

Welcome to CNF & The 2006 NNIN REU Convocation

NNIN

Nanoscale Science,
Engineering & Technology



**August 9-12, 2006
Cornell University**

2006 NNIN REU Convocation Welcome

Completing a comprehensive experimental research task in 10 weeks can be a very formative experience. NNIN attempts to do this with the strong collaborations and challenging tasks brought together. The presentations you are about to hear demonstrate that enthusiastic participating students coupled to sustained support from staff, faculty, and graduate students leads to significant accomplishments.

The students participating in this effort have just started on the path of technical education and many are getting their first exposure to advanced hands-on research as part of our REU program. The focus on advanced research and knowledge, the strong mentoring and support, the strong contact with a professional research environment, the strong expectations built into the research and presentations, the exposure to a wider variety of research conducted by peers and other users in diverse disciplines of science and engineering within the unifying facilities, and the strong scientific and social interactions across the network, have been critical to the program's success. Equally critical is the continuing dedication and effort from our staff, faculty, and graduate students.

I wish the participants the best wishes for future technical careers; NNIN hopes to see them build on this summer's experience, and my thanks to the staff, the graduate student mentors, and the faculty for their participation and involvement. Particular thanks are due to Melanie-Claire Mallison and Lynn Rathbun at Cornell, Michael Deal at Stanford, and Nancy Healy at Georgia Institute of Technology for making their contributions in organizing the logistics of the program and the convocation.

Sandip Tiwari
Director, NNIN



WEDNESDAY, AUGUST 9TH

7:00-9:00 Casual Welcome Dinner - Pizza Party

Robert Purcell Multipurpose Room

*Cover Photographs: Taughannock Falls by Michael Breed, Chenango Valley High School.
CNF REU in the CNF Clean Room and Duffield Hall above by Charles Harrington Photography. All other photographers unknown.*

THURSDAY, AUGUST IOTH

8:00-8:30 Registration and Continental Breakfast

Baum Atrium, Duffield Hall, for all breakfasts

8:30-8:40 Welcome & Announcements

101 Phillips Hall for all presentations

Morning Session Moderator: Sandip Tiwari

- 8:40-8:52 **Mr. Michael Adams** page 9
Research and Development of Electron-Beam Lithography Using a Transmission Electron Microscope at 200 kV
- 8:52-9:04 **Ms. Alina Ainyette** page 9
Synthesis of Semiconductor Nanoparticles
- 9:04-9:16 **Mr. Ravneet Bajwa** page 10
Fabrication and Characterization of Metal Nanocrystal Nonvolatile Memory Cells
- 9:16-9:28 **Mr. Andrew Ballinger** page 10
Manufacture of Nanoscale Interconnects using Nanoimprint Lithography in PMMA
- 9:28-9:40 **Mr. Lawrence Bazille** page 11
Characterization of Etching Techniques on SiC for High Temperature MEMS Applications
- 9:40-9:52 **Mr. Matthew Blosser** page 11
Nanoscale Materials Morphology Control using a Focused Ion Beam
- 9:52-10:04 **Mr. Anthony Breitbach** page 12
Nanoparticles in the Environment: A Study of Surface Reactivity of Pyrite and Arsenopyrite

10:04-10:24 Break

Morning Session Moderator: Angela Berenstein

- 10:24-10:36 **Ms. Sarah Bryan** page 13
Diffusion of Aqueous Solutions in Oxycarbosilane Nanoporous Thin Films During Processing of Interconnect Structures
- 10:36-10:48 **Ms. Christine Chin** page 13
Fabrication of Metallic Nanoparticle Arrays using Nanoimprint Lithography
- 10:48-11:00 **Mr. David Coats** page 14
Combined Electron-Beam and Nano-Imprint Lithography Techniques for Creating Patterned Media
- 11:00-11:12 **Ms. Alicia Cohn** page 14
Formation of Magnetite Nanoparticles by Thermal Decomposition of Iron Bearing Carbonates: Implications for the Evidence of Fossil Life on Mars

11:15-12:00 Discussion #1; Discussion of Patents and Intellectual Property page 41

12:00-1:30 Lunch at Sage Hall, Atrium Cafe

Afternoon Session Moderator: Kathryn Hollar

1:30-1:42	Ms. Eva Cornell	page 15 <i>Analysis of Gold and Silver Nanoparticles in Mast Cells</i>
1:42-1:54	Ms. Sonia Cortés-Jiménez	page 15 <i>Site Specific Nanowire Growth</i>
1:54-2:06	Ms. Kelly Costello	page 16 <i>Microfluidic Systems for Protein Crystal Growth</i>
2:06-2:18	Mr. George Cramer	page 16 <i>Fabrication and Comparison of ZnO Thin Film Transistors with Various Gate Insulators</i>
2:18-2:30	Mr. Joseph D'Silva	page 17 <i>Microfluidic Cell Sorters for Stem Cell Separation and Size-Profiling Using Pressurized Laminar Flows at High Spatial-Temporal Resolution</i>

2:30-3:00 Break

Afternoon Session Moderator: Alan Bleier

3:00-3:12	Mr. Henry Daise, III	page 17 <i>β-SiC Growth on AlN-on-SiC</i>
3:12-3:24	Ms. Ying Yi Dang	page 18 <i>Rational Assembly of Semiconductor Nanowires via Dielectrophoresis</i>
3:24-3:36	Mr. Paul De Andrade	page 18 <i>Nano-Fabrication of Sub-Micron Structures using Conventional Photolithography</i>
3:36-3:48	Ms. Luxue Rose Deng	page 19 <i>Design of Mid-Infrared Ridge-Waveguide Directional Couplers by OptiWave Simulation</i>

3:48-4:00 Announcements & bus to picnic

FRIDAY, AUGUST IITH

8:00-8:30 Registration and Continental Breakfast

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8:42-8:54	Ms. Jenna Hagemeyer	page 20 <i>Photoluminescence of Silicon Nanocrystals Fabricated by Sputter Deposition and Annealing for Photonic Applications</i>
8:54-9:06	Ms. Dewi Harjanto	page 20 <i>Gold Nanoparticle-Assisted Delivery of TNF-Alpha in Thermal Treatments of Cancer</i>
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Morning Session Moderator: Michael Skvarla

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	<i>Single Cell Studies on Patterned, Sculptured Thin Films</i>	

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Morning Session Moderator: Mandy Esch

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	<i>Engineered Proteins for Binding and Organization of Inorganic Particles</i>	
11:46-11:58	Mr. John Kroger	page 24
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	<i>Nanostructure Lithography for High Throughput Cancer Screening</i>	

12:10-1:30 Lunch & Photos
Baum Atrium, Duffield Hall

Afternoon Session Moderator: Jennifer Tatham Root

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2:39-2:51	Ms. Juliet Lawrence	page 26
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	<i>The Effect of Atomic Surface Structure on the Catalytic Efficiency in Nanocatalysis</i>	
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4:48-5:00	Mr. Cary Smith	page 34
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7:00-9:30	Dinner & Explore the Museum of the Earth	

SATURDAY, AUGUST 12TH

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	<i>Fabrication of Nanometer-Scale Gaps on Thin Nitride Membranes using Electron Beam Lithography</i>	

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	<i>Crystallization of Amorphous Si Nanowires using Electro-Migration and Self-Heating for TFT Applications</i>	
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	<i>Finding Dielectric Constant of Nano Materials Using Fourier Transform Infrared Spectroscopy</i>	
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	<i>Heat Transfer through Nanogaps</i>	
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	<i>Freestanding Cadmium Selenide Semiconducting Nanorods for Solar Cell Application</i>	
1:48-2:00	Mr. Claude Wu	page 39
	<i>Fabrication of Surface Acoustic Wave Sensors for Early Cancer Detection</i>	
2:00-2:12	Mr. Jason Wang	page 39
	<i>Loss, Reflection and Transmission Measurement and Analysis of Silicon-on-Insulator Ring Resonators</i>	
2:12-2:30	Wrap-Up & Release!	

2006

**National Nanotechnology Infrastructure Network
Research Experience for Undergraduates Program**

Abstracts

(in alphabetical order)

Research and Development of Electron-Beam Lithography Using a Transmission Electron Microscope at 200 kV

Michael Adams, Physics, University of North Carolina at Chapel Hill

Center for Nanoscale Systems, Harvard University

David Bell, CNS, Harvard University

Contact: dcb@deas.harvard.edu

Conventional electron-beam lithography is done using a scanning electron microscope (SEM), with a resolution limit of ~10 nm [1]. However, there is continued need for higher resolution lithography. The goal of this project is to investigate higher resolution electron-beam lithography using a transmission electron microscope (TEM). In principle, the TEM has two main advantages: less scattering of incoming high energy electrons, and a smaller electron probe diameter.

An important practical test of these advantages is ablation of aluminum on a 100 nm silicon-nitride membrane.

- [1] C. Vieu, F. Carcenac, A. Pepin, Y. Chen, et al, "Electron Beam Lithography: Resolution limits and applications", Applied Surface Science 164, 111-117, 2000

Synthesis of Semiconductor Nanoparticles

Alina Ainyette, Neuroscience, Smith College

Howard Nanoscale Science and Engineering Facility, Howard University

Dr. Gary Harris, Dept. of Engineering, Howard University

Dr. Jason Matthews, Dept. of Chemistry, Howard University

Contact: gharris@mscre.howard.edu

Three secondary amines, N-methylaniline, diisopropylamine and diethylamine, were reacted with carbon disulfide in the presence of diethylzinc to yield the corresponding bis (dialkylamidodithiocarbamate) zinc complexes in yields ranging from 10 to 24%. Benzoic acid was reacted with diethylzinc to afford bis (benzoate) zinc in 62.7% yield. The metal complexes were characterized via FT-IR and NMR spectroscopy. These precursors were then combined with tri-octylphosphineoxide, TOPO, to afford ZnS and ZnO nanoparticles respectively. The nanoparticles were evaluated via UV-Vis spectroscopy. The λ -max for ZnO was 279 nm, which was different from that of the bulk material (370 nm). The λ -max range for ZnS was 272-287 nm, which was different from that of the bulk material (340 nm).

Fabrication and Characterization of Metal Nanocrystal Nonvolatile Memory Cells

**Ravneet Bajwa, Electrical Engineering & Computer Science,
University of California, Berkeley**

*Cornell NanoScale Science & Technology Facility, Cornell University
Edwin C. Kan, Electrical & Computer Engineering, Cornell University
Jaegoo Lee, Electrical & Computer Engineering, Cornell University
Contact: kan@ece.cornell.edu*

Nonvolatile memory cell in a thin film transistor (TFT) level consisting of a heterogeneous self assembled gold nanocrystal floating gate and an ultra thin gate oxide was fabricated. The memory cell is designed to be used in flash memory applications and to improve the conventional design in terms of faster write/erase operation and lower operational voltage. To achieve a controllable thin body layer, a chemical mechanical planarization (CMP) process for polysilicon was established. It was important to achieve this so that the charge storage in the gate stack layer could effectively control the channel conductance, instead of being dominated by the traps in the grain boundaries. There on the rest of the process, namely ultra thin oxide growth, self assembled gold nanocrystal formation, oxide and chromium deposition, was completed. In the coming days, the devices would be characterized for their performance by measuring the memory window, write/erase voltage, write/erase time, retention time and cycling endurance.

Manufacture of Nanoscale Interconnects using Nanoimprint Lithography in PMMA

**Andrew Ballinger, Undeclared,
Texas Academy of Mathematics and Science at the University of North Texas**

*Microelectronics Research Center, Georgia Institute of Technology
Devin Brown, Microelectronics Research Center, Georgia Institute of Technology
Contact: Devin.Brown@mirc.gatech.edu*

Electron beam lithography is a key process that has been used to fabricate nanoscale patterns on a variety of substrates. Though e-beam lithography is a very powerful tool in the laboratory, the process is far too slow to be used in industry.

Nanoimprinting lithography is a method that has recently been investigated to bring the small scale patterning capabilities of E-beam lithography to speeds acceptable for mass-manufacture.

This project has been to characterize all of the processes leading from a bare silicon wafer to the ultimate use of stamps to manufacture interconnects for electronics on the 20-100 nm scales. We created our initial patterns in hydrogen silsesquioxane (HSQ) using e-beam lithography. We then used reactive ion etching (RIE) to transfer the patterns onto a silicon wafer. This wafer was coated in a fluorinated anti-stick layer and then used as a stamp to transfer interconnect-patterns onto PMMA. These patterns were then metalized by electron beam evaporation to produce interconnects which were tested with a DC parametric probe station.

We successfully created patterns and imprinted interconnects below 20 nanometers.

Characterization of Etching Techniques on SiC for High Temperature MEMS Applications

Lawrence Bazille, Mechanical Engineering, Southern University

Howard Nanoscale Science & Engineering Facility, Howard University

Dr. Gary L. Harris, Director, Howard Nanoscale Science & Engineering Facility, Howard University

Contact: gharris@msrce.howard.edu

Silicon carbide (SiC) possesses characteristics such as high mechanical hardness, chemical inertness, large band gap, high thermal conductivity, and electrical stability at temperatures well above 300°C, which makes it very attractive for high temperature micro-electro-mechanical-systems (MEMS) applications. In order to create a SiC MEMS, the SiC must be etched. Some of the same properties that make SiC desirable for MEMS also limit SiC to certain etching techniques. The objective of the project is to examine the strengths and limitations of two etching methods.

The methods for etching SiC that are being investigated are reactive ion etching (RIE) and photo-electro-chemical etching (PEC). RIE etching of SiC was done using SF₆/O₂ and SF₆/Ar gas. The gas ratios and etch rates were evaluated. Surface morphology characterization by atomic force microscopy (AFM) was also performed on samples using both methodologies.

Nanoscale Materials Morphology using a Focused Ion Beam

Matthew Blosser, Physics, Carleton College

Center for Nanoscale Systems, Harvard University

Prof. Michael Aziz, Div. Engineering & Applied Sciences, Harvard University

maziz@harvard.edu

Ripple formation on silicon caused by irradiation with a focused ion beam can create features on the nanometer scale. A phenomenon where a rippled regime nucleates throughout the irradiated area is explored. A model has existed for some time to explain the formation of ripples from ion irradiation. However, there is disagreement between theory and experiment; while theory predicts linear instability at all incident angles, experiments show many cases of flat surfaces under irradiation.

Ripple nucleation is a transitional case in which a surface is stable until some perturbation is made.

Self-Assembly of Lithographically-Designed Colloidal Particles on Templated Surfaces

McIntosh Bonthera, Chemical Engineering, New Jersey Institute of Technology

Cornell NanoScale Science & Technology Facility, Cornell University

Abraham Stroock, Chemical Engineering, Cornell University

Stephane Badaire, Chemical Engineering, Cornell University

Contact: ads10@cornell.edu

The formation of a diversity of structures via the assembly of colloidal particles is hindered by the scarcity of available particles, the difficulty of attaining mono-dispersed samples, and the lack of tunable and selective interactions. The success of this project will lead to advancement in the field of optics. With the aid of depletion interactions, we have recently been able to induce and control structure in systems of photolithographically designed cylindrical particles. The structures that have been formed thus far consist of isolated columns of cylinders that do not present order on a larger scale. The aim of this project is to show that patterned surfaces can be used advantageously to compensate for this lack of control. As of late, we have used lithography to design a patterned surface on glass coverslips, used surface chemistry to control the specific adhesion of the particles, and developed a cell made of PDMS to prevent evaporation of the suspension under observation via optical microscopy. Preliminary experiments have shown that the particles adhere to the patterned surfaces. However, refinement of the process is necessary.

Nanoparticles in the Environment: A Study of Surface Reactivity of Pyrite and Arsenopyrite

Anthony S. Breitbach, Chemistry, Clarke College

Michigan Nanofabrication Facility, University of Michigan, Ann Arbor

Professor Udo Becker, Department of Geological Sciences, University of Michigan, Ann Arbor

Devon Renock, Department of Geological Sciences, University of Michigan, Ann Arbor

Contact: ubecker@umich.edu

Mineral surface reactivity is ultimately dependent on three surface properties: chemical composition, atomic structure, and microtopography. The purpose of this project was to compare the surface reactivity of pyrite (FeS_2) and arsenopyrite (FeAsS) by analyzing how surface characteristics influence the deposition of gold. Understanding the process of gold deposition in these experiments has implications for the recovery of gold from ore deposits, the control of acid mine-drainage, and understanding arsenic release into the environment.

Arsenopyrite and pyrite samples were immersed in 100 ppm Au(III) solution for 24 hours. Scanning electron microscopy (SEM) coupled with energy dispersive spectroscopy (EDS) showed that the arsenopyrite had a higher surface coverage of gold after equal exposure time. Surface analysis using x-ray photoelectron spectroscopy (XPS) indicated that gold was reductively adsorbed as Au^0 , and that arsenic was oxidized during the reaction in the case of arsenopyrite. Atomic force microscopy (AFM) was used to image the gold growth on the pyrite and arsenopyrite surfaces as a function of time. The AFM results show preferential growth on surface defects and a higher rate of growth on the arsenopyrite within the first hour of deposition. In conclusion, the surface of arsenopyrite better facilitates the reductive adsorption of gold.

Diffusion of Aqueous Solutions in Oxycarbosilane Nanoporous Thin Films During Processing of Interconnect Structures

Sarah Bryan, Physics, Florida International University

*Stanford Nanofabrication Facility, Stanford University
Reinhold Dauskardt, Materials Science & Engineering, Stanford University
David Maxwell Gage, Materials Science & Engineering, Stanford University
Contact: dauskardt@stanford.edu*

For the microelectronics industry to begin manufacturing smaller and faster devices, thin films utilized as interconnect structures must have lower dielectric constants and increased mechanical stability. By introducing nanopores into certain materials, the dielectric constant can be significantly lowered, but at the cost of changing the mechanical properties of the material. Oxycarbosilane, a new type of spin-on glass, has shown not only an extremely low dielectric constant, but also exhibits the highest level of mechanical reliability in comparison to similar nanoporous thin film glasses. During the fabrication of processors and integrated circuits, thin films are subjected to active chemical solutions which have been shown to diffuse into the material. This type of diffusion can adversely affect the performance and reliability of the resulting device. The current study will focus on the extent to which different solutions diffuse into oxycarbosilane thin films. Measurements will be made of diffusion distance as a function of time for a variety of different solutions and porosity levels. Oxycarbosilane thin film glasses haven't been subjected to many characterization tests and therefore remain relatively unexplored. The outstanding mechanical properties and low dielectric constant of the material make this type of thin film a prime candidate for integration into new types of nano-scale devices.

Fabrication of Metallic Nanoparticle Arrays using Nanoimprint Lithography

**Christine Chin, Mechanical Engineering and Biology,
Massachusetts Institute of Technology**

*Michigan Nanofabrication Facility, University of Michigan, Ann Arbor
Professor L. Jay Guo, Electrical Engineering and Computer Science/Applied Physics, University of Michigan
Brandon Lucas, Applied Physics, University of Michigan, Ann Arbor
Contact: guo@eecs.umich.edu*

Localized surface plasmon resonance (LSPR), a collective electron density oscillation found exclusively in metallic nanostructures, is a phenomenon that is of practical significance. The LSPR response of nanoparticles to changes in their surrounding dielectric environment may be exploited to use nanoparticle arrays as sensing platforms for biological or chemical sensors. This project focuses on the fabrication of such platforms using the method of nanoimprint lithography (NIL). NIL provides a way to produce significant areas of monodispersed nanoparticles of controlled size, shape and composition directly onto a wide range of substrates using a two-dimensional nanoblock array mold. Such a mold is derived from a simple one-dimensional grating pattern using a double-imprinting method.

We will study how the surface plasmon resonance of our fabricated Ag and Au nanoparticle arrays using NIL is affected as their composition as well as dielectric environment changes.

Combined Electron-Beam and Nano-Imprint Lithography Techniques for Creating Patterned Media

David W. Coats, Physics, Harvey Mudd College

Minnesota Nanotechnology Cluster, University of Minnesota, Twin Cities
Jian-Ping Wang, Electrical Engineering, University of Minnesota, Twin Cities
Hao Meng, Electrical Engineering, University of Minnesota, Twin Cities
Contact: jpwang@umn.edu

Magnetic nano-structures have attracted momentous attention in recent years. However, most nano-scale devices are fabricated by electron beam lithography; a very expensive and time consuming process. In this work, we present a combined electron beam/nano-imprint lithography process that is cheap, fast, and effective, and demonstrate its utility in creating magnetic nano-structures for patterned exchange coupled composite (ECC) media, which can support recording areal density up to 10 Terabit/in².

Electron beam lithography was used to pattern a 1 mm x 1 mm matrix containing over 1 million holes with diameters as small as 50 nm. This master stamp is used in a nano-imprint process to cast etch resistant dots of PMMA on an exchange coupled composite bilayer, which when ion-milled, produces separated islands of magnetic nano bits. This nano-imprinting technology allows inexpensive mass production of nanometer scale features by repeatedly and quickly casting patterns that were slowly and painstakingly created.

The developed nano-imprinting technology could be applied to any other product from logic devices to quantum computing which requires large numbers of inexpensive nano-scale features.

Formation of Magnetite Nanoparticles by Thermal Decomposition of Iron Bearing Carbonates: Implications for the Evidence of Fossil Life on Mars

Alicia Cohn, Chemistry, Gettysburg College

Nanoscience @ UNM, University of New Mexico
Dr. Adrian Brearley, Earth and Planetary Sciences, University of New Mexico
Jana Berlin, Earth and Planetary Sciences, University of New Mexico
Contact: brearley@unm.edu

The thermal decomposition of Fe-bearing carbonates was studied in order to better understand the parameters of the reaction in which nanoscale magnetite particles are formed. Samples of siderite (FeCO₃) and Ankerite ((Ca,Fe,Mg,Mn)CO₃) were heated at 1 atm in a CO₂ environment at temperatures ranging between 500°C and 800°C. The extent of the reaction was judged based on percent weight loss. The decomposition of siderite was found to follow the Avrami-Efroeov mechanism between 500°C and 700°C. Ankerite was observed to decompose between 600°C and 800°C but the decomposition was not identified with a specific mechanism. The reaction products were characterized using scanning and transmission electron microscopy (SEM/TEM) and energy dispersive spectrometry (EDS). The main product in the reacted ankerite was isolated from the carbonate and identified as magnetite based on electron diffraction patterns and EDS. With reaction progress, the grain size was found to increase and the magnetite began to incorporate more Mg and Mn. The surface of the reacted ankerite grains were also observed in the SEM, but nanoparticles of magnetite were not found on the surface. Instead, clumps of the magnetic particles were found on the surface of highly textured carbonate.

Analysis of Gold and Silver Nanoparticles in Mast Cells

Eva Cornell, Physics, Gustavus Adolphus College

*Minnesota Nanotechnology Cluster, University of Minnesota, Twin Cities
Greg Haugstad, Characterization Facility, University of Minnesota, Twin Cities*

Christy Haynes, Chemistry, University of Minnesota, Twin Cities

Contact: Haugs001@umn.edu

Mast cells are a type of immune cell found in connective tissue of the body that secrete chemical messengers, such as serotonin, into the blood stream upon stimulation. In this work, peritoneal mast cells were harvested from mice and cultured with various concentrations of gold and silver nanoparticles. A type of electrochemical analysis method called amperometry was used to study the effects of the nanoparticles on the cells. Amperometry investigates exocytosis of serotonin from the cell. It appears that the nanoparticles do influence the mast cells' release of serotonin. Transmission electron microscopy (TEM) and atomic force microscopy (AFM) were used to determine the location of the nanoparticles in the cells. TEM images show cross-sectional pictures of the cells where image intensity varies according to how a beam of electrons travels through the sample. AFM analysis uses a force probe to study the surface characteristics of cells. Using TEM and AFM, this work demonstrates that the nanoparticles are primarily located either on or directly underneath the cellular membrane of the mast cells.

Site Specific Nanowire Growth

**Sonia Y. Cortés-Jiménez, Mechanical Engineering,
University of Puerto Rico, Mayaguez Campus**

Penn State Nanofabrication Facility, The Pennsylvania State University

Dr. Aman Haque, Mechanical and Nuclear Engineering, The Pennsylvania State University

Amit Desai, Mechanical and Nuclear Engineering, The Pennsylvania State University

Contact: mah37@psu.edu

In recent years one-dimensional solids like nanowires have received increased attention as building blocks for future nanoscale devices. Their small length scale and unique physical and chemical properties make them interesting materials from technological and pedantic viewpoints. In order to fully exploit their advantages, it is necessary to perform experimental characterization on single nanowires. As a first step towards this goal, we are aiming to synthesize zinc oxide nanowires at the site of experimentation. This will enable *in-situ* experimentation on single nanowires inside a scanning electron microscope (SEM). We aim to perform mechanical characterization experiments on the nanowires by integrating the nanowire synthesis process with micro-electromechanical systems (MEMS) experimental test-bed. The nanowires are grown by vapor-liquid-solid (VLS) mechanism. The zinc oxide nanowires are synthesized using 1:1 weight mixture of zinc oxide powder and graphite as precursor and gold as catalyst. At 1000°C, the graphite reduces zinc oxide to form zinc and oxygen vapor. The nanowire growth is initiated when the gold (evaporated on (100) silicon substrate) is saturated with zinc vapor. The diameters of the nanowires are 30 nm to 200 nm and the lengths are up to 20 μm .

As future research, we will grow the nanowires on MEMS devices and study the size effect on mechanical properties of zinc oxide nanowires.

Microfluidic Systems for Protein Crystal Growth

Kelly Costello, Mechanical Engineering, Corning Community College

*Minnesota Nanotechnology Cluster, University of Minnesota, Twin Cities
Victor Barocas, Biomedical Engineering, University of Minnesota, Twin Cities
Masano Sugiyama, Chemical Engineering, University of Minnesota, Twin Cities
Contact: baroc001@umn.edu*

X-ray diffraction is the preferred method to obtain the atomic structure of a protein. When the structure is established, the function of the protein can be better understood. Diffraction requires large (on the order of 10^3) protein crystals with few defects to produce a suitable pattern. Producing quality crystals in sufficient, harvestable quantities remains the rate-limiting step in structure determination. Crystallization relies on manipulation of the protein phase diagram. Nucleation of crystals occurs in the labile region, while growth occurs slowly in the metastable region. The ideal technique for creating a large amount of diffracting crystals involves nucleating few crystals and allowing slow, unimpeded growth. Our research involves devices where crystallization occurs in a small chamber with controlled levels of protein and precipitate. Physically reaching crystals formed in existing chambers is difficult, so we are developing and fabricating new devices which can be disassembled easily. Finally, we are inducing and controlling the site of nucleation of lysozyme crystals using a growth stage. The growth stages consist of various patterned arrays of n-type and p-type silicon which utilize the electrostatic forces between charged surfaces and protein molecules to induce heterogeneous nucleation.

Fabrication and Comparison of ZnO Thin Film Transistors with Various Gate Insulators

George Cramer, Electrical Engineering, The Cooper Union

*Michigan Nanofabrication Facility, University of Michigan, Ann Arbor
Jamie Phillips, Electrical Engineering & Computer Science Department, University of Michigan, Ann Arbor
Jeffrey J. Siddiqui, Electrical Engineering & Computer Science Department, University of Michigan, Ann Arbor
Contact: jphilli@engin.umich.edu*

Thin film transistors (TFTs) are field-effect transistors fabricated by depositing thin layers of metal contacts, an insulator, and a semiconductor on a substrate. A voltage supplied at the metal “gate” of the TFT induces an accumulation of charge at the semiconductor/insulator interface. The semiconductor doping concentration is changed in order to reduce the resistance between source and drain contacts and allow for greater current flow. The devices studied in this project are an alternative technology to amorphous silicon TFTs, since the higher electron mobility and visible transparency of the ZnO material are desirable for transistors used in flat panel displays.

In this project, the gate dielectric material of ZnO TFTs was studied. In particular, $(\text{Pb,Zr})\text{TiO}_3$ (PZT), a high-k dielectric, was compared with SiO_2 and SiN_x with the goal of improving switching characteristics and achieving lower operating voltages. ZnO thin films were deposited by pulsed laser deposition, PZT by a sol-gel process, and SiO_2 and SiN_x by PECVD. All three insulators have yielded working transistors. Despite increased gate leakage current, ZnO TFTs utilizing PZT or PZT/ SiO_2 insulators demonstrate significantly improved gate control.

Microfluidic Cell Sorters for Stem Cell Separation and Size-Profiling Using Pressurized Laminar Flows at High Spatial-Temporal Resolution

Joseph D'Silva, Electrical and Computer Engineering, Cornell University

Microelectronics Research Center, The University of Texas at Austin
Dr. Xiaojing Zhang, Biomedical Engineering, The University of Texas at Austin
John.Zhang@enr.utexas.edu

The sorting and isolation of target cells and suspended particles from a medium is of great importance to cell biology, drug delivery, and related fields in biomedicine. Furthermore, the ability to separate and sort stem cells, which have tremendous medical applications, is of profound interest to the biomedical community. The focus of this project is to develop an acoustically driven, polymeric microfluidic cell sorter that will separate particles according to size-based differential migration with high throughput and accuracy, tunable spatial-temporal resolution, and low power consumption. We fabricated a photoresist-on-silicon master to create $150\ \mu\text{m} \times 150\ \mu\text{m} \times 40\ \text{mm}$ microfluidic channels in polydimethylsiloxane (PDMS) through the rapid-prototyping technique. We modeled the acoustic field within a $150\ \mu\text{m} \times 12.5\ \text{mm} \times 25\ \text{mm}$ PDMS microchannel actuated with a PZT transducer attached to one channel wall. We measured the energy coupled into a glass slide covered with $200\ \mu\text{m}$, $500\ \mu\text{m}$, and $1000\ \mu\text{m}$ of PDMS by the PZT to verify the model and simulation. The velocity, pressure, and energy density profiles within the main channel of the device are used to quantify the energy coupled into the separation device to achieve high spatial-temporal resolution cell sorting.

β -SiC Growth on AlN-on-SiC

Henry Daise III, Computer Science, Morehouse College

Howard Nanoscale Science & Engineering Facility, Howard University
Dr. Gary L. Harris, Director, Howard Nanoscale Science & Engineering Facility, Howard University
Mr. Crawford Taylor, Howard Nanoscale Science & Engineering Facility, Howard University
Contact: gharris@msrce.howard.edu, crawford@msrce.howard.edu

Available forms of silicon carbide exist as 6H-SiC and 4H-SiC polytypes, but suffer from crystal defects such as micropipes, which affect the electrical properties of the material. Because of its advantageous properties, such as the lack of micropipe defects, high electron and hole mobilities, and non-anisotropic nature, cubic silicon carbide (3C-SiC), has potential applications in semiconductors and microelectronics, such as complementary CMOS electronics in computers. Cubic silicon carbide, also called β -SiC, is formed at temperatures below 1800°C . The quality of the substrate that it's grown on affects the quality of the β -SiC epilayer. The AlN-on-SiC substrate prevents current leakage, which makes it possible for growth of micropipe free SiC.

In this project, the production of high quality β -SiC, is grown on an AlN-on-SiC substrate by chemical vapor deposition. The process included an *in-situ* HCl etch, used varying ratios of propane and silane precursors to produce the epilayer, with growth times ranging from 10-30 minutes, and temperatures, from 1200 - 1400°C , with resulting growths reaching 200-400 nm.

Rational Assembly of Semiconductor Nanowires via Dielectrophoresis

Ying Yi Dang, Applied Physics, Columbia University

Michigan Nanofabrication Facility, University of Michigan, Ann Arbor

Wei Lu, Electrical Engineering & Computer Science and Applied Physics, University of Michigan, Ann Arbor

Wayne Y. Fung, Electrical Engineering & Computer Science, University of Michigan, Ann Arbor

Contact: wluee@eecs.umich.edu

In the fabrication of nanowire-based devices, nanowire deposition on the surface of a substrate, until recently, was mainly either random or directed by fluidic flows or field-assisted assembly. However, these approaches lack the control over end-to-end registry and orientation of the nanowires. Dielectrophoresis (DEP) addresses the issue of rational assembly of nanowires by relying on the interaction of the induced dipole moment and an inhomogeneous electric field. With DEP, the motion of a neutral subject, such as a nanowire, can be manipulated by voltages on nearby electrodes, and the nanowire can be deposited precisely across the electrodes. This project studies DEP trapping of nanowires on electrode patterns defined with photolithography. The first part was designing the electrode patterns, which contain resist features ranging from $0.5\ \mu\text{m}$ to $7.0\ \mu\text{m}$, enabling the investigation of nanowire alignment with respect to feature size and nanowire length. Then DEP studies were conducted to explore the effects of other parameters such as voltage and frequency.

Nano-Fabrication of Sub-Micron Structures using Conventional Photolithography

Paul De Andrade, Biomedical Engineering, Georgia Institute of Technology

Center for Nanoscale Systems, Harvard University

Jiangdong Deng, Center for Nanoscale Systems, Harvard University

Erli Chen, Center for Nanoscale Systems, Harvard University

Contact: jdeng@deas.harvard.edu

Conventional photolithography is a process in which light is passed through a patterned photomask onto a light-sensitive material (photoresist) on the surface of a substrate. The substrate is then placed into developer solution during which time the exposed areas of photoresist dissolve away, leaving a replica of the photomask pattern carved into the photoresist layer. Although serving many applications in the micrometer region, the major disadvantage of this technology is that it has traditionally been incapable of effectively producing finer nano-scale features. However, by implementing a technique in which metal is deposited onto a Si/SiO₂ wafer from two opposing angles through a single-micron photoresist pattern-gap into a lift-off resist undercut below, we have produced features less than 80 nm in size using conventional photolithography. After lifting off the layers of resist from the substrate surface, the patterned features were refined using reactive ion etching and soft-lithography was then utilized to develop a PDMS “stamp” of the surface for the subsequent reproduction of the nano-scaled pattern.

Design of Mid-Infrared Ridge-Waveguide Directional Couplers by OptiWave Simulation

Luxue Rose Deng, Physics, Hamilton College

Nanoscience @ UNM, University of New Mexico

Marek Osinski, Optical Science Engineering, University of New Mexico

Gennady Smolyakov, Optical Science Engineering, University of New Mexico

Contact: osinski@chtm.unm.edu

Quantum cascade ring lasers are simulated to help determine the structure for the real device. The purpose of the simulation is to design a structure that supports only the fundamental mode. After we find a successful design, we simulate the straightaway part of the ring laser where the energy is coupled. This shows the coupling length, which helps determine if the structure can be applied to the real structure. A successful design would mean no more than 10% of the ring laser's energy is coupled into the waveguide. The simulations find the previous design for quantum well and quantum dot structure does not support quantum cascade ring lasers.

The best design for the quantum cascade structure has an etching between 1.695-1.895 μm , a ridge width of 5 μm and 6 μm , and a gap between the ridges of 12 μm . The coupling length for an etching of 1.695 μm , ridge of 5 μm and a gap of 12 μm is 12 mm. In the actual device the straightaway part of the ring laser is 2 mm and 4 mm, so the amount of energy coupled is 5% and 20% respectively. The design supports 2 mm straightaway. A ridge width of 6 μm also allows for a strong mode.

Thermal Management at the Nanoscale

Michael J. Fox, Electrical Engineering, The Cooper Union

Center for Nanotechnology, The University of Washington

Alexander Mamishev, Electrical Engineering, The University of Washington

Chih-Peng Hsu & Nels Jewell-Larsen, Electrical Engineering, The University of Washington

Contact: mamishev@ee.washington.edu

Traditional rotary fan technology acts as a bottleneck in the cooling of ever shrinking electronic and electromechanical devices. A novel solution to produce airflow which can be miniaturized and integrated on-chip is needed. Electrostatic fluid acceleration (EFA) produces ionic wind by creating ions via electron bombardment. These ions are then accelerated between two electrodes of opposite polarity. Large electric field intensity is required in the vicinity of the corona (emitting) electrode to conduct electrons into the air gap. Wide spread implementation of EFA depends on the ability to generate this field intensity without excessive voltage between the electrodes. High tip curvature microelectrodes exploit geometric optimization to lower devices' onset voltages.

Several devices were micro-fabricated from bulk silicon using industry standard practices. These devices were tested for their basic current-voltage and heat transfer characteristics.

Photoluminescence of Silicon Nanocrystals Fabricated by Sputter Deposition and Annealing for Photonic Applications

Jenna Hagemeyer, Physics, Northwest Nazarene University

*Stanford Nanofabrication Facility, Stanford University
Prof. Yoshio Nishi, Electrical Engineering, Stanford University
James P. McVittie, Electrical Engineering, Stanford University
Hiroyuki Sanda, Electrical Engineering, Stanford University
Contact: nishiy@stanford.edu*

CMOS compatible photonic devices hold great promise for the future of information technology, because optical interconnections have many advantages over electronic interconnections, including less delay and less power consumption. Silicon nanocrystals, a CMOS compatible photoluminescent material, can be fabricated by RF magnetron sputter deposition. A thin film of silicon-rich silicon dioxide is deposited, followed by thermal annealing. In this project, we have created silicon nanocrystals using this process. By controlling the deposition conditions, a sample was made with a gradient of excess Si in a SiO₂ matrix. The Si concentration ranged from 31.4%-52.8%, as measured by XPS. Various annealing processes were done, including thermal annealing at 1100°C for one hour, forming gas annealing (FGA) at 400°C for 30 minutes, and high-pressure water vapor annealing (HWA) at 260°C for five hours. Photoluminescence (PL) was measured as a function of Si concentration. The maximum PL was found to occur at 33.5% Si, which could be underestimated by the measurement, for all annealing conditions. A consistent phase shift was also observed in the PL intensity peak, which indicates a change in nanocrystal size. These results indicate the conditions for optimal PL, which will improve the quality of Si photonic devices.

Gold Nanoparticle-Assisted Delivery of TNF-Alpha in Thermal Treatments of Cancer

**Dewi Harjanto, General Engineering with a Concentration in Bioengineering,
Franklin W. Olin College of Engineering**

*Minnesota Nanotechnology Cluster, University of Minnesota, Twin Cities
Professor John Bischof, Mechanical Engineering, University of Minnesota, Twin Cities
Rachana Visaria, Mechanical Engineering, University of Minnesota, Twin Cities
Contact: bischof@umn.edu*

Gold nanoparticles are seen as a promising drug carrier for anti-cancer treatments because of their size, non-toxicity, high binding capacity, inertness and stability in the human body. The effects of the gold nanoparticle-based delivery of the inflammatory cytokine, TNF-alpha, to breast cancer, prostate cancer, and microvascular endothelial cells in combination with freezing and laser-induced heating were examined. Specifically, cell viability, clonogenicity, and temperature changes were studied.

Crystallization of Amorphous Si Nanowires using Electromigration and Self-Heating for TFT Applications

Nathan Henry, Biomedical Engineering, Electrical Engineering,
Michigan Technological University

Cornell NanoScale Science & Technology Facility, Cornell University
Ali Gokirmak, Electrical & Computer Engineering, Cornell University
Contact: gokirmak@ece.cornell.edu

Thin film transistors (TFTs), made from amorphous silicon (a-Si), are used for control circuitry in flat panel displays. Different approaches are investigated to replace a-Si with nano-crystalline or single-crystal Si which provide higher mobility, hence reduced power. In this work, we have investigated crystallization of a-Si nano-wires through electromigration and self-heating by passing electrical current through the nano-wires.

The nano-wires were fabricated by depositing 100 nm N⁺ a-Si on Si substrates with thermally grown oxide. An array of nano-wires with contacts, ranging from 10's of nm to microns in width and variations in length; were patterned using photolithography, and etched with CF₄ reactive ion etching (RIE). Electrical tests were performed in ambient atmosphere by measuring I-V characteristics before and after applying constant voltage across the wires. Measurements are performed using a parameter analyzer through a LabVIEW interface. We have observed that the current carrying capacity of the wires increase as current is passed through the wires, which suggests structural changes. The color of the nanowires also changed, which can be attributed to oxide formation. The nano-wires break after passing excess current as observed in current measurements. The fractures in the broken wires and oxide formation over the wires are observed in the SEM images.

Measuring the Size Dependence of the Magnetic Properties of Alkanethiol-Coated Gold Nanocrystals

Sarah C. Hernandez, Astronomy and Physics, Texas Christian University

Microelectronics Research Center, University of Texas at Austin
Brian A. Korgel, Chemical Engineering, University of Texas at Austin
Andrew Heitsch, Chemical Engineering, University of Texas at Austin
Contact: korgel@che.utexas.edu

Bulk gold is diamagnetic but 2 nm dodecanethiol (thiol) capped gold nanoparticles have been reported to exhibit ferromagnetic properties [1]. Ferromagnetism is believed to result from spin-orbit coupling between the surface-bound thiol molecules and the gold surface atoms [2]. Therefore, as the gold nanoparticles size decreases and the surface area to volume ratio increases, ferromagnetism is expected to increase. The size dependence of the magnetic properties of thiol-capped gold nanocrystals was studied. Thiol-capped gold nanocrystals were synthesized using Brust's method [3] with diameters that ranged from 2 to 6 nm. The magnetic susceptibility of the nanocrystals were measured using a super quantum interference device (SQUID) at room temperature and 5 Kelvin (K) [1]. Contrary to two published reports [1,2] but consistent with another study [4], the thiol-coated gold nanocrystals did not exhibit ferromagnetism, and were in fact diamagnetic, even down to diameters of 1.8 nm.

[1] Crespo, P., et al. Phys. Rev. Lett. 93 (2004) 087204.

[2] Hernando, A.; Crespo, P.; Garcia, M. A., Phys. Rev. Lett. 96 (2006) 057206.

[3] Brust, M.; Walker, M.; Bethell, D.; Schiffrin, D.J.; Whyman, R., J. Chem. Soc., Chem. Commun., (1994) 801.

[4] Yamamoto, Y.; Hori, H., Re. Adv. Mater. Sci. 12 (2006) 23-32.

Nanoscale Focused Ion Beam Patterning and Characterization of Perpendicular Magnetic Recording Media

Irene Hu, Electrical Engineering, Princeton University

Stanford Nanofabrication Facility, Stanford University

Robert Sinclair, Materials Science, Stanford University

Unoh Kwon, Materials Science, Stanford University

Contact: bobsinc@stanford.edu

In perpendicular magnetic recording, a single magnetic domain in a thin film magnetic medium represents a bit of data by its up or down magnetization. A potential method to increase the density and stability of this data is to pattern the medium into arrays of islands, thus defining the domains by their physical isolation. However, the behavior of such islands in response to applied fields is still incompletely understood. In this study, we use a focused ion beam (FIB) to cut arrays of islands into a CoCrPt-alloy perpendicular magnetic thin film and then examine the physical properties and magnetic characteristics of the islands with atomic force microscopy (AFM) and magnetic force microscopy (MFM), respectively. By varying island parameters such as dimension, period, and shape, and observing the resulting switching properties, we will be able to more completely characterize the switching behavior of the islands. This allows an increased understanding of the nature and behavior of patterned perpendicular magnetic media and leads to the eventual development of optimum parameters.

Advanced Fabrication of Electroactive Nanowell Sensors

Suraj Kabadi, Biomedical Engineering, Johns Hopkins University

Cornell NanoScale Science & Technology Facility, Cornell University

David Erickson, Mechanical and Aerospace Engineering, Cornell University

Bernardo Cordovez, Mechanical and Aerospace Engineering, Cornell University

Contact: de54@cornell.edu

Particle trapping using electrical fields presents itself as an effective way to trap particles for many biological applications due to the vast amount of charged substances present. An investigation is conducted into the ability to effectively fabricate a flexible electronic architecture for use in electroactive nanowell particle trapping. This architecture consists of perpendicular fluidic channels and gold electrodes patterned into PDMS, which allows for controlled particle flow and specific targeting of wells. Fabrication is achieved by first patterning fluidic channels on a silicon wafer, then patterning gold electrodes on top of these channels, and finally transferring the pattern in its entirety onto PDMS. The lack of adhesion between PDMS and gold requires the use of a self-assembling monolayer, mercaptosilane, to effectively transfer the gold pattern. The patterned PDMS chip is then bonded to an ITO substrate, which contains micron-scale wells made from polyimide. By flowing polystyrene beads through this device and applying a voltage across the wells and electrodes, localized electrophoretic and electro-osmotic effects are observed in trapping these particles in the wells. The techniques presented here can be furthered to allow for individual x-y addressability of wells.

Processing for Enabling Ultra-Fast Modulators on Chip

Albert Kamanzi, Physics Major, University of Massachusetts at Boston

*Cornell Nanoscale Science and Technology Facility, Cornell University
Prof. Michal Lipson, School of Electrical and Computer Engineering, Cornell University
Carl Poitras, School of Electrical and Computer Engineering, Cornell University
Contact: ML292@cornell.edu*

One important step for ultra-fast electro-optic modulators on SOI wafers is minimizing the contact resistance between the semiconductor and the metal contacts. In order for ultra-fast modulators to perform faster, ohmic contacts are required. Several methods have been developed to achieve ohmic contacts. For silicon chips, transition metals are made to react with the silicon at the contact points, forming silicides. Hence three layers are obtained, Si metal-Si and then metal. As a result the change in chemical and electrical properties is more gradual, allowing for ohmic contacts. The most used silicide is titanium disilicide (TiSi_2) due to its low resistivity. For very thin layers (nanoscale) of silicon (SOI), this technology faces challenges with the difficulty to obtain TiSi_2 , with higher resistivity TiSi being formed instead. Recently nickel has been found as a good alternative for thin silicon, with NiSi being the silicide formed. We focus on forming contacts using both titanium and nickel for silicidation. The metal deposition and annealing times will be carefully controlled and varied to determine the best contacts on thin silicon layers of 50, 100 and 150 nm.

Identifying Novel Peptides for Binding to Semiconductor Substrates to Create Nanobiomaterials

Athra Kaviani, Biomedical Engineering, University of Texas at Austin

*Nanotech @ UCSB, University of California, Santa Barbara
Professor Patrick Daugherty, Chemical Engineering, University of California, Santa Barbara
Jeffery Rice, Chemical Engineering, University of California, Santa Barbara
Contact: psd@engineering.ucsb.edu*

Nanobiomaterials can potentially be used in a wide range of applications including, but not limited to, the development of biochips, biolabels, drug delivery systems, and bioelectronics. With the purpose of creating nanobiomaterials, we have identified peptide sequences that bind to gold substrates using bacterial surface display. A 7-mer peptide library (X2CX7CX2) was presented on the surface of *E. coli* as an insertional fusion within loop two of outer membrane protein OmpX. Stringent bacterial selections were performed using both gold particles and gold surfaces, causing bacteria with the ability to bind gold to remain immobilized while non-binding cells are washed away. After four rounds of selection individual clones were isolated and co-transformed with a plasmid that encodes for a green fluorescent protein making it possible to use flow cytometry to detect fluorescent cells bound to gold particles. Bacterial clones were incubated in a PBS gold particle solution. Clones were isolated with the ability to bind over half of the gold particles present in solution. The clone with the highest affinity to gold displayed the 15 residue sequence of, VCYWSYSRMCKNGGS. This method can be extrapolated to other material surfaces, increasing our knowledge of protein-material interactions and advancing the field of protein engineering.

Engineered Proteins for Binding and Organization of Inorganic Particles

Elaine Kirschke, Biochemistry, University of California Santa Barbara

*Center for Nanotechnology, University of Washington
Beth Traxler, Microbiology, University of Washington
Eliora Gachelet, Microbiology, University of Washington
Contact: btraxler@u.washington .edu*

The focus of this project is the exploitation of the self-assembly properties of proteins to arrange inorganic compounds in predictable patterns. This involves the genetic engineering of the DNA binding protein, Lac repressor (LacI), such that it binds to inorganic compounds without significant functional loss. LacI binds to sequence specific regions of double stranded DNA with high affinity. Addition of an inorganic binding site would allow for the assembly of a DNA-protein-nanoparticle structure. Inorganic binding can be incorporated into the protein by insertion of specific polypeptide binding sequences into previously identified permissive sites in the LacI protein.

Two inorganic binding sequences were identified for insertion; platinum (3SD152) and silica (QBP3) binding motifs. These two sequences were inserted into two different permissive sites in LacI; LacI317 and LacI338. The four derivatives are then assayed for *in vivo* DNA binding function and binding to the respective inorganic nanoparticles.

Desorption-Ionization Mass Spectrometry on Nanoporous Polymer

John Kroger, Biomedical Engineering, Georgia Institute of Technology

*Penn State Center for Nanotechnology Education & Utilization, The Pennsylvania State University
Tony Jun Huang, Engineering Science and Mechanics, The Pennsylvania State University
Vincent Hsiao, Engineering Science and Mechanics, The Pennsylvania State University
Contact: junhuang@psu.edu*

Experimentation of desorption-ionization mass spectrometry was tested on nanoporous polymer. Matrix assisted laser desorption-ionization (MALDI) is used in a wide series of applications having the most use in specific biological experiments such as peptide sequencing and the analysis of small biomolecules. The goal of this experiment was to improve the accuracy of analyzing larger biomolecules as well improve the sensitivity typically achieved with other matrices. In this experiment nanoporous polymer was substituted as an ultraviolet light absorbing matrix. In MALDI the matrix used typically absorbs in the frequency of the laser being used, and indirectly transfers the energy of the laser to the sample, causing the sample to sublime and ionize. In our experiment the MALDI micro MX with a nitrogen laser (337 nm) was used to ionize each sample plated on our nanoporous polymer. The recipe for our nanoporous polymer was slightly modified throughout the experimentation in order to improve in its operation as a substituted matrix.

Nanostructure Lithography for High Throughput Cancer Screening

Herbert Lannon, Physics, Rensselaer Polytechnic Institute

Cornell NanoScale Science & Technology Facility, Cornell University
David Erickson, Sibley School of Mechanical and Aerospace Engineering, Cornell University
Allen Yang, Chemical Engineering, Cornell University
Contact: de54@cornell.edu

Optofluidic surface plasmon resonance (OSPR) is a process that can be used to detect multiple biomarkers in human sera by detecting of shifts in the plasmon coupling wavelength of ordered arrays of metallic nanostructures due localized changes in the refractive index of the surrounding environment. Previously these metallic structures have been grown using “nanosphere lithography,” however our group has been working on a new technique. Using photoresist on a silicon or glass substrate, cylinders are first grown. After development, gold is evaporated onto the substrate. The cylinders are then removed and the nanostructures are left on the substrate. Currently structures of 500 nm can be made to a long-range order, but these results show there is potential for reaching 200 nm or lower. Future work will involve these structures being integrated into OSPR devices that can interrogate thousands of disease markers in parallel, minimize handling and analysis time, will not require target labeling, and are inherently inexpensive to mass produce.

The Stability and Catalytic Reactivity of Palladium Colloidal Nanoparticles on Supports

David Lavenson, Chemical Engineering, Lehigh University

Center for Micro-Engineered Materials (CMEM), University of New Mexico
Prof. Abhaya K. Datye, Dept. of Chemical and Nuclear Engineering, University of New Mexico
Ayman Karim, Dept. of Chemical and Nuclear Engineering, University of New Mexico
Contact: Datye@unm.edu

Palladium nanoparticle catalysts prepared using colloidal synthesis routes are characterized in terms of their stability with and without a surfactant as well as their catalytic activity after different treatments. The palladium colloidal nanoparticles were synthesized through a novel mesityl route, combining palladium (II) chloride with magnesium bromide mesityl to form palladium mesityl and magnesium bromochloride as a precipitate. The palladium nanoparticles formed are stabilized by the surfactant TOP - trioctylphosphine. Supported on alumina substrates, the colloidal nanoparticle samples were analyzed for catalytic activity for CO oxidation. TEM, STEM, particle size using light scattering and XRD were used to characterize the palladium nanoparticles. Samples were examined before and after thermogravimetric analysis (TGA), as well as before/after CO oxidation using TEM and STEM imaging. The particle size distribution of the Pd/Al₂O₃ catalyst after reactivity measurements was very similar in the presence and after removal of the surfactant (TOP). We also show that the surfactant used to stabilize the particles and prevent sintering results in lowering the Pd nanoparticles activity for CO oxidation. The colloidal synthesis method allows for fine control over the Pd nanoparticles size using different surfactant. However, the surfactant removal is crucial for the supported particles in gas phase reactions.

AlGaAs/GaAs Heterojunction Prosthetic Retina

Juliet Lawrence, Health and Humanities, University of Southern California

Howard Nanoscale Science and Engineering Facility, Howard University

Dr. Gary L. Harris, Electrical Engineering, Howard University

Mr. James Griffin, Electrical Engineering, Howard University

Contact: gharris@msrce.howard.edu

Diseases such as retinitis pigmentosa and age-related macular degeneration lead to gradual loss of eyesight due to the progressive loss of retinal photoreceptors. Currently, several treatments for these diseases, such as administering doses of vitamin A, are being used to slow loss of vision. Many other treatments are also being developed to offset the effects of these diseases. One in particular hopes to restore partial vision using an artificial retina with solar cells to provide electrical stimulation of the ganglion cells of the eye when exposed to light. Previously these solar cells have been made of silicon which has its highest spectral response in the infrared region. Aluminum gallium arsenide/gallium arsenide (AlGaAs/GaAs) has a spectral response which more closely resembles that of the human eye.

The objective of this work was to fabricate an AlGaAs/GaAs prosthetic retina with an array of 10 μm diameter solar cells on a 3 x 3 mm² chip. Open circuit voltages of 0.7V were obtained under illumination for these cells. Mesas were etched into both sides of this chip to minimize electrical crosstalk between cells and minimize movement of the chip once implanted.

Microfluidic Systems for DNA Sequencing

Christina Lu, Biochemistry, Brandeis University

Stanford Nanofabrication Facility, Stanford University

Professor Jim Plummer and Dr. Peter Griffin, Electrical Engineering, Stanford University

Ali Agah, Electrical Engineering, Stanford University

Contact: plummer@stanford.edu, griffin@stanford.edu

DNA sequencing is one of the most important tools in biological studies and provides a key insight into the functioning of all living organisms. The recent development of pyrosequencing has proven itself to be a much simpler and faster means for sequencing than traditional methods. It is currently limited, however, by its ability to produce only short read lengths. In order to make the process more efficient, we integrated the pyrosequencing technique into microfluidic systems to increase the reaction speed and also reduce the required sample size. We did this by creating a new technique that implements continuous liquid flow through microfabricated channels in silicon. We matched the dimensions of the channels to that of the capillary tubes to minimize the dead volume loss, and in doing so, hoped to achieve longer read lengths. To test the chip we will introduce the liquids into the system through a syringe and measure the resulting light-producing reaction. The ability to achieve longer read lengths from the pyrosequencing technique will simplify the genome assembly process.

Analysis of Experimental Data in Bacterial Adhesion

**Albert Mach, Bioengineering and Electrical Engineering & Computer Science,
University of California Berkeley**

*Center for Nanotechnology, University of Washington
Wendy Thomas, Bioengineering, University of Washington
Brian Kidd, Bioengineering, University of Washington
Contact: wendyt@u.washington.edu*

Understanding the molecular basis of bacterial adhesion creates opportunities for treating infectious diseases and developing novel adhesives for nanotechnology. In *Escherichia coli*, this adhesion is governed by a complex interplay among: (1) the receptor-ligand interaction as mediated by the adhesive protein FimH and mannose-covered surfaces, (2) the cellular mechanics, and (3) the fluid properties. To determine the force of the bond mediating this adhesion, single FimH-mannose bonds were pulled apart with an atomic force microscope (AFM). This paper presents a computational tool for automating the calculation and analysis of the data gathered from measuring the force response of single receptor-ligand bonds with an AFM. The program detects valid adhesion events between the mannose-covered cantilever and the FimH-coated surface. It also accurately calculates the spring constant and rupture force of the FimH. This methodology eliminates dozens of painstaking hours of manual calculations that are prone to error due to difficulty of addressing noise in the readings. The program offers greater insight into the interaction between FimH and mannose by providing a tool to guide experimental work and calculating accurate physical parameters for modeling simulations.

Effects of N Incorporation on the Electronic Properties of GaAsN-Based Modulation-Doped Heterostructures

Niall M. Mangan, Physics and Mathematics, Clarkson University

*Michigan Nanofabrication Facility, University of Michigan, Ann Arbor
Rachel S. Goldman, MSE/EECS, University of Michigan, Ann Arbor
Matthew Reason, MSE; Yu Jin, Cagliyan Kurdak, Physics; University of Michigan, Ann Arbor
Contact: rsgold@umich.edu*

Dilute nitride GaAsN and InGaAsN alloys are useful for applications in infrared laser diodes, high efficiency solar cells, and high performance heterojunction bipolar transistors. To date, literature reports of dilute nitride semiconductor alloys have presented substantially lower electron mobilities than (In)GaAs. Furthermore, for (In)GaAsN alloys, the electron mobility has been reported to decrease as the N incorporation increases. In order to study the nitrogen-related electron scattering effects in InGaAsN, with minimal contributions from ionized impurity scattering, we are studying the transport properties of modulation-doped AlGaAs/InGaAs(N) heterostructures, with Si dopants in the AlGaAs barrier layer spatially separated from the nominally undoped InGaAs(N) channel layer.

To examine the effects of N incorporation mechanisms on the transport properties of GaAsN-based modulation-doped heterostructures, we have fabricated gated Hall bar devices using photolithography and performed temperature-dependent Hall and magnetoresistance measurements. We will discuss the dependence of mobility on carrier concentration, with a focus on the insulating phenomena associated with multiple scattering effects past a critical carrier density.

Fabricating Superconducting Quantum Interference Device Nanostructures for Single Spin Detection

Myranda Martin, Biology-Chemistry, Lock Haven University of Pennsylvania

*Penn State Center for Nanotechnology Education & Utilization, The Pennsylvania State University
Dr. Khalid Eid and Dr. Jeffrey Catchmark, Penn State Nanofabrication Facility, The Pennsylvania State University
keid@enr.psu.edu*

The goal of this project was to create a more sensitive microbridge Superconducting QUantum Interference Device (SQUID) using two high resolution electron beam resists stacked in a bilayer. The geometry of the microbridge SQUID is needed because this type of SQUID is used to detect the spin of single molecule magnets. In order to make the SQUID more sensitive than current microbridge SQUIDS, the goal was to make the lines in the junction of the SQUID rings 20 nm in width. The SQUID rings were created using the Leica EBPG-5HR electron beam lithography tool. Two types of metal were then used to make the SQUID devices; niobium and aluminum. Niobium was deposited through sputtering and aluminum through thermal evaporation. Images of the SQUID rings were then taken using field emission scanning electron microscopy. The SQUIDS, along with their images, were then sent to the University of California, Berkley, for characterization.

Single Cell Studies on Patterned, Sculptured Thin Films

Robert Patrick Martin, Chemistry, Erskine College

*Penn State Center for Nanotechnology Education & Utilization, The Pennsylvania State University
Dr. Melik Demirel, Earth and Engineering Science, The Pennsylvania State University
Eric So, Earth and Engineering Science, The Pennsylvania State University
Contact: MDemirel@enr.psu.edu*

In this experiment, cell studies were conducted on a patterned, sculptured thin film (STF) surface. STFs are a bionanomaterial that features a tightly-packed field of chiral, polymeric projections. This unique shape exhibits a large surface area to volume ratio; giving it significant and valuable properties as a growth medium for cells. Use of this material in transplant and biomedical might require cells to be grown in a specific pattern. To study that phenomena, a silicon wafer was patterned using lithography techniques to show squares of 30 μm on a side, spaced 30 μm apart. An STF was then deposited on the surface of the wafer and the excess removed by solvent. HEK 298 kidney cells were then deposited onto the platforms. The cell growth on the platforms was studied, and the quantity and location (on or off the platforms) of the cells after set intervals of time were tabulated.

Design and Fabrication of Nanoelectrodes for Single Cell Biosensor Application

Esha Mathew, Bioengineering, Cornell University

Penn State Center for Nanotechnology Education & Utilization, The Pennsylvania State University

Dr. Jian Xu, Earth and Engineering Sciences, The Pennsylvania State University

An Cheng and Myo Thein, Earth and Engineering Sciences, The Pennsylvania State University

Contact: jianxu@psu.edu

A biosensor refers to an analytical device that converts a biological response into an electrical signal. The focus of this paper is the design and fabrication of gold nanoelectrodes for the enhanced performance of cell-based biosensor applications. Proteins will be covalently bonded to the arrays of surface-engineered nanoelectrodes, over which cells will be immobilized selectively for the purpose of biosensing. The basic electrode patterning consists of 50 x 50 nm² gold squares spaced a distance of 1 μm apart on a SiO₂ wafer substrate.

Due to the small nature of the features, an electron-beam lithography tool is needed to perform the exposure. In order to determine the correct charge per area to come from the electron-beam, a dose array test must be carried out in which different areas of a test sample will be exposed to different charges, ranging from 250 to 800 μC. The proper dose is determined by observing which dose produces the sharpest features. Once the proper dose is established, more samples can be made.

The samples will then be sent to the University of Washington where patterning will be verified.

The Effect of Atomic Surface Structure on the Catalytic Efficiency in Nanocatalysis

Katrina Murphy, Bioengineering, Oregon State University

Microelectronics Research Laboratory, Georgia Institute of Technology

Dr. Mostafa A. El-Sayed, Chemistry and Biochemistry, Georgia Institute of Technology

Christopher Tabor, Chemistry and Biochemistry, Georgia Institute of Technology

Contact: mostafa.el-sayed@chemistry.gatech.edu

Nanocatalysis is a promising area within the field of nanoscience due to the specifically higher surface-to-volume ratio and higher atomic surface energy nanoparticles offer to other types of catalysts. It has been reported that nanoprisms lower the activation energy of the electron transfer reaction between hexacyanoferrate(III) and thiosulfate ions in solution more so than nanospheres. In the current work, the reaction rates of the electron transfer reaction catalyzed by gold surface-bound nanoprisms and nanospheres, solution suspended nanoprisms, and rough and smooth thin film surfaces. For large nanoprisms on a substrate, slight changes in the bisector were observed spectroscopically. The activation energies of the reactions were measured with each type of catalyst over the 23-60°C temperature range. An analysis of the results suggests that unannealed surface atoms with unsaturated valency (e.g. present on substrate-bound prisms and rough thin film surfaces) have the highest catalytic activity. By adding energy to the particles through thermal heating or photothermal irradiation, the activation energy was found to increase and thus lowering their catalytic efficiency.

Solution-Growth of Zinc Oxide Nanowires for Dye-Sensitized Solar Cells

**Yasuhide Nakamura, Chemistry and Chemical Engineering,
University of California Santa Barbara**

*Minnesota Nanotechnology Cluster, University of Minnesota, Twin Cities
Eray Aydil, Chemical Engineering, University of Minnesota, Twin Cities
Janice Boercker, Chemical Engineering, University of Minnesota, Twin Cities
Contact: aydil@tc.umn.edu*

Zinc oxide nanowires grown from aqueous solution of methenamine and zinc nitrate are used in dye-sensitized solar cells. However, the growth mechanism of the ZnO nanowires and the solution chemistry is not yet well understood. Two aspects of the nanowire synthesis were studied. First, heterogeneous growth of nanowires is limited by homogenous nucleation of ZnO particles, which quickly deplete growth precursors after high supersaturation is reached.

To understand the homogeneous formation of ZnO particles, the reaction kinetics were studied by complexometric titration of zinc ion by EDTA and characterization of particles by powder X-ray diffraction. It was determined that homogeneous nucleation is first order in methenamine and zinc nitrate concentration and that the particles formed are indeed ZnO. Secondly, the nanowire growth is limited by nucleation of nanowires that are not perpendicular to the substrate. Many of the wires stop growing at an angle to the substrate normal when they run into other wires. ZnO nanoparticles are used as seeds to grow nanowires. The orientation of these nanoparticles also determine the orientation of the nanowires, X-ray micro diffraction was used to understand the dependence of nanoparticle orientation annealed at various temperatures.

Freestanding Cadmium Selenide Semiconducting Nanorods for Solar Cell Application

**Emily Norvell, Materials Engineering,
California Polytechnic State University, San Luis Obispo**

*Nanotech @ UCSB, University of California, Santa Barbara
Martin Moskovits and Galen Stucky, Chemistry and Biochemistry, University of California, Santa Barbara
Martin Schierhorn, Department of Chemistry and Biochemistry, University of California, Santa Barbara
Contact: MLPSDean@LTSC.ucsb.edu*

Cadmium selenide nanorods were electrochemically fabricated in nanoporous aluminum oxide templates. The stoichiometry of the rods was controlled by using cyclic voltammetry deposition with a potentiostat and varying concentrations of SeO_2 in the plating solution. The optimal stoichiometry of 1:1 for Cd:Se was achieved with a solution containing 0.3M CdSO_4 and 2.8 mM SeO_2 (< 100 fold excess of Cd ions). The length of the rods was controlled by the number of voltage cycles, with 1200 cycles yielding $\sim 1 \mu\text{m}$. The CdSe rods were annealed at 600°C to increase their crystallinity as determined by x-ray diffraction (XRD). The alumina matrix was etched away with NaOH and dried in supercritical CO_2 to yield uniform, freestanding rods as confirmed by the scanning electron microscope (SEM).

Chemical Crosslinking and Temperature Dependant Conductivity of Ligand-Stabilized Gold Nanoparticles

**Stephanie Petrina, Materials Science and Engineering,
Virginia Polytechnic Institute and State University**

*Nanotech @ UCSB, University of California, Santa Barbara
Galen Stucky, Chemistry and Biochemistry, University of California, Santa Barbara
Shannon Boettcher, Dept. of Chemistry, University of California, Santa Barbara
Contact: stucky@chem.ucsb.edu*

The unique nanoscale properties of gold particles make them a special area of interest in current nanotechnology investigations. Gold nanoparticles (NPs) have an approximate diameter of 2 nm: this particle size determines the discrete charges transferred in nanoparticle films. These properties make tunable gold NPs ideal for use in electronic devices as miniaturization becomes the new condition to maximize efficiency in electronics. This research focuses on chemical modifications of gold nanoparticle arrays to manipulate conductivity. Photolithographic methods have also been developed to pattern NP arrays on the microscale.

These nanoparticles are solution synthesized using the Brust method and the gold cores are stabilized with insulating hexane thiolate ligands. Individual particles are made into concentrated solutions by dissolving in toluene or heptane. Nanoparticle solutions are spincoated into thin films (~300 nm) on small electrical devices such as interdigitated electrodes (IDEs) or sandwich electrodes made in lab. The NP films can be crosslinked using dithiols like nonanedithiol and benzenedithiol to interlink the attached ligand chains. We studied the temperature dependant conductivity of NP films as a function of the degree of chemical crosslinking. It was found that crosslinking ligands exponentially enhance conductivity, as does increasing temperature.

Template-Directed Epitaxial Crystal Growth of Colloids with Short-Range Attraction

Erica Pratt, Mechanical/Biomedical Engineering, Carnegie Mellon University

*Cornell NanoScale Science & Technology Facility, Cornell University
Itai Cohen, Physics, Cornell University
Sharon Gerbode, Physics, Cornell University
Contact: ic64@cornell.edu*

Colloids are used in all levels of science to model atomic structures. One example is to model atomic epitaxial growth. Current models use the depletion effect to induce in colloids the forces atoms experience while they crystallize. However, the substrate is not modeled and its own flaws and atomic composition will exert an influence upon crystallization. The goal of this project is to simulate the substrate surface by using templates of different lattice constants. The colloids will be imaged using confocal microscopy as they settle onto the templates and the surface/colloid interaction will be analyzed.

Fabrication and Characterization of Nanoporous Gold Thin Films

Leila Joy Roberson, Biochemistry, Samford University

Cornell Nanoscale Science and Technology Facility, Cornell University

Dr. Christopher (Kit) Umbach, Department of Materials Science & Engineering, Cornell University

Totka Ouzounova, Department of Materials Science & Engineering, Cornell University

Contact: umbach@ccmr.cornell.edu, tdo4@cornell.edu

Nanoporous gold thin films (less than 1 μm) have been of great interest in large part due to the fact that such material shows great promise for use in diagnostic applications [1] or in MEMS devices [2] because of its inertness, conductivity, and increased surface area. While previous research has been focused on modeling the evolution of such films [3,4], there have not been many studies devoted to their mechanical properties. Understanding mechanical properties of NPG films is fundamental for gaining insight into the workings of these films so that they may eventually be implemented into a device.

The focus of this project has been to optimize the processing of NPG films on silicon substrates (not previously done) and to measure the stress (via a laser scanning technique) induced in the porous gold films by the dealloying method (selective removal of silver) used to fabricate these films. Changes in stress as a function of temperature are also measured. Scanning electron microscopy (SEM) imaging is used to determine porosity changes due to exposures in various concentrations of nitric acid and as a function of annealing. Surface-enhanced Raman spectra of alkanethiol self-assembled monolayers (SAMs) were acquired using a near-IR confocal Raman microscope with an excitation wavelength of 785 nm.

References:

1. H. Azzazy, M. Mansour and S.C. Kazmierczak, *Clinical Chemistry*, 2006, 52, 1238-1246.
2. M. Cortie and E. van der Lingen, *Gold 2003*, 28th September-1st October 2003, Vancouver
3. J. Erlebacher, M. Aziz, A. Karma, N. Dimitrov and K. Sieradzki, *Nature*, 2001, 410, 450-452.
4. J. Erlebacher and K. Sieradzki, *Scripta Materialia*, 2003, 49, 991-996.

Suspended Carbon Nanotubes for Nano-Optoelectronic Devices

**Anthony Sanders, Electrical Engineering,
Prairie View Agricultural and Mechanical University**

*Stanford Nanofabrication Facility, Stanford University
Hongjie Dai, Chemistry Operations, Stanford University
Xinran Wang, Chemistry, Stanford University
Contact: hdai1@stanford.edu*

Single walled carbon nanotube field effect transistors (SWNT-FETs) have been the subject of much research over the last decade due to their unique electrical and small dimensions. In this project we fabricate structures that suspend carbon nanotubes over a trench, as opposed to laying them on some layer of oxide, and use the air in between the substrate and the SWNT as the dielectric. High electrical currents are applied through the nanotubes to measure light emission, essentially making electroluminescent measurements of individual nanotube molecules. This structure has been built, and has shown to give higher light emission efficiency than nanotubes lying on a substrate. Electroluminescence from self-heating of large diameter tubes (> 2 nm) have been measured in our lab, but the band gap energy of such tubes is out of the range of our detector. Therefore, we are attempting to measure smaller diameter (< 1.5 nm) SWNT's, whose band gap energy falls in our detection range. We are seeking out ways to grow the tubes on our structure because CVD growth of small diameter tubes is not easy. One option is a spin and coat method. By measuring the electroluminescence of small diameter tubes, we want to understand the physics of the luminescence, and figure out how to optimize the device structure to get high efficiency for further applications.

Fabrication of Nanometer-Scale Gaps on Thin Nitride Membranes using Electron Beam Lithography

**David M. Schluneker, Mechanical/Electrical Engineering,
Rose-Hulman Institute of Technology**

*Microelectronics Research Center, Georgia Institute of Technology
Dr. Kevin Martin, Microelectronics Research Center, Georgia Institute of Technology
Farhana Zaman, Microelectronics Research Center, Georgia Institute of Technology
Contact: kevin.martin@mirc.gatech.edu*

Electron beam lithography, with its incredible accuracy and patterning precision, is on the forefront of nanotechnology and nano-gap fabrication. Nano-gaps hold promise for a variety of reasons. In molecular detection, smaller gaps can detect fewer particles, having applications in airport security, chemical warfare and environmental monitoring. Nano-gaps could also be used for better DNA detection and research in molecular electronics. To achieve these applications, several methods have been undertaken to help increase the resolution of the electron beam lithography system, including the use of thin resist thicknesses, beam interference, limiting apertures and thin membranes.

In this project the state-of-the-art JEOL JBX-9300FS 100kV system at Georgia Tech was used to obtain high resolution and very precise patterns. A drawback of this system is the backscattering of electrons, which can expose unpatterned resist, blurring patterns. This drawback can be nearly eliminated by using thin membranes. To obtain these membranes the wafer was selectively etched away to leave a layer of silicon nitride with a thickness of a few hundred nanometers. The e-beam pattern was then written on the membranes and the sample underwent a gold lift-off process. Characterization, using the SEM and AFM, has shown successful fabrication of nanometer scale gaps.

Sidewall Metallization of High Aspect Ratio Perpendicular Polymer Structures for Chip I/O Interconnections

**Tajudeen Shodeinde, Electrical Engineering,
North Carolina Agricultural & Technical State University**

Microelectronics Research Laboratory, Georgia Institute of Technology

Dr. Muhannad Bakir, Electrical Engineering (MicroElectronics Department), Georgia Institute of Technology

Calvin R. King Jr, Electrical Engineering (MicroElectronics Department), Georgia Institute of Technology

Contact: muhannad.bakir@mirc.gatech.edu

As CMOS ICs continue to advance, the needs for ever better chip I/O interconnect technology becomes ever more critical. In this research, we explore the use of “Sea of Polymer Pillars” to transmit electrical and optical signals rapidly from die to the substrate. The pillars are processed through certain steps which include spin coating, pre baking, exposing to UV light, hard baking, developing and curing. However, before these pillars could actually be used on a chip they must satisfy certain conditions such as mechanical reliability and possession of low resistance as well as low inductance. Mechanical reliability plays a major role, due to the fact that these pillars must be compliant enough to withstand the thermomechanical stresses induced as a result of the difference of the CTE of the board and the chip. Thus, many publications have been published on how various mechanical attributes are needed from advanced chip I/Os. On the other hand, before these polymer pillars can actually transmit electrical signals, the pillars need to be metallized with an electrical conductor, Cu, on the sides, and not the tips. The primary focus of this research is to develop unique processes for single sided metallization of polymer pillars to allow them to operate as electrical and optical I/Os.

Ferrofluidic Alignment of Carbon Nanotubes

Cary Smith, Physics and Mathematics, Jackson State University

Cornell NanoScale Science and Technology Facility, Cornell University

Professor Sandip Tiwari, School of Electrical Computer Engineering, Cornell University

Jay VanDelden, Visiting Scientist, School of Electrical and Computer Engineering, Cornell University

Contact: st222@cornell.edu, jsv25@cornell.edu

The alignment of carbon nanotubes using a Ferrofluid is explored. By applying a colloidal liquid suspension of ferrous nanoparticles to a wafer with CVD-grown carbon nanotubes, we observe evidence of a mechanical interaction between the nanoparticles and nanotubes facilitated by an externally-applied magnetic field. Future use of this interaction may include the alignment of nanotubes in micro-electronic devices.

Silver Nano-Ring Arrays: Nanofabrication and Optical Properties

Julie Stern, Physics and Chemistry, State University of New York at Stony Brook

*Center for Nanoscale Systems, Harvard University
Prof. Ken Crozier, Department of Engineering and Applied Sciences, Harvard University
kcrozier@deas.harvard.edu*

Metallic nanoparticles have become of interest to a wide variety of applications areas due to their optical properties. These properties include optical surface resonance, localization, confinement, and enhancement of electric fields, and resonance wavelength tunability as a function of geometry. The main goal of this study is to elucidate the viability of silver nanorings in achieving the optical confinement and the enhancement of electric fields. Silver having less optical loss than gold is expected to achieve better results. In addition, another goal of this study is to achieve the resonant wavelength redshift from visible towards infrared wavelengths often observed with gold nanoshells and gold nanorings when geometrical parameters are tuned. The geometrical parameters under consideration consist of varying the inner ring radius as compared to the outer ring radius and fabricating nanorings with subwavelength dimensions. Geometrical tunability of resonant wavelengths will be investigated in this study and parameter ranges determined for silver. To obtain subwavelength spatial dimensions the nanofabrication process includes e-beam lithography at ultra-high resolution. Preliminary results from nanofabricating the silver nanorings and optical analysis are presented.

Nanocrystalline Nd:YVO₄ Lasing Medium

**Chris Stoaffer, Chemistry, California Polytechnic
State University, San Luis Obispo**

*Nanotech @ UCSB, University of California, Santa Barbara
Dr. David Clarke, Materials Department, University of California, Santa Barbara
Matthew Chambers, Materials Graduate Student Researcher, University of California, Santa Barbara
Contact: Clarke@engineering.ucsb.edu*

Ceramic production of lasing crystals offers many benefits for solid-state lasers in comparison to the classic single crystal growth method. This project focuses on using the ceramic method to create Neodymium doped Yttria-Vanadate crystals (YVO₄). The method involves creating Yttria stabilized Zirconia nanocrystalline with varying elemental ratios in the structure. These crystals are then formed into separate pellets and sintered at 1500°C. Each pellet is heat fluxed with Lithium Vanadate powder (LiVO₃) at 1050°C. A chemical reaction takes place at the surface of the nanocrystalline pellet with the LiVO₃ to form Nd:YVO₄ nanocrystalline (Neodymium doped Yttrium Vanadate). This reaction should create crystals with higher concentrations of Nd in YVO₄ than previous methods allowed.

This method allows for many benefits for solid-state lasers because of the higher dopant concentration. These benefits include higher efficiency, more power, smaller, and cheaper lasers. This project contributes to the current research aimed at improving the ceramic process of solid-state lasing media production.

Patterning of Dendrimer-Like DNA

Jon Swaim, Biomedical Engineering, University of Alabama at Birmingham

*Cornell NanoScale Science & Technology Facility, Cornell University
Dan Luo, Biological and Environmental Engineering, Cornell University
Wenlong Cheng, Biological and Environmental Engineering, Cornell University
Contact: DL79@cornell.edu*

The assembly and positioning of nanoscale building blocks in order to fabricate complex, high-order functional structures remains to be a challenge in nanodevices. Dendrimer-like DNA (DL-DNA) is a functional nanoscale building block capable of carrying a variety of functional groups. The objective of this project was to fabricate poly (dimethylsiloxane) (PDMS) stamps and assemble λ -DNA and DL-DNA into patterns using a molecular combing technique. In molecular combing, the PDMS stamp is placed in contact with a small solution of DNA. Subsequent peeling off of the PDMS will result in a one-dimensional arrangement of DNA. Photolithography and reactive ion etching were employed to pattern 5 μm holes into PDMS and create uniform arrangements of λ -DNA. Currently, PDMS stamps with nanowells are being fabricated to pattern DL-DNA into hierarchical multifunctional nanostructures.

Droplet Transport using Surface Ratchets

Dane Taylor, Physics/Electrical Engineering, University of Wyoming

*Center for Nanotechnology, University of Washington
Karl F. Böhringer, Department of Electrical Engineering, University of Washington
Ashutosh Shastry, Department of Electrical Engineering, University of Washington
Contact: karl@ee.washington.edu, ashutosh@washington.edu*

In this work, we report the design, fabrication, and preliminary experiments to study textured surface ratchets for droplet transport. Droplet microfluidics has far reaching impact on disparate areas ranging from lab-on-chip systems to opto-fluidic components. The ratchet utilizes pinning of the three phase contact line due to the force of hysteresis, which opposes any edge movement of a droplet. Because hysteresis is only present at the solid/liquid/vapor interface, the force is dependant on the length of this line, and thus surface roughness. By creating periodic, asymmetric surface roughness in phase with one side of a droplet and out of phase with the other, the total hysteretic force will have direction. Experiments have been done to determine the energy limits where this net hysteretic force can result in droplet movement. Edge-tracking software was developed to track droplet edge movement and to choose the correct range of operating parameters. Vibrating droplets of varying sizes were tracked on a first generation of straight ratchets. Based on these preliminary experiments, we have designed and fabricated the next generation of curved ratchets where we expect to observe droplet movement. The test experiments of the new ratchets are about to commence.

Fabrication and Characterization of MnAs/GaAs Heterostructures for Studies of One-Dimensional Spin Transport

David Toyli, Physics, University of Minnesota

*Nanotech @ UCSB, University of California, Santa Barbara
David Awschalom, Physics, University of California, Santa Barbara
Jesse Berezovsky, Physics, University of California, Santa Barbara
Contact: awsch@physics.ucsb.edu*

MnAs is an attractive material for use in studies of ferromagnet/semiconductor heterostructures. It is a room-temperature ferromagnet and can be grown by molecular beam epitaxy (MBE) on III-V semiconductors. In this work we present results detailing the fabrication and characterization of GaAs freestanding nanowires with MnAs caps. MnAs/GaAs freestanding nanowires with aspect ratios as great as 7:1 and diameters as small as 100 nm have been fabricated using a reactive ion etch (RIE) process. The structural properties of the nanowires were characterized using scanning electron microscopy (SEM) and atomic force microscopy (AFM). Ongoing measurements of the magnetic and electrical properties of the nanowires are being conducted using magnetic force microscopy (MFM) and conductive atomic force microscopy (CAFM). The fabrication and characterization of these MnAs/GaAs nanowires represent the first steps toward creating a ferromagnet/semiconductor heterostructure suitable for use in studies of one-dimensional electron spin transport.

Quantum Dot Modulators

Brendan Turner, Physics, Brigham Young University

*Center for High Technology Materials, University of New Mexico
Diana Huffaker, Electrical and Computer Engineering, University of New Mexico
Manish Mehta, Electrical and Computer Engineering
Contact: huffaker@chtm.unm.edu*

Mach-zender devices are an ideal modulation source for communication networks at 1.3 μm and 1.55 μm . Superlinear electro-optical effects are a desirable feature in mach-zender modulators since their large second order electro-optical coefficient would give complete signal extinction at a small voltage. Quantum dot devices show promise for such applications in the 1.3 μm band.

In this project we will perform free-space characterization of stacked InAs quantum dot devices. A crossed polarizer and analyzer combination will be used to determine the phase retardation/voltage relation and electro-optical coefficients for said materials. We will use different pump wavelengths to analyze their effect on modulation. Further calculations will be carried out to determine the theoretical extinction ratio of such devices as part of a mach-zender modulator.

Microcantilever-Based Sensors for Proteins

Amit Vasudev, Biomechanical Engineering, Stanford University

Microelectronics Research Center, University of Texas at Austin

Dr. Nicholas A. Peppas, Chemical Eng and Biomedical Eng, University of Texas at Austin

Carolyn Bayer, Biomedical Engineering, University of Texas at Austin

Contact: peppas@che.utexas.edu

The focus of this project was to detect microcantilever deflection when an intelligent polyethylene glycol-based hydrogel, applied to the surface, swells at variable pH levels. Microcantilevers can act as precise sensors due to variations in surface stress both outside and inside liquid. The hydrogel was patterned onto microcantilevers of various sizes using UV photolithography. When the cantilevers were soaked in different buffers, the swelling hydrogel induced surface stress and therefore the bending phenomenon. This deflection was quantified by observing the change in focus with a Nikon Eclipse ME600 microscope. The deflection was evident, and differed accordingly at various pH levels.

Heat Transfer through Nanogaps

Josef Velten, Materials Science and Engineering, Illinois Institute of Technology

Nanoscience @ UNM, University of New Mexico

Dr. Kevin Malloy, Center for High Technology Materials, University of New Mexico

Ryan Martin, Center for High Technology Materials, University of New Mexico

Contact: malloy@unm.edu

Traditionally, heat transfer is modeled into three basic categories—conduction, convection, and radiation—all of which have their own equations that govern their procedures (Stefan-Boltzmann, Fourier, et al). Due to the evanescent effect found in optical research, it is speculated that at the nanoscale, heat transfer cannot be so sharply defined between the three categories as it is on the macro scale. The focus of this project is to fabricate a chip that has a gap between two layers on the nanometer scale so that the transition between radiative heat transfer and conductive heat transfer can be studied. The first method of making this gap was by spinning on e-beam resist onto a silicon-silicon dioxide wafer and etching micron sized holes in the silicon dioxide so that a top layer of a-Si could be deposited onto the wafer. Then various methods of undercutting were tested for the purpose of creating a gap between the two remaining layers of the chip.

Loss, Reflection and Transmission Measurement and Analysis of Silicon-on-Insulator Ring Resonators

**Jason Wang, Electrical Engineering and Bioengineering,
University of Pennsylvania**

Nanotech @ UCSB, University of California, Santa Barbara

John Bowers, Department of Electrical and Computer Engineering, University of California, Santa Barbara

Alexander Fang, Department of Electrical and Computer Engineering, University of California, Santa Barbara

Contact: bowers@ece.ucsb.edu

Silicon ring resonators are becoming an increasingly interesting area of focus in silicon photonics. When light of specific wavelengths is coupled into the ring resonator, there can be a build up or cancellation of optical power due to interference between the light from multiple round trips within the resonator. This, in conjunction with silicon's low loss coefficient, makes silicon ring resonators excellent passive low-loss filters with high quality factors. This project aims to characterize the wavelength dependent transmission characteristics of a straight silicon-on-insulator waveguide coupled to a silicon-on-insulator ring resonator. The transmission loss of straight silicon waveguides was determined through Fabry-Perot loss measurements. Finally, the ring resonator parameters, such as ring loss, ring-waveguide-coupling efficiency, quality factor, and finesse are determined by taking wavelength dependent transmission measurements for various ring radii, ring-waveguide-gap distances, and waveguide widths.

Fabrication of Surface Acoustic Wave Sensors for Early Cancer Detection

Claude Wu, Electrical Engineering, University of California, Los Angeles

Microelectronics Research Laboratory, Georgia Institute of Technology

William Hunt, Electrical and Computer Engineering, Georgia Institute of Technology

Christopher Corso, Bioengineering, Georgia Institute of Technology

Contact: bill.hunt@ece.gatech.edu

Surface acoustic wave (SAW) technology can be applied to create highly sensitive biosensors due to its extreme sensitivity to surface perturbation. The velocity of an acoustic wave depends upon the mass density and stiffness of the piezoelectric substrate. The binding of antigens with antibodies, which immobilized in the path of the traveling wave, changes the mass of the biolayer. The mass loading effect perturbs the surface boundary which changes the velocity of the wave and consequently, shifts the frequency of the traveling SAW. With a pair of transmitting and receiving interdigital transducers (IDT), surface acoustic wave of frequency 2.44 GHz can be generated through RF interrogation. The nanoscale SAW IDTs have been successfully fabricated through electron beam lithography. The device insertion loss is approximately 36 dB and has center frequency around 2.25 GHz. In the future, biolayer testing and optimization of the IDTs will be needed to develop fully functional devices.

Synthesis and Galvanic Replacement Reaction of Silver Nanocubes in Organic Medium

Kaylie Young, Chemistry, Brown University

*Center for Nanotechnology, University of Washington
Younan Xia, Department of Chemistry, University of Washington
Xianmao Lu, Department of Chemistry, University of Washington
Contact: xia@chem.washington.edu*

Silver nanocubes 30-50 nm in diameter have been synthesized using a polyol process in which silver nitrate is reduced by ethylene glycol in the presence of a capping agent poly(vinylpyrrolidone) (PVP). The cubes are single crystals, characterized by a slightly truncated shape bounded by {100}, {110}, and {111} facets. A ligand exchange reaction was used to replace the PVP with another capping agent, allowing the nanocubes to be soluble in chloroform solvent. Oleylamine, oleic acid, decane-thiol, and trioctylphosphine oxide (TOPO) were among the ligands investigated. The silver cubes were then used as sacrificial templates to generate hollow gold nanocages using a galvanic replacement reaction during which the silver cubes were titrated with chloroauric acid. Transmission electron microscopy and scanning electron microscopy were used to monitor these processes. The use of different capping agents allows us to further understand the role of the ligand in the galvanic replacement reaction. The ability to tune the optical properties of these nanostructures to the infrared region promises uses as both contrast agents for optical imaging in early stage tumor detection and as therapeutic agents for photothermal cancer treatment.

Finding Dielectric Constant of Nano Materials Using Fourier Transform Infrared Spectroscopy

**Caleb Yu, Electrical Engineering,
California State Polytechnic University, Pomona University**

*Microelectronics Research Center, The University of Texas at Austin
Dean Neikirk, Electrical and Computer Engineering, The University of Texas at Austin
Sangwook Han, Electrical and Computer Engineering, The University of Texas at Austin
Contact: neikirk@mail.utexas.edu*

The main focus of this research group is getting basic constants on nano materials through infrared sensors, Fourier Transform Infrared Spectroscopy (FTIR). Due to the fact that FTIR mainly gives you transmission percentage or absorption percentage vs. wave number, the transmission line theory and ABCD matrix are used to produce the sample, sample holder, and to transform data from FTIR into dielectric constants and power absorption percentage.

The focus of this project is to first design the structure of the sample and the sample holder so that transmission line theory can be applied. This is important since figuring out thickness of the sample holder that will be hold the sample is key in getting as close as possible to the actual dielectric constant. Second is to design a simple diaphragm made up of silicon nitride. Since we already know the dielectric constant of silicon nitride, this test will allow us to see how close the dielectric constant from FTIR is to the official one. The third step is to use the diaphragm as a sample holder and drop cast a layer of Ge nanowires made by the Chemical Engineering Department. Then we will measure the dielectric of the Ge nanowires with the above methods.

Discussion #1, Thursday, 10:30-11:15am

Discussion of Patents and Intellectual Property

Ernest Davis
Senior Technology Manager

Office of Intellectual Property & Management
Cornell University
Ithaca, New York, 14850
emd37@cornell.edu

Ernest Davis joined the Cornell Center for Technology, Enterprise and Commercialization as a physical sciences Technology Manager in September 2002. He comes to CCTEC with several years of experience in engineering, business and program/project management.

Before joining CCTEC, Ernest was a program manager and advisory engineer for IBM's microelectronics division in Endicott, NY. As a program manager in Endicott, Ernest served as a customer liaison and new products manager for IBM's complex printed circuit board group.

Ernest started his career with IBM in Research Triangle Park, NC where he played key roles as a lead engineer, business operations manager and program manager in the personal systems division. Ernest received a Bachelor of Science degree in Mechanical Engineering from North Carolina State University in 1995. And in 2000, he graduated from North Carolina State University's Master of Science in Management (MSM) program.

Discussion #2, Friday, 1:30-2:15pm

Discussion of Society and Ethics Issues in Nanotechnology

Dr. Anna Viseu
NNIN Social & Ethical Issues Coordinator

Cornell NanoScale Science & Technology Facility
Cornell University
Ithaca NY 14853
viseu@cnf.cornell.edu

Nanotechnology is a revolutionary technology. What are the ethical and social implications of this technology. What are your ethical obligations as a scientist in general. What are your ethical obligations in this revolutionary technology. What are the lab safety issues as well as public safety issues.

In last year's REU program, we had one student, Priscilla Paul of Cooper Union, study the Social and Ethical Issues in Nanotechnology by interviewing lab users and other REU students. The results are presented in a video summary. We will view the video as a basis for further discussions of the SEI issues in Nanotechnology.



Dr. Ana Viseu is a Research Associate in the Department of Science at Technology Studies, Cornell University, where she researches the social and ethical dimensions of nanotechnology and nanoscience. She specializes in science and technology studies, studies of innovation, and ethnographic research. Her research interests focus on questions of technological agency, embodiment and identity and the ways in which these notions are constructed and transformed through and within emergent information technologies. Ana received her doctorate from the University of Toronto in 2005. Her thesis critically examined the multiple meanings of physical and cognitive augmentation through wearable computers, from the visionary discourses of developers to the conflicted experience of implementation on the ground.

Discussion #3, Saturday, 10:15-11am

Introduction to the Journal of Young Investigators

Ali Dalipi
Public Relations Officer

Journal of Young Investigators
www.JYI.org
Dalipi@jyi.org
516-410-2290

The screenshot shows the homepage of the Journal of Young Investigators. At the top, there is a navigation bar with links: Home, Browse, Submit, Join, Resources, About, Archives, SCC. A search box is also present. The main content area is divided into several sections:

- Latest Issue:** Features an article titled "Magnetic Nanoparticles Enhance Medical Imaging" with a sub-image of two MRI scans. The text describes how iron oxide nanoparticles can enhance medical imaging techniques.
- Research:** Includes a literature review on childhood obesity and a comparison of LAM-MPI and MPICH.
- Features:** Includes a letter to the editor about radiosurgery and the Gamma Knife.
- NEWS BRIEFS:** A vertical list of short articles with dates, such as "New System Identifies Bacteria Using Light" (31 July 2006) and "Little Fish in a Big Pond" (28 July 2006).
- BROWSE JYI:** A section for browsing by category, currently showing "Astronomy & Space".

JYI, Inc. is an exciting, student-led initiative to broaden the scope of the undergraduate scientific experience. JYI provides opportunities for students to participate in the scientific review and publication processes, primarily through the operation of its peer-reviewed journal for undergraduates. Incorporated as a non-profit, entirely student-run corporation, JYI's staff members currently represent over 30 different academic institutions. JYI has been featured in EurekaAlert!, Chemical Engineering News, and The Chronicle on Higher Education. Recently, an article highlighting JYI appeared in The New York Times (17 February 1999).

JYI's web journal (which is also called JYI) is dedicated to the presentation of undergraduate research in science, mathematics, and engineering. It publishes the best submissions

from undergraduates, with an emphasis on both the quality of research and the manner in which it is communicated. The journal, JYI, also allows students to experience the other side of the scientific publication process: the review process. Students working with their faculty advisors review the work of their peers and determine whether that work is acceptable for publication in JYI.

Ali Dalipi will walk us through the JYI experience!

Conference and Program Evaluator

Prof. Mathew C. Sullivan
Department of Physics

Center for Natural Studies 262
Ithaca College, Ithaca NY 14850
607-274-3964
mcsullivan@ithaca.edu

To provide us with an independent view of the NNIN REU program and the REU convocation, we have retained Prof. Matthew Sullivan, Professor of Physics at Ithaca College. He will be observing some of the talks and talking to some of the participants. We encourage you to freely give him your impressions of your NNIN REU experience.



Prof. Matthew C. Sullivan is an Assistant Professor of Physics at Ithaca College, Ithaca, NY. He has a Ph.D from the University of Maryland studying superconductivity. Prior to coming to Ithaca College he spent a year as a process engineer at Intel. He has also been a high school physics teacher and a Peace Corps volunteer.