Rice University/University of Houston

Research in Quantum Theory

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In our research our goal was to understand the principles supporting quantum mechanics. By attending lectures, research meetings and even a business presentation, we were able to begin understanding theory as well as practical applications. As the program progressed, we furthered our knowledge of what quantum mechanics is and of advanced mathematical methods. In the end, the applications of theoretical properties and physical applications can span from economics to the oil industry.

Applications of MATLAB in Imaging Physics

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The purpose of this research was to identify the applications of MATLAB within imaging physics. The aspects explored included the mathematics and projections of multiple medical imaging technologies, which produced the identification of the many benefits that MATLAB may bring to the field—including image measurement and evaluation. MATLAB has the ability to aid both medical and physics communities through its user-friendly data analysis and visualization capabilities.

YBCO Superconductivity

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The purpose of our research was to narrow the known field in which superconducting compositions of $YBa_2Cu_3O_7$-σ; and its impurity Y_2BaCuO_5-σ; can be found by experimentally making different compositions and determining the characteristics of each. We started by making biphasic $Y_4Ba_5Cu_7$, whose superconducting phase would yield a 3:1 Y123/Y211 mixture, and $Y4Ba_{11}Cu_{17}$, whose superconducting phase would yield a 3:1 Y123/$BaCuO_2$ mixture, then heated the two mixtures at different temperatures. We then studied their compositions on a scanning electron microscope and an x-ray diffractometer. The results for the $Y_4Ba_5Cu_7$, when plotted on a ternary phase diagram, showed characteristics of being both copper deficient and high in yttrium content while the $Y_4Ba_{11}Cu_{17}$ trended towards a higher $BaCuO_2$ content and lower yttrium. Our results trended mostly with previous findings of the superconducting field of Y123 and its pinning center of Y211. Further research in chemical composition and crystallography of YBCO would determine the ideal chemical composition (including the experimentally determined oxygen content) that is necessary in producing a perfect perovskite crystal structure, thereby creating a perfect superconductor.

Determination of Silver Sputtering Yield by Argon Cluster Ion Beam at Normal Incidence

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The purpose of our research is to determine the silver sputtering yield by argon cluster ion beam. We irradiated the silver thin film by argon cluster ion beam with different doses and obtained Rutherford backscattering spectrum (RBS) with high-energy accelerator. We then used a simulation program, "SIMNRA," to compare the experimental data with the simulated spectrum obtained by SIMNRA to determine the thickness variation with respect to irradiation dose. Then the sputtering yield of silver is determined by simple calculation, which is 98 atoms/cluster according to us. We also used the atomic force microscope (AFM) to obtain the surface topography of the samples and learned the sputtering mechanics. Further research can use this same method to find the sputtering yield of many different materials.

QuarkNet Summer Research Fellowship at University of Houston

A. Mo
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T. Brown (Clear Creek High School)

Alex Mo participated in the six-week QuarkNet Summer Fellowship and was mentored by Professor Gunaratne. The purpose of our research was to formulate a predictive method by which certain nodes of an interconnected, complex system could be manipulated so as to affect other nodes into expressing desired levels. We constructed a surrogate network composed of a circuit of transistors and resistors, which would express non-linear voltages at different nodes much like the expression levels of genes in a gene network, which was the eventual network that the method could hopefully be applied to. We first recorded the various wild-type voltages of each node with a total voltage drive through the whole circuit of 10 volts. We then proceeded to force certain “master” nodes, or nodes that greatly affected the entire system, to possess certain voltages, thereby altering the affected “slave” nodes. From the recorded data, we plotted how each node’s voltage changed as the two master nodes were adjusted, creating a non-linear three-dimensional surface. We then took three points from which to construct a plane: the wild type, one master node brought to 0 volts, and the other master node. This plane mimics a realistic situation of limited data, and was analyzed to see how accurate it was compared to the actual surface. An accurate enough plane would then be utilized to estimate how the master nodes should be manipulated to bring an erroneous voltage back to actual. The final experiment to analyze the efficacy of this method has yet to be conducted. Further research can apply this idea to a large variety of networks, ranging from the original intent of mutated gene networks all the way to ecosystems or even gravitational systems.

Molecular Beam Epitaxy and Solar Photovoltaics

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In 1961, Shockley and Queisser theoretically calculated the efficiency limit of a 1.1 eV single p-n junction solar cell, concluding the limit to be approximately 33%. Many improvements have been made since 1961, pushing the laboratory solar cell efficiency to 25% present day. At the Center for Advanced Materials (CAM), I explored the process of producing an efficient solar cell and new techniques employed to surpass the theoretical limit. At the CAM, solar cell production begins by growing pure gallium arsenide (GaAs) samples on a substrate by using molecular beam epitaxy under high vacuum, typically 10^{-9} to 10-^{12} torr. Solid gallium and arsenide are heated using a cracker into molecular beams, and impinge on the heated substrate surface, depositing epitaxially. Afterwards, the sample is n-type or p-type doped with phosphorous and boron, respectively. Paired together, a p-n junction creates an electric field that generates a current as the solar cell absorbs light. The sample is then fitted with electrical contacts via photolithography, the main research of my stay. After degreasing, the sample is spin-coated with negative photo resist and placed under UV exposure with desired mask, allowing only specific areas of the wafer to be deposited with the contact material. In our case, gold was to be evaporated using molybdenum boats under high-vacuum bell jar. During this time, we experimented on depositing more gold inexpensively using electroplating using Au^{3+} solution. Electroplating was successful after observation by the scanning electron microscope, but produced varied results such as mushroom-shaped gold contacts or uneven plating of gold. Finally, further photolithography using positive photoresist to selectively etch the GaAs into uniform geometrical shapes, followed by adding anti-reflective back contact and window layer coating, will complete the solar cell. Selective etching of GaAs to form shapes (mainly pyramids) and anti-reflective back contact serve to trap as much light as possible to maximize light absorbed. As almost 30% of sunlight is reflected upon initial contact, the window layer anti-reflective coating allows for full absorption. In the University of Houston, major improvements have been made to surpass the Shockley and Queisser limit, mainly in the form of multijunction, or multiple p-n junction solar cells and using more than one type of semiconductor. As each semiconductor has a certain band-gap, and correspondingly different levels of energy absorbed, different semiconductors of varying band-gap can maximize the amount of energy absorbed. The University of Houston has reached efficiency levels of up to 40%.