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Nanoscale Science, Engineering & Technology

The 2004 NNIN Research Experience for Undergraduates Convocation

NSF

2004 NNIN REU Convocation
The Pennsylvania State University, August 11-14, 2004

WEDNESDAY, AUGUST 11TH, 2004

Arrive at Penn State University, University Park, PA

7:00-9:00 pm Casual Welcome Dinner-Pizza Party, *Mars Room, Johnston Commons*

THURSDAY, AUGUST 12TH, 2004

8:30-9:30am Registration and Continental Breakfast, *IST Building, Atrium (west area)*

9:30-9:45am **Welcome: Dr. Judith Todd,** *Cybertorium, IST Building*
P. B. Breneman Department Head Chair
Department of Engineering Science and Mechanics, Penn State

TIME	Location A: Cybertorium, IST Bldg	Location B: Rm. 206, IST Building	Page #
Facilitators	*Michael Deal*	*Gregory McCarty*	
9:45-10:00am	**Mr. R. Louis Alley**	**Ms. Tina Soumahoro**	**5**
10:00-10:15am	**Ms. Mary Anito**	**Mr. John Gannon**	**6**
10:15-10:30am	**Mr. Jay Gantz**	**Ms. Ana Arias**	**7**
10:30-10:45am	**Ms. Neha Bagga**	**Ms. Lynette Tally**	**8**
10:45-11:15am	**Break**	**IST Building, Atrium (west area)**	
Facilitators	*Bill Mahoney*	*Samia Sulliman*	
11:15-11:30am	**Mr. Nick Bastianon**	**Mr. William Hammond**	**9**
11:30-11:45am	**Ms. Priya Bhatia**	**Mr. Brian Goodfellow**	**10**
11:45-12:00pm	**Mr. Kevin Brady**	**Ms. Jill Gliem**	**11**
12:00-12:15pm	**Mr. Nathaniel Burt**	**Mr. Yan Zheng**	**12**
12:15-1:15pm	**Lunch**	**IST Building, Atrium (west area)**	
1:15-1:45pm	**Photo Session**		
Facilitators	*Bob Ehrmann*	*Amy Brunner*	
1:45-2:00pm	**Ms. Heather Carroll**	**Ms. Yenyun Fu**	**13**
2:00-2:15pm	**Mr. Kovner Chalumo**	**Mr. Steven Froelich**	**14**
2:15-2:30pm	**Mr. Peter Cochran**	**Ms. Elizabeth Freeman**	**15**
2:30-2:45pm	**Ms. Diana DeRosa**	**Mr. Eric Fraser**	**16**
2:45-3:15pm	**Break**	**IST Building, Atrium (west area)**	
Facilitator s	*Gary Harris*	*James Griffin*	
3:15-3:30pm	**Mr. Carl Dietz**	**Mr. Isaac Finger**	**17**
3:30-3:45pm	**Ms. Maribella Domenech**	**Ms. Diane Fields**	**18**
3:45-4:00pm	**Mr. Blake Stevens**	**Mr. Hsan-Yin Hsu**	**19**
4:00-4:15pm	**Ms. Jessica Huang**	**Mr. Brandon Karlsgodt**	**20**
4:15-4:45pm	**Bus to Dorms**		
6:30-7:00pm	**Bus to Nittany Lion Inn**		
7:00-8:45pm	**Dinner at Nittany Lion Inn**		

8:00-8:45pm **Keynote Speaker, Dr. Hiroshi Ohmoto**
"The Evolution of Atmosphere and Biosphere"
Professor of Geochemistry and Director of the Penn State Astrobiology Research Center
Department of Geosciences, The Pennsylvania State University

8:45pm **Bus to Dorms**

FRIDAY, AUGUST 13TH, 2004

9:00-9:30am Registration and Continental Breakfast, *IST Building, Atrium (west area)*

TIME	Location A: Cybertorium, IST Bldg	Location B: Rm. 206, IST Building	Page #
Facilitators	*Angela Berenstein*	*Sandrine Martin*	
9:30-9:45am	**Ms. Lisa Krueger**	**Mr. Edward Kung**	**21**
9:45-10:00am	**Mr. William Lee**	**Mr. Nate Miller**	**22**
10:00-10:15am	**Mr. Eric Moore**	**Mr. William Moss**	**23**
10:15-10:30am	**Mr. Brad Newsome**	**Ms. Mai Ng**	**24**
10:30-11:00am	**Break**	**IST Building, Atrium (west area)**	
Facilitators	*Kathryn Hollar*	*Samia Sulliman*	
11:00-11:15am	**Mr. Kabongo Ngandu**	**Mr. Khiem Nguyen**	**25**
11:15-11:30am	**Mr. Alexander O'Day**	**Mr. Nathan Olds**	**26**
11:30-11:45am	**Ms. Vaidehee Padgaonkar**	**Ms. Heyjin Park**	**27**
11:45-12:00pm	**Mr. Peter Philips**	**Mr. Sean Pursel**	**28**
12:00-1:30pm	**Lunch**	**IST Building, Atrium (west area)**	
Facilitators	*Bill Mahoney*	*Bob Ehrmann*	
1:30-1:45pm	**Ms. Rena Rudavsky**	**Ms. Marjan Saboktakin**	**29**
1:45-2:00pm	**Mr. Ludwig Salomon**	**Mr. Francis Sammy**	**30**
2:00-2:15pm	**Mr. Steven Santangelo**	**Mr. John Sarik**	**31**
2:15-2:30pm	**Mr. Cortland Setlow**	**Mr. Shahid Shaikh**	**32**
2:30-3:00pm	**Break**	**IST Building, Atrium (west area)**	
3:00-4:30pm	**Poster Session**		
4:30pm	**Bus to Dorms**		
5:00pm	**Bus leaves Dorms for Tussey Mountain**		
5:30-9:00pm	**Dinner/Recreation at Tussey Mountain**		
9:00pm	**Bus to Dorms**		

SATURDAY, AUGUST 14TH, 2004

9:00-9:30am Registration and Continental Breakfast, *IST Building, Atrium (west area)*

TIME	Location A: Cybertorium, IST Bldg	Location B: Rm. 206, IST Building	Page #
Facilitators	*Greg McCarty*	*Mike Deal*	
9:30-9:45am	**Mr. Gregory Slavik**	**Mr. Allen Yang**	**33**
9:45-10:00am	**Ms. Margo Smith**	**Ms. Alyssa Xia Wu**	**34**
10:00-10:15am	**Ms. Danielle Gainor**	**Mr. James Willett**	**35**
10:15-10:30am	**Ms. Tabitha Staniszewski**	**Mr. Rogers Whitlock Jr.**	**36**
10:30-11:00am	**Break**	**IST Building, Atrium (west area)**	
Facilitators	*Amy Brunner*	*Gary Harris*	
11:00-11:15am	**Ms. Nicole Staszkiewicz**	**Mr. Steven Virost**	**37**
11:15-11:30am	**Ms. Briony Horgan**	**Mr. Damian Vaughan**	**38**
11:30-11:45am	**Mr. Alexander Stolyarov**	**Mr. Paul Vallett**	**39**
11:45-12:00pm	**Ms. Patricia Tillman**	**Mr. Marshall Silver**	**40**
12:00-12:15pm	**Closing Comments**		
12:15-1:00pm	**Lunch**	**IST Building, Atrium (west area)**	
1:00-2:30pm	**Penn State Nanofabrication Facility Tours**		
2:30pm	**Free Time for Interns**		
2:30-3:30pm	**NNIN Administrative Mtg**	**Cybertorium, IST Building**	

The 2004 NNIN REU Convocation
The Pennsylvania State University
August 2004

2004 NNIN REU Abstracts in Order of Presentation:

A LOCATION A

Nanoelectromechanical Devices Based on Suspended Carbon Nanotube and Ge Nanowire Field Effect Transistors

Robert Louis Alley, Engineering Physics, Cornell University
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: Hongjie Dai, Department of Chemistry, Stanford University
REU Mentor: Qian Wang, Department of Chemistry, Stanford University
Contact: hdai1@stanford.edu

Semi-conducting carbon nanotubes and germanium nanowires are desirable field-effect transistor (FET) elements because of their unique electrical properties and physical stability. Previous electromechanical measurements on CVD-grown suspended carbon nanotubes have shown that the band-gap of the tube can grow or shrink depending upon both the tube's chirality and on a tensile or perpendicular force from an AFM tip.

Shorter PECVD-grown tubes exhibit higher percentages of semi-conducting rather than metallic tubes. We are developing a process to suspend PECVD-grown nanotubes and germanium nanowires in FET's and to take similar measurements to determine the mechanical as well as electromechanical properties of nanotubes and nanowires. We will be investigating the compatibility of PECVD with previous techniques for measuring CVD-grown tubes by first fabricating and then measuring nanotube devices. In parallel, we will be exploring techniques to suspend nanowires in FET's, which has not yet been accomplished. AFM cantilever deflection and I-V curves will be used to obtain results.

B LOCATION B

Surface-Enhanced Raman Scattering Substrates: Highly Sensitive Sensors for the Detection of Adsorbate Molecules

Tina Soumahoro, Bio-Chemistry, Rosemont College
NNIN REU Site: Penn State Nanofab, Pennsylvania State University
Principal Investigator: David Allara, Penn State Nanofabrication Facility/Material Research Institute and Department of Engineering Science and Mechanics, The Pennsylvania State University
REU Mentor: Gregory S. McCarty, Penn State Nanofabrication, The Pennsylvania State University

Surface-enhanced Raman spectroscopy is one of the most sensitive tools for the detection of adsorbate molecules on roughened metal surfaces down to the spectra of a single molecule. Surface enhanced Raman scattering techniques increase the intensity of Raman signals, commonly observed on the order of 10^4-10^6, to as high as 10^{14}. Electromagnetic (EM) and chemical (CHEM) mechanisms concurrently contribute to the enhancement factor (EF) on the order of 10^6. The EF is acquired by the interaction of a photon with the vibrational state of molecules adsorbed on metal features. SERS substrates, consisting of nano-scale surface roughened Au particles on SiO_2\Si wafers, were manufactured by electron-beam lithography in combination with the molecular rulers method of self-assembled multilayered resists. The initial Au posts (~100 nm in diameter with 300 nm spacing) were defined by thermal deposition of a Cr/Au layer onto developed e-beam samples followed by a lift-off process. Subsequent daughter structures were defined by alternating self-assemble monolayers of an alkanethiol and coordinated metal ions to produce features with ~20 nm spacing. The EM effect, associated with roughen metal surface and decreased interparticle separation, has the most significant contribution to the overall EF. The CHEM effect was obtained by the electronic coupling of 4-nanobenzenethiol molecules adsorbed on the roughened Au features. A confocal Raman optical microscope with an incident Ar^+ laser of 514 nm collected the spectral measurements for the 4-NBT adsorbed on the SERS substrates.

A LOCATION A

Fabrication of Microfluidic Channels with Integrated Transducers for Fluid Pumping

Mary Anito, Biomedical Engineer, Johns Hopkins University
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: Pierre Kyuri-Yakub, Electrical Engineering, Stanford University
REU Mentor: Goksen G. Yaralioglu, Electrical Engineering, Stanford University
Contact: khuri-yakub@stanford.edu

The ability to fabricate miniaturized channels for the handling of biofluids is helping to advance the biomedical field. To further develop the use of these channels, we are incorporating transducers, which allow for pumping of fluids throughout the system. After etching channels into a double-side polished silicon wafer, the wafer will be placed between two quartz wafers. Once this construction is completed, transducers will be added on top.

Transducers convert electrical energy into sound waves. The generated sound waves in the channel will serve the purpose of exerting radiation pressure on the fluid allowing for the mixing of the fluids and pushing them though the channel. We are testing the use of sound radiation to facilitate movement of fluids through the channels.

The overall layout we are using has already been created but we are trying to consolidate this fabrication into a very compact device with channels formed in a complex geometric layout. Once constructed, we will be monitoring the movement of fluid throughout the channels by taking pictures with a CCD camera. By knowing the time between pictures and trajectory of the particles in the channel, we will be able to measure the fluid velocity. Our success will be measured by whether or not liquid flows through the system. Eventually, through use of these developed channels and transducers, advancements in the field of microfluidics can be made.

B LOCATION B

Process Development for Novel Fibrous MEMS Structures

John Gannon, Mechanical Engineering, University of California Santa Barbara
NNIN REU Site: Cornell NanoScale Facility, Cornell University
Principal Investigator: Michael Thompson, Materials Science and Engineering, Cornell University
REU Mentor: Shahyaan Desai, Material Science and Engineering, Cornell University
Contact: mot1@cornell.edu

Micro Electronic Mechanical Systems (MEMS) have been developed primarily using isotropic materials such as silicon, and are processed using traditional semiconductor fabrication techniques. It is of interest to investigate other materials which exhibit anisotropic material properties, that allow for the design and development of specifically tailorable micro-mechanical structures.

Fibrous materials display a broad range of anisotropic behavior depending on the type of material they are composed of. This project focused on the development of a simple fabrication process to incorporate fibrous materials into MEMS structures.

Since cantilevers are the most basic of MEMS structures, a fabrication process was developed to make graphitic fiber-based cantilevers on silicon wafers using conventional photolithography, wet and dry etching techniques. Currently, the devices fabricated are undergoing testing to characterize their mechanical behavior.

A LOCATION A

Diffusion of Electrolyte Solutions in Nanoporous Thin-Films

Jay Gantz, Mechanical Engineering, Franklin W. Olin College of Engineering
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: Reinhold H. Dauskardt, Materials Science Engineering, Stanford University
REU Mentor: Eric P. Guyer, Materials Science Engineering, Stanford University
Contact: dauskardt@stanford.edu

A number of next generation nano-scale devices require nanoporous thin films for advanced functionality. Though such materials are currently available, the chemical interactions the films will encounter during standard manufacturing processes are not well understood and can potentially limit the practical effectiveness of the films.

We are studying the diffusion of electrolytic solutions through 400 nm thick films with porosities ranging from ~50 to ~10 vol.%. The solutions selected for testing are similar to those that might be employed during manufacturing or in service. We are observing the diffusion front using an optical microscope, tracking the diffusion front distance and velocity, ultimately allowing the determination of diffusion coefficient and activation energies for the films.

Preliminary data suggests that the diffusion rate is indeed very sensitive to aqueous solution chemistry. We will elucidate the chemical mechanisms responsible for these differing rates.

B LOCATION B

The Media Coverage of Nanotechnology

Ana I. Arias, Computer Engineering & Business Economics with emphasis in Accounting, University of California Santa Barbara
NNIN REU Site: Cornell NanoScale Facility, Cornell University
Principal Investigator: Bruce Lewenstein, Communication Department & Science and Technology Studies Department, Cornell University
Contact: B.Lewenstein@cornell.edu

Work on the social and ethical issues surrounding the emerging field of nanotechnology has long been supported by the nano community. Some of the key issues being discussed among this group are ethical, legal, economical, business-related, or political in nature. A preliminary content analysis was completed last summer as a first effort at exploring the extent to which such social and ethical issues are reflected in the media and in public opinion. Articles relating to nanotechnology published between the dates of 1 January 1986 and 30 June 2003 in the New York Times, Washington Post, Wall Street Journal, and Associated Press were used in an analytical approach similar to a study done in Europe regarding the field of biotechnology. The focus of this project is to update the existing preliminary analysis by coding articles published from the dates of 1 July 2003 to 30 June 2004 and to pursue the analysis in greater depth. The work involves identifying and retrieving media stories using computer databases, reading the stories and coding their content based on the prominence of themes, perspectives and positive or negative assessments, entering the data into a statistical database, and analyzing the results.

A LOCATION A

Anion Exchange in GaAsSb/GaInAs Interfaces

Neha Bagga, Electrical Engineering, Oklahoma State University
NNIN REU Site: Microelectronics Research Center, University of Texas at Austin
Principal Investigator: Archie L. Holmes, Jr., Electrical Engineering, University of Texas
Contact: Archie.Holmes@engr.utexas.edu

The objective of this project is to investigate and study the anion exchange process at the interfaces of GaAsSb/GaInAs hetrostructures. These superlattices were grown using Molecular Beam Epitaxy and characterized using High Resolution X-Ray Diffraction (HRXRD). GaInAs exposed to Sb_2 flux and GaAsSb exposed to Sb_2 and As_2 flux were studied in this work. The composition and thickness profiles of these grown samples were further determined using fully dynamical simulations.

The analysis shows that approximately 20% exchange takes place on the GaInAs interface where the thickness is dependent on the time of exposure. It appears that the simulations are not sufficient to analyze the GaAsSb to As_2 flux.

B LOCATION B

Effect of Solution pH on the Retention and Flux of Aqueous Solutions of G_3-NH_2 PAMAM Dendrimer by Regenerated Cellulose Ultrafiltration Membranes

Lynette Tally, Biology, Tennessee State University
NNIN REU Site: Materials Science Research Center of Excellence, Howard University
Principal Investigator: Dr. Mamadou Diallo, Department of Civil Engineering, Howard University
REU Mentor: Dr. Piraba Swaminathan, Civil Engineering, Howard University
Contact: mdiallo@howard.edu

A PAMAM dendrimer (from Greek *dendra* for tree) is an artificially manufactured or synthesized molecule built up from branched units called monomers and can be used to remove ions from water systems. It is removed through Polymer Enhanced Ultrafiltration (PEUF), which uses partially permeable membranes to separate fluids or ions. Experiments with dendrimer to remove metal ions have been performed; however, this paper will discuss how an aqueous solution, with dendrimer alone, filters through an ultrafiltration membrane.

The focus of the project is to filter the dendrimer solution through Regenerated Cellulose (RC) membranes, so that we can (a) observe the surface of membranes with Atomic Force Microscopy (AFM), (b) observe the concentration of dendrimer using Ultra-Violet Visible Spectrophotometer (UV), and (c) also study flux with time. The pH of solution is adjusted before being filtered through the RC membrane (3k Dalton). During the ultrafiltration process, the solution filters through a RC membrane. Filtered samples are collected in ten minute increments to record the weight while combining the samples after thirty minutes to observe the concentration. The expected results of the project should be that the concentration of dendrimer and flux of the samples should decrease as time increases.

A

LOCATION

A

Measuring the Electrical Properties of Molecules via Nano-Gap Metal Electrodes

Nickolas Bastianon, Chemistry, University of California Santa Barbara
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: Hongjie Dai, Chemistry, Stanford University
REU Mentor: Ali Javey, Chemistry, Stanford University
Contact: hdai1@stanford.edu

The ability to measure the electrical properties of individual molecules is a crucial step enroute to the possible use of molecules in transistors. Measuring the electronic properties is limited by difficulties encountered when trying to capture a single molecule and place it between the two electrodes.

In this work, we are developing a new process to make such measurements possible. Using conventional photolithography, a procedure is being developed to create nano-gap metal electrodes on a wafer scale. During fabrication, the source and drain are connected, and this connection is designed to have a weak spot, which can easily be broken with an applied voltage. The actual size of the gaps can be determined by measuring the tunneling current across the gap. The molecule can be trapped in the gap by placing the electrode in a dilute solution of the desired molecule. Once the molecule is trapped, the electrical properties can easily be measured using standard procedures.

B

LOCATION

B

Etching and Characterization Studies of Ag/n-Si Nanocomposite Films

William Hammond, Physics, College of William and Mary
NNIN REU Site: Materials Science Research Center of Excellence, Howard University
Principal Investigator: Clayton W. Bates, Jr., Electrical Engineering, Howard University
REU Mentor: Juan White, Electrical Engineering, Howard University
Contact: bates@msrce.howard.edu

Studies were done on Ag/n-Si composite films 3 μm thick prepared by magnetron co-sputtering. This process creates a material with uniformly embedded Ag particles in an n-Si matrix. This material will be used in a photodetector for absorption of wavelengths from 8-14 μm.

The purpose of this project is to characterize samples prepared at different sputtering temperatures to determine which will create the most efficient device. During sputtering, however, some Ag particles coalesce and rise to the surface to create a segregated monolayer. In order to characterize the optoelectronically sensitive composite layer, this segregated layer must be removed. Both wet etch and dry etch techniques were employed. Resistivity measurements by a four-point probe were taken to determine when, during the etching process, the segregated layer was removed; SEM imaging was used to confirm these conclusions.

It was found that the etching processes not only removed the surface segregated layer, but also altered the physical structure of the composite layer below. Once the segregated layer was removed, Hall Effect measurements were taken to find the electrical transport properties of the Ag/n-Si composite.

A LOCATION A

Selective Oxidative Patterning of Self-Assembled Monolayers on AU

Priya Bhatia, Chemical Physics, Rice University
NNIN REU Site: Penn State Nanofab, Pennsylvania State University
Principal Investigator: Paul S. Weiss, Chemistry & Physics, Pennsylvania State University
REU Mentors: Amanda Moore and Adam Kurland, Chemistry, Pennsylvania State University
Contact: stm@psu.edu

Self-assembled monolayers (SAMs) of organothiols on gold are well-recognized for their use in applications such as surface patterning and nano-lithography. The sulfur headgroups of the organothiols covalently bind to metal forming a thin film of ordered molecules. SAM oxidation converts stable thiolates into weakly-bound sulfonates and sulfinates that are easily displaced by new thiols in solution. Ambient air, ozone, and ultraviolet light have all been implicated in SAM oxidation. Although these agents have been successfully used to fabricate simple patterns of alternating oxidized and non-oxidized species at the micron scale, the full potential of oxidative patterning has yet to be explored. Specifically, the possibility of selectively oxidizing different organothiols using various combinations of oxidative agents could lead to patterning applications with nanoscale resolution. SAM oxidation chemistry is highly complex and the precise oxidation mechanisms by which environmental conditions interact with SAM structure and functionality are far from clear. We report several new methods for 1) elucidating the oxidation reaction dependence on oxidative agents and organothiol traits i.e. chain length and functionality 2) fabricating oxidized surface-patterns. Our methods utilize commonly available tools and instruments, and afford ease and simplicity in comparison to conventional methods.

B LOCATION B

Self-Assembled Monlolayers for Adhesion Control in Fiber-Reinforced Polymers

Brian Goodfellow, Materials Science and Engineering, Cornell University
NNIN REU Site: Microelectronics Research Center, University of Texas at Austin
Principal Investigator: Kenneth M. Liechti, Aerospace Engineering and Engineering Mechanics, University of Texas at Austin
Contact: kml@mail.utexas.edu

A fiber pullout test for examining controlled interfaces in fiber reinforced polymers has been designed and demonstrated. This test has been utilized in determining interfacial fracture toughness for sapphire/epoxy single fiber composite specimens. Some of these specimens incorporated a self-assembled monolayer at the sapphire/epoxy interface as a means of adhesion control—thus altering its interfacial fracture toughness. The application of self-assembled monolayers as controlled interfaces has a wide variety of applications in composite materials—predominantly in MEMS applications where near-frictionless interfaces are desired. The understanding and characterization of these self-assembled monlolayers as fiber/polymer interface adhesion control is crucial to their potential in future applications.

LOCATION A

Microwells for DNA-Sequencing on Chip

Kevin Brady, Biomedical Engineering, Johns Hopkins University
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: Peter Griffin, Electrical Engineerng, Stanford University
REU Mentor: Ali Agah, Electrical Engineering, Stanford University
Contact: griffin@plumb.stanford.edu

One of the methods for microdroplet actuation is electrowetting, which involves using an electric field to modify the wetting behavior of a nano-liter sized droplet that is in contact with an insulated electrode. Electrowetting allows for controlled dispensing, transport, mixing, and splitting of large numbers of these droplets across electrode arrays, without the use of pumps or fixed continuous-flow channels. We extend the use of the electrowetting device to DNA sequencing on a silicon wafer. In our study we designed and built arrays of electrodes, wired to a series of programmable control pads, which will facilitate dispensing of droplets containing one of four nucleotides and DNA polymerase. The droplets containing these reagents will be transported automatically across the electrode grid to a bead of DNA, which has been immobilized by a magnet. As a result of incorporation of the nucleotide, a pyrophosphate molecule is released, which will be converted to ATP and produce light in a cascade reaction involving several enzymes. The droplet containing the products of the pyrosequencing cascade reaction will then be transported automatically to a site away from the reagents for detection of visible light. By utilizing the electrowetting device to perform miniaturized pyrosequencing of DNA, the development of a more reliable, higher-automated sequencing technology is in sight.

LOCATION B

Spreading of Cells on Supported Peptide Amphiphile Bilayer Membranes

Jill L. Gliem, Chemical Engineering, Lehigh University
NNIN REU Site: Materials Research Lab, University of California Santa Barbara
Principal Investigator: Matthew Tirrell, Chemical Engineering, UC Santa Barbara
REU Mentor: Dimitris Stroumpoulis, Chemical Engineering, University of California Santa Barbara
Contact: Tirrell@engineering.ucsb.edu

Peptide amphiphile bilayer membranes, once fully understood, will have a variety of uses in medical research. A couple of these areas include *in vitro* organ synthesis and cell specific drug delivery. Currently, work is being done to determine a composition of lipid and peptide amphiphile that will facilitate cell adhesion and spreading. Vesicle solutions of synthetic (or natural) lipids and peptide amphiphiles are prepared. These vesicles are allowed to rupture onto a hydrophilic glass substrate and subsequently a bilayer will form. Mouse fibroblast cells are introduced to the bilayer environment and allowed to adhere for six hours. After the time has passed, the bilayers are visualized with optical and fluorescent microscopy to see if any spreading occurred. To quantify these results, Scion Imaging software is used to determine the shape factor of the cells.

A LOCATION A

Design and Fabrication of a Tapered Waveguide in Aluminum Gallium Arsenide (AlGaAs) for Coupling Light in Nanoscale Optoelectronic Devices

Nathaniel Burt, Electrical Engineering, Kansas State University
NNIN REU Site: Stanford Nanofabrication Facility, Stanford University
Principal Investigator: James S. Harris, Electrical Engineering, Stanford University
REU Mentor: Luigi Scaccabarozzi, Applied Physics, Stanford University
Contact: harris@snowmass.stanford.edu

Modern optical communications networks make extensive use of wavelength-division multiplexing (WDM) in order to maximize data throughput. Researchers have shown that non-linear optical materials, particularly $LiNbO_3$ and (more recently) $Al_xGa_{1-x}As$, can be used to all-optically convert one wavelength into another. While typical frequency-conversion devices in use today require that optical signals be transformed by power consuming electrical circuitry, all-optical devices require power only in the form of the incident optical beams and have conversion rates determined only by the propagation time of light through the devices. Our work is concerned with improving the coupling efficiency into existing submicron-scale AlGaAs waveguides having an embedded microcavity. This is achieved by adding a tapered structure at each end, which allows for significantly greater coupling at both the input and the output.

We have optimized certain geometrical parameters of the devices through semi-vectorial 2-D finite-difference frequency-domain simulations. We will employ the well-documented selective oxidation of $Al_xGa_{1-x}As$, which depends primarily on layer thickness and Al mole fraction, in fabricating the tapered ends. After fabricating the devices, we will thoroughly analyze their optical characteristics.

B LOCATION B

Biosensors on Surface Acoustic Wave Phononic Band Gap Structures

Yan Zheng, Electrical Engineering, University of California San Diego
NNIN REU Site: Microelectronics Research Center, Georgia Institute of Technology
Principal Investigator: Dr. William D. Hunt, Electrical Engineering, Georgia Institute of Technology
Contact: bill.hunt@ee.gatech.edu

Already proven in a wide array of industrial applications, surface acoustic wave devices (SAWs) also have been demonstrated to hold substantial potential in the biosensor arena. Currently, SAW resonators coated with a biolayer can distinguish specific biomolecules in both liquid and vapor phases. By incorporating periodic perturbations in the design of a SAW delay line, we were able to introduce a phononic band gap in the propagation of surface waves. With the coating of a specific biolayer on these band gap structures, we looked at how the phononic crystal affected the detection of molecules. Finally, we will discuss our results and compare them with current acoustic wave biosensors.

A LOCATION A

Etch Resistance of Polymers used in Supercritical Carbon Dioxide Development

Heather Carroll, Chemical Engineering and World Literature, North Carolina State University

NNIN REU Site: Cornell NanoScale Facility, Cornell University

Principal Investigator: Christopher Ober, Materials Science and Engineering, Cornell University

REU Mentor: Nelson Felix, Chemical and Biomolecular Engineering, Cornell University

Contact: cober@ccmr.cornell.edu

Photoresists are commonly developed in such corrosives as tetra-methyl ammonium hydroxide. Supercritical carbon dioxide development offers a more environmentally-friendly alternative, as it is readily available for use and very easy to recycle or discard. Reactive Ion Etch testing using oxygen and trifluoromethane gases is being performed on photoresists that become soluble or insoluble in supercritical carbon dioxide upon ultraviolet exposure. The photoresists being analyzed include positive-tone fluorinated photoresists containing perflurooctyl methacrylate groups, negative-tone silicon-containing polystyrene-based photoresists and positive-tone polysilesquialazane photoresists. Current research yields data that shows the fluorinated photoresists have the least etch resistance of the three sets previously mentioned. The silicon-containing polystyrene-based photoresists etch at about half the speed of the fluorinated resists, most likely due to their lack of fluorine and negative-tone behavior. This etch data is currently being used to further the characterization of these photoresists for their use in development in supercritical carbon dioxide.

B LOCATION B

Nanoscale Cantilevers for Ultrasonics and Nanoscale Folding

Yenyun Fu, Electrical Engineering, University of California Santa Barbara

NNIN REU Site: Cornell NanoScale Facility, Cornell University

Principal Investigator: Amit Lal, Electrical Engineering, Cornell University

REU Mentor: Serhan Ardanuc, Electrical Engineering, Cornell University

Contact: al274@cornell.edu

The aim of this project is to fabricate nanoscale cantilevers and to demonstrate the ability to write charge onto the cantilevers. We will investigate the use of a conductive AFM and radioactive beta-emitting probes, to inject charge into thin film sandwiches that can store charge. We propose to investigate charging nanoscale oxide/nitride interfaces that can hold charges at the interface traps. This approach will allow us to make multiplayer charge sheets with mechanical hinges that can eventually fold in a predictable manner. The rationale behind this approach is two-fold. Firstly, a scanned probe method to develop arrays will allow the group to investigate many of the predicted phenomena (and discover new ones) in a fast and rapid manner. Secondly, the ability to charge sheets that when released can fold into 3D shapes under the influence of electrostatic forces programmed into the arrays. The first part of this project was focused on writing and reading charge with the AFM with both lift mode and phase locking methods. Next, cantilever structures consisting of oxide/nitride layers were fabricated to write charge. The sacrificial layer of the cantilevers will then be etched and we will observe whether the programmed charge survives the etch.

A LOCATION A

Silicon Carbide MEMS-ph Meter

Kovner Chalumo, Computer Engineering, Howard University
NNIN REU Site: Materials Science Research Center of Excellence, Howard University
Principal Investigator: Gary L. Harris, Ph.D., P.E., Electrical Engineering, Howard University
REU Mentor: Abhishek Motayed, Electrical Engineering, Howard University
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This paper focuses on the design and characterization of a micro-implantable telemetric system used for monitoring inter-arterial blood pressure, primarily monitoring parameters (physical dimensions, inductance, capacitance, resistance) of the device that effectively modify the efficient transmission of power. Evaluation and characterization of an implantable telemetric unit is of grave importance because of several parasitic electrical effects that occur when transmitting EM waves at high AC frequencies. These parasitic electrical effects are responsible for attenuating signal degradation and several other hindering phenomena. There are minimum requirements that this system must fulfill; this system must be powered remotely, ergo, doing so efficiently, consume low power and present little, if any effects to the human body. Silicon carbide technology offers interesting perspectives for inter-arterial, inter-cranial and inter-ocular sensor development.

B LOCATION B

New Materials and Applications of Nanoimprint Technology

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Nanoimprinting is a lithographic process that provides a simple and efficient way of patterning nanostructures. The primary motivation for accurate and efficient nanolithography is the ability to create smaller functional device structures, such as those found in nanoscale transistors. In nanoimprint lithography, a rigid mold that contains nanosized features is duplicated into a polymer material under prescribed temperature and pressure conditions. Nanoimprint lithography presents new challenges for further optimization of the technology. There is a demand for new materials with properties more appropriate for the particular requirements of nanoimprinting. The focus of this project is to analyze a new graft copolymer material. By investigating the spin coating rate, the plasma based anisotropic etching characteristics and the imprinting conditions, the material was tested for properties suitable for the imprint application. Comparing these results with other industry standard thermoplastics, this material offers some unique properties for high-throughput patterning of nanostructures.

A LOCATION A

Nanometer-Scale Lithography Using an Atomic Force Microscope

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With the current development of nanoscale mechanisms, the necessity to create < 50 nm features on surfaces is becoming an important ability for researchers to have. Current lithography tools are either too inadequate or too expensive, e.g. Optical and Electron-Beam lithography, for modest researchers to employ, which has led to the development of Atomic Force Microscope (AFM) Lithography. AFM Lithography is an emerging technology praised for its cost-efficient potential to create < 50 nm (as low as 10 nm) features on silicon and other substrates. However reproducibility issues have plagued researchers in realizing this tool's potential. During our research, we have discovered key methods to resolve these issues to make AFM Lithography a robust tool. These methods include using non-contact mode microscopy during oxidation to reduce AFM tip wear, and increased control of oxide size. Controlling variables such as tip voltage, scan height, scan speed, and humidity enable the user to systematically calibrate the size of the oxide written. Through these methods we were able to consistently produce oxide lines 50 nm in width, 1 nm in height and several microns in length, and were able to reproduce these lines over 30 times without sign of tip decay.

B LOCATION B

Living Microorganisms Entrapped in Nano-Structured Latex Formulations Piezoelectrically Printed onto Bioelectronic Devices

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Using piezoelectric deposition, living microorganisms in a latex formulation can be printed onto bioelectric devices for mercury (Hg^{+2}) detection. When *Escherichia coli* containing the mer-lux plasmid is entrapped in a nano-porous latex ink it survives piezoelectric printing, drying, rehydrating, and being induced with Hg^{+2} to luminescence through Lux synthesis. The reactivity of *E. coli* mer-lux when printed in dot arrays with two piezo tips (diameter: 25 μm and 50 μm) was examined by inducing with 1 to 10,000 nM Hg^{+2}. The ability of *E. coli* to survive piezoelectric deposition and the necessity of forming nano-pores in the dried latex ink was investigated. Reactive microbial inks have many potential applications such as detecting mercury in the environment, in fish, or in metal recovery.

A LOCATION A

Biomaterials in Microsystems: An Investigation of the Effect of Parent Ti Microstructure on the Morphology of Nanostructured Titania

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Nano-structured titania (ns-TiO_2) has many desirable properties for integration into biological systems and nano/micro electrical mechanical systems (N/MEMS). Ns-TiO_2 is being considered for applications ranging from catalyst for organic decontamination, cell scaffolds for implantable devices and sensing elements for detection of gases and biological macromolecules.

One promising route for implementing ns-titania into N/MEMS devices is by reacting titanium films with aqueous hydrogen peroxide (H_2O_2) solution. Hence the effect of parent Ti microstructure and H_2O_2 solution on the morphology ns-titania produced needs to be understood. This work investigates the kinetics of the above reaction using an electro-oxidation method. The effect of parent Ti film thickness, deposition rate of Ti films, H_2O_2 concentration and temperature on the reaction kinetics was investigated.

We found two reaction kinetics depending on thickness of the parent Ti film. For films less than 50 nm thick, the kinetics is interface-reaction controlled. For thicker films, the reaction is controlled by diffusion of Ti through an intermediate gel layer. The titania gel layer has a porous sponge-like morphology and is amorphous. Upon annealing at 300°C, the gel crystallizes into anatase nano-crystals about 5-25 nm diameter. The ns-titania layer was evaluated using UV-Vis, XRD, AFM, and SEM.

B LOCATION B

Characterization of AlGaN Material Quality for use in Deep-Ultraviolet Light Emitting Diodes

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High-power deep-UV light emitting diodes and laser diodes can be used in a variety of applications, including the detection of anthrax and other biological agents, water purification, and high-density optical storage. Deep-UV LEDs are composed of an AlN template layer and AlGaN active device layers grown epitaxially by metal-organic chemical vapor deposition on c-plane sapphire. To achieve efficient LEDs with reasonable lifetimes and light output, the material must be high quality. This project focuses on characterizing the crystal quality and surface morphology of the AlN and AlGaN using X-ray diffraction, atomic force microscopy, and other methods, and relating these qualities to device performance. Additionally, we seek to determine the relationship between AlN layer quality and AlGaN layer quality. Plan-view transmission electron microscopy data suggest that current dislocation densities in the AlN template layers range from $5 \times 10^{9}\ cm^{-2}$ to greater than $1 \times 10^{10}\ cm^{-2}$, which will propagate into subsequent layers and affect device performance. Finally, we are designing a procedure using x-ray rocking curve analysis to determine the dislocation density in the AlGaN layers as a function of growth parameters, including growth temperature, pressure, and composition, as well as AlN template quality.

A LOCATION A

Development of Carbon-Nanotube Interface for Retinal Prostheses

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Electrical stimulation is known to result in visual perception. Optical-electrical prostheses are being developed to replicate the stimulation process in the retina and restore vision in blind patients. A device has previously been fabricated using an array of self-aligning multi-walled carbon nanotubes, fabricated on a silicon substrate, which have been shown to interface well with retinal cells. The tubes now need to be insulated so that the electronic signals communicate selectively with the layer of retinal cells and no others. We will find a coating and process which will insulate the walls of the tubes, leaving only the tips exposed to transmit the electrical field. The coating must be biocompatible with the retina, must be biostable (i.e., will not dissolve in body fluids), and must be electrically non-conductive. Conventional insulators will be tested, including silicon dioxide and silicon nitride, as well as polymer coatings. We will soak the devices in saline and test the insulation for efficacy using impedance spectroscopy and cyclic voltammetry. Selective stimulation of retinal sites will substantially improve the effectiveness of retinal prostheses.

B LOCATION B

Optimization of Electrical Properties of Titanium Oxide Films Formed via Photochemical Metal Organic Deposition (PMOD)

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Photochemical Metal Organic Deposition, or PMOD, combines the ease of spin coating and direct photopatterning to overcome limitations encountered with other high-k dielectric patterning methods. The process can be performed at low temperatures (< 400°C) making it ideal for use in temperature sensitive applications. Deposition of titanium oxide by this methodology results in an amorphous, nanoporous thin film. The general objective of this project is to identify the effects that thermal annealing, hydrothermal annealing and plasma annealing have on the porosity, thickness, k-value, breakdown voltage and leakage current of this dielectric material. One focus of this project is to find a processing scheme that maximizes breakdown voltage of the titanium oxide film while retaining a k-value greater than 15. We have used thermal annealing and O_2 plasma annealing to achieve these specifications. Titanium oxide films having breakdown voltage of 13.7 V and k-value of 22 have been fabricated by the above method.

A LOCATION A

Development of Devices for Nanofiltration of Biomolecules

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The genetic testing of samples derived from whole blood requires the separation of DNA (1.5-3 nm in diameter, negatively charged) from hemoglobin (5.5 nm, pH dependent charge). Our goal is to fabricate a biocompatible porous membrane device that can be compatible with nano and microscale devices, for molecular sieving and dialysis applications.

While even e-bean lithography cannot reliably generate features smaller than 20 nm laterally, metal films thinner than 10 nm can routinely be deposited and later wet-etched away as a sacrificial layer to leave behind channels which may measure several microns laterally, yet be thin enough to exclude by size alone biomolecules larger than the initial film thickness.

The project consists of three parts: fabrication of channels, SU-8 molding of PDMS chambers and flow tests. The development of the constrictions consisted of depositing alternate layers of metals and oxide over a thin silicon wafer (100-200 μm) using photolithography techniques. In general, we deposited alternate layers of SiO_2 to make the floor of the channel hydrophilic and prevent the electrodes from shorting out, and used Al as the sacrificial layer because it can be removed selectively vs. Si, SiO_2, and Au. The constricted channels were less than 4 nanometers wide, which means that hemoglobin should not be able to pass through them. The PDMS chambers should act as a reservoir for the molecules. Presently our research is directed toward addition and improvement of electrical gates (Au) above the channels that allow passage through the constriction to be modulated by charge as well as size.

B LOCATION B

Comparison of Fabrication Methods for Tunnel Regions in a Biosensor

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Recently biosensor devices have become a major area of interest in nanotechnology. Many of these devices require microfluidic systems that include tunnel regions. The focus of this project is to fabricate tunnel regions using various methods so that we can (1) compare the clarity of the tunnel regions and (2) recommend a method for fabricating tunnel regions to be used in a biosensor.

The first two methods involved etching into the substrate, depositing aluminum as a sacrificial layer, spinning on SU-8 or polyimide as a cover material, and then removing the aluminum. With this process, tunnels as small as 200 nm in height were achieved. Other methods studied include patterning channels in SU-8, polyimide, and PDMS.

A LOCATION A

Surface Functionalization of Barium Titanate Nanoparticles

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Barium titanate nanoparticles were synthesized using an aqueous coprecipitation reaction with barium hydroxide and titanium n-propoxide at a temperature of 90˚C. A surfactant was added to cap the particles in order to inhibit particle growth and agglomeration. A variety of surfactants were used: anionic, cationic, and non-ionic. The samples were then analyzed using a series of techniques including x-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FT-IR), scanning electron microscopy (SEM), dielectric measurements, and secondary harmonic generation.

Based on XRD the particles were cubic in nature with average size varying from 25-50 nm. FT-IR spectroscopy was used to measure the effectiveness of the capping agents. The influence of these capping agents on size, structure, and dielectric properties of the $BaTiO_3$ powder is discussed.

B LOCATION B

Fabrication and Optical Characterization of Metallic and Semiconductor Nanoclusters

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Nanostructured metallic materials' optical and catalytic properties depend on their sizes and shapes. This is of great interest because of their application in biology, optoelectronics, and magnetic devices. This research focused on gold nanoparticle fabrication using UV irradiation to form interesting shapes. Xenon lamp irradiation with a filter to select light with 250 nm to 350 nm wavelengths was used to excite gold precursor, hydrogen tetrachloroaurate(III) trihydrate ($HAuCl_4$). The light-excited gold ion precursor is then reduced to gold metal atoms by reaction with the solvent, ethylene glycol. Polymer Polyvinylpyrrolidone (PVP) was used as the surfactant to control growth rate and stabilize the particles formed. In these studies, both optical spectroscopy and transmission electron microscopy were used. The effects of photo-sensitizer's addition, $HAuCl_4$ concentration, PVP concentration, PVP/$HAuCl_4$ concentration ratio, irradiation intensity and solution stirring were investigated. While each factor played a role, PVP/ $HAuCl_4$ ratio, $HAuCl_4$ concentration, and solution stirring mainly controlled particle shapes, sizes, and uniformity, respectively. Controlled particle sizes ranged from 30 nm (± 10nm) to 1000 nm (± 100nm) with triangular, pentagonal, and hexagonal shapes were fabricated. It was demonstrated that this convenient method is versatile to fabricate gold nanoparticles with controlled size and shape.

A LOCATION A

Manganese Doping of Germanium Nanowires Seeded from Gold Nanocrystals

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Recent reports of a ferromagnetic semiconductor Mn_XGe_{1-x} have motivated the attempted synthesis of Mn doped single crystal Ge nanowires. The combination of semiconducting properties with ferromagnetic order in these nanostructures not only provides an ideal experimental system for the fundamental study of spin dependent electron transport but also represents many technological opportunities combining information storage and computing in nanowire devices. The supercritical solution phase synthesis of Ge nanowires was performed via thermal degradation of organogermane precursor in the presence of alkanethiol-capped Au seed nanocrystals. Solution phase Mn doping of the Ge nanowires was attempted via the injection of various organomanganese precursors into a heated and pressurized reactor cell. Following nanowire synthesis, Mn doping of Ge was immediately performed under supercritical conditions. The Mn doped Ge nanowires were characterized using HRSEM and TEM. EELS and EDS were used for elemental analysis, and magnetic properties were measured by SQUID.

B LOCATION B

Patterning Microspheres in a Microchamber

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Frequently, applications of microspheres require a methodology for selectively placing the spheres. This paper discusses the creation of a methodology for placing a near monolayer of spheres inside of microchambers (ranging in size from approximately 100 microns to approximately 3 millimeters) attached to two channels (20 microns in diameter). Capillary forces cause the spheres to be pulled toward the edge of the microchamber and into the two channels. In addition, a droplet's pinned contact line causes an outward flow pattern which causes the spheres to form a ring upon drying, a ring that is commonly referred to as a "coffee ring." A polydimethyl siloxane (PDMS) mask allows a selected area of the microchamber to be treated with oxygen plasma creating an interface between the treated area of the microchamber and the non-treated area of the channels. This causes the water containing the spheres to stay out of the channels, thereby reducing the capillary force that draws the beads to the edge of the chamber. Heating the sphere-containing droplet altered the flow pattern of the spheres in the droplet, and, consequently, the "coffee ring" was less pronounced. Further experimentation with this method could lead to a more uniform monolayer of spheres.

A LOCATION A

Hybrid Nano-Scale Pattern Formation Through Nanocrystal Self-Assembly

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This project aims to create ordered arrays of semiconducting nanocrystals (NC) on silicon and silicon dioxide surfaces by taking advantage of template-assisted self-assembly. The ability to integrate optically-active materials with nano-scale precision onto silicon substrates in a cost-effective fashion is one of the key technologies necessary to build hybrid electronic-photonic integrated circuits.

In our approach, a nano-scale template is fabricated via electron-beam lithography. This template contains recessions on the surface that form arrays of dots and lines. By dispensing a solution containing semiconducting nanocrystals, we aim to show that the NC's self-assemble onto the template due to tuned capillary and electrostatic interactions. We have made the templates by electron-beam lithography with 100 nm features in Poly(methyl methacrylate) PMMA. We transferred the patterns made in PMMA to silicon or silicon dioxide surface via reactive ion etching. We have used two types of core/shell CdSe/ZnS nanocrystals for the self-assembly experiments. In order, they were 8 nm (dispersed in toluene) and 45 nm (dispersed in water) in diameter with peak photoluminescence emission at 680 nm.

B LOCATION B

Optical Readout of MEMS-Based Infrared Detectors

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In this project we construct and characterize a simple optical readout system for a bimorph micro-electromechanical system (MEMS) based infrared detector array. In our project, a bimorph MEMS is a heat absorbing pixel attached to a bimorph beam consisting of two different materials, each with different coefficients of thermal expansion (CTE). The difference in CTE causes the beam to deform when exposed to IR radiation, and the angular deflection may be measured optically using a laser and a beam position detector. This approach to infrared imaging has the advantage of being more easily scaled to large arrays and more sensitive than existing technologies.

A LOCATION A

Making Connections to Molecules for Molecular Electronics

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Cross-bar molecular electronic devices can be used for both memory and logic purposes. The structure of our device will consist of a pattern of parallel electrodes with macroscopically accessible contact pads, a molecular layer formed by a self-assembling monolayer (SAM), and another set of parallel electrodes perpendicular to the first. This configuration forms an electrode grid with a monolayer sandwiched between the top and bottom electrode layers. The objectives of this project, the ultimate goal being to fabricate a cross-bar array to characterize molecule-based electronic junctions, are to learn how to optimize the growth of SAMs on blanket films and learn how to pattern the bottom electrodes into a substrate. To optimize SAM growth, blanket platinum films were deposited on substrates. SAMs are reported to form better on platinum than on gold. Using the atomic force microscope (AFM), the roughness of chemical mechanical polished (CMP) and non-CMP samples were analyzed. CMP is reported to be important in molecular electronics. An octadecanethiol SAM was then grown on each of the samples. Through more AFM analysis, it was seen that the SAM grew more uniformly on the CMP sample, as expected. The electrode patterning into the substrate is being done via standard fabrication techniques.

B LOCATION B

Patterning Arrays of 20-nm Pillars for Bulk Heterojunction Solar Cells

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Due to their high cost of production, the use of inorganic-semiconductor-based solar cells has been relatively limited. Organic-semiconductor-based devices are inherently much less expensive, but less efficient due to low charge mobility. The most common strategy for making more efficient organic photovoltaics is to use a bulk heterojunction in which excitons (coupled electron-hole pairs) are split at an interface between two semiconductors with offset energy levels. Since excitons only diffuse 4-20 nm in most organic semiconductors, the interface must be patterned at this scale. An ideal bulk heterojunction consists of a 100-300 nm thick film of one semiconductor with arrays of 10-20 nm wide pores filled with the other semiconductor. The goal of this project was to obtain the desired nanostructure in Si as a proof of concept. Nanosphere Lithography and Block Copolymer Lithography are two methods we used to align Cr nano-dots on the surface of the substrate to act as a mask during reactive ion etching. With these techniques we have produced arrays of Si pillars on the order of 20 nm wide and 120 nm in height, as characterized by Ultra High Resolution SEM. When mated with the organic photovoltaic, this ordered nanostructure interface should allow for improved charge collection and overall cell efficiency, which could pave the way for truly affordable solar energy.

A LOCATION A

Reactive Electrospinning of Hydrogel Nanofibers

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Electrospinning has been used to produce networks of hydrogel nanofibers. These fibers were spun from a mixture of monomer, cross-linker and photoinitiator, pre-polymerized to achieve the necessary viscosity. UV irradiation of the fibers in flight allows polymerization and cross-linking of the nanofibers prior to collection. Using this technique, fibers of sub-micron diameter have been produced; although a wide distribution of fiber diameters are produced at any given time. The fibers have been characterized by optical microscopy, confocal microscopy and SEM. Effects of applied voltage, flow rate and needle-substrate spacing have been investigated. In aqueous solution the swollen fiber network allows efficient mass transport of ions and other dissolved species, as well as serving as a support structure; these properties make hydrogel nanofibers a good candidate for biomedical applications.

B LOCATION B

Micromagnetic Manipulation of Cardiac Tissue

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Studies of failing heart tissue have shown numerous changes in the cellular microenvironment. More specifically, changes in the cell shape, alignment, and gap junction distribution suggest that stresses and strains within the cell have caused both structural and electrical changes. The focus of this project is to fabricate a device capable of stressing and straining cells in patterns that mirror the experimental findings. We hope to elucidate how these changes in the cellular microenvironment can effect the electrophysiological functioning of the cell and perhaps precipitate arrhythmias. The fabrication of this device focuses around the construction of nano-wires, capable of exerting highly controlled and localized magnetic fields. We attach protein-coated magnetic beads to specific receptors on the cell membrane. The cells can then be easily manipulated by running discrete currents through the nano-wires, creating highly controllable magnetic fields that exhert forces on the beads on the membranes of the cells. Currently, the fabrication of some experiment devices has been completed, and we tested them with unattached magnetic beads. We are looking forward to testing our devices with living tissues in the near future.

A LOCATION A

Molecular Substrates for Nanobiotechnology

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For nearly two decades, phage display has been used as an extraordinarily powerful tool for many biotechnological and biological applications. It is a very effective tool for isolation of specific peptides for performing specific functions from very high numbers of diverse peptides and proteins. DNA sequences of interest are inserted into the phage genome and the encoded protein is displayed on the surface of the phage as a fusion product to one of the phage coat proteins. It serves as a tool for linking phenotype of phage displayed peptide or protein with the genotype encoding that molecule. Whereas phage display usually involves protein-protein interactions, the focus of this research is using inorganics as substrate to isolate polypeptides capable of binding inorganic material with high affinity. Single-crystal quartz pieces (001 plane) were used as the substrate for the selection of quartz-specific 12-amino acid peptides from a PhD-12 phage display library. Five biopanning rounds were carried out to obtain DNA sequences and the binding properties of 001 plane quartz were compared to that of 100 plane quartz. The amino acid sequences are compared to search for trends or convergence to a specific sequence.

B LOCATION B

Investigation of Novel Thermal Barrier Coating Materials by Minimum Thermal Conductivity

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Recently, there has been a renewal of interest and focus in developing new materials and new methods with improved thermal conductivity and thermal diffusivity properties. With the rapid advancement of technology, there is a growing need for new materials that are applicable and functional at elevated temperatures. One such endeavor is that of thermal barrier coatings. Thermal barrier coatings are used to increase the efficiency of gas turbine engines and provide the metal engine components with a measure of protection from the particle impacts and corrosion. The current standard thermal barrier coatings consist of yttria-stabilized zirconia, however, other material systems with superior properties are being sought for the next generation of turbine engines.

In this study, the Flashline 3000 is utilized to determine the thermal diffusivity and heat capacity of a variety of ceramic mixtures containing zirconia and hafnia. The resulting data is then employed to calculate the intrinsic thermal conductivity of these ceramic mixtures. From these experiments, the effect of ion combinations on thermal conductivity and thermal diffusivity properties are examined for better future material system design. The underlying goal of this research is to establish a method by which new materials with desirable thermal properties may be developed.

A LOCATION A

Phase Shifting Lithography

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Increasing demand for smaller device structures in integrated circuits has pushed traditional optical lithography to its resolution limit. However, several techniques have been developed to extend the use of optical lithography. Examples of such techniques are Phase Shifting Lithography (PSL) and Immersion Lithography (IM). PSL allows for the fabrication of sub 200 nm high aspect ratio features. This is achieved by using a quartz mask which is reactive ion etched to a depth that will produce the desired phase shift when exposed to ultra-violet light. IM has the ability to increase resolution even further, using a layer of water in between the mask and photoresist. This layer of water has a higher index of refraction than air and, hence, allows for higher resolution.

The work reported herein uses PSL to fabricate high aspect ratio sub 200 nm features. Subsequently IM is used to produce even higher resolution features. Both processes utilize a Karl Suss Contact Aligner and SPR 3012 photoresist.

B LOCATION B

Fabrication and Characterization of Nano-Nozzles

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This paper summarizes the experimental phase of implementing a nano-nozzle with a triangular orifice diameter in a few hundred nanometer range through high temperature (1100°C) wet oxidation. The initial orifice of the nozzle was designed with a diameter in a few micron range. The orifice diameter was reduced by growing an oxide layer covering the inside of the silicon nano-nozzle. Cross-sections of the nozzle at various distances from the orifice were examined with a scanning electron microscope (SEM). The data from the SEM were analyzed to characterize the oxide growth layer inside the nozzle, which appeared not to follow the standard Deal-Grove model.

A LOCATION A

Fabrication of a Discriminating Gas Sensor

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Gas sensors have been used for many years for equipment control and environmental monitoring. A basic problem is that they typically are unable to discriminate between gasses that are chemically similar. This generic problem is the source of considerable research, typically involving the creating of arrays of sensors that are slightly different and then developing an empirical signature for different gasses. In this project, we have designed and fabricated a new type of gas sensor. The gas must diffuse down a nano sized cavity to reach the sensing elements. By spacing the elements along the cavity one can determine the diffusion coefficient and from that infer the size of the diffusing species.

We laid out the test chip for this project, and developed several critical processing steps needed to build the device. Next the necessary materials were deposited and patterned. Finally, we intend to package the device and test its response.

B LOCATION B

Characterization and Optimization of ZEP520A Electron Beam Lithography Resist

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The goal of this project is to determine the ultimate nanometer pattern resolution in ZEP-520A electron beam resist. E-beam lithography is done using a JEOL JBX 9300FS system. Thickness measurements of ZEP-520A are taken using a Woollam Ellipsometer, Tencor KLA Profilometer, and a Veeco Atomic Force Microscope (AFM). Line edge and surface roughness will be compared across a range of E-beam doses using the AFM. E-beam dose is compared to the depth and clarity of trenches of varying dimensions drawn in AutoCAD and written in ZEP-520A. Exposed resist is developed using ZED-N50. Trenches of 18 nm have been demonstrated previously. Resolving 10 nm trenches is the specific goal in achieving the maximum resolution of ZEP-520A.

A LOCATION A

Thermal Effects in Silicon Based Resonant Cavity Devices

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Constructing an optical modulator on a silicon based chip has the advantages of CMOS compatibility and high index contrast. The basic structure of our optical modulator is a waveguide with a ring spaced 200 nm to 300 nm from the waveguide closer to the input. When a resonant wavelength is reached such that n = $2\pi r$ – where n is an integer constant, is the wavelength of the input source, and *r* is the radius of the ring – the light in the ring scatters, resulting in less light at the output. This drop in transmission causes the modulation effect. One obstacle that needs to be overcome is the unwanted resonance shifts that occur as the chip heats up. Therefore, we will characterize the thermal effects in silicon based resonant cavity devices.

B LOCATION B

Fabrication of Diamond Membranes for a High Brightness Electron Source

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For electron emission, diamond’s most important attribute as an electron source is the ability to be activated to a condition of negative electron affinity (NEA) by hydrogen termination on the dangling surface bonds. When this condition is met, low-energy electrons within the conduction band find no energy barrier to the vacuum potential and are emitted freely. By bombarding the back surface of a very thin diamond membrane with high-energy electrons, we can inject the requisite conduction band electrons. Such a device shows tremendous promise for a low energy spread, high brightness electron source. The main obstacle to its demonstration is fabrication of the very thin single crystal diamond membranes (i.e. $< 0.5\ \mu m$ thick). In this work, the goal is to optimize a fabrication technique for thinning the membranes to the requisite dimensions and mounting them for subsequent transport and emission measurements. To achieve these objectives, we have milled and polished the membranes with a 30 kV Ga focused ion beam. With this process, we have fabricated thin single crystal p-type diamond membranes with thicknesses ranging from 0.3 to 2 μm along a specific crystal orientation. After successful mounting of these membranes, we will begin a series of measurements to determine the transmission and surface properties of diamond with the aim of optimizing the internal electron multiplication and the longitudinal energy spread.

A LOCATION A

Simulations of Simplified Cell Membranes

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Macroscopic properties of cell membranes can be simulated using a simple, flexible, solvent-free model. Each amphiphilic lipid composing the membrane is represented as a chain of five beads governed by four potential energy parameters. The simulations are conducted according to Metropolis Monte Carlo algorithms, effectively minimizing the free energy of the system. Obtaining the proper parameters such that the membrane remains structurally intact has been a challenge, as pores have developed in many of the simulated membranes. Results for the bending rigidity for these parameters will be presented. Furthermore, membrane flexibility is correlated to the molecular flexibility of the amphiphiles.

B LOCATION B

An Investigation of the Formation of Polymeric Structural Thin Films as a Functional Template for Collagen Growth and Attachment

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Structural Thin Films (STFs) are films that are deposited by glancing angle deposition. This angle is typically seventy-five degrees or more measured normal to the direction of the incoming flux. This type of deposition introduces shadowing effects that force the film to grow in a highly oriented manner. The film grows in the direction of the flux and can be manipulated into columnar, chiral, chevron, or numerous other growth patterns. The focus of this project was to form STFs from a polymeric material and to test the films as a base for collagen growth. Polymeric STFs have not been grown according to the literature. Polymeric STFs would provide a very porous surface for collagen growth and if grown in a chiral pattern would mirror the natural structure of collagen. Collagen would provide a biocompatible material for medical implants and biological sensors. This project explored the thermal evaporation of Paralyne or poly-para-xylylene and the sputtering of Teflon® or polytetrafluoroethylene. A universal substrate motion control device was designed and fabricated to be used in any vacuum system. Chiral growth patterns were observed for paralyne. Currently, Teflon® films are being explored as well as collagen attachment to the chiral paralyne films.

LOCATION A

Viscoelastic Response of Stratum Corneum to Varied Levels of pH

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The stratum corneum (SC), the outermost layer of the skin, is the first barrier against external environmental factors. As such, the influence of these factors upon the underlying microstructure and mechanical properties of the SC is an area of fundamental and practical interest. While pH treatments have been shown to influence lipid characteristics, changes in the mechanical properties of the SC have not been examined thoroughly. In particular, we will look at pH-induced changes in the viscoelastic response of human SC. Creep-recovery tests will be completed in ambient conditions on pH treated specimens of SC using a Dynamic Mechanical and Thermal Analysis device. The changing pH levels are expected to affect both the keratin filled corneocytes and their surrounding lamellar matrix of lipids, in turn influencing the viscoelasticity of the SC. Since many topically applied substances such as surfactants, creams, and adhesives for transdermal technologies possess varying pH levels, it is important to fully understand any resultant changes in the physical properties of the SC.

LOCATION B

Ordered Growth on Nanostructured Glass Surfaces

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Corrugated glass substrates were used as growth templates for ordered gold and SiO_2 nanostructures. The corrugations had an amplitude of ~1.5 nm and a wavelength of ~50 nm and were formed through bombardment with Ar^+ ions with an energy of 0.45 keV at a 45° off-normal angle. Small amounts of gold with nominal thicknesses ranging from 0.5 to 1.5 nm have been deposited on these corrugated glass surfaces with thermal and E-gun evaporation in both normal and off-normal deposition geometries. Using atomic force microscopy (AFM), the dependence on annealing time at 450°C of the size and spatial distribution of the deposited gold particles has been determined. Ordered metallic nanoparticles may have an application for high-density floating gate memory.

We have also investigated how to create higher amplitude corrugations through depositing SiO_2 in an off-angle geometry at various thicknesses ranging from 0.5 to 3 nm. Increasing the amplitude of the corrugations is useful for aligning macromolecules such as the liquid crystals used in active matrix displays.

A LOCATION A

Silicide Contacts to Ultra-Thin Silicon Films for Nano-Scale Devices

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Techniques have been developed to build metal oxide semiconductor (MOS) devices on thin single-crystal silicon films. Such films are on the order of tens of nanometers thin, but at this size it is difficult to produce low-resistance contacts to the devices. A solution to this is silicidation, a process that results in the formation of a low-resistance metal-silicon alloy. This silicide interface between the silicon and metal serves as a good ohmic contact and significantly improves the performance of nano-scale devices using MOS technology. The focus of this project is to develop a recipe to fabricate cobalt silicide ohmic contacts that are reproducible, have low resistance, and are on the order of 10 nm thick. In the first part of the project, test structures were designed to measure contact resistance and to monitor the growth of the silicide. A series of processes was then developed to form the silicide and measure the efficacy of the process with respect to the thickness of the polycrystalline silicon film.

B LOCATION B

Growth of Gallium Nitride Nanowires using a Nickel Catalyst

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The growth of nanowires having the same length, direction and size is essential for LED and semiconductor technology. Therefore, this process needs to be perfected. To accomplish this, photo-lithography is used to create nickel disks on a silicon substrate. These disks aid the growth of uniform wires. Half of the samples are N_2 plasma etched, creating a rough surface for the wires to grow from. Rough and smooth surfaces were then compared in their ability to grow wires more uniformly. After the samples were properly prepared, they were placed into a furnace and heated to 1000˚C in a gallium and ammonia environment for 20 minutes. This process resulted in the growth of nanowires in the range of 5-7m in length and approximately 150 nm in diameter. These wires were approximately all the same size but grew in different directions. Currently preparations are being made to have all the wires grow in one direction.

A LOCATION A

Solution Phase Thermal Annealing Studies on the Activation Barrier to Ferromagnetism in Nanocrystalline Diluted Magnetic Semiconductor $Co^{2+}TiO_2$

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Diluted magnetic semiconductors (DMS) are envisioned as vital components of many spin-based semiconductor devices. If successfully produced, such devices may offer lower power consumption and greater operating speeds than conventional charge-based devices, and promise entirely new spin-based functionalities. Recently, a novel wet-chemical approach has proven successful in yielding high quality colloidal suspensions of Co^{2+} doped titania ($Co^{2+}:TiO_2$) nanocrystals and nanorods, and when processed into thin films, yield strong room temperature ferromagnetism. The paramagnetic to ferromagnetic transition occurring from colloidal nanocrystals to high temperature processed nanocrystalline thin film, suggests that a thermal activation barrier to ferromagnetism must be overcome during the spin coating process. Recent studies indicate cobalt migration within or even out of the titania host lattice during thermal treatment may play an important role in ferromagnetic activation. We report high temperature solution-phase thermal treatment studies of $Co^{2+}:TiO_2$ nanorods and their characterization by electronic absorption, elemental analysis, magnetometry. In an attempt to further understand the kinetics behind transition metal dopant incorporation in the lattice and control ferromagnetic activation in solution, an alternative synthetic procedure was also attempted.

B LOCATION B

Scaling up Catalytic Nanomotors

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The creation of miniature “engines” than can convert stored chemical energy to motion is one of the great remaining challenges of nanotechnology. In previous studies, nanometer diameter platinum/gold rods placed in a hydrogen peroxide solution have been shown to catalyze the spontaneous decomposition of hydrogen peroxide and exhibit autonomous, non-Brownian movement. The purpose of this project is to fabricate micron diameter platinum/gold rods with aspect ratios similar to the previous nanorods to study their movement in a dilute solution of hydrogen peroxide. While the nanometer diameter rods are fabricated in sacrificial alumina membranes, the micron diameter is fabricated in a sacrificial template formed using high-aspect-ratio photolithography. SJR 5740, a positive photoresist that produces high-aspect-ratio features with vertical sidewalls, was patterned on a silver coated silicon wafer to form the template. The template is then connected to a standard three-electrode cell and a voltage is applied to electroplate gold then platinum into the template features. Once the platinum/gold rods are formed, the photoresist and the silver seed layer are then removed and the rods are collected. Currently, rods have been fabricated using this process and are ready to be studied in dilute solutions of hydrogen peroxide.

A LOCATION A

Self-Assembly of Sub-Micron Channels for Nanofluidic Applications using Interferometric Lithography and Spin-Coating

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Nanoscale channels offer an experimental apparatus for validating theoretical predictions of fluid flow in the nanometer regime, as well as practical applications in biology, chemistry, and engineering. In nanochannels, the electrical double layer becomes large compared to the dimensions of the channel, and flow is strongly dependent on the electrical properties of the channel and the fluid. The focus of this project is to fabricate nanochannels using a faster, cheaper method.

Interferometric lithography is used to create a template in Shipley 510A photoresist and a wet-i ARC layer, on which silica beads self-assemble during spin-coating. The sample is then calcinated, burning off the photoresist and wet-i ARC template and leaving the beads. Nanochannels as narrow as 300 nm have been fabricated. These devices will provide a good basis for further investigation of nanofluidic flow.

B LOCATION B

Electron Cyclotron Resonance Reactive Ion Etching Process Development and Characterization

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Reactive Ion Etching (RIE) is a major process in the fabrication of semiconductor devices for transferring patterns from masks to semiconductor substrates. From neutral gases and the utilization of a glow discharge, chemically reactive species are generated to react with the materials being etched and form volatile by-products. This research focuses on the etching process developments of SiO_2, Si_3N_4, GaAs, and InAs and studies etch rate, selectivity, wall angle, and surface roughness.

Approximately a 1.5 mm photo resist (PR) is coated on the materials being etched and patterned prior to etching. After etching, the samples are analyzed using a Profileometer, Scanning Electron Microscope (SEM), Ellipsometer, and Atomic Force Microscope (AFM). Etch depths as functions of etch time have been measured for all the above materials.

The AFM results showed that a very smooth surface (Ra: ~ 0.17 nm) was obtained on the GaAs substrate etched using the process developed in this research. The other properties are still being investigated.

A LOCATION A

Applications of Nanofluidic Devices in Chemistry

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Nanofluidic channels have many uses in the chemical field, including site specific combinatorial synthesis, macro- and bio-molecular analysis, and other "lab on a chip" applications. The objective of this research is to fabricate arrays of nanochannels designed to facilitate the transport of aqueous ionic solutions by adapting a form of the nanoimprinting technique. Nanoimprinting relies on mechanically embossing or deforming the resist material under elevated pressure and, typically, temperature to replicate a mold surface. Since the contribution of capillary force is insufficient for extended channel lengths, the device is designed to employ the principle of asymmetric AC-field electro-osmosis to drive fluid flow. To accomplish this task, the design integrates interdigitated asymmetric electrodes patterned by electron beam lithography. The fabrication also incorporates the non-traditional resist of hydrogen silsesquioxane (HSQ). This material was selected due to its resulting hydrophilic surface property and unique ability to be imprinted at room temperature and later cross-linked for mechanical stability. This work is dedicated to developing and optimizing the processing conditions for fabricating arrays of nanochannels in HSQ capable of active pumping.

B LOCATION B

Fabrication & Stabilization of Non-Spherical Colloids for Self-Assembly

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The self-assembly of ordered structures using non-spherical micron-scale components is a challenging problem that current work mainly theorizes about. The challenge is two-fold: the fabrication of non-spherical objects at the limit of micron-scale technology, and manipulating specific interactions to force the ordered assembly of said objects. Our work focused on this first challenge, to experimentally produce these non-spherical particles. We utilized photolithography techniques to fabricate removable cylindrical particles on a silicon wafer. Interferometer tests determined the average height of the particles to be 1.2 µm ± 3%. Examination under SEM showed that the cylindrical particles were approximately 1µm in diameter and mono-dispersed in both shape and size. The particles displayed Brownian motion when suspended in an aqueous solution. Our work also studied the possibility of fabricating particles that could compliment each other, introducing structures comprised of particles with different shapes. For this, we produced mono-dispersed particles with a negative curvature of approximately one micron which could assemble with the cylinders.

A LOCATION A

Controlled Neuron Growth by Patterned Protein Gradients

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Neuron growth is controlled by the growth cone, located at the end of the axon. Extra-cellular components, such as the presence of various proteins, control the directional growth of these neurons; this allows for the possibility to manipulate extra-cellular factors to aide in the re-growth of damaged neurons. The objective of this project is to create protein gradients using an electrospray system, ultimately producing a system to target the growth of axons to specified endpoints. The electrospray system is first studied using polystyrene latex (PSL) particles as a substitute to the growth-effecting proteins. The electrosprayer deposits particles uniformly on a substrate of silicon, and the ultimate surface concentration of particles is controlled by moving the substrate under the electrospray tip at a constant velocity or various accelerations. Neuron cells from extracted dorsal root ganglia (DRG) of fetal chickens are deposited on the substrate, and the growth patterns are observed under varying conditions, including several protein gradient slopes and the presence of different proteins.

B LOCATION B

Miniaturizing DNA Sequencing Technology: Designing Microfluidic Channels for Performing Chemistry on Beads

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The availability of complete genomic sequences for several organisms, made possible by drastic reductions in sequencing cost in concert with advances in sequencing technology, has revolutionized the nature of biological and biomedical research. Yet for this rapid progress to continue and to enable the genomes of countless more organisms to be sequenced cheaply and efficiently, a new approach to DNA sequencing that exponentially decreases its current costs must be developed. Pyrosequencing is one such novel approach that is based on the detection of visible light generated via an enzymatic reaction cascade occurring in response to the successful incorporation of nucleotides during DNA elongation.

In this work, we will design, fabricate, package, and test a miniaturized microfluidic version of the pyrosequencing process as a prototype of a potentially more cost-effective and rapid method of DNA sequencing. The progression of microfluidic channels is etched in a silicon wafer; the wafer is then bonded to a glass wafer with holes drilled at positions corresponding to the channel inlet/outlet ports; finally, the enclosed channels are connected to the macroscopic world of reagent supplies and tested for successful pyrosequencing capabilities. A successful prototype will demonstrate the potential for miniaturizing DNA sequencing to a lab-on-a-chip scale.

A LOCATION A

Flow Through Amperometric Sensors

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Amperometric biosensors are commonly used in clinical diagnostics. In this work, a flow through amperometric biosensor platform for the detection of biologically important species is microfabricated and tested. The sensor was created by bonding PDMS microchannels to a glass wafer containing platinum electrodes. Using common surface chemistry techniques, enzymes were immobilized onto the platinum electrodes. Varying the enzyme used enables the sensor to be tailored for detection of a particular species. In this case, the enzyme localized on the electrode was glucose oxidase, enabling the system to detect glucose concentration. Glucose oxidase catalyzes a reaction that oxidizes glucose and ultimately produces electrons. The electrons are then detected by a platinum electrode and converted into interpretable results. This electron flow is proportional to the number of glucose molecules or the glucose concentration in the sample. The objective of this project is to examine how different ionic concentrations influence the detection of glucose concentration at a constant voltage.

B LOCATION B

Nanomagnetic Sensors

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Hall probes can be used to effectively image magnetic fields with submicron resolution and sub flux quantum, making them very useful in the study of superconducting materials. One major impediment to improved magnetic field measurements is resistance noise. Resistance noise in hall bars, fabricated using GaAs/AlGaAr with a two dimensional electron gas below the surface, seems to be related to the scaling of the hall bars. In this work, we will perform noise measurements on a range of hall bars (2-30 μm), which should help to clarify the relationship between resistance noise and hall bar width.

LOCATION A

MEMS Based Real-Time Non-Invasive Biological Cell Diagnostics

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Electrical impedance measurement provides a method of ascertaining and monitoring a biological cell's characteristics, such as health, size and amount of DNA present, in a non-invasive manner. We are utilizing this technique to study qualitatively and quantitatively the reaction of a single cell to external mechanical forces and loading. The reaction of a cell to external mechanical strain and the process of conversion of mechanical signals to chemical signals are for the most part unknown because there are very few ways to observe and measure a cell's reaction without changing how the cell behaves. In order to subject the cell to mechanical forces, we fabricated an AFM tip-like structure which will be used to poke the cell uni-axially while it is positioned between two microfabricated electrodes. The electrodes are a part of an of an impedance measuring electrical circuit. We propose that the impedance measuring technique will enable us to accurately measure to what extent the cell is affected by mechanical forces, how long it takes the cell to recover and resume normal functioning, and whether or not it permanently affects the cell.

LOCATION B

Quantum Computing via Single Charges in Self-Assembled Coupled Quantum Dots

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Quantum computers take advantage of the phenomenon known as quantum theory. The qubits that comprise these computers have the capability of existing in two states simultaneously, allowing them to provide more bit representation then the conventional transistor. As a result, quantum computers will be faster, contain more memory and possess superior encrypting capability than today's traditional computers. The purpose of this research is to define the independent control of both the loading and tuning of quantum dots using applied voltage as opposed to sample doping. The tunnel splitting of the coupled electronic states is in the terahertz regime but they are only split at specific applied electric fields. The quantum dot sample being used is comprised mainly of InAs and GaAs. That is, InAs layers deposited between GaAs layers, which are deposited on top of a AlGaAs sample.

A LOCATION A

Synthesis and Properties of ZnO Nanostructures

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Zinc Oxide (ZnO) nanowires hold a promising key to the world of nanotechnology. With its wide-band gap (3.37 eV), high breakdown strength, and large excitonic binding energy, ZnO possesses several advantages for use in electronic and photonic devices. Nanowires hold promise for future electronic devices and novel sensing devices. Past research has focused on chemical vapor deposition (CVD) and metal organic CVD as methods of producing nanowires, while pulsed laser deposition has been largely unexplored.

In this work, ZnO materials obtained by pulsed laser deposition were studied to examine the potential of nanowire formation. ZnO was deposited (26 kV, 5 Hz, 30.3 mtorr O_2) on a variety of substrates including glass and sapphire. The use of nanoscale metal clusters obtained by annealing thin films (600°C, 10 min) was studied with the intent to form nucleation sites for ZnO nanowires. The structural characteristics of the deposited ZnO were studied by scanning electron microscopy, and optical properties were studied by optical reflectance.

B LOCATION B

Micro-Scale Two Phase Flow Heat Transfer

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As computer chips get smaller and faster, there rises a need for new innovative ways to keep them cool without making the computer chip bulky. This study investigated the possible heat transfer abilities of micro-scale two-phase flows, primarily in water. The devices used varied in surface roughness, temperature, flow regime, length, and methods of two-phase heat exchange. They were fabricated with three main components: micro channels, a heater, and a thermistor. The micro channels were etched into silicon substrates and then bonded to glass. An external pump created the flow through the channels. On the bottom sides of the substrates, in order to model a hot computer chip, Aluminum heaters were installed. Also, for measurement accuracy, polysilicon thermistors were introduced underneath the heaters (in close proximity to the channels). Preliminary testing has begun, but no results have been measured currently.

A LOCATION A

A Modular 90-GHz High-Gain Corrugated Compact-Packing Focal-Plane-Layout Platelet Antenna Array

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Corrugated feed horns are a method of channeling light into a detector to reduce noise and interference. The focal-plane array improves upon our previous scalar designs by allowing the array to focus on one point (i.e. the center of the primary mirror in a telescope).

Our tests have shown that the scalar horn design results in a gain of 20 dB, and has a bandwidth encompassing the full W-band range (75-110 GHz). The side lobes in the scalar horns are attenuated from the main lobe by -22 dB, a requirement comparable to horns used for observation of the Cosmic Microwave Background (CMB). We expect these parameters to remain the same with the implementation of the new focal-plane array. The design and fabrication methods presented in this paper are straightforward and inexpensive, allowing efficient development of large arrays of hundreds of corrugated horns—essential for comprehensive CMB surveys.

B LOCATION B

SiC Light Emitting Diode (LED) Fabrication and Characterization

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LED's are the next level of technology when it comes to a light bulb. LED technology is about finding a semiconducting material that emits different color light. We will discuss SiC LED fabrication and characterization. SiC LED stands for silicon carbide light emitting diode. This project will be focusing on what a LED is and how it works. Talking about LED briefly, it is a semiconductor diode that emits incoherent monochromatic light when electrically biased in the forward direction. This report will explain in detail how this device emits light and how it emits multi-color light by using different semiconductor material. To understand this, there will be a brief explanation of what a semiconductor and a diode are. We will be explaining silicon carbide which is the semiconducting material that we used to fabricate the LED while working in the lab. Also, we will explain in this paper the fabrication technique that we followed in processing this device. Pictures and photos on how this device looks will be included. In the results and conclusion, we will give opinions on the LED performance, and compare and contrast the LED bulb to the incandescent bulb of today.

A LOCATION A

Characterization of Individual Single Walled Carbon Nanotubes by Photoluminescence and Resonant Raman Spectroscopy

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The recent discovery of band gap photoluminescence (PL) from semiconducting single walled carbon nanotubes (SWNTs) has provided an experimental tool to study their electronic band structure. Moreover, results of these PL measurements have indicated that a discrepancy exists between experiment and theory. The aims of the research presented here are to characterize individual SWNTs based on their PL and resonant Raman signals. To realize this goal, a multi-step fabrication and nanotube synthesis process was developed, which includes techniques of electron beam lithography, reactive ion etching, thermal evaporation, and chemical vapor deposition, yielding SWNTs suspended over trenches. Using a tunable Ti-Sapphire laser, resonant Raman shifts were measured from a number of nanotubes. Combining this data with anticipated PL measurements on the same nanotubes will provide new and valuable insight into the electronic and optical properties of SWNTs.

B LOCATION B

The Effect of Organic Compounds on the Synthesis of Nanophase Materials

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The synthesis of zinc sulfide nanocrystals is of considerable importance because of potential applications in future nanoscale optoelectronic devices. In this study, we investigated the effect of the organic molecules glycine and ethylamine on the synthesis of ZnS nanocrystals. The organic molecules were introduced during a low temperature (180°C) hydrothermal synthesis of ZnS. High resolution transmission electron microscope (HRTEM) images show that the morphology and structure of the ZnS crystals formed in the experiments were affected by the ethylamine, but not by the glycine. Using ethylamine as the organic molecule, the morphology of the nanocrystals changed from spherical, to lamellar, to rod-like aggregates as the concentration of ethylamine was increased. The crystals were mostly in the stable cubic form. The thermodynamically-unstable hexagonal phase of ZnS was also observed in nanorods and stacking faults within the cubic phase in experiments run with intermediate concentrations of ethylamine.

A LOCATION A

Stability of Silver Nanoparticles in Aqueous and Organic Media

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Several chemicals have been used to research the stability of silver nanoparticles in aqueous and organic media for use in electrophoretic deposition and, ultimately, the fabrication of an infrared detector. Every chemical component in the electrophoretic medium must be compatible with the ultrapure reaction conditions required for the fabrication of a semiconductor infrared detector. They must introduce no detrimental impurities and be easily removed by decomposition or volatilization. Moreover, the silver nanoparticles must be pure. In this experiment, silver nanoparticles are obtained commercially and by an electrochemical synthesis in alkaline aqueous media. After preparing and obtaining the silver nanoparticles, the relative abilities of ethylene glycol, water, sodium dodecyl sulfate, methanesulfonic acid, formic acid, and 1,1,1-trifluoro-2,4-pentanedione to stabilize silver nanoparticles are compared using UV-Vis spectrophotometry, and plotted in an absorbance vs. time graph. A decrease in absorbance is analogous to a decrease in stability and an increase in agglomeration. Current UV-Vis results indicate ethylene glycol is the best stabilizing agent. Its absorbance evens out at approximately 0.68, while the other chemicals have leveled out between 0.1 and 0.4. To ensure the silver nanoparticles are the appropriate 10 nm size, particle-size distributions of some samples have been obtained using the Zetasizer 3000.

B LOCATION B

The Novel Formation of Photodefinable Porosity to Fabricate Direct-Write Waveguides for Optoelectronic Applications

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A direct-write waveguide may be patterned by selective decomposition of photodefinable sacrificial polymers templated in a spin-on-glass matrix (SOG). Porosity is formed in the irradiated areas where the sacrificial polymer is decomposed leading to a drop in the refractive index, whereas the unexposed parts of the wafer retained a higher refractive index. To avoid thermal activation of the photoacid generators (PAGs), which are unstable at the glass transition temperature of the SOG, photobase generators were used to initiate base-catalyzed hydrolysis of the silane bonds in the SOG. The silane bonds in the SOG structure are converted into highly reactive silanol groups, which condense via a sol-gel mechanism to form a rigid network consisting of siloxane bonds between SOG cage units. After cross-linking the SOG, 248 nm UV radiation is used to activate the PAG to form photoacid, decomposing the sacrificial polymer only in the irradiated regions of the wafer thus allowing selective decomposition to form patterns of porosity. In the irradiated areas, the refractive index dropped to 1.3579, whereas the unexposed parts of the wafer retained a higher refractive index of 1.4162.