University of California, Santa Barbara

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Summer Applied Biotechnology Research Experience

ICB

Institute for Collaborative Biotechnologies

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MRI APPLICATIONS IN NEUROIMAGING

Magnetic Resonance Imaging (MRI) is one of the safest modalities used in the medical field because it is non-invasive and does not expose the patient to ionizing radiation. However, typically its resolution does not go beyond one millimeter (mm). Taking advantage of Fine Structural Analysis (fineSA), a technique which can measure structural frequency, a greater resolution can be achieved (100 microns). The innovative fineSA program offers a great advantage because doctors can detect and diagnose tissue abnormalities at an early stage, which is not possible with MRI because of its spatial resolution limitations. Because fineSA is a new technique, the goal of the present study was to validate its reliability and optimize parameters before it can be used for diagnostic purposes. The present study 1) tested the reliability of the signals obtained from fineSA by comparing repeated scans and 2) compared data between different MRI sequences in order to select what sequence is optimal for future use.

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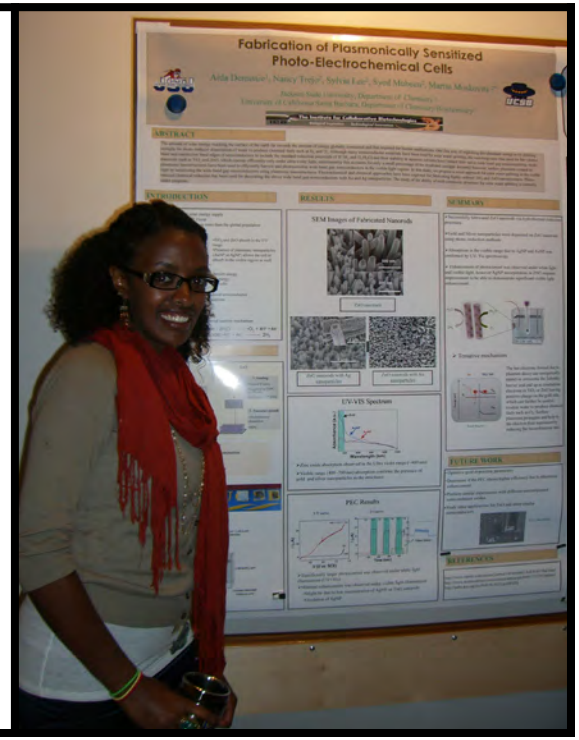
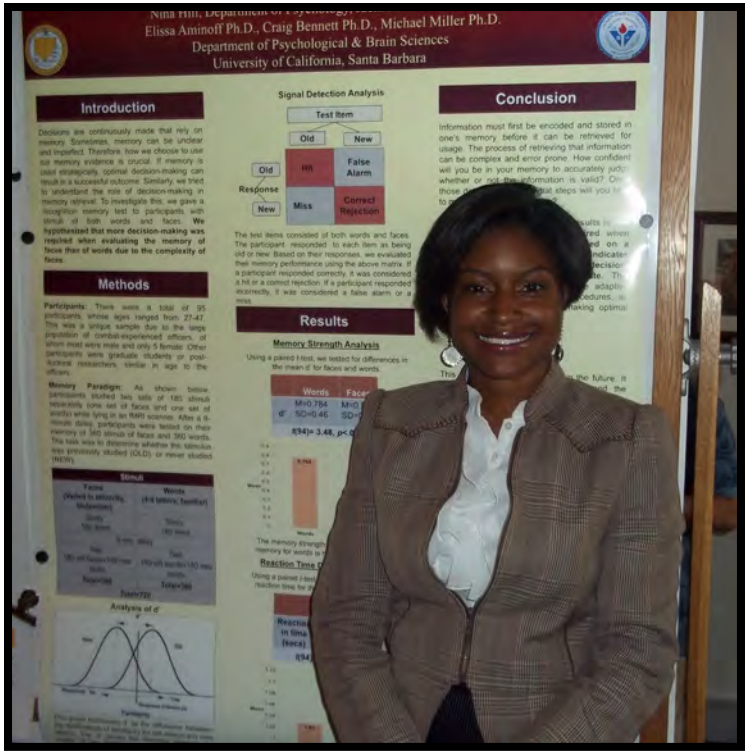
FABRICATION OF PLASMONICALLY SENSITIZED PHOTOELECTROCHEMICAL CELLS

The amount of solar energy reaching the surface of the earth far exceeds the amount of energy globally consumed and that required for human applications. One fine way of exploiting this abundant energy is by utilizing sunlight for photo-induced dissociation of water to produce chemical fuels such as H_2 and O_2. Although many semiconductor materials have been tried for solar water splitting, the matching rules (the need for the valence band and conduction band edges of semiconductors to include the standard reduction potentials of H^+/H_2 and O_2/H_2O) and their stability in aqueous solvents have limited their use to wide band gap semiconducting oxide materials such as TiO_2 and ZnO, which operate efficiently only under ultra-violet light; unfortunately this accounts for only a small percentage of the irradiated sunlight. Recently however, surface plasmons created in plasmonic nanostructures have been used to efficiently harvest and photosensitize wide band gap semiconductors in the visible light regime. In this study, we propose a novel approach for solar water splitting in the visible light by sensitizing the wide band gap semiconductors using plasmonic nanostructures. Electrochemical and chemical approaches have been explored for fabricating highly ordered TiO_2 and ZnO nanostructures. Photo-induced chemical reduction has been used for decorating the above wide band gap semiconductors with Au and Ag nanoparticles. The study of the ability of such composite structures for solar water splitting is currently under progress.





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THE ROLE OF DECISION-MAKING IN RECOGNITION MEMORY

The purpose of this research project is to understand the role of decision-making in memory retrieval. The main focus is placed on measuring decision-making with regard to memory strength. The strength of memory was examined by giving a recognition memory test to 95 participants. The memory test was composed of 360 words and 360 faces, with a 50% chance of each stimulus being either old or new. Participants had to determine whether the words and faces were previously studied before during an encoding session or had only been seen during the test. It was assumed that the memory strength for faces would be lower than that of words. We hypothesized that more decision-making is required when evaluating memory for faces than for words. The importance of reaction time was identified as a measurement for decision-making, which was operationally used for subsequent data analysis. To test whether there were any statistically significant differences between the memory performance of words and faces, a paired samples t-test was used. We found that the memory for faces was worse than that of words as measured by d-prime. We also found a longer reaction time for faces than for words, indicating that more decision-making was required when memory is weak. The reaction time differences were highly significant based on the p-value of the t-test, which demonstrates strong support for our initial assumption.

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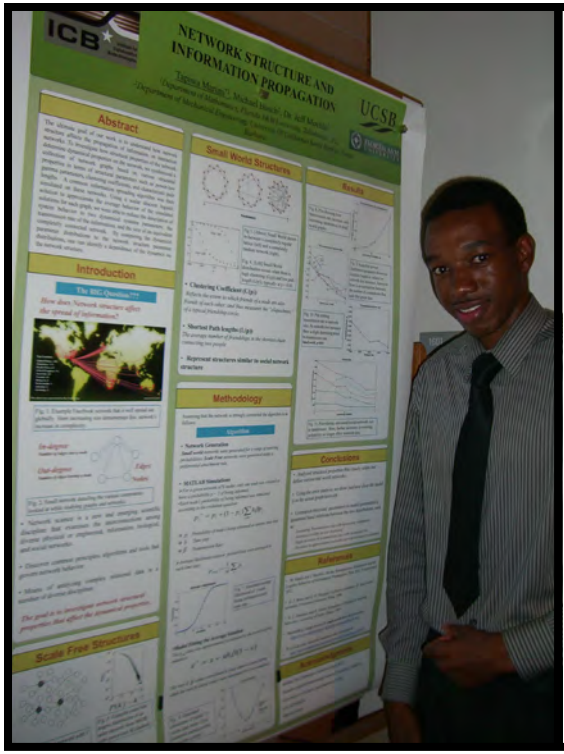
LOCATING A RIGID BODY IN 3D SPACE USING KINECT SENSORS

Microsoft Kinect sensors are 3D cameras that are promising to quickly produce 3D terrain models for robotic locomotion applications. Laser scans can be used for this purpose, but they are time consuming. On the other hand, Kinect sensors update continuously. In order to construct a complete terrain, it is necessary to combine data from multiple Kinect sensors. The goal of this project is to develop an algorithm for detecting the position and orientation of a specially constructed rigid body which is visible to the Kinect sensor. Because of their distinct color and shape, tennis balls are used as markers on the rigid body. To locate each marker, an algorithm is used to first filter the point cloud data by color, then by removing outlying points, and finally by shape using a RANSAC (random sample consensus) algorithm to detect the spherical markers. ROS (Robotic Operating System) and PCL (Point Cloud Library) are used to implement this algorithm in C++. Finally, the marker locations are matched to the rigid body using knowledge of the correct distance between each pair of markers. The algorithm is able to identify the position and orientation of the object up to a distance of two and half meters in the horizontal direction from the Kinect sensor. Although this project did not itself solve the problem of combining data from multiple Kinect sensors, it does provide a method for defining a global coordinate system as a first step toward this goal.



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HOMOGENEOUS ASSUMPTION AND LOGISTIC APPROXIMATION OF INFORMATION PROPAGATION

The ultimate goal of our work is to understand how network structure affects the propagation of information on interaction networks. To investigate how structural properties of the network determine dynamical properties on the network, we synthesized a collection of network graphs based on various structural properties in terms of structural parameters such as power-law gamma parameters, clustering coefficients, and characteristic path lengths. A common information spreading algorithm was then simulated on these networks. Using a scalar discrete logistic solution to approximate the average behavior of the simulated solutions for each graph, we were able to reduce the description of system behavior to two dynamical systems parameters: the transmission rate of the information, and the size of an equivalent completely connected network. By comparing the dynamical parameter distributions to the network structure parameter distributions, one can identify a dependence of the dynamics on the network structure.

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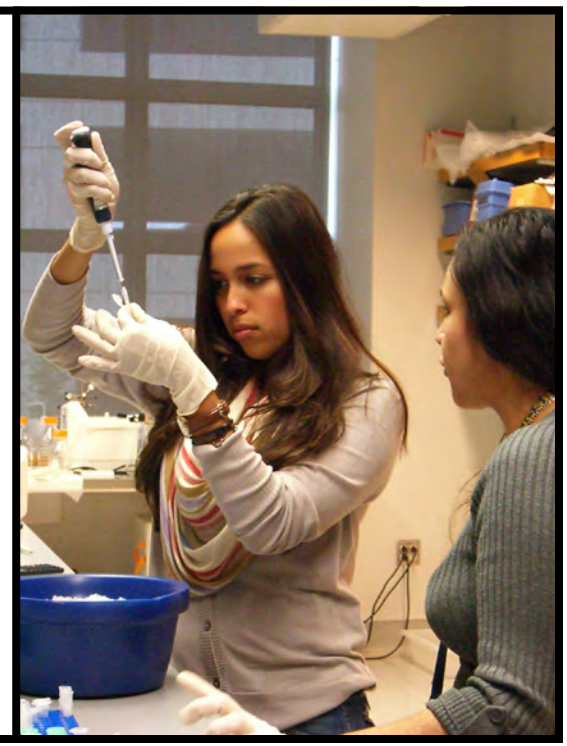
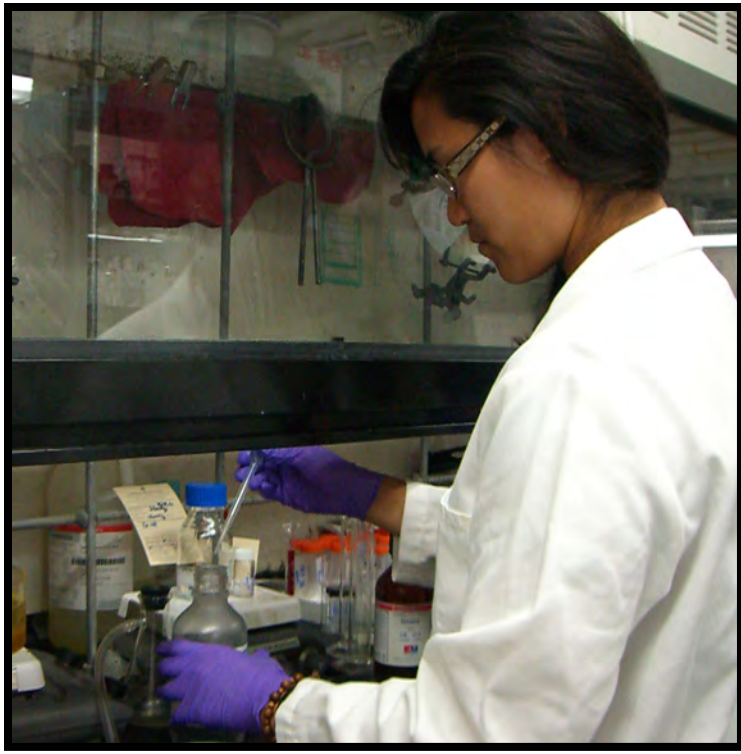
USING mRNA DISPLAY TO SELECT FOR INHIBITORS OF BMP SIGNALING

Human embryonic stem cells (hESC) are derived from the early embryo and can differentiate into the three embryonic germ layers, making them potential cell sources for regenerative medicine. Prior to the use of hESC's in patients, it is essential to understand fully the signaling pathways that maintain pluripotency and direct differentiation pathways. The bone morphogenetic protein (BMP) family of signaling molecules controls multiple biological responses during early development. Recent work has demonstrated that depending on culture conditions, BMP signaling induces the differentiation of hESC's into trophectoderm or extraembryonic tissue, and in some cases, mesendoderm, presumptive mesoderm and endoderm. However, the molecular mechanism by which BMP signaling specifies the mesendoderm or trophectoderm fate remains unknown. Using a fibronectin based protein mRNA display library, our goals are to identify novel affinity reagents targeting the BMP receptor with high affinity and specificity. These reagents will be used to further explore the role of BMP signaling in hESC biology.





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SYNTHESIS OF FUNCTIONALIZED SILICA NANOPARTICLES THAT AID IN COAGULATION

Currently there is no set universal treatment for internal bleeding yet it accounts for a high mortality rate in hospital admission. In previous research, silica nanoparticles have been functionalized with material to enhance coagulation in external wounds. The goal of this research was to synthesize nanoparticles that could be loaded with a procoagulant material such as polyphosphate or thrombin. Direct administration of these loaded particles could increase the concentration of the overall threshold for clotting activity in an internal wound and thus reduce healing time. The final product of this research was composed of three components 1) a silica nanoparticle which acted as a transport 2) an intermediate which was a coupling agent and 3) a procoagulant material which increased clotting activity. Two nanoparticles were synthesized, MCF and ZJU1, which were later tested with either polyphosphate or thrombin. The intermediate for polyphosphate was 3-aminopropyltriethoxysilane (APTES) and for thrombin, a HEPES buffer. 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC) was used to activate APTES and thus this increased its ability to functionalize with the surface of the nanoparticles. BET and X-Ray Diffraction were used to characterize the particles while ZetaPotential was used to indicate the presence of the adhered intermediates. After the addition of the procoagulant material, UV spectroscopy was performed to confirm the presence of such molecules. Future analysis will be done to determine the functionalization of thrombin on the silica nanoparticles.

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DELAMINATION OF A BIMATERIAL INTERFACE

Many modern technologies involve multilayered materials, including electronic devices, microelectromechanical systems (MEMS), and orbital mirrors. One challenge to device reliability is failure due to delamination between layers, which is governed by the toughness of the interface. However, many existing tests for fracture toughness only describe rectangular geometries. The goal of this research project is to validate an interfacial fracture toughness test for delamination on a circular wafer. A test based on a circular geometry is of interest for many device applications that are based on circular semiconductor wafers. A 3-point bending test in a circular geometry was designed and optimized to determine fracture toughness between a glass-epoxy interface on a circular wafer. Upon completion, this will allow engineers to design layered systems that are more resistant to failure by delamination in circular geometries.