

2006
Student Abstracts

Novel Quantum Well Intermixing using sputtered layer

James Anderson

Advisors: Prof. Boon S. Ooi and Prof. Himanshu Jain

We studied Quantum Well Intermixing using sputtered layer and its effect on the bandgap of our GaAs/AlGaAs grown on Si material. With our three step process; sputtering, rapid thermal annealing, and photoluminescence, we performed experiments with our material and gathered results. Sputtering rates between 1 -4 hours were used to deposit a thin film of sputtered layer on to our GaAs/AlGaAs material.

Annealing temperatures between 850°C – 950°C were used in our experiments to induce different levels of intermixing. With photoluminescence we found sputtered layer, with a high concentration dopant, yielded a bangap shift as large as 119nm. These incredible shifts in bandgap energy are essential in further research and experimentation of Photonic Integrated Circuits.

Funding for this work was supported by International Materials Institute (NSF-IMI, DMR-0409588).

The Effects of Heat and Chemical Treatments on the Structure of Bioactive Glass-Ceramics for Bone Scaffolds

Greg Brentrup

Supervisors:
Prof. Himanshu Jain,
Dr. Hassan Moawad

Abstract:

Bioactive glasses and glass-ceramics were made from the system $\text{Na}_2\text{O}-\text{CaO}-\text{SiO}_2-\text{P}_2\text{O}_5$ by the melt quench method. The optimal conditions for heat and chemical treatments were determined. The effects of the heat and chemical treatments on the structure of the glasses and glass-ceramics were investigated using optical microscopy. Heat treatments of nine hours produced a higher degree of crystallization and larger crystals than heat treatments of three and six hours. The samples from batch 45S exhibited greater crystallization than the other samples tested. 1.0M HCl for the chemical treatment was found to be superior to 0.3M and 3.0M HCl because the 1.0M acid produced the highest pore density and the most uniform structure. One hour and 85°C were determined to be the best time and temperature, respectively, for the chemical treatment because they resulted in the highest porosity and most even structure compared to temperatures of 70°C and times of two hours. Overall, the six hour heat treated and chemically treated samples have a structure that demonstrates the best balance between crystallization (leading to high strength) and porosity.

This preliminary work will be followed by future characterizations, including x-ray diffraction, scanning electron microscopy, mercury porosimetry, and mechanical testing of the bioactive glasses and glass-ceramics.

Supported By:

National Science Foundation Research Experiences for Undergraduates
and
The International Materials Institute for New Functionality in Glass

Sandpiles: Conforming Simulation To A Real Pile

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July 31, 2006

Avalanches on granular piles have parallels in natural events, such as earthquakes, neuronal transmissions in the brain, fractures and stock market crashes. Measurements in experimental piles can only be done to precisions of approximately 500 nanometers but whether two grains are in contact may require resolution of the gap between them to about a nanometer. In order to increase this precision to an arbitrary value, computer simulations are used to build 2-D granular piles with uniform spheres. The current simulated piles have steeper and more regular angles of repose, and larger, more uniform defects, in part due to the simulation not accounting for gravity and friction forces acting between the grains. Gravity causes avalanches to occur during the building of a pile. To simulate avalanches, the simulation program calculates the stability of each grain in a pile. The forces acting on a grain due to the weight of other grains, as well as the supporting normal force of each grain is calculated. If the net force on the grain is non-zero, the maximum possible static friction is calculated, and if it is not at least opposing the net force, then the grain is considered unstable. An unstable grain is then moved in small increments, along with any grain that becomes unstable due to that movement. When all grains are stable again, the avalanche is over. The next step in the simulation program development is to build a large pile. The detail of inter-particle interaction is fine tuned until a pile of given size grains compares well to a real pile in terms of the angle of repose, density of defects within the pile and the response of pile features to changes in gravity and grain size. The plan is to perform simulated experiments on them, such as introducing perturbative forces or imposing fixed distortions on the pile to trigger avalanches and measure network properties of the pile.

Rotational-Vibrational Li-OH and Li-OD Defects in MgO

Supported by the National Science Foundation, Research Experiences for
Undergraduates Program

Abstract:

II-VI oxides have become useful in the optical and electronic fields, and consequently we study the Li-OH and Li-OD complexes in MgO. Theoretical models were fit to the temperature dependence of the center frequency and the full width at half maximum (FWHM) of the main absorption peak for both the OH and OD IR vibrational absorption spectrum, which had been measured by Dr. Stavola and his graduate students. Four strong and closely spaced absorption lines (on the order of 8cm^{-1} to 12cm^{-1} each) were then discovered inside the main band of the OD spectrum at low temperatures (4K to 39.4K). These absorption lines suggest that in addition to vibrational motion, the OH and OD have an additional degree of freedom, probably related to a rotation. Weaker absorption lines, seemingly equally spaced (approximately 70cm^{-1} apart) on both sides of the main band, were evident as well. The OH spectrum has similar weak absorption lines apparently equally spaced on the low side, but the main band itself was too broad, not allowing for us to determine how many absorption lines it contained. We attempt to explain the spectra by developing detailed theoretical models.

Eric Diamond
Aug. 4th, 2006
Advisors: Dr. Kevin Martin
Dr. W. Beall Fowler

Functionalization of Nanosilica Spheres and Their Use as Epoxy Resins Fillers

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Acknowledgements: This work was supported by the National Science Foundation, Research Experience for Undergraduates, and the International Materials Institute. Grant number NSF-IMI, DMR-0409588

Abstract:

It is widely known that distributing silica particles into epoxy strengthens and toughens the final cured epoxy resin. However, it is not known what role the size and surface treatment of the silica play in the physical characteristics of the epoxy. This research studied four samples of functionalized silica dispersed in epoxy- 10 and 20 weight percent of 12nm and 21nm silica.

Two commercial nanosilica particles were obtained from GRACE Davison through Brenntag Northeast: LUDOX Colloidal Silica TM-50 (21nm diameter, 51 weight %) and HS-40 (12nm diameter, 40 weight %). For functionalization, the LUDOX was dispersed in acetic acid and methanol to obtain a 95:5 methanol: water mixture. Glycidoxypropyltrimethoxysilane (GPS) was added and the solution was refluxed for 3 hours. FIB-SEM determined that a 2.5nm, 5-monomer layer of GPS formed on the silica.

Because MeOH, water, and acetic acid are all foaming agents for epoxy, the solution was mixed with cyclohexanone and the foaming agents were removed through distillation, which was verified using Thermogravimetric Analysis. Epoxy DER-331 was added to the solution and the cyclohexanone was removed via distillation. The resulting silica/epoxy suspension contained 20 wt.% and 10 wt% of silica. The epoxy was cured with 5phr of piperidine for 6 hours at 160°C. The glass transition temperature (T_g) and the fracture toughness (K_{IC}) were obtained for both silica sizes and both weight percent. FIB-SEM showed the silica was evenly dispersed through the epoxy in all four cured samples. Dynamic Mechanical Analysis (DMA) was used to find the T_g , and 3-point bending was used to determine the K_{IC} for fracture toughness.

As the size and weight percent lowered, the T_g decreased and the K_{IC} increased. In other words, the epoxy with 20% 12nm silica had the lowest T_g and the highest K_{IC} values. These results are contrary to the trend seen in macrosized-silica/epoxy resins, where the T_g plateaus as the silica drops in size. We can therefore state that reducing silica to nano-sized particles produces strengthening effects not seen with larger silica particles. Further research will investigate the interactions of silica and rubber particles together in epoxy.

Hyperfine State Changing Collisions in Atomic Cesium

Tyler Drake (Drew University)*

Advisors: Profs. Laurie Morgus (Drew University), Tyler Morgus (East Stroudsburg University)
and John Huennekens (Lehigh University)

Abstract

We have used a two-laser experiment to study Cs($6P_{1/2}$) atoms that have undergone a single Cs($6P_{1/2}$)–Ar hyperfine state changing collision. The double-resonance technique uses a fixed Ti:sapphire pump laser to excite the Cs[$6S_{1/2}(F=4) \rightarrow 6P_{1/2}(F')$] transition where $F' \in \{3, 4\}$. Then, a ring dye probe laser further excites atoms from the $6P_{1/2}(F')$ level populated by the pump laser to the $8S_{1/2}(F'')$ states. Absorption of the probe laser is monitored by detecting $8S_{1/2} \rightarrow 6P_{3/2}$ fluorescence. The addition of Ar buffer gas to the cell allows for collisional transfer between the hyperfine levels of the $6P_{1/2}$ state, leading to additional double-resonance signals. Since the experiment is conducted at room temperature, the probability of a Cs-Cs collision is negligible during the radiative lifetime of a Cs atom in the $6P_{1/2}$ state. From the $8S_{1/2}(F'') \rightarrow 6P_{3/2}(F')$ fluorescence intensities, we are able to determine the Cs[$6P_{1/2}(F')$]-Ar hyperfine state changing collision rate coefficient and the one-dimensional velocity changing collision kernel for Cs[$6P_{1/2}(F')$] atoms prepared with $v_z = 0$ that have undergone one $F' = 3 \leftrightarrow F' = 4$ hyperfine state changing collision. By comparison to reference cell signals, we also measured Cs[$6P_{1/2}(F') \rightarrow 8S_{1/2}(F'')$] pressure broadening rates and shifts due to argon perturbers.

* Supported by the NSF REU Site Grant at Lehigh University

Characterization of SONOS Non-Volatile Semiconductor Memory (NVSM) Devices

Nathan Eichenlaub
August 4, 2006

Advisor: Dr. Marvin H. White

Sherman Fairchild Laboratory
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Abstract:

The demand for high-capacity, low-power memory is increasing rapidly as modern portable electronic devices boost performance while decreasing in size. Due to its many advantages over tradition floating gate memory, SONOS non-volatile semiconductor memory seems to be the next step in the evolution of NVSM technology. Its simple structure, compatibility with CMOS technology, low power dissipation, and radiation hardness make SONOS an attractive alternative to current NVSM technology. This paper focuses on the techniques used to electrically characterize these devices in order to gain a better understanding of the physical processes governing their operation and to quantify device performance and achieve future design improvements.

Fast Photoinduced Refractive Index Modulation in Chalcogenide Glasses

Annemarie L. Exarhos

August 4, 2006

By writing a volumetric grating in an $\text{As}_{0.5}\text{Se}_{0.5}$ chalcogenide glass film, we investigated the time dynamics of the induced refractive index modulation. The 532 nm output from a frequency doubled Nd:YAG, 20 ps pulsed laser was split into two writing beams. These beams were crossed within the sample to create an interference pattern which induced a refractive index grating in the material. The time dynamics were measured by diffracting a 633 nm continuous wave HeNe laser off the grating at the angle that satisfied the Bragg condition. After the pulse, the refractive index change reverted to its initial state with a 35 ± 1 ns relaxation time, which was found to be independent of the writing beam intensity. We also verified the polarization independence of the refractive index modulation. This was accomplished by cross polarizing the two write beams to create a polarization rather than an intensity grating. In addition, the Kogelnik diffraction efficiency equation provided an estimate for the refractive index change, giving $\Delta n \approx 0.1$. Funding provided by the National Science Foundation, Research Experiences for Undergraduates (REU) Program.

Advised by Dr. Ivan Biaggio.

Microshutters: MEMS for the James Webb Space Telescope

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Abstract — The James Webb Space Telescope (JWST) is the next generation space telescope scheduled to enter service in 2013. Its focus is to peer into deep space and collect light from the first galaxies. This goal is reflected in its use of infrared-optimized instruments, including the Near Infrared Spectrograph (NIRSpec), an instrument that allows scientists to gather light individually from hundreds of objects within the field of view. Under the umbrella of the Lehigh University / Mid-Atlantic Partnership for NASA Nanomaterials, the scope of this particular project is wide, but focuses on a Micro-Electro Mechanical System (MEMS) device that allows the NIRSpec to collect light from one object at a time. The Microshutters system is comprised of arrays of small shutters each 100 μm by 200 μm . The magnetic and electrical properties of the shutters allow for their actuation by sweeping a quadrupole magnet 2mm above the surface of the array, and the latching of individual shutters in the open position by an electrical bias. In the latched (open) position, the shutter door effectively creates a capacitor with the wall of the array.

The goal of the Compound Semiconductor Technology Laboratory at Lehigh University is to characterize the charging effects of the dielectric in this capacitive system. When a bias voltage is applied to the shutters, electron charging of the dielectric material changes its properties, thereby altering the performance of the shutter. In particular, the latching and release voltages are affected. The main focus is therefore to investigate how these voltage levels change under a variety of biases and bias times, as well as at a variety of operating temperatures.

Acknowledgments — Thanks to: James Hwang, Ph.D., Subrata Halder, Rick Antrobus, Peng Zhen, and the rest of the ECE-CSTL Lab for all of their help with this project.

Optical Characterizations of TeO₂ Fibers*

Jessica A. Harris

Advisor: Dr. Volkmar Dierolf

Abstract

Telluride fibers doped with rare earth ions such as Er³⁺ offer drastically increased emission bandwidth and allow higher doping levels compared to standard silica fibers and hence make more compact optical fiber lasers and amplifiers possible with a wide spectral amplification range. Such devices would find application in a variety of fields such as telecommunication and biomedical-sensing. However, to this date, the exploitation of these favorable properties has been limited by the lack of high-quality fibers. In this work, we studied and characterized such telluride fibers and erbium doped telluride fibers (Er³⁺:TeO₂) that have been drawn in the fiber drawing facility at Lehigh University. The fibers we studied have the following compositions: undoped fiber, cladding 5Na₂O - 20ZnO - 75TeO₂, core 5KNbO₃ - 95(5Na₂O - 20ZnO - 75TeO₂); Er-doped fiber: cladding 99(5Na₂O - 20ZnO - 75TeO₂) - 1 WO₃, core 94(5Na₂O - 20ZnO - 75TeO₂) - 2 WO₃ - 2 Er₂O₃. The addition of potassium niobate to the core of the undoped fiber (1) was intended to increase not only the refractive index but also the nonlinearities. For the characterization of these fibers we used Fabry-Perot interferometry to determine the propagation losses, confocal Raman spectroscopy to determine the structural changes across the fiber cross-section and Er³⁺ luminescence spectroscopy to determine the properties of the Er ions in the glass matrix.

For our loss measurement, we measured the contrast between maxima and minima in the transmission of a tunable laser diode. Our measurements indicated that the fibers have a reasonably low losses but accurate measurements of it was not possible yet due to difficulties in exciting only a single mode and in creating clean-cut fiber ends. We are currently pursuing ways to solve both problems. Raman and emission spectra were taken in a 2D scan over a 50x50µm area with 0.5 µm step size for the Er-doped fiber. We arranged the measurements such that laser reflection, Raman, and emission could be measured simultaneously giving as the topography of the end-face, the changes in the vibrational modes across the core and the Er³⁺ dopant distribution. In the Raman spectra, significant changes between cladding and core could be observed that give a straightforward way for the determination of the core diameter (approx. 7.5µm). This value could be confirmed by the Er³⁺ emission measurements. In the continuation of this work, we will further conduct detailed Raman measurements to determine structural changes in the core along with combined excitation-emission spectroscopy (CEES) measurements on Er³⁺ in the core to optimize fibers for their respective application and to get an understanding of the origin of the large emission bandwidth.

* Supported by International Materials Institute (NSF-IMI), the Research Experiences for Undergraduates (REU) program at Lehigh, NSF-Europe grant (DMR-0349632) and NSF-MWN (DMR-0602986).

Rheological Testing of Hyaluronan Hydrogels Using Optical Tweezers

Corey Hewitt, Jing Wang, H. Daniel Ou-Yang

Lehigh University

Abstract

Hyaluronan Hydrogels are gels made from Hyaluronic Acid (HA). HA is most commonly found in mammalian connective tissue as a lubricating substance. The use of HA hydrogels in biological applications has increased, requiring a better understanding of its molecular properties. HA possesses a unique viscoelastic behavior which can be modified through its chemical makeup. By using an oscillating optical tweezer, these viscoelastic properties can be quantified. The optical tweezer provides several benefits over previous measurement techniques, including the ability to run several trials simultaneously, and to test inhomogeneity. In conclusion, the testing of HA hydrogels has aided in improving the optical tweezer system, while providing insight into further improvements.

Characterization of a CMOS Device with an Ultra-Thin High-K Dielectric

James Hillegass, Lehigh University 2006 REU Program

Funded by the National Science Foundation NSF

Advisor: Dr. Marvin White

Mentor: Yanli Zhang

Abstract

In examining a solution for the aggressive scaling of CMOS devices in recent years, transistor devices from IMEC and Sematech with HfO_2 as a dielectric were characterized for their reliability. Several tests such as gate current leakage, sub-threshold drain current response, gate capacitance, and transconductance curves were performed. The data from these tests were used to extract commonly used characteristics of CMOS transistors such as threshold voltage and acceptor doping density. In addition to the high-K dielectric modification to the gate stack, a metal gate electrode was implemented in both designs using TiN. The metal work function was also extracted using the computerized extraction program, written in MATLAB.

Science and Properties of Sugar Glass

By: Sean Kelly

Abstract

My project involved developing experiments involving sugar glass that could be used to help teach high school students about the interesting properties of glasses. The idea was to simply use a home-made substance, such as sugar glass, and perform experiments on it to discover some basic scientific principles of glasses in order to get students to learn about glasses and to hopefully become interested in all that they have to offer.

The project began by creating a set of samples with varying amounts of sugar, corn syrup, and water. The pouring temperature was very crucial because if the sample was poured too early, it would contain too much water and would not form into a glass correctly. It was concluded that as percent sugar of the sample increased, the temperature to pour at decreased. Using these different compositions and the subsequent crystallization that occurred, a ternary diagram was established and a range for the “best” glass area was created. Some portions of the diagram were found to be too syrupy and never became a glass, and some portions became a glass, but crystallized too quickly. A series of photographs were taken of the samples every day and a nucleation trend became very apparent. The samples that had higher percentages of sugar had severe crystallization. The samples that had higher percentages of corn syrup had very minimal crystallization over the same time period.

A specific gravity experiment was developed in hopes of finding a correlation with the sample composition. Though error still exists, statistics show from my data that there is a slight upward trend of specific gravity as the corn syrup is increased in the sample.

A demonstration was set up and performed for a couple of the science camps that were being held in the area during the summer. The demonstration for high school students showed how a glass is made and how fiber can be drawn from it. Using the stable glass range found previously, the students pulled their own fibers during the experiment and were better able to understand some of the issues involved with pulling glass fibers, such as temperature and fragility.

I am currently completing measurements for the index of refraction for the sugar glasses. Using a student spectrometer available in most high schools, the glass is poured into a prism shape, so that the index can be found just as it would be using a Silicon glass prism. Data for these and other measurements will be available on the IMI website (www.lehigh.edu/imi) under educational resources.

All of my experiments can be created either at home or in a high school classroom and they each exhibit interesting properties associated with glasses and varying compositions.

Acknowledgements:

Dr. Bill Heffner, and the International Materials Institute for New Functionality in Glass for funding this work. (NSF-IMI, DMR-0409588).

Visualization of Dissociative Recombination of Electrons with $C_3H_3^+$

Ruth Malenda

Advisor: Dr. A. P. Hickman

This project addressed dissociative recombination (DR) of electrons with $C_3H_3^+$ and the branching ratios for the formation of various products. The process of dissociative recombination takes place in tokomaks and is important in research on fusion plasmas. A molecular dynamics (MD) program was written and used to model the vibrational motion of the initial $C_3H_3^+$ ion (a triangular carbon ring with one H bound to each C). A visualization program (VMD) allowed the results to be animated and easily interpreted. The potential was modelled using a sum of Lennard-Jones interactions. In addition to the pairwise interactions, a torsion term was added to represent the H flopping motion. A spring constant for this term was determined from self-consistent field (SCF) calculations performed with the GAMESS electronic structure program. Future work will address the dissociation on the autoionizing potential surface, but for this summer only the ionic surface was available. We performed several calculations to explore dissociation for trajectories that started with significant amounts of excess energy (at least a couple of eV). We found that excess energy in the C-C bonds was readily transferred to C-H motion and could lead to dissociation.

The Electrostatics of Nanotube Systems

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(Dated: August 4, 2006)

Carbon nanotubes possess great potential for nanoelectronic applications. For this reason, we would like to model their characteristics to better understand their properties. We are studying systems in which metallic nanotubes are deposited between two electrodes over a backgate. In the process of dielectrophoresis, nanotubes are deposited between the electrodes at near random angles and positions.

We were interested in studying the capacitance of nanotube systems when a potential is applied between the tube and gate electrode. To understand the gating of the system we must know the inter-capacitance between tubes because in addition to screening from the back gate, the nanotubes also gate each other. This capacitance will give us the total charge of the system. To study these cases we simplified the system to two infinitely long metallic nanotubes to see the effects of one tube on another. We found the geometrical capacitance term for a system of two nanotubes horizontally parallel to each other over a backgate, the geometrical capacitance term for a system of two nanotubes vertically parallel to each other over a backgate, and then we generalized the term for two nanotubes at an arbitrary angle and arbitrary distance from each other over a backgate.

We then looked at the system of two tubes crossed with each other at an arbitrary angle over a backgate. We modeled this system using finite length metallic nanotubes. We could not find an analytical solution and are in the process of finding a numerical solution and fitting an geometrical capacitance term to the result.

In addition we created an experimental setup. We designed an electromagnetic shielding device to block any interference from external electric fields while we were taking measurements on nanotube samples. The shielding box was designed to take I-V and photoelectric measurements. Samples of nanotubes electrophoretically deposited between electrodes over a backgate will likely be tested in the device. These are prototypes of nanotube transistors and hold great promise for the future of nanoelectronics.

Acknowledgement: This research was made possible by the National Science Foundation's Research Experience for Undergraduates (REU) program at Lehigh University.

Ultraviolet Spectroscopic Analysis of Interacting Binaries

RS Vulpeculae and U Cephei

By: Amber Marsh, Christopher Newport University

Advisors: Prof. George E McCluskey, Lehigh University

Prof. Gary G. DeLeo, Lehigh University

Thank-you to the support of the National Science Foundation, Research Experiences for Undergraduates program

ABSTRACT:

Seven far-ultraviolet and five mid-ultraviolet high resolution spectra of the interacting Algol-type binary RS Vulpeculae obtained by the International Ultraviolet Explorer (IUE) satellite and retrieved from the Multi-mission Archive at Space Telescope (MAST) have been analyzed. The resonance lines of Si IV and C IV are present at all phases and weak N V resonance lines are likely present at several phases. As in the case of many short-period Algol systems, a high-temperature pseudo-photospheric region of variable strength exists on the equatorial region of the B5 V primary star. During the period of observation, about August 20th – August 26th 1983, RS Vul was in a relatively low activity state; more active than β Per and less active than U Sge. The resonance lines of Al III, Si IV, and C IV are a little stronger at phases 0.6-0.8 compared to phases 0.1-0.4, with an apparent doubling of the C IV profile at phase 0.8. The results are consistent with gas flow observations in the ultraviolet spectra of other known Algol systems.

Nine far ultraviolet, high resolution spectra of the interacting Algol-type binary, U Cephei, obtained with the Far-Ultraviolet Spectroscopic Explorer (FUSE) satellite and retrieved from the Multi-mission Archive at Space Telescope (MAST) have also been analyzed. The resonance lines of P V are present at all phases and are a good indication of gas flow within the system as compared to spectral observations of other Algol systems.

Second Harmonic Generation in Electro-optic Polymer Films

Ethan Marsh

Advisors: Dr. Ivan Biaggio, Dr. David McGee

Graduate Student Advisor: Bweh Esembeson

Acknowledgements: Michelle Scimeca

Financial Support provided by: NSF RUI grant and the REU program, Lehigh University

Abstract

This summer, I worked on detection of Second Harmonic Generation in electro-optic polymer films. The polymer we used was amorphous polycarbonate doped with push-pull chromophores. The aim of the research was to compare the SH signal generated by corona-poled films with that of unpoled films, and to learn how to use SHG to determine second order non-linear susceptibilities. The poled films were found to generate a strong SH signal, while unpoled films generated little or no SH signal. Using a quartz crystal as a reference, the second order non-linear susceptibilities for the poled film was estimated at 7.1 pm/V. The next step in our research is to develop a method for using SHG to measure the stability of the chromophores in a poled film over time and under varying temperatures.

Summer Research Abstract - Glass Capillaries

I have spent the past 8 weeks doing research and performing experiments with Japanese exchange student, Toshikazu Irisawa, on the optimization of glass capillary shape for x-rays under Professor Cargill. Toshikazu Irisawa had been successful in this field in Japan and former Lehigh graduate student, Keith Hwang, had been able to create parabolic capillaries that produced optimum results with x-rays while doing research at Lehigh.

Glass capillaries have been used to focus x-rays through reflection. Tapered capillaries are able to focus x-rays and increase intensity, but tapered capillaries with walls at angles smaller than the critical angle allow for greater x-ray concentration and increased intensity. The purpose of this research project was to fabricate a glass capillary with a parabolic shape, capable of total external reflection to focus x-rays through a very small exit diameter.

Theoretically, a parabolic capillary will have a single focal point, resulting in the highest possible x-ray intensity and a small beam diameter. All x-rays should enter the capillary through a large diameter entrance, but should all be redirected by the capillary to the focal point. Such a focused beam could then prove quite useful when it comes to doing things with x-rays such as spatially resolved x-ray diffraction analysis of crystal structures or x-ray fluorescence mapping of the chemical composition of materials.

Before experimentally testing these theories, computer simulations were run using programs written by Keith Hwang. The simulations, written in C++, showed that by tapering a capillary at a low angle, total reflection could be achieved and that the x-rays could be focused this way.

Due to the high cost of glass capillaries, borosilicate glass rods were first used for experiments. Data was recorded initially using a stationary furnace at various temperatures in order to observe the rate of elongation and change in diameter. After sufficient measurements were made using the stationary furnace, it was decided that the furnace would be set to a temperature of 760°C.

Work was then done to establish the correct furnace velocity profile in order to create a rod with the desired parabolic shape. Trials were performed and compared to simulation data until the correct velocity profile was determined. Once several parabolic rods were successfully produced using this profile, two different types of borosilicate glass capillaries with inner diameters of 25 μm and 100 μm respectively were used in the same situation (the same viscosity, temperature, furnace velocity profile, etc.). This resulted in the formulation of several parabolic glass capillaries for use in focusing x-rays.

Over the course of this project, we were successful in generating a method and then making several parabolic capillaries. Preliminary data of the capillary profiles found by measuring diameter vs. distance show a good shape capable of total reflection. Further x-ray testing will be done to further test the capillaries.

SITE-SELECTIVE SPECTROSCOPY OF ERBIUM ION IN LITHIUM TANTALATE*

Keiko Miyahara

Advisor: Prof. V. Dierolf

Abstract

Lithium tantalate (LiTaO_3), as well as lithium niobate (LiNbO_3), is known for its electro-optical and nonlinear optical properties. Since it enables us to create low-loss waveguides, there are a number of applications for telecommunication and a variety of other fields. Moreover, adding rare earth ions (such as Er^{3+}) allows the realization of integrated optical amplifiers and laser. In earlier work on RE-doped LiNbO_3 , it was shown that such ions, once understood of their behavior, can be used in imaging application to probe local changes in strains and intrinsic electric fields. In order to extend this powerful approach to LiTaO_3 we chose Er^{3+} as our probe ion and studied its optical transitions in stoichiometric LiTaO_3 samples at low temperature (4K). We applied combined excitation-emission spectroscopy (CEES) in which the external cavity excitation laser was tuned in small steps between 960nm-990nm. The resulting photoluminescence spectra are collected in CCD-equipped spectrometer. We measured the spectra in the near infrared (1550nm) corresponding to one-step excitation as well as the visible (550nm and 670nm) emission that is produced by two-step (up-conversion) excitation. Data were taken for z-cut samples both before and after annealing the as-grown sample at 250°C for 5 hours.

We unambiguously identified three major sites for all emission regions and determined their energy levels (“fingerprinting”). However, it is apparent especially in the up-conversion data, that even more different defect sites exist. The presence of various sites is a consequence of the charge compensation requirement of trivalent Er^{3+} replacing the monovalent Li^+ . We would expect the relative number of defects and type of defect configurations to change after annealing at temperatures at which Li ions are mobile. However, we did not observe (in contrast to LiNbO_3) any major change. Apparently, the thermal history of the as-grown sample resulted already in a thermal equilibrium of the Er^{3+} /charge compensator complexes. Only very careful measurements, in which we measured spectra for both samples under exactly the same conditions (temperature, excitation wavelengths, spectrometer position), revealed a slight narrowing of the emission peaks for the annealed sample. We suspect that this effect is caused by rearrangement of distant defects. Identification of up-conversion pathways and fingerprinting additional sites will require some additional measurements that are part of our ongoing studies.

* supported by NSF, Research Experiences for Undergraduates (REU) Program, NSF-Europe grant (DMR-0349632), and MWN-grant(NSF-DMR-0602986)

Square Well Model of Globular Protein Phase Diagram
- Swapna Mudigonda
Advisor: Dr. Jim Gunton

Abstract:

It is important to crystallize proteins using x-ray diffraction to understand their structure; however, only high quality crystals can produce an accurate diffraction pattern of the structure. Understanding the optimal conditions for crystallization requires the knowledge of the phase diagram of proteins. We have studied a square well model of globular proteins, concentrating on the solid and the liquid phases. Using Monte Carlo simulations for an interaction range of $\lambda = 1.3$, we did several simulations in order to obtain the equation of state for the liquid and solid phases. Further work is needed to determine the full phase diagram of this model.

*supported by NSF grant

Direct UV Writing of Waveguides in Lithium Niobate*

David Newby

Advisor: Prof. V. Dierolf, Prof. D. McGee

Lithium niobate (LiNbO_3) is a prominent material in integrated optics due to its favorable electro-optical, acousto-optical and nonlinear properties. The required waveguides are typically produced by methods, such as Titanium in-diffusion, that require multiple steps including photolithographic patterning and diffusion. Our goal is to simplify this process and to write optical waveguides directly onto the sample using a method first explored by Eason and his group [1]. The technique uses a focused UV laser to induce lithium out-diffusion in a sample of LiNbO_3 , which causes a slight increase in the local index of refraction. By scanning the beam along the sample at a uniform rate we hope to be able to produce functional waveguides.

As earlier studies showed, it is essential in the writing process to have feedback of the location of the laser focus and if the proper out-diffusion has taken place. For the latter, we used Erbium doped LiNbO_3 samples and used the Erbium emission as a probe. Using this probe along with Raman spectroscopy, we hope to explore the detailed processes that are responsible for the laser-induced changes in refractive index.

Our experimental set-up (developed and tested by last years REU student Nate Woodward) combines a home-built confocal luminescence and Raman microscope with the ability to tightly focus the laser onto the sample. Using about 80mW of power from a 244nm frequency doubled Argon laser, we succeeded in etching straight lines in the LiNbO_3 sample with the help of computer-controlled translation stages running on a LabVIEW program. Our preliminary results indicated that the power at the sample was excessive, due to the obliterated appearance of our first “guides”. Keeping this in mind we created a sample, which varied the fluence by moving the focus of the beam through the crystal between successive lines. The result is a group of lines that seem to fade out as we defocus the laser beam, a visual indication of the change in fluence. However, utilizing the Er^{3+} luminescence, we are able to determine changes that occurred in the lithium concentration have also taken place in areas where no lines are visible in a regular microscope. Exactly these areas that are candidates for good waveguides, because the required index change is very small and melting of the surface has to be avoided for low-loss waveguides, First attempts to write lines long enough for waveguide testing, we realized the importance of controlling the focus. We are currently implementing an auto-focus procedure that uses the reflected laser light as its feedback signal.

As we continue to make improvements to our setup we hope to conduct Raman spectroscopy and photoluminescence scans on samples in real time as we are writing the waveguides. This will likely provide an accurate indication of lithium concentration which will allow us to create consistent and, hopefully, functional waveguides.

[1] S. Mailis, C. Riziotis, I.T. Wellington, P.G.R Smith, C.B.E. Gawith, R.W. Eason, Optics Letters 16, 1433 (2003)

* supported by NSF, Research Experiences for Undergraduates (REU) Program, NSF-Europe grant (DMR-0349632), and MWN-grant(NSF-DMR-0602986)

CMOS IC Patch Clamp Instrumentation Amplifier for Bio-Chip Application

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Summer 2005

Abstract:

Ion channel proteins facilitate the flow of ions across cell membranes and are responsible for a variety of critical tasks such as neural communication and maintaining proper ionic concentrations within the cell. However, ion channel dysfunction is responsible for a host of human diseases including cystic fibrosis and epilepsy.¹ A better understanding of how various chemicals effect ion-channel function could lead to the development of new drugs and treatments for these diseases. Unfortunately, current electrophysiological techniques for such characterization are labor intensive and low throughput, making them unsuitable for large scale drug testing. In an attempt to address these issues, progress has been made in the development of an integrated circuit patch clamp amplifier. The amplifier uses an integrating head stage and discrete analog signal processing to measure low amplitude, high frequency current signals, and can currently achieve 30pA resolution at 2kHz. The small size and relative simplicity of this amplifier opens the door to the development of an automated, high throughput planar patch clamping bio-chip for ion channel characterization.

Characterization of photopatternable spin-on elastomers with applications in BioMEMS and cell patterning

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Advisor Professor Tatic-Lucic

August 4th 2005

Abstract:

Photopatternable spin-on silicone is useful for applications in cell patterning and Bio-Micro-Electro-Mechanical Systems (BioMEMS). To be functional in these applications the silicone needs to have a concrete recipe for getting the best resolution. Currently the minimum resolution for the photopatternable spin-on silicone WL-5351 is unknown. Fabrication dictates how well the resolution of the minimum features will turn out. While patterning the WL-5351 we used two fabrication techniques, therefore two resolution characterizations were done, enabling a comparison between the two methods to find the best fabrication recipe. Photopatternable spin-on silicone WL-5351 is an excellent material because it has low stress, a low young's modulus, low shrinkage, it creates films of 6 to 18 microns in thickness, and it has a negative tone [1]. WL-5351 can be a great alternative to current materials such as Polydimethylsiloxane (PDMS) in both cell patterning and BioMEMS devices because it's easier to make and it avoids problems such as roof collapse [2]. The photopatternable spin-on silicone WL-5351 is a new material given to Lehigh University and four other research groups by Dow Corning,

*Thanks to the National Science Foundation for Support

The atomic force microscope and its application to the measurement of the magnetic gradient surrounding a single magnetic tweezers tip

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Acknowledgement: This work is supported by the National Science Foundation

ABSTRACT A sample holder design for magnetic tweezers has been constructed for the manipulation of micron-sized paramagnetic beads. The entire manipulation setup (aside from the leads and power source) was built on a standard microscope slide. The electromagnets were constructed with two Hymu-80 electrochemically sharpened wires and two insulated copper wires to carry current. Both the mu-metal wire and the copper wire are .005" in diameter (~127 μm). Conceptually, our analysis suggests that due to the small dimensions, the traditional electromagnets made with coils are not needed; rather, a single current carrying wire should be enough to saturate the tip of the mu-metal pole piece and provide the desired force. In previous experiments, the sample holder design was successful in manipulating 1- μm -diameter Estapor magnetic latex beads. The force that was applied to the bead, however, was not determined. This paper focuses on the efforts to measure the force capabilities of the aforementioned magnetic tweezers design. The atomic force microscope (AFM) is commonly used for magnetic force microscopy (MFM) in order to qualitatively map the magnetic force gradient above a surface at the microscopic level. With further efforts, quantitative values can be attained. In this experiment, a modified magnetic tweezers sample was designed and analyzed under the AFM. The AFM was able to image the magnetic force gradient when scanning the sample at a height above the mu-metal pole piece. Further analysis using the AFM was limited by the available software, and the difficulties that arose with the magnetic tweezers being an unconventional sample for MFM analysis.

Polyimide Thin Film and Substrate Layer Stress Analysis

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Funding for this work was supported by International Materials Institute (NSF-IMI, DMR-0409588).

Abstract

NASA has micro shutters that they developed that have an operating temperature of 35K. These micro shutters are composed of three layers of materials from bottom to top: silicon nitride, aluminum, and molynitrate. The molynitrate acts as a “stress balancer” with regard to the CTE. Without this top layer deposited on top the micro shutter would curl up under the stress as it is cooled to its operating temperature of 35K. The CTE of molynitrate is similar to that of silicon nitride, so if the thickness of each are right then very little curvature is induced. To this point the correct thickness of molynitrate has been determined by trail and error. The ultimate goal of this research is to ascertain the true measurements of the molynitrate thin film’s CTE and elastic modulus.