SRI REU 2009 STUDENT PROJECTS AND PROGRAM ACTIVITIES

SRI REU 2009 students

2009 REU Student Research Projects and Accomplishments

Aya Eid (Illinois Institute of Technology)
Mentor: Drs. Sanhita Dixit and Gregory Faris

Title: Droplet Based Artificial Lipid Bilayers

To test water drop formation in organic solvents with a lipid monolayer at the water-oil interface, preliminary observations were performed using different lipids (DphPC, POPC, and DMPC). Initially, drops of PBS were imaged with the lipids dissolved either in hexadecane or mineral oil over a period of 40 minutes in a polystyrene Petri dish. I wrote a Matlab program that allowed me to make repeated measurements on the size of the contact area and plot this value as a function of time. From these experiments, we were able to conclude that the drop contact area stabilized faster in the less viscous hexadecane. Further, in the more dense mineral oil, the drop contact area remained much smaller.

During these experiments we were able to move aqueous drops immersed in a solution of DphPC in mineral oil with an IR laser at a power of about 10mW and successfully form lipid bilayers at the interface of adhering drops. However, while utilizing convection-based currents to initiate drop motion, several drops in a wide area were displaced. This led us to approximate how much force would be required to move the drops in order to legitimately consider optical tweezers as a controlled means of optical motion. After fabricating a Petri holding device, I ran a series of experiments to tilt the Petri dish with stabilized drops and determine the critical angle at which they began moving in both hexadecane and mineral oil. From these results, we could calculate the force required to move such drops with optical tweezers. A value of about 100 pN was determined for drop sizes in the 400 μm diameter range.

Additionally, we experimented with several surfaces, solid and liquid, to house the aqueous drops, including silicone oil, hydrophilic glass, APTES-coated slides, hydrophobic fluorinated oil, Teflon-coated Petri dish surfaces and OTS-coated glass coverslips. Glass and APTES-coated surfaces showed a contact area that steadily decreased, but even after stabilization, the drops were not mobile enough to move with the IR laser. Silicone and fluorinated oil allowed for enough mobility for bilayer formation. Silicone oil was viscous enough to anchor the drops, and 50 mW of laser power successfully moved them. Fluorinated oil naturally allowed drops to aggregate, but the laser actually inhibited the movement of drops. Drops on Teflon and OTS surfaces adhered immediately and maintained a very large contact area. Due to extremely hydrophilic properties, a piranha-solution cleaned surface may be the optimal surface to experiment with in the future.

Convective fluid currents induced in the oil phase due to the IR laser were the only method that yielded reproducible drop mobility in mineral oil.

Rosanne García (Washington State University)
Mentors: Dr. Kostas Kalogerakis

Title: Oxygen Atoms in the Terrestrial and Planetary Atmospheres

This summer, I worked on a project involving laboratory studies of oxygen-atom recombination in a background of CO_2. While the end goal was to determine the rate coefficient for the $O + O + CO_2$ reaction, there were many more steps along the way. First, it was important to make sure all of our equipment was working correctly, and a lot of time was spent getting everything to function properly together. As such, I became familiar with equipment I had never used before (dye laser, monochromator, and frequency doubler, just to name a few), as well as applied my prior experience with some equipment (oscilloscope, photomultiplier tube, etc) and gained a much better understanding of their use and application. The knowledge I gained through working with all these parts, individually and as a whole, cannot be overemphasized.

By employing a laser-based technique to produce oxygen atoms, generate 2-photon laser-induced fluorescence and detect 845-nm oxygen emissions, we were able to monitor the time-dependent decay of the initial oxygen concentration. Using a kinetic model for the reaction, we were able to extract the rate coefficient in a couple of different graphical ways. Although it took a while to get everything working well (and reliably enough to do multiple runs, which was necessary to do different initial oxygen concentrations), we have been able to obtain some

preliminary results. So far, it appears that the biggest uncertainty contributing to error in our calculations comes from being unsure about the true initial value of the oxygen concentration. Nevertheless, our results are generally in agreement with what literature predicts for the $O + O + CO_2$ rate coefficient.

Karen Heinselman (Harvey Mudd College)
Mentor: Dr. Gregory Smith

Title: Mesospheric Cooling and Heating Mechanisms: Vibrational Excitation of CO_2

The study of vibrationally excited CO_2 in the mesosphere contributes directly to our understanding of the global energy cycle. In that part of the upper atmosphere, CO_2 radiation actually produces global cooling, although the magnitude and altitude prevent this from overcoming the opposite effect on temperatures at lower altitudes. The research for this summer was directed towards understanding vibrational excitation level of CO_2 more thoroughly, particularly the population and quenching of $CO_2(001)$, the asymmetrical stretching state. As additional motivation, there is the NASA TIMED mission with an instrument called SABER, which measures the 4.3μm emissions of $CO_2(001)$. In order to understand the data obtained from the nighttime emissions, we need a more thorough understanding of vibrationally excited CO_2.

In order to obtain data on the population and decay of $CO_2(001)$, an InSb IR detector was placed looking into a cell through which the various gases flowed. To limit the range of detection to 4.3μm emissions of $CO_2(001)$, a 3.8-4.7μm filter was placed between the detector and the cell. An excimer laser in the UV range dissociated ozone in the cell to form $O(^1D)$, which then transferred its vibrational excitation to other constituents in the cell. Experiments were run with different concentrations of various constituents in the cell, usually with a noble gas (argon or helium), ozone, carbon dioxide, and some additional gas. The reactions and subsequent decays that occurred with O_2, H_2, H_2O, and N_2 as that additional gas were all researched.

When nitrogen was the additional constituent in the cell, the nitrogen was excited by the $O(^1D)$, and subsequently formed in equilibrium with the vibrationally excited CO_2. With O_2 in the cell, the O_2 also reacted with the $O(^1D)$ to form vibrationally excited $O_2(b)$. This then underwent a delayed reaction with CO_2, repopulating $CO_2(001)$ in the cell. When hydrogen and water were flowed through the cell, however, the reaction mechanism became more complicated. Both H_2 and H_2O formed vibrationally excited OH through reaction with the $O(^1D)$ and O_3. This, again, repopulated the vibrationally excited CO_2.

Through analysis of the data from the experiments, yields of the processes of population of CO_2 through $O_2(b)$, N_2 with $O(^1D)$, and CO_2 with OH(v) were obtained, relative to the population of CO_2 directly with $O(^1D)$. Using data from past experiments on the population of N_2 by $O(^1D)$, approximate absolute yields were determined from these numbers.

Ian Jarvis (Beloit College)
Mentors: Drs. Gregory Faris and Marissa Yañez

Title: Nanobiophotonics

Optimization of Metal Enhanced Fluorescence for Bioassays. Nanoparticles exhibit unusual properties because of their size, and open new biomedical applications. Noble metal

nanoparticles can produce strongly enhanced local electric fields due to surface plasmons. These enhanced fields can increase the optical response of molecules on or near the particle surface. We use this enhancement effect to increase the luminescence of Cyanine dye attached with proteins to silver nanoparticles. Using different layers of protein to vary distance between the dye and the nanoparticles, we found the optimal distance to couple the dye and take full advantage of the surface plasmons. Next, we found the optimal concentration of dye to coat onto the nanoparticles to decrease quenching effects caused by saturation. With this protein layer method, we can optimize the response of bioassays that use lanthanides or other biomarkers for biomedical applications.

Single Target Detection Using Brownian Motion. Scientists are currently using heterogeneous approaches for single target detection, which often require the use of functionalized surfaces. Our goal is to eliminate the need for a surface component and to detect the binding of a single target solely in a solution. We are investigating an approach that detects the Brownian motion of silver nanoparticles and tracks changes in the Brownian motion as the metal nanoparticles bind to their target. We used a virus as our single target given its large size relative to other biomolecules (protein/DNA). Viruses allow us to observe the largest changes in Brownian motion, and thereby detect the largest changes in the size of silver nanoparticles.

Functionalized nanoparticles were observed under dark field microscopy before and after mixing them with our target virus. ImageJ software with particle detection and tracking plugins were used to track the particles. Using Excel, we calculated the particle displacements over a given amount of time. This allowed us to solve for the particle diameter using the characteristic Brownian motion equations. Next, using Igor Pro, we observed large instantaneous changes in the particle diameter upon the binding of silver nanoparticles to our target virus. These results demonstrate the ability to detect a single virus target in real time by tracking the Brownian motion of nanoparticles using dark field microscopy.

Alexander Marakov (Carnegie Mellon University)
Mentor: Drs. Richard Copeland, Constantin Romanescu, and Gregory Smith

Title: Vibrational Energy Tranfer in OH(u)

This summer I, with a great deal of help from Dr. Constantin Romanescu, investigated the vibrational relaxation of OH($\upsilon = 1$) due to CO_2. As of 08/20/2009, we have been able to measure the relaxation rate constant (k) of OH($\upsilon = 1$) at three different temperatures, 228K, 263K and 298K. The lowest temperature measurements were done first and we noticed that the relaxation rate constant did, in fact, increase as the temperature decreased. The result for k at 263K appeared to be anomalously large compared to k at 298K. Since the previous work at 298K used a procedure that differed slightly from the one we used, we repeated the 298K measurements and came up with a k that agrees with the number measured previously. We did additional measurements on the relaxation of OH($\upsilon = 1$) by O-atoms (at 298K) and the relaxation of OH($\upsilon = 2$) by CO_2, as well as solely by O-atoms at 298K to verify the correctness of our fitting parameters.

The measurements themselves were done by monitoring the population of OH($\upsilon = 1$) via laser induced fluorescence. We chose to excite the OH($\upsilon = 1$) using the A-X(1,1) (315nm) band

and monitored the A-X(1,0) (280nm) transition. The exponential decay in the population of OH($\upsilon = 1$) can be fitted to a sum of exponentials (which accounts for other chemistries influencing the population) and returns a value for the relaxation rate constant.

Further work will probably be focused on pushing the temperature at which these experiments are performed to even lower values. We can achieve 210K with liquid nitrogen, but this necessitates certain alterations to the experimental procedure. Unfortunately, we were unable to take a shot at doing these experiments in the time available.

Victor Shia (University of California, Berkeley)
Mentors: Drs. Sanhita Dixit and Gregory Faris

Title: High-Speed Frequency Domain Camera for Time Resolved Bioimaging

This summer, I worked on a high-speed frequency domain imaging system to conduct time-resolved tissue imaging and determine fluorescence lifetime imaging. The amount of time it takes for light to pass through tissue can yield important data for detecting cancer, monitoring brain activity, and quantifying fluorophore decay rate. These time-resolved measurements can be performed in time or frequency domain. We are using the frequency domain because phase, which corresponds to time resolution, can be determined to a small fraction of a period.

We performed an opto-electrical heterodyne transform with a laser modulated at 100.0001 MHz and an image intensifier modulated at 100 MHz to obtain a 100 Hz signal containing phase data. The camera then takes images containing frequency domain information and relays it to the FPGA, which performs all of the data processing and outputs the phase information.

My part was to integrate and analyze the system. Along the way, I encountered several problems, had to think of various ways to find the source of the problem, and fixed them. This project required me to use almost all I had learned in school, ranging from programming FPGAs, creating circuitry to perform frequency mixing and provide high bias voltages, and analyzing signals and systems.

In the end, we successfully built the imaging system, and preliminary analysis shows we can distinguish phase changes of at least 5 degrees with low noise.

Anna Nicole Tchenakina (Washington and Lee University)
Mentors: Drs. Gregory Faris and Chia Pin-Pan

Title: Optical Imaging of Cancer

The main goal of my project this summer was to synthesize an NIR-dye labeled tTG peptide substrate that would serve as a target-specific contrast agent suitable for near-infrared in vivo imaging and then optimize its size. I worked on the peptide pegylation that resulted in the final target probes. These probes were injected into wound healing and tumor rats for in vivo imaging.

The wound healing model saw enhanced fluorescence as anticipated, while the tumor model lacked the predicted specificity at the boundaries demarcating the tumor. Following the experiment and data analysis, I looked into literature pertaining to TG expression levels at various stages of the tumor progression cascade. According to Kotsakis and Griffin (1), TG

activity is “reduced as the tumor mass expands and appears to be lost in the mature tumor body”. Since no specific information was available regarding the precise relationship between tumor size and TG expression, it was concluded that tumor cells do not evoke enough of a stress response from the surrounding tissue to activate tTG activity and expression to the levels seen in the wound healing model, thus explaining the poor contrast in the tumor. My final task this summer was to look into a different target probe that exhibits some sort of tumor-specific binding mechanism.

Reference

(1). Griffin, Martin. "Amino Acids." *Tissue Transglutaminase in tumor progression: friend or foe?* 3320 June 2007 373-384. Web.27 Aug 2009

Joy Zhang (Harvard University)
Mentors: Dr. Harald Oser

Title: Microbial Synthesis of Hydrocarbons

This summer, I did work on a project to determine the headspace composition of bacterial cultures, especially methicillin-resistant *Staphylococcus aureus* (MRSA). The goal was to extract volatile organic compounds (VOCs) from the headspace of the bacteria using solid phase micro extraction (SPME), and then to analyze this in the gas chromatography / mass spectrometer (GC/MS). The objective of this project was to recognize the unique headspace compositions of bacteria cultures, which would allow for a more rapid method of diagnosing diseases and a more effective treatment in patients in the early stages of the disease.

Each experiment day, Dr. Kristien Mortelmans would inoculate the bacterial strain at 8 am in a special locked room with an incubator. She would insert the blue & gray SPMEs I had provided to her the day before. After 8 hours (around 4 pm), I would take the SPMEs downstairs to the GC/MS to analyze the VOCs. Then I would bake the SPMEs at high temperatures to condition them and remove all collected compounds, to prepare it for the next day's experiment. Each day, we tested a different strain of bacteria (MRSA, MSSA, or none at all). The first few days we just did blanks, testing the room and incubator for any nascent VOCs, and then testing the two types of media (MHB & TSB) for headspace VOCs.

After I compiled a list of compounds for each strain of bacteria, I singled out the compounds that were found in MRSA’s headspace, but not in MSSA’s headspace (ignoring compounds that could be attributed to the room or the medium), which we hypothesize may be relevant to MRSA’s methicillin-resistant property. Knowing which of these compounds are related to the methicillin-resistant property can help us better understand MRSA’s biochemistry and metabolic processes, which would help us understand how to fight MRSA.

SRI 2009 REU Program Activities

1. Seminars

The REU program at the SRI's MPL has weekly meetings throughout the summer. During the summer, SRI staff members or guest speakers present a series of seminars. In addition, several other opportunities are available within SRI departments or at local events.

Date	Time	Speaker	Seminar Title
6-3-09	11-12 noon	Dr. Riccardo Melchiorri, NASA Ames	Image Spectroscopy for Planetary Observation from Satellites
6-10-09	11-12 noon	Adrian Brozell, University of California, Davis	Wetting and Emergent Properties of Support Membranes on Planar Photonic Crystals
6-15-09	1-2 PM	Dr. William Risk, IBM Almaden Research Center	Understanding Nanoscopic Structures Through Macroscopic Measurements
6-17-09	11-12 noon	Dr. Constantin Romanescu, SRI International	Laboratory Measurement of the CO Cameron Bands and Visible Emissions Following EUV Photodissociation of CO_2
6-29-09	1-2 PM	Augustus P. Lowell, Chief Systems Architect, Triple Ring Technologies Inc.	Applications of ATCA – High Performance Medical Imaging and Beyond
6-30-09	11-12 noon	Dr. Tina Kasper, Sandia National Laboratories	Mass Spectrometric Investigations of Combustion Chemistry
7-10-09	12-1 PM	Dr. Deepali Saran, SRI International	Vibrational Relaxation of Ground-State Oxygen Molecules With Atomic Oxygen and Carbon Dioxide

2. Student Presentations

All the students present their work at the end of the summer. These presentations last approximately 20 minutes, with an additional 10 minutes reserved for questions and discussion. The following is the schedule of student presentations for the summer of 2009:

Date	Time	REU Student	Seminar Title
8/4/2009	10:00-10:30 AM	Aex Marakov	Vibrational Energy Transfer in OH(υ)
8/4/2009	10:30-11:00 AM	Aya Eid	Droplet Based Artificial Lipid Bilayers
8/4/2009	11:00-11:30 AM	Joy Zhang	Microbial Synthesis of Hydrocarbons
8/4/2009	11:30 AM-noon	Victor Shia	High-Speed Frequency Domain Camera for Time Resolved Bioimaging
8/5/2009	10:00-10:30 AM	Ian Jarvis	Nanobiophotonics
8/5/2009	10:30-11:00 AM	Karen Heinselman	Mesospheric Cooling and Heating Mechanisms: Vibrational Excitation of CO_2
8/5/2009	11:00-11:30 AM	Anna Nicole Tchenakina	Optical Imaging of Cancer
8/5/2009	11:30 AM-noon	Rosanne García	Laboratory Studies of O-Atom Recombination Relevant to the Atmospheres of Mars and Venus

3. Academic / Industrial Visits in 2009

a) On June 30, the REU students attended a graduate school workshop at Stanford University, organized by the Center on Polymer Interfaces and Macromolecular Assemblies (CPIMA), a partnership between Stanford University, the University of California at Berkeley, the University of California at Davis, and the IBM Almaden Research Center. A detailed schedule of the day's events is appended.

b) On July 17, we visited the Lawrence Berkeley National Laboratory and had a tour of the Molecular Foundry. Dr. Babak Sunii and Aditi Risbud hosted our visit.

c) On July 21, the REU students attended a career day workshop at the IBM Almaden Research Center, organized by CPIMA. A detailed schedule of the day's events is appended.

d) On July 24, we visited SRI's Engineering Division where engineers Roy Kornbluh and Harsha Prahlad gave us lectures and tours of SRI's artificial muscle laboratory and the telepresence robotic surgery projects.

e) On, July 31, we held our own REU lab tours: Each student gave a brief oral overview of his or her project in the laboratory (or by the computer for a computational project). Each presentation lasted approximately 8 minutes with another 4-5 minutes for questions. The students were asked to summarize the project and its importance, and then focus on the methods and instrumentation used for the experiments. On that day, we had a visit of 5 summer interns from LBL's Molecular Foundry who visited our laboratory and attended the student lab tours. Dr. Babak Sunii and Aditi Risbud accompanied the LBL interns.

4. Social Events

Besides several weekend outings and activities the students organized on their own, we hosted informal gatherings for the students who had their birthdays in the summer, various "happy hour" and pizza lunches, payday bagel meetings, and a farewell celebration. In addition, the students attended several SRI events (e.g., New Staff luncheon, a meeting hosted by SRI's CEO, SRI Postdoctoral Fellow Meetings).

5. James R. Peterson Award for Excellence in Undergraduate Education

This award is given to the REU student who best combines technical excellence with a spirit of friendliness and cooperation. The award was established in 2006 and is dedicated to the memory of James R. Peterson, the first hire into SRI newly formed Molecular Physics Laboratory in 1956. The decision for the award is based on the nominations of the students at the end of the summer. The award recipients to date are:

1) Anand Oza, Princeton University (2006)
2) Zachary Geballe, University of Michigan (2007)
3) Brad A. Hartl, Univeristy of Wisconsin, La Crosse (2008)
4) Aya Eid, Illinois Institute of Technology (2009)