## City College Interns in Materials Research (CCIMR) Summer 2002 - Student Projects

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**Project:** SYNTHESIS AND ASSEMBLY OF MAGNETIC AND SEMICONDUCTOR NANOPARTICLES
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**Project:** ANALYSIS OF LOW MOLECULAR WEIGHT GLUTENIN VIA ATOMIC FORCE MICROSCOPY AND SINGLE-MOLECULE FORCE SPECTROSCOPY
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**Project:** POLYDIMETHYLSILOXANE INTERFACE FOR AN INDIUM PHOSPHIDE LASER MICROFLUIDIC SYSTEM
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**Faculty Sponsor:** Dr. Jacob Israelachvili  
**Department:** Materials/Chemical Engineering  
**Project:** OPTICAL PROPERTIES OF CADMIUM SELENIDE
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**Department:** Physics  
**Project:** OBSERVING TUBULIN ORGANIZATION USING IMMUNOFLUORESCENCE METHODS IN YEAST
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**Project:** TRANSDERMAL DRUG DELIVERY: ULTRASOUND AND CHEMICAL ENHANCERS
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**Project:** DOPING ZINC OXIDE WITH TRANSITION METALS TO
CREATE A FERROMAGNETIC SEMICONDUCTOR

Tran Van

School: Ventura College
Mentor: Rafi Tadmor and Nianhuan Chen
Faculty Sponsor: Dr. Jacob Israelachvili
Department: Chemical Engineering
Project: LIPID BILAYERS AT THE MOLECULAR LEVEL

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SYNTHESIS AND ASSEMBLY OF MAGNETIC AND SEMICONDUCTOR NANOPARTICLES

Nanoparticles are small particles that are the intermediate between molecular and bulk phases, which leads to their physical properties being size dependent. Semiconductor and magnetic nanoparticles are being looked to for device technology such as optoelectronics, light emitting diodes, and ultra high density disks. In order for this to happen the synthesis, surface properties and assembly of the particles must be studied. I am involved in the synthesis of CdSe nanoparticles which are used in solid state and solution NMR to study the surface property.

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ANALYSIS OF LOW MOLECULAR WEIGHT GLUTENIN VIA ATOMIC FORCE MICROSCOPY AND SINGLE-MOLECULE FORCE SPECTROSCOPY

Gluten is a protein fraction isolated from the endosperm of wheat plants. It displays a variety of unique characteristics including visco-elasticity, insolubility in water, and the ability to reorganize single molecules into a somewhat fibrous network. These properties suggest that gluten might play a crucial role in the development of new biomaterials (for example, biodegradable or renewable plastics). In order to learn more about these properties, individual components of gluten were isolated and then observed by means of atomic force microscopy (AFM). Single-molecule force spectroscopy is another tool by which gluten's molecular architecture can be analyzed. One of the major constituents of the gluten complex is low molecular weight (LMW) glutenin. This was isolated from a crude gluten fraction (previously defatted with chloroform) by utilizing different solubility properties of each component after a reducing agent, DTT, had been introduced to the system. The reduction reactions essentially break any disulphide bridges maintaining the glutenin fraction's networked configuration. Our preliminary AFM data indicates that at low protein concentrations, in DTT reduced conditions (though the DTT was washed away and the reduced proteins were bound to flat mica disks) LMW glutenin exists as single, identifiable proteins. When the concentration of protein increases, individual LMW glutenin proteins reorganize themselves into a fibrous-like network by re-oxidizing the formerly reduced cysteine residues, thus recreating a disulphide bridge. This phenomenon occurs in the same reduced conditions as more dilute samples, but this organization only occurs when the protein concentration is high. Because cysteine is located primarily in the protein termini, the molecular rearrangement would appear long and filamentous, as it does. When studying the physical properties of this network, a device called a single-molecule force probe can yield great insight relevant to the conformation of proposed gluten network arrangements.
POLYDIMETHYSILOXANE INTERFACE FOR AN INDIUM PHOSPHIDE LASER MICROFLUIDIC SYSTEM

Polymethylsiloxane (PDMS) is an inexpensive silicone elastomer that is gaining considerable use in microfluidic devices. This material is used because it is inexpensive, relatively inert, and transparent. These properties make PDMS a possible candidate for wide spread usage in microelectromechanical systems (MEMS). The interface created is essentially a gasket, designed to keep fluid in the fluid channel. Creation of this gasket involved the development of a mask for the lithography process as well as reactive ion etching procedures in fabrication of the whole device. With a working circuit, research can be done on antigen attachment to biomolecules in the fluid. Attachment will effectively change the modal index of refraction of the guided laser, which in turn changes the laser’s frequency, thereby allowing detection. Theoretical analysis predicts this chip will be able to measure changes in the modal index of refraction with a resolution of ~10^-7. Because of this chip’s portability, it may become the first portable field biosensor detection system employed by the US Government.

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OPTICAL PROPERTIES OF CADMIUM SELENIDE

The development of processes to fabricate thin films with thickness in the range of 1-1,000 nm is of crucial importance to many technological fields. This development is dependent upon the properties of the thin films in question and its intended use. By studying the effects of electric fields, inter-surface forces, mechanical and pressure-dependent properties, and changes in the luminescence and absorption spectra on cadmium selenide (CdSe), we are characterizing the potential of CdSe nanoparticle films for use in optical devices such as touch screen displays or pressure sensitive warning devices. The surface force apparatus (SFA) is the instrument we used for our investigations because of its ability to measure the aforementioned properties with great versatility. The initial results are promising; cadmium selenide nanoparticles of ~3.5 nm diameter were tested under a variety of pressures. White light was then shone on the nanoparticles and an intensity spectrum was measured. The resulting measurements present the emission of green light from CdSe when under high pressure. It is anticipated that by changing the initial conditions of the cadmium selenide (i.e. the size of the nano-particle, applying a shear, et cetera) we will be able to get the CdSe to emit light of wavelengths in the red and blue range as well as the green range. Follow up research and confirmation of results is underway.

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OBSERVING TUBULIN ORGANIZATION USING IMMUNOFLUORESCENCE METHODS IN YEAST

Our interest is to understand the laws that govern biological mechanics and the design of macromolecular architecture and chemical regulatory systems. We are currently interested in studying the organization of proteins and polymers, such as DNA. The motivation to study macromolecular architecture is to understand how the function of a molecule is related to its structure. Of particular interest are the mechanics and dynamics of macromolecular assembly; which include the affect of structure and external conditions on macromolecules. In order to test a hypothesis that would describe an aspect of macromolecular design, I am observing the organization of the protein tubulin in various strains of yeast cells by using immunofluorescence techniques. Tubulin self-assembles into microtubules within eukaryotic cells. Some of our yeast strains are mutated to synthesis a modified form of tubulin. It is predicted that the modified tubulin will self-assemble into microtubules whose structure is different than that of normal microtubules. The difference in the microtubule organization may describe some basic principles in macromolecular architecture. It is expected that a successful analysis of the distribution and structure of microtubules in our subjects should result in a confirmation of our hypothesis.

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TRANSDERMAL DRUG DELIVERY: ULTRASOUND AND CHEMICAL ENHANCERS

Low-frequency sonophoresis (LFS) and chemical enhancers is a non-invasive method of transdermal drug delivery and diagnostics. In these methods, a short application of ultrasound or chemicals is used to permeabilize the skin for a prolonged period of time. During this period, ultrasonically or chemically permeabilized skin may be used as an interface to the body, for extraction of analytes or delivery of drugs. The main objective of this study is to understand the mechanisms of ultrasound and chemical enhancers synergistically. Although the principal mechanism of LFS is known to be cavitation, little is known about how cavitation actually enhances skin permeability. We are interested in assessing the structural alterations in the skin introduced by ultrasound and chemical enhancers. We hypothesize that ultrasound and chemical enhancers generate defects that are responsible for enhanced delivery of large hydrophilic solutes such as proteins (e.g. insulin). In this work, we studied to determine the dependence of LFS transport pathways on ultrasound parameters and lead to a better understanding of the effects of the enhancers on skin permeability.

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DOPING ZINC OXIDE WITH TRANSITION METALS TO CREATE A FERROMAGNETIC SEMICONDUCTOR

The development of a functional ferromagnetic semiconductor is key to the development of spintronics, or spin electronics. Using ferromagnetic first row transition metals, we are hoping to develop a ferromagnetic semiconducting material, which will manipulate the spins of the electrons to create an added degree of freedom in powering electronic devices. For this project we are using ZnO, which besides being abundant, inexpensive and environmentally friendly, also has a wide band-gap, predicted high Curie temperature when doped (above room temperature), is transparent, and has piezoelectric properties. For our preliminary trials, I have been using the sol-gel technique with metal acetate precursors, citric acid and ammonia to dope ZnO with cobalt, manganese and nickel. The primary challenge of this research is to extend the solid solubility of the transition metals in ZnO, as the normal solubility is not enough to induce ferromagnetism. So far I have succeeded in extending the solid solubility of cobalt to 30% in ZnO (the equilibrium solubility is 6.5%), as a single-phase sample. Although we have yet to determine the Curie temperature, x-ray diffraction of this sample shows that the cobalt has been incorporated into the wurtzite crystal structure of ZnO without two-phase separation into CoO. Only single-phase samples can be used in electronic applications.

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LIPID BILAYERS AT THE MOLECULAR LEVEL

Biological membranes are composed of phospholipids, which have unique physical properties. Phospholipids are amphiphilic, possessing both hydrophobic fatty acid chains and a hydrophilic phosphate group. In biological cells, phospholipids arrange themselves into a bilayer with the hydrophilic heads facing aqueous environment and the hydrophobic tails facing each other. To mimic such a bilayer, the Langmuir-Blodgett technique is used to form the organic films on a flat but hydrophilic mica surface. Atomic force microscopy (AFM) is employed to characterize the molecular properties of the lipid bilayer at the surface level. Different materials can be added to the lipid bilayer. Streptavidin is added to form bonds with the biotin caps, found on some of the lipid hydrophilic heads. Streptavidin is a protein isolated from the microorganism, Streptomyces avidinii, and binds to biotin very well. The lipid bilayer with streptavidin is scaffolding for a model. This project is part of the overall research goal to understand the biolubrication mechanism of hyaluronan, a gel like polysaccharide found in joints, connective tissues, and other cartilage fluids in the human body.

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