SRI REU 2008 Student Projects and Program Activities

REU 2008 students during visit at SRI's Microsystems Center

Student Research Projects and Accomplishments

Impact Testing of Ultra-High Temperature Ceramics

Daniel Brenneman (University of Missouri – La Rolla)
Mentor: Dr. Jochen Marschall

Daniel's project was to study the impact resistance and fracture toughness of hot-pressed ZrB_2 composites containing 20 percent volume SiC, with several different SiC grain sizes. Daniel manufactured the bulk materials at the Missouri University of Science and Technology. The materials were machined into bend-bar specimens, which Daniel impacted using a compressed gas gun facility while at SRI. He performed biaxial fracture testing on the impacted specimens after returning to Missouri at the end of the summer. At SRI he also prepared polished samples, thermally etched them, and characterized their microstructure and grain size distributions using a combination of electron microscopy and image analysis. Daniel's research is incorporated into a manuscript to be submitted to the Journal of the American Ceramic Society later this year.

Oxygen Atoms in Terrestrial and Planetary Atmospheres

ROSIE (Remote Oxygen Sensing by Ionospheric Excitation)
Eleanor Byler (New York University / Wellesley College)
Mentor: Dr. Kostas Kalogerakis

The main objective of ROSIE is to analyze and model observations of the 630-nm atomic oxygen red line emission from ionospheric modification experiments and to extract the corresponding local O-atom densities. The work I did on the project involved reading articles on previous work done in the subject area, extracting data, and graphing the data on Origin. From the papers I read, I went through and recorded the lifetimes they found for $O(^1D)$ and the altitudes they were found at. I graphed the results in Origin and did comparisons based on location (latitude, observatory) and altitude. This project enabled me to become familiar with a subject I was not previously knowledgeable on and gain experience using the Origin program, which was very useful when I started work on my other project.

Oxygen Atoms in Terrestrial and Planetary Atmospheres

My work for the "Oxygen Atoms in Terrestrial and Planetary Atmospheres" was a bit more hands-on than my work for ROSIE. The objective of this project is to look at oxygen atom recombination in the presence of CO_2 as relevant to the atmospheres of Mars and Venus. My mentor and I worked on setting up the experiment for much of the summer. I helped prepare the lasers for the experiment, making sure all the parts were in working order and beams were the right power and shape. We had to find the proper optics and instruments to guide our beam where we wanted it to go, and align the whole experimental system. We also performed some preliminary experiments with ozone to make sure we could see signal, to develop different methods of finding information, and to gain some general knowledge about our subject area. I graphed our initial results in Origin, and fit exponentials to the lifetimes of the different states of atomic and molecular oxygen that formed during the process of photodissociating ozone.

A Homogenous Assay for Single Target Detection Using Brownian Motion

Angelo Chandler Jr. (Worcester Polytechnic Institute)
Mentors: Drs. Marissa Yanez, Sanhita Dixit, and Gregory Faris

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. The characteristic Brownian motion of a spherical particle depends largely on the viscosity of the liquid medium and the particle size. We will use a virus as our single target given its large size relative to other biomolecules (protein/DNA). Using a virus will allow us to observe the largest changes in Brownian motion, and thereby detect the largest changes in the size of silver nanoparticles.

We functionalize silver nanoparticles with a probe antibody using Protein G. Pairs of protein G are linked together with a DTSSP linker, which creates a dilsulfide bond between the protein pairs. The disulfide bond is then “cut in half” using TCEP. This creates thiol (S-H) groups on the protein G, which allows it to covalently bind onto silver nanoparticles. Our probe antibody then binds to three receptor sites on Protein G, which functionalizes our silver nanoparticles to bind to our target virus in solution. Dynamic Light Scattering measurements were used to confirm that our nanoparticles were properly functionalized.

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. 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.

Virtual Organization of Combustion Kinetics

Kameron Harmon (Arcadia University)
Mentor: Dr. Gregory Smith

Kameron wrote Java language code to translate kinetics database entries, sponsored by an NSF Engineering project, Collaborative Research Engineering Virtual Organization: Combustion Kinetics. The code will remedy existing errors and serious gaps in the transfer of data from the ASCII-based NIST Chemical Kinetics Database to the XML-based Prime Kinetics Database, thus enabling the combustion kinetics community to perform Web-based evaluation of reactions for combustion mechanisms. Required functions include locating and matching the corresponding entries among thousands, searching for missing or incorrect information, and writing the proper revised Prime output file. The code is undergoing debugging currently.

Tumor Boundary Imaging Using Liposomes Incorporated with Near-Infrared Fluorescent Tissue Transglutaminase Substrates

Brad Hartl (University of Wisconsin)
Mentors: Drs. Chia Pin-Pan, Sanhita Dixit and Gregory Faris

<u>Composition</u>
During the first weeks of the summer various compositions of lipids were used to practice the production of liposomes. From there our main composition was slowly developed which included DPPC, DPPC-PEG 2000, Cholesterol (Molar ratio of 80:10:10), and Indocyanine Green dye (100 Molar). This final composition was developed from a mix of published information and whatever seemed to work best when actually producing the liposomes in our laboratory. At the end of the summer a composition of DPPC, DSPE-PEG 2000, Cholesterol (Molar ratio of 1.85:0.2:1), and ICG (10 Molar), which has been used in previous studies where liposomes were injected in rats.

Production

The production protocol developed was more or less based from the directions on Avanti's website with small modifications made as seemed necessary. Standard methods for purification of the liposomes were also used. A total of three different methods were tried but because of the unique properties of ICG problems were found with all. More work with other dyes and different setups will need to be tried.

Characterization

Dynamic light scattering was the primary method used to characterize the liposomes. Their diameter was measured which gave information regarding what the different changes to composition or procedure were doing. The only other characterization performed was absorbance spectroscopy. In theory a measure of absorbance before and after purification should correlate to the encapsulation efficiency. However, because we could not trust our purification method with ICG, this data was irrelevant.

In Vivo

Three experiments were performed using rats. The first experiment used free ICG dye injected into the rat in the imaging box. The entire event was captured by movie from injection to localization to the liver. The rat was then opened up two hours later to reveal the exact organs to which the dye was accumulating in. The results were that the dye was concentrated in the liver and from there being excreted with bile into the duodenum of the small intestine. Therefore the small intestine and colon also showed fluorescence.

The second experiment involved a comparison between free ICG dye and liposomes encapsulated with ICG but not purified—meaning that there would also be free dye in it. Both were injected and imaged immediately and then 2 hours later. The results for both were similar to the previous experiment with the fluorescence concentrating in the liver and intestines. However, it should be noted that the dye concentration, which was used for encapsulation, is above the quenching limit. This means that theoretically, we should not have seen the liposomes.

The last experiment we performed used encapsulated Hylite Fluor 750 inside of our old composition and a new test composition using DSPE-PEG in addition to a free dye injection. To date this experiment has not been finished.

Laboratory Studies of Ammonia Relevant to the Outer Solar System

Deena Kim (Carnegie Mellon University)

Mentors: Drs. Constantin Romanescu and Kostas Kalogerakis

This summer at SRI, I worked on a sub-project for "Laboratory Studies of Ammonia Ices Relevant to the Outer Solar System." The purpose of the original project is to explore the atmospheres of the Jovian planets, and to specifically examine ammonia ices in the clouds of Jupiter. An important problem to be addressed with this project is the disagreement between thermochemical studies and spectroscopic observations of the atmosphere. While thermochemical models of Jupiter indicate ammonia to be everywhere in the atmosphere, the spectroscopic observations do not agree and instead show ammonia to make up less than 1%.

The hypothesis is that there are two possible reasons for the scarcity of ammonia observations: (1) a photochemical process called "tanning" in which aerosols in the atmosphere create a stratospheric haze in the clouds, causing a darkening and suppression of ammonia's spectroscopic features, and (2) hydrocarbons coating the ammonia and therefore altering its optical properties.

To better understand the aforementioned discrepancy, one must fully understand the optical properties of the ices. I used a vacuum chamber as a simulated, cryogenic atmosphere for depositing ammonia gas onto a gold mirror, while employing laser interferometric methods to deetermine the refractive indices of that gas. I varied either the deposition rate, or the temperature for the experiment and investigated for any dependence. In the end, I was able to obtain values for refractive indices at varying temperatures.

Vibrational Relaxation of OH (υ = 2)

Henry Timmers (The College of Wooster)
Mentors: Drs. Constantin Romanescu and Richard Copeland

The study of phenomena related to airglow can help give insight about the chemical processes occurring in planetary atmospheres. The Meinel Bands, representing vibrational and rotational transitions within OH radicals, represents a key component in the airglow emissions from the atmospheres of Earth, Venus, and Mars and are therefore important to studying the energetics of these atmospheres. This summer's research was directed towards measuring various reaction rate constants for the relaxation of OH (υ = 2) by different quenching gases.

A two-laser set-up was used in the experiment in which a KrF excimer laser was used to photodissociate ozone to form O (^{1}D). The excited oxygen atom would react with water vapor to create vibrationally excited OH (υ = 0-2). The evolution of the population of OH (υ =2) was probed by using Laser Induced Fluorescence following excitation of $Q_1(1)$ rotational line of the $A\,^2\Sigma^+ - X\,^2\Pi_i$ transition. By varying the delay between the pump and probe lasers, a temporal profile of the OH radical was constructed which depicted an exponential decay as the radical collided with various quenching gases in the system. The reaction rates were then obtained by plotting the decay constants versus partial pressure of the quenching gases and fitting the data to a multi-dimensional linear fit. The slope of each of the population vs. partial pressure plot represented the reaction rate for the respective quenching gas.

Experiments were run at two different temperatures, at room temperature and at the temperature of a slush of dry ice in isopropanol. At room temperature, removal rate constants of $(6.3 \pm 0.4) \times 10^{-11}$ cm^{3}s^{-1}, $(8.5 \pm 0.9) \times 10^{-13}$ cm^{3}s^{-1}, and $(3.4 \pm 0.2) \times 10^{-13}$ cm^{3}s^{-1} where obtained for quenching by O (^3P), CO_2, and O_2, respectively. These values agree within error bars with the rate constants previously found for OH (v = 2). For the dry ice bath temperature of T = 232 K, removal rate constants of $(8.6 \pm 1.0) \times 10^{-11}$ cm^{3}s^{-1}, $(9.1 \pm 1.7) \times 10^{-13}$ cm^{3}s^{-1}, and $(4.3 \pm 0.5) \times 10^{-13}$ cm^{3}s^{-1} [1] where measured for O (^3P), CO_2, and O_2, respectively. There have been no previous measurements for OH (υ = 2) at this temperature, however, the rate constants seem to follow similar temperature dependences observed for higher vibrational levels of OH. The results of this research will be used in conjunction with data recorded by NASA's TIMED satellite as well as other satellites to obtain a better understanding of the chemical dynamics and energetics of both Earth's and Venus' atmosphere, as well as to help model the effects of human activities in the Earth's atmosphere.

Collisional Removal of NO in the A State

Erin van Erp (Tufts University)
Mentors: Drs. Constantin Romanescu, Deepali Saran, and Richard Copeland

Current models of the atmosphere predict its characteristics as a result of changing conditions, such as solar variability. These models will be improved by the addition of accurate rate constants. To find these rate constants, we can use a technique called laser-induced fluorescence. In order to meaningfully utilize LIF, we must be able to quantify collisional removal, a process that competes with fluorescence. My project was to determine the rate constants for the collisional removal of NO in the A state by three different colliders: itself, carbon dioxide, and oxygen. These numbers will be used in interpretations of LIF results for atmospherically relevant reactions.

I also worked on a second project that explored the reaction of $O(^3P)$ with excited oxygen. The rate constant for this reaction is directly relevant to our atmospheric models. I assisted with the assembly of the set-up and laser alignment for this experiment.

Droplet Array for a High-Throughput Real-Time PCR System

Siarhei Vishniakou (Cornell University)
Mentors: Drs. Hanyoup Kim, Sanhita Dixit, and Gregory Faris

This summer I have set up a method to produce small droplet arrays in a controlled manner. I used two approaches to accomplish the task: ink-jet printing and contact printing. Contact printing was chosen as the final solution to our problem.

My work this summer included the following:

<u>Interfacing components to a PC through LabVIEW</u>

New Era SyringePump – fluid intake and pressure control
MicroJet III controller – waveform generator for piezoelectric tip
Newport linear actuator – vertical motion
Parker linear stage – lateral motion
Omega pressure sensor – pressure indicator

<u>Experiment setup</u>

a. Ink-jet printing method

I set up a system for producing small droplets with the ink-jet tip and depositing them on a substrate of choice. This technique was found capable of producing droplets of about 50 pL at a frequency of over 2 KHz. However, the experiment was sensitive and the operation was unreliable.

b. Contact printing method

I modified the setup and LabVIEW scripts to use the contact printing method. The method proved to be reliable. Droplet sizes were less than 300 nL. The top frequency of droplet deposition was 0.7 Hz.

Data collection

I have taken pictures, videos, and notebook notes throughout my lab work. The current setup is capable of producing an array of chosen dimensions with most liquids. The coefficient of variation in droplet diameter is 3.2% for 25 droplets (5x5 array).

SRI MPL 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 local events.

Date	Speaker	Seminar Title
6-2-08	Dr. Jordi Perez, SRI Materials Research Lab	Low-Cost Solar Grade Silicon
6-10-08	Prof. Patricia Burchat, Stanford University	Dark Energy Dark Matter
6-12-08	Dr. G. Scott Hubbard, SETI Institute and Stanford	Exploring Mars
6-13-08	Dr. Vineeth Chandrasekar, SRI MPL	Equatorial Aeronomy – An Introduction
6-13-08	Dr. Hanyoup Kim, SRI MPL (postdoc series)	Development of All Optical Real-time PCR System using Laser Heating
6-20-08	Dr. Ripu Malhotra, SRI Chemical Science and Technology	A Cubic Mile of Oil: Realities and Options for Averting the Global Energy Crisis
6-27-08	Dr. Amy Rubinstein, SRI Biosciences	Fluorescent Zebrafish Arrays for Preclinical Drug Development
6-30-08	Pramod Kulkarni, California Energy Commisssion	Public Interest Energy Research Program
7-1-08	Dr. Janet Stillman, SRI Microscience and engineering Laboratory	Sometimes Thinking Inside the Box is Smaller, Faster, and Better: Integrating Microsensors and Microactuators with Eleectronics
7-11-08	Dr. Constantin Romanescu, SRI MPL (postdoc series)	Temperature dependence of NO ($\upsilon = 1$ and 3) vibrational relaxation by NO and O atoms
7-18-08	Dr. Michael Bartsch, Sandia National Laboratory	Improbable Adventures in Small-Scale R&D Research
7-18-08	Dr. Dmitry Geraschenko, SRI Biosciences	Identification of Neuronal Phenotypes Involved in Sleep/Wake Regulation
7-27-08	Dr. Noah Goldberg, Stanford University	Vibrational Excitation through Tug-of-War Inelastic Collisions

8-1-08	Dr. David Huestis, SRI MPL	Earth, Venus, Mars, and the Greenhouse Effect
8-6-08	Dr. Fabio Iocco, INAF / Osservatorio Astrofisico di Arcetri	Dark Matter, From Cosmology to Stars
8-19-08	William Boenig, VNUS Medical Technologies	Current Research Projects
8-22-08	Dr. Sanhita Dixit, SRI MPL	A Label-Free Optical Technique to Study the Mechanics of Protein-DNA Interactions

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 2008:

Date	REU Student	Seminar Title
8/13/2008	Daniel Brenneman	Impact Testing of Ultra-High Temperature Ceramics
8/13/2008	Brad Hartl	Tumor Boundary Imaging Using Liposomes Incorporated with Near-Infrared Fluorescent Tissue Transglutaminase Substrates
8/13/2008	Deena Kim	Studies of Ammonia Relevant to the Outer Solar System
8/14/2008	Angelo Chandler	Homogenous Assay for Single Target Detection Using Brownian Motion
8/14/2008	Erin van Erp	Collisional Removal of NO in the *A* State
8/14/2008	Siarhei Vishniakou	Droplet Array for a High-Throughput Real-Time PCR System
8/15/2008	Eleanor Byler	Studies of Oxygen in Planetary Atmospheres
8/15/2008	Kameron Harmon	Virtual Organization of Combustion Kinetics
8/15/2008	Henry Timmers	Vibrational Relaxation of OH(υ = 2)

3. Academic / Industrial Visits in 2008

- On June 27, we visited SRI's Engineering Division where engineers Pablo Garcia, and Harsha Prahlad gave us lectures and tours of SRI's telepresence robotic surgery projects and the artificial muscle laboratory.
- On July 16, Dr. Regis Vincent of SRI's Artificial Intelligence Center introduced us to the autonomous robotics technologies his group is developing and we witnessed a live autonomous robot demonstration.
- On, July 24, 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 7 minutes with another 4-5 minutes for questions. The students were asked to cover briefly their project, why they do it, and then focus on how they do the experiments and the instrumentation they use.
- On July 29, we visited AKT (a division of Applied Materials), a local Silicon Valley company that makes equipment for manufacturing flat panel displays. The equipment uses PECVD (plasma enhanced chemical vapor deposition) to deposit a-Si, SiN and SiO films on large glass substrates. We attended a lecture and then toured the manufacturing facility.
- On August 4, we visited the Electrical Engineering Department at Stanford University, where our REU 2004 alumnus Nader Moussa, currently a graduate student at Stanford, gave us a brief presentation/overview of ongoing studies in Prof. Umran Inan's Very Low Frequency Research Group and then showed us the laboratories, where they assemble remote data collection equipment for polar upper atmospheric science. Afterwards, we had a brief tour at Stanford's Bio-X Department.
- On August 12, we visited the Lawrence Berkeley National Laboratory and had a tour of the X-Ray Laser Facility and the Advanced Light Source.
- On August 19, William Boenig, an REU student in MPL during the summer of 2003, gave a short presentation on his current work followed by informal discussions with the students on REU experiences, career paths, and biotechnology companies in the San Francisco Bay Area. William is currently an R&D Engineer with VNUS Medical Technologies, Inc. in San Jose.

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, meeting hosted by SRI's CEO, SRI Summer BBQ, SRI Postdoctoral Fellow Meetings, etc.).