

Lehigh University
Summer REU Program
2011
Student Abstracts

Encapsulation by Janus Particles

Genevieve Brett, Skidmore College
Lehigh University Summer REU 2011

Advisor: Jim Gunton

Collaborators: Ya Liu, Wei Li

Abstract:

Janus particles have dissimilar semi-surfaces, e.g. hydrophobic and hydrophilic, respectively. One class, colloidal Janus spheres, has been shown in experiments and simulations to exhibit self-assembly into micelles and vesicles. Another class of Janus particles is that of ellipsoids, in which one can vary the aspect ratio to form oblate or prolate spheroids, for example. These also have been shown to self-assemble into aggregates whose morphology depends on the aspect ratio. Our current work investigated the possibility of encapsulating spherical particles by Janus ellipsoids, as a function of the density and aspect ratio of the ellipsoids. Our model assumes that the sphere-sphere interaction is hard-core repulsion, whereas the ellipsoid-ellipsoid and ellipsoid-sphere interaction is taken to be hard core repulsion plus a square well attractive interaction. By using standard Monte Carlo simulation, we have found a maximum efficiency of encapsulation of 44.4% for an ellipsoid number density of 0.04 and aspect ratio of 0.6. This method of encapsulation is of potential value in both the pharmaceutical and materials science community.

Resolving Contradictions in Highly Anisotropic Photoluminescence and Absorption Properties of Rubrene Molecular Single Crystals: Intrinsic Optical Properties Revealed

Isaac Clark
Advisor: Dr. Ivan Biaggio

Abstract

Understanding the creation, diffusion, and disassociation of excitons in semiconducting organic molecular single crystals is important for future electronic and photovoltaic applications, and we use optics to study these processes in rubrene single crystals grown by vapor transport. Rubrene ($C_{42}H_{28}$, 5,6,11,12 - tetraphenyltetracene) has the highest reported charge carrier mobility of organic semiconductors to date as well as high photoconductivity, making it one of the organic molecular crystals of choice for current organic semiconductor research. We determine the photoluminescence spectra of excitations created under different conditions in rubrene single crystals. We show that the spectra undergo strong variations depending on which facet of the crystal is illuminated and on the polarization and wavelength of the excitation light, and assign this variability to the effect of the strong anisotropic absorption of rubrene. We extract the absorption spectra for all three light polarizations and use them to model the spectral shape of the rubrene luminescence. In addition, we confirm that exciton diffusion processes reported by our group earlier are independent of excitation conditions.

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Crystallization in TeO₂-ZnO-BaO (TZB) Glass

Rebecca Conneely

Advisor: Dr. Jean Toulouse

Lehigh University IMI-NFG REU 2011

Because of its advantageous optical properties (Raman gain coefficient), TeO₂-ZnO-BaO (TZB) glass has recently become of interest for the fabrication of optical fibers. However, these fibers still exhibit losses that limit their use. A significant cause of signal loss in optical fibers is scattering. Rayleigh scattering can happen due to the presence of very small crystals (microcrystals or nanocrystals) within the core of the fiber, with sizes much smaller than the wavelength of light. . These crystals can appear as a result of the processing of the glass into fibers (temperature and duration of the different processing treatments). In a TZB preform, the temperature and time duration of the glass anneal (343°C for 5 hours) can lead to crystal nucleation. Crystals can then form during the fiber draw process when the preform is reheated close to 450°C and held for 1-2 hours. In this project, TeO₂, ZnO, and BaO powders were dried, then melted at 800°C for 4 hours and poured onto a flat metal plate. Samples were then annealed for 5 hours at 343°C. Four of the samples were reheated to chosen test temperatures (490°C, 475°C, 460°C, and 445°C) and held for one hour to emulate the reheating involved in the fiber drawing procedure. The heat treated samples were then observed using an optical microscope to detect the possible formation of crystals, measure their sizes and understand their formation.

Acknowledgement: Funded by NSF supported International Materials Institute for New Functionality in Glass (IMI-NFG), Lehigh University (Grant DMR-0844014).

Hollow Shells Of Dipoles: A Group Theoretical Approach

Christopher Devulder. Advisor: Dr. Slava V. Rotkin
Lehigh University Department of Physics

Abstract: We use Group Theory to solve for the dipole interaction part of the Hamiltonian of various types of one (chain), two (ring) and three (cylinder) dimensional shells of dipoles. The fabrication of such structures has been recently achieved for various plasmonic devices, such as gold nanoparticles surrounding carbon nanotubes (1). These systems present various levels of rotational and translational symmetry that can be put in correspondence with symmetry groups and their matrix representations. This mapping of our physical system onto mathematical groups enables us to use several powerful results and theorems from linear algebra to diagonalize the interaction potential tensor that appears in the Hamiltonian. This tensor is initially expressed in terms of a real vector space, whose basis set is rotated to a reciprocal space given by the irreducible representations of the symmetry groups under consideration. This enables us to re-express our Hamiltonian as a block diagonal matrix, which can be further diagonalized to display the eigenenergies of the system. The change of coordinate matrices also contain the information that yields the eigenmodes of the system, giving us an accurate, three dimensional representation of the dipoles and their oscillation modes for each eigenenergy. The extension of the model to cylindrical shells is also discussed.

Acknowledgment: This work has been supported by the Sherman Fairchild Center for Solid State Studies at Lehigh University.

(1) Bing Li, Lingyu Li, Bingbing Wang and Christopher Y. Li. Alternating patterns on single-walled carbon nanotubes. *Nature Nanotechnology* 10.1038/NNANO.2009.9 (2009).

Multiscale Physics of Nanotube Devices

Alex Edelman
Carnegie Mellon University

August 5, 2011

Abstract

Electronic devices built with semiconducting carbon nanotubes are exciting both as probes of nanotube physics and a practical path to technological applications. We report progress toward developing a flexible, robust, and modular simulation environment for multiphysics (electromagnetic, quantum mechanical, statistical mechanical) computational studies of these devices. We use finite element analysis to compute a Green's Function matrix for a given nanotube device and a relaxation method to find the potential and statistical mechanical charge distributions in the system under an arbitrary external potential. We demonstrate the feasibility of this approach by computing the self-consistent potential and charge distributions for a nanotube in transistor and diode geometries under a variety of external potentials, incorporating materials properties including electrode work functions and metal-dielectric surface dipole layers.

Simulation of Non-Equilibrium States in Two Dimensions

William N. Ferm, University of Maine at Orono, Maine

Advisor: Professor Yong W. Kim

Department of Physics, Lehigh University

ABSTRACT

Little literature is available which discusses the physical properties of non-equilibrium systems due to their complex nature and lack of workable models. In this investigation we model the atoms of a dense fluid, which is close in number density to a disordered binary alloy of two different atoms. In order to model both the crystal and glassy regions in a disordered binary alloy, steel ball bearings at two different sizes are mixed in a 2-D cell, initially in a random close packed (RCP) state. RCP describes the state at which particles structure themselves if they were to be poured into a confinement area and allowed to reach a meta-stable state. In the realm of a dense fluid near an RCP state, there are altogether four available degrees of freedom for the atoms: vibrational and translational, each in two directions. Both types of motion are simulated by forcing the 2-D cell into vibration with the use of two stepper motors under computer control. In addition, to model the force of attraction between atoms in an alloy, the base plate of the cell is tilted by approximately one degree with respect to the horizontal plane. By tilting the base plate, this inter-atom interaction is incorporated into the experiment by substituting the particle-particle attraction with a component of the gravitational field tangential to the cell's base plate. A mixture of steel spheres in two sizes constitutes the dense fluid medium: 306 small spheres (radius = 2.488 mm, mass = 0.065 g) are mixed in with 297 large spheres (radius = 3.193 mm, mass = 0.141 g) within the 76.2 mm square area.

We simulate non-equilibrium states in the 2-D fluid by forcing the base plate of the cell in two mutually orthogonal directions as a function of time. Two stepper-motor-driven translation stages actuate the vibratory motions independently of each other. During the past ten weeks a preliminary analysis of these states has been undertaken, identifying several patterns of behavior relating to non-equilibrium states. The experiment setup consists of a digital camera fixed directly above the 2-D cell, which is illuminated from below by a diffuse light source consisting of a tungsten-halogen lamp, diffuser and a diffuse white reflector. A laptop computer directs two independent sets of machine-code instructions to the controllers that are interfaced to the stepper motors. Each sequence of the instructions is cyclic but chaotic and out of phase from each other to insure randomized and independent excitations. At the start of each measurement sequence the spheres in the cell are randomized in placement before the stepper motors are turned on. The camera takes a set of several 33-picture frame bursts at the rate of 14 fps at a time, and another set is taken after a period of time delay; the delay has been set at 2 min, 10 min or 30 min. Each picture frame is first pre-processed using ImageJ, image-processing software, to: crop the photograph; convert it into a b/w image; generate the outer edges of the spheres in it; and finally capture a one-pixel thick outer contour (0.00035") of each sphere. The image is then input into a program: i) to detect the center of each sphere by a Hough transform; and ii) to determine the displacement of each sphere in the x and y directions from two successive picture frames, thus the two Cartesian velocity components. Typically, histograms of x- and y-component velocities are constructed for both the large and small spheres from six such bursts of images. The histograms are best fitted with Gaussian curves to find the effective temperatures of the spheres in the dense fluid. By controlling the stepper rates, we change the 'effective temperatures' of the fluid medium.

By choosing the symmetry patterns of stepper drives, we have observed several classes of non-equilibrium states reproducibly. Non-equilibrium states vary both in terms of the measures, such as the average kinetic energy (or the 'effective temperatures') of large and small spheres, and the degree to which the histograms of x- and y-velocities deviate from the respective Gaussian forms. We have found that gravity plays a significant role in suppressing the width of the velocity distribution parallel to the direction of the gravity component. It appears possible, however, to counteract the suppressing effect of gravity by adjusting the intensity of the stepper motor drive in the direction of the gravity component. Significant temporal evolutions in the 'effective temperatures' and deviations of the velocity histograms from their respective Gaussian profiles have also been observed; the larger the asymmetry of the stepper drive intensities, the more intense are the fluctuations in the functional form of the velocity histograms.

This research was made possible through generous funding from the National Science Foundation's REU program.

Identification of Single Wall Carbon Nanotubes Using Advanced Microscopy Techniques: AFM, PLE, TIRFM

Thomas Flores

Advisor: Dr. Slava V. Rotkin

Lehigh University Department of Physics

Implementation of single wall carbon nanotubes (SWCNT) into nanostructures and devices would allow the scientific community to produce revolutionary electronics. Precise microscopy techniques must first be mastered in order to ensure their proper placement and function within these devices. Our group at Lehigh University has therefore set out to combine two forms of observation, atomic force microscopy (AFM) and total internal reflection microscopy (TIRFM), to observe these nanotubes with a new depth of clarity. In order to carry out this process, AFM, TIRFM, and photoluminescence excitation spectroscopy (PLE) must be mastered individually before simultaneous execution. Samples composed of surfactant wrapped SWCNT were observed in all three systems, with the most success stemming from laser ablation grown SWCNT suspended in 1% by weight sodium cholate and water solution, as well as DNA wrapped CoMoCAT grown tubes in a buffer solution provided by NIST. Our group has successfully imaged SWCNT in both electronic systems and dried solution with an NT-MDT NTEGRA AFM system using NSG-10/Pt tips in semicontact mode with a scanning speed of 0.75Hz. We have also observed tube photoluminescence, predominately from (6,4) and (6,5) tube variety, by use of an Ocean Optics spectrometer and 442nm laser. Observation of tubes using our IX71 TIRFM setup and 532nm laser is still a work in progress, however we have successfully observed polyurethane beads infused with rhodamine 6G. Combination of AFM and TIRFM methods will therefore be completed after adjustments to the Olympus IX71 optical path. Our group has successfully paved the road for future work using these two highly sophisticated forms of microscopy.

Daniel Fredeman

Advisor: Sabrina Jedlicka

Research Experience for Undergraduates Abstract

August 1, 2011

Spectroscopic, Thermal, and Mechanical Characterization

Of Bioactive Glass-Modified Poly(Glycerol Sebacate)

Bioactive glass-modified poly(glycerol sebacate) potentially provides an effective composite for the repair of bone tissue in the field of regenerative medicine. PGS is a biodegradable polymer that has exhibited mechanical properties similar to the extracellular matrix. In a recent study, Jaafar et. al. reported Young's moduli in the range of 0.07 – 2.3 MPa for cure temperatures between 120 and 165 °C. Bioactive glass, on the other hand, exhibits osteoinductive behavior. As a result, PGS and bioactive glass composites may provide the ideal scaffold for bone tissue engineering.

Over the course of the program, we aimed to complete a spectroscopic, thermal, and mechanical characterization of PGS/bioactive glass composites. Samples were prepared under twelve different conditions. Four bioactive glass compositions were used: 0, 5, 10, and 15% w/v. Three different cure temperatures were used: 120, 140, and 165 °C. Fourier-transform infrared spectroscopy identified the presence of ester cross-links as well as the formation of metallic carboxylates in the composite samples. Differential scanning calorimetry did not produce conclusive results. Thermal gravimetric analysis results displayed a decrease in onset and degradation temperatures as cure temperature and bioactive glass content increased. Compressive testing is ongoing but clear patterns are developing. In all tests, the degree of cross-linking, hydrogen bonding, formation of metallic carboxylates, and agglomeration of bioactive glass particles are believed to play a crucial role in the materials' properties.

To test the biocompatibility of the PGS/bioactive glass composites, we applied human mesenchymal stem cells (passage n = 9) to the samples. Subsequent staining and analysis showed a low cell count on our samples. To assist the HMSC's in adhering to our samples, we applied a collagen coating to a batch of samples prior to HMSC addition (passage n=12). This modification improved cell adhesion and produced a larger cell count; however, the behavior of the HMSC actin filaments is abnormal.

Acknowledgements: This work was supported by IMI-NFG at Lehigh University through the NSF (Grant DMR-0844014).

O-H Defect Structures in Oxides

Rachel Henderson, Slippery Rock University

Advisor: Professor Michael Stavola

Lehigh University REU Summer 2011

Abstract:

The introduction of hydrogen into metal oxides has been found to give n-type conductivity in several materials such as ZnO¹ and SnO₂.² Our research has been focused on the properties of H in TiO₂, a metal oxide with the rutile structure. A O-H vibrational line at 3276 cm⁻¹ was studied many years ago.³ Recent experiments performed by Herklotz et al. suggest that this IR line is due to a shallow donor in TiO₂ that exhibits two charge states and gives rise to free carriers.⁴

The focus of our research has been on how the new results of Herklotz et al. differ from older results in the literature from the 1970's. Our results show that subtle differences in how TiO₂ samples are prepared play an important role. If the samples are not quenched quickly, defect properties and spectra are changed. We found two different O-H centers with similar vibrational frequencies but otherwise different properties. One center does not give rise to free carriers or multiple charge states, similar to the results from the 1970's.³ The second center is due to a shallow donor and is only produced in samples that are quenched quickly following hydrogenation at elevated temperatures, similar to the results of Herklotz et al.⁴

Future studies will investigate TiO₂ samples grown by different methods to see what role unintentional defects might play. Our experimental results help to explain why researchers studying O-H centers in TiO₂ find inconsistent and puzzling results.

1. M. D. McCluskey and S. J. Jokela, J. Appl. Phys. **106** 071101 (2009).

2. F. Bekisli, M. Stavola, W. B. Fowler, L. Boatner, E. Spahr, and G. Lupke, Phys. Rev B., in press.

3. J. B. Bates and R. A. Perkins, Phys. Rev. B **16**, 3713 (1977).

4. F. Herklotz, E. V. Lavrov, and J. Weber, Phys. Rev. B **83**, 235202 (2011).

Effect of Light and Temperature on the Electrical Conductivity of As₂S₃ Thin Films

Mia Korngruen

Chalcogenide glasses are commonly studied for their photoactive properties. In the chalcogenide As₂S₃, electrical conductivity increases with light. In general, the electrical conductivity of As₂S₃ is known to increase with temperature; however, the effect of temperature on photoconduction has not been thoroughly investigated. The primary focus of this experiment was to develop an apparatus that allowed for observation of the effect of temperature and light on conductivity simultaneously. However, a secondary focus was to build a low-cost apparatus from readily available supplies. Our apparatus was based on a student-built electrometer which successfully measured conductance on the order of 10⁻¹² Siemens, and a heated sample cell chamber which enabled us to determine the effect of temperature on photoconductivity between 22°C to 180°C. The ratio of photoconductivity to dark conductivity measured with this apparatus demonstrated a maximum between 90°C and 100°C. In addition, this maximum was observed to occur at 50°C in samples that had not previously been heated and these previously unheated samples exhibited higher conductivities than the conductivities observed during subsequent trials. This difference in behavior was attributed to the removal of structural defects through heating, similar to an annealing process. Therefore, electrical conductivity measurements were found to be able to track changes in the thin film samples that occur due to annealing. The student built apparatus was found to be experimentally feasible and useful as a probe for future studies.

Li-OH Defect in MgO: A Vibrating, Spinning Top System

By: Kaitlyn Kreutzer

Advisors: Dr. Kevin Martin, Dr. Beall Fowler
Physics Department, Lehigh University

*Supported by the National Science Foundation,
Research Experience for Undergraduates Program*

While the Li-OH and Li-OD defect in the ionic crystal MgO has been studied previously, a new approach is taken to confirm previous theories and provide a deeper understanding of the system. The theoretical model utilizes a Hamiltonian where the potential of the system was expressed specifically to be $V_o(1-\cos4\Phi)$. This potential is assigned using symmetry arguments. MATLAB programs then calculate the energy levels and wave functions at different potential depths. The theoretical model produces a full spectrum that can be compared to experimental data provided by Dr. Stavola and his graduate students. From this comparison, a transition that had not been predicted by the earlier theory is matched to a transition that had been present in the Li-OD experimental data at approximately 2627 cm^{-1} . This transition is determined to be from the ground vibrational, first excited rotational state to the first excited vibrational, fourth excited rotational state.

Also, the moment of inertia of the OH system is compared to the moment of inertia predicted by theory. The larger theoretical moment of inertia suggests that something else is contributing to the motion of the defect for our model. We provide strong evidence that this motion belongs to the lithium, and calculate its radius of rotation to be approximately 0.27 Angstroms.

Transfer of Orientation and Alignment in NaK-He Scattering

Alexander Kuczala

August 5, 2011

Abstract

We implement a quantum mechanical coupled-channel program to calculate numerically rotationally inelastic transitions in NaK for collisions with helium. Computed transition probabilities are used to calculate the transfer of population, orientation, and alignment. Calculations confirm the expectation that collisions diminish the orientation and alignment of the NaK. Recent experimental techniques utilizing fluorescence and polarization spectroscopy can accurately probe these quantities. It is hoped that future spectroscopic experiments at Lehigh University will verify the properties of studied NaK-He collisions. While large computation times constrain the size of calculations, we find that a suitable approximation may reduce computation cost, yielding orientation and alignment with errors under 10 percent.

Mapping optical trapping energy of nanoparticles via confocal microscopy

Min Yao Lim, Carleton College

Lehigh University REU 2011

Advisor: Dr. H. Daniel Ou-Yang

Abstract

Optical traps are highly focused laser beams that can hold and manipulate objects of microscopic scale. They are used to study the motion and energy of particles such as colloids or DNA molecules. In order to achieve this purpose we first propose to determine the energy of optical traps. Junio et al. introduced a fluorescent nanoparticle ensemble within the optical trapping volume to determine the depth of the potential well of the trap¹. We extend this notion of an ensemble of particles within the trap and use confocal microscopy to map the fluorescence intensity distribution of nanoparticles. This mapping allows us to calculate the trapping energy profile in three dimensions. We repeat this process with different trapping powers to find the depth of the trapping potential well as a function of trapping power. Trapping energy per trapping power thus measured is consistent with results obtained through previous methods such as fluorescence correlation spectroscopy conducted by our research group. With this technique of mapping trapping energy we can further study particle-particle interactions.

This research was funded by the National Science Foundation (NSF) Research Experience for Undergraduates (REU) grant PHY-0849416, NSF grant DMR-0923299 and the Karas Undergraduate Research Internship.

Polarization Dependent Measurements of Eu-doped GaN

Zuri McClelland¹, Jonathan Poplawsky², Volkmar Dierolf²

August 3, 2011

¹University of California at Berkeley, Berkeley, CA

²Lehigh University, Bethlehem, PA

Abstract

Several light emitting centers have been identified for Eu:GaN. We have investigated the results of the polarization of the excitation and emission of the Eu ions for these centers in situ doped in GaN. We have done this under resonant excitation from the 7F_0 to 5D_0 states. We oriented the GaN such that the laser traveled perpendicular to the c-axis in order to investigate the intensities of the sigma and pi polarized excitation for characteristics of C_{3v} symmetry. Light waves that are parallel to the c-axis have pi polarization and waves perpendicular to the c-axis have sigma polarization. We studied the ratio of pi versus sigma polarized excitation because the larger the ratio the less perturbed the site. We found that one center, Eu1, had the largest ratio of all the sites studied. We also compared the pi and sigma polarized emission peaks of Eu^{3+} . This presented a new problem; the number of emission peaks between pi, sigma and magnetic measurements was more than the allowed number of energy states for Eu1. To further investigate this problem further research must be done on polarized magnetic measurements.

***In Situ* Optical Spectroscopic Study of Annealing in Tin-doped Ruby-Gold Glass**

Clare McDonough, University of Dallas

Advisor: Dr. Himanshu Jain, Dept. of Materials Science, Lehigh University

Chatree Saiyasombat, Dept. of Materials Science, Lehigh University

August 6, 2011

Abstract

The famous ruby color of ruby-gold glass is due to a colloidal dispersion of metallic gold nanoparticles in glass brought about by reheating a quenched gold-doped glass above the glass transition temperature (annealing). In our particular research, the effects of tin on the formation of gold nanoparticles in sodium trisilicate glass during the glass annealing process were studied. Samples of sodium trisilicate ($\text{NaO} \cdot 3\text{SiO}_2$) glass were doped with a constant concentration of gold (0.1 mole% Au) and variant concentrations of tin (0 to 0.1 mole% Sn^{4+}). The quenched-glass samples were mounted on a heating platform so that optical spectroscopic measurements could be collected during the annealing process. It was found that the addition of tin to ruby-gold glass significantly reduced the required amount of time at the glass transition temperature for the formation of gold nanoparticles in sodium trisilicate glass. The presence of tin also significantly increased the rate of formation of gold nanoparticles. A blue shift in absorption was observed for tin-doped gold-ruby glass which indicated smaller gold nanoparticle size than in an undoped system. Further research is required to determine by what mechanism tin interacts with gold nanoparticles in a sodium trisilicate glass.

This research was made possible with support from the International Materials Institute for New Functionality in Glass (IMI-NFG) at Lehigh University and the National Science Foundation (NSF) Grant DMR-0844014.

MEASURING GLASS FIBER-EPOXY ADHESION

Nerrissa Mitchell¹ and Raymond A. Pearson²

¹Xavier University of Louisiana, New Orleans, LA 70125

^{1,2}Center for Polymer Science and Engineering, Lehigh University, Bethlehem, PA 18015

nmitche1@xula.edu and rp02@lehigh.edu

A single-fiber pullout test set-up was developed to measure the interfacial bond strength between a glass fiber and an epoxy matrix. Experimentation focused heavily on the design and fabrication of the test specimens. The test specimens consisted of E-glass fibers embedded in an epoxy matrix, which was composed of a standard, pure bisphenol A liquid epoxy resin (DER 331) and a polyether triamine amine curing agent (JEFFAMINE T-403). Prior to conducting the pull-out test, glass fiber tensile tests were made in order to determine the maximum load the glass fibers could withstand. Also, this maximum load was used to predict the maximum embedded length that could be tolerated without breaking the glass fiber. Unfortunately, the inability to control the embedded length resulted in almost all of the specimens failing by fiber breakage and not fiber pullout. It is recommended to add a microscope to the current set-up for improved control of the embedded length.

The Distance to the γ -ray Binary 1FGL J1018.6-5856

Vanessa J. Napoli

Advisor: M. Virginia McSwain

Funding from the National Science Foundation

Lehigh University Department of Physics

ABSTRACT

1FGL 1018.6-5856 is in the rare class of 6 high mass X-ray binaries that also emit radiation in the γ -ray range. We observed the proposed optical counterpart to this source, 2MASS 10185560-5856459, with the Strömngren *by* filters at the Cerro Tololo Inter-American Observatory (CTIO) 0.9m telescope in 2011 May and 2011 June. By performing photometry in the optical range we were able to provide a better understanding of the photometric variability of the proposed optical counterpart, the reddening, $E(B-V)$, and the distance, d , to the system. We determined that this γ -ray binary has $E(B-V) = 1.34 (+0.05, -0.08)$ and $d = 5.4 (+1.3, -0.5)$ kpc. $E(B-V)$ is in agreement with previous X-ray observations of the neutral hydrogen column density but the distance is closer than other authors have indicated.

Analysis of Polarized Cell Growth and Scar Distribution

Thienbao Nguyen, University of Denver
Dr. Dimitrios Vavylonis, Advisor

Summer 2011

Scarring of yeast cells during the process of division is crucial to understanding their growth as well as cell ageing. Fission yeast cells have a tube-like shape and grow from their two tips. Using images of several strains of fission yeast provided by collaborators at the University of Miami, we measured the distance of the birth scar to the new end (the end formed after cell division) as a function of total cell length, following an earlier analysis [Mitchison and Nurse, *Journal of Science*, **75**: 357-373, 1985]. We found that, similarly to this earlier report, our measurements were piecewise linear around the point of "new end take off" (NETO), but with a smaller change in slope. We also developed a model of scar inheritance, which we implemented by computer simulation. The model included cell growth and division and produced a Poisson-like distribution of scar occurrence in individual cells. The resulting distribution was not very sensitive on the presence of NETO. Our results suggest a random distribution of scars among cells. Comparing this data to real data from wild type and mutant fission yeast show that some strains may also display this randomness whereas for other strains, mothers tend to distribute scars evenly amongst daughters.

Analog Design of Comparators and Operational Amplifiers using State of the Art CMOS Modeling

Jordan Thimot, Thomas Charisoulis, Dr. Miltiadis Hatalis

Operational amplifiers are an essential circuit component in any analog design that is implemented in modern electronics. One focus of this research was to design an operational amplifier that is capable of performing with certain ideal properties that were necessary for functioning under given specifications. The amplifier created was then tested using a variety of CMOS transistor models to see the effects on the specifications of the op-amps due to transistor models used. In all, a total of six transistor models were simulated using Cadence 16.3 and the specifications of the designed op-amp using the six models were compared. All models were obtained from ON Semiconductor. One model, which was used as the control model, was designed when ON Semiconductor was known as AMIS, and was fabricated using 1.5 μm length technology. The other five models were newer models consisting of C5, a 0.6 μm length technology. The five 0.6 μm models were separate variations of the same model with the different models representing the five most likely device corner models if actually fabricated. The five corner models were slow-fast, fast-slow, slow-slow, fast-fast, and typical-typical. These variations represent the likely inequalities in oxide thicknesses that would exist on a single wafer during fabrication that would lead to faster, slower, or typical programming speeds and properties. For the AMIS model, the transistor properties were: length 2.5 μm , width 6 μm , output impedance 275 k Ω , 3dB frequency of 14.5 kHz and a maximum gain of 64 dB. For the C5 models, the typical transistor had properties of: length 0.7 μm , width 2 μm , output impedance 373 k Ω , 3 dB frequency of 11.1 kHz and a maximum gain of 67.5 dB. The other four models had the same length, width, and similar output impedances and 3dB points to the typical-typical model. The maximum gain ranged from 66.7 dB for the fast-fast to 68.5 for the fast-slow model. These results indicate that all five of the new C5 models had similar enough properties to the AMIS control model to be implemented for the specifications required for the operational amplifier. The C5 models were also successful in that their fabrication size would be only approximately 75.6 μm^2 compared to the AMIS model's required size of 810 μm^2 . This indicates that not only will the C5 models be successful in replacing the control in implementation, but will also be more efficient in the amount of wafer space that will be required during fabrication.

Determination of the Third-Order Hyperpolarizability and Two-Photon Absorption Coefficient of Organic Molecule FT102

Colleen Treacy

Advisor: Dr. Ivan Biaggio

Lehigh University Department of Physics 2011

The Nonlinear Optics Group at Lehigh University is investigating the structures of small organic molecules to determine which will have the best properties for nonlinear optical applications. In this work, I performed two separate measurements that give access to the third-order susceptibilities. They are degenerate four-wave mixing and nonlinear transmittivity measurement. Due to time restraints, only one molecule from a batch synthesized by Dr. Francesca Tancini at ETH Zurich has been studied. It comes from the code name FT102, with the chemical formula $C_{17}H_{16}N_4$. It has been found to have a third-order hyperpolarizability on the same order of magnitude as other well-studied nonlinear molecules. Conversely, the transmission measurement has not conclusively shown whether the two-photon coefficient is comparable to these other molecules. More research will have to be done to complete the characterization of the family of molecules to which the investigated FT102 belongs.

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Electrical Conductivity of Gold- and Tin- doped Sodium Trisilicate Glass

Patrick Wanninkhof¹, Chatree Sayamsobat², Himanshu Jain²

¹ Department of Material Science and Engineering, University of Florida, 32611

² Department of Material Science and Engineering, Lehigh University, PA 18015

Abstract

The addition of tin induces a deeper red color in gold ruby glass. To explore an electrical effect of the addition of tin, sodium trisilicate was doped with 0.1 mol% gold and variant amounts of tin ($0.005 \leq 0.1$ mol%) and electrical conductivity was determined. AC conductivity was measured as a function of frequency and temperature in order to ascertain the Arrhenius behavior. Separately adding 0.1 mol% gold and 0.1 mol% tin increased the electrical conductivity compared to pure sodium trisilicate by 1.9 and 2.6 times, respectively. Combining the dopants resulted in an increase in conductivity compared to pure sodium trisilicate, varying from 4.1 times for 0.02 mol% tin-0.1 mol% gold to 2.1 times for 0.1 mol% tin-0.1 mol%. No trend was observed in the glass's activation energy when the amount of tin was varied with the gold held constant. Future research will focus on the effect of the annealing process on conductivity and the location of the dopants in the glass structure.

This work was supported by International Materials Institute for the New Functionality of Glass at Lehigh University through the NSF (Grant DMR-0844014).

A Low Cost Apparatus For Measuring the Low Conductivities Of Glass

Abstract

A theme of our research group is to develop low cost, hands on, experiments in glass science suitable for the undergraduate laboratory. The focus of my project was to develop a low cost apparatus for measuring conductivity in a glass and determine the glass transition (T_g) with repeatability. During the previous REU (2010), we developed a simple electrometer circuit capable of measuring conductivity in the pico Siemens range, and a simple parallel-plate style conductivity probe for immersion in test tube containing the molten glass sample. An oil bath was used to heat the test-tube, sample and probe. In our current experiment we have replaced the immersion style conductivity probe with an internally heated conductivity cell and added AC noise filtering to the amplifier. The cell consisted of an aluminum block with imbedded heaters for heating, as well as an Aluminum heat sink embedded in an ice bath for cooling. The improved conductivity cell allows for convenient change of sample, greatly facilitating replicate testing. Our test glass sample was a sugar glass, prepared from a mixture corn syrup, sucrose and water. The sugar glass was placed in between two electrodes in our conductivity cell in the molten state followed by subsequent cooling and reheating as we measured the conductivity. The conductivity vs. temperature data shows a clear signature to the glass transition, T_g around 30° . This T_g also corresponded with the glass transition we observed in our DSC measurements. In early runs we also observed an abrupt conductivity increased at low temperatures. Thinking that this might be from condensation we solved this problem by pumping dry nitrogen into our conductivity cell and with this further improvement the increase at low temperature was eliminated. In the future we plan to use a include a temperature controller to keep our heating and cooling rate constant and a thermal electric cooler to achieve lower.

A Novel Design for Micro-particle Entrapment by Negative Dielectrophoresis

Sam York¹, Yi Hu², and H. Daniel Ou-Yang²

¹Department of Physics, Bowdoin College, Brunswick, ME 04011, USA

²Department of Physics, Lehigh University, Bethlehem, PA 18015, USA

Abstract

Dielectrophoresis (DEP) is a well-known method for the separation and controlled movement of particles, however it is not typically utilized as a tool for the enhancement of particle solution concentrations. This study aimed to develop a new electrode design that could create significant enhancements in the concentration of solutions of micro and submicron sized particles. The electrode design was intended to be effective in high salt concentration solvents. Advanced computer modeling was employed to develop an electrode that would trap dielectric particles in negative DEP. The efficacy of the design was observed using red fluorescence Polystyrene (PS) particles and confocal microscopy. Particle concentration enhancements were analyzed using image analysis software. The concentration of 1 micron PS particles in D.I. H₂O was enhanced to a factor of 7.8 during negative DEP. The concentrations of solutions of 1 micron PS particles in 1 mM and 2.5 mM KCl were enhanced by a factor of 9.8 and 3.1, respectively. The effectiveness of the proposed negative Dielectrophoresis particle trapping electrode design proved to be influenced by the conductivity of the surrounding solvent medium.

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Polymerization Kinetics of Actin Filaments

Jialei Zhu, Colgate University
Dr. Dimitrios Vavylonis, Advisor

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Abstract

The polymerization of actin monomers into filaments underlies many fundamental biophysical processes such as cell motility and cell division. Actin filament polymerization occurs by addition of actin monomers from a bulk solution to the barbed and pointed ends of actin filaments. In the presence of ATP, actin monomers in the bulk bind ATP (ATP-actin). The ATP bound to actin is hydrolyzed after polymerization, leading to ADP-Pi-actin. The release of phosphate from the actin subunits occurs as a second step, leading to ADP-actin. The polymerization and depolymerization rate constants of ATP-actin, ADP-Pi-actin and ADP-actin are essential to a complete knowledge of the actin polymerization process. The rate constants of actin depolymerization can be measured in experiments in which actin is polymerized in an ATP buffer, followed by wash out of the actin monomers in solution. We modeled the depolymerization kinetics in such buffer-wash-out experiments and their dependence on the rate constants of actin depolymerization. ATP subunits undergo fast hydrolysis, so that the presence of ATP actin at the terminal subunit is negligible soon after the start of depolymerization. Under this assumption, actin could exist in either the ADP-Pi or ADP form. The initial stage of depolymerization can be considered as a coexisting stage of both ADP-Pi and ADP subunits, while the end stage of depolymerization is due to pure ADP subunits. This model made possible the determination of the phosphate release rate at the terminal subunit. This rate was enhanced compared to the rate of phosphate release in the interior subunits. The results from our analysis agree with results recently reported by other groups and the measured data from experiments conducted by collaborators at NIH.