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 2016

Electrochemical Production of Multi-Junction Nanorod Solar Cells

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Rachel Alvelais Chemistry	Will Elliott	Martin Moskovits	Chemistry and Biochemistry

Optimization of DNA Nunchuck Seed Design for Accurate Measurement of DNA Bend Angle

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Sebastian Arias Physics	Lourdes Velazquez	Deborah K Fygenson	Physics

Molecular Regulation of δ -catenin Protein Production in Neural Networks

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Karla Bernardo Pharmacology	Elmer Guzman	Kenneth Kosik	Cellular, Molecular and Developmental Biology

Towards a Quantitative Understanding of How Artificial Materials Affect Biomolecules

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Amanda Caceres Chemistry	Martin Kurnik	Kevin Plaxco	Chemistry and Biochemistry

Incorporating Nitrogen Functionality Into Small Molecules by Utilizing a Radical Trap Cyclization Process

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Luis Limon Chemistry	Jamie Shaum	Javier Read de Alaniz	Chemistry and Biochemistry

Does a romantic partner's compassionate love predict the other partner's sense of feeling supported? Effects of compassionate love on empathy, responsive behavior, and perceived partner responsiveness

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Michelle Marin Biopsychology	Lauren Winczewski	Nancy Collins	Psychological and Brain Sciences

Assessing the Effects of Nearshore Brushfires on Heavy Metal Concentrations in Mussels near Pitas Point, California

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Jacobo P-Pacheco Environmental Science	Cruz Ortiz	Arturo Keller	Environmental Science and Management

The Role of Membrane Hydration in PEGylated Cationic Lipid Vectors for Targeted Gene Delivery

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Andrea Ramirez Pharmacology	Emily Wonder	Cyrus Safinya	Materials

Effect of Side-Chain Architecture on Conjugated Polymer Self-Assembly

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Isaac Robledo Chemical Engineering	Brenden McDearmon	Craig Hawker	Materials

Temperature Controlled Electrodeposition for Low Platinum Loading on Proton Exchange

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Charlene Salamat Chemistry	Cynthia Cooper	Steven K. Buratto	Chemistry and Biochemistry

Unraveling the Mechanism of Transition Metal Sulfide Conversion Electrodes with Local Structure Methods

Student	Mentor(s):	Faculty Sponsor(s)	Department(s):
Catrina E. Wilson Chemistry	Vicky V.T. Doan-Nguyen Joshua D. Bocarsly	Ram Seshadri	Materials

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Rachel Alvelais

Major: Chemistry

Mentor(s): Will Elliott

Faculty Sponsor(s): Martin Moskovits

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

Project Title: Electrochemical Production of Multi-Junction Nanorod Solar Cells

Project Description:
Most commercial silicon-based photovoltaics do not effectively use all the light they absorb. Multi-junction solar cells made out of non-silicon materials, such as cadmium chalcogenides, can obtain higher efficiencies, but these cells require painstaking and costly techniques to produce. With electrochemical bath processing and chemical depositions, we can economically produce nanorod-based photovoltaic devices with large usable surface areas. As a proof of concept, we have produced a solar cell by depositing cadmium telluride, followed by gold onto silver nanowires fabricated in porous alumina which functions as a template for the growth of nanostructures. This work details the construction of such a device and the characterization that must be done to prove a device's merit.

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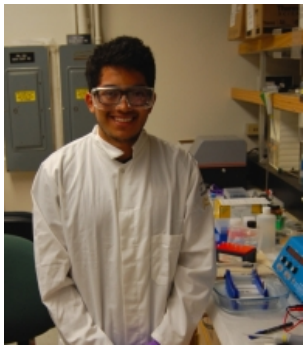
Sebastian Arias



Major: Physics

Mentor(s): Lourdes Velazquez

Faculty Sponsor(s): Deborah K Fygenson

Faculty Sponsor's Department(s):
Physics

Project Title: Optimization of DNA Nunchuck Seed Design for Accurate Measurement of DNA Bend Angle

Project Description:
DNA has been studied extensively because its base pair sequence stores information that guides living systems. However, there is more to DNA function than its sequence. There is increasing evidence that DNA bending plays a crucial role in enzymatic processes as well as information storage and retrieval. In particular, DNA bending dynamics and its effects on gene regulation remain to be fully understood. This is due, in part, to the absence of a reliable method of measuring DNA bend angle and bend angle dynamics. We have shown that DNA structures resembling nunchucks can be formed via tile-based DNA nanotubes whose nucleation is controlled by DNA origami seeds. We aim to use these DNA nunchucks as mechanical amplifiers with which to visualize DNA bend angle and bending dynamics. To test this approach, we have made nunchucks with intrinsically straight and intrinsically bent linkers, and measured their bend angles over time via fluorescence video microscopy. However, the observed angles do not correlate with linker type. We hypothesize that the discrepancy is due to an unintended feature of the nunchuck design, which places a >4kb loop of single-stranded DNA protruding in the middle of each nucleating seed. We are using the asymmetric polymerase chain reaction (aPCR) to produce smaller DNA origami seeds void of any such loop. Here we compare DNA nanotube yields in order to describe the efficiency of aPCR at producing desired DNA sequences without affecting DNA seed formation and or function.

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Karla Bernardo

Major: Pharmacology

Mentor(s): Elmer Guzman

Faculty Sponsor(s): Kenneth Kosik

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

Project Title: Molecular Regulation of δ -catenin Protein Production in Neural Networks

Project Description:
δ-catenin plays an integral role in neural communication and has been shown to affect cognitive function when mutated or insufficiently expressed. Inadequate amounts of δ-catenin present between synapses during neurodevelopment has been linked to Cri-du-Chat syndrome, Alzheimer's disease, and specific forms of autism. To further elucidate the processes by which δ-catenin expression is inhibited, our research genetically manipulates segments of the δ-catenin mRNA – more specifically, the 5' untranslated region (5'UTR), coding sequence (CDS), and 3' untranslated region (3'UTR) – to examine how molecular structure may regulate protein production. Each segment is incorporated in plasmids alongside a fluorescent reporter that allows us to visualize produced protein upon introducing the DNA in mouse primary cells. By photobleaching the primary cells prior to temporal analysis, we are able to detect the amount of new protein produced through fluorescence microscopy. We expect that, in cell cultures containing the 5'UTR mutation, non-specific ribosomal proteins may bind to the hairpin structure of the sequence, causing lessened δ-catenin expression over time. Interactions with microRNAs present in the cytoplasm by the 3'UTR may degrade expression at a greater extent than the 5'UTR. Thoroughly understanding these effects on δ-catenin production will ultimately aid in the development of neurological pharmaceuticals at a molecular level.

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Amanda Caceres

Major: Chemistry

Mentor(s): Martin Kurnik

Faculty Sponsor(s): Kevin Plaxco

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

Project Title: Towards a Quantitative Understanding of How Artificial Materials Affect Biomolecules

Project Description:
Proteins tend to misfold and adhere to artificial surfaces, limiting our ability to employ proteins and their many functions in technologies. Understanding the physics behind such surface-induced protein misfolding would enable design of improved biocompatible surfaces on which proteins retain their structure and function. Such materials could be used to design new protein-based biosensors for detection of a variety of biomarkers. Thus motivated, I aim to experimentally determine the origins of surface-induced protein adsorption and misfolding using a new, quantitative, technique to measure the thermodynamic stability of surface-tethered proteins. To this end, I have designed, produced, and purified proteins that can be site-specifically attached to surfaces, and characterized their thermodynamic stability in bulk solution. Comparison of the stability of the protein in solution to that of the surface-tethered protein will inform on the effect surfaces have on protein structure and function. Ultimately, I expect my work to lead to the first high-precision measurements of how artificial surfaces affect protein function and stability. These results can then be used to build new, quantitative theoretical models of protein-surface interactions, models that ultimately can be used to guide rational design of new artificial surfaces that are optimally compatible with protein structure and function.

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Luis Limon

Major: Chemistry

Mentor(s): Jamie Shaum

Faculty Sponsor(s): Javier Read de Alaniz

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

Project Title: Incorporating Nitrogen Functionality Into Small Molecules by Utilizing a Radical Trap Cyclization Process

Project Description:
Although many efforts have come forth towards the construction of sterically hindered anilines, methodologies for their synthesis have left room for refinement. Their utilization in medicinal chemistry has led to syntheses that employ highly reactive organometallic reagents to form these molecules. While the construction of these compounds often requires reactions such as Buchwald-Hartwig Coupling or reductive amination, we are instead employing a radical trap cyclization process that makes use of readily available starting materials. We are using a cheap and mildly reactive copper catalyst to incorporate nitrogen functionality into small molecules. We hope to develop new routes to the synthesis of pharmaceutical drugs that are cheaper and more versatile than the ones currently employed. The same reaction conditions have been utilized to construct several macrocycles that are often difficult to synthesize. Future work will focus on optimizing these conditions in hopes of applying this process to fabricate albuterol derivatives, a common commercially used bronchodilator used in inhalers.

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Michelle Marin

Major: Biopsychology

Mentor(s): Lauren Winczewski

Faculty Sponsor(s): Nancy Collins

Faculty Sponsor's Department(s):
Psychological and Brain Sciences

Project Title:
Does a romantic partner's compassionate love predict the other partner's sense of feeling supported? Effects of compassionate love on empathy, responsive behavior, and perceived partner responsiveness

Project Description:
Recent research suggests that empathic concern, or feelings of compassion and sensitivity towards others, motivates people to be responsive towards their partner. In the current study, we argue that partners who feel empathic concern in specific interactions are those who generally feel compassionate love towards their partner. We proposed a process model wherein support-providers high in compassionate love would feel greater empathic concern, which would facilitate an increase in responsive behavior. We further predicted that this responsive behavior would be associated with support-recipients' perceived partner responsiveness (i.e., beliefs that their partner understands, cares for, and accepts the self). To examine this interpersonal process, we recruited couples (N = 91) to discuss the support-recipients' personal or relationship stressor. Before the laboratory discussion, we measured support providers' compassionate love. After the discussion, we assessed support-providers' empathic concern, responsive behavior, and the support-recipients' perceptions of their partner's responsiveness. Objective observers rated the degree of support-providers' responsive behavior. In line with predictions, we found support for the proposed process model: There was a positive association between support providers' compassionate love and empathic concern, which predicted more responsive behavior and support-seekers' perceived partner responsiveness. Findings indicate that people high in compassionate love not only felt more concern and expressed more responsive behavior, but their partners were also able to detect their partner's concern and ultimately felt more understood, validated, and cared for. The findings suggest a need for future experimental studies that would illuminate causal effects of compassionate love on benevolent responding and perceptions of responsiveness.

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Jacobo P-Pacheco

Major: Environmental Science

Mentor(s): Cruz Ortiz

Faculty Sponsor(s): Arturo Keller

Faculty Sponsor's Department(s):
Environmental Science and Management

Project Title: Assessing the Effects of Nearshore Brushfires on Heavy Metal Concentrations in Mussels near Pitas Point, California

Project Description:
Filter feeding mussels serve as bioindicators of intertidal coastal ecosystems, in particular for heavy metals that can be toxic to wildlife and humans. This study investigated the concentration of heavy metals (Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Zn) in ocean water, beach sediment, and mussels (*Mytilus californianus*) near Pitas Point, California. The samples were procured before, during, and after the 2015-2016 rain season (October-July); during which time a nearshore brushfire broke out near the sampling site. Metal concentration in samples were determined with an Agilent inductively coupled plasma mass spectrometer (ICP-MS) 7900 series using EPA Methods 3052 and 3051A. Baseline (October) mean concentrations in mussels (dry weight) were 282±39 ppm, 1.46±0.2 ppm, 361±46 ppm, and 1.5±0.15 ppm for aluminum (Al), chromium (Cr), iron (Fe), and nickel (Ni), respectively. Mussels collected in January showed a percent increase of 130, 124, 143, and 120 for Al, Cr, Fe, and Ni, respectively. Overall, the data suggests that pyrogenic remobilization of trace elements can significantly alter water quality in intertidal coastal ecosystems with nearshore brush prairies. A cycle that can be exacerbated by drought conditions resulting from climate change in California.

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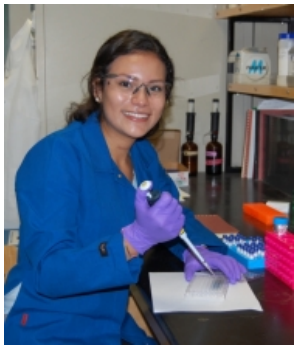
Andrea Ramirez



Major: Pharmacology

Mentor(s): Emily Wonder

Faculty Sponsor(s): Cyrus Safinya

Faculty Sponsor's Department(s):
Materials

Project Title: The Role of Membrane Hydration in PEGylated Cationic Lipid Vectors for Targeted Gene Delivery

Project Description:
Gene therapy aims to provide an alternative method for treating a wide range of diseases by correcting, replacing, or silencing defective genes. Synthetic lipid vectors composed of cationic lipids that self-assemble with DNA form safe, efficient, and versatile gene delivery vehicles. Attachment of polyethylene glycol (PEG) chains to the outer lipid headgroups provides particles with steric stabilization and “stealth” but also inhibits cell-nanoparticle interactions. Attaching peptides to the distal ends of the PEG chains recovers interactions by facilitating binding to cell receptors for targeted delivery. Because the hydration repulsion layer on the surface of lipid membranes creates a hurdle for transfection efficiency, understanding the importance of neutral phospholipids and their role in hydration of targeted nanoparticles is key to optimization. However, because PEGylation inhibits membrane interactions with nanoparticles, we expect the effect of hydration to be reduced relative to non-PEGylated particles. In this study, we reduced the hydration repulsion layer by substituting in neutral lipids with smaller headgroups (e.g. phosphatidylethanolamine vs. phosphatidylcholine). Flow cytometry, fluorescence microscopy, and biological assays were used to measure cellular uptake and binding, endosomal escape, and transfection efficiency of different nanoparticle formulations. Preliminary results show the substitution of phosphatidylethanolamine does create a small effect in binding, uptake, and transfection efficiency, providing more information about their ability to fuse with the cell membrane and deliver genetic material.

MATERIALS RESEARCH LABORATORY AT UCSB: AN NSF MRSEC

Isaac Robledo

Major: Chemical Engineering

Mentor(s): Brenden McDearmon

Faculty Sponsor(s): Craig Hawker

Faculty Sponsor's Department(s):
Materials

Project Title: Effect of Side-Chain Architecture on Conjugated Polymer Self-Assembly

Project Description:
Conjugated polymers have proven to have remarkable and useful electrical properties, such as conductivity, which has stimulated a rapid growth in interest in these materials for semiconductor applications in both academia and industry. Their overlapping p-orbitals create a system of delocalized electrons that allows for conductivity. Organic semiconductors also present a unique set of characteristics such as flexibility, processability, low production cost, and versatility in synthesis that promise the advent of fully flexible semiconductor devices such as photovoltaic cells and large-area displays. Their electronic performance is linked to how efficiently charge carriers (electrons and/or holes) are able to move across the pi-conjugated network. Fundamental to charge mobility is the morphology of the material. The focus of our research is to study how side-chain architecture affects morphology. Using organic chemistry techniques, we synthesized various benzodithiophene (BDT) based monomers with different side-chain architectures. These BDT based monomers are then co-polymerized with different co-monomers to generate a library of distinct donor-acceptor conjugated polymers. The effects of side chain architecture on the resulting thermal, optical, and morphological properties will then be studied through differential scanning calorimetry (DSC), ultraviolet-visible spectroscopy (UV-Vis).

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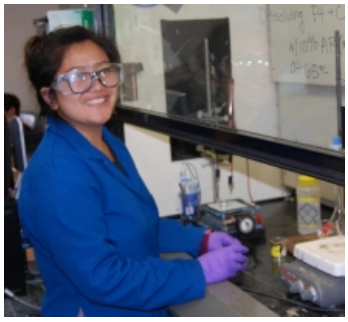
Charlene Salamat



Major: Chemistry

Mentor(s): Cynthia Cooper

Faculty Sponsor(s): Steven K. Buratto

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

Project Title: Temperature Controlled Electrodeposition for Low Platinum Loading on Proton Exchange

Project Description:
Proton exchange membrane fuel cells (PEMFC) are a promising power conversion technology with low emissions and power outputs that rival that of the internal combustion engines. One of the prevailing problems of PEMFCs is the high cost due to the platinum catalyst needed at both the anode and the cathode. Since most of the losses in performance happen during the oxygen reduction reaction at the cathode, a larger amount of Pt is needed here. Our approach utilizes pulse potential deposition (PPD) of Pt onto carbon electrodes to create platinum nanoparticles containing high surface area to lower the Pt loading. Using PPD, we also alloy Pt with non-precious metals such as cobalt to create Pt-Co nanoparticles, further reducing the loading while still improving the fuel cell performance. An increase in fuel cell performance has been reported using a seeding method accompanied by an increased temperature of a colloidal deposition solution. We are interested in studying how the temperature during electrodeposition influences the size, shape, and distribution of the nanoparticles and how these properties may affect catalytic activity at the cathode and overall fuel cell performance. Preliminary results indicate that raising the temperature of the deposition solution increases the performance of the electrode so much that it outperforms a commercial electrode with predictably less catalyst.

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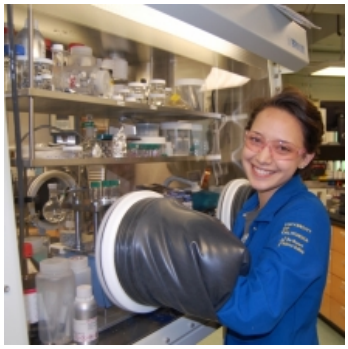
Catrina E. Wilson



Major: Chemistry

Mentor(s): Vicky V.T. Doan-Nguyen
Joshua D. Bocarsly

Faculty Sponsor(s): Ram Seshadri

Faculty Sponsor's Department(s):
Materials

Project Title: Unraveling the Mechanism of Transition Metal Sulfide Conversion Electrodes with Local Structure Methods

Project Description:
Energy storage for portable applications requires low cost batteries capable of high gravimetric capacity and reliable cyclability. Conversion electrodes operate by a different mechanism than intercalation electrodes, giving rise to theoretical capacities several times larger than current available technology. Titanium trisulfide (TiS_3) is a promising cathode material for conversion batteries due to its high theoretical capacity (186 mA.h g^{-1} per Li) and low materials cost. Electrochemical performance of TiS_3 batteries will be discussed in the context of a local structure investigation during galvanostatic cycling. The local atomic structure of the active material is probed with *in-situ* pair distribution function (PDFs) technique from total x-ray scattering. This type of analysis provides valuable quantitative insight into the local chemical environment of titanium and sulfur. A comparison of the as-prepared cathode before cycling, and during subsequent cycles of discharge and charge, shows formation of intermediate phase transformations that correlate with the electrochemical performance of the battery and capacity fade. The evolution of local structure of TiS_3 with cycling may be tied with other transition metal sulfides to inform what chemistries are most promising for better conversion materials. Such fundamental understanding is essential for improving conversion battery technology and pursuing it as a viable alternative to the intercalation mechanism for next generation materials for energy storage.