Summer 2005 Abstracts of REU Final Reports

Department of Physics & Astronomy
The University of Toledo
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Meredith Rogers, "*Chemical Analysis of CO-rich Diffuse Interstellar Clouds*," (S. Federman)

Contrary to popular belief, space is not a cold, dark vacuum devoid of matter. There are regions that have a higher density that are referred to as diffuse molecular clouds. Unlike dense clouds, which look black and empty because the dust and gas absorbs or scatters the light of background stars and those forming inside, diffuse clouds are invisible, betrayed only by the reddening of stars whose light passes through them. These clouds are being studied because they maintain a rich chemistry within them which allows the formulation of evolutionary models of interstellar space. This will provide answers as to how galaxies form and if the appearance of galaxies changes with respect to stellar birth and death. The goal of this project was to focus on extracting the density of these clouds from a chemical analysis of CH and CN observations. This work can be linked with the work of others in the research group to determine the relationship between density and amount of CO present.

Atomic/Molecular/Optical Physics

Miguel Cervoni, "*Beam Transport in the UT-P/NIELS Accelerator*," (T. Kvale)

The UT-P/NIELS accelerator is a positive/negative ion energy loss spectrometer. Recently the research conducted with it has dealt with the excitation of helium by proton impact where the resulting positive ions are diverted to an energy analyzer. To attain accurate results, high beam intensities are needed to resolve the different excitation states at certain energies. The problem is that the majority of the beam is dispersed and lost before the target cell but energy loss afterwards was negligible meaning that the problem was in the acceleration portion. This research project dealt with modeling the acceleration portion in two sections. The first section modeled the ion source and einzel lens, while the second section modeled the injector and accelerator column. The einzel model showed that the beam behaved normally and this was later confirmed by experimental data. The accelerator column model showed that the beam did disperse before the target cell. The electrical configuration of the accelerator was altered by adding a resistor at the beginning of the column which helped improve the beam transport percentage at the target cell. The potential on the center element of the injector was also related to beam dispersion. The model found that the center element should be at the same potential as the other elements. Experimentally this could not be verified due to a possible wiring problem in the deflection plates which could have caused experimental error.

Andrew J. Larkoski, *Numerical implementation of Einstein-Brillouin-Keller quantization for arbitrary potentials*, (D. Ellis)

The Einstein-Brillouin-Keller (EBK) quantization equation can be used in lieu of the Schrödinger equation to determine quantized energy levels of a bound system in an arbitrary potential. For all but the simplest potentials, an analytic solution does not exist, thus numerical methods must be used to approximate the equation. The diatomic molecule system is given as an example of the numerical application of the EBK equation. From the energy eigenvalue solutions to the EBK equation which are determined by the Newton-Raphson method, a multitude of aspects of the system can be systematically analyzed such as the effect of the angular momentum of the system on the effective potential, or the classical orbits and the possibility for closed orbits. While the treatment is nearly purely classical, the Wentzel-Kramers-Brillouin (WKB) approximation of the wave function can also be readily derived for any state of the system.

Stephanie Torok, "*Experimentally Analyzing the Branching Fractions and Life Times of PII using the THIA*," (L. Curtis)

This purpose of this experiment was to determine the accuracy and reliability of theoretical and semiempirical estimates of branching fractions in singly ionized phosphorus, P II. We specifically studied the transitions between the levels $3s^2 3p4s\ {}^3P^o_J$ levels and the ground configuration $3s^2 3p^2$. Lifetimes were measured for *J*=0 and *J*=2 and branching fractions were measured for J=*1* and *J*=2. The results were compared with MCHF calculations of Tayal, Hibbert, and Fischer and semiempirical estimates of Curtis. The results have applications both in the interpretation of astrophysical data and in providing intensity calibration standards in the ultraviolet spectral region.

Condensed Matter Physics

DeMarco Camper, "*Low Temperature Routes to Negative Thermal Expansion Materials in the ZrW_2O_8 Family*," (C. Lind/A. Lukaszew)

Thermal Expansion is the process that always occurs when materials are heated. This concept is based on the coefficient α, which is defined as the change of length per unit length of material for a one degree centigrade change in temperature. Negative thermal expansion (NTE) occurs in materials that shrink upon heating. Zirconium Tungstate (ZrW_2O_8) is a known NTE material that exhibits NTE behavior in its cubic form. As NTE materials have the potential to be used in controlled thermal expansion composites, small particles are desirable. My research investigates low temperature routes for ZrW_2O_8 that allow us to control particle morphology. Powder X-ray Diffraction and Scanning Electron Microscopy are used for characterization.

Sheriff Ceesay, "*Other Trace Elements During CdS/CdTe Deposition*," (A. Compaan)

In the development of thin film relative to solar technology, Spectrography becomes very important in determining efficiency of solar cells. One way Spectrography can be used is for elemental identification. Since Spectrography allows us to use light given off by different elements at different wavelengths of light to identify an element. In thin film application in relation to solar technology, Spectrography can be used during a process called deposition. Deposition applies to the use of sputtering an elemental target, CdTe for example. During this process a thin layer of the element from the target is place on to a surface of glass/substrate. However another event occurs during deposition, light is given off during the process of sputtering caused by ionization of gasses during deposition. All this occurs inside of a sealed vacuum environment called a Sputter Deposition Chamber. To obtain our data for Spectroscopic analysis, we ensure that we can acquire light from the sputter chamber. Most likely the sputter chamber has a glass window allowing easy viewing of the process of sputtering. While deposition occurs, light emitted from the Sputter Chamber is used for spectroscopic analysis. With Spectrography we can find elements that are present within the thin film solar cell. To ensure the elements that we find are indeed what they are, we use a common reference NIST (National Institute of Standard and Technology). We used NIST in finding the type of elements present within layers of thin film solar cells. Spectrography gives an insight of how efficiency is affected within a solar cell, by telling us what contaminants exist within it.

Zachary Ferraro, "*Nano-Magnet Growth in Thin Films*," (A. Lukaszew)

In this project we wished to create nano sized magnets in a thin film. There are several ways to create such magnets, growing thin films of ferromagnetic metals, laser etching them, or creating masks to evaporate the metals through. All these techniques limit the amount you can restrict the dimensions of the magnets. To get nano-magnets which were truly small in each dimension, we had to take a different approach than what is traditionally taken when creating nano-magnets. Our choice was to use ion implantation, traditionally avoided because of lack of any accuracy in creating any structure. But our goal was not to make regular structures, just small ones, so ion implantation was a reasonable choice. We wanted to do this because interesting effects occur when you reduce the dimensions of a magnet. This is evident when the thickness is reduced, but the reduction of the other two dimensions is relatively unexplored.

Patrick Hunley, "*Sputter Deposition of Fe_2O_3/In Films for Photoelectrochemical Hydrogen Production*," (W. Ingler/X. Deng)

Indium-doped Fe2O3 films were created by RF magnetron sputter deposition at temperatures ranging from 150ºC to 250ºC with a deposition rate of 100 watts for Fe2O3 and deposition rates ranging from 5-20 watts for Indium in both an Argon atmosphere and an Argon/Oxygen atmosphere. The effects of the Indium doping on Iron Oxide's conductibility, band gap, stability, and photoactivity in a 5.9M KOH solution were examined for possible future use in a-Si triple-junction solar cells.

Jacob Warner, "*Ab Initio Calculations for Properties of MAX Phases Ti2GaN, V2GaN, and Cr2GaN*," (S. Khare)

Using ab initio calculations we have computed the lattice constants, bulk moduli, and local and total density of states of the MAX phases, Ti_2GaN, V_2GaN, and Cr_2GaN in the hexagonal $P6_3/mmc$ space group. The results for lattice constants are in reasonable agreement with experiments. The bulk moduli are predicted to be 158, 170, and 180 GPa respectively. The electronic density of states shows that all three materials are conducting and that the Cr_2GaN compound is the most conducting.

Randolph White, II, "*Electron Tunneling through a Metal Semiconductor Junction*," (V. Karpov)

Quantum tunneling is the physical phenomenon that allows particles to pass through seemingly impenetrable barriers. The overall purpose of my project was to in some small way contribute to the further understanding of quantum tunneling. More specifically my assignment was to emulate the statistical output (current readings) of lab research that showed signs of electron tunneling through a barrier created within a metal semiconductor. I ultimately accomplished this with a computer program written in the C++ programming language. The final program consists of two particles moving randomly within a barrier of controlled size. The location of each particle is simultaneously recorded 50 times, almost like a snapshot of the particles' movement within the barrier. At each new set of locations the program determines the best possible path an electron would take in order to pass from one side of the barrier to the other via quantum tunneling. This output is then turned into graphical data which can be compared to the original lab statistics for similarity.

Optical Physics

Kevin Wells, "*Optical Analysis of Thin Films for Photovoltaics Technology: Spectroscopic Ellipsometry of Multi-Layer Transparent Conducting Oxide Films*," (R. Collins)

Spectroscopic ellipsometry (SE) is extremely useful in photovoltaics research for determining the optical properties of solar cells from the polarization state change that occurs when polarized light is reflected at an oblique angle from the surface. Tec-15 glass is a commercially produced glass that is coated with transparent conducting oxide layers and is used as a substrate in the production of solar cells. Using various techniques, we have developed a model for the dielectric functions of the layers on Tec-15 glass that leads to an improvement in the quality of the fit to SE data over that provided by previous models. This improvement came primarily from substituting Tauc-Lorentz oscillators for Lorentz oscillators in the previous models. Further analysis found that this model can be further improved in the future through the use of transmittance measurements in addition to the SE measurements.

Plasma Physics

Christopher Muscatello, "*Calculation of UV Production Efficiencies in the Glow Discharge Cathode Fall of Ne/Xe Mixtures*," (A. Shvydky/C. Theodosiou)

A one-dimensional Monte-Carlo / Particle-in-cell kinetic code was used to simulate a self-sustaining glow discharge between two electrodes. The code provided calculation of the electric potential, electric field, charged-particle densities, and distribution among particles of power dissipation along the length of the discharge. The distribution of power dissipation among electrons and ions in the cathode fall region was studied for nine different Ne/Xe mixtures at varying applied voltages. From this, UV production efficiencies were calculated for each unique Ne/Xe-mixture-and-applied-voltage combination.