biomarker. Two optical signatures of hemozoin, birefringence and absorbance, were evaluated in increasingly complex biological environments using a mouse model of malaria. The optical contrast of hemozoin birefringence suffered in highly scattering tissue; however hemozoin absorbance was readily detected in an optical phantom and excised tissue samples from a malaria-infected animal. Using hemozoin absorbance, we demonstrated the ability to detect and quantify hemozoin over four orders of magnitude of clinically relevant levels of parasitemia in vivo. Hemozoin was detected within 30 seconds for 95% of the FOV collected. These results demonstrate the potential for a quantitative, rapid, needle-free malaria diagnostic using in vivo microscopy. Additionally, the use of in vivo microscopy allows for visualization of endothelial cytoadhesion and microvasculature dysfunction, physiological parameters that may act as indicators of disease severity. Future work will incorporate the detection of other blood constituents to further enhance the diagnostic capabilities of this approach.

**GP-B-5 - Charge-Dependent Transport Switching of Single Molecular Ions in a Weak Polyelectrolyte Multilayer**

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The tunable nature of weak polyelectrolyte multilayers makes them ideal candidates for drug loading and delivery, water filtration, and separations, yet the lateral transport of charged molecules in these systems remains largely unexplored at the single molecule level. We report the direct measurement of the charge-dependent, pH-tunable, multimodal interaction of single charged molecules with a weak polyelectrolyte multilayer thin film, a 10 bilayer film of poly(acrylic acid) and poly(allylamine hydrochloride) PAA/PAH. Using fluorescence microscopy and single-molecule tracking, two modes of interaction were detected: (1) adsorption, characterized by the molecule remaining immobilized in a sub-resolution region and (2) diffusion trajectories characteristic of hopping ($D \sim 10^{-9}$ cm$^2$/s). Radius of gyration evolution analysis and comparison with simulated trajectories confirmed the coexistence of the two transport modes in the same single molecule trajectories. A mechanistic explanation for the probe and condition mediated dynamics is proposed based on a combination of electrostatics and a reversible, pH-induced alteration of the nanoscopic structure of the film. We have also made preliminary modifications to our instrument to allow for imaging of these dynamics in 3D. Our results are in good agreement with ensemble studies conducted on similar films, confirm a previously-unobserved hopping mechanism for charged molecules in polyelectrolyte multilayers, and demonstrate that single molecule spectroscopy can offer mechanistic insight into the role of electrostatics and nanoscale tunability of transport in weak polyelectrolyte multilayers.

**GP-B-6 - Neurotransmitter Detection by Surface Enhanced Raman Spectroscopy (SERS)**

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The detection of neurotransmitters within a solution can be achieved by the use of surface enhanced Raman spectroscopy (SERS) on gold nanorods. Depending on the type of molecules that encapsulate the nanorods, the neurotransmitter can then selectively bind to the molecule on the surface. For the initial development, we are creating 4-amino-3-hydrazino-5-mercaptop-1,2,4-triazol (AHMT) conjugated nanorods which then bind dopamine in solution. Dopamine can induce aggregation of the nanorods, which affects their plasmonic spectrum possibly allowing colorimetric detection. Due to the plasmonic properties of the nanorods, the Raman signal for the dopamine can then be observed by SERS as a means to further confirm the identity the detected neurotransmitter. We hope find an array of molecules to bind to nanorods that can detect dopamine, epinephrine, norepinephrine, and other neurotransmitters in real time.
**GP-B-7 - Determining the Mechanism of Hydrogen Generation by Single Gold-Platinum Nanocatalysts**

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We present a comprehensive single particle analysis of catalytically active platinum coated gold nanorods (Au@Pt NRs) that relates plasmonic excitation and decay to the catalytic mechanism. Recent studies have demonstrated that bimetallic nanoparticles such as Au@Pt NRs generate hydrogen from water with visible light excitation. However, due to inherent heterogeneity present in nanoparticle samples, bulk catalytic studies are not sufficient to determine how catalysis occurs and which nanoparticle characteristics are desirable. In order to understand what factors influence the catalytic potential of a bimetallic nanoparticle, we investigate both radiative and non-radiative relaxation on a single particle level. We characterized Au NRs with increasing Pt coverage to determine the interaction between the Au NR and the Pt islands as well as the relationship between this interaction and catalytic activity. The single particle absorption spectrum, which we measure for the first time using a novel technique, photothermal spectroscopy, reveals that the Pt islands do not reduce light absorption, but instead damp radiative relaxation of the plasmon (scattering and photoluminescence). These results indicate that hydrogen generation is in fact mediated by a hot electron transfer process and that the electrons are removed from the Au NR following light absorption. This unique analysis reveals a connection between hot electron generation and catalytic activity that can be used to efficiently screen potential nanocatalysts and elucidate other plasmonic catalytic mechanisms.

**GP-B-8 - Photoluminescence Studies of Single-Walled Carbon Nanotubes**

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A model has been developed for the photoluminescence (PL) profiles of semiconducting single-walled carbon nanotubes (SWCNTs). Experiments were performed on purified bulk samples with only one or two structural species, and on individual nanotubes under a microscope. The microscopic data show emission profiles with three main components: the allowed electronic band gap transition (E_{11}) and two weak satellites (E_{Y1} and E_{X1}) shifted ~300 cm\(^{-1}\) and ~1062 cm\(^{-1}\), respectively, below E_{11}. In bulk samples another weak sideband (E_{G}) is observed ~1600 cm\(^{-1}\) below E_{11}. E_{Y1} and E_{G} are assigned as vibronic modes coupling RBM and G vibrations with the E_{11} bright exciton. However, our study of the E_{X1} band in more than 100 nearly defect-free individual SWCNTs prepared from \(^{12}\)C and \(^{13}\)C shows an isotope shift of ~40 cm\(^{-1}\). This indicates that E_{X1} is a vibronic transition involving the D vibrational mode coupled with the K-momentum dark exciton (~232 cm\(^{-1}\) above E_{11}). Except for E_{Y1}, all satellite features shift parallel to E_{11} with changes in sample preparation, dielectric environment, and axial stretching. Their separations from E_{11} are almost independent of SWCNT structure.

For constructing the PL model, we represent each of the three satellites with a Voigt function. However, we find that the E_{11} band is asymmetric and is better modeled by a Pearson IV line shape function. The asymmetry may be caused by defects within the nanotubes that let excitons migrate to lower energy environments and emit at lower frequencies than in pristine nanotubes. Our findings enhance basic understanding of SWCNT spectroscopy and permit more accurate analysis of heterogeneous bulk samples based on emission spectra.
**GP-B-9 - Variance Spectroscopy:**
A New Bridge between Bulk and Single-Particle Studies

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Single-walled carbon nanotubes (SWCNTs) are family of nanomaterials with remarkable properties and a wide range of proposed applications. Typical SWCNT samples contain a variety of structural forms, each with distinct optical properties. This spectral heterogeneity makes it difficult to characterize and study mixed samples. We present here a new experimental method, termed Variance Spectroscopy, that can analyze the composition of such samples and measure the fluorimetric efficiency, homogeneous emission line shapes, and aggregation state of specific structural forms.

This technique, a member of the fluorescence fluctuation spectroscopy family, measures and analyzes the changes in photoluminescence intensity resulting from statistical variations in the local composition of dilute SWCNT suspensions. Through the use of customized instrumentation, several thousand statistically independent emission spectra are collected from different spatial regions in a liquid sample. The data are analyzed to find the mean and variance of the emission intensity at each wavelength. These statistical parameters are then used to extract the abundances of different nanotube species and their relative emission efficiencies, values which cannot be obtained from other optical experiments. Spatial correlations between intensity fluctuations at different wavelengths are also analyzed to give novel two-dimensional correlation maps. These provide the spectra of homogeneous sub-populations (such as single SWCNT structures) free of inhomogeneous broadening or spectral congestion. They also reveal the earliest stages of nanoparticle aggregation. Variance spectroscopy thus provides unique single-particle-like views of bulk samples containing carbon nanotubes or other heterogeneous nanoparticle samples. We predict that it will become a powerful tool in experimental nanoscience.

**GP-B-10 - Temperature Dependence of Efimov Resonances**

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Collisions of atoms at ultra-low temperature are very simple to describe. In the regime where the atom’s de Broglie wavelength is large compared to the range of the interaction, the scattering amplitude of the particles is determined entirely by the s-wave scattering length. Because the details of the short range interaction potential are unimportant, collisions in this regime are described by a universal theory. Under such conditions, atoms can form a series of three-body bound states called Efimov trimers, whose energies obey a universal scaling. In this work, we experimentally determine the effect of temperature on the Efimov trimers, by measuring the rate of recombination into two-body bound-states (dimers). We create a thermal gas or a Bose-Einstein condensate of 7Li atoms in the least-energetic hyperfine state in an atom trap and measure the atom loss rate. We use a magnetically-tuned collisional (Feshbach) resonance to map out the loss rate as a function of the scattering length, and determine the effect of the Efimov trimer on atom loss at different temperatures. We find that the location of the Efimov state depends linearly on temperature.

**GP-B-11 - Enhanced noise at high bias in low-temperature, atomic-scale Au junctions**

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We report measurements of current noise as a function of applied bias in STM-style Au break junctions, recorded at 77K. Previous work on similar junctions at room temperature found that at high bias (>150mV), the measured shot noise was greater than expected, exceeding the predicted linear dependence of noise on scaled bias. Candidate explanations for this enhanced noise included: 1) nonequilibrium electron-phonon effects, and 2) local heating of the electronic distribution. At 77 K it is expected that thermal phonon populations will be greatly reduced; therefore if nonlinearity persists this explanation may be ruled out as a source of increased noise.

We will present the bias dependence of the observed low-temperature noise, which exhibits nonlinearity at high bias, as well as estimates of the local electronic heating as a function of bias for a range of conductances.
**GP-B-12 - High chromaticity, LCD-compatible aluminum plasmonic pixels**

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Colorants and filters based on nanomaterials have benefitted significantly from the addition of aluminum as a viable plasmonic material, producing colors that span the visible region while remaining cost effective and compatible with the semiconductor industry. The range of colors produced by aluminum displays based on arrays of nanoparticles has been mostly muted and pigment-like because of the reliance on the single nanoparticle plasmon resonance, which is size and shape tunable but heavily damped in the visible region. In this work, we present a series of rationally designed aluminum plasmonic pixels capable of producing far more vibrant colors than have been previously reported. These pixels are based on oriented nanorods with highly polarized resonances and take advantage of the spectrum enhancing effects caused by diffractive coupling. With optimized pixel parameters, we are able to produce color gamuts with 100% of the number of colors of a standard color definition display, with enhanced definition in the blue-green colors, as evidenced by dark field microscopy measurements and calculations using a coupled dipole model. The same pixels are also shown to be compatible with alternative excitation geometries, switchable liquid crystal displays, and their sizes can be scaled up from 1 μm to greater than 1 mm without significant changes to the pixel color.

**GP-B-13 - Global Spontaneous Alignment of Single-Wall Carbon Nanotubes**

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To create a macroscopic ensemble of nano-objects while preserving their extraordinary properties is one of the main pursuits and challenges in nanoscience and nanotechnology today. For example, the extremely anisotropic electronic, thermal, and photonic properties of individual single-wall carbon nanotubes (SWCNTs) due to the one-dimensional character of their electrons, phonons, and excitons have found general interest in diverse disciplines, but their macroscopic demonstrations are quite limited. Here, we report a simple, robust and universal method for preparing wafer-scale (>cm²) monodomain films of aligned and highly packed SWCNTs based on spontaneous alignment during slow vacuum filtration. The produced films are globally aligned with a standard angle deviation of ±1.5⁰ (the nematic order parameter ~ 1) and are highly packed with a density ~10³ nanotubes/μm²; the film thickness is controllable from a few nm to ~100 nm. The films with enough metallicity act as ideal polarizers in an ultrabroadband frequency range. Moreover, by combining this method with recently-developed sorting techniques, we fabricated highly-aligned and chirality-enriched semiconducting SWCNT thin-film optoelectronic devices exhibiting polarized light emission, polarization-sensitive photodetection, and anisotropic conductivities and transistor behavior. These results significantly advance the frontier of research toward scalable carbon-base electronics and photonics.

**GP-B-14 - Nanoscale Suspended Electrode Arrays for Studying Neurological Diseases in Small Organisms**


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The nervous system of the roundworm *C. elegans* is a powerful model for studying human neurological diseases. However, measuring how these diseases affect the electrical signaling of the nervous system is a slow and difficult process that requires a highly invasive dissection. A method to rapidly measure the electrical activity in these worms would greatly increase our ability to...
understand and develop treatments for diseases such as Alzheimer’s disease, Parkinson's disease (PD) and Amyotrophic Lateral Sclerosis (ALS). In order to create a platform for highly versatile and scalable studies of these diseases in intact worms we developed nanoscale SusPended Electrode ARrayS (nano-SPEARS). Using scalable methods, we nanofabricated platinum electrodes that horizontally protrude above the surface of a microfluidic channel. When we immobilized worms tightly against the electrodes, we measured *in vivo* activity from the *C. elegans* neuromuscular junction – a synapse commonly used to model human diseases. Using this technique, we made the first electrical measurements in PD and ALS *C. elegans* models and showed that as these diseases progress they increasingly degrade neuromuscular activity. Furthermore, we pharmacologically treated PD worms with a known neuroprotective drug and showed a nearly complete rescue of healthy electrical activity. These results in combination with scalability indicate that nano-SPEARS are a high-throughput platform that have the ability to not only measure the effects of neurological diseases, but also screen for potential drug treatments.


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We are developing a scale-less theoretical framework for modeling interactive systems, ranging from nano to micro scales. Using this theory, the behavior of molecular fluids, like DNA, proteins, surfactants, water, and alcohols which are the famous examples, is perfectly captured. Also, the framework proved work promisingly in advanced materials area where patchy colloids have opened a bright way to the future of material design for predetermined features. These colloidal particles are showing a wide range of applications in photonics, self-healing materials, solar panels, etc. With this theoretical approach, the optimized design for targeted properties is easily obtained, and trial and error experimental efforts are not a necessity anymore. Liquid crystals (LC) are the other area we are targeting to develop the theory at. LC is the best example of complex fluids which have a well known application in electronic displays. The model shows promising results in predicting the characteristics of chain-like structure systems, and accordingly it is expected to model liquid crystals very well. The essential effect of my research becomes obvious when the prediction power of the theory eliminates the need for expensive experiments to understand the system of complex fluids.

**GP-B-16 - Investigation of the Effect of Nanoparticle Morphology on Its Electro-Catalytic Activity; A Single Particle Study**

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Plasmonic nanoparticles have been studied as potential electrocatalysts to enhance the efficiency of many industrially important chemical reactions. However the ensemble measurements are unable to provide a complete picture of the effect of nanoparticle size, shape and surface properties on catalytic activity due to sample heterogeneity. In this study, we are conducting a single particle level study to derive direct correlation between electron densities and induced spectral changes of single gold nanoparticles as a function of nanoparticle morphology. The intrinsic surface plasmon resonance of plasmonic nanoparticles is used as a local probe to monitor the local charge density. CTAB-capped gold nanorods and CTAB-capped spherical gold nanoparticles of similar initial electron densities are deposited on an electrochemical cell, and their spectral tuning is compared using high sensitive hyperspectral single particle scattering microscopy.
A main challenge in neurobiology is to determine how the electrical activity of specific cell populations affects neural computation and behavior. To overcome this challenge we are developing a neuromodulation technique that is fast, targeted to specific cells, and does not damage the surrounding tissues. Our approach is based on magnetic fields that can penetrate living tissues without damaging cells. To engineer cells to respond to this field we are combining paramagnetic nanoparticles with small peptide-sequence recognition proteins (bungarotoxin, nanobodies) encoded into mechanically sensitive ion channels. To create these new ion channels we propose to re-engineer the mechanosensitive protein Piezo-1 to connect with artificial magnetic nanoparticles. Specific extracellular domains of the protein will be tagged with the c-Myc-tag and BgTx-Tag to react with 5, 10 and 30 nm paramagnetic nanoparticles conjugated to anti-Myc nanobodies or to bungarotoxin.

This alternative channel gating mechanism will offer new opportunities for basic research in the neuroscience, and for treatment of neurological disease. This application will permit the exploration of neural networks, the mapping of regions of the brain that cannot be reached with optogenetic tools or the stimulation of neurons in freely moving animals. Such an application can also be used to treat Parkinson disease, epilepsy, and neuropsychiatric disease, with less secondary effects than the invasive deep brain stimulation approach.
extensive theoretical simulations, we observe diverse CD signal behavior for individual particles that is highly sensitive to the dimer structure. Understanding how small structural changes in self-assembled plasmonic nanomaterials impacts the CD response of the sample could enable single particle CD to be used as a tool to probe structural features too subtle to be resolved in ensemble or even single particle scattering spectra.

**GP-B-20 - Plasmonic hot-electron generation for solar-to-fuel energy conversion**

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Plasmonic metal nanostructures have recently received considerable attention in the quest for efficient solar-to-fuel energy conversion due to their unique light harnessing capabilities.1 2 3 4 A novel approach toward solar-to-fuel energy conversion is the injection of hot carriers, resulting from the non-radiative plasmon decay, into the antibonding orbitals of adsorbed molecules.5 6 7 This approach promises to open up novel photoreduction pathways that are inaccessible by conventional methods such as heating or applying an electrochemical bias. A major challenge of this approach lies in the short lifetimes of the hot-carriers before they relax due to electron-phonon interactions. Hence, hot-carriers need to be harvested on femtosecond to picosecond timescales. To address these challenges, we recently designed a novel photoelectrode structure consisting of high density of gold nanoparticles for efficient hot-electron generation and direct injection into adsorbed molecules for photocatalytic water splitting. In contrast to past work, our structures do not rely on a semiconductor/metal Schottky junction to collect hot-electrons, they use a minimum amount of gold, and most importantly, they do not require the use of an expensive catalyst such as Platinum, and yet they produce similar photocurrents as state-of-the-art work recently published.8 9 The key ingredients to achieve these large photocurrents are increased light absorption due to optical impedance matching8 9, and improved hot-carrier injection in an optimized architecture that takes into account hot-carrier separation and injection. Finite Difference Time Domain (FDTD) simulations were used to maximize light absorption within the gold nanodots in a broad wavelength region of the solar spectrum.

References