Using Dielectrophoresis to Trap Living and Dead Cells
Justin Antolin
Advisor Dr. Hwang

The overall goal for this project is to create a microfluidic channel mounted on electrical circuit to trap and distinguish between live and dead bacteria for bioterror detection applications for the Department of Defense Defense Threat Reduction Agency (DTRA). The research group created a device with gold broadband transmission lines integrated with a microfluidic device such that the cells or bacteria of interest could be trapped with dielectrophoresis and measured with the transmission electrodes. To characterize the system, the chip is attached to a network analyzer (VNA), living or dead cells are flown through the microchamber while a dielectrophoresis trapping signal is applied. An inverted microscope is used for verification of cell state and trapping. Greater amounts of data needed to be processed than was possible by extant methods, so automation programs using MATLAB were developed this summer. These programs greatly reduced repetitive data processing tasks and allowed for an increase in the rate of scientific progress on the project. In the future the research group plans to compare impedance signatures of different types of cells, redesign the electrode for single cell trapping and investigate different voltage waveforms for possible subcellular detection.

Acknowledgements: This work could not have been completed without the Sherman Fairchild Center for Solid State Physics, Lehigh University and the National Science Foundation
Laser induced fireworks on SbSI glass

Katherine Atwater\textsuperscript{1}; Dmytro Savytskyy\textsuperscript{1}; Brian Knorr\textsuperscript{2}; Volkmar Dierolf\textsuperscript{2}; Himanshu Jain\textsuperscript{1}

\textit{Materials Science and Engineering Department\textsuperscript{1}, Physics Department \textsuperscript{2}}

\textit{Lehigh University, Bethlehem, PA}

\textbf{Abstract:}

Laser writing was used on stoichiometric, SbSI chalcogenide glass to produce SbSI crystalline architectures on the sample surface. An explosive change in line morphology was observed within the line during the writing process. Energy Dispersive X-ray Spectroscopy (EDS) and Electron Backscatter Diffraction (EBSD) were used to analyze the laser induced line. It was found that Sb\textsubscript{2}S\textsubscript{3} crystal grains were produced on SbSI glass during CW 520nm laser irradiation due to SbI\textsubscript{3} evaporation. These crystals grew in the \textit{<001>} direction with respect to the laser scanning. The oxidation of the Sb\textsubscript{2}S\textsubscript{3} crystals led to the formation of antimony oxide (Sb\textsubscript{2}O\textsubscript{3}) on the glass sample surface. The reaction energy from this process perpetuated the explosive oxidation of the Sb\textsubscript{2}S\textsubscript{3} crystalline phase like a firework, in which Sb\textsubscript{2}S\textsubscript{3} is the main component.

\textbf{Acknowledgement:}

This work has been supported by the National Science Foundation via IMI Grant DMR 0844014
Degenerate four wave mixing allows one to investigate the third-order optical nonlinearity of material, but the intensity of the detected signal only depends on the absolute value of the third-order susceptibility. Since the latter can become complex-valued in the presence of, e.g., two photon resonances, it is interesting to develop a way to also measure its phase. This project investigated a novel design for a nonlinear optical interferometer with better stability than other designs proposed in the past. The interferometer was successfully constructed, complete with a frame-grabber system for the automatic acquisition of the interferogram and its phase-shift from a video camera. The position of the interference fringes in the interferogram directly relates to a change in the phase of the third-order susceptibility. The robustness of the setup and its resistance to vibrations was investigated by acquiring nonlinear optical interferograms under different conditions and studying the stability and reproducibility of the phase information extracted from them. The tests showed that both the degenerate four-wave mixing setup and the newly constructed interferometer maintained phase stability over a period of a few minutes. As long as interferograms for two different concentrations can be acquired within this stability period, the new setup allows the separate determination of the real and the imaginary part of the third-order polarizability of a molecule.

This research was funded by the National Science Foundation’s Research Experience for Undergraduates program.
An investigation of chitosan-based injectable systems containing nanoporous bioactive glass powder

Macauley Breault, Ukrit Thamma, Himanshu Jain

Muhlenberg College, Allentown, PA
IMI for New Functionality in Glass, Lehigh University, Bethlehem, PA

Abstract

Recent research has focused on developing minimally invasive ways of implanting bone-regenerating bioactive glass. One such approach could be to suspend bioactive glass particles in an injectable matrix, which subsequently (1) is injectable at room temperature, (2) harden in situ, (3) suspend bioactive glass particles, and (4) is biodegradable and biocompatible. This work explores the possibility of combining the bone regenerate ability of nanoporous bioactive glass powder with the thermal-responsive gelling nature of chitosan–β-glycerolphosphate salt to create an injectable for medical purposes. The pH of the composition has been shown to play a role in the gelation temperature. Preliminary tests indicate that the presence of β-glycerolphosphate salt neutralizes the chitosan solution, raising the pH to physiological range while controlling the pH-dependence to reveal a temperature-dependence. The addition of bioactive glass further alters the pH of the bioactive composite.

I would like to acknowledge the National Science Foundation for supporting this research conducted at International Materials Institute for New Functionality in Glass at Lehigh University via IMI Grant DMR 0844014.
Analyzing the Glass Transition of Sugar Glasses

Kerem Ege Calay
Lehigh University- Materials Science and Engineering

Abstract
The motivation of this work was to develop a low-cost experiment for students to explore and understand the glass transition and relaxation behavior in glasses. It is intended as an extension to the IMI-NFG’s existing collection of low-cost experiments centered on making glass and material science accessible to a wide range of students. The glass transition is an important property of glasses and one quite sensitive to thermal history of the metastable glassy material. The thermal history can in turn affect many properties such as density, index of refraction, viscosity, all important to final applications such as fiber optics, bioglasses, and many others. The effect of thermal history on the glass transition behavior was investigated in isomalt, a common sugar substitute, using a student-built DTA and compared to results obtained from a commercial DSC. Glassy samples of isomalt were prepared and subject to different thermal histories, including rapid quenching and slow cooling. Short term aging was also examined. Our DTA show a very clear Tg for the isomalt glass at around 45º C. In addition, the measurements show a clear difference between the samples cooled slowly and aged for a day or more and the rapidly quenched samples. The samples cooled slowly and aged for at least a day show a distinct post Tg exotherm which is absent in the quenched sample. Baseline stability and run to run repeatability for the home-built DTA were inferior to that of the commercial DSC, leaving room for further improvement. Nonetheless, the method does provide a reasonable, low-cost laboratory experiment for introducing students to the glass transition and the relaxation effect.

Acknowledgements
I would like to thank primarily my advisor Dr. Heffner for his willingness and eagerness to also keep me excited for this project as well, IMI for their support in funding the experiments conducted in this research and Daniel Davis and Maria Salamon for giving me the training for the DSC apparatus at Lehigh University. This work has been supported by the National Science Foundation via IMI Grant DMR 0844014.
The Search for Periodicity in Irregularly Shaped Planetary Nebulae
Anna Carr and Joshua Pepper
Department of Physics, Lehigh University, Bethlehem, PA 18015, USA

After a period of high mass loss late in the stellar life cycle, during the asymptotic giant branch phase, stars may form planetary nebulae, consisting of circumstellar clouds of ionized gas. These nebulae are theoretically expected to be spherical, but are observed to have quite irregular shapes. The mechanisms behind these irregularities are unknown. We explore the notion that unseen binary companions to the central stars of the nebulae may be the cause of the irregularly shaped nebulae. We examined six planetary nebulae observed in the KELT survey, searching for periodicity in the light curves of each nebula. We were unable to identify any conclusive periodicity, partly due to observational and technical limitations.
Evaluating the Bioactivity of 45S5 Bioglass Samples Specifically Quenched at Varying Temperatures

Tanuj R. Chokshi, Tia J. Kowal, BS, Roman Holovchak, PhD, Matthias M. Falk, PhD, and Himanshu Jain, EngScD

NSF Funded International Material Institute for New Functionality in Glass, Lehigh University, Bethlehem, Pennsylvania

Abstract:

Bioglass, recognized for its remarkable biocompatibility and potential, has recently been growing in interest as one of the most promising materials for hard tissue repair and regeneration in regions of diseased bone. Although the osteoconductivity and regenerative properties of 45S5 bioglass are well-known and supported, current research surrounding this surface reactive glass-ceramic biomaterial focuses on understanding the mechanisms of bioactivity, mainly that of apatite layer formation and the regeneration process on various implanted bioceramics. To elaborate, implanted bioceramics are instantaneously coated with proteins from bodily fluids, mainly from blood, and it has been shown that the mechanism of detection, response, and cell attachment occurs through interactions with this crucial mineralized apatite layer. Although this may be the case, it is believed that slight modifications in glass fabrication procedures could potentially disrupt the uniformity of the hydroxyapatite layer through transformative processes as phase separation ultimately affecting the bioactivity/potency of 45S5 bioglass.
Synthesizing PGS for PGS/Bioglass Composites

Allison P. Fletcher\textsuperscript{1}, Forest S. Blanchard\textsuperscript{2}, and Richard P. Vinci\textsuperscript{1,*}

\textsuperscript{1}Department of Materials Science and Engineering, Lehigh University, Bethlehem, PA
\textsuperscript{2}Department of Chemical Engineering, University at Buffalo, The State University of New York, Buffalo, NY

Abstract
Poly(glycerol sebacate) (PGS)/45S5 Bioglass composites show remarkable potential for applications in biological tissue engineering, drug delivery, and tissue adhesives. Thermoplastic PGS (TPGS), synthesized by Liu et al. in 2005, is an attractive alternative to PGS due to the additional processing capabilities it would provide, such as 3D printing. However, insufficient information was provided in Liu’s publications to confirm the thermoplastic nature of TPGS in the cured state; furthermore, there are no published reports on TPGS/Bioglass composites. PGS and TPGS were synthesized and compared using Differential Scanning Calorimetry (DSC), Fourier Transform Infrared Spectroscopy (FTIR), tensile testing, and rheometry. The DSC results showed that the two polymers were nearly identical thermally. Thus, both prepolymers exhibit thermoplastic properties, but after curing both are thermoset polymers. However, the FTIR results hinted towards a higher crosslink density in the TPGS. This was supported by the tensile tests of the polymers showing the TPGS to have a Young’s modulus of 3.92 MPa compared to the 3.09 MPa of conventional PGS, indicating the mechanical benefits of TPGS over PGS for applications that require higher stiffness. While the synthesized TPGS cannot be 3D printed using fused deposition modeling because it is not thermoplastic, there exists a potential for other chemical variants of PGS to be printed and UV cured. Plans for additional investigation in the near future include comparing PGS/Bioglass and TPGS/Bioglass composites by varying the particle size of Bioglass and performing mechanical tests at various time intervals of their degradation.

Acknowledgement
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A Dynamic Model for Mate Selection Through Cdc42 Exploration in Fission Yeast

Daniel Hurwitz$^1$ and Dimitrios Vavylonis$^2$

$^1$Department of Physics, University of Texas at Austin, $^2$Department of Physics, Lehigh University, Bethlehem, PA

During conditions of nitrogen starvation, the model eukaryote *S. pombe* (fission yeast) undergoes sexual sporulation. Because fission yeast are non-motile, contact between opposite mating types during spore formation is accomplished by polarizing growth, via the Rho GTP-ase Cdc42, in each mating type towards the selected mate, a process known as shmooing. Recent findings have shown that fission yeast locate their nearest compatible mate by randomizing the position of the Cdc42 complex about the cell membrane, such that the complex is stabilized near areas of high concentration of the opposite mating type pheromone. This mechanism seems to be crucial in selecting appropriate mates. Here, we present a dynamic model of mate selection in *S. pombe* whereby Cdc42 dwell time increases in response to increasing pheromone concentration. By exploring the model parameter space via Monte Carlo simulation, we show that effective mate selection requires both a linear and non-linear component to the response of Cdc42 dwell time to pheromone concentration. We also show that there exists an optimal value around 1 micron for the effective pheromone decay length. We conclude that for a given subset of parameters, efficient mate selection can occur in a population of fission yeast simply by stabilizing the Cdc42 complex near high pheromone concentration of the opposite mating type. We thank Felipe Bendezu and Sophie Martin (University of Lausanne) for discussions and motivating this project, the National Science Foundation for providing financial support, and the Lehigh University REU Program in Physics.
The self-assembly of amelogenin protein into microribbons is crucial for the oriented growth of apatite in the development of tooth enamel. In order to better understand this self-assembly process, the phase diagram for the protein must be studied. Previous in vitro experiments have allowed theorists to create a model based on the Asakura-Oosawa potential for attraction between hard spheres in a solvent containing smaller macromolecules. Since amelogenin is a globular, hydrophobic protein with a charged hydrophilic tail, it is modeled as a hard sphere with a point charge on its surface. By adding a Coulomb repulsion component to the AO potential, we are able to successfully simulate amelogenin self-assembly. Based on past experiments, scientists were able to place amelogenin in the fluid+fluid regime of phase separation for the AO phase diagram. We would use these parameters to look for phase separation in our simulation, which used a Gibbs Ensemble with Monte Carlo method at varying temperatures. We found that the system initially phase separates, but has yet to equilibrate after 5 million MCS. Our future plans are to resubmit our files and run over longer time scales in order to learn more about the phase separation and, subsequently, the self-assembly process of amelogenin.
Be stars are B-type stars that have emission lines of hydrogen, helium, and other elements due to a circumstellar disk. Be stars rotate near the critical limit, the point where the gravitational force at the equator equals the centrifugal force. Nonradial pulsations combined with the rapid rotation are thought to eject material to form the characteristic disk from which the emission lines originate. Assuming the polar radius does not change as the star rapidly rotates, we use the Roche model for rapidly rotating stars to show that the equatorial radius increases with respect to the polar radius. We used the Von Zeipel Theorem to model the surface temperature of the rotating star. The nonradial pulsations were modeled using spherical harmonic functions with \( l=2 \) and \( m=2 \). The models showed that with an increase in angular velocity, the equatorial radius increased, the equatorial temperature decreased, and the total luminosity decreased. We would like to thank the National Science Foundation for the grant AST-1109247 and REU site grant PHY-0849416.
Light Induced Fields in Lithium Niobate Crystals
T.Lewis¹, B.Knorr², V. Dierolf²

¹ Physics Department, Wheeling Jesuit University, 316 Washington Ave, Wheeling, WV 26003
² Physics Department, Lehigh University, 16 Memorial Drive East, Bethlehem, Pa 18015

Abstract:
Lithium Niobate (LiNbO₃) is a ferroelectric material with favorable properties such as piezoelectric, electro-optical, and nonlinear properties, which is used in variety of applications including light modulators, optical memory, and optical parametric oscillator (OPO) based tunable light sources. In this work, we focused on space charge fields that are created when the sample is irradiated with a focused laser due to the photovoltaic effect and ionization of impurities in the material. We observed this build-up and occasional discharges through spectral shifts of phonon modes in Raman spectroscopy. These shifts are a result of the ionic displacement due to the piezoelectric effect. Previous studies exhibited inconsistent results suggesting a hidden parameter. The goal of this work was to identify this parameter.

Samples of LiNbO₃ were cooled down to 4K, excited with a 488nm laser at various powers. Raman spectra are recorded as a function of time for about 10 minutes and changes in the positions in the Raman modes were monitored (as shown in Fig.1). After each run the samples are heated to 200K and cooled down again after each run to ensure equal starting conditions. Since the conduction between the sample and the cold finger was suspected as a hidden parameter we tested both silver paint and copper tape. Our results suggest however that discharges occur in both cases. In a second type of variation, we varied the relative orientation of the samples in regards to the laser illumination. We find that we have discharge thresholds when we excited the c+ face versus the c- face. We further identified some basic trends for discharges to occur:

1. More than 80 mW of tightly focused laser power with a .5 NA objective
2. A minimum initial shift of the 150cm⁻¹ Raman mode needs to be established. This threshold corresponds to an intrinsic field of 36 kV mm⁻¹ is necessary for a discharge to be observed which is similar to the field levels required for an electric breakthrough to occur.

However, some inconsistencies remain which are likely to be related with the spatial distribution of the space charge field which has not been measured and controlled in our experiments.

This work was partially supported by Physics Department REU program (MPS-PHY-0849416) and NSF grants ECCS-1140038 and DMR-1008075
Resonance and Relaxation in the Ferroelectric Relaxor $K_{x-1}Li_xTaO_3$

Joseph Lundeen, Bucknell University  
Advisor: Dr. Jean Toulouse

Ferroelectrics have generated a great deal of interest because microscopic electric interactions within them have macroscopic, often visible, consequences. $K_{x-1}Li_xTaO_3$ (abbreviated KLT) is one such crystal, in which the Li$^+$ ions become dipoles due to the structure of the unit cell granting them limited freedom of movement. This causes KLT exhibits mechanical resonant behavior when exposed to an AC (oscillating) electric field as the oscillating Li dipoles deform the unit cells. The mechanism behind KLT’s resonance is the presence of polar nanodomains (PNDs), regions in which several Li dipoles align in the same direction and effectively act as a single dipole. Consequently, resonance can only occur with addition of a DC (constant) electric field, which aligns the PNDs and allows the deformation of the unit cells to “build up,” yielding a net macroscopic strain oscillation. Curiously, we see not one, but two peaks in the resonance spectrum, one narrow and one broad. We believe this behavior to be due to the simultaneous existence of two slightly different configurations of Li dipoles that create two distinct modes of oscillation. The behavior of the peaks is highly temperature dependent, with the broad peak shifting to lower frequencies as temperature decreases. In addition, we observed a temperature range in which both peaks flatten and eventually disappear, only to reappear when the sample is cooled further. We believe this to be due to KLT’s capability of undergoing dielectric relaxation, in the form of a $\pi/2$ radian flip and a $\pi$ radian flip of the dipoles. A comparison of the resonance and relaxation spectra shows that the flattening of the peaks corresponds roughly to the temperature range in which the $\pi/2$ relaxation is strongest. This supports the conclusion that dielectric relaxation has a damping effect on the resonance as the settling of the dipoles into their new position transfers energy away from the oscillatory motion.

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Special thanks to Ling Cai
Modeling of Water Molecules in the Presence of Carbon Nanotubes:  
The Dipole Moment Correlation Function  
Joseph Monti, Rensselaer Polytechnic Institute  
Advisor: Dr. Slava V. Rotkin  
Lehigh University Summer 2013 REU  

Abstract: Water dynamics of the local hydration shell for finite single wall carbon nanotubes is an active area of research within the molecular dynamics (MD) community. Water molecules are of particular interest due to their polar structure and near-omnipresence in physical systems. In addition, the dipole moment vector of a water molecule is a strong indicator for its molecular orientation because the vector bisects the H-O-H angle. Carbon nanotubes have numerous applications in aqueous environments, such as acting as accurate biosensors and variable-width osmotic channels, and for bio-molecular targeting. The open source software NAMD (1) was utilized for all MD simulations, which were conducted at 300 K and 1 atm, within and outside pristine carbon nanotubes. The position vector data for individual oxygen and hydrogen atoms in the solvation box was studied to determine the radial dependence of the probability distribution functions for both atom types. The molecular response in close proximity (|r - R_{wall}| \approx 5 \text{ Å}) and at a large distance (r \approx 2R_{wall}) was especially evident. The cylindrical dipole moment components of each molecule, as well as the dipole moment magnitude, were collected in combination with the radial distance with respect to the central axis to search for trends in net molecular orientation within the solvation shells, relative to the nanotube wall. Per molecule averages were found for each component as a function of radius; correlations between the radial probability distribution functions and the dipole moment were observed. Future work will involve altering system parameters for studying more complex phenomena. This type of study extends naturally to charged carbon nanotubes and other biological solvents.

This research project was conducted with the generous support of the National Science Foundation through the REU site grant and grant number ECCS-1202398.

Scalable molecular dynamics with NAMD.  
Lagrange Point Hopping: Developing a Sustainable Architecture for Mars Missions
Sean Napier, Andrew Abraham, Dr. Gary DeLeo (Lehigh University)

Abstract
Lagrange points in the Circular Restricted 3-Body Problem (CR3BP) open up an array of unusual and potentially beneficial applications for Earth-Moon-system and interplanetary missions. Accordingly, station-keeping models for orbits around co-linear earth-moon Lagrange points, and their possible role in forming a sustainable architecture for interplanetary missions, are of interest to the astrodynamics community. The primary goal of this work is a characterization of energy-cost and $\Delta v$ differences between conventional Low-Earth-Orbit (LEO) to Mars-Low-Orbit (MLO) Hohmann trajectories and those utilizing Earth-Moon-Lagrange 2 (EM L2) orbits and/or Sun-Mars-Lagrange 1 (SM L1) orbits. We refer to trajectories in the latter category as "Lagrange Point Hopping" (LPH). Computed $\Delta v$’s using preliminary (not optimized) patched-conics LPH (EM L2 to SM L1) and conventional LEO to MLO trajectories are 8.6 km s$^{-1}$ and 5.6 km s$^{-1}$, respectively, a difference of approximately 3 km s$^{-1}$ in favor of the conventional approach. Our continuing work is aimed at rigorously optimizing the LPH mission trajectory and comparing both architectures in Full Ephemeris models in an effort to determine the efficacy of using Lagrange-point orbits as intermediate rendezvous points in future Earth-Mars missions. In addition the advent of developing, say, a reusable spacecraft as shuttle between Lagrange point orbits could lead to cost savings over multiple missions rather than just one. We are grateful for support from the Lehigh NSF-REU program and the Lehigh Department of Mechanical Engineering.
The percolation threshold marks the beginning of the phase transition between liquid and solid states of matter thereby defining a critical point in the system. The aim of this experiment was to identify and characterise the percolation threshold with the view to investigating the nature and genesis of disorder in solids.

Our experimental arrangement consisted of a 2-dimensional aluminium cell resting on a horizontal driving plate driven by two mutually orthogonal stepping motors. The base plate is transparent but electrically conducting to prevent surface charge build up. The stepping motors are driven according to a chaotic algorithm which simulated a thermal system. We concluded this through the analysis of the velocity distribution histograms of the spheres contained within the system which were found to be in excellent agreement with the Gaussian distribution. When a Maxwell Boltzmann distribution is applied, using the sigmas of the Gaussians, we could derive a constant for the system which turns out to be the temperature. Increasing the driving speed of the motors allows us to observe our system in a variety of thermal states. Steel spheres of 1.5mm and 2mm in diameter were added in various packing fractions to the cell which then simulated a gas, liquid or solid phase of matter. The 2-D medium at different packing fractions consisted of both mono-dispersed and 50-50 binary mixtures of spheres, and they were driven at two different speeds corresponding to two different thermal states. In order to examine the percolation threshold solely in terms of packing fraction, the driving plate was kept horizontal by means of an optical setup calibrated to the free surface of a liquid pool of mercury. Images of the cell were taken using a 10 mega-pixel camera in bursts of 33 images at 13.5 frames per second. A Hough transform program was then applied to determine both the degree of crystallinity (number of particles contained within crystallites in the system) of the system and to identify particles in contact with neighbour particles to identify the existence of a spanning cluster. The transform was applied in two steps in order to deal with the variance in image definition as a result of the effect of light saturation on the spheres- the first time to locate the particle centres using one diameter and the second to determine their contacts between particles.

From the analysis of the system we found a characteristic decrease in the degree of crystallinity at packing fractions where a spanning path first becomes apparent. This decrease was also observed in the crystallite size distribution measured in terms of both effective radius of a crystallite and contained particle number. This was found to occur at a higher packing fraction in the case of the 50-50 binary mixture. We expect this to increase with mixtures favouring the 1.5mm spheres, i.e., with increased particle number in the system. This decrease in crystallinity may provide a new insight into the definition of the percolation threshold; whether it is coincident with the first appearance of spanning clusters requires further scrutiny. The extent to which the dynamics at the onset of the liquid-solid phase transition control the disorder in solid alloy specimens is an interesting question. Recommendation for continuing study would be to increase the sample size so that the approach to the thermodynamic limit may be examined.
**Einstein’s Sedimentation Equilibrium Revisited: Quantifying particle interaction through analysis of sedimentation equilibrium**

Kathryn Reddy

Dr. H. Daniel Ou-Yang

August 2, 2013

Abstract:

In one of his three celebrate papers published in 1905 Albert Einstein postulated the relationship between particle number density and osmotic pressure for non-interactive colloidal particles in suspension. In 1911, using Einstein’s theory, Jean Baptist Perrin conducted his Nobel Prize winning experiment in which he determined the Boltzmann constant and therefore Avogadro's number. To accurately define the Boltzmann constant Perrin minimized particle interactions by using sufficiently low particle concentrations. Having a precise value for the Boltzmann constant allows us to extend Perrin's experiment to the interactive particle regime and therefore quantify multi-particle interactions in samples with relatively high densities. Our experiment simulates a gravitational force by using a centrifuge to drive the suspended particles into sedimentation equilibrium. We measure particle concentration distribution in the sediment by their turbidity and use Einstein’s equation to determine colloidal osmotic pressure for 233 nm diameter polystyrene particles in deionized water and in 1 mM KCl solution. Experimental data of extremely dilute samples are consistent with non-interactive particle suspensions. As concentration increases osmotic pressure deviates from the ideal. We quantify this non-ideality, caused by particle interactions, through the plot of osmotic pressure as a function of number density.

This research was made possible through funding from the National Science Foundation’s Research Experience for Undergraduates program and support of NSF-DMR-0923299.
The focus of this research was to explore the different possible designs for a high voltage solid state relay while concentrating on minimizing the device’s power consumption. Other parameters set for the device were to minimize the area it would take up on an integrated circuit while also maintaining high speed switching. Two types of MOSFET technologies, SCMOS and an all NMOS technology, were tested to see which was more appropriate to use for the relay. The SCMOS was found to be quicker and smaller while consuming less power, but was not able to handle high voltages. Alternatively, the all NMOS technology was larger, slower, and consumed more power, yet was able to handle the high voltages the SCMOS could not. Using the NMOS technology, the initial relay design was built off of a 2T1C pixel configuration with an additional load capacitance attached from the output of the diode to ground. This configuration allows the user to use two digital data lines to control the relay, allowing for future possibility of having an array of relay switches. However, the power consumption of the 2T1C configuration was calculated and simulated to be 450 mW when on and 0 W when off, ignoring leakage currents. In its current state, the device was consuming too much power to meet parameters. Therefore, the design was reworked into a 5T2C configuration, using a diode-connected NMOS as the driving diode. The power consumption of the new design was found to be 5.4 mW when on, giving a 98.8% reduction in power consumption from the previous design, while also maintaining the 0 W consumed when off.
Spectral Analysis of Gamma-Ray Binary Candidates
2FGL J0642.9+0319 and 2FGL J1151.5-1347

Erich Schmitz Lehigh University, Benedictine College
M. Virginia McSwain Lehigh University

ABSTRACT

2FGL J0642.9+0319 and 2FGL J1151.5-1347 are gamma-ray binary candidates with proposed orbital periods of 21.5 and 76 days, respectively. Using data from the Fermi Large Area Telescope (LAT) taken between 2008 and 2013, the sources were fit to spectral models and their gamma-ray spectra were obtained. The data analysis tools from the Fermi Science Support Center (FSSC) were used for a binned likelihood model of all of the sources within a 30 degree region of interest. Convergence of the likelihood function was obtained for both sources, but further analysis is needed to improve each fit. From the initial convergence, the modeled flux was calculated to be $4.3 \pm 0.1 \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ for 2FGL J0642.9+0319 and $6 \pm 2 \times 10^{-9}$ photons cm$^{-2}$ s$^{-1}$ for 2FGL J1151.5-1347. Further research should include an analysis of the periodic variability of the sources using light curves and a search for their optical counterparts.

Acknowledgement: We are thankful for support from the National Science Foundation through the grant AST – 1109247 and REU site grant PHY – 0849416
Improving Thermal Conductivity Apparatus with Vacuum Chamber

By John Scruggs (Tuskegee University, Tuskegee, AL)

Abstract:

The aim of this project was to improve upon a simple, low-cost, student-built apparatus for measuring the thermal conductivity apparatus of glassy materials developed during a previous REU. Our apparatus is designed for measuring the thermal conductivity of over a range from 0.15 to 1.5 W/(m*K), appropriate for polymers and oxide glasses. The apparatus consists of a sample sandwiched between a heated top plate and a cold bottom plate mounted on a pedestal for the independent monitoring of heat flow. In the original implementation the apparatus was operated in ambient air. In the current version we incorporate a low-cost vacuum chamber to remove the stray conductivity from the heater through the surrounding air. The vacuum platform was home built with parts costing less than $100 which even included a home-built electrical feed through. Using the improved design we measured the thermal conductivity of three commercially available glass materials spanning the range 0.2 through 1.2 for which the literature value could be ascertained (Acrylic, HDPE and Pyrex). We also examined for any sample area dependence of the measured thermal conductivity. Pyrex samples with 5 different areas (from 12.5 mm$^2$ to 114 mm$^2$) were used to examine for any area dependence of the measurement. We found that samples with areas of at least 30% of the heat block area produced measurements independent of sample area. Samples below that area percentage began to show increased value, and are not recommended (unless a separate calibration for sample area is included). We found good linear correlation between the values measured in air or vacuum with the literature values, although the values measured in air were actually closer to the literature values with those in vacuum; the in vacuum measurement being about 10% higher. We believe this apparatus provides an accurate low cost approach to measuring thermal conductivity of glassy material suitable for the undergraduate laboratory and for introducing the student to the concepts of thermal conductivity and its measurement, further enabling a variety of interesting applications.

Acknowledgement: This work has been supported National Science Foundation through the International Materials Institute for New Functionality in Glass, DMR 0844014
Surface Polariton Scattering on a Carbon Nanotube

Kevin P. Seltzer

Physics Department, Loyola University Maryland*

Advised By: Slava V. Rotkin

Physics Department, Lehigh University

Abstract

The thermal properties of carbon nanotubes are of particular interest for heat removal in nanoscale electronics. Interactions between electronic excitations of nanotubes and the evanescent field of surface polaritons of a substrate have been shown to greatly increase the interface (Kapitza) conductance. We examine surface phonon polariton scattering from a metallic single wall carbon nanotube that is parallel to and above the polar substrate hosting the polariton. The potential is shown to be separable and a simple integral equation for the eigenvalues is obtained. The problem allows some analytical treatment. We can expand the interaction Hamiltonian for the polariton with approximately linear dispersion or the dispersionless frequency at small or large momentum values, respectively. The remaining region will be treated numerically.

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* kpseltzer@loyola.edu
Crystallization Kinetics of 45S5 Bioactive Glass

Paarth Thapar, Roman Golovchak, Himanshu Jain
IMI-NFG, Lehigh University, Bethlehem, PA 18015

I. Abstract

The crystallization kinetics of the bioglass 45S5 was studied using differential scanning calorimetry (DSC). The thermal properties, such as the glass transition temperatures, activation energies for viscous flow and crystallization, thermal stability, Johnson-Mehl-Arvami (JMA) exponent were determined for two different batches of 45S5 glass (one commercially available from VIOX corporation and one made at Lehigh University). The Lehigh University glass had gone through spinodal phase decomposition during melt-quenching, while the uniform VIOX glass was used as an etalon for comparison. Four glass fractions were used: <32µm, 150-300µm, 300-500µm and bulk to study the peculiarities of bulk and surface crystallization in this material. The results testify a general validity of the JMA model for the spinodally phase separated glass, while the commercially available uniform glass went through a complicated crystallization mechanism involving phase separation in the initial stage that could not be explained by the JMA model. The results from this study make it possible to develop guidelines for tailoring thermal treatment parameters to achieve desired glass-to-crystal ratios in 45S5 bioceramics.
Calculating a Potential Energy Surface for rotational excitation of NaK molecules by He atoms.

Sri Laalitya Uppalapati
Department of Physics
Mount Holyoke College, South Hadley MA 01075
Advisor: Dr. A. Peet Hickman
Department of Physics
Lehigh University, Bethlehem PA 18015
Summer 2013

Abstract

Calculations of the cross-sections for rotational energy transfer during inelastic collisions of NaK molecules with He atoms are underway to model experimental data from Dr. Huenneken’s group at Lehigh University. The data for collisions of the $A^1\Sigma^+, v = 16, J = 14$ state of NaK with He show a strong propensity for transitions to occur for $\Delta J = \text{even}$. The corresponding calculations require a potential energy surface for the first excited state of NaK ($A^1\Sigma^+$), followed by quantum mechanical, coupled channel, scattering calculations. Using a preliminary potential surface obtained by high quality electronic structure calculations with the GAMESS code, the Lehigh group previously calculated rate constants for $v = 0$. These calculations exhibited a strong propensity for $\Delta J$ to be even, but for this work the bond length of NaK molecule was fixed at its equilibrium distance. This simplification is reasonable for calculating rate constants for $v = 0$, but it is not suitable for treating $v = 16$ because in that case the vibrational motion extends over a much greater range of bond length, and the wave function exhibits rapid oscillations. Therefore additional calculations with GAMESS were performed to determine the dependence of the potential surface on the NaK bond length. Since the GAMESS calculations require large amounts of computer time, an interpolation scheme was developed. The potential of the $A^1\Sigma^+$ state was represented by three pair-wise interactions that could be fit with analytic functions, plus a residual term. Large variations in the potential energy of NaK-He system were accounted for by the pair-wise interactions, so the residual potential was found to be smooth and easy to interpolate. Exact calculations of the potential surface for bond lengths $R = 6, 7, 8, 9, 10, 11 \, \text{a}_0$ were sufficient to obtain a reliable interpolation of the surface over the range of $R$ covered by vibrational state $v = 0$ to 16.

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In-situ Transconductance Measurement of Silicon during Atomic Layer Deposition

Morgan Watt and Nicholas Strandwitz

Abstract:

In this study, we analyze the effect of atomic layer deposition (ALD) on the near-surface conduction in silicon during deposition. Both Al₂O₃ and TiO₂ were deposited on n- and p-type silicon. Transconductance measurements were used to measure the effect of the exposure of each ALD precursor and the growth of the thin oxide layers on the silicon. Some of the samples were also rapid thermally annealed prior to and after ALD. The growth of both Al₂O₃ and TiO₂ films increases the conductivity in p-type silicon and decreases conductivity in n-type silicon. It was shown that each exposure of the sample to trimethylaluminum caused a notable change in the conductivity in the samples.

Acknowledgements:

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Abstract- Beth Anne Wieber

There is an increasing interest in multifunctional materials. Ruby gold glass, known for centuries, has been widely researched for optical properties but the electrical properties are less known. To make the glass, 0.1 % gold is added to sodium trisilicate glass, where gold nanoparticles are formed upon annealing the quenched glass. A second annealing for 12 hrs increased the nanoparticle size. Longer annealing times did not display the same growth. The electrical conductivities were measured over a large range of frequency and temperature. The conductivity was found to increase with an increase in temperature as previously observed. Activation energy was calculated using the dc conductivity, found using complex impedance analysis. Overall, the activation energy increased with a second annealing time. The gold nanoparticles do not appear to have any significant effect on the magnitude of conductivity. More data must be taken to understand how the activation energy changes with increasing annealing time.
Differences in Predictions using the MMM8.1 and MMM7.1 Multi-Mode Transport Models

Christopher Wilson
Advisors: Prof. Arnold Kritz, Dr. Tariq Rafiq
Lehigh University REU 2013

Abstract
The updated Multi-Mode anomalous transport module version 8.1 (MMM8.1) [1] includes several advancements over the previous version (MMM7.1). In particular, the new version of the Multi-Mode transport model includes improved formulations of the flow shear effects and of the toroidal and poloidal momentum diffusivities. The MMM8.1 model can be used to compute toroidal and poloidal angular momentum transport as well as thermal and particle transport in Tokamaks. To facilitate the research carried out, a new efficient tool has been developed to examine simulation results obtained using the PTRANSP code. The effective diffusivities are computed for several DIII-D discharges using the MMM8.1 model. These diffusivities are compared with those predicted using the previous model, MMM7.1. In addition, systematic scans over a range of plasma parameters such as plasma collisionality, magnetic shear, and \( \mathbf{E} \times \mathbf{B} \) flow shear are carried out. These scans are used to identify those plasma parameters that would result in the most significant differences in predictions using the MMM8.1 transport model in contrast to using the MMM7.1 model.


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Investigating Fluorescence Observed in Sugar Glass

Donald Wright III, Dr. Bill Heffner

Abstract:

This study investigated fluorescence observed in sugar glass (hard candy) when excited with a single wavelength of visible light. Fluorescent light was captured using a homebuilt “Fluorescent Monitoring System.” High intensity LEDs of various wavelengths were used to excite the fluorescence, and a student grade, lower-cost Ocean Optics Red Tide Spectrometer was used to measure the fluorescence emitted normal to the exciting beam. We found that candy glass is fluorescent when excited with a single wavelength of visible light below about 550nm with fluorescent spans between 470nm and 650nm. We measured the fluorescence as a function of temperature and found it to decrease with increasing temperature. However, the room temperature fluorescence increased as the glass caramelized (browned) with further heat treatment (cooking). Significant caramelization also resulted in an increased absorption of both the fluorescence and visible light in the short wavelength spectrum. To clarify this later point, we also measured the absorption and transmission at various levels of caramelized candy glass with the Red Tide Spectrometer and compared with measurements made on a state of the art, PerkinElmer LAMBDA 9 Spectrophotometer available in University lab. The Red Tide Spectrometer provided quite suitable characterization of the absorption and fluorescence in the caramelization of the sugar glass system and we propose the experiment could be an interesting and appropriate one for an undergraduate lab in physics, chemistry or material science.

Recent literature [1] has shown fluorescence in caramelized sugars and even breads to be due to the production of carbon nanoparticles (CNPs) and the wavelength range of the fluorescence they observe is in good agreement with the range observed in our experiments.

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