UC Santa Barbara MRL Materials Research Laboratory
NSF Materials Research Science and Engineering Center [DMR-2308708]

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Camp Summer Student Projects 2011

Establishing Evolutionary Pathways Between RNA Building Blocks

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Ed Aguilar Biochemistry	Erin Calkins	Professor Luc Jaeger	Chemistry and Biochemistry

An Experimental Investigation of the Thermal Contact Resistance in a Thermal Barrier Coatings System

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Aimee Flores Chemical Engineering	Raymond Valdes	Professor Ted Bennett	Mechanical Engineering

Analytical Investigation of Thermal Contact Resistance in a Thermal Barrier Coating System

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Amelia Herrera Mechanical Engineering	Raymond Valdes	Professor Ted Bennett	Mechanical Engineering

The Relationship Between Pollen Performance and Seed Size in Selfing and Outcrossing Clarkia, an Annual Native Wildflower

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Karlon Johnson Environmental Studies	Alisa Hove	Professor Susan Mazer	Cellular, Molecular and Developmental Biology

Standardizing Toughness Measurement Tests of Stabilized Zirconia Materials

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Damian Leon Mechanical Engineering	Jessica Krogstad Erin Donohue	Professor Carlos Levi	Materials

Measuring the Evaporation Rate of Sessile Droplets Placed on Heated Hydrophilic and Hydrophobic Surfaces

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Irving Martinez Mechanical Engineering	Meysam Barmi	Professor Carl Meinhart	Mechanical Engineering

Hybrid Kinetic Monte Carlo - Transition Path Sampling Study of Solid-State Precipitate Nucleation

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Antonio Ortiz Chemical Engineering	Professor Baron Peters	Professor Baron Peters	Chemical Engineering

A Comparision of Microtubule Bundling Induced by Different Tau Protein Isoforms and Fragments

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Thomas Oyuela-Trachter Biological Sciences	Peter Chung	Professor Cyrus Safinya	Materials

An Investigation of the Flourescence Quenching Properties and Raman Spectra of Graphene

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Anthony Quintana Biochemistry	Alex Heilman	Professor Michael Gordon	Chemical Engineering

Systhesis of Heterobifunctional Polyethylene Glycol Derivatives for the Applications of Nanomedicine

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Christina Rodriguez Chemistry	Dr. Nathanial Lynd	Professor Craig Hawker	Materials

Siliccon Nitride Ultralow Loss Laser

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Alfredo Torres Electrical Engineering	Jock Bovington	Professor John Bowers Professor Daniel Blumenthal	Electrical and Computer Engineering

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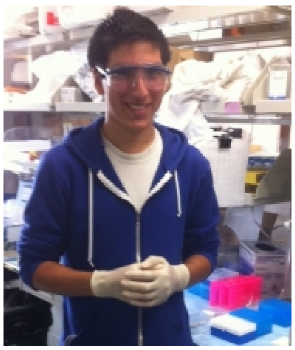
MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Ed Aguilar



Major: Biochemistry

Mentor(s): Erin Calkins

Faculty Sponsor(s): Professor Luc Jaeger

Faculty Sponsor's Department(s):
Chemistry and Biochemistry

Project Title: Establishing Evolutionary Pathways Between RNA Building Blocks

Project Description:
Nucleic acids, such as DNA and RNA, are pertinent to applied science at the nanoscale because of their tertiary structures. RNA tertiary structure, when compared to DNA, is considered more dynamic in nature because it can fold into multiple structural motifs, such as tetraloops and receptors. The objective was to analyze evolutionary pathways between receptors selected in vitro and the naturally occurring 11-nucleotide receptor to provide insight on how evolutionary changes might have occurred. For this study, we organized functional receptors, for GNRA tetraloop sequences—where N is any nucleotide, and R is any purine, into a network linked through mutated intermediates. We were interested in determining how designable these tertiary interactions were, and whether or not the naturally occurring 11-nucleotide motif was a result of evolutionary convergence. The principle methods used involved DNA amplification, transcription and radiolabeling to provide the RNA samples, and polyacrylamide gel electrophoresis (PAGE) to test them. The analysis of these PAGE gels provided qualitative and quantitative data for receptor interactions with different GNRA tetraloops. Analysis of these results revealed that these RNA tertiary interactions have a high degree of plasticity, which led to the characterization of intermediates between receptors with varying specificity. The susceptibility to mutation and multiple proposed evolutionary pathways suggest that convergence is a likely reason for the prevalence of the 11-nucleotide motif in nature. Furthermore, the establishment of this receptor network provides groundwork for potential developments in nanoconstruction, as the receptors have been characterized and compiled into a library of functional sequences.

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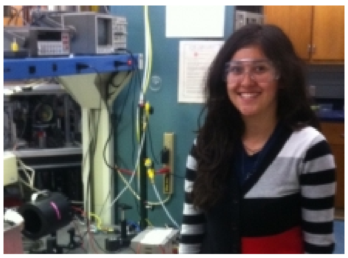
Aimee Flores



Major: Chemical Engineering

Mentor(s): Raymond Valdes

Faculty Sponsor(s): Professor Ted Bennett

Faculty Sponsor's Department(s):
Mechanical Engineering

Project Title: An Experimental Investigation of the Thermal Contact Resistance in a Thermal Barrier Coatings System

Project Description:
Thermal barrier coating (TBC) systems have the potential to provide increased thermal efficiency and reliability in our nation's aircraft propulsion and power plants. However, evidence indicates high temperature cycling in these environments and thermal property mismatch between the ceramic coating and metal substrate may cause coating delamination and TBC failure. To probe the effects of this, we sought to design a process to fabricate a model TBC system with a "prescribed" delamination and to experimentally determine the thermal contact resistance. To test this, a TBC system was created using glass as a model ceramic coating and a nickel superalloy as a metal substrate. One side of the glass was coated with an etchant and sanded to control the surface roughness. This surface texture introduced microgaps at the interface and a test fixture was developed to induce a pressure bond between the materials. To measure the thermal contact resistance, a CO2 laser pulse heated the glass side of the TBC system and a thermal imaging camera was used to measure the thermal response of the substrate. Subsequent data was fitted against a theoretical heat transfer model, based on specifications of the TBC system, to determine the unknown contact resistance and compared against theoretical results. By testing different samples with varying levels of roughness, we anticipate the thermal contact resistance to be greater in rougher surfaces and hope that the understanding of thermal contact resistance of thermal barrier coatings will lead to greater efficiencies and advancements in electronics, biomedicine, and aircraft propulsion.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Amelia Herrera

Major: Mechanical Engineering

Mentor(s): Raymond Valdes

Faculty Sponsor(s): Professor Ted Bennett

Faculty Sponsor's Department(s):
Mechanical Engineering

Project Title: Analytical Investigation of Thermal Contact Resistance in a Thermal Barrier Coating System

Project Description:
Thermal Barrier Coatings (TBC) systems are thin ceramic coatings that are applied in aircraft propulsion and power generation to improve thermal efficiency and reliability by protecting components from high temperature gases. Aging and environmental factors may cause the coatings to delaminate, creating micro gaps at the coating-substrate interface which slows down the heat transfer rate at the interface and creates hotspots. These microgaps are precursors to total TBC failure. In this study, we characterized and quantified the effective thermal contact resistance (TCR) induced by degradation of TBC systems. We used a two–layered model system, nickel superalloy and borosilicate glass, because it closely approximates the thermal and optical properties of conventional TBC systems. The interface was characterized by using a profilometer and through hardness testing. These parameters were measured combined with known material properties to analytically determine the TCR. A theoretical heat transfer model of our system was developed and was used for further analysis. We compared the results against a noncontact TCR measurement method which irradiates the front side of the sample using a CO_2 laser and used a thermal imaging camera to obtain a temperature field response on the back end. A successful comparison will allow us to determine the TCR using this noncontact test method and further our understanding of TCR in TBC systems.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Karlon Johnson

Major: Environmental Studies

Mentor(s): Alisa Hove

Faculty Sponsor(s): Professor Susan Mazer

Faculty Sponsor's Department(s):
Cellular, Molecular and Developmental Biology

Project Title:
The Relationship Between Pollen Performance and Seed Size in Selfing and Outcrossing Clarkia, an Annual Native Wildflower

Project Description:
Scientists have strived to understand the nature of the mating systems that allow plant species to flourish in their respective environments. The annual wildflower genus *Clarkia* contains several pairs of outcrossing and selfing sister taxa with different mating systems. The goal of this project is to: (1) determine the relationship between pollen performance and seed size in two self-compatible *Clarkia* sister taxa (*C. exilis*, a predominant selfer) and *C. unguiculata* (a predominant outcrosser) and (2) whether the nature of this relationship depends on the mating system of a given taxon. Numerous pollen samples and seed samples from 190 individual plants were extracted from eight sites across the Sierra Nevada foothill region in 2008. We weighed 30 seeds from each of the samples to obtain the average seed size of the taxa. In addition, fluorescence microscopy was used to measure pollen tube growth rates of each *Clarkia* taxon. We predicted that there would be a positive linear correlation between seed size and pollen performance for each taxon. Furthermore, we expected this relationship to be stronger in *C. unguiculata* (the outcrosser) taxa because of the potential for intra-male pollen competition to promote the evolution of rapid pollen tube growth. Contrary to our expectation, we found that there was no relationship between pollen performance and seed size in either taxon. We did detect, however, differences between the sister taxa in pollen performance and in seed size. *C. unguiculata* had faster pollen tube growth rates and heavier average seed weight than its selfing sister species, *C. exilis*. Our project will provide information regarding the effects of environmental change and the evolutionary outcomes of mating system transitions in plants.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Damian Leon

Major: Mechanical Engineering

Mentor(s): Jessica Krogstad
Erin Donohue

Faculty Sponsor(s): Professor Carlos Levi

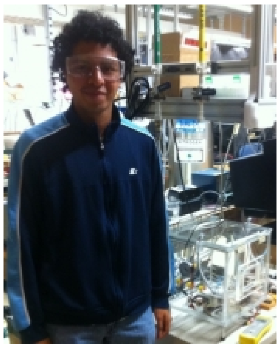
Faculty Sponsor's Department(s):
Materials

Project Title: Standardizing Toughness Measurement Tests of Stabilized Zirconia Materials

Project Description:
Thermal barrier coatings (TBCs) increase the thermal capability and enhance efficiency of gas turbines and jet engines. Their industrial and commercial importance has motivated researchers to discover more effective material compositions. One difficulty arises in comparing the toughness of emerging materials with those currently in use. Hence, this study focuses on validating a toughness test in order to have a means of comparison, specifically between 7 wt% yttria stabilized zirconia (7YSZ) and cerium titania stabilized zirconia (CeTiSZ). 7YSZ is the current state of the art TBC and as such the toughness has previously been determined and will be used as a baseline. The phase stability and hypothesized higher toughness of CeTiSZ makes it a material of interest. Sample preparation relies on the production of fine and uniform powders that are subsequently formed into homogeneously dense, bulk ceramic bars of 7YSZ. These specimens are then placed under a three point bend test to assess their toughness values. Use of a three point bend test is due to its simplicity as well as its well developed testing mechanism. Accurate values for 7YSZ, will be compared with additional stabilized zirconia materials, such as CeTiSZ. Thus, initial studies will provide useful information of potential material compositions for future thermal barrier coatings.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Irving Martinez



Major: Mechanical Engineering

Mentor(s): Meysam Barmi

Faculty Sponsor(s): Professor Carl Meinhart

Faculty Sponsor's Department(s):
Mechanical Engineering

Project Title: Measuring the Evaporation Rate of Sessile Droplets Placed on Heated Hydrophilic and Hydrophobic Surfaces

Project Description:
Free surface microfluidics has received much attention for its applications, especially in airborne chemical detection. In free surface microfluidics the evaporation rate plays an important role in the flow dynamics therefore we quantified the evaporation rate of a droplet of water from 0.5 to 3 microliters on different types of hydrophilic and hydrophobic surfaces at various temperatures ranging from ambient temperature to 70C. We also recorded the change in the contact angle of the water droplet through time on the different surfaces. The evaporation rate was measured by placing a droplet of water on a surface inside of a chamber and finding the average evaporation time and then the rate was related to temperature through an equation similar to the Antoine equation which relates vapor pressure and temperature. The contact angle was recorded throughout the experiment by taking pictures of the droplet at different times and using image analysis software. From these experiments we observed a correlation between constants in the equation used and using the evaporation rate and information obtained from the pictures we related the constants to the different surfaces they were placed on and parameters such as surface temperature and humidity. From the experiments performed in a controlled environment we observed a pattern between the constants that relate evaporation to temperature and then related the constants to the different surfaces. This study will provide important information to the development of devices for airborne chemical detection.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Antonio Ortiz

Major: Chemical Engineering

Mentor(s): Professor Baron Peters

Faculty Sponsor(s): Professor Baron Peters

Faculty Sponsor's Department(s): Chemical Engineering

Project Title: Hybrid Kinetic Monte Carlo - Transition Path Sampling Study of Solid-State Precipitate Nucleation

Project Description:
As concern grows for the development of clean and sustainable energy sources and the advances in computation, engineering, and materials science converge, emphasis is placed in the development of more efficient materials. A problem in material science is that nucleation is poorly understood. Nucleation is the process by which the first stable embryo of a precipitate forms. Precipitates grow and then coarsen to form the microstructure of the material, which largely influences material properties. Simulations exist for the later stages of growth and coarsening but not for the nucleation step. Simulating nucleation is difficult as a successful nucleation event may involve millions of atom hops and exceed the limits of standard kinetic Monte Carlo simulations. We hypothesize that a timescale separation between the atom hopping time and the nucleation time can be exploited to understand nucleation mechanisms in metastable solids at realistic supersaturations.

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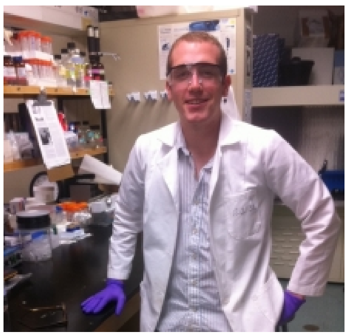
Thomas Oyuela-Trachter



Major: Biological Sciences

Mentor(s): Peter Chung

Faculty Sponsor(s): Professor Cyrus Safinya

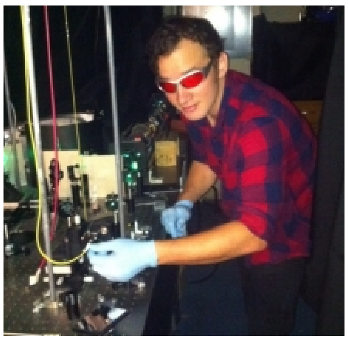
Faculty Sponsor's Department(s):
Materials

Project Title: A Comparision of Microtubule Bundling Induced by Different Tau Protein Isoforms and Fragments

Project Description:
A leading hallmark of Alzheimer's disease is the formation of neurofibrillary tangles (NFT's) in the neurons of our central nervous system. NFT's are almost entirely accumulations of insoluble microtubule-associated protein tau fragments. Tau is a highly disordered protein and its normal function seems to be the assembly and stabilization of microtubules in neuronal cells. In the adult human brain, tau exists in six different isoforms that possess either three or four imperfect repeats constituting the microtubule-binding domains. Previous studies have analyzed tau function in vitro: however it is unclear how tau induces microtubule bundling at physiological conditions. Herein, we compared how different tau isoforms and tau protein fragments induce bundling of microtubules at physiological conditions. Different tau isoforms, mutants and deletion constructs were synthesized using expression vectors in E. Coli bacteria. Once purified, tau and tubulin were mixed and polymerized to form microtubule bundles. Our previous work determined the structure of these microtubules using reciprocal-space imaging techniques. This current study imaged these microtubule structures using real-space imaging techniques to complement the reciprocal-space technique. With this approach, we were able to observe and confirm that all wild-type isoforms induce microtubule bundling. Some fragments and deletion constructs induced bundling as well. These experiments allow us to characterize tau dysfunction in context of the microtubule-tau complex. Furthermore, understanding the functional properties of tau fragments and deletion constructs enables us to find out the structural dependence of certain segments of the protein. We hope that this data provides insights to the discovery of new ways to combat Alzheimer's disease.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Anthony Quintana



Major: Biochemistry

Mentor(s): Alex Heilman

Faculty Sponsor(s): Professor Michael Gordon

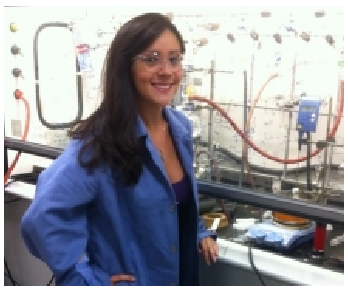
Faculty Sponsor's Department(s):
Chemical Engineering

Project Title: An Investigation of the Flourescence Quenching Properties and Raman Spectra of Graphene

Project Description:
The development of novel methods of microscopy at the atomic scale will revolutionize the imaging and control of materials in the near future. Although the concept of Raman light scattering in microscopy is not new, a reliable Tip Enhanced Raman Spectroscopy [TERS] system has yet to be perfected. One reason for this is that Raman signals are inherently weak and greatly overshadowed by fluorescence. This summer we focused on growing high quality, monatomic layers of graphene. Graphene's fluorescence quenching properties have the potential to advance the development of TERS. Samples were prepared on Cu foils via a chemical vapor deposition process and transferred to a silicon substrate for study. We have confirmed the presence of quality few layer graphene (<10 layers) using Atomic Force Microscopy and Raman spectroscopy. Raman spectroscopy has also been used to analyze the quality of the graphene samples through direct comparison with graphite. This data is being used to develop a reliable and reproducible procedure for growing high quality single layer graphene. Our next goal is to qualitatively analyze the fluorescence quenching properties of graphene by examining the Raman spectra of several aromatic compounds when adsorbed to it. Anthracene, pentacene, and pyrene were chosen for initial study because these compounds not only fluoresce in the UV-Vis range, but are also Raman active. Gaining better understanding of graphene's fluorescence quenching behavior will allow for its future use as a substrate for chemically patterned surfaces to be analyzed via TERS.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Christina Rodriguez



Major: Chemistry

Mentor(s): Dr. Nathanial Lynd

Faculty Sponsor(s): Professor Craig Hawker

Faculty Sponsor's Department(s): Materials

Project Title: Systhesis of Heterobifunctional Polyethylene Glycol Derivatives for the Applications of Nanomedicine

Project Description:
Heterobifunctional polyethylene glycol was synthesized with specific functional groups for convenient attachment to nanoparticles and biologically active molecules. Functionalizing PEG and allowing it to bear different functional groups, enables the use of nanoparticles as drug delivery carriers, imaging agents for diagnostics, and specific targeting systems. Present studies suggest that PEG facilitates in the hydrophilicity of biomaterial substrates and subsequently aids in attaining a receptive immune system response. PEGylation of biomaterial substrates also decreases their immunogenicity and enzyme degradation. An important characteristic of PEGylation is the selection of the functional groups on PEG since these are used to attach the PEG to biologically active molecules, such as peptides or proteins. The present study is aimed at synthesizing PEG derivatives in the most efficient and effective manner, while still maintaining the stability of the attached functional groups. We chose to create a heterobifunctional PEG derivative carrying a thiol group on one end and an active ester on the other end. The synthesis of this PEG derivative was verified by 1H NMR and involved the evolution of synthetic methods to determine the appropriate synthetic steps to maximize yield and functional group compatibility. To create the most useful PEG derivatives we will design methods of preparation that provide a simple route for the synthesis of heterobifunctional PEGs. This study will provide useful information regarding PEGylation and its potential uses in nanomedicine.

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MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Alfredo Torres

Major: Electrical Engineering

Mentor(s): Jock Bovington

Faculty Sponsor(s): Professor John Bowers
Professor Daniel Blumenthal

Faculty Sponsor's Department(s):
Electrical and Computer Engineering

Project Title: Siliccon Nitride Ultralow Loss Laser

Project Description:
This project involves the development of a new platform enabled by ultra-low loss Si3N4 waveguides integrated into optical circuits with active III-V semiconductor devices. Integrating the new platform merging the low loss silica waveguides with the III-V bonding technology used in the Silica hybrid platform. Characterization is being performed in different optical and electrical scenarios. This new platform integrates waveguides, amplifiers, lasers and other passive devices used for optoelectronic systems. For example optical gyroscopes could be conceived by measuring phase differences of counter-propagating signals in such ultralow loss waveguides, which can be applied to jets, or robots.

Long cavity laser devices will be fabricated which must be characterized to confirm the proper function. In one such design, a mode-locked laser, the long cavity of the laser will provide a low repetition rate thus allowing higher peak power. The target wavelength for this laser is 1.03µm, and required a new characterization setup which has been built. The initially fabricated Fabry Perot (FP) laser diodes are currently being tested to analyze electrical and optical characteristics of the bonded III-V gain material. The setup allows us to control the stage temperature, and the input current for initial electrical pulsed and continuous wave (CW) measurements. The initial results of two similar processing chips have shown that the initial chip lasers have better optical characteristics than the second chip lasers, but the electrical characteristics are better on the second chip. Further data must be organized and analyzed to determine what processing methods can be improved to get an ideal FP laser diode which exhibits reasonable optical and electrical characteristics.