The 2003 NNUN Research Experience for Undergraduates Convocation

August 6th thru 9th, 2003

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

National Nanofabrication Users Network

The 2003 NNUN REU Convocation

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The 2003 NNUN REU Convocation

Welcome, everyone, to the University of California, Santa Barbara.

We're excited to have you all here to join us for three days of exciting science and interesting people. This is our second opportunity to host the NNUN Research Experience for Undergraduate Convocation, with much guidance and support from the Cornell staff. We hope that our combined efforts will result in an event for you to remember.

We've organized a variety of activities in the next few days which we hope will be fun, interesting and possibly educational. However, it is your presentations that will be the main focus of this convocation, as each of you shares with us all that you've learned and the accomplishments that you've made this summer. We will be running a live web-cast of your presentations, so that your distant friends and family will have a chance to see you in action. We are very pleased that the National Science Foundation and each NNUN site will be able to tune in.

We hope you will enjoy your visit with us here in California (and think of us when you apply for graduate school!)

Liu-Yen Kramer
NNUN REU Program Coordinator at UCSB

The 2003 NNUN REU Interns

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Ms. Adele Tamboli	Physics	Harvey Mudd College	UCSB	pg. 31
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Ms. Yu Zhao	Materials Science & Engr	Cornell University	SNF	pg. 32

Wednesday, August 6th

7:00 PM .... Group Orientation Dinner

(Interns, Staff, Administration, Organizer's)

To be held outside of Manzanita Village - Casual Event

Ms. Megan Maness, PSNF, will give presentation this evening due to her departure time on Thursday

Cell Adhesion for Applications in Intracellular Communication Research

Megan Maness, Biomedical Engineering, Case Western Reserve University

Penn State Nanofabrication Facility, The Pennsylvania State Unversity

Gregory S. McCarty, Penn State Nanofabrication Facility, The Pennsylvania State University

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The development of a device that enables directed neuronal growth, multiplexed stimulation solutions, and detection of exocytosis is of fundamental importance to research into intracellular communications, drug discovery, and disease diagnosis and treatment. The creation of such devices will provide the opportunity to study and characterize cell to cell communication and to monitor neurotransmitter release patterns. Attachment of PC-12 cells (used in the place of neurons at this point in the research) was guided by a protein patterned surface. Microcontact printing using a polydimethylsiloxane (PDMS) stamp was employed to pattern proteins onto the surface of the substrates. Specifically, laminin was patterned on the substrates achieving a 40-60 nm thick layer. Following the protein-patterning the substrates were placed in a physiological solution containing PC-12 cells. After 2-4 days of incubation, cells were observed to be patterned on the surface. Successful cell adhesion led to the next step of the process, which involved observing exocytosis. We are currently implementing the calcium indicator dye, fluo-4, in an attempt to monitor exocytosis of the PC-12 cells using fluorescence microscopy.

Thursday, August 7th

Photo Day: Please do dress-up
All Events held at UCSB / Engineering II / Pavillion

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

9:30 - 9:45 .... Welcome - Site Director: Mark Rodwell

9:45 - 10:15 ..... Keynote Speaker: Harry Kroto from the University of Sussex

I May be Wandering, but I Don't Think I'm Lost

(Facilitator: Liu-Yen Kramer, UCSB)

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

(Facilitator: Brian Thibeault, UCSB)

12:15 - 1:15 .... Lunch

1:15 - 2:15 .... Photographer: Tony Mastres

(Facilitator: Ram Seshadri, UCSB)

3:15 - 3:30 .... Break

5:00 .... Goleta Beach B-B-Q (Cliffs & Co)

Friday, August 8th

All Events held at UCSB / Engineering II / Pavillion

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

(Facilitator: Michael Deal, SNF)

9:45 - 9:57 Mr. Steven Floyd
Novel Design Techniques for Nanotube-Based Field Effect Transistors using Electron Beam Lithography 17

9:57 - 10:09 Mr. Lucas Fornace
Organic Light Emitting Devices by Molecular Beam Epitaxy 18

10:09 - 10:21 Ms. Rachel Gabor
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Electrical Characteristics of Organic Molecules on GaAs for Micro-Computing Purposes 19

10:33 - 10:45 Ms. Karen Havenstrite
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(Facilitator: Krista Ehrenclou, UCSB)

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Microwave Digestion of Magnetic Oxide Nanoparticles 20

11:39 - 11:51 Mr. Matthew Jacob-Mitos
Atomic Force Microscope Lithography 21

11:51 - 12:03 Mr. Douglas Jorgensen
Substrate Temperature Measurement during Molecular Beam Epitaxial Growth of GaInNAsSb Quantum Wells 21

12:03 - 12:15 Ms. Aminata Kone
Catalytic Growth of GaN and other Nitrides Nanowires for Electronic and Photonic Applications 22

12:15 - 2:00 .... Lunch

(Facilitator: James Griffin, MSRCE)

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Adhesion of Lithographically Patterned Thin Film Structures 22

2:12 - 2:24 Ms. Heather Levin
Fabrication and Measurement of Four Probed Semiconductor Nanowires 23

2:24 - 2:36 Mr. Rylund Lewis
Nanoparticle Based Detection of Biological Materials 23

2:36 - 2:48 Mr. Tony Lin
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2:48 - 3:00 Mr. Jason Lurie
Combining Conventional Nanolithography with Self and Directed Assembly to Create Ultra High Resolution with Precision 24

3:00 - 3:12 Ms. Heather McKnight
Embossing Polymer Waveguides for Integrated Optical Devices 25

3:12 - 4:30 .... Poster Session (Afternoon Snacks to be provided)

4:30 - 5:00 .... Engineering Science Building Facility Tour *(Optional / External View Only)*

Rest of Friday .... Free Time for Interns

(Shuttling will be available to downtown Santa Barbara from 7:00 pm - 1:00 am)

Saturday, August 9th

All Events held at UCSB / Engineering II / Pavillion

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

(Facilitator: Liu-Yen Kramer, UCSB)

9:33 - 9:45 Mr. Alireza Masnadi-Shirazi
Chemistry-On-A-Chip: Functionalizing Microfluidic Devices 25

9:45 - 9:57 Mr. Michael Miranda
Novel Gate Stack Processes for MOS-Based Structures 26

9:57 - 10:09 Mr. Andrew Newton
Ultrasonically Driven Microneedle Arrays 26

10:09 - 10:21 Ms. Marie D. Nguyen
Positive Development of Random Copolymer Photoresist using SuperCritical Carbon Dioxide as Environmental Benign Solvent 27

10:21 - 10:33 Mr. Christopher Pontius
Sol-Gel Derived Functionalized Coatings for DNA Immobilization 27

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(Facilitator: Krista Ehrenclou, UCSB)

11:00 - 11:12 Mr. William Quinones
Fabrication of Silicon Carbide Atomic Force Microscopy Probes 28

11:12 - 11:24 Mr. Michael Reichman
Growth of ZnO Nanowires and their Application in Solar Cells 28

11:24 - 11:36 Ms. Sarah Rickman
Ferroelectric Thin Films for Nonvolatile Memory Applications 29

11:36 - 11:48 Ms. Kristy Schmit
Organometallic-based Photovoltaic Cells 29

11:48 - 12:00 Mr. Justin Scott
A Novel Method of Creating Nanoscale Interconnects by Radioactive Decay 30

12:00 - 1:00 .... Lunch

(Facilitator: Greg McCarty, PSNF)

1:00 - 1:12 Mr. Moussa Souare
Developing IR (8-14 µm) Detectors (External Photoemission) 30

1:12 - 1:24 Mr. Nicholas Strandwitz
Fabrication and Testing of Nano-Scale Gas/Vapor Sensor 31

1:24 - 1:36 Ms. Adele Tamboli
Amphiphile Aspect Ratio and Membrane Bending Rigidity in a Solvent-Free Cell Membrane Model 31

1:36 - 1:48 Mr. Peter Waldrab
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1:48 - 2:00 Ms. Yu (Jennifer) Zhao
Optimizing Platinum Coating for Spin Magnetic Injection 32

2:12 ....Final Words from NNUN REU Program Coordinators

(Liu-Yen / Melanie-Claire)

Rest of Saturday .... Free Time for Interns / NNUN Admin Meeting

Sunday, August 10th

Shuttling available from Manzanita Village and Best Western South Coast Inn

Keynote Speaker:

Harold Kroto, University of Sussex, Brighton

I May be Wandering, but I Don't Think I'm Lost

Harold Kroto was born in 1939 in Wisbech, Cambridgeshire, and brought up in Bolton, Lancashire. He graduated in Chemistry at the University of Sheffield in 1961, and in 1964, received his Ph.D. there for research with R. N. Dixon on high resolution electronic spectra of free radicals produced by flash photolysis. After two years postdoctoral research in electronic and microwave spectroscopy at the National Research Council in Ottawa, Canada, he spent one year at Bell Laboratories, N.J., studying liquid phase interactions by Raman spectroscopy and he also carried out studies in Quantum Chemistry. He started his academic career at the University of Sussex at Brighton in 1967, where he became a professor in 1985, and in 1991, he was made a Royal Society Research Professor.

In 1996, Harry was jointly awarded the Nobel Lauriate for chemistry with Richard Smalley and Robert Curl of Rice University, Texas. Later that year he received a Knighthood by Queen Elizabeth II.

Current Research Interests:

- Synthetic Fullerene Chemistry (with R. Taylor and D. R. M. Walton) - Production and characterisation of novel multifunctional derivatives of C_{60} and C_{70}.

- Nanotubes and nanoparticles (with D.R.M. Walton) - Application of electrolysis, pyrolysis and laser vapourisation techniques to the production of multi-walled nanostructures with and without endohedral metals.

- Cluster beam studies (with A. J. Stace) - Generation of small fullerenes (C_{24}, C_{28} etc...) by laser vaporisation. The dynamics of metal/carbon aggregation.

- Astrophysical studies monitoring of red giant stars in the search for C_{60} in space.

2003 NNUN REU Abstracts:

in order of presentation

Laser Lysis of Liposomes in a Microfluidic Device

Olabunmi Agboola, Molecular and Cellular Biology, University of Illinois at Urbana-Champaign

Cornell NanoScale Facility, Cornell University
Antje Baeumner, Ph.D., Assistant Professor of Biotechnology,
Dept. of Biological & Environmental Engineering, Cornell University
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The focus of this project is to study the lysis of liposomes using lasers. Laser lysis has been found to be highly successful with *E. coli* and other bacterial, yeast, and mammalian cells. The lysis principle is assumed to be due to the heating of intracellular water and interactions with the cell membrane. Liposomes are phospholipid membrane vesicles that are used as signal amplification systems in microbiosensors for the detection of RNA molecules. They entrap electrochemically or optically active molecules that are detected upon lysis of the liposomes. Currently, liposomes are lysed using a detergent beta-octyl glucopyranoside (OG). Laser lysis will be compared to the detergent lysis in order to determine its efficiency. It will be analyzed using a spectrophotometer, a fluorometer, and a laser light scattering device. In order to laser lyse the liposomes, a liposomal solution (aliquot) will be passed through a microchannel made from polydimethyl siloxane (PDMS) and exposed to a laser mounted perpendicular to the channel. Experimental conditions will be varying the flow rates 1 microliter/min, 2 microliter/min, and 5 microliter/min, and varying laser wavelength with 980 nm and 1480 nm lasers. The varying flow rates correlate directly to varying exposure times and the varying wavelengths correlate to different water absorption coefficients, i.e. the water absorption coefficient is about 50 times higher at 1480 nm which should result in a more effective liposome lysis.

Pyrosequencing in a Microchannel

Mariam Aghajan, Molecular & Cell Biology, University of California at Berkeley

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Peter Griffin, Electrical Engineering, Stanford University
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Pyrosequencing is a quick and versatile real-time DNA sequencing technique used for genome sequencing, expression analysis, and ecogenomic studies. Currently 96 free DNA samples of 50 mL each can be run simultaneously. With these numbers, however, genetic studies are very costly and time consuming, resulting in the lack of commonality of genetic analyses within the public realm. To alter this, we aim to maximize the number of samples and decrease the cost by demonstrating pyrosequencing on DNA immobilized beads in a capillary. Since the glass beads have a diameter of 30 μm, many beads can be analyzed concurrently; also, the small size allows for less chemical consumption, resulting in a lower cost for DNA sequencing. To meet these goals, pyrosequencing must be optimized under these new conditions. Thus, initially we performed pyrosequencing experiments under a variety of conditions aimed at simulating the reaction on a chip, adjusting the concentrations of the various enzymes involved to achieve the desired results. Next, we will fabricate the capillary-chip and further optimize the pyrosequencing reaction for DNA immobilized on glass beads placed within the capillaries. Once these goals are achieved, rapid genetic analysis on-demand and for diagnosis in the health sciences will soon be able to follow.

Improving InGaAsN and GaAsN by Thermal Annealing

James Q. Boedicker, Chemical Engineering, MIT

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Mr. James Griffin, MSRCE, Howard University
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Dr. Gary Harris, MSRCE, Howard University
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Band-gap engineering is the control of a semiconductor's energy-gap by varying its molecular composition. It can be used to tailor the properties of photo detectors and solar cells. This project examined the effects of thermal annealing on the properties of InGaAsN and GaAsN epilayers with various nitrogen (N) concentrations. The epilayers were grown on GaAs substrates using molecular beam epitaxy (MBE) with N concentrations of approximately 1%. Although nearly perfect samples of GaAs can be grown using MBE, the inclusion of N in the GaAs and the InGaAs crystals causes lattice defects. Therefore, it has been suggested that thermal annealing of these samples should improve material properties such as carrier mobility. Electronic properties of these semiconductors can improve after thermal annealing at 1023 K for 30 seconds. The Hall effect and photo luminescence measurements were taken. Increases in carrier mobilities of up to 20% were recorded.

Characterization of Ion-Implanted Nanofiltration Membranes

Edgar Allen Cabrera, Biological and Environmental Engineering, Cornell University

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Dr. Kimberly Jones, Civil Engineering, Howard University
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Besides operating pressures, a key contrast between reverse osmosis (RO) membranes and nanofiltration (NF) membranes is the difference in ion rejections. RO membranes highly reject divalent ions and effectively reject monovalent ions. NF membranes effectively reject divalent ions but poorly reject monovalent ions. Because of lower operating pressures, it will be advantageous to increase the NF membranes, rejection of monovalent ions without decreasing the pore sizes. It has been determined in previous studies that electrostatic interactions have an important role in the rejection of charged species and contaminants. By increasing the magnitude of the net electric charge of the membrane, we can tailor the NF membranes to more effectively reject monovalent ions. This was done by using ion implantation to embed highly electronegative F- ions on the surface of NF-90 membranes at doses of 1E10 atoms/sq. cm and 5E10 atoms/sq. cm. Using various feed solutions, flux experiments were then performed to compare these membranes with RO membranes. Atomic force microscopy and contact angle measurements were also done on the modified and unmodified membranes in order to determine the effect of ion implantation on the morphology, pore size, and hydrophobicity of the membrane surfaces.

Interdigitated Microelectrode Arrays for Organic Light Emitting Diodes

Michael Campolongo, Electrical and Computer Engineering, Rowan University

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George Malliaras, Materials Science and Engineering, Cornell University
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Organic light emitting diodes (OLEDs) are being researched extensively for applications in flat panel display technology. The essential capabilities of the organic semiconductor material are that of electron and hole transport, and high luminescence efficiency. The purpose of this project is to investigate the elementary processes that occur in OLEDs that utilize the transition metal complex ruthenium tris-bipyridine. The devices were constructed with a planar geometry consisting of arrays of interdigitated electrodes, each electrode being 2 µm in width. Standard photolithographic techniques were used in the construction of the devices, and low work-function materials, such as gold and platinum, are used as the ohmic contacts. Various processes are investigated through electrical and optical characterization including surface potential, charge injection, and electron-hole recombination in the semiconductor material. A thorough understanding of the function of OLEDs will allow researchers to eventually overcome the challenging issues of long turn-on times and limited life spans.

GaAs Prosthetic Retinas

Stephanie Cheng, Biology, Cornell University

Materials Science Research Center of Excellence, Howard University
Dr. Gary L. Harris, MSRCE, Howard University
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Several diseases that deteriorate the retina have created a need for prosthetic retinas in the medical community. Most notably, Age Macular Degeneration (AMD) and Retinitis Pigmentosa (RP) have affected 1.5 million people worldwide and continue to be a serious problem. Several technologies are being explored, among them artificial electrical stimulation of the optic nerve. Such stimulation can be accomplished through the use of solar cells. In the past, solar cells have been made using silicon. However, because the spectral response of silicon is better suited for the infrared, other materials need to be explored. One such material, GaAs and GaAlAs device structures, provide a much closer spectral response to that of the human eye than silicon does. Thus, the project focuses on the development and testing of a GaAlAs solar cell for prosthetic retinas. GaAlAs solar cells were fabricated using a photolithography evaporation/etching process and then implanted into frog eyes for preliminary studies. The main concern is biocompatibility of the cells and to address this, preliminary tests of the effects of GaAs inside of frog eyes were performed. Work is currently still being done.

High Throughput Screening (HTS) of Transdermal Chemical Penetration Enhancers (CPE)

Tiffany Coleman, Biology, University of Missouri at Kansas City

UCSB Nanotech, University of California Santa Barbara
Pankaj Karande Chemical Engineering University of California at Santa Barbara
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It is hypothesized that certain CPE extract lipids in the skin by creating micelles in the skin allowing for larger molecules to pass through the Stratum Corneum and into the blood stream. Each CPE has its own inherent strengths and weaknesses in moving larger molecules across the skin. We hypothesize that combining two or more CPE's will increase skin permeability, while decreasing skin irritation caused by the CPE.

HTS has been shown to be a faster screening tool than Franz Diffusion cells (FDC). Therefore we will use HTS to accelerate the screening process of the 300 to 350 different CPE known to increase skin penetration. Further analysis of the chosen CPE will be done using FCD with 3H (tritium) as a marker.

Preliminary results indicate that NLS and Cineole where the best candidates we tested during the summer of 2003. These chemicals are being tested using FDC to ensure their ability to increase skin permeability.

Investigation of Heating's Effect on the Performance of Ultra-Violet Light-Emitting Diodes

Tristan Cossio, Electrical Engineering, University of Florida

UCSB Nanotech, University of California Santa Barbara
Tom Katona, Electrical and Computer Engineering, University of California, Santa Barbara
Steve DenBaars, Materials Science & Electrical and Computer Engineering, UCSB
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Ultra-violet light emitting diodes (UV LEDs) with peak wavelengths of 292 and 340 nm were prepared using Metal Organic Chemical Vapor Deposition (MOCVD). UV LEDs have applications in the detection of biological and chemical weapons and in solid-state white lighting. A maximum output power of 131 uW at 100 mA DC was measured using a broad area silicon photodiode. Relative external quantum efficiency deteriorated from .036% to .028% as DC current increased from 25 mA to 100 mA respectively. We believed device self-heating is the primary cause for the decrease in quantum efficiency with increasing current.

In order to investigate this, pulsed measurements will be taken using a 1 kHz pulse with 1% duty cycle and compared to DC measurements. Under pulsed conditions, we will measure the output power at varying currents, along with the relative external quantum efficiencies By comparing these values to those at D.C., we hope to observe a Light-Current relationship that is more linear, confirming the effect of heating on device performance.

This work was also funded by Dr. John Carrano through the SUVOS program and by the Solid State Lighting and Display Center at UCSB.

Fabrication of Polymer-Bound Electrophoresis Chips

Keith Craig, Bioengineering, University of Washington

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Capillary electrophoresis (CE) has been widely used in microfluidic systems to separate biological samples because of its high-efficiency, short separation time, and low consumption rate. The best material for CE separation is glass; however, fabrication of fluidic channels in glass is quite laborious and time-consuming mainly because of the high temperatures and skills required for bonding glass. Our project explores a simple method for producing glass chips in ambient temperature with a fast turnaround time. After fluidic channels are etched in a glass wafer, it will be pressed against another glass wafer coated with a thin layer of UV-curable resin. Heating the resin slightly will bond these two pieces of glass together. After protecting the resin area in the channel with a dark liquid, any area surrounding the channel will be crosslinked under UV light. The remaining resin in the channel will be dissolved by a developer to expose the underlying glass surface. Because the thickness (~2 μm) of the crosslinked layer is much smaller than the periphery (usually > 100 μm) of the channel, it is expected that the glass chip, fabricated using this simple technique, will have similar efficiency in CE as the conventional one.

SuperGhost: A Method of Writing Accurate Nanopatterns with an Inaccurate Tool

Siavash Dejgosha, Applied and Engineering Physics, Cornell University

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Electron beam lithography suffers from proximity effects when exposing dense patterns. Forward-scattered and back-scattered electrons cause undesirable exposure surrounding exposed elements. A previously published method, Ghost, corrects these errors by exposing the inverse pattern with a lose-dose defocused beam. The scattering from the inverted pattern and the original pattern combine to cancel each other. This project investigates an improved method called SuperGhost. This method refers to the general technique of using defocused low-dose beam to tune the critical dimensions (CD). SuperGhost may write on the inverted pattern, or on every pixel, or on some combination of the two. It has the ability to tune CD for all patterns, and to tune CD with different amounts for isolated patterns and for dense patterns. The algorithm achieves a desired CD change and desired iso-dense difference. A computer simulation of wafer exposure with the SuperGhost method, and, time-permitting, a physical wafer exposure will determine the effectiveness of this novel method. SuperGhost promises to be a better correction method than Ghost.

Study of the Effect of Domains on Thin Stripes of Magnetic Material

Ashley Evans, Electrical Engineering, California State University Fresno

Stanford Nanofabrication Facility, Stanford University
Shan X. Wang, Materials Science Eng. and Electrical Eng., Stanford University
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The performance of planar spiral inductors can be greatly enhanced by the use of one or two magnetic ground planes. However, the magnetic properties of a ground plane are significantly affected by the physical construction. It has already been shown that leaving gaps within the magnetic ground plane reduces eddy current loss. In this project, the effect of varying the width of the stripes of magnetic material on the magnetic properties will be explored. Layers of 0.2 µm and 0.4 µm thick CoTaZrTb were constructed, in different patterns varying from 2 µm to 15 µm wide and 140 µm long, using standard photolithography processes and ion etching. The magnetic domains will be observed with a microscope that utilizes the Kerr effect, and furthermore the magnetization of the material will be measured with respect to the variation of the magnetic field. If a relation can be found between these characteristics and the width of the stripes, then the performance of the magnetic ground plane can be understood with respect to the construction. The investigation of the magnetic ground plane construction will then provide an understanding of the performance of the CMOS compatible planar spiral inductors which can be used in a variety of applications that utilize integrated passive components.

Back-Plane Based Nano-CMOS Transistors

Ardavan Farjadpour, Nanoengineering, University of Toronto

Cornell NanoScale Facility, Cornell University
Sandip Tiwari, Electrical & Computer Engineering, Cornell University
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Uygar Evren Avci, Applied & Engineering Physics, Cornell University

The unavoidable effects of electrical interference that influence proper device behavior are a growing concern as electronic devices shrink to nanometer dimensions and device densities increase within silicon dies. In this regard, a reliable method is required to allow for precise device isolation while also not placing constraints on device density and functionality. Shallow trench isolation (STI) is a standard process used in nanofabrication to isolate the active areas of semiconductor devices that consists of digging trenches in the silicon wafers and filling them with a dielectric oxide material. In order to optimize the STI process for SOI CMOS transistors having feature sizes in the tens of nanometers certain experimental parameters relating to the formation of the trenches must be carefully chosen. The most important of these parameters involves the nitride layer thickness in the oxide-nitride-oxide (ONO) layer, growing conditions of the various layers, as well as the type of dielectric oxide placed in the trenches. The ability to achieve planar post-polished surfaces that are also defect free is vital to normal device operation. The focus of this project is the optimized fabrication and characterization of uniform, nanosize trenches to enable further size reduction of semiconductor electronic devices.

In Situ Optical Monitoring of Selective Wet Oxidation of AlGaAs Alloys

**Nick Fichtenbaum, Electrical Engineering,
Washington University in St. Louis**

Stanford Nanofabrication Facility, Stanford University
James S. Harris, Electrical Engineering, Stanford University
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Recent work in the field of optoelectronics, particularly vertical-cavity surface-emitting lasers (VCSEL), has shown that wet oxidation of selected AlGaAs layers significantly improves the optical and electrical properties of the devices. One essential component to VCSEL performance is the creation of highly reflective mirrors called distributed Bragg reflectors (DBR), which are formed by creating alternating layers of GaAs and AlGaAs. Oxidizing the AlGaAs layers changes the refractive index of the material, such that it has a greater contrast with its coinciding GaAs layer. This in turn makes the DBR much more reflective. In addition, it will provide more defined current apertures, which will improve the VCSEL efficiency by eliminating surface recombination. Present oxidation systems for AlGaAs are in place, but there is minimal control over the present procedure. A new method for wet oxidation has been developed. It is the goal of our research to get this system working consistently and accurately and develop suitable calibration and control techniques. A particular challenge for this system is achieving strict control through in situ optical monitoring. This system will greatly expand the efficiency and performance of VCSEL technology.

Two-Dimensional Nanobumps Using Ion Sputtering and Reactive Ion Etching

Sterling D. Fillmore, Physics, Brigham Young University

Cornell NanoScale Facility, Cornell University
Christopher Umbach, Dept. of Materials Science and Engineering, Cornell University
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Corrugations with wavelengths of 30 to 65 nm and amplitude of 2 to 4 nm are created on the surface of a boroaluminosilicate glass through bombardment with Ar^+ ions in a conventional ion mill. The Ar^+ ions range in energy of 0.5 to 0.9 keV. The orientation, wavelength, and amplitude of the corrugations are dependent upon the angle of incidence. By ion bombarding a surface at both high and low angles of incidence, we have studied the effects of superimposing corrugations that run perpendicular to one another. The corrugations were characterized by atomic force microscopy (AFM).

Microfluidic Device for Pharmaceutical Research

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Pharmaceutical research currently includes large robotics spread over numerous labs. To resolve this inconvenience, a small, integrated tool was developed to perform all of the operations that the robotics carry out. The multiplexed, multi-layered microfluidic device cultures cells, compartmentalizes the drugs to be tested, applies the test drugs to the cells, and image responses the cells. The device is cheap and able to improve the quality of data collected while fitting on a single microscope slide. The device is fabricated using soft lithography in polydimethylsiloxane (PDMS), a technique available to most researchers at universities around the world. Process integration is accomplished by pneumatic valves and pumps.

Novel Design Techniques for Nanotube-Based Field Effect Transistors using Electron Beam Lithography

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The electrical properties of carbon nanotube field-effect transistors (CNFETs) can be drastically altered by adjusting a number of device parameters. These parameters include contact (gate, source, drain, etc.) material and shape. In order to properly utilize these advanced properties, devices must be designed to take advantage of all device parameters and still be conducive to the consistent forming of carbon nanotubes. Electron beam lithography, in conjunction with metal evaporation and conventional lithography methods, is used as a means of creating new devices with necessary feature sizes. We plan to fabricate and characterize different device geometries and contact materials to optimize both n-type and p-type CNFETs. Potential material choices include platinum, gold, titanium, and palladium. These optimizations could lead to the generation of high performance, nanometer scaled electronics.

Organic Light Emitting Devices by Molecular Beam Epitaxy

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The dream of using organic materials in high performance optoelectronic devices is rapidly becoming a reality. These include, but are not limited to: organic light emitting devices (OLEDs); photovoltaic cells; and photo detectors. Such organic devices have reached performance levels comparable to or, in some cases, even better than their inorganic counterparts. They are inexpensive, can be fabricated on flexible substrates and can be easily modified with the addition of a large variety of chemical functional groups.

This project was focused on the fabrication of organic light emitting devices. To this end, we put together a high-vacuum chamber for thermal evaporation of organic compounds, which was optically coupled to a remote diode-array spectrophotometer. This allows for acquisition of absorption spectra during thin film deposition and thus provides immediate feedback regarding the film thickness and composition. Typical device geometry consists of a transparent, yet conductive, indium-tin-oxide substrate on which we deposit an active organic layer sandwiched between a hole-transport layer and an electron-transport layer. The active layer is a strongly luminescent organic material. On top of this we deposit a thin aluminum electrode layer.

Fabrication of Biomolecular Sieves with Novel Geometry

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Two different devices were fabricated for the purpose of filtering mixtures of proteins with a size range of 1-20 nm.

The first device consisted of arrays of 2, 4, 6, or 8 µm holes in a nitride layer over a through-etched window in a silicon wafer. Collagen monomers, rigid rods 300 nm long by 2 nm in diameter, were spun over the nitride layer. The monomers deposit on the surface in a 'hairball' geometry, leaving holes on the nanometer scale which can then filter the solution.

Another device was fabricated by etching holes through the silicon wafer from the backside, and through an oxide layer on the topside. These holes are skewed and joined by a thin layer of aluminum laterally. Aluminum can be evaporated reliably to thicknesses of 5-10 nm, and when etched away will leave channels of that height (though they may measure tens of µm laterally). These channels are then small enough to filter a solution containing biomolecules. Electrical gates were added to these channels to also separate the molecules based on charge.

Electrical Characteristics of Organic Molecules on GaAs for Micro-Computing Purposes

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Organic molecules were assembled on GaAs to determine if these molecules had electrical characteristics that would make them suitable for use in computers circuitry. In order to collect the necessary electrical characteristics, modified Schottky diode devises were made. Self assembled monolayers (SAM)s of the molecule of interest were formed on GaAs, and a gold contact was deposited on top of the SAM in order to obtain electrical measurements of the modified Schottky diode. The current/voltage curves of the modified Schottky diode were compared to those of regular Schottky diodes whose electrical properties are well known. Thus, the electrical characteristics of the SAM could be determined. The top gold contacts of the modified Schottky devices were made using two different methods. The first method used micro-contact printing to transfer gold to the SAM. The other method made use of a shadow mask to allow the evaporation of gold onto the SAM. The results from the electrical measurements of the two methods were compared to determine the best approach of making the modified Schottky diode and of obtaining reproducible properties.

Optimization of Carbon Nanotube Based Sensors for Biosensing Applications

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Micro- and nano-fabrication in combination with methane chemical vapor deposition has enabled the fabrication of novel carbon nanotube based field effect transistor devices. These transistors have led to a new generation of carbon nanotube based devices, including new electronic materials and gas phase sensors. The quality and sensitivity of these sensors is largely dependent on the nanoscale structure of the devices. The goal of this project is to alter the device architecture and observe how the changes affect the sensing capabilites. We will apply this knowledge to create a new architecture which maximizes sensitivity and quality for solution phase biosensing.

Terahertz Circular Dichroism Spectroscopy

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Terahertz cirular dichroism (TCD) spectroscopy uses the chiral structure of biological materials to detect life, fingerprint proteins, and study biological phenomena at the molecular level. Biological molecules are composed of chiral polymers of amino acids or nucleic acids that absorb right circularly-polarized light differently than its left-handed counterpart. CD in the visible range is well understood and widely used to study real-time conformational changes of polymers undergoing environmental and structural perturbations. CD in the terahertz range has yet to be explored. It provides a different set of information on biological molecules, because at this frequency, the entire molecule oscillates.

One challenge of a TCD spectrometer is creating perfectly circularly polarized light in the terahertz range. This project involves interfacing a computer to a stepper-motor-coupled translation stage that will automate the phase shift of the interferometer, hence creating circularly polarized light for the TCD spectrometer. This project includes writing software in HP VEE to communicate with the stepper motor controller and building apparatuses to both mount the stepper motor and couple it to the translation stage. This will allow reliable and automated positioning of the interferometer's translation mirror in conjunction with automated CD measurements.

Microwave Digestion of Magnetic Oxide Nanoparticles

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Prior to the process of digestion, metal oxide nanoparticles (MONNP) have a poorly formed crystalline structure and do not exhibit any magnetic properties. During digestion, ions in poorly crystallized nanoparticles detach from one another and then reattach into better ordered crystalline structures exhibiting ferromagnetism. Currently, this is done by heating MONNP's in a hot-air oven for a given number of hours at low temperatures. These heating conditions bring about the proper crystal structure, size of 3 to 10 nm, and induce magnetic properties. Substituting the hot-air oven with a conventional microwave in this process has shown much promise.

Contrariwise, nanoparticles attach to each other when overheated. To overcome this, pH levels and microwave digestion times are varied. Following digestion, the MONNP's are analyzed by X-Ray Diffraction (XRD). XRD patterns of properly structured MONNP's from previous works are used as references for comparison. Efficiency is achieved with microwave digestion by bringing down digestion time down to a matter of minutes. Recently experimental data has shown that the microwave as a practical application for nanoparticle digestion is very much possible.

Atomic Force Microscope Lithography

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Researchers in science and engineering are now requiring sub-100 nanometer features which conventional optical lithography techniques cannot easily produce. In this paper we attempt to develop a process to consistently reproduce these nanoscale features through lithography with an atomic-force microscope (AFM). AFM-based lithography uses electrically conductive tips to inject current locally into a material to change its chemical structure. Due to the small size of AFM tips, this results in nanoscale-sized features which can be used to transfer patterns directly into the material of interest.

This research explores the various parameters involved in oxidizing silicon surfaces as well as other materials, such as metals or GaAs. These parameters include tip bias, room humidity, tip height from surface, surface preparation and scan rate across surface by the tip. We have found that tip bias, room humidity and surface preparation are most important for oxidation on silicon. By using a tip bias of -8 volts, < 50% humidity and a scanning rate of 6 µm/sec, we were able to produce oxide features 1-2 nanometers high and < 100 nanometers wide. These oxides withstood KOH etching, resulting in efficient pattern transfer to silicon.

Substrate Temperature Measurement during Molecular Beam Epitaxial Growth of GaInNAsSb Quantum Wells

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Molecular Beam Epitaxy is used to create quantum well lasers by heating a substrate and depositing layers of semiconductor material. Though rough temperature estimation methods have historically been sufficient, the recent fabrication of temperature sensitive GaInNAsSb lasers requires more precise measurement techniques. Varying substrate temperatures during growth varies the bandgap of GaInNAsSb.

In this project we intend to accurately monitor the substrate temperature through reflectance spectroscopy. In this technique, a broadband light source is reflected from the surface of the substrate into a spectrometer. Because the bandgap of the material is dependent on its temperature, the reflected spectrum provides an indication of the substrate temperature. We are creating a system to monitor the reflected spectrum in real-time during epitaxial growth, allowing better control of the quantum well bandgap and thus better lasers.

Catalytic Growth of GaN and other Nitrides Nanowires for Electronic and Photonic Applications

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Gallium Nitride nanowires have applications for UV light sources, high temperature nano devices, diodes, and others scientific tools. GaN nanowires can be grown by a direct reaction of ammonia with pure gallium at a temperature between 850°C and 900°C. Under these conditions, the wires were mixed with a matrix which makes their separation difficult; to prevent the formation of the matrix, a catalyst technique using NiO or Ni film has been investigated. Either catalyst should allow the control of the nucleation sites, the location, and the size of the wires. In the case of NiO particles, SEM micrograph indicates that the GaN nanowires, diameter was between 11.1 and 21 nm with a typical length of 1-5 µm. In the case of Ni catalyst, the wires length and diameter have not been determined yet.

Adhesion of Lithographically Patterned Thin Film Structures

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The dimensions of materials utilized in emerging device technologies play an important role in determining their mechanical behavior, particularly when confined to the micron length scale. Recent studies of the adhesion of blanket thin-film interconnect structures have established that plastic energy dissipation can dominate the interfacial adhesive characteristics of thin film structures containing thin metal and polymer films. Currently, there is little understanding of how the geometry and size of features utilized in technologically relevant structures will influence plasticity and hence the fracture resistance of such patterned structures. The intent of the present study is to investigate the role of two-dimensional elastic constraint on the interfacial adhesion of lithographically patterned thin films. Arrays of Cu lines will be fabricated using liftoff processing, such that the feature width varies between 2 and 12 mm. Interfacial adhesion will be determined by measuring the critical strain energy release rate (Gc) of a stable debond located at a select interface within the patterned thin-film structure. Measurements of critical strain energy release rate of a stable debond located at a select interface within the patterned thin-film structure determines interfacial adhesion. Surface characterization techniques, such as XPS, AFM, and SEM, will be employed to characterize the resulting fracture surfaces. Trends in adhesion and the associated fracture surface characterization related to the patterned structures will be discussed in terms of the prevailing plastic deformation mechanisms.

Fabrication and Measurement of Four Probed Semiconductor Nanowires

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Semiconducting nanowires have been used to make nanoscale p-n junctions, and field-effect and bipolar transistors. It is therefore important to investigate the physics governing these nanowires. The wires are first grown by pulsed laser vaporization (PLV), dispersed in solution that is then spun on to a wafer that contains an array of die. The die are created by photolithography and consist of a 3 x 3 matrix of gold covered 100 x 100 µm squares (pads) and four sets of 1 x 3 matrices of gold covered alignment markers which are important for electron beam (e-beam) lithography. The die is then observed under an atomic force microscope (AFM) to determine the coordinates of a suitable wire that is positioned in the junction of four of the pads. These coordinates are then used to draw up an e-beam lithography gds file that allows the e-beam writer to draw four 80 nm wide lines from the nanowire to the four pads. Evaporation is followed by liftoff to form four aluminum-gold lines with ohmic connections to the nanowire. The four pads are then wire bonded to a dual inline package (DIP) to observe the photoconductivity, temperature dependent resistivity and gate dependant current-voltage (IV) characteristics of the nanowire.

Nanoparticle Based Detection of Biological Materials

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Surface-enhanced Raman scattering (SERS) is one of the most sensitive spectroscopic methods for detection of molecules. The SERS approach studied here makes use of metal nanoparticles, which, when excited by light, can set up a plasmon mode. This mode, in turn, creates a near field around each particle. This field can couple to analyte molecules in the near field region. As a result, concentration of the incident light occurs at close vicinity of the nanoparticles enhancing the inelastic (Raman) scattering from the analyte molecules. Since this Raman scattering signature can be very molecule-specific, it can detect certain biological molecules and molecular interactions. We pursued this using a novel SERS nanoparticle material developed in PSU Nanofab. This target material is composed of Ag nanoparticles mono-dispersed in nanostructured void-column Si films. While biological molecules and their interactions have been studied before using Ultra-Violet Raman Resonance (UVRR), the wavelengths of UVRR resonate with the bonds of the molecules leading to degradation. On the other hand, the visible light SERS of this work, with its remarkable signal enhancement, offers the advantage of biomolecular detection at the nonresonant (visible) light excitation without degradation.

Mechanical Characterization of Ultra Sensitive Mass Sensors

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Ultra sensitive mass sensors can provide a far more precise and compact method of mass detection. With purported sensitivity of mass detection down to 10-12 grams, the potential to surpass today's most precise mass sensors can already be seen. Before these sensors can be applied in the real world for applications such as bio and chemical sensing, issues of controllable dynamic and static response, sensitivity, reliability, and quality must be addressed. The focus of the project is to characterize the mechanical properties of our MEMS devices including frequency response, spring constants, sensitivity of mass detection and motion behavior. ANSYS software is used to model our devices and give a reference calculation of behavior. A laser vibrometer setup is used to characterize the motion and frequency response of the devices with special attention being paid to the resonance frequency and nonlinear parametric resonance behavior. Different designs and methods are used to vary mass for sensitivity tests. A Hysitron nanoindenter is used to characterize the static properties of our devices. Various fabrication techniques are also looked at for solutions to certain issues. We hope to collect enough data on our devices to fully understand and model their behavior and are optimistic about achieving resolutions better than 10-12 grams.

Combining Conventional Nanolithography with Self and Directed Assembly to Create Ultra High Resolution with Precision

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"Molecular rulers" are self-assembled multilayers of controlled thickness that allow lithographic techniques to be used to create nanometer-scale features. Selective deposition of self-assembled multilayers on initial metal structures form a "molecular ruler resist" for metal deposition, creating secondary structures whose spacing from the initial structure is dependent on resist thickness. In the work described, molecular rulers combine the ease and cost-effectiveness of conventional photolithography with feature sizes approaching and even surpassing those of electron beam lithography. Molecular rulers thus hold promise as a tool to miniaturize electronic devices further. One area in which the process could use improvement is the chemical lift-off of the molecular ruler resist. Utilizing a different multilayer system is one solution to this problem. Another approach to remove the multilayers is to utilize alternative lift-off conditions, such as different solvents, amounts of agitation and temperatures. Both of these methodologies were used to improve the lift-off of molecular rulers. Attempts were made to utilize a multilayer system with 1,10-decanediylbisphosphonic acid as the organic component, instead of the previously used mercaptoalkanoic acids, and different metal ions, namely Zr4+ and Zn2+. This multilayer framework has different stability conditions than the multilayer system initially utilized. Attempts were also made to lift-off the 16-mercaptohexadecanoic acid / copper multilayer system with an assortment of different solvents and environmental conditions.

Embossing Polymer Waveguides for Integrated Optical Devices

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Polymers are currently being investigated for many optical applications as a result of their ruggedness, low cost, flexibility and optimal light propagation.

Embossing is an easy, low cost method to produce sub-micron devices by pressing a master with a negative image of the final structure into a polymer substrate under conditions of high temperature and pressure. The focus of the project was to produce a reproducible method to nanoimprint, or emboss waveguides in polymers spun onto silicon substrates. Conventional lithography and electron beam processes were used to produce masters in silicon and on silicon oxide.

These were embossed in polymethylmethacrylate (PMMA), teflon, and a cyclo-olefin polymer in both positive and negative relief to produce channels and ridges for light propogation. The results were analyzed using scanning electron microscopes (SEM) and an atomic force microscope (AFM). Surface texture and the quality of pattern transfer was observed to be highly dependent on the materials used, and the temperature of embossing. Submicron test structures, waveguides, and ring resonators were embossed successfully and the method is being investigated to produce multilayer devices such as gratings or mirrors and integrated optics for biosensing, display technologies, and optical switching.

Chemistry-On-A-Chip: Functionalizing Microfluidic Devices

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This project focuses on the design and fabrication of a novel microfluidic system capable of handling any chemical and physical operation requiring a gas/liquid interface, such as heat exchanging, stripping, absorbing and mixing. Using microfluidic devices to perform these operations increases the efficiency due to the large surface area to volume ratio.

The project consists of three major steps: (1) Fabrication of a liquid phase wafer with microfluidic channels on the front side and small perforations ranging from 10 to 40 µm in diameter on the back side of the wafer such that these perforations connect the back side of the wafer to the channels etched on the front side of the wafer. (2) Fabrication of a gas phase wafer with microfluidic channels etched on the front side. (3) Bonding the liquid phase wafer to the gas phase wafer such that the perforations on the back side of the liquid phase channel align completely with the channels on the gas phase wafer. Thus we have parallel gas/liquid channels connected by perforations that facilitate the formation of a gas/liquid interface. At the end, a Pyrex wafer will be bonded to the top side of the liquid phase channel so the dynamics of the operations can be seen and characterized from above.

Novel Gate Stack Processes for MOS-Based Structures

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Asymmetric charge injection has been achieved in metal oxide silicon (MOS) capacitor structures through the introduction of metal nanocrystals embedded in another metal with different work functions. The MOS capacitors are used in a tunneling diode configuration. From CV measurements, we can reliably characterize the effective insulator thickness (the tunneling barrier) and work functions. From IV measurements, the nanocrystal triple interface (metal-metal-insulator) gives much higher current injection than the control samples without nanocrystals. The fringing fields derived from the high sheet charge density at the metal-metal interface significantly lowers the potential barrier. The lower effective barrier height allows significant injection at voltages as low as 3 V (the conduction band offset between oxide and Si) which is 10^3 to 10^4 times higher than at 3 V. This can be explained by the exponential increase in Fowler-Nordheim (F-N) tunneling with decreased barrier height. The amplification factor can be much larger if the nanocrystal distribution is designed to minimize current crowding effect. This property of asymmetric injection coupled with the large energy barrier of SiO_2 can potentially be used to create a large population of electrons confined in SiO_2, one component necessary for developing optoelectronic applications in Si systems. The charge injection properties of this device are also favorable for the construction of low-voltage floating-gate CMOS applications.

Ultrasonically Driven Microneedle Arrays

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New advances in nanofabrication have enabled silicon MEMS production of minimally invasive, potentially painless microneedles that can be used in biomedical and fluid delivery applications. Microneedles can be powerful tools in transdermal drug delivery, blood or interstitial fluid sampling and the chemical analysis of small quantities of organic matter. Although fabrication of microneedles is relatively new and its applications are very attractive, researchers have discovered that there are major challenges concerning the penetration of microneedles into human skin. If the microneedles are not sharp enough, or their spatial density is too high, the skin will deflect rather than break due to the penetration attempt, and will create a flexed bending in which the microneedles cannot penetrate. Transversely, if the microneedles are too long, the upper portion of the microneedle may not have enough rigidity and can break off before penetration or under the skin.

Here, we have fabricated microneedle arrays using deep reactive ion etching (DRIE) and have tested the force required for skin penetration by using similarly permeable silicon rubber and vegetable skin simulates. We propose that by driving the microneedle arrays ultrasonically, we can alleviate many current problems and can provide a more effective and efficient means to use microneedles in the penetration of human skin. Ultrasonic drive provides extra force to cut skin via inertial stiffening and after penetration provides a fluid lubricating layer for smoother insertion. Preliminary experiments with piezoelectric actuators bonded to silicon microneedles are presented.

Positive Development of Random Copolymer Photoresist using SuperCritical Carbon Dioxide as Environmental Benign Solvent

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Due to its chemical and physical properties, supercritical carbon dioxide has become a leading candidate for substituting aqueous and organic solvents used in the development of photoresist patterns. In addition to its environmental benefits, this supercritical fluid has solubility parameters and density variations that can be adjusted by manipulating pressure and temperature. In this study, tetrahydropyran methacrylate-r-1H, 1 H-perfluoroctyl methacrylate (THPMA-F7MA), a random copolymer, acts as a negative tone resist on a silicon substrate when developed in $scCO_2$. The image reversal (from negative to positive) is based on the Diffused Enhanced Silylated Resist (DESIRE) process with an addition of two steps after EBeam or 248 nm (Nikon) exposure: silylation and flood exposure. The focus of this study was to manipulate various parameters at different steps of the process to minimize film swelling and acid diffusion. Special attention was given to the manner in which the $scCO_2$ is pressurized and depressurized. Because patterns are etched using E-Beam and 248 nm photolithography, careful adjustments were made to avoid under/overexposure of the resist which have noticeable effects on the resolution of the patterns after developmentóprimarily polymer cross linking. Photoresist features as small as 300 nm were achieved, however features are distorted due to the potential problems mentioned.

Sol-Gel Derived Functionalized Coatings for DNA Immobilization

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The immobilization of biomolecules on solid surfaces is a common strategy used in performing various bioassays. One technological application is the array-type platform known as the DNA microarray. These rely on chemical activation of the glass surface to attract and immobilize DNA strands in an orderly fashion after the controlled deposition of DNA solutions. The objective of this project is to explore the physical interaction of DNA solutions with functionalized coatings developed on glass surfaces. A comparative study for a standard amino-functionalized monolayer coating and sol-gel derived microporous coatings has been prepared. The physical interaction between the DNA solutions and coatings was studied through contact angle measurements as functions of time, buffer type, and DNA concentration. These observations were related to the morphological and micro-structural properties of the coatings characterized by AFM. The potential of XPS to study DNA retention/penetration on hybrid microporous coatings was explored. The performance of the coatings was also evaluated by optical microscopy studies for actual array elements (spots) containing fluorescently-tagged DNA probes deposited by an automated arrayer. In this case, the effects of post printing parameters (rehydrating and drying conditions) on spot morphology were investigated.

Fabrication of Silicon Carbide Atomic Force Microscopy Probes

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Atomic Force Microscopy (AFM) provides three-dimensional surface topography at nanometer lateral and sub-angstrom vertical resolution on insulators and conductors. The objectives of the project are to research the operational aspects of atomic force microscopy, design and fabricate AFM probes out of silicon carbide (SiC), and compare results obtained with the SiC probes to those obtained using a standard Si probe. The various modes of AFM are reviewed, namely contact, non-contact, and tapping. Two approaches to the probe design are proposed, and an outline of the fabrication steps for each is given. The favorable electrical and mechanical properties of SiC are addressed, along with the advantages of using SiC for AFM probes. Epitaxial growth of SiC on Si and the subsequent processes for the fabrication of the probes are reviewed. Results of topographic tests with the SiC probes are discussed and compared to tests using a Si probe. Conclusions on the benefits and drawbacks of using silicon carbide for AFM probes are made.

Growth of ZnO Nanowires and their Application in Solar Cells

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Growth of ZnO nanowires was achieved through Metal Organic Chemical Vapor Deposition (MOCVD) using the precursor, Zinc Acetylacetonate, and characterized by Scanning Electron Microscopy (SEM). Well-aligned ZnO nanowires with lengths of 1mm and diameters of 50 nm were grown on a-plane Al_2O_3. ZnO nanowires with random directional growth were also produced on silicon and various transparent conducting oxides with 1 mm to 2 mm lengths and 25 nm diameters. The important factors determining the morphology are the pressure within the vacuum chamber, carrier gas flow, time duration of growth, and the heating ramp. The wires have many applications including use in photoelectrochemical cells due to their large surface areas and unique electron transport properties. Photoelectrochemical cells use a mesoporous semiconductor, typically sintered TiO_2 nanoparticles, to accept electrons from an adsorbed photosensitive dye. Replacing the TiO_2 with densely packed and high surface area ZnO nanowires may improve electron transport and higher efficiencies may be possible.

Ferroelectric Thin Films for Nonvolatile Memory Applications

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Ferroelectric random access memory (FeRAM) has shown much potential in replacing volatile dynamic random access memory (DRAM), the current choice for computer technology. FeRAM is nonvolatile, meaning that any charge placed upon the capacitor is stable, preventing the constant refreshing of the data. This gives it an advantage in power conservation over DRAM.

One reliability issue encountered with FeRAM is fatigue, which is defined as a loss of switchable polarization, or signal strength, with repeated switching. In this work, this phenomenon will be studied in two ways. One involves measuring the energy levels and populations of defect levels in a capacitor, which may trap electronic charge during device operation, through illumination of the thin films with wavelength-specific light. The other uses deep level transient spectroscopy (DLTS) to identify trap levels within the capacitors. The capacitors consist of lead zirconate titanate (PZT) sandwiched between rectifying and ohmic metal contacts. Electron beam deposition will be used to deposit several different metals onto the PZT to find a suitable ohmic contact as one has not yet been found. The significance of this project is to shed some light on an issue that if overcome, could integrate FeRAM even further into today's state of the art technology.

Organometallic-Based Photovoltaic Cells

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Photovoltaic (PV) cells provide a source of energy that is renewable and clean. The goal of this project is to make more efficient and more affordable, solid-state PV cells. A new approach was taken, by attempting to make the hole transport material of the PV cell out of an organometallic compound. Not only is organic material inexpensive and readily available, it has many other desirable properties. Organic compounds can be spin-coated easily on a variety of substrates, and their properties make them flexible as well. Several organometallic iridium complexes were designed and synthesized for this use. After synthesis of the compound iridium tris(2-thiophene-5-(pyridine-2,-yl) thiophene), tests were run to determine the hole mobilities, lowest unoccupied molecular orbital levels (LUMO), and highest occupied molecular orbital levels (HOMO). When characteristics were found to be favorable, the material was integrated into a basic Graetzel PV cell. The basic components of the Graetzel cell include the titanium layer, which acts as the cathode or electron transport; rubidium dye, used to absorb the incoming photons; and our iridium compound, the hole transport material. These components are layered on an indium tin oxide (ITO) glass substrate.

A Novel Method of Creating Nanoscale Interconnects by Radioactive Decay

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Despite the negative association many have with radioactivity, there are numerous applications that can benefit from doses no larger than the amount inside a standard smoke detector. One proof of this functionality is a proposed method to form nanoscale interconnects. This method works by harnessing the power of nuclear tracks that radioactive emitted particles inherently form. Our hypothesis insists that paths of higher conductivity can be produced along nuclear tracks due to the damaging properties of radioactive decay. Ultimately, we want to take various blocks of bombarded materials and line up paths of the emitted particles, essentially forming an interconnect.

In order to prove these tracks exist and are detectable, we are creating capacitor-like devices of various sizes and materials. Once fabricated, the Atomic Force Microscope (AFM) is used to characterize the surface of the samples and initial conductivity is determined with a probe station. Samples are then bombarded with emitted particles from a radioactive source.

Following this step, conductivity is re-characterized and a Scanning Tunneling Microscope (STM) will be used to pictorially demonstrate the existence of paths with increased conductivity. Potentially this method could increase the success of three-dimensional devices and create the possibility of neural-like networks of connectivity.

Developing IR (8-14 µm) Detectors (External Photoemission)

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A composite film of Ag-Si was sputtered on the substrate of Si (111) to study the electrical properties using the Hall Effect. The composite is designed to be used to make a detector in the wavelength range of 8-14 µm. A volume fraction of 20% and 80% Ag and Si were used respectively. The sample of thickness of 2.0 µm was subjected to chemical cleaning until complete removal of the segregated layer, a thin conductive layer caused by the rising of Ag atoms to the surface. The following step after etching was the evaporation of 200 Å chromium (Cr) and 2000 Å gold (Au) in the chamber of the vacuum. To create lower resistance between the evaporated metals and composite, the sample was annealed at 700°C in an RTA for 30 seconds. An I-V measurement was taken to ensure that the contacts were ohmic, i.e. linear. The final step before measuring the Hall Effect was to sand-blast a cloverleaf pattern on the composite with the contact on the periphery of each leaf.

Finally, the Hall measurement showed average carrier concentration of 2.5E20 (cm^3) and the average mobility of 367.7 (cm^2/ volt-second).

Fabrication and Testing of Nano-Scale Gas/Vapor Sensor

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A gas/vapor nano-sensor has been created using a deposited nano-structured silicon thin film. This film is an arrayed void-column network deposited by ECR-PECVD and has a large surface to volume ratio, making it an ideal material for gas/vapor sensing. The sensor's process flow begins with oxidation of a silicon oxide layer on a silicon substrate to produce electrical isolation. After deposition of the porous film, gold electrical contacts with separations ranging from 100 nm to 1 μm were formed by a lift-off process with e-beam lithography and thermal evaporation. Finally, another lift-off process was used to define the sensing area using optical lithography. The fabricated sensor was then used to monitor changes in electrical conductivity in the film between the Au contacts caused by gas/vapor adsorption. Gas sensing responses explored included water vapor, ammonia, and carbon monoxide.

Amphiphile Aspect Ratio and Membrane Bending Rigidity in a Solvent-Free Cell Membrane Model

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Cell membranes can be simulated efficiently using a solvent-free model. Monte Carlo techniques, which minimize the free energy of a system, were used with a model that treats lipids as rigid rods. These rods interact according to three potential energy parameters that simulate amphiphilic interactions with a solvent. The region of parameter space for which the membrane is fluid was found in terms of these parameters. This fluid region narrows in size as the length of the amphiphiles decreases and becomes negligibly small for rods with an aspect ratio of 1.5 or less. The effect of aspect ratio on bending rigidity was also examined. Decreasing the aspect ratio causes the membranes to have a lower bending rigidity, corresponding to more flexible membranes. Real membranes are composed of multiple types of lipids, so mixtures of rods with different aspect ratios were also examined.

Deposition of Molecular Rulers on a Patterned Sacrificial Layer

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This work is focused on developing the science of molecular ruler nanolithography into practical nanolithography manufacturing processes. The strategy is to implement a bi-layer host structure consisting of a metallic host layer on top of a sacrificial resist using materials and techniques that are compatible with standard semiconductor device manufacturing processes.

"Molecular ruler" nanolithography consists of a process for scaling down the dimensions of a metallic host structure by assembling alternating layers of mercaptohexadecanoic acid and copper (II) ions. The mercaptohexadecanoic acid molecule consists of a carbon chain that exhibits a precise length—2 nm in our case – leading them to be referred to as 'molecular rulers'. When layered, these 'rulers' allow for an incremental decrease in feature size limited only by the number of layers applied.

The work is exploring the use of a sacrificial bi-layer host structure consisting of a metallic host on top of a sacrificial resist. By using a sacrificial resist, the molecular ruler process can be extended to reducing the dimensions of features produced by industry standard lift-off processes, including optical and electron beam processes.

Optimizing Platinum Coating for Spin Magnetic Injection

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Spin magnetic injection involves injecting electrons through one ferromagnet of a fixed state to alter the state of another ferromagnet. Thus the state of the second magnet can be induced to be spin up or spin down. This mechanism can be used for high density information storage such as memory for the computer. Platinum is used as the conducting lead for electron transportation. Since the magnetic injection structures are on the nano-scale, the roughness of the platinum coat may cause unwanted variation in the induced magnetic field. The atomic force microscope will be used to characterize the surface of sputtered platinum and for roughness analysis. New methods of ensuring the smoothness of platinum coating will be developed in this project.