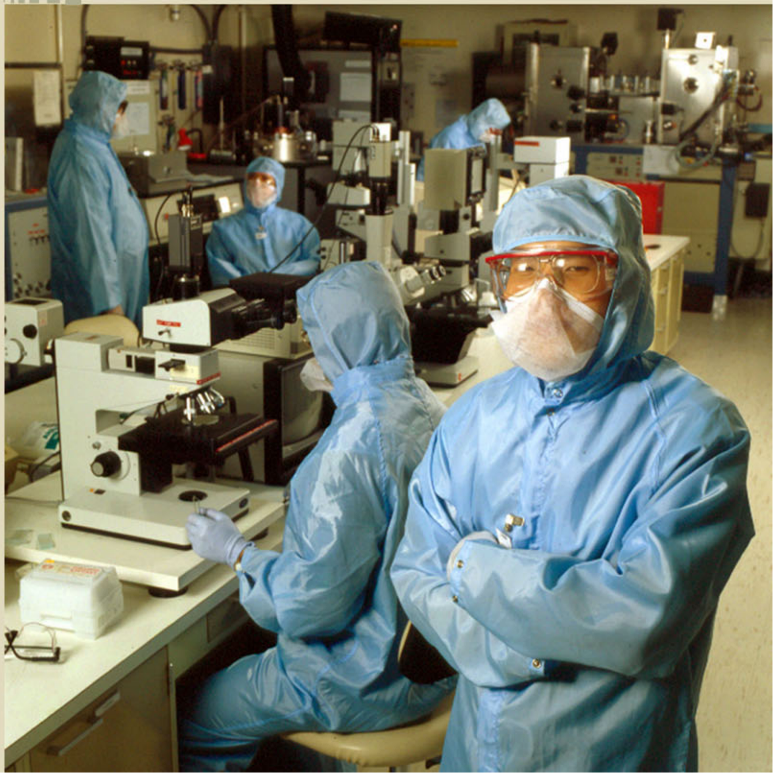
The 2002 NNUN REU Convocation

Cornell Nanofabrication Facility
August 8-10, 2002



The 2002 NNUN REU Convocation

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The 2002 NNUN REU Convocation

Hello, everyone and welcome to New York State, Ithaca, Cornell University, and the Cornell Nanofabrication Facility.

It's been a long time since we've hosted the NNUN REU Convocation and we've had fun planning for your visit, starting with our keynote speaker, Dr. Stephen Turner of NanoFluidics, Inc., a nano-company based in Ithaca that started life in our own cleanroom. Steve was a graduate student here in Cornell's School of Applied and Engineering Physics. He became a CNF User in 1994, working in the Craighead Research Group. His research led to the company he now directs and we know his success will be inspiring. Your presentations will be the main focus of the next three days, as each intern will have their 12 minutes to present. As a new addition to the convocation, we will be running a live web-cast of you and your presentations. We are very pleased that the National Science Foundation and each NNUN site will be able to tune in. We are also having a poster session to which the entire CNF User and Cornell REU communities are invited.

Since some of you are new to New York State, we want you to see and taste some of the best Ithaca has to offer. Dinner on Thursday will be at the Tower Club Restaurant on Ithaca College campus. Set on the 14th floor of the East Tower, the Tower Club offers wonderful food and a panoramic view of our beautiful hills, lakes and gorges. On Friday, we'll take a closer look at Cayuga Lake with a dinner cruise on the MV Manhattan. Joining us on the cruise will be Warren D. Allmon, Director of the Paleontological Research Institution. He'll fill us in on the local fossils, land shifts and mastodons as Cayuga Lake Cruises fills us with more wonderful food. Last but least, we'll give you option of hopping a bus to the Taughannock Falls State Park on Saturday. Once at the park, getting to Taughannock Falls is an easy walk along Taughannock Creek, but well worth it to see one the highest falls this side of the Rocky Mountains. (215 feet!) We've arranged for wonderful summer-into-fall weather so be sure to enjoy the grand outdoors that inspired our favorite local bumper sticker — Ithaca is Gorges!

We hope you enjoy the 2002 NNUN REU Convocation on every level.

Melanie-Claire Mallison
NNUN REU Program Coordinator

WEDNESDAY, AUGUST 7TH:

Everyone arrives at Cornell University (Staff at Statler, Students at Dickson Hall)

7PM at Dickson: Pizza Party/Welcome Games/Packets

THURSDAY, AUGUST 8TH:

All convocation events are being held at 101 Phillips Hall. See map on page 30.

9:00-9:30 .... Registration & Continental Breakfast

9:30-9:45 .... Welcome: Sandip Tiwari, Cornell University

9:45-10:15 .... Keynote Speaker: Stephen Turner, Nanofluidics, Inc.

(Facilitator: Sandip Tiwari, CNF)

10:15-10:27	Ms. Diane Colello, PSNF ***Hybrid Sol-Gels for DNA Transport and Immobilization***
10:27-10:39	Ms. Rose Deeter, PSNF ***The Use of Nanostructured Thin Films to Control Cell Adhesion on Patterned Surfaces***
10:39-10:51	Ms. Cara Govednik, CNF ***Fabrication of Xylophone Resonators***

10:51-11:15 .... Break

(Facilitator: Michael Deal, SNF)

11:15-11:27	Mr. Michael Adler, UCSB ***Using Butyllithium to Create Alkali Clusters in Sodium Sodalite***
11:27-11:39	Ms. Celia See-Ah Chan, UCSB ***Delivery of 10 µm Diameter Jet into Human Skin***
11:39-11:51	Mr. Hani Aldhafari, UCSB ***Dopant Incorporation of GaN Using MBE***
11:51-12:03	Mr. Robert Caldwell, SNF ***Nanotubes as Piezoresistors for a Pressure Sensor***
12:03-12:15	Ms. Amy Cosnowski, SNF ***Pyrosequencing of DNA using Electrowetting on Dielectrics***

12:15-2:15 .... Lunch & Photographer, The Plantations

(Facilitator: Greg McCarty, PSU)

2:15-2:27	Ms. Janelle Crane, UCSB ***Atomic Force Microscopy and Force Spectroscopy on Wheat Glutenins***
2:27-2:39	Mr. Mark Elias, SNF ***Simulation and Fabrication of Vertical Metal-Semiconductor-Metal Sub-Wavelength Aperture Photodetectors***
2:39-2:51	Mr. Robert Gagler, SNF ***Manufacture of Gold and Crystalline Silicon Nanowires***
2:51-3:15	Mr. Thomas Graziano, UCSB ***Electron Spin Coherence in Silicon Hall Bars***
3:15-3:27	Ms. Karrie Houston, HU ***Optimizing Flux and Rejection in Pressure-Driven Nanofiltration Membrane Processes by Exploiting Electrostatic Interactions near the Membrane Surface***

4:00-5:30 .... CNF Cleanroom Tours

Dinner at the Tower Club, Ithaca College Campus, 6:30pm to 9:00pm

FRIDAY, AUGUST 9TH:

9:00-9:45 .... Registration & Continental Breakfast

(Facilitator: William Rose, Howard)

9:45-9:57 Mr. Scott Howard, SNF
Electron Beam Energy Dissipation and Transient Induced Conductivity Profiles in E-Beam Lithography

9:57-10:09 Ms. Gizaida Irizarry, CNF
Characterization and Fabrication of Microfluidic Chambers by Hot Embossing

10:09-10:21 Mr. Jacob Jordan, CNF
A Multifactorial Approach to Optimizing T7 Immobilization to Gold-Patterned Silicon Wafers

10:21-10:33 Mr. Michael Krause, CNF
Micropatterning of Optical Waveguides and Bulk Glass

10:33-10:45 Mr. Chun-Cheng Thomas Lin, CNF
Fabrication and Characterization of Microfluidic Devices for Emulsion Polymerization System

10:45-11:15 .... Break

(Facilitator: Alexander Pechenik, CNF)

11:15-11:27 Mr. John Liu, SNF
Design, Fabrication, and Testing of Piezoresistive Pressure Sensors using Carbon Nanotubes

11:27-11:39 Ms. Kelly McGroddy, UCSB
Preparation of SiC Substrates using Hydrogen Etching for Epitaxial Growth of Nitride Heterostructures

11:39-11:51 Mr. Curtis Mead, SNF
Controlled Thinning of AlGaAs\GaAs Photocathode Structure

11:51-12:03 Ms. Schuyler Mudge, SNF
Design and Fabrication of an AlGaAs Oxidation System

12:03-12:15 Ms. Laura Zager, SNF
Design and Characterization of a AlGaAs Oxidation Furnace with Real-Time Monitoring Capability

12:15-2:15 .... Lunch, Sage Hall

(Facilitator: Krista Ehrenclou, UCSB)

2:15-2:27 Mr. Omar Negrete, CNF
Fabrication of Variable-Thickness Structures with E-Beam-Sensitive HSQ Resist

2:27-2:39 Ms. Nicole Schilling, CNF
Low Temperature Wafer Bonding and Bonding of Unconventional Materials

2:39-2:51 Ms. Jennifer Park, UCSB
A Simple Procedure for Evaluating the Contribution of a Dense Functional Group Phase to Refractive Index

2:51-3:13 Ms. Eszter Horanyi, SNF
Investigation of New Techniques for Mixing Solutions in Biology Labs on Chips

3:30-5:00 ....POSTER SESSION, Phillips Lounge

Dinner cruise on the MV Manhattan, 6:00pm to 10:00pm

SATURDAY, AUGUST 10TH:

9:00-9:33 .... Registration & Continental Breakfast

(Facilitator: James Griffin, HU)

9:33-9:45 Mr. Matthew Pickett, PSNF
Novel Materials and Processes for Electron Beam Lithography

9:45-9:57 Mr. Diego Rey, CNF
Novel Filtration Geometry: Molecular Sieves

9:57-10:09 Mr. Hector Luis Rodriguez, PSNF
Electroless Ag Coated Nanostructure Void-Column Films for Surface Enhanced Raman Spectroscopy

10:09-10:21 Ms. Trang Nguyen, CNF
Developing Biosensors Based on Organic Thin Film Transistors

10:21-10:33 Mr. Michael Shearn II, SNF
Fabrication, Characterization and Imaging of Magnetic Thin Films

10:33-11:00 .... Break

(Facilitator: Melanie-Claire Mallison, CNF)

11:00-11:12 Mr. Jason Smeltz, HU
Design and Fabrication of SiC as a High-Temperature Semiconducting pH Sensor

11:12-11:24 Ms. Mahmooda Sultana, SNF
Fabrication of Novel Silicon Pillar Transistors using Low Temperature Processing

11:24-11:36 Ms. Mamie Thant, PSNF
Nanometer-Thickness Oxide and Organic Gate Film Evaluation

11:36-11:48 Ms. Veronica Valeriano, HU
GaAsN and InGaAsN MBE Growth and Characterization

11:48-12:00 Mr. Kenneth Vampola, CNF
Growth and Characterization of Various Metal Nanocrystals

12:00-1:00 .... Lunch, Phillips Lounge

(Facilitator: Lynn Rathbun, CNF)

1:00-1:12 Ms. Kristen Van Horn, UCSB
The Effects of Doping on the Lateral Oxidation of AlAsSb

1:12-1:24 Mr. Alexandar Hansen, CNF
Characterization of a Random Copolymer Photoresist for Supercritical CO_2 Development Processes

1:24-1:36 Mr. William Whitaker, HU
Self-Assembling Diblock Copolymers as Masks for Reactive Ion Etching

1:36-1:48 Ms. Kelly Wright, PSNF
The Fabrication of Electrode Structures with Tailorable Nanometer Scale Gaps

1:48-2:00 Ms. Sara Yazdi, CNF
Characterization of a Lift-Off Material for Standard Photolithography Processing

2:00 .... Final Words from Melanie-Claire

FREE TIME / NNUN Admin Meeting / Trip to Taughannock Falls State Park

SUNDAY, AUGUST 11TH: *EVERYONE MUST CHECK OUT BY 10:30AM.*

2002
NNUN
REU
Abstracts

in order of presentation

Hybrid Sol-Gels for DNA Transport and Immobilization

Diane Colello, Biomedical Engineering, Rensselaer Polytechnic Institute

Penn State Nanofabrication Facility
Carlo Pantano, Materials Science, The Pennsylvania State University, pantano@ems.psu.edu

The sol-gel process yields an amorphous bonded silica network at low temperatures by hydrolysis condensation reactions using suitable monomers. The above statement defines the process used to synthesize our base material, hybrid sol-gels. What make hybrid sol-gels differ from ordinary sol-gels are its organic groups embedded in the silica network for chemical and/or functional modification.

The objective of this project was to synthesize and analyze the physical and chemical properties of a hybrid sol-gel. These gels were intended to interact with biomolecules such as DNA. The main objective for making particular hybrid sol-gels is its positively charged amine group that are then able to attach to the negatively charged phosphate groups in which DNA strands are made up of. Different processing strategies have been examined in an attempt to synthesize a hybrid sol-gel product in bulk form. Various systems using a variety of sol-gel monomers were investigated for optimum gelation properties yielding to a bulk product. The structural properties of selected samples were then examined to correlate the structural properties with interaction of DNA.

The Use of Nanostructured Thin Films to Control Cell Adhesion on Patterned Surfaces

Rose Deeter, Chemical Engineering, Lehigh University

Penn State Nanofabrication Facility
Dr. Stephen Fonash, Director, Penn State Nanofabrication Facility, sfonash@psu.edu
Amy Brunner, Engineering Science, Pennsylvania State University, axb914@psu.edu

Currently many on-going research projects are investigating the manipulation and interrogation of isolated cells in uniquely controllable environments. This study focuses attention on strengthening column/void silicon films to maximize cell adhesion and stability, with the ultimate goal being the production of a cell-based biosensor. The strengthening of the column/void silicon films is performed during the annealling process, which takes place in a furnace. Hepatocyte cells are deposited on the column/void silicon films, where cell adhesion and film stability are measured. This can be done using an optical as well as a scanning electron microscope. Increased cell densities coupled with high viabilities on the column/void silicon films allow determination of cell adhesion to and stability of the films.

Fabrication of Xylophone Resonators

Cara Govednik, Chemical Engineering, The University of Texas

Cornell Nanofabrication Facility
John Marohn, Chemistry, Cornell University, jam99@cornell.edu

Xylophone resonators have been fabricated as force detectors for use in Magnetic Resonance Force Microscopy (MRFM). In MRFM, magnetic resonance is detected as a gradient-dipole force between the nuclear or electronic spins in a sample and a small magnetic particle near the sample using a nanofabricated oscillator, such as a cantilever. Xylophone resonators are expected to have an increased ring down time and thus a higher quality factor in comparison to cantilevers, which therefore allows a smaller minimum force to be detected. Xylophones are also ideal for use in monolayer NMR experiments because they offer a large area to deposit the sample directly onto the resonator. So far, xylophone resonators with dimensions of 300 and 400 µm widths and 800-1500 µm lengths have been fabricated, and the determination of their feasibilty for use in magnetic resonance experiments is on-going.

Using Butyllithium to Create Alkali Clusters in Sodium Sodalite

Michael Adler, Physics, Stony Brook University

University of California Santa Barbara
Vojislav I. Srdanov, Chemistry, UCSB, srdanov@chem.ucsb.edu

Formation of Na_4^{+3} clusters in sodalite has been achieved using high temperature doping with pure metallic sodium vapor. This is believed to occur by the transfer of an electron from surface sodium followed by the inclusion of a remaining sodium ion into the sodalite cage. This ionic cluster behaves as an F center giving rise to a bluish color in the sodalite. Yoon et al. used an alternate method, namely using butyllithium as an electron donor in zeolites. Mixing sodalite and butyllithium does not cause a similar reaction because the butyllithium is too large to enter the sodalite cage, but upon exposure to light, this reaction will occur, resulting in the bluish color characteristic of F centers in sodalite. ESR spectroscopy is used to ascertain energy thresholds of the reaction and to show the species involved in the reaction as well as a means to understand the mechanisms of this reaction in the sodalite.

Delivery of 10 µm Diameter Jet into Human Skin

Celia Chan, Biological and Environmental Engineering, Cornell University

University of California Santa Barbara
Samir Mitragotri, Chemical Engineering, UCSB, samir@engineering.ucsb.edu

Pressure-driven jets have been used for intradermal delivery of a variety of drugs. In spite of their introduction into clinical medicine, variability and occasional bruising have limited their widespread acceptance. Traditional jet injectors typically produce a 150 µm diameter jet that travels 150 m/s. We report on the proposed use of a 10 µm diameter jet to deliver drugs intradermally. The formation of a jet from a 10 µm diameter nozzle has been observed with a high-speed camera. To assess the cutting power of the jets, injections have been made into polyacrylamide gels of 8-30 % acrylamide. The depth of the hole remaining in the gel along with the dispersion of the jet obtained from this experiment allows us to predict the likelihood of delivery in human skin. With the introduction of a 10 µm diameter jet, we hope to devise a jet injector incorporating an array of microjets which will eliminate the discomfort in an conventional jet injection.

Dopant Incorporation of GaN Using MBE

Hani Aldhafari, EECS, UC Berkeley

University of California Santa Barbara
Dr. James Speck, Mel Mclaurin, Materials Science, UCSB, mclaurin@engineering.ucsb.edu

The group I work with builds Field Effect Transistors (FETs) by growing layers of AlGaN on (0001) GaN, which are both grown on a (6H) SiC substrate. The growth process is done using plasma assisted Molecular Beam Epitaxy (MBE). The charge carrier's mobility in the grown heterostructure FETs is subject to halting mechanisms, namely: dislocations, impurities, and interface roughness. I have learned to characterize the grown samples using AFM, which is a method to monitor the interface of the samples (excess material, surface roughness, cracks, etc.), x-ray diffraction which gives us the orientation of the grown crystal and interplanar spacing, and the Hall Mobility test which is used to identify carriers, their concentration, and their mobility. As a member of the group, I collect the data obtained after several weeks and I organize it and try to note special patterns and correlations. During the analysis, I try to figure how pits, droplets, roughness, and other surface features influence the carrier mobility of the grown samples. Using the given tools, the goal of the group is to study what hampers the charge carriers and our aim is to reach a mobility (900-1200 cm^2/volt*s).

Nanotubes as Piezoresistors for a Pressure Sensor

Robert Caldwell, Physics, Boston College

Stanford Nanofabrication Facility
Hongjie Dai, Physical Chemistry, Stanford University, hdai1@stanford.edu

Current piezoresistors (materials whose electrical resistance changes with an induced strain) are normally made from highly doped silicon, resulting in a small patch of a chip that is highly sensitive to changes in acceleration, pressure and other basic states. One of the biggest problems with using silicon to make the piezoresistor is that its resistance is highly sensitive to changes in temperature, forcing companies to spend large amounts of money to compensate for this dependency. Instead of using highly doped silicon to make our measurements, we will be growing nanotubes, which also possess piezoresistor qualities, from catalyst islands located on the chip and use them as our piezoresistors for a pressure sensor. The nanotube will lie on the edge of a membrane that will bulge outwards due to a decrease in pressure, thus deforming the nanotube and changing its resistance. We are anticipating that due to the low temperature coefficient of the nanotubes, which is almost two orders of magnitude lower than in silicon, and increased sensitivity, we will have made a pressure sensor that will be almost as easy to make, equally efficient and significantly cheaper than the ones currently available.

Pyrosequencing of DNA using Electrowetting on Dielectrics

Amy Cosnowski, Chemical Engineering/Pre-Medical, University of Michigan

Stanford Nanofabrication Facility
Peter Griffin, Ali Agah, Electrical Engineering, Stanford University,
griffin@plumb.stanford.edu

Pyrosequencing is a technique that uses enzymatic reactions between DNA, DNA's four nitrogen bases, ATP, and light producing luciferase to accurately sequence short segments of DNA. While the current process is flexible and automated, the machinery used is expensive, cumbersome, and inefficient. In order to decrease the cost of the process, while still maintaining the current benefits, we plan on performing the process on a microchip. The creation of this so-called "lab on a chip" has been hindered by laminar flow mixing problems. To surpass this problem, we are using electrowetting on dielectrics (EWOD) to mix the substrates. Using various electrode layouts, we will measure droplet speed, mixing time, and sequence accuracy to find the most efficient design for pyrosequencing on a chip. These chips can than eventually be used to easily identify genetic diseases quickly and inexpensively.

Atomic Force Microscopy and Force Spectroscopy on Wheat Glutenins

Janelle Crane, Biochemistry and Molecular Biology, UC Santa Cruz

University of California Santa Barbara
Prof. Helen Hansma, Emin Oroudjev, Physics, UCSB, hhansma@physics.ucsb.edu

Wheat gluten has the unique property of high viscoelasticity, which is responsible for holding the structure of baked bread. High molecular weight (HMW) glutenins are thought to be one of the key protein groups in gluten that create this property. Since wheat gluten is abundant, renewable, and biodegradable, its use as a replacement for viscoelastic materials used in a variety of products is invaluable. If researchers can verify the predicted structure and organization of the glutenins, they can synthesize and modify these proteins to suit their needs. The first part of my project is choosing a procedure to isolate and semi-purify HMW glutenins from crude gluten. The second part of my project involves taking Atomic Force Microscope images of HMW glutenins which allow me to test the ability of the sample to bind to a surface, verify the amount of the sample deposited on a surface, and examine the state of the sample. Finally, I will create force curves by performing force spectroscopy on single glutenin molecules and their matrixes with the Molecular Force Probe. I am going to compare and analzye these force curves in order to gain a better understanding of HMW glutenins, structure and organization.

Simulation and Fabrication of Vertical Metal-Semiconductor-Metal Sub-Wavelength Aperture Photodetectors

Mark Elias, Materials Science and Engineering, Ohio State University

Stanford Nanofabrication Facility
Piero Pianetta, Dominik Schmidt, Electrical Engineering, Stanford University

In a Metal-Semiconductor-Metal (MSM) Photodetector, incoming photons create an electron-hole pair in a resistive silicon film placed between two electrical contacts that serve both to apply an electrical field and collect the resulting current. By controlling the thickness of the silicon, all the photo-generated electrons experience a large electric field, which quickly sweeps them to the electrodes. The use of very thin absorption layers will be explored to improve the high-speed performance of the device while maintaining a large quantum efficiency. In addition, the top electrode will be replaced with a series of sub-wavelength apertures to high-pass filter the incoming light and provide color selectivity.

Manufacture of Gold and Crystalline Silicon Nanowires

Robert Gagler, Chemical Physics, University of Colorado at Boulder

Stanford Nanofabrication Facility
Bruce M. Clemens, Materials Science Engineering, Stanford University,
Clemens@soe.stanford.edu

The current level of optical lithographic techniques for producing nanoscale structures is reaching a fundamental limit of roughly 200nm. In order to explore new methods of producing nanostructures smaller than this limit, we will be attempting two novel approaches for manufacturing gold and crystalline silicon wires of roughly 10nm in size. The first of these methods (for making gold nanowires) will consist of depositing a multilayer film (~10nm) of alternating amorphous silicon and amorphous gold/silicon layers onto a silicon wafer. The structure will be annealed, resulting in segregation of the gold and silicon. Surface energy considerations should drive the gold to the exposed edge of the multilayer, resulting in gold nanowires. The second method (for making crystalline silicon wires) consists of depositing gold nanoparticles (~5-10nm) onto a silicon wafer and then coating the particles with a film of amorphous silicon. During annealing, silicon will diffuse from the amorphous Si, through the gold, resulting in migration of the Au nanoparticles and formation of crystalline Si nanowires. In this work, we will be varying anneal temperature, composition and thickness in order to investigate and optimize these processes.

Electron Spin Coherence in Silicon Hall Bars

Thomas Graziano, Electrical Engineering, Cornell University

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David Awschalom, Vanessa Sih, Department of Physics, UCSB,
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Time-resolved Faraday rotation can be used to probe electron spin coherence in direct bandgap materials such as GaAs. A circularly polarized pump laser spin-polarizes electrons as they jump to the conduction band. If a linearly polarized probe pulse is incident on the semiconductor, its polarization is rotated by an angle proportional to the net electron magnetization of the system; this effect is called Faraday rotation and is sensitive to the spin component along the direction of the incident light.

Normally Faraday measurements would yield a decaying magnetization curve versus time. But if we subject the material to a magnetic field, the electrons in the conduction band will precess; this will produce a decaying electron magnetization sinusoid versus time. By varying the delay between the pump and probe pulses, we can observe how the spin-magnetization develops. Also, by adjusting the applied magnetic field, we can manipulate the Zeeman energy and precession frequency. But optical transitions are more complicated in indirect bandgap semiconductors (such as Si) than direct semiconductors (such as GaAs); so the effectiveness of time-resolved Faraday techniques for probing silicon is questionable. In this project, we will fabricate silicon Hall bars and attempt to probe them for electron spin coherence.

Optimizing Flux and Rejection in Pressure-Driven Nanofiltration Membrane Processes by Exploiting Electrostatic Interactions near the Membrane Surface

Karrie D. Houston, Chemical Engineering, Howard University

Howard University
Dr. Kimberly L. Jones, Civil Engineering, Howard University, kjones@scs.howard.edu

A novel method for modifying polymeric membranes was designed to render them less susceptible to fouling and flux decline. This method involves electrostatic interactions. The exploitation of electrostatic charges near the membrane surface was achieved using an ion implantation process. Due to the membranes ease of operation and their high surface area, they have recently become a promising alternative for chemical and biological sensors.

This experiment was designed to investigate the effects of ion implantation and its ability to efficiently reject contaminants while increasing the overall flux. Polyamide and cellulose acetate membranes were compared to identical ion implanted membranes through a comparison of flux and percentage rejection of specific salt ions.

Electron Beam Energy Dissipation and Transient Induced Conductivity Profiles in E-Beam Lithography

Scott Sheridan Howard, Electrical Engineering, University of Notre Dame

Stanford Nanofabrication Facility
R. Fabian Pease, Electrical Engineering, Min Bai, Applied Physics, Stanford University

As increasingly fine resolution lithography becomes more necessary, the electron beam energy dissipation profile in polymethyl methacrylate (PMMA) during e-beam lithography will need to be analyzed. One way of profiling energy dissipation is to map out the region of electron hole pairs created from electron beam energy dissipation. The increase in electron hole pairs in the dissipation region give rise to a transient increase in conductivity that can be measured to determine the width of the energy dissipation region. Metal-oxide-semiconductor test structures will be fabricated to measure this transient conductivity by measuring the current through the region when biased. The design of the test structures will be guided by Monte Carlo modeling of electron-solid interactions. Defining the lateral profile of this region will allow us to understand how energy is dissipated in PMMA, and thus understand the process by which induced storage charge from e-beam lithography can leak to the substrate.

Characterization and Fabrication of Microfluidic Chambers by Hot Embossing

Gizaida Irizarry, Mechanical Engineering, University of Puerto Rico

Cornell Nanofabrication Facility
Mandy Esch, Cornell Nanofabrication Facility, Mike Shuler, Chemical Engineering,
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Embossing provides a way for constructing microfluidic chambers in plastic. These devices can be used for drug delivery into single cells. The flow inside the chambers must be uniform and smooth in order to keep the cells from washing away. All the cells must be exposed to the same dosage of drug. To achieve this, the walls in the chamber must be even and upright. The entrance and exit of the chamber should make the flow constant throughout the chamber. The design of the entrance and exit of the chamber, as well as the fabrication method, influences the flow behavior through the chamber.

The earliest approach used to fabricate the master for embossing was Deep Reactive Ion Etching. The embossing with this master was not effective because the etching created ridges on the walls of the chambers. It is difficult to smooth out these ridges. It is better to create straight walls right from the beginning. The negative resist SU8 is used to create a pattern on a wafer that would be embossed directly to the plastic. As a very thick and strong resist, the pattern is raised, so etching is not needed. SU8 is a viscous and adhesive substance that creates a well-defined and stiff pattern. These characteristics make SU8 ideal to fabricate microfluidic chambers in plastic by hot embossing.

A Multifactorial Approach to Optimizing T7 Immobilization to Gold-Patterned Silicon Wafers

Jacob L. Jordan, Chemical Engineering, Vanderbilt University

Cornell Nanofabrication Facility
Carl Batt, Christine Campagnolo, Department of Food Science, Cornell University
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Gold-patterned silicon surfaces were created with feature sizes ranging from 2mm to 20mm as substrates for determining the optimal conditions for bacteriophage T7 immobilization. The pattern was designed using CAD software and used to create a template masking using a pattern generator. The CAD was transferred using a 5x g-line stepper. After exposure, the wafers were developed and a gold layer was evaporated onto the silicon. Following this, lift-off was performed to remove the remaining photoresist and leave the desired pattern.

The T7 bacteriophage has in its major coat protein a genetic insert to enable binding to the protein streptavidin. Using a thiol-based surface chemistry, the streptavidin will be bonded to the gold-patterned surfaces. Experiments will then be performed under varying conditions of pH and ionic strength to evaluate the binding and specificity of T7. To confirm binding of the bacteriophage and protein, fluorophores will be used for viewing with a fluorescence microscope.

Micropatterning of Optical Waveguides and Bulk Glass

Michael P. Krause, Electrical and Computer Engineering,
Wayne State University

Cornell Nanofabrication Facility
Dieter Ast, Cornell Center for Materials Research, Cornell University, dast@ccmr.cornell.edu

To manufacture microfluidic systems (MEMS) for biology and optical switching, glass provides significant advantages over the current techniques in silicon due to its optical properties and similar index of refraction to optical fibers. This project investigates the characteristics of patterning glass in the micron (bulk diffusion) and sub-micron scale (surface diffusion), using optical and advanced e-beam lithography respectively. In both cases, uniform rectangular patterns were etched into three series of seven different glass compositions (BED, BEC, BEB, BDW, BEA, BEN, and BDY). These series of samples were annealed at three different temperatures around the activation energy of the respective glass samples. The sample profiles before and after annealing were obtained to characterize the flow mechanism as the glass relaxed. The three trials per composition provided enough data to determine the exact mechanisms that control thermal stability of the desired glass type. The data collected and analyzed will provide the limitation of micron and sub-micron glass features with respect to elevated temperatures.

Fabrication and Characterization of Microfluidic Devices for Emulsion Polymerization System

Chun-Cheng Thomas Lin, Electrical Engineering,
University of Southern California

Cornell Nanofabrication Facility
James Engstrom, Chemical Engineering, Tyler McQuade, Chemistry, Cornell University,
jre@cheme.cornell.edu, dtm25@cornell.edu

A microfluidic device was fabricated in order to study dynamic pattern formation by shearing one liquid into another immiscible liquid to create droplets, known as micelles, in order to continuously produce polymer fibers. It has been shown that micelles' size and shape varies with microchannel width and the pressures of the immiscible liquids, therefore possibly affecting the properties of the resulting polymer fibers. This project employed two different processes to build the device, (1) standard lithography processing resulting in trenches that defined the microchannels, and (2) the image reversal technique resulting in a mold used for soft lithography. We first designed the channels using a CAD program, created the masks, performed the necessary proximity photolithographic steps, and finally etched the microchannel formations using the Bosch etching technique. The resulting channels were 50 µm wide and 50 µm deep, as revealed by SEM. Work is still in progress on the characterization of the device with respect to polymer fiber formation.

Design, Fabrication, and Testing of Piezoresistive Pressure Sensors using Carbon Nanotubes

John Liu, Computer Engineering, University of California at Irvine

Stanford Nanofabrication Facility
Hongjie Dai, Chemistry, Randy Grow, Applied Physics, Stanford University,
hdai@chem.stanford.edu, rgrow@stanford.edu

Single-walled carbon nanotubes (SWNTs) have been shown to exhibit the piezoresisitve effect, in which the electrical resistance of the material changes under mechanical deformation. Therefore, piezoresistive pressure sensors can be designed and built by mechanically deforming SWNTs as electrical wires. We will perform backside etching on four-inch wafers and create suspended square polysilicon membranes on the front sides. SWNTs will be grown at the center and the edges' midpoints on each membrane. Pressure will be applied uniformly on the membranes and the resistance change in the SWNTs will be measured. The potential of SWNTs as pressure sensors will be evaluated.

Preparation of SiC Substrates using Hydrogen Etching for Epitaxial Growth of Nitride Heterostructures

Kelly McGroddy, Materials Science and Engineering,
University of Pennsylvania

University of California Santa Barbara
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Hydrogen etching of (0001) silicon carbide has been studied to achieve atomically smooth, unit cell-stepped surfaces, ideal for use as substrates for epitaxial growth of aluminum gallium nitride heterostructures. AlN films, epitaxially grown on GaN on sapphire have been utilized for the growth of GaN quantum wells and quantum dots, but these films typically exhibit cracking due to the 2.5% tensile strain of AlN on GaN. SiC has been demonstrated to be a superior substrate for crack-free AlN growth because of lower in-plane lattice mismatch and closely matched thermal expansion coefficients of SiC and AlN. Commercially available SiC has many surface defects such as large scratches from polishing that lead to highly defective films. Atomic force microscopy shows that scratches can be eliminated by hydrogen etching and smooth, stepped surfaces can be achieved. Etching is carried out on (0001) oriented 6H SiC at temperatures of 1500-1700°C under hydrogen. Results depend on time, temperature, hydrogen flow rate and sample preparation. The steps that result are about 15Å in height, which corresponds to the length of the 6H SiC lattice in the <0001> direction. The step widths are several hundred nanometers and vary depending on the off-axis miscut of the sample.

Controlled Thinning of AlGaAs\GaAs Photocathode Structure

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Photocathodes are structures that receive radiation on one side and emit a photoelectric current (electrons) from the other side. They can be constructed by depositing a 3 µm layer of $Al_{0.3}Ga_{0.7}As$ and 100nm layer of GaAs on top of a GaAs wafer. Although the electron emitting side of the photocathode structure is accessible, the bulk GaAs wafer must be etched through to access the radiation receiving side, the $Al_{0.3}Ga_{0.7}As$ layer, of the photocathode. The goal of this project is to selectively remove bulk GaAs material by a controlled, repeatable wet chemical etching process, creating $Al_{0.3}Ga_{0.7}As$\GaAs photocathode membranes. Two different etchants are employed; 40:1 NH_4OH and H_2O_2, and 5:1 Citric acid and H_2O_2. Measurements on a profilometer are made periodically throughout the fast etching cycle (Citric acid and H_2O_2). When the bulk GaAs layer is down to 30 µm, further etching is done with a slower, more selective etchant, NH_4OH and H_2O_2. During the slow etching cycle, the intensity of transmitted light (840nm) through the photocathode membrane is used as an indication of when the entire GaAs substrate has been etched through, leaving only a 3 µm layer of $Al_{0.3}Ga_{0.7}As$\GaAs and a 100nm layer of GaAs.

Design and Fabrication of an AlGaAs Oxidation System

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The goal of the project I am working on is to optimize the production of vertical cavity surface emitting lasers (VCSELs). One important step in VCSEL processing is the oxidation of a current apperature through the selective oxidation of AlGaAs. Currently, oxidation of the current aperture is unstable and unpredictable, as there is no method in which you can consistently and accurately oxidize the AlGaAs layer. I am working towards making this production more accurate, stable, and predictable. I will do this by building a furnace with a viewport and a microscope hooked up to a viewing screen so you can see the oxidation in real time. In this work, I will help to design and build this apparatus. I will then observe the extent of oxidation in the AlGaAs layer in various samples in order to test and optimize this process.

Design and Characterization of a AlGaAs Oxidation Furnace with Real-Time Monitoring Capability

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Stanford Nanofabrication Facility
James Harris, Evan Thrush, Electrical Engineering, Stanford University

A crucial step in the fabrication of vertical cavity surface-emitting lasers (VCSELs) is the oxidation of an AlGaAs layer to serve as a current aperture for the laser beam. Existing oxidation furnaces require the use of test specimens to roughly calibrate the rate of oxidation and provide poor control over the process. In order to more carefully control the oxidation of the AlGaAs layer, a novel furnace has been designed and constructed with a glass viewport and imaging system to provide real-time optical monitoring of the VCSEL oxidation. It is anticipated that the system will achieve an oxidation resolution of 1 um. This performance is much better than is currently achievable in standard oxidation furnaces.

Fabrication of Variable-Thickness Structures with E-Beam-Sensitive HSQ Resist

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Hydrogen Silsesquioxane or HSQ is desirable in the electronics industry as an inter-level material because of its planarity and its low dielectric constant. We have investigated a use for this material, HSQ (Fox-17 Dow Corning Inc), for grayscale e-beam lithography to ultimately create optical devices. The main tool used for this work was the Leica VB6 e-beam writer. For preliminary data we wrote several 4x16 arrays of 20µm x 40µm and 40µm x 80µm rectangles. To find the optimal contrast curve for grayscale we varied exposure dose and development parameters. Each trial was measured by the Alphastep P-10 profilometer for resist height measurement. Profile information was gathered by the AFM by Digital Instruments for analyzing proximity effects due to electron backscatter. A structure with stepped dosing was also created in which AFM imaging revealed roughness across the height variations. O_2 plasma etching is being introduced to the process in hopes of smoothing out the roughness. Also, fabrication of an actual device is being further investigated.

Low Temperature Wafer Bonding and Bonding of Unconventional Materials

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The main focus of this project was to bond wafers of materials previously considered nontraditional to the bonding process. The two main strategies used in this study were direct bonding and anodic bonding. Various trials were implemented involving unconventional materials such as Si_3N_4, GaAs and SiC. After bonding, these materials were subjected to low anneal temperatures and compared to more traditional anneal temperatures. Other variations in these trials included different chemical pre-treatments and plasma treatments. A comparison of bonding hydrophilic and hydrophobic surfaces was conducted to determine the effects of surface alterations caused by chemical and plasma treatments. Following the bonding process, the total bonded area was analyzed to determine its effectiveness. Upon this qualitative analysis, a more quantitative approach was taken by using the blade insertion method to determine the surface energy and subsequently the bond energy. The concept of wafer bonding is potentially useful in areas involving superconductivity, MEMs and various other fields. Bonding of unconventional materials at lower temperatures could thus open up a wide variety of possibilities regarding the application of wafer bonding.

A Simple Procedure for Evaluating the Contribution of a Dense Functional Group Phase to Refractive Index

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In solvated surfactant coated surfaces there appears to be a discrepancy between measured forces, using surface force apparatus, and calculated van der Waals attraction, in which the measured attraction is always considerably bigger than the calculated one. It has been shown in one case that the difference can be ascertained to the orderly placement of functional groups within the surfactant layer by considering a layer of identical functional groups as a distinct dense phase with its distinct refractive index. In this study, we have devised a simple method for calculating the refractive index of any such functional group phase. (Surface forces are a function of the index of refraction.) Since the real functional group phase along the surfactant molecule is merely a thin shell and not a bulk phase, the orderly arrangement of functional groups is pertinent, because the refractive index is also dependent on the interaction of electron clouds between neighboring atoms. Our calculation takes this into account, and thus the same functional group may have somewhat different refractive indices for different molecules.

Investigation of New Techniques for Mixing Solutions in Biology Labs on Chips

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A major problem in producing biology labs on chips is the inability to mix the solutions needed for specific reactions. A proposed solution involves using electowetting on a dielectric, where a voltage is applied to a liquid droplet to cause it to move and resume it's original shape. With this method, different drops of solution could be brought together and mixed on a chip. For this to occur, the surface of the chip must be extremely hydrophobic.

In this work, layers of different thicknesses of a teflon like polymer are to be deposited on top of the dielectric on the chip and tested for different properties. The goal is to decrease the amount of voltage needed to move the liquid droplet while still maintaining the hydrophobicity of the surface.

Novel Materials and Processes for Electron Beam Lithography

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Benzocyclobutene (BCB) is a photosensitive spin-on dielectric that is currently being used in industry for electronic and optoelectronic device and circuit fabrication. BCB exhibits several advantages over many other dielectric materials including low dielectric constant, low tangential loss, excellent planarization properties and patternability using optical lithography. It was recently discovered that, in addition to its photosensitive properties, BCB is sensitive to exposure to an electron beam. The focus of this project was to develop an optimal electron beam lithography process for patterning BCB that provides the best resolution at the lowest possible dose. A software mask designed to determine the ultimate resolution for a variety of different feature geometries was developed in the first part of the project. The second stage was to fabricate and characterize several dose arrays using different development parameters. The dose arrays were characterized using both atomic force and scanning electron microscopy.

Novel Filtration Geometry: Molecular Sieves

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With the use of photolithographic techniques, filters can be made with constrictions in the nanometer scale. A thin silicon wafer with a layer of aluminum deposited on one side is etched from the front and back up to the interface with the aluminum. The aluminum is then etched laterally producing a restrictive passage. The thickness of the aluminum layer can be accurately controlled and is in the order of nanometers allowing for the fabrication of sieves that are specific to protein sizes. There are many possible uses for this technology including separating specific proteins from a mixture. Specifically, the capability of these sieves to separate DNA from hemoglobin will be tested. This new technology can also be implemented in a microscopic size making it easy to integrate into portable systems.

Electroless Ag Coated Nanostructure Void-Column Films for Surface Enhanced Raman Spectroscopy

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This work is focused on enhancing Ag particle deposition by using nanostructured films and on characterizing the resulting material system using Raman Spectroscopy. The goal is to create a structure that has an improved Raman signal. To accomplish this task, we make 0.001 M solutions of silver sulfate (Ag_2SO_4) and silver nitrate ($AgNO_3$) for the electroless deposition. We have found that nanostructured void-column silicon films exhibit very fast Ag deposition. We have seen that this does not happen in Si wafers.

Developing Biosensors Based on Organic Thin Film Transistors

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Biosensor transistors have the potential of detecting the presence of certain DNA strands within aqueous solutions traveling between its source and drain. The goal of this research project is to fabricate and test the functionality of transistors while: a) varying the width between the transistor's source and drain; b) varying the microfluidic channel width of the aqueous solution traveling across the transistor and; c) varying the transistor's semiconductor material. Transistor patterns with varying widths between source and drain were designed on CAD and transferred to glass masks. Gold electrodes were then patterned onto silicon wafers using standard photolithographic techniques. Different kinds of organic semiconductor materials were later deposited onto the transistors and aqueous solutions were flown across them. The current and voltage across the transistor was measured while varying each parameter. These data points made it possible to create a set of current versus voltage curves.

Fabrication, Characterization and Imaging of Magnetic Thin Films

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The aim of this work is to fabricate and characterize magnetic thin films patterned into rectangles in the 1.5 to 10 μm range. These films are patterned using various optical lithography techniques. The magnetic domains are visualized using magnetic force microscopy (MFM) and Kerr effect microscopy. Also, the susceptibility of the rectangles is measured over a wide frequency range (1 MHz to 3 GHz). The primary goal of this work is to understand the relationship between micron-scale film geometry, magnetic domains, and frequency response of the susceptibility. This knowledge can be applied to increase the bandwidth and resolution of magnetic sensors, like those used in hard drives.

Design and Fabrication of SiC as a High-Temperature Semiconducting pH Sensor

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The creation of a silicon carbide pH sensor for operation in harsh environments is being fabricated. A normal silicon pH sensor exposed to harsh conditions would fail because of two main reasons. The first being the presence of heat — silicon pH sensors are not accurate over 150°C. The second problem comes from the reactive nature of some solutions we would like to measure — silicon will not resist corrosive condition before failing. The first step of the process is to grow silicon dioxide onto a piece of SiC wafer and characterize the nature of the SiO_2 wafer (i.e. growth rate, n, etc). Then, through the process of photolithography, we created Si pH devices on the surface. The next step is to grow 3C-silicon carbide onto 6H-silicon carbide, followed by photolithography. The use of silicon first before silicon carbide is explained by the expense of silicon carbide substrates. This also will let you perfect the process, with little difference in characteristics. The final step is characterizing the device to assure its integrity.

Fabrication of Novel Silicon Pillar Transistors using Low Temperature Processing

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Crystallization of amorphous silicon at low temperature is a technique for making 3-D integrated circuits and heterogeneous integration. One of the methods for low-temperature crystallization is to introduce a metal to amorphous silicon and to anneal. The metal works like a seeding material and allows silicon to crystallize at a lower temperature. In this project, we study nickel-induced crystallization process by varying the temperature and the time of anneal, the size of pillar transistors and the stress acting on the pillars by the sidewall oxide. The results of this project will enable us to find the parameters that crystallize amorphous silicon the most.

Nanometer-Thickness Oxide and Organic Gate Film Evaluation

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Silicon oxide holds much promise as a dielectric for molecular-scale electronic devices because of its ability to be spun into nanometer-thick films. Thus study of metal-insulator-metal (MIM) structures, in which the insulator is silicon oxide, is critical. The goal of this project was to characterize SiO_2 films created by different techniques — specifically, various kinds of sputtering methods as well as the use of tetraethyl ethoxy silane-based sol-gels — both electrically and optically. Furthermore, techniques for depositing small amounts of metal to create micron-scale MIM structures on these SiO_2 films were explored. This provides a basis for making ever-smaller electronic devices.

GaAsN and InGaAsN MBE Growth and Characterization

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The addition of a few percent of nitrogen and/or indium to GaAs significantly reduces the material's bandgap, and this discovery is of great interest for opto-electronics and solar cell applications. Test samples of GaAsN and InGaAsN alloys have been grown using molecular beam epitaxy (MBE) with different doping concentrations. The first part of the characterization process involved the use of Van der Paw Hall measurements. These measurements were taken at both room and liquid nitrogen temperatures. Hall measurements were also taken at various temperatures over the range of 77K to 473K. A computer program written at Howard University was then used to calculate the activation energies of the samples from the Hall data. Second, photoluminescence was used to determine how much the bandgap has shifted after the addition of nitrogen. Last, a MODFET structure was fabricated to investigate the possibility of detecting a 2-dimensional electron gas (2DEG) between the AlGaAs-GaAsN and AlGaAs-InGasAsN layers. The results of these experiments will be shared.

Growth and Characterization of Various Metal Nanocrystals

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This project is concerned with creating and characterizing metal nanocrystals. Metal nanocrystals are deposited on a film of thermal oxide grown on a silicon substrate. They are deposited by evaporating a layer of metal onto the oxide surface. This layer is very thin, typically 1.3-1.5nm. The total energy of the film is reduced when the metal surface area is minimized by forming discrete, roughly spherical nanocrystals. This is the driving force for nanocrystal formation. Afterwards, the samples are annealed near their eutectic temperature. The time and temperature of the annealing directly impacts the size and density of the nanocrystals. Longer annealing times and higher temperatures lead to the formation of fewer but larger nanocrystals. The resulting nanocrystals were characterized by SEM imaging. Throughout this project, parameters such as the evaporated metal thickness, substrate doping type and level, annealing temperature and metal types were varied and the results compared. Finally, test structures were made to measure the contact resistance of an embedded metal nanocrystal structure.*

*Note: This last part has just been started, but it should be completed by the time of the convocation.

The Effects of Doping on the Lateral Oxidation of AlAsSb

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Professor James Speck, Max Andrews, Materials Department,
University of California Santa Barbara

Semiconductors fabricated from Group III-Group V compounds are superior to those made from silicon, allowing electronic and photonic devices to be smaller and faster. By laterally oxidizing III-V semiconductor interlayers, an oxide layer is created between the substrate and semiconducting layers, where it acts as an insulator. Also, apertures can be created in the oxide layer for transistors and lasers. For a substrate of indium phosphide (InP), aluminum arsenide antimonide (AlAsSb) is good choice for the oxidation layer, given that aluminum-bearing compounds oxidize readily. However, during oxidation, antimony segregates from the AlAsSb layer and migrates to the interfaces between the oxide and the semiconducting layers. The segregated antimony inhibits further processing of the sample. Testing the published theory that n-type doping of the AlAsSb layer would decrease the antimony segregation, samples of AlAsSb grown on gallium arsenide (GaAs) substrates were doped with silicon (Si) or tellurium (Te) to $1 \times 10^{18}/\mathrm{cm}^3$. The samples underwent wet oxidation in a vapor mixture of water:methanol. The temperature of the furnace and the concentration of the water:methanol solution were varied. Optical microscopy and high resolution x-ray diffraction were used to characterize the oxidation and antimony segregation. Results showed that neither Si nor Te doping effectively suppressed antimony segregation.

Characterization of a Random Copolymer Photoresist for Supercritical CO_2 Development Processes

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Use of supercritical CO_2 ($SCCO_2$) as a developer in photolithography has many advantages over aqueous and organic solvents currently used in industry and research. Aqueous developments cause resist pattern collapse due to capillary forces. $SCCO_2$ does not have surface tension and can remove resist without any pattern distortion. Furthermore, it is environmentally friendly and readily removes fluorinated resists, which will be crucial for future 157nm DUV photolithography.

In this study, a random copolymer of tert-butyl methacrylate and 1H, 1H-perfluoroctyl methacrylate (TBMA-F7MA) was used for 248 nm photolithography. In the past, block copolymers were used, which are much more difficult to synthesize. These are negative photoresists and reversal is necessary in order to be compatible with industry's positive-tone lithography standards. Past resolution for the block copolymers was 0.1 µm and ~1 µm for negative and positive tones respectively. Currently 1 µm features have been achieved with the TBMA-F7MA.

Self-Assembling Diblock Copolymers as Masks for Reactive Ion Etching

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Certain diblock copolymers, when applied as thin films, can be induced to "self-assemble" into films containing uniform geometric shapes on the nanoscale. These thin films can provide a means of creating masks with structures smaller than the limits of current lithography techniques.

The project objective concerned the formation of copolymer masks containing uniform dot arrays adhered to silicon substrates. A diblock copolymer composed of polystyrene and poly (methyl methacrylate) was annealed on a silicon substrate. By varying parameters (deposition spin speed, molecular weight ratio, and exposure time), the diblock copolymer formed cylindrical columns of poly (methyl methacrylate) ~ 20 nm in diameter with a spacing of ~ 45 nm. The poly (methyl methacrylate) columns were then selectively removed leaving a mask with uniformly spaced holes. The silicon substrate may then be etched by means of Reactive Ion Etching. The copolymer may then be removed leaving a silicon wafer with a porous surface. The results, which include AFM characterization micrographs, will be discussed in detail.

The Fabrication of Electrode Structures with Tailorable Nanometer Scale Gaps

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Nanometer scale gaps have been created between electrode structures using molecular rulers and traditional lithographic techniques. In this work, we utilized the ability of alkanethiol monolayers to self assemble into molecularly precise films on metallic surfaces. Using alternating layers of mercaptohexadecanoic acid and copper ions, gaps from 4-40 nm could be created between microfabricated electrodes. The Ti/Au electrode structures were created using a photolithography lift-off process. The fabricated electrode structures were characterized and utilized to probe the electronic properties of nanostructured materials.

Characterization of a Lift-Off Material for Standard Photolithography Processing

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This project is intended to characterize the process performance of a lift-off material. Metal lift-off is a method used to generate metal conducting structures on a substrate. Conventional metal lift-off is done using a chlorobenzene dip or image reversal. Despite their wide use in industry, chlorobenzene dip poses health and safety concerns because of the hazardous nature of the chemicals, and image reversal method proves to be highly time consuming. This project does not rely on either method, and optimization of the proposed process provides a cost-effective and simpler alternative to the conventional techniques of metal lift-off.

In this process, four-inch silicon wafers are spun with lift-off material and they are coated with photo resists. The photo resist is exposed using a stepper; during the development step the lift-off material is dissolved away, resulting in an undercut profile and allowing successful metal lift-off. The resulting bi-layer is inspected using optical microscopy and scanning electron microscopy (SEM). Bake temperature/duration, exposure/focus sensitivity, adhesion and ease of removal are the critical factors considered in this project.

The 2002 NNUN REU Interns

NNUN REU Intern	***Field of Study, School Affiliation***	***Principal Investigator(s)***	***Site***
Mr. Michael Adler	Physics / Math, SUNY Stony Brook	Vojislav Srdanov	UCSB
Mr. Hani Aldhafari	Electrical Engineering, Contra Costa College	Jim Speck	UCSB
Mr. Robert Caldwell	Physics, Boston College	H. Dai, Q. Wang & A. Ural	SNF
Ms. Celia See-Ah Chan	BioEngr, Cornell University	Samir Mitragotri	UCSB
Ms. Diane Colello	BioMedEngr, Rensselaer PolyTech	Carlo Pantano	PSNF
Ms. Amy Cosnowski	ChemEngr, University of Michigan	Peter Griffin	SNF
Ms. Janelle Crane	BioChem, UC Santa Cruz	Helen Hansma	UCSB
Ms. Rose Deeter	ChemEngr, Lehigh University	Stephen Fonash & A. Brunner	PSNF
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Mr. Robert Gagler	Physics/Chem, University of Colorado Boulder	Bruce Clemens	SNF
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Mr. Thomas Graziano	Electrical Engineering, Cornell University	David Awschalom	UCSB
Mr. Alexandar Hansen	ACS Chemistry, Carthage College	Christopher Ober	CNF
Ms. Eszter Horanyi	Physics/ChemEngr, Univ of Colorado Boulder	Peter Griffin	SNF
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Mr. Michael Krause	Electrical Enge, Wayne State University	Dieter Ast	CNF
Mr. Chun-Cheng Thomas Lin	Electrical Engineering, Univ of S. California	James Engstrom	CNF
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Mr. Curtis Mead	Electrical Engineering, University of Minnesota	Fabian Pease	SNF
Ms. Schuyler Mudge	Physics, University of Washington	Jim Harris & Wonnill Ha	SNF
Mr. Omar Negrete	Electrical Engr, University of New Mexico	Alan Bleier	CNF
Ms. Trang Nguyen	Electrical Engr, San Jose State University	George Malliaras	CNF
Ms. Jennifer Park	ChemEngr, University of Colorado Boulder	Jacob Israelachvili	UCSB
Mr. Matthew Pickett	EngrSci, The Pennsylvania State University	Jeff Catchmark	PSNF
Mr. Diego Rey	Electrical Engineering, UCSB	Michael Spencer	CNF
Mr. Hector Luis Rodriguez	ChemEngr, University of PR Mayaguez	S. Fonash & A. K. Kalkan	PSNF
Ms. Nicole Schilling	Physics, Corning Community College	Vincent Genova	CNF
Mr. Michael Shearn II	EE/Math/Physics, Southern Methodist University	Shan Wang & Jason Jury	SNF
Mr. Jason Smeltz	Electrical Engr, Penn State Capital Campus	Gary Harris	Howard
Ms. Mahmooda Sultana	ChemEngr, University of Southern California	Mike Deal & Yaocheng Liu	SNF
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Ms. Sara Yazdi	ChemEngr, University of MA Amherst	Garry Bordonaro	CNF
Ms. Laura Zager	Engr/Math, Swarthmore College	Jim Harris & Evan Thrush	SNF

Map of Central Cornell Campus

1 = Clara Dickson Dorm

2 = Statler Hotel

3 = 101 Phillips Hall (Upper ☼)
CNF, Knight Lab (Lower ☼)