National Nanotechnology Infrastructure Network
Research Experience for Undergraduates Program

2012 NNIN REU Convocation

August 2012

National 4-H Youth Conference Center
Chevy Chase, MD 20815

Welcome to the National Nanotechnology Infrastructure Network
Research Experience for Undergraduates Program

2012 NNIN REU Convocation

Sunday, August 12 - Wednesday, August 15, 2012

National 4-H Youth Conference Center, Chevy Chase, MD 20815

Saturday, August 11th

Participants Arrive; ALL DAY

1:00-8:00 p.m. **Registration in Front Lobby**

You must wear your nametag at all times while on the 4H campus

Sunday, August 12th

7:00-9:00 a.m. Breakfast in the Cafeteria

9:30 a.m. **Buses leave for the National Mall**

SEE BUS ASSIGNMENTS on PAGES 69-70

5:30 p.m. **Buses leave from National Mall for 4H**

(PLEASE DON'T MISS YOUR BUS!)

7:00-9:00 p.m. **Welcome Pizza Party in The Ohio Room**

Monday, August 13th

7:30-8:30 a.m. Breakfast in the Cafeteria

THE OHIO ROOM • MORNING SESSION

8:30-8:35 a.m. (OHIO) **Good Morning and Announcements; Dr. Lynn Rathbun**

8:35-9:05 a.m. (OHIO) **Dr. Lawrence Goldberg, National Science Foundation (Page 64)**

A1 Moderators *Tomoko Borsa and Kathy Gehoski*

9:10-9:21 a.m. **A-01** **Mr. Abubakar Abid** **NNIN REU Site: Georgia Institute of Technology**
Fabricating Microring Biosensors to Detect Toxins 13

9:21-9:32 a.m. **A-02** **Mr. Ali Abdallah** **NNIN REU Site: University of Michigan**
Patterning of Biomolecules using Dip Pen Nanolithography. 13

9:32-9:43 a.m. **A-03** **Ms. Brianna Thielen** **NNIN REU Site: University of Washington**
Characterization of Polymer-Modified Silicon Nanophotonic Biosensors. 58

9:43-9:54 a.m. **A-04** **Ms. Camryn Johnson** **NNIN REU Site: Cornell University**
Development of an in vitro muscle regeneration model using a combination of microfluidics and micropatterning 35

9:54-10:14 a.m. Break

10:14-10:25 a.m. **A-05** **Ms. Corinne Lampe** **NNIN REU Site: Stanford University**
The Effectiveness of Physical Sunscreens in Preventing UVB-Induced Mechanical Damage to the Stratum Corneum 38

10:25-10:36 a.m. **A-06** **Ms. YooSun Shim** **NNIN REU Site: Harvard University**
Engineering Carbon Nanotube Microdrops Using Microfluidic Devices 56

10:36-10:47 a.m. **A-07** **Mr. Geoffrey Vrla** **NNIN REU Site: University of Minnesota**
High Fidelity Method For Microfabricating In Vitro Neural Networks 60

10:47-10:58 a.m. **A-08** **Mr. Jonathan Lee** **NNIN REU Site: University of Minnesota**
Giant Magnetoresistive Sensors for Biological Applications 39

10:58-11:09 a.m. **A-09** **Mr. Jonathan Schoening** **NNIN REU Site WUSTL**
Uptake of Nanoparticles in the Olfactory System and Transport to the Brain in Locust55

11:09-11:21 a.m. Break

11:21-11:32 a.m. **A-10** **Mr. Oliver Switzer** **NNIN REU Site: Cornell University**
Fabrication of a Spin Torque Ferromagnetic Resonance (ST-FMR) Device. 57

11:32-11:43 a.m. **A-11** **Ms. Katherine Nygren** **NNIN REU Site: University of Michigan**
Sub-Wavelength Gratings for Multi-Spectral Infrared Detection and Imaging 48

11:43-11:54 a.m. **A-12** **Ms. Melissa Gosse** **NNIN REU Site: Arizona State University**
Biomineralized Nanopore Membranes on Silicon for Nanoparticle Translocation . . . 29

11:54-12:05 p.m. **A-13** **Ms. Melinda Jue** **NNIN REU Site: Georgia Institute of Technology**
Effect of Inert Nanoparticles on Cement Hydration 36

12:05-12:55 p.m. Lunch in the Cafeteria

Monday, August 13th

7:30-8:30 a.m. Breakfast in the Cafeteria

THE MINNESOTA ROOM • MORNING SESSION

(8:30-9:05 a.m. in the OHIO ROOM)

B1 Moderators Nathan Reed and Christine Wood

9:10-9:21 a.m. **B-01 Ms. Kelsey Hirotsu NNIN REU Site: Stanford University**
Fabricating parylene-C shadow masks for applications in short-channel top-contact carbon nanotube flexible transistors 32

9:21-9:32 a.m. **B-02 Mr. Andrew Knight NNIN REU Site: Arizona State University**
Influence of Optical Stress on Mixed Oxide Transistors 37

9:32-9:43 a.m. **B-03 Ms. Cherrelle Thomas NNIN REU Site: The University of Texas at Austin**
$CuInSe_2$ nanocrystals with inorganic ligands for photovoltaic devices 58

9:43-9:54 a.m. **B-04 Mr. Dashiell Bodington NNIN REU Site: UCSB**
Production of Solid State Spin Qubits. 19

9:54-10:14 a.m. Break

10:14-10:25 a.m. **B-05 Mr. Hans Banerjee NNIN REU Site: University of Texas at Austin**
Silicon Heterojunction Photovoltaic Cells 16

10:25-10:36 a.m. **B-06 Mr. Soichi Hirokawa NNIN REU Site: University of Colorado Boulder**
Transparent and Stretchable Metal Electrodes 32

10:36-10:47 a.m. **B-07 Mr. Jacob Rothenberg NNIN REU Site: University of Colorado, Boulder**
Top-Gated Graphene-Based Ultrafast Electro-Optic Modulators 53

10:47-10:58 a.m. **B-08 Ms. Jia Gloria Lee NNIN REU Site: University of Texas at Austin**
Fabrication and Characterization of a Micromachined In-Plane Directional Piezoelectronic Microphone. 39

10:58-11:09 a.m. **B-09 Mr. Patrick Yu NNIN REU Site: Cornell University**
Electrically and Optically Obtaining Q of High Stress SiN Devices 62

11:09-11:21 a.m. Break

11:21-11:32 a.m. **B-10 Mr. Ryan Parry NNIN REU Site: Georgia Institute of Technology**
Electrochemical Deposition of Polythiophene onto Carbon Nanotube Arrays. 51

11:32-11:43 a.m. **B-11 Mr. William Gaviria NNIN REU Site: University of Minnesota**
The Effects of Surface Passivation on Trap Levels in Silicon Nanocrystals. 27

11:43-11:54 a.m. **B-12 Ms. Whitney Wong NNIN REU Site: WUSTL**
Effects of Membrane Surface Modification on Calcium Carbonate Fouling and Membrane Efficiency for Desalination 61

11:54-12:05 p.m. **B-13 Mr. Isidro Calderon Jr. NNIN REU Site: UCSB**
Correlation between surface morphology and Hall mobility in AlGaAs/GaAs (111)A heterojunctions 22

12:05-12:55 p.m. Lunch in the Cafeteria

Monday, August 13th

THE OHIO ROOM • AFTERNOON SESSION

12:55-1:55 p.m. **NNIN iREU Program; Dr. Lynn Rathbun & The NNIN iREU Interns**

(See pages 14, 36, 50, 51, 59, 63)

1:55-2:05 p.m. Break

A2 Moderator *Mack Carter*

2:05-2:16 p.m. **A-14** **Ms. Lauren Cosgriff** **NNIN REU Site: University of Colorado Boulder**
Ionic Transport Across Atomically Thin Graphene Membranes 23

2:16-2:27 p.m. **A-15** **Mr. Kamil Makhnejia** **NNIN REU Site: University of Washington**
Testing the Properties and Characteristics of Chitin Thin Films 42

2:27-2:38 p.m. **A-16** **Ms. Stephanie Swartz** **NNIN REU Site: University of Colorado**
Progress Towards Electrical Interface Chips for BioMEMS 56

2:38-2:49 p.m. **A-17** **Ms. Sharlin Anwar** **NNIN REU Site: Cornell University**
Towards Electrochemical Gating using Transistors 15

2:49-3:00 p.m. **A-18** **Mr. Adam Overvig** **NNIN REU Site: Arizona State University**
Fabrication and Characterization of Vertical Silicon Nanopillar Schottky Diodes . . . 50

3:00-3:15 p.m. Break

3:15-3:45 p.m. **Dr. Mihail Roco, National Science Foundation (Page 65)**

3:45-4:15 p.m. *Break (Set up your poster per the poster session assignments on pages 69-70)*

4:15-5:30 p.m. **Poster Session 1 (Both Rooms)**

5:30-7:30 p.m. Dinner in the Cafeteria

SPORTS NIGHT & REC ROOM

Monday, August 13th

THE MINNESOTA ROOM • AFTERNOON SESSION

(12:55-1:55 p.m. in the OHIO ROOM)

B2 Moderator *Kathryn Hollar*

2:05-2:16 p.m. **B-14** **Mr. William Gilpin** **NNIN REU Site: Harvard University**
Engineering the Charge Occupancy of Nitrogen Vacancies in Diamond. 28

2:16-2:27 p.m. **B-15** **Mr. Jordan Occena** **NNIN REU Site: Stanford University**
Work Function Tuning in Amorphous TaWSiC Metal Gates for Integrated Circuits 49

2:27-2:38 p.m. **B-16** **Mr. Phillip Meyerhofer** **NNIN REU Site: Penn State**
Construction of a Modulated Potential Superlattice 44

2:38-2:49 p.m. **B-17** **Mr. Peter Luo** **NNIN REU Site: Washington University in St. Louis**
Optimizing the Electrochemical Performance of Cathode Materials for Lithium Ion Rechargeable Batteries 41

2:49-3:00 p.m. **B-18** **Mr. Ryan Murphy** **NNIN REU Site: Georgia Institute of Technology**
Controlling the Composition and Morphology of $Si_{1-x}Ge_x$ *Alloy Nanowires.. .. .. 46*

3:00-3:15 p.m. Break

(3:15-3:45 p.m. in the OHIO ROOM)

3:45-4:15 p.m. Break (Set up your poster per the poster session assignments on pages 69-70)

4:15-5:30 p.m. **Poster Session 1 (Both Rooms)**

5:30-7:30 p.m. Dinner in Cafeteria

SPORTS NIGHT & REC ROOM

Tuesday, August 14th

7:30-8:30 a.m. Breakfast in the cafeteria

THE OHIO ROOM • MORNING SESSION

8:30-8:35 a.m. (OHIO) Good Morning and Announcements; Dr. Lynn Rathbun

C1 Moderators Michael Deal and Jim Marti

8:35-8:46 a.m. C-01 Mr. Adam Blonsky NNIN REU Site: University of Washington
Production and Characterization of Topological Insulators (TI) 19

8:46-8:57 a.m. C-02 Mr. Adam Roberge NNIN REU Site: WUSTL
Synthesis of CdSe Quantum Dots by Aerosol Reactor 52

8:57-9:08 a.m. C-03 Mr. Adel Azghadi NNIN REU Site: Arizona State University
Two-Dimensional Buckled Nanoscale Nanomembrane as Tunable Grating. 15

9:08-9:19 a.m. C-04 Mr. Alexander Lee NNIN REU Site: University of Washington
Implementing Gaussian Quadrature in Molecular Plasmonics 38

9:19-9:30 a.m. C-05 Mr. Codey Henderson NNIN REU Site: Penn State
Controlling and Understanding the Effects of
Reactive Colloids' Packing on Silicon Etching Patterns 31

9:30-9:41 a.m. C-06 Ms. Annabel Chew NNIN REU Site: Harvard University
Electrical Characterization of Heat-treated Tin Monosulfide (SnS) Thin Films. 22

9:41-9:55 a.m. Break

9:55-10:06 a.m. C-07 Ms. Briana James NNIN REU Site: Howard University
The Electrochemistry of Catalyzed Metal Multilayers 35

10:06-10:17 a.m. C-08 Mr. Andrew Tam NNIN REU Site: Howard University
Heteroepitaxial Growth of Diamond on SiC Substrates 57

10:17-10:28 a.m. C-09 Ms. Camille Everhart NNIN REU Site: Cornell University
AFM-Assisted Etching and Electrical Characterization of Graphene 26

10:28-10:39 a.m. C-10 Ms. Caroline Yu NNIN REU Site: UCSB
Carbon Doping on (10-11) GaN by Plasma-Assisted Molecular Beam Epitaxy. 62

10:39-10:55 a.m. Break

10:55-11:06 a.m. C-11 Mr. Michael Hovish NNIN REU Site: Harvard University
Self-Organized Nanostructural Pattern Formation Under Ion Beam Irradiation. . . . 34

11:06-11:17 a.m. C-12 Mr. Ramon Alonso NNIN REU Site: University of Michigan
Characterization of Etching for Release of Piezoelectric Micro-Robots 14

11:17-11:28 a.m. C-13 Mr. Ryan Gaudreau NNIN REU Site: Howard University
Fabrication of MEMS Using Cheap Substrates 27

11:28-11:39 a.m. C-14 Mr. Nathaniel Wendt NNIN REU Site: The University of Texas at Austin
Enhancing the Luminescence Efficiency of GaSb-Based Dilute-Nitrides by RTA 61

11:39-11:50 a.m. C-15 Mr. Christopher Nakamoto NNIN REU Site: UCSB
Fabrication of a Selective Ion Pump: Aluminum Oxide Membrane Anodization 47

11:50-12:50 p.m. Lunch in the Cafeteria

Tuesday, August 14th

7:30-8:30 a.m. Breakfast in the Cafeteria

THE MINNESOTA ROOM • MORNING SESSION

(8:30-8:35 a.m. in the OHIO ROOM)

D1 Moderators *Brandon Lucas and Jorge Pozo*

8:35-8:46 a.m. **D-01 Ms. Kaleigh Margita NNIN REU Site: WUSTL**
Monitoring and Imaging Hypoxic Cells Using Perfluorinated Near-Infrared Florescent Micelles . . . 42

8:46-8:57 a.m. **D-02 Mr. Leon Dean NNIN REU Site: University of Minnesota-Twin Cities**
DNA Extension in Nanochannels . . . 24

8:57-9:08 a.m. **D-03 Mr. Michael Bellavia NNIN REU Site: University of Michigan**
Carbon Nanotube Microfluidic Channels for Cell Manipulation . . . 17

9:08-9:19 a.m. **D-04 Ms. Quachel Bazile NNIN REU Site: Georgia Institute of Technology**
Cellular Binding of Quantum Dots . . . 17

9:19-9:30 a.m. **D-05 Ms. Rachel Baarda NNIN REU Site: UCSB**
Nanoparticle sorting in a label-free electronic microfluidics system . . . 16

9:30-9:41 a.m. **D-06 Ms. Rachel Benton NNIN REU Site: University of Washington**
Interaction of Engineered Nanoparticles with Artificial Cell Membranes . . . 18

9:41-9:55 a.m. Break

9:55-10:06 a.m. **D-07 Mr. Andrew Sanville NNIN REU Site: Cornell University**
Etch Study of Zirconium Oxide Nanoparticle Photoresist . . . 54

10:06-10:17 a.m. **D-08 Ms. Donna Deng NNIN REU Site: Pennsylvania State University**
Phase Transformations in Metal Contacts and InGaAs Nanowires . . . 24

10:17-10:28 a.m. **D-09 Ms. Ashley Truxal NNIN REU Site: University of Michigan**
Optimization of inkjet-printed ITO electrodes for fabrication of sub-micron gate length transistors using surface chemistry manipulation . . . 59

10:28-10:39 a.m. **D-10 Mr. David Goldfeld NNIN REU Site: Georgia Institute of Technology**
Sacrificial polymers and their use in patternable air-gap fabrication . . . 28

10:39-10:55 a.m. Break

10:55-11:06 a.m. **D-11 Ms. Donnita McArthur NNIN REU Site: Howard University**
Growth and Characterization of GaAs/InAs Quantum Dots by MBE . . . 43

11:06-11:17 a.m. **D-12 Mr. Adam McMullen NNIN REU Site: The University of Texas at Austin**
Metasurface Dichroic Mirrors & Applications to Solar Energy via Spectral Splitting 44

11:17-11:28 a.m. **D-13 Mr. Colin Burns-Heffner NNIN REU Site: Penn State University**
Optimization of Protocol for Fabrication of a Polymer Filter from a PDMS Mold . . 21

11:28-11:39 a.m. **D-14 Ms. Amanda Ellison NNIN REU Site: WUSTL**
Fabrication of Metallic and Dielectric Nanowires for Realizing Optical Filters . . . 26

11:39-11:50 a.m. **D-15 Ms. Elisa Russo NNIN REU Site: Cornell University**
Monolayer Molybdenum Diselenide ($MoSe_2$) . . . 54

11:50-12:50 p.m. Lunch in the Cafeteria

Tuesday, August 14th

THE OHIO ROOM • AFTERNOON SESSION

C2 Moderators *Brandon Lucas and Jorge Pozo*

12:50-1:01 p.m. **C-16** **Mr. Ian Holmes** **NNIN REU Site: Harvard University**
Assembly of Thermoresponsive Microcapsules *33*

1:01-1:12 p.m. **C-17** **Ms. Gwendolyn Hummel** **NNIN REU Site: University of Michigan**
Characterization of Phase Change Material for Radio Frequency Applications. *34*

1:12-1:23 p.m. **C-18** **Mr. Lee Hamstra** **NNIN REU Site: University of Colorado Boulder**
Fabrication of Graphene Field Effect Transistors *30*

1:23-1:34 p.m. **C-19** **Ms. Maria Michael** **NNIN REU Site: The University of Texas at Austin**
Electrical properties of LaLuAs films *45*

1:34-1:45 p.m. **C-20** **Mr. Patrick Butera** **NNIN REU Site: Arizona State University**
Fractal Electrodes. *21*

1:45-1:56 p.m. **C-21** **Mr. Ryan McMorris** **NNIN REU site: University of California**
Transport In Near-Surface Two-Dimensional Electron Systems *43*

1:56-2:12 p.m. Break

2:12-2:42 p.m. **Intellectual Property, Nicole Jantzi (Page 66)**

2:42-2:47 p.m. Break

2:47-4:02 p.m. **Nanotechnology (and Related) Careers; Panel (Pages 67-68)**

4:02-4:32 p.m. Break (Set up your poster per the poster session assignments on pages 69-70)

4:32-5:47 p.m. **Poster Session 2 (Both Rooms)**

5:30-7:30 p.m. Dinner in the Cafeteria

8:00-10:00 p.m.

DJ Dance with Dance Lesson by Jorge Pozo

Tuesday, August 14th

THE MINNESOTA ROOM • AFTERNOON SESSION

D2 Moderator *Stefan Myhajlenko*

12:50-1:01 p.m. **D-16** **Mr. Alexander Buck** **NNIN REU Site: University of Texas at Austin**
Anti-Reflective Coatings for Room Temperature Terahertz Quantum Cascade Laser Sources. 20

1:01-1:12 p.m. **D-17** **Mr. Aubrey Michael Shapero** **NNIN REU Site: University of Colorado**
Volume Nano-Structured Optics for 3D Superresolution Imaging 55

1:12-1:23 p.m. **D-18** **Mr. Ian MacKenzie** **NNIN REU Site: WUSTL**
Identification of Carbon Nanostructures (Fullerenes) in Cigarette Ash 41

1:23-1:34 p.m. **D-19** **Mr. Daniel Klemme** **NNIN REU Site: University of Colorado Boulder**
Microring Resonators for Silicon Photonic Circuits. 37

1:34-1:45 p.m. **D-20** **Mr. Jared Newton** **NNIN REU Site: WUSTL**
Strain Color Coding Using Localized Surface Plasmon Resonance of Gold Nanoparticles. 47

1:45-1:56 p.m. **D-21** **Mr Isao Mori** **NNIN REU Site: The University of Texas at Austin**
Photovoltaic devices fabricated with $CuIn_{1-x}Ga_xSe_2$ (CIGS) nanocrystal inks. 45

1:56-2:12 p.m. Break

(2:12-2:42 p.m. in the OHIO ROOM)

2:42-2:47 p.m. Break

(2:47-4:02 p.m. in the OHIO ROOM)

4:02-4:30 p.m. Break (Set up your poster per the poster session assignments on pages 69-70)

4:30-5:45 p.m. **Poster Session 2 (Both Rooms)**

5:30-7:30 p.m. Dinner in the Cafeteria

8:00-10:00 p.m.

DJ Dance with Dance Lesson by Jorge Pozo

Ohio Room

Wednesday, August 14th

7:30-8:30 a.m. Breakfast in the Cafeteria

THE OHIO ROOM • ALL DAY

8:30-8:35 a.m. **Good Morning and Announcements; Dr. Lynn Rathbun**

E1 Moderator *Lynn Rathbun*

8:35-8:46 a.m. **E-01** **Ms. Sonali Gupta** **NNIN REU Site: Georgia Institute of Technology**
Optimizing Liposomal Uptake and Content Release u
sing Glioblastoma Multiforme as a Model System *30*

8:46-8:57 a.m. **E-02** **Mr. Stephen Olson** **NNIN REU Site: University of Minnesota**
Engineered Metallic Structures and
Nanofabrication Techniques for Plasmonic Biosensors *49*

8:57-9:08 a.m. **E-03** **Mr. Duy Do** **NNIN REU Site: Georgia Institute of Technology**
Nanotechnology Companies in the U.S.A:
A Web-based Analysis of Companies and Poverty Alleviation *25*

9:08-9:19 a.m. **E-04** **Ms. Merrill Brady** **NNIN REU Site: Cornell University**
A Study of Integrating Societal and Ethical Issues into NNIN REU *20*

9:19-9:30 a.m. **E-05** **Mr. Timothy Welsh** **NNIN REU Site: Stanford University**
Development of Air Spaced VIPA's for Use in Optical Coherence Tomography *60*

9:30-9:55 a.m. **Fellowship Opportunities; Dr. Lynn Rathbun**

9:55-10:15 a.m. Break

10:15-11:30 a.m. **NNIN SEI Discussion; Dr. Gina Eosco (Page 68)**

11:30-11:40 a.m. Break

E1 Moderator *Lynn Rathbun*

11:40-11:51 a.m. **E-06** **Ms. Elsie Bjarnason** **NNIN REU Site: Stanford University**
Water-in-Ferrofluid Digital Microfluidic System
for Single Cell Isolation and Transport *18*

11:51-12:02 p.m. **E-07** **Mr. Keevin Hood** **NNIN REU Site: Arizona State University**
Simulation Studies of SiC MOS Capacitors.. .. .. *33*

12:02-12:13 p.m. **E-08** **Mr. Kyle Guess** **NNIN REU Site: University of California**
Integration of Embedded CMOS Chips for On-Chip Optical Communication *29*

12:13-12:24 p.m. **E-09** **Mr. Clay Long** **NNIN REU Site: Cornell University**
Selective Atomic Layer Deposition. *40*

12:24-1:24 p.m. Lunch in the Cafeteria

Wednesday, August 15th

THE OHIO ROOM • ALL DAY

E2 Moderator *Nancy Healy*

1:24-1:35 p.m. **E-10** **Mr. Anderson Hayes** **NNIN REU Site: Howard University**
Growth of Boron Nitride Nanowires 31

1:35-1:46 p.m. **E-11** **Mr. Dmitriy Davydovich** **NNIN REU Site: Penn State University**
Synthesis and Characterization of
Potassium Sodium Niobate, a Lead-Free Ferroelectric 23

1:46-1:57 p.m. **E-12** **Mr. Juan Llinas** **NNIN REU Site: University of Colorado Boulder**
Microheaters for Thermo-Optic Tuning of Silicon Photonic Devices 40

1:57-2:08 p.m. **E-13** **Mr. Marcos Echeverria** **NNIN REU Site: University of California**
Improving Superconducting Resonators for use in Quantum Computing 25

2:08-2:19 p.m. **E-14** **Ms. Emily Ross** **NNIN REU SITE: Stanford University**
Atomic Layer Deposition Process Optimization
and Characterization of Amorphous Metal-Oxide Films 53

2:19-2:30 p.m. **E-15** **Mr. Frazier Mork** **NNIN REU Site: Cornell University**
Substrate Conformal Imprint Lithography 46

2:30-2:41 p.m. **E-16** **Mr. Radu Reit** **NNIN REU Site: University of Washington**
A microfluidic gradient generating device integrated with nanopatterned matrices for
studying cell migration in response to matrix topography & diffusible guidance cues 52

2:41-2:52 p.m. **E-17** **Mr. Justin Norman** **NNIN REU Site: University of California**
InAs Quantum Dot Laser 48

2:52-3:30 p.m. **Wrap Up, Q&A; Dr. Lynn Rathbun and Ms. Melanie-Claire Mallison**

NNIN REU PHOTOGRAPH SESSION (Location TBD)

5:30-7:30 p.m. Dinner in the Cafeteria

7:30 p.m.

Movie Night in the Auditorium with Popcorn!

Thursday, August 16th

7:30-8:30 a.m. Breakfast in the Cafeteria

Everyone Leaves! Check Out is 11:00 a.m.

Patterning of Biomolecules using Dip Pen Nanolithography

Ali Abdallah

Biomedical Engineering, Wayne State University

NNIN REU Site: Lurie Nanofabrication Facility, University of Michigan

REU Principal Investigator: Edgar Meyhofer, Mechanical Engineering, University of Michigan
REU Mentor: Pilar Herrera-Fierro, Electrical Engineering and Computer Science, University of Michigan
Contact: ahabdallah27@gmail.com, meyhofer@umich.edu, pilarhf@umich.edu

The overall objective of this work is to pattern kinesin, a biomolecular motor in eukaryotic cells that transports intracellular cargoes along cytoskeletal networks of microtubules, on glass surfaces and facilitate the development of novel *in vitro* motility assays to examine unresolved mechanistic questions of how these motors interact and transports cargo in live cells. Critical for such assays is the ability to pattern functional motors into precisely known geometries and densities, ultimately with single molecule precision. Our general strategy to achieve this was to directly pattern biomolecules via Dip Pen Nanolithography (DPN) using a NanoInk DPN 5000. As first step towards such assays we used fluorescently-labeled bovine serum albumin (BSA) as a protein model system and patterned BSA using a single cantilever tip and loaded the tip by directly pipetting the solution atop it. We evaluated the consistency of the dot sizes and any undesirable streaking by quantitatively analyzing the generated patterns with epifluorescence microscopy. Our results indicate that tip loading, bleeding, and preparation of the substrate are critical for reproducibly patterning protein molecules on glass surfaces. We also conclude that the constant height control mode of the DPN, rather than constant force mode, generates preferred results. We are now in the process of extending our observations to kinesin.

Fabricating Microring Biosensors to Detect Toxins

Abubakar Abid

Computer Science with Molecular Biology, MIT

NNIN REU Site: Georgia Tech Nanotechnology Research Center, Georgia Tech

NNIN REU Principal Investigator: Ali Adibi, Electrical and Computer Engineering, Georgia Tech
NNIN REU Mentor: Farshid Ghasemi, Electrical and Computer Engineering, Georgia Tech
Contact: aabid93@mit.edu, adibi@ee.gatech.edu, farshid.ghasemi@gatech.edu

Microring resonator biosensors allow for precise, real-time, and label-free detection of biomolecules. Similar to other refractive index-based biosensors, ring resonators permit different frequencies of light to resonate, as a function of the concentration of target molecules, such as toxins, which bind to receptors, such as glycans, on the resonator. The focus of this project is to optimize the delivery of these glycans and other reagents to the surface of the biosensor. In order to detect multiple toxins, different glycans must be dispensed on the various resonators on the biosensor. As such, a system of microfluidic channels was tested and printed, allowing users to dispense glycans, as well as reagents, with high throughput. In order to increase resolution and reduce droplet size, an intermediate layer of 15-micron parylene was deposited above the microfluidic channels for delivering reagents. It was shown that a system of channels to deliver glycans could be patterned on top of this parylene, and could be peeled off mechanically along with the parylene. Finally, contact angle measurement revealed the need for a pumping mechanism, so cladding layers were tested and deposited. Currently, these separate components for a biosensor have been developed and have paved the way for the fabrication of the device as a whole.

Noise Spectra Measurements of Silicon Nanowire Field Effect Transistors for Biosensor Applications

Andrew Acevedo

Biomedical Engineering, Washington University in St. Louis

NNIN iREU Site: Forschungszentrum Jülich, Jülich, Germany

NNIN iREU Principal Investigator: Dr. Svetlana Vitusevich, Peter Grünberg Institute 8, Forschungszentrum Jülich
NNIN iREU Mentor: Sergii Pud, Peter Grünberg Institute 8, Forschungszentrum Jülich
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Silicon nanowire field effect transistors (SiNW FETs) are promising tools in the development of new biosensors due to their ability to directly translate interactions with target molecules into readable signals. They are highly sensitive and selective and capable of real-time response and label free detection. However there are challenges with stability and reproducibility in the development of such sensors due to the imperfections of the thin gate dielectric when exposed to the electrolyte, low signal to noise ratio due to small size, and surface effects.

In order to find optimal dielectric passivation for SiNW sensors this project is focused on the investigation of the influence of an electrolyte liquid gate on the physical and electric properties of the NW FETs. Noise spectroscopy was employed to characterize the state of the devices in the absence and presence of the electrolyte. Noise spectra were measured and analyzed for SiNW FETs of 500 nm width and a variety of lengths (2-16 μm) in air and PBS buffer at different liquid gate and back gate voltages. Parameters of interest include the effects of threshold voltage and charging time of the device gate dielectric. Noise spectra measurements were also used in the differential measurement of the transconductance of the devices in PBS.

Characterization of Etching for Release of Piezoelectric Micro-Robots

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Thin-film piezoelectric micro-robots could potentially help save human lives with their ability to do reconnaissance in hazardous places or to avoid a costly demolition process during infrastructure maintenance with images provided from inconvenient locations. In order to achieve these goals there needs to be an optimized fabrication process for these micro-robots using microelectromechanical systems (MEMS) technology. A critical fabrication step in MEMS technology is the safe release of these micro-robots using etching, which etches only silicon in an isotropic manner. Due to the nature of isotropic etching, the etching results depend on the amount and location of the silicon's open surface area. Micro-robots can also be designed with trenches such that XeF_2 flows through the trenches and undercuts piezoelectric actuators, allowing free movement. Thus, the geometry and location of the trenches is important to successfully release micro-robots. In this work, XeF_2 etching of several piezoelectric micro-robot designs has been characterized, which can be used to modify the design of the micro-robots for a faster and safer release. Additionally, the etching of C_4F_8 polymer, which was deposited on the side wall of the trenches in deep reactive ion etching, was characterized after the polymer was observed to protect silicon from being etched.

Towards Electrochemical Gating using Transistors

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We developed electrolyte-oxide-semiconductor (EOS) capacitors to demonstrate; (a) the dynamics of the ionic double layer under field effect modulation, (b) the role of electrolyte composition on the CV profile, and (c) the role of insulator surface groups on the overall capacitance of the double layer. Surface groups owing to their amphoteric nature are known to get charged under an applied potential and it has been shown to affect double layer formation [1]. This study will help us understand the complex interplay between double layer dynamics, ionic composition and surface groups through CV measurements. Various EOS capacitor devices were fabricated, each composed of different insulating oxide layer. The fabrication steps included using GSI PECVD, LPCVD furnace, oxide furnace, n^+ polysilicon furnace and ALD for oxide layer deposition. The Ellipsometer was used for characterizing the oxide layers. Photolithography was done using ABM Contact Aligner, and measurements were made using Keithley 4200 Semiconductor Characterization System. The results obtained showed a strong hysteretic effect dictated by surface charge density. Varying valency and pH of an electrolyte caused shifts in the CV curve described by an electrostatic effect. The Hysteretic effect is further shown to be different for varying valency of the ion indicating adsorption effects. This study is the first step towards creating a transistor capable of fluidic actuation and ionic modulation.

References: [1] Jiang, Z.; Stein, D. Langmuir 2010, 26, (11), 8161-8173.

Two-Dimensional Buckled Nanoscale Nanomembrane as Tunable Grating

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We have developed a tunable, optical two dimensional (2-D) grating which can be used for measuring thermal-induced strain based on buckled thin film with periodic sinusoidal patterns on elastomeric substrates. 1-D sinusoidal gratings and 2-D herringbone gratings with a submicron scale have been fabricated with nanometer-thick gold film coated on uniaxial and biaxial pre-tensioned polydimethylsiloxane (PDMS) substrates, respectively. Due to the competition between the soft elastomeric substrates and relatively stiff films, uniform periodic wavy profiles are created upon releasing the pre-tension. The level of pre-strain, the mechanical properties of the PDMS and gold, and the thicknesses of gold films determine the amplitudes and wavelengths of wavy structures. The buckling profiles can be tuned mechanically by changing the level of pre-strain applied on the elastomeric substrate. Moreover, characteristics of the buckles vary based on the thickness of the nanomembrane stiff film (gold). Different methods of producing a stiff film on top of an elastomeric substrate have been established so far, while for this project we focus on deposition of gold on PDMS by argon plasma sputter coating to create 2-D herringbone buckles, which has the advantage of being low cost and extremely time efficient.

Nanoparticle sorting in a label-free electronic microfluidics system

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A device capable of detecting, characterizing and sorting nanoparticles and important biological targets would be an invaluable tool both for public health monitoring and for biomedical research. Examples of the utility of such a device include aggregating rare particle types or efficiently imaging representative particles in a diverse mixture. Current methods of sorting particles are impractical for use in processing polydisperse samples.

We describe the development of a microfluidic device that should permit the high-thoughput sorting of nanoparticles, potentially able to sort hundreds to thousands of particles per second. The device consists of a microchannel cast in poly-dimethyl siloxane (PDMS), an optical sensor, and a fluid actuator. Sorting is accomplished by driving fluid on-demand using a piezoelectric transducer (PZT), actuated by an optical sensor sensitive to particles passing through the microfluidic device. We have done a systematic study of the PZT actuation, using a range of analytic tools including a laser vibrometer, and have explored various means of coupling the PZT and the microfluidic device. As a result of this study, we have developed an improved method for mounting the PZTs to the microfluidic device that we expect will demonstrate more effective fluid actuation.

Silicon Heterojunction Photovoltaic Cells

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A key advantage of silicon heterojunction photovoltaic cells over conventional cells is that they have potentially higher efficiency. They can be made using Remote Plasma Chemical Vapor Deposition (RPCVD), a low temperature process which prevents carrier lifetime degradation and thus improves open-circuit voltage (V_{oc}). Both single (SHJ) and dual (DHJ) heterojunction cells were fabricated by depositing a-Si:H onto silicon wafers using RPCVD. SHJ cells were fabricated with and without intrinsic silicon "i-layers," and with different thicknesses of p-doped a-Si:H at the front. According to I-V testing, the SHJ cells with an i-layer produced a higher Voc than those without one, suggesting the i-layer aids in passivation. Thicker p-doped layers resulted in lower short-circuit current density (J_{sc}), due to absorption in the p-doped layer, reducing quantum efficiency at short wavelengths. DHJ cells were fabricated with varying back surface field (BSF) layer thicknesses. A 30 nm BSF layer produced a similar V_{oc} and J_{sc} to one of 20 nm, indicating that thicker BSF layers do not significantly reduce back surface recombination. SHJ cells and DHJ cells show similar efficiencies (~15%). This may be due to non-optimized doping of the BSF layer in the DHJ cells, or their lack of an i-layer leading to lower quantum efficiency.

Cellular Binding of Quantum Dots

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Cellular imaging and sensing are biological applications of quantum dots (QDs). Since QDs can be used in many aspects of the medical field, it is vital to understand how QDs interact with cells. The purpose of this project was to determine if the surface charge of the QD had an effect on the cellular binding of QDs. Carboxylate-modified QDs (Invitrogen, 525 nm emission) were used as model anionic QDs. We then measured binding of these QDs to BS-C-1 epithelial cells in medium with and without serum proteins. We found that anionic QDs bind to cells in the absence of serum proteins. In comparison, cellular binding of QDs is inhibited in the presence of serum proteins. In the future, a coupling reaction will be carried out to form cationic QDs. Ethylene diamine will be used as a coupling group to add amine groups to the carboxylate groups present on the QDs. 1[3-(dimethylamino)propyl]-3-ethylcarbodiimide will be used as the coupling reagent for the reaction. The surface charge of the modified QDs will be measured using the Zetasizer (Nano-ZS, Malvern Instruments).

Carbon Nanotube Microfluidic Channels for Cell Manipulation

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Due to their remarkable porosity (~99%) and ability to be chemically functionalized, vertically-aligned carbon nanotube (CNT) forests are a promising material for use in lab-on-a-chip devices. Previous studies placed CNT pillars within microfludic channels, demonstrating that unlike solid elements utilized in bio-MEMS, these nanoporous structures can enable selective flow either through them, around them, or both. This allows for more interaction between particles and functionalized nanotubes as well as greater selectivity for small particles (10-100 nm) [1]. This project aimed to demonstrate the capability of patterned CNT forests in microfluidics as channel walls. Flow through various channel geometries was to be examined. Via photolithography, patterned flow channels were transferred onto a silicon wafer. Next, a base layer of alumina and an overlaid layer of iron catalyst were deposited by sputtering. Individual devices were diced from the wafer and forest growth was induced in a tube furnace using ethylene as the carbon source. These devices were integrated with a benchtop fluidic system consisting of a syringe pump, acrylic/PDMS chip dock, and a camera-equipped stereoscope for visualization. Flow through the channels using deionized water and polystyrene beads was observed.

References: [1] Fachin et al. Integration of Bulk Nanoporous Elements in Microfluidics for Multiscale Manipulation of Bioparticles. Journal of Microelectromechanical Systems. vol. 20,no.6, pp. 1428-1438.Dec. 2011.

Interaction of Engineered Nanoparticles with Artificial Cell Membranes

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Understanding the potential toxicity of engineered nanoparticles (ENPs) is vital due to their presence in over 1300 commercial products (e.g. toothpaste, sunscreen, and anti-bacterial coasting on blankets). To further evaluate these potential consequences of ENPs, research must be performed to determine the exact nature of the interaction and mechanistic behavior between these particles and biological systems. This study seeks to understand these interactions by characterizing the effects of ENPs on artificial cell membranes. Understanding the interaction of engineered nanoparticles with lipid bilayers is an important step toward predicting subsequent biological effects and facilitates the design of safe nanoproducts. We believe that under some conditions ENPs can passively translocate across, and cause nanoscale defects in lipid membranes. In this work, we quantify the disruption of liposomes induced by ENPs using a dye leakage assay. We measure dye leakage from lipid vesicles loaded with carboxy-fluorescein dye which are exposed to a diverse selection of ENPs. The amount of dye released correlated directly to the level of interaction between nanoparticles and the lipid vesicles.

Water-in-Ferrofluid Digital Microfluidic System for Single Cell Isolation and Transport

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The isolation and study of circulating tumor cells is of great interest to researchers and clinicians in the medical field. Current approaches involve labeling the cells, which negatively affects their viability. We envision a label-free microfluidic device capable of isolating and transporting single cells while preserving the viability of the cells. Cells will be encapsulated by aqueous emulsions in an oil-based ferrofluid microfluidic system. The system will use a magnetic field generated by an electrode array embedded in the device to transport the emulsions via a process called negative magnetophoresis. Our project focuses on the design and fabrication of a microfluidic channel to be used in the study of water-in-ferrofluid emulsions. We successfully controlled the size and stability of the water-in-ferrofluid emulsions by varying the microchannels' geometries, the input flow rates, and the surfactant concentrations. The microchannels were fabricated using SU-8 photoresist on quartz wafers. SU-8 was chosen over other materials for its hydrophobic nature and resistance to swelling in the presence of hydrocarbon oil. Quartz wafers were used to allow for imaging from both the top and the bottom. The results from this project will drive the final design and fabrication of the water-in-ferrofluid microfluidic architecture, where stability and optical imaging of the cellular emulsions are critical.

Production and Characterization of Topological Insulators (TI)

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Topological Insulators (TI) represent a novel category of material whose bulk insulates but whose surface conducts. Because of electron states which cross the insulating band gap, surface conduction, and spin locking, being able to produce topological insulators would be of great interest [1]. Bismuth Selenide (Bi_2Se_3) is one of the best candidates for 3D Topological Insulators. Our project focuses on developing a method to produce undoped and doped Bi_2Se_3 via vapor-liquid-solid(VLS) deposition. Upon examination with a Scanning Electron Microscope (SEM), Energy Dispersive X-ray Spectroscopy (EDS) and X-ray Diffraction (XRD) we found that both nanoribbons and nanowires about 5 μm in length formed; the doped sample with 61.4% Selenium, 33.30% Bismuth, 5.66% Antimony by atomic percentage and the undoped sample with 38.38% Bismuth and 61.62% Selenium. Being able to produce these doped and undoped topological insulators open up exciting new avenues of research into their properties and possible applications.

References: [1] M. Hasan, et al. Reviews of Modern Physics 82 (2010).

Production of Solid State Spin Qubits

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The focus of this project is to design and create an electron irradiation setup to produce crystal defect spin quantum bits (qubits) at the University of California, Santa Barbara (UCSB). Specific vacancy complexes in diamond and silicon carbide create localized electron densities with manipulable spin properties. The spin states of these qubits can be read out optically, and long coherence times at room temperature make them prime candidates for quantum information devices, magnetometry, and sensing. The production of these defects involves the use of the UCSB Free Electron Laser facility to irradiate samples with electrons in the custom irradiation assembly designed during this project. The assembly allows the user to irradiate up to five samples individually without breaking the ultra-high vacuum required. It is designed to cool the samples as they are irradiated, and stands up to the high energy electron beam to allow for higher irradiation doses and defect densities than previously possible. It also gives precise control over irradiation, and faster turnaround time than what can be done outside the university. At this point the assembly has been designed and is under construction.

A Study of Integrating Societal and Ethical Issues into NNIN REU

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Societal and Ethical Issues (SEI) in nanotechnology has gathered recent attention and importance given its federal focus under the 21st Century Nanotechnology Act [1] (2003). Perceptions of how effective SEI training is, as well as to what extent ethical conceptions perpetrate into undergraduate work and beyond, is of particular interest to better the Research Experience for Undergraduates (REU) of the National Nanotechnology Infrastructure Network (NNIN). Interviews of both current education coordinators at NNIN REU sites and former REUs from the Cornell NanoScale Facility (CNF) are used to accumulate and compare SEI training practices. The review and interview results of the ethics education is used to formulate a summary report of findings and best practices for NNIN sties to use as a program guide.

References: [1] Pub. L. 108-153 (2003).

Anti-Reflective Coatings for Room Temperature Terahertz Quantum Cascade Laser Sources

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This work investigates methods of improving the output power for terahertz (THz) sources based on intracavity difference-frequency generation in dual wavelength mid-infrared quantum cascade lasers (QCLs). Anti-reflective (AR) coatings in the THz spectral range are investigated as a method to improve upon the output power. SiO_2 is chosen as the AR material because it has the proper refractive index properties and negligible absorption loss in the 1-5 THz range. Simulations show that an improvement in power by ~30% is achievable. SiO_2 is deposited using electron beam evaporation onto high-resistivity silicon and semi-insulating indium phosphide wafers. Deposition is also achieved by plasma-enhanced chemical vapor deposition. The resulting films are characterized by a profilometer and by a Fourier transform infrared spectrometer (FTIR). Electron beam evaporation is then used to deposit SiO_2 on the emitting facet of a QCL. The emission spectrum of the laser before and after the application of this AR coating is recorded.

Optimization of Protocol for Fabrication of a Polymer Filter from a PDMS Mold

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Microfabricated structures have been demonstrated to filter specific types of cells out of blood samples when incorporated into a parylene filter. However, the process for creating these parylene filters can be time consuming, and requires expensive equipment. Also, the fabrication process utilizes harsh temperatures and specific techniques that are incompatible with softer polymers such as PDMS, biodegradable polymers, or other implantable biomaterials. The focus of this project is to optimize a protocol for an alternative micromolding fabrication process. Soft lithography is used to make a mold out of a parylene filter using PDMS which is implemented to first make more filters out of PDMS, and then out of biodegradable polymers or other soft implantable biomaterials once the previous process has been optimized. We have found the optimal combination of surfactant-based release agents to consistently create high quality molds with a high aspect ratio and features as small as 1 μm. We have also successfully fabricated a PDMS filter using this micromolding process.

Fractal Electrodes

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Fractal electrodes (dendrites) provide an opportunity to improve many electrical and optical areas including solar cells, sensors, and in the future, retinal replacements. They offer a unique ability to carry either information or charge with minimal resistance, while only covering a small fraction of surface area. These electrodes can be easily made by applying an electric field between an anode and cathode which causes the dendritic metal electrodeposit to form. One key characteristic of the fractal electrodes is the fractal dimension, which is used to describe non-Euclidean geometries. The purpose of the project was to determine the level of control that can be obtained through use of constant current and constant voltage during electrodeposit growth. Thin films of silver were deposited on slides via thermal evaporation. The mask used provided channels between the silver electrodes in which the dendrites could grow. The dendrites were then imaged and processed to determine their fractal dimension. It was found that the fractal dimension decreases with an increase in field, in both constant current and voltage trials. The data confirms that a stronger field leads to more one dimensional growth.

Correlation between surface morphology and Hall mobility in AlGaAs/GaAs (111)A heterojunctions

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Most of modern electronics are composed of the Si metal-oxide semiconductor field-effect-transistor (MOSFET). The rate at which we can improve the Si MOSFET is decreasing due to leakage current and power dissipation from quantum tunneling effects as we make the MOSFET dielectric thinner. Changing the channel material in the MOSFET can provide a resolution to this problem. InGaSb grown by Molecular Beam Epitaxy (MBE) serves as a candidate for outperforming Si as a channel material by providing multiple conducting energy states when grown in the (111) orientation. However, crystal defects occur when growing InGaSb on GaAs (111) substrates because of their lattice mismatch. In this work, we study AlGaAs and GaAs grown on GaAs (111) substrates, in order to understand future growth of InGaSb materials. Experiments of varying V:III Beam Equivalent Pressure (BEP) ratios of GaAs grown on GaAs (111) substrates can assist the process of increasing surface quality in the growth of InGaSb. Experiments of varying Si dopant temperatures of AlGaAs on GaAs (111) substrates were also performed to identify similar methods we can incorporate to control the electrical and growth properties of InGaSb.

Electrical Characterization of Heat-treated Tin Monosulfide (SnS) Thin Films

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SnS thin films have generated much interest in recent years due to its potential application as an absorber layer in thin film photovoltaic cells [1]. The goal of this project was to improve the quality of SnS films through various methods of heat-treatment by means of grain growth, a reduction in bulk defects, and increased carrier mobility, which can increase the probability of charge collection and thus potentially improve cell efficiency. The effects of the annealing atmosphere (inert nitrogen (N_2) versus hydrogen sulfide (H_2S) gas), temperature (250 - 540°C), and annealing time (10 s versus 60 min) on the film's electrical properties were investigated. Scanning electron microscope images and Hall measurement results revealed that annealing the films in H_2S atmosphere produced larger, columnar, and uniform grains with greater mobility as compared to the as-deposited and N_2 annealed SnS. While the heat-treatment of SnS films in H_2S for 10 s and one hour both produced films of comparable mobility, the film that underwent the 10 second process had a relatively lower carrier concentration, which is an indicator of the amount of bulk defects present. Therefore, the most desirable SnS films were found to be produced through annealing in a H_2S atmosphere at 400°C for 10 s.

References: [1] Sinsermsuksakul, P.; Heo, J.; Noh, W.; Hock, A. S.; Gordon, R. G., Atomic Layer Deposition of Tin Monosulfide Thin Films. Advanced Energy Materials 2011, 1, (6), 1116-1125.

Ionic Transport Across Atomically Thin Graphene Membranes

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The mechanical robustness and atomic thinness of graphene make it a promising candidate as a membrane for ionic separation in fluids. Such technology has potential applications ranging from desalination to high throughput drug testing. The focus of the project is to electrostatically control the flow of ions through a graphene membrane suspended over a silicon substrate. A device was first designed, fabricated, and characterized to serve as a base for testing the separation properties of the membrane. A voltage was applied to an ionic solution suspended on the graphene to drive ions through the membrane. To introduce control over the flow ions, a separate gate voltage was applied to the graphene membrane itself. Currently a device has been fabricated and electrical testing is in progress.

Synthesis and Characterization of Potassium Sodium Niobate, a Lead-Free Ferroelectric

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Many ferroelectrics used in today's devices are lead based materials because of the high piezoelectric and dielectric properties of these materials. Due to the volatility and toxicity of lead, these materials pose environmental and health concerns. For the past decade many scientists have began gearing towards lead-free alternatives. This allows the material to be integrated on bio-related devices. One of these promising materials is potassium sodium niobate (KNN). This material shows higher piezoelectric and ferroelectric properties than its lead-free competitors. Thus the main goal of the project was to design a solution which can be laid as a thin-film and be eventually utilized on biomedical devices. We have created an array of solutions with different concentration and additives such as chelating agents, stabilizers, and dopants. Currently nine solutions have been deposited via a chemicals solution deposition technique. The crystal structure of the films was characterized by XRD. The microstructure of the films was also investigated through the use of a FESEM. They are now ready for further electrical testing.

DNA Extension in Nanochannels

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Controlled manipulation of single DNA molecules is crucial for modern genomics techniques, including DNA barcoding. Confining DNA in nanochannels has proven to be an effective method for achieving the elongation necessary for DNA barcoding. Because DNA is a semiflexible polymer, classical Odijk and de Gennes confinement behavior only apply as limiting cases. Monte Carlo simulations have suggested that there are two additional confinement regimes between the Odijk and de Gennes regimes for DNA in a high ionic strength buffer. The purpose of this study is to measure the fractional extension of λ-DNA as a function of nanochannel width in these transition regimes and to compare experimental results to the aforementioned simulation results. Several nanofluidic devices containing arrays of nanochannels with widths between 50 and 500 nm were fabricated and preliminary extension measurements were made. The results should improve theoretical understanding of the dynamics of single DNA molecules confined in nanochannels.

Phase Transformations in Metal Contacts and InGaAs Nanowires

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III-V compound semiconductors such as indium gallium arsenide (InGaAs) are being studied for use in nanoscale transistors as a faster, more power efficient alternative to silicon counterparts. In order to make use an InGaAs channel, there must be low resistance contacts to its source and drain regions. In this project, to facilitate the development of appropriate source-drain contacts, phase transformations between InGaAs nanowires and metal contacts are studied. Nanowires were etched from an InGaAs film on an InP substrate, and a nickel or palladium layer was sputtered on to the wires. Analysis of SEM images and EDS data show no observable diffusion of either metal into the nanowires, despite both being fast diffusers in thin film and bulk InGaAs. Samples with palladium pads showed roughening of wires under and close to the pad, suggesting that the presence of the metal is causing decomposition of the wires. Furthermore, the roughening is more pronounced in samples annealed at lower temperatures, suggesting multiple mechanisms for the decomposition of InGaAs wires in Pd.

Nanotechnology Companies in the U.S.A: A Web-based Analysis of Companies and Poverty Alleviation

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In the United States, many firms are expanding their research and development on nanotechnology products. But what products are being developed and who will benefit from them? This study answers these questions by analyzing the goals, nanotechnology experience, corporate social responsibility and products from information on the companies' websites. Based on patent data from the Center for Nanotechnology and Society-Thematic Research Cluster 1, we got a list of fifty-five firms that are leaders in nanotechnology in water, energy and agri-food. We chose these areas because we think they will have a big impact on the poor and inequality. Out of the fifty-five companies, twenty-seven mention nanotechnology. Moreover thirty-one firms are developing products that will benefit both rich and poor while only seven firms, such as computer and textile industries, focus on rich consumers. In general, agri-food companies do not discuss nanotechnology on their websites. Most of the products produced by these companies are intermediate materials used by other companies; very few companies on the list sell nano-products directly to consumers. Overall, we conclude that nineteen out of fifty-five companies are developing nanotechnology products, like low cost water filters or solar cells that could help the poor and reduce inequality.

Improving Superconducting Resonators for use in Quantum Computing

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Superconducting coplanar waveguides are central elements in building a quantum computer and in single photon detectors for astrophysics. Reducing energy loss in these waveguides is critical to improving their performance. One source of energy loss in coplanar waveguides arises from parasitic coupling to unwanted electromagnetic modes that occur when there are asymmetries or discontinuities in the circuit layout. The effect of these asymmetries and discontinuities can be minimized by adding additional wiring ("crossovers") to the waveguide geometry. However, the dielectric materials that serve as structural supports for the crossovers add additional loss through a different mechanism. We will discuss a method of fabricating crossover wiring in the form of freestanding air bridges, which will still suppress unwanted modes, but will not use a lossy dielectric for structural support.

Fabrication of Metallic and Dielectric Nanowires for Realizing Optical Filters

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In this paper we present a technique for fabricating an array of varying micron squares using contact photolithography with a positive or negative photoresist in order to further study the crosstalk effect between pixels. Contact photolithography is achieved while an image is printed on a substrate by the use of a photomask and ultraviolet light. After the array was exposed and developed, height measurements were taken using an atomic force microscope (AFM), and photos were taken using an optical microscope. The samples were then subjected to a reactive ion etch using various gases to etch through the photoresist, silicon dioxide, aluminum oxide layers and partially through an aluminum layer. More measurements and pictures were taken to verify the height of the remaining aluminum layer.

We attained an aluminum layer with a maximum height of 100 nanometers and squares from 3 by 3 microns to 7 by 7 microns. This array will further be used to measure the crosstalk effect between a pixel exposed to 1000 photons and the neighboring pixels.

AFM-Assisted Etching and Electrical Characterization of Graphene

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A pressure sensor, consisting of graphene transferred onto Cr/Au electrodes and Si_xN_y membranes, exhibit high sensitivity. The high piezoresistive gauge factors found in the current device are explored and confirmed, and further measurements on the fabricated devices are taken for optimal design. The graphene devices are patterned with a custom, feedback-controlled AFM/STM system, creating viable electronic devices though tip-based nanofabrication. The etched feature size made through this process is minimized.

Fabrication of MEMS Using Cheap Substrates

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The purpose of this project was to create MEMS with a paper substrate rather than the currently used semiconductors. The idea behind this approach is to minimize cost and maximize ease of production. The premise behind our project is to use piezoresistive carbon ink on paper to create a device that is sensitive to force. Using a paper cantilever design, the relationship between force and change in resistance, and consequently change in current, was examined and found to be linear. The next part of the project required us to apply this relationship to create a useful device. We opted on creating a microphone made from paper and the piezoresistive material. This was based on the fact that the relationship between force and resistance would facilitate the modulation of current in much the same way as the moving coil in a magnetic field in a conventional microphone. We were able to successfully accomplish our goals after several designs were tested and optimized. Possible applications for this design could be for toys and cheap medical applications.

The Effects of Surface Passivation on Trap Levels in Silicon Nanocrystals

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Si nanocrystals (Si-NC) systems have a wide variety of applications due to their optical properties and recent developments have allowed for the synthesis of Si-NCs that are resistant to oxidation through surface passivation. However, the effects of surface passivation on the electronic properties of Si-NCs remain unknown. With this in mind, our research focused on the investigation of trap levels in Si-NCs and the effects of passivation on these traps. The Si-NCs were created using non-thermal plasma synthesis with both SiH_4 and SF_6 gas in order to produce H and F terminated Si-NCs. Metal-Oxide-Semiconductor (MOS) capacitors were fabricated by annealing n-type Si (100) in a O_2 ambient in order to create a thin SiO_2 interface, followed by the deposition of Si-NCs on the SiO_2 layer. In order to optimize our measurements, we then utilized Atomic Layer Depostion (ALD) to deposit a high-κ dielectric (HfO_2) layer on top of the Si-NCs, and finished by evaporating Al back and gate contacts. The trap centers of our fabricated MOS structures were then investigated using CV profiling and Deep Level Transient Spectroscopy (DLTS) in order to confirm the presence of traps as well as to characterize the energy level and trap cross-section of these trap centers.

Engineering the Charge Occupancy of Nitrogen Vacancies in Diamond

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Nitrogen Vacancy (NV) centers are point defects in a diamond lattice that occur when a carbon atom is substituted with a nitrogen atom while a neighboring carbon atom is removed entirely. The resulting gap in the lattice has many desirable properties, such as paramagnetism and optical energy level transitions, that make it an ideal candidate for single-photon optics and quantum computing applications. But the NV center tends to lose one of its surrounding electrons due to either thermal agitation or attraction to wandering positive charges in the crystal, providing a damaging barrier to the development of large-scale, multipartite quantum networks. The project sought to deter this process by depositing transparent metal oxides and films on the surface of diamond nanowires, with a goal of inducing charge discontinuities at the surface that would stabilize the electronic configuration of the lattice by inducing a negative charge excess in the region around the defect. Additionally, devices were designed that used a voltage gate on the surface of bulk diamond to accomplish the same effect, albeit with more control of the dopant level in the region due to modulation of surface voltage. Designs and fabrication processes for both devices were created and ensemble measurements of devices using confocal microscopy have begun.

Sacrificial polymers and their use in patternable air-gap fabrication

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Patternable air-gaps are useful electrical and mechanical structures in semiconductor and MEMS devices as a means to decrease dielectric constant, add mechanical compliance, and facilitate microfluidics. In this study, we utilized sacrificial polymers and standard photolithographic techniques as a way to create air gaps. A photodefinable sacrificial polymer was created by adding a photoacid generator (PAG) to the sacrificial polymer mixture. Air gaps were made by patterning the desired structure, covering it with an overcoat polymer, and decomposing the remaining sacrificial material. There are three main problems associated with this fabrication technique: (i) the patterning resolution was course, (ii) residue was produced during the decomposition of the polymer, and (iii) large structures tended to collapse. We investigated these problems through process optimization, quartz crystal microbalance (QCM), and overcoat modification. In addition, we investigated a new sacrificial polymer, PDM-1088. PDM-1088 increased the resolution of the pattern, QCM measurements allowed us to quantify the amount of remaining residue, and hardening the overcoat allowed the fabrication of structures on the scale of several hundred micrometers. Micrometer scale air gaps were successfully fabricated through common photolithographic techniques, allowing for the integration of these structures into semiconductor processing.

Biomineralized Nanopore Membranes on Silicon for Nanoparticle Translocation

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Diatoms are a major group of algae that synthesize a three tier network of silica pores for their cell wall. They can grow up to 300 μm in diameter, yet the smallest pores are approximately 40 nm wide. These diatoms offer a great alternative to nanopores fabricated using top-down processes. In order to have access to these nanopores, the diatoms are placed over 20 μm pores etched in silicon wafers. The goal was to secure the diatoms over the micropore without having any leakages, clogging of the nanopores and breaking or cracking of the diatom. SU-8, a photo-patternable epoxy, was explored in order to be able to employ standard contact photolithography techniques to form an efficient and less time consuming process. This photoresist proved to be successful in meeting the criteria in combination with a sulfuric-peroxide mixture (SPM) treatment. The SPM treatment was performed after the SU-8 exposure to help remove residual SU-8 that might clog the diatom nanopores. Removal of the epoxy from the nanopores was tested using a nanoparticle solution. Nanoparticle translocation measurements were taken using a setup similar to that of a Coulter counter. When a nanoparticle passed through a diatom pore, a quick dip in current was observed, indicating open pores.

Integration of Embedded CMOS Chips for On-Chip Optical Communication

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The rapid development of telecommunications infrastructure in developing nations, the advent of high-speed cellular data networks and the recent popularization of cloud computing continue to drive demand for more robust and energy efficient data networks. The dominant source of power utilization is the electrical interconnect, due to the high energy cost of moving data between the computing and communication blocks. Losses inherent in electrical interconnects between computing and telecommunications infrastructure may be mitigated by utilizing optical interconnects instead. In recent decades, many electronic-photonic integration techniques have been explored, however, a process that is truly compatible with complementary metal-oxide-semiconductor (CMOS) technology has yet to be developed. We present a novel integration technique that circumvents most of the difficulties faced by the existing methods. It allows for the integration of CMOS dies into silicon photonic substrates. The process is based on the creation of a chip-specific imprinted hard mask utilizing localized polymerization of a heat-curable poly(dimethylsiloxane). The local polymerization is performed by the independent temperature control of the arm and stage of a flip-chip bonder. The masked substrate is then subjected to deep reactive ion etching to create cavities with length and width dimensional tolerances of less than 9 μm, enabling tight integration of the CMOS die and photonic substrate.

Optimizing Liposomal Uptake and Content Release using Glioblastoma Multiforme as a Model System

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The Enhanced Permeability and Retention effect has been demonstrated using 150-200 nm liposomes containing imipramine blue (IB), an anti-invasive agent with low circulation time, which were selectively delivered to glioblastoma multiforme (GBM) cells. Here, we test whether 25-100 nm liposomes, or small unilamellar vesicles (SULVs) will have greater uptake by GBM cells. Creating SULVs is challenging due to their high surface curvature, and therefore, lower stability. We based our protocol on the spontaneous formation of SULVs in solutions of phospholipids with tightly controlled temperatures and concentrations since these parameters dictate the structure and size of the liposomes. Membrane extrusion was used to reduce polydispersity of the liposomal solutions. Liposome sizes were measured using dynamic light scattering (DLS). SULVs were successfully created, with different pathways of formation yielding characteristic size ranges. Current studies measure the absorbance and diffusivity of liposomes using conjugated fluorescent dye during formation, and measuring retention through fluorescent imaging after application to cell cultures. The dependence of the rate of leakage of liposomal contents on particle size will also be imaged using fluorescent dye loading. These studies will reveal the effectiveness of SULVs packaged with IB, followed by SULVs containing doxorubicin on GBM cells, which will also be quantitatively tested in ongoing studies.

Fabrication of Graphene Field Effect Transistors

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Graphene is an exciting new material because of its two-dimensional nature and interesting mechanical and electrical properties. There is still much room for development in methods for growing graphene, such as Chemical Vapor Deposition (CVD) on copper. Making Field Effect Transistors (FETs) with graphene is a practical way to assess the characteristics of a given sample of graphene and determine if a method for creating graphene is effective. The focus of the project is to fabricate graphene FETs to assess the quality of graphene grown through CVD on copper. This process breaks down into three main steps: (1) the electrochemical transfer of graphene from copper to silicon wafers, (2) the patterning of electrodes onto the graphene covered wafers, and (3) the electrical testing of resulting devices through four-point-probe and transistor measurements. Graphene was transferred through the application and removal of poly(methyl methacrylate) (PMMA) on copper. The electrodes were patterned using photolithography and a variety of deposition systems. Four-point-probe and transistor measurements were used to assess the sheet resistance, carrier mobility, and carrier density of the graphene.

Growth of Boron Nitride Nanowires

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The objective of this project is to use a horizontal chemical vapor deposition (CVD) reactor to grow boron nitride nanowires on a silicon substrate using a metal catalyst. Boron nitride is shown to have properties that are compatible with complementary metal oxide semiconductors (CMOS) chips allowing it to be easily incorporated into current and future technology. Efforts to grow boron nitride nanowires on silicon substrates <111>, <111> with silicon dioxide and <100> using 7 nm metal catalyst of aluminum, cobalt, iron and nickel have not produced expected results, but boron nanowires were grown on a silicon substrate <100> using a gold catalyst. All experiments were carried out in the CVD system at a pressure of 200 torr, at temperatures of 900-1200°C and flow rates of diborane at 100 sccm and ammonia at 250-800 sccm.

Controlling and Understanding the Effects of Reactive Colloids' Packing on Silicon Etching Patterns

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Previous research found that amidine-functionalized polystyrene latex (APSL) adsorbed to a silicon substrate and heated produces nanowells whose sizes are dependent on the size of APSL particles. These surface features have applications to mechanical, optical, and electronic devices as well as many procedures in which maskless fabrication is desirable. This study focuses on understanding what effect a highly dense particle packing will have on the etching process and the observable features. A dense monolayer was achieved through spin-coating APSL directly onto the silicon. After heating and toluene cleaning to remove the layer of glassed polystyrene which formed, there was observed an assumed silicon re-deposition covering the nanowells and appearing to coat favorably to particles resting within the nanowells. Preliminary results show the surface to become more hydrophilic with the presence of the deposited material. Further research aims to confirm the identity of this re-deposition as well as control the formation and removal of the deposited material through an understanding of the formation mechanism. Research will also be conducted examining the effect of the deposited material on the physical properties, such as the hydrophobicity and reflectance, of the sample.

Transparent and Stretchable Metal Electrodes

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Block copolymers are macromolecules composed of two chemically distinct blocks that self-assemble on certain substrates to create periodic microdomains, each of which exclusively contains one of the polymers that make up the diblock copolymer. Varying the volume fraction of the blocks creates different morphologies on the substrate. For this project, a thin layer of lamellar-forming polystyrene-block-poly(methyl-methacrylate) (PS-*b*-PMMA) was used as a template to create nanowires with a fingerprint morphology. Upon removal of the PMMA, the remaining polystyrene lamellae act as a mask for the deposition of metal nanowires, which can be electrically characterized by photolithographically applying contact pads onto the nanowires and by using a two-point probe measurement. Due to their highly curved morphology the nanowires are a good candidate for electrical testing on a flexible substrate under compression and elongation. As shown by their high transmittance when placed on a glass substrate, the wires are practical transparent metal electrodes for use in new electronic devices.

Fabricating parylene-C shadow masks for applications in short-channel top-contact carbon nanotube flexible transistors

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Flexible transistors with semiconducting carbon nanotubes offer better mobility and stability than current organic material transistors for applications in flexible display and sensor devices. With carbon nanotubes as the semiconducting material, the transistors offer a higher performance due to the extraordinary electrical properties of single-walled carbon nanotubes (SWNTs). However, conventional metal shadow masks can only create flexible device electrodes with a channel length of 50 μm or greater. Parylene-C shadow masks can be used instead of metal masks because of their flexibility, adaptability for patterning, and their ability to fabricate electrodes with much smaller channel lengths. Previously it has been shown that parylene-C masks, patterned through aluminum hard masks by conventional optical lithography methods, allow for a fine resolution with a smallest feature size of 4 μm. We fabricated masks with features as small as 2 μm wide and additionally are utilizing our masks to create short-channel transistors for flexible thin film transistor applications. We successfully constructed short-channel top-contact SWNT network transistors on a non-flexible substrate with a mobility of 0.1 to 2 cm^2/V^{-s} and on/off ratios on the magnitude of 10^2 to 10^3. Currently we are fabricating flexible transistors, utilizing polyimide as the flexible substrate and parylene shadow masks to create short-channel devices.

Assembly of Thermoresponsive Microcapsules

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Microcapsules are currently employed for a number of applications ranging from drug delivery vehicles to capsules contained in cosmetic products. In these applications, it is desirable that the microcapsules be able to control the timing of the release of their contents with external stimuli such as temperature changes or light illumination. The focus of this research is to design thermoresponsive microcapsules and to determine the temperature response of the shell of the capsule as a function of the shell thickness and composition. Microcapsules are manufactured using microfluidic PDMS devices. By varying the flow rates of the inner and middle phases, and by varying the composition of the middle phase that, after it has been polymerized, yields the capsule shell, it is possible to control the thickness and thermoresponse of the capsules.

Simulation Studies of SiC MOS Capacitors

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Fabricating semiconductor devices is very expensive and time consuming, but most importantly can be wasted if there is no clear understanding of what to look for. Computer simulations can accurately predict the fabrication process and device behavior and can show how a device can be improved for better performance. MOS capacitors are the basic components of MOS transistors which can store or amplify charges and are the building blocks of integrated circuits. Using the simulation of an MOS capacitor, we model silicon carbide (SiC) semiconductor so that production of higher quality SiC can become a common process. With the simulation software Silvaco, we simulated a MOS capacitor using molybdenum, Mo, for the metal or gate, silicon carbide, 4H-SiC, for the semiconductor and silicon dioxide, SiO_2, for the oxide. After simulation, we measured the device including different effects such as interface charge, oxide charge, and compared our results to the simulated CV curve of an MOS capacitor. Our purpose is to introduce SiC for more use in devices by; (a) testing a SiC MOS capacitor with basic production characteristics, (b) measure the CV curve of the MOS capacitor with different characteristics, and (c) compare case results with ideal results.

Self-Organized Nanostructural Pattern Formation Under Ion Beam Irradiation

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Ion bombardment is a diverse laboratory technique with many applications including reactive ion etching, focused ion beam milling, ion implantation, sputter deposition, and ion beam characterization techniques such as Rutherford backscattering spectrometry (RBS). Of particular interest are the nano-topologies which form under the presence of ion irradiation. Periodic nanoscale ripples, dots, and high-aspect ratio structures can self-organize under ion bombardment. However, the relative importances of various mechanisms which underlie the self-organization process are poorly understood. This project aims to investigate the importance of ion beam-injected stress as a mechanism influencing the dynamics of nanoscale ripples. It has previously been observed that ripples will propagate along the surface of certain materials during ion bombardment, and a recently developed theory attributes this phenomenon to beam-injected stress. Our study aims to test this theory by quantitatively measuring ripple propagation velocity for comparison with the value predicted by theory. A 30 keV Ga^+ focused ion beam was used to irradiate Si(001). *In situ* scanning electron microscopy was used to directly record the ripple dynamics. Additionally, a methodology for measuring the propagation of ripples with respect to fluence (ions*cm^{-2}) was developed and preliminary measurements were made.

Characterization of Phase Change Material for Radio Frequency Applications

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Phase change materials are a class of compounds that can alter states between crystalline and amorphous when specific heating conditions are applied to them. Due to fast switching speed, long life cycles, and potential for high-density integration, these materials are currently being investigated for use in non-volatile memory applications. The focus of this project is to characterize a specific phase change material, $Ge_{50}Te_{50}$, to determine its possible capabilities for RF applications. This material was chosen for use in RF switches due to a low crystalline state resistance and a high ON/OFF resistance ratio. The method of characterization is to fabricate simple ohmic switches and then apply voltages or currents with different pulse shapes and durations in order to obtain the phase transitions. The goals of this project are to optimize the switch design and fabrication method to achieve a low ON resistance and high ON/OFF resistance ratio and to optimize the biasing conditions to obtain repeatable and reliable phase transitions. An extension of the project is investigating the effects of direct heating versus indirect heating. If the switches are successful, this material can be incorporated to design more advanced passive elements such as filters, phase shifters, and antennas.

The Electrochemistry of Catalyzed Metal Multilayers

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Self-assembled multilayers (SAM) are a product of the bottom up method, a technique in which substances are built from the molecular level through chemical reactions. With the correct manipulation such fabrications could perform as numerous components to molecular devices. This project utilizes the bottom up method to produce multilayers of the 4'4 dimercaptobiphenyl (DMBP) attached to the group (II) B metal mercury. The focus is to analyze the multilayers' electrochemical properties by cyclic voltammetry to determine if the structure can successfully conduct electricity, possibly leading to the growth of desired length molecular wires. The experiment consists of sweeping the potential energy of a DMBP monolayer and multilayers of DMBP and mercury from +0.6V to -0.6V. No Cathodic or anodic peaks are observed for a monolayer of DMBP. Both a cathodic and anodic peaks were observed for multilayers formed by alternating depositions of DMBP and Hg (II). The results demonstrate multilayers of DMBP made by this method undergo reduction and oxidation and there is a measurable current. Further trials are being conducted to confirm present data and offer greater insight on the chemical properties of these multilayers.

Development of an *in vitro* muscle regeneration model using a combination of microfluidics and micropatterning

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Mutations in nuclear envelope proteins that connect the cell nucleus to the surrounding cytoskeleton cause muscular diseases. The exact disease mechanism remains unknown. Here, we are developing an *in vitro* cell culture model to study the effect of these mutations on muscle development. During normal muscle development, single-nucleated muscle cells (myoblasts) fuse together to form multi-nucleated myotubes. Subsequently, the nuclei migrate to the periphery of the myotube. Biopsies of muscle fibers from patients with muscular dystrophy instead show nuclei abnormally positioned at the myotube center. We will test the hypothesis that mutations in nuclear envelope proteins disturb nuclear positioning, thereby causing muscular diseases.

We have fabricated a device using a combination of microfluidics and micropatterning to create an *in vitro* system to image muscle development of mutant and normal myoblasts. The micropatterning is used to deposit collagen lines on a non-cell adherent gel on which myotubes can form in precisely controlled geometries. Microfluidic channels are used to feed the cells, and to locally deliver molecules to the myotubes that induce migration of the myonuclei to the periphery. We will use this system to observe the maturation of muscle cells both with and without properly functioning nuclear envelope proteins.

Effect of Inert Nanoparticles on Cement Hydration

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Inert nanoparticles of titanium dioxide and ultra-fine limestone are used as fillers in portland cement because of their potential to reduce the amount of required cement without compromising early age mechanical properties. These fillers have been shown to enhance early age hydration through heterogeneous nucleation. The effect of these fillers on early age hydration of cement was investigated using isothermal calorimetry and specific surface area analysis to determine their effect on activation energy. Isothermal calorimetry measurements in the presence of different concentrations of nanoparticles and at different temperatures were used to determine the apparent activation energy of cement hydration according to the Arrhenius equation. Inert nanoparticles of titanium dioxide and limestone were shown to alter the apparent activation energy of the cement depending on their size and rate of use.

Cryoelectronic Characterization of Organic Molecules

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The temperature dependence of electronic properties of conducting and semi-conducting materials is a well studied phenomenon, with many interesting effects in low temperature ranges. This project seeks to develop a method by which the temperature dependence of capacitance of gold on glass or sapphire inter-digital capacitors could be characterized, in addition to their inherent frequency dependence. The purpose of this was to establish a reference capacitance for each substrate, such that the capacitance of subsequently deposited or grown organic monolayers could be calculated independently of inherent capacitance via subtraction of the coated samples' values from the reference values. This is especially pertinent in the lower temperature ranges (sub 100K) as unusual effects have been observed previously, especially with ferroelectric materials. The capacitors were first fabricated via photolithography, gold deposition, and liftoff processes in the cleanroom. Afterwards, their capacitance was measured across a wide range of temperature and frequency, from 50K to 300K and 20Hz to 2MHz respectively. With referencing complete, the samples underwent oxygen plasma cleaning, followed by silinization in an inert atmosphere with octyltrichlorosilane under various pressures and concentrations of the reagent to yield organic monolayers on the substrate surface. The presence of monolayers was verified via contact angle measurements. Finally, the capacitances of the newly coated substrates were measured in the same fashion as the references and their results compared.

Microring Resonators for Silicon Photonic Circuits

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Silicon photonics is an emerging technology that promises to allow for control of light on a compact chip analogously to how silicon microelectronics manipulates electricity. Silicon photonics may save the continued Moore's Law scaling of microelectronics by providing a solution to the energy efficiency problem faced by today's microelectronics. It will also potentially allow many table-top optical systems to be condensed onto a single chip. Microring resonators are ring-shaped, closed-loop optical waveguides with a radius on the order of a micron which are capable of selecting a narrow frequency band of light from a spectrum. The narrow resonant band is transferred to another waveguide while the remaining spectrum continues on the original path. This selectivity property causes microring resonators to be of interest to the telecom industry, where resonant microrings can be used as filters in wavelength-division multiplexed (WDM) communication systems. The project focus is to fabricate devices that incorporate microring resonators via electron beam lithography, and to characterize their optical frequency response, including bandwidth, quality factor (Q) and free spectral range (FSR). An additional goal is to investigate the dependence of the optical response to parameters such as the ring radius, thickness and coupling distance between the waveguide and the ring resonator.

Influence of Optical Stress on Mixed Oxide Transistors

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To meet the growing demands of thinner and larger display panels, an improved and reliable semiconducting channel material must be used. Indium-gallium-zinc oxide (IGZO) based thin-film transistors (TFT) have presented themselves as a viable option to achieve better carrier mobility, optical transparency and robustness under optical stress conditions. However, the instability of IGZO TFTs remains a problem that must be resolved. In particular, there is deterioration in the threshold voltage (V_{th}) during sustained operation because of continuous optical stress. In this investigation we perform illumination stress on TFTs in an attempt to elucidate root-cause of the V_{th} shift and several post fabrication anneals to reduce defects due to low temperature fabrication process. The as-fabricated TFTs displayed a V_{th} shift of -17 V under optical stress, but demonstrated high stability with post-fabrication anneals in different ambients.

The Effectiveness of Physical Sunscreens in Preventing UVB-Induced Mechanical Damage to the Stratum Corneum

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The stratum corneum (SC) is the outermost layer of skin and is the body's first line of defense against environmental exposures such as ultraviolet (UV) radiation. The SC consists of dead cells, called corneocytes, held together by corneodesmosomes and intercellular lipids. Previous research in the Dauskardt lab has shown that UVB decreases the cohesion of corneocytes, quantified by the delamination energy, by affecting the properties of intercellular lipids and corneodesmosomes. The focus of this project was to investigate whether commercial physical sunscreens containing micron- and nano-particle zinc oxide and titanium dioxide prevent UVB-induced damage to the mechanical properties of the SC. Currently, the use of nanoparticles in sunscreens is not regulated and little research has been done regarding the safety of these particles within the body. Experiments were conducted with broadband UVB (280-315 nm) and narrowband UVB (311 nm). Delamination energy values for SC samples with sunscreen were determined through double cantilever beam (DCB) testing. UV-visible spectroscopy was done to determine the wavelengths of light absorbed by the sunscreens. In addition, dynamic light scattering (DLS) was used to characterize particle size within the sunscreens. We found the sunscreens typically provided good protection from UV, although they did not completely preserve the native mechanical properties of the SC.

Implementing Gaussian Quadrature in Molecular Plasmonics

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For certain metals that support localized surface plasmon resonances, the resonant frequency of the material's electrons fall within the realm of visible light. We can use light to collectively and coherently oscillate the surface electrons in such metals, magnifying the light in intensity. Such an environment could potentially be used to catalyze reactions occurring near these particles. Interactions between the molecules and the nanoparticle may alter the molecular electronic landscape into a configuration that is favorable to the reaction. This interaction occurs in part through the image effect. The goal of this project is to develop a computationally feasible process in which to determine the molecule's electronic structure after it has been image-dressed by a nanoparticle of arbitrary shape. In order to make larger molecules more tractable, we implemented Gaussian quadrature instead of the trapezoidal rule to calculate the contour integral describing the electron density of the molecule. This change resulted in the code running approximately 100 times faster than before.

Fabrication and Characterization of a Micromachined In-Plane Directional Piezoelectronic Microphone

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The fabrication and characterization of a novel microelectromechanical system (MEMS) microphone, which consists of a rocking beam that measures the pressure gradient across its longer axis and employs a lead zirconate titanate (PZT) piezoelectronic readout system, is described. The advantages of this design include its small form factor, directionality, low self-noise, and the ability to apply active feedback loops to the system. The microphone beam is 2.5 mm x 1.54 mm x 20 μm in size and is fabricated out of epitaxial silicon.

The acoustic frequency response, directivity function, and piezo-driven response of the device are presented, along with proposed modifications for optimizing the fabrication process.

Giant Magnetoresistive Sensors for Biological Applications

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Field-induced domain wall motion through the free magnetic layer of a spin valve nanowire has been observed both electrically and with Bitter Method on scanning electron microscope. The giant magnetoresistance effect is used to determine the position of the domain wall. A series of experiments have been performed with various notch sizes to trap domain walls near the center of the nanowires. Controlled domain wall pinning and depinning is observed for designed notches and fabrication roughness on both 100 nm and 200 nm wire widths. Change in depinning field strength due to the presence of magnetic nanoparticles (MNPs) in the vicinity of a NiFe nanowire has previously been demonstrated in literature. This work serves as preparation to extend to the sensing of biological molecules tagged with MNPs.

Microheaters for Thermo-Optic Tuning of Silicon Photonic Devices

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Silicon photonic devices have a broad range of application, from chemical sensors to filters and modulators integrated with CMOS microelectronics. As a result, these devices have applications that include future microprocessors, signal processing, biomedical devices, telecommunications, and more. A major drawback of silicon photonics is the sensitivity to device dimensions. Changing the width of a ring resonator by as little as a single atomic lattice constant will shift the resonant frequency by several GHz. This level of dimensional control is impossible in fabrication, so it is necessary to actively tune devices for operation. Because silicon has a high thermo-optic coefficient, microheaters can be used to efficiently tune silicon photonic devices and change their behavior. In this work, chromium microheaters were fabricated on top of microring resonators using photolithography and lift-off. Using a PID controller, the heaters were programmed to dissipate constant power over the rings and change their resonant frequencies. The main focus of this work was on the durability and the tuning ability of the microheaters.

Selective Atomic Layer Deposition

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Atomic layer deposition (ALD) of tantalum nitride (TaN_x) has been performed on Cu and SiO_2 substrates with the goal of selective deposition using self-assembled monolayers as an ALD blocking layer. Selective deposition between these two surfaces would be useful in the semiconductor industry to only deposit material on one surface and not the other. The films have been analyzed using spectroscopic ellipsometry (SE), atomic force microscopy (AFM), contact angle, x-ray photoelectron spectroscopy (XPS), and low energy ion scattering spectroscopy (LEISS). The molecule (Heptadecafluro -1,1,2,2-tetrahydrodecyl)triethoxysilane (HDFTEOS) was deposited as a self-assembled monolayer onto both substrates before ALD. HDFTEOS is a heavily fluorinated molecule and could create an unreactive surface for ALD. We find that HDFTEOS binds strongly with SiO_2 but is not thermally stable on Cu at an ALD temperature of 300°C. It impedes growth on SiO_2 for the first 20 cycles and this result is shown both with SE as well as XPS. After the initial growth impedance, TaN_x appears to grow on itself with a growth rate similar to the surfaces without HDFTEOS.

Optimizing the Electrochemical Performance of Cathode Materials for Lithium Ion Rechargeable Batteries

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Electric vehicles (EVs) and Plug-in Hybrid Electric Vehicles (PHEVs) are capable of being fueled with sustainable power sources via electricity. In order for EVs to become competitive, their batteries must have a large capacity and good capacity retention. In our study, we used spray pyrolysis to develop cathode materials. We focused on identifying the optimal spray pyrolysis synthesis conditions that yield the best electrochemical performance. We varied parameters in the process such as furnace temperature, flow rate of the inlet gas, and precursor solution concentration. The product desired is a layered-layered material of the form xLi_2MnO_3 $(1\text{-}x)Li(MnNiCo)_{1/3}O_2$, where x = 0.5. The precursor solution was aerosolized in an ultrasonic spray pyrolysis process, with the reactor temperatures varying from 350°C and 650°C. We discovered that the process produced exclusively the desired product. The battery produced from nanomaterial synthesized at 575°C yields the greatest capacity. We have also observed that with increasing synthesis temperatures, the change in the voltage plateau becomes smaller, showing better voltage capacity retention, without greatly compromising total capacity. Layered-layered materials perform very well, though there is a tradeoff between producing batteries with high capacities and producing batteries with good capacity retention.

Identification of Carbon Nanostructures (Fullerenes) in Cigarette Ash

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The commercial production of fullerene materials (C_{60}, C_{70}, etc.) has recently become a matter of increasing interest and concern. Although the issue of fullerene toxicity is not currently well-defined, some forms have been shown to have cytotoxic effects, particularly when exposed to microbial communities. Therefore, the identification of potential fullerene sources is an important step towards more efficient containment and increased environmental protection. In this work we test the hypothesis that fullerenes (as C_{60} and C_{70}) are formed in burning cigarettes by analyzing ash from several scenarios, including mimicked smoking events.

Testing the Properties and Characteristics of Chitin Thin Films

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Chitin is the second-most abundant polysaccharide in nature after cellulose. However, what makes chitin special compared to cellulose is its increase in biocompatibility and biodegradability (Green Chem., 2011, 13, 1708). Found in crustaceans, cephalopods and mushrooms, chitin can be used as a sustainable resource in the material science field to create new polymeric devices and to reinforce pre-existing technologies for biomedical applications. In this project, chitin nanofiber thin films were fabricated and characterized to further understand their material properties. The fabrication process uses a highly volatile solvent called HFIP, allowing it to evaporate slowly, resulting in a thin film of the solute (Soft Matter, 2010, 6, 5298). The thin films were then tested and measured for material properties on an Instron 4505 (mechanical properties), Dynamic Mechanical Analyzer (mechanical properties), X-Ray Diffractometer (composition), Thermomechanical Analyzer (thermal properties) and a Porosimeter (physical characteristics). From the results of the experiments, it was found that the chitin thin films contain long and dense nanofibers that provide structural integrity for the samples. These fabricated thin films contain amazing properties and provide an avenue to create potential applications in wound healing, tissue scaffolds, and reinforcing on polymeric materials for biomedical applications.

Monitoring and Imaging Hypoxic Cells Using Perfluorinated Near-Infrared Florescent Micelles

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In the poorly formed blood vessel networks of solid tumors, hypoxic regions, or areas of low oxygen concentration, develop due to the ineffective delivery of oxygen by the cells. These hypoxic tumors are resistant to conventional treatment methods. Therefore, development of complementary strategy to detect and deliver oxygen to hypoxic tumors would improve treatment response. This could be achieved with multifunctional nanoparticles that are designed to report hypoxia and deliver oxygen to the target tissue. Specifically, quantum dots (Qdots), nanometer semiconductor particles, are used in optical imaging because of their near infrared florescence properties and potential for multivalent functionalization. In this study, we functionalized Qdots with perfluorocarbons to form novel micelles. We chose perfluorocarbons because of their oxygen carrying abilities. To solubilize the nanoparticle in aqueous solution, an amphiphilic molecule was also prepared and used to formulate the hydrophilic construct. Thus, we developed new perfluorocarbon-coated quantum dots that are capable of monitoring and imaging hypoxic cells. In addition, the materials can effectively deliver oxygen to hypoxic tissue, which will improve the treatment of these difficult tumors.

Growth and Characterization of GaAs/InAs Quantum Dots by Molecular Beam Epitaxy

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Quantum dots are three-dimensional structures that have electronic properties between those of molecules and bulk materials. They can be assembled through molecular beam epitaxial growth or fabricated using lithography. In this work, quantum dots were self-assembled by molecular beam epitaxy (MBE). Growth rates for GaAs and InAs were calibrated by reflection high-energy electron diffraction (RHEED). Doping profiles were determined for GaAs using silicon as the n-type dopant. Quantum dot devices were fabricated and compared to quantum well and quantum free devices. Quantum dot devices had ideality factors and series resistance values of 1.34 and 61 Ω, respectively, and were similar to quantum well and quantum free devices.

Transport In Near-Surface Two-Dimensional Electron Systems

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Near-surface two-dimensional (2D) electron gases are enabling platforms for controlling single electrons in quantum dots and using electron spin as a quantum bit in quantum computation. The requirements for the material system that forms the 2D electron gas are low levels of disorder to reduce scattering, the 2D electron gas be as close to the surface as possible to lead to abrupt confinement potentials created by depletion top gates, and spacer layers between the 2D electron gas and surface have low leakage currents under an applied gate bias. The design of a sub-50 nm deep modulation doped AlGaAs/GaAs heterostructure that forms a 2D electron gas at the AlGaAs/GaAs interface is presented. Magneto-transport measurements in a sub-50 nm deep 2D electron gas formed at the interface of a modulation doped AlGaAs/GaAs heterostructure grown by molecular beam epitaxy are presented. The addition of a high-κ dielectric layer is implemented with the purpose of decreasing gate leakage. Characterization of the dielectric and processing techniques are presented and discussed.

Metasurface Dichroic Mirrors and Applications to Solar Energy via Spectral Splitting

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Multi-junction solar cells are the current leaders in efficiency since they reduce thermal losses by employing series-connected sub-cells with different bandgap energies. However, they are costly to produce and limited by current matching because each solar cell is connected in series with one another. One alternative is to simply split light into ideal bandwidths and tailor separate photovoltaic modules to each bandwidth. Conventional dichroic mirrors can selectively split light by reflecting certain bandwidths while transmitting others. However, these mirrors do not operate well under different incident angles, which is critical for concentrated photovoltaics. Simulations show that metasurface structures can achieve similar characteristics to those of conventional dichroic mirrors while remaining resilient to the incident angle of light. Two such structures were created using electron beam lithography and were subject to transmittance testing. We propose a low-loss, incident angle resilient single-layer metasurface dichroic mirror that can split light into ideal bandwidths for such a solar module. Simulation and experimental data show promising results, however, a multi-layer structure may be more ideal.

Construction of a Modulated Potential Superlattice

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A superlattice is a periodic structure composed of at least two different materials and may be used to change the band structure of a semiconductor. We study the construction of a periodically modulated potential superlattice (with a 60-200 nm period) which is predicted to allow microscale manipulation of electron transport properties in graphene. Using electron beam lithography and reactive ion etching followed by metal deposition we construct complete 200 nm and 140 nm period superlattices. We also push the size limitations of our process to lay ground work for 100 nm and 60 nm period superlattices.

Electrical properties of LaLuAs films

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Alloys of III/V and rare earths are suggested to be "beyond graphene" materials, and as such may show thin film properties. In exploration of this, lanthanum lutetium arsenic (LaLuAs) alloys were characterized. The electrical conductivity of LaLuAs was determined as a function of thickness and temperature. Three LaLuAs (48 weight% La) films were grown using molecular beam epitaxy (MBE), with thicknesses 500, 100, and 30 nm. Samples were fabricated with van der Pauw (VDP) structures in order to take measurements of current and voltage, and the VDP formula was used to find corresponding sheet resistance. Alloys exhibited semi-metallic behavior. The linear fit of the resistivity vs. temperature graphs could be indicative of electron-phonon scattering as the dominant mechanism, for the temperature range from 77K to 295K (Heremans et al, 1977). The difference in resistivity between 30 and 500 nm samples averaged 193% and between 30 and 100 averaged 26%, with the 30 nm sample showing the lower resistivity in both cases. This change in resistivity is most likely an effect of the greater potential for surface roughness between interfaces as thicker layers are grown.

Photovoltaic devices fabricated with $CuIn_{1-x}Ga_xSe_2$ (CIGS) nanocrystal inks

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Photovoltaic devices (PVs) convert sunlight directly to electricity, making them a promising renewable energy resource. Thin-film PVs have the potential for low cost and high efficiency and one of the highest efficiency PV materials, $CuIn_{1-x}Ga_xSe_2$ (CIGS), is particularly attractive. CIGS manufacturing, however, has been relatively expensive because of the need for high temperature processing under selenium vapor. Nanocrystal inks with tailored composition are being explored as a route to CIGS PVs with much lower cost, while retaining high efficiency. In this project, CIGS nanocrystal inks were spray-deposited under ambient conditions and then sintered. Various processing parameters were studied in order to achieve the highest quality, crystalline films with highest device efficiency. Using CIGS nanocrystal inks, PVs with power conversion efficiency under Air Mass (AM)1.5 illumination of 6.56 % were achieved.

Substrate Conformal Imprint Lithography

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Current nanoimprint technologies have significantly better resolution than common photolithography methods and greater throughput than electron beam lithography. Together, these characteristics make nanoimprint a powerful technology with the potential to continue the progress of Moore's law. Substrate Conformal Imprint Lithography (SCIL) removes the sensitivity to defects inherent in traditional nanoimprint techniques by using a flexible PDMS stamp. This allows SCIL to pattern over irregularities instead of leaving large regions void of patterns, making it promising for both industrial and research applications. Our PDMS stamps for SCIL are molded from a master stamp made of silicon, patterned with dense features down to 20 nm in ZEP using electron beam lithography. We employed dose and feature size biasing tests to maximize resolution along with development tests to minimize line edge roughness (LER) to 2-3 nm. We replicated the resulting features into a PDMS stamp to test the resolution of SCIL and determine whether the features would deform at 20 nm critical dimensions (CDs). Lastly, the SCIL process employs a wave generation process to accomplish pattern transfer, with localized and global distortions possible from stretching the flexible PDMS stamp. To characterize this, we performed pattern placement accuracy tests to determine feature fidelity across the width of entire wafers.

Controlling the Composition and Morphology of $Si_{1-x}Ge_x$ Alloy Nanowires

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Silicon (Si) and germanium (Ge) semiconductor nanowires can be utilized in next generation electronic, photonic, and energy conversion devices. Si, Ge, and $Si_{1-x}Ge_x$ materials are also well studied and currently used in industry. Optoelectronic properties, such as the band gap, can be tuned by modulating the alloy composition thus allowing for a wider range of uses.

The focus of the project was to create arrays of $Si_{1-x}Ge_x$ alloy nanowires with varying, but simultaneously uniform compositions. This goal has been difficult to achieve to date. Nanowires were grown with the gold catalyzed, bottom-up, vapor-liquid-solid mechanism throughout the compositional range. Using Scanning Electron Microscopy (SEM), Energy-Dispersive X-Ray Spectroscopy (EDX), and Raman Spectroscopy, we demonstrated control of $Si_{1-x}Ge_x$ alloy composition, but struggled to achieve highly aligned arrays. Nanowires frequently kinked to the <112> directions as a result of surface chemical effects. Therefore, we employed sidewall species such as tri-ethylsilane and methylgermane in an attempt to overcome this.

Fabrication of a Selective Ion Pump: Aluminum Oxide Membrane Anodization

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Anodized aluminum oxide nanoporous membranes show great potential for biological interfaces due to their controllable pore size, pore regularity, and biological stability. In this study anodized aluminum oxide was investigated for use in a through silicon selective neural ion pump. These vertically integrated stack devices were fabricated by depositing an aluminum and silicon nitride stack onto one side of a double-side polished silicon wafer. On the reverse side a photolithographically patterned silica hard mask was used to form a 120 μm by 120 μm window. Bosch etching was then used to reach the silicon nitride layer. This left a thin layer of aluminum and silicon nitride over a window in the silicon wafer. The anodization of the aluminum layer was achieved using sulfuric acid or oxalic acid at voltages between 12.5 and 40 V conditions at 1°C to form pores between 12.5 and 27.5 nm. The silicon nitride and alumina barrier layer formed were then etched using phosphoric acid or reactive ion etching to form a suspended aluminum oxide nanopore membrane capable of being loaded with ion-selective material.

Strain Color Coding Using Localized Surface Plasmon Resonance of Gold Nanoparticles

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Current methods for measuring and quantifying strain are generally only applicable at the macro scale due to material properties, temperature sensitivity, and adhesion difficulties. Consequently many disciplines that require small scale strain measurements rely on simulation-based data. A previous study of localized surface plasmon resonance (LSPR) of gold nanoparticles (AuNP) led to the development of a plasmon ruler equation which relates plasmon peak shift with interparticle separation and particle diameter. The current project optimizes this methodology to develop a novel technique involving AuNP that could potentially be used for lower micro and nano scale strain measurements. AuNP were deposited onto polydimethylsiloxane (PDMS) using thermal evaporation. Strain was systematically applied to the coated PDMS and the plasmon shift was measured using ultraviolet-visible (UV-Vis) spectroscopy. Six different AuNP depositions were investigated to determine the effect of AuNP size and distribution on the sensitivity of strain measurements: 2, 5, 9, 12, 17, and 20 nm. The 9 nm deposition sample allowed for sensitive measurements between 0.2 and 16.5 percent strain. If this method was applied to a smaller scale, it would allow for sensitive nano scale strain measurements. This novel approach could lead to the development of a new style of strain gauge that could quantify deformation over extremely small distances.

InAs Quantum Dot Laser

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InAs quantum dot lasers (QDL) represent a potential light source for use in optoelectronic devices. The confinement from quantum dots results in discrete energy levels that can be tuned to the most commonly used telecommunication wavelengths. Meanwhile, the ability to produce a QDL on a silicon substrate means that the device would be compatible with existing silicon based technology. For this project, lasers were grown on a GaAs substrate to fine tune the growth parameters in preparation for producing the devices on silicon. Molecular beam epitaxy was used to grow the laser structures. Calibration samples were grown and characterized using a combination of photoluminescence measurements and atomic force microscopy to determine the morphological and optical properties of the quantum dots. Once satisfactory results were achieved in the calibration samples, those conditions were used to grow laser devices. Satisfactory structures were then processed into broad area laser bars with a minimum threshold current density of 275 A/cm^2.

Sub-Wavelength Gratings for Multi-Spectral Infrared Detection and Imaging

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Infrared spectral filtering based on Fabry-Perot etalons requires high reflectance, low loss mirrors to enable next generation infrared imaging and spectroscopy. A silicon on air (Si/air) diffraction grating has been investigated as broadband mirrors in the long wavelength infrared (8-12 μm) based on the concept of high refractive index contrast subwavelength grating (HCG). Conventional and Bosch process reactive ion etches (RIE) have been optimized and their field responses compared. The sidewall profiles obtained from the conventional RIE were non-vertical while those from the Bosch process were vertical but scalloped. Fourier transform infrared (FTIR) spectroscopy was used to characterize the gratings and COMSOL Multiphysics simulations were used in analyzing the results. The grating reflectance has been found to be insensitive to either etch method and the suspended structure shows agreement with simulations despite adhesion problems, a consequence of the fabrication process.

Work Function Tuning in Amorphous TaWSiC Metal Gates for Integrated Circuits

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As transistors continue to scale down in size to allow faster, denser, and more efficient integrated circuits, polycrystalline silicon, traditionally used as the transistor gate material, has been replaced by polycrystalline metal. However, as transistor sizes further decrease, polycrystalline metal gates exhibit increasing work function variation due to their varying grain orientations, which degrades both transistor and overall circuit performance. Because of its lack of grains, amorphous TaWSiC has shown promise as a gate metal that would reduce work function variation, but for application in integrated circuits, its work function should also be tunable to selected values. In this work, we study a method to adjust the work function of amorphous TaWSiC gates by varying their relative compositions. Amorphous TaWSiC gates of various compositions are sputter deposited and patterned to form metal oxide semiconductor (MOS) capacitors, and capacitance-voltage measurements are used to extract the work function of each. The resulting understanding of work function tuning in amorphous metal gates could be used in applications of TaWSiC as well as contribute to the development of new gate metals.

Engineered Metallic Structures and Nanofabrication Techniques for Plasmonic Biosensors

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Optical energy can be harnessed on the nanoscale by exploiting plasmonic resonances in metallic nanostructures. These resonances are the result of the unique optical properties of metals and their abundance of conduction electrons. Utilizing these properties, it is possible to engineer metallic nano-devices that operate with large electric field intensities confined in and around the structure. Due to these large fields, optical, chemical and spectroscopic properties can be probed with high sensitivity. This project covers the various fabrication methods unique to the precise fabrication of metallic nano-structures as well as some applications as nano-optical sensors.

Optical characterization and solar cell application of $GaAs/Al_{0.8}Ga_{0.2}As$ quantum wells

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The theoretical efficiency limit of current single p-n junction solar cells is approximately 33%. This limit may be surpassed via the introduction of intermediate energy states in the solar cell's band gap, allowing low energy photons to also induce carrier excitations. Quantum well solar cells contain such states, providing a potential increase in efficiency; however, carriers excited in the barriers often relax into the wells where they become trapped and recombine, reducing their efficiency. In an indirect barrier quantum well, the relaxation process is expected to be reduced because of the large momentum difference. Therefore, the use of an indirect material may suppress carrier trapping and recombination in the wells, resulting in greater solar cell efficiency.

$GaAs/Al_{0.8}Ga_{0.2}As$ quantum well structures were grown using molecular beam epitaxy, and their material quality and carrier escape properties were evaluated via temperature dependent photoluminescence experiments. We have found that carriers trapped in our quantum wells cannot easily escape, and voltage dependent photocurrent spectra show that no significant recombination occurs among carriers generated in the indirect barrier region. Our data suggest that the trapping of these carriers may indeed be suppressed, but further investigation is necessary.

Fabrication and Characterization of Vertical Silicon Nanopillar Schottky Diodes

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Schottky contacts (rectifying metal-semiconductor contacts) have widespread use in electronics, particularly in high frequency and power devices. As devices shrink to the nanoscale, Schottky diodes too must be miniaturized to preserve their uses, such as voltage clamping and rectification. As scaling in the two planar dimensions continues, the challenge in maintaining performance while shrinking devices is increasing. Since nanopillars are vertical, they can exploit the third dimension while maintaining a miniscule two-dimensional footprint. We fabricated sub-100 nm diameter nickel-silicon diodes using *n*-type silicon nanopillars created top-down by applying the Bosch process. Patterned with electron beam lithography and deposited by thermal evaporation, square-shaped islands of silicon dioxide (SiO_2) were used as hard masks for vertical etching. The resulting nanopillars were covered with a conformal layer of SiO_2 for stability and electrical insulation and polished to reveal their silicon tips. Nickel contacts were then patterned, deposited, and annealed to form nickel silicide, yielding Schottky diodes with barrier heights between 0.6 and 0.7eV. We have therefore established a straightforward, low temperature process (no thermal oxide required) for constructing vertical Schottky diodes with approximately circular cross-sections of diameters from 40 nm to 100 nm. We also observed non-ideal current-voltage characteristics that differentiate these nanoscale diodes from planar Schottky barrier diodes.

Electrochemical Deposition of Polythiophene onto Carbon Nanotube Arrays

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Each new generation of electronic products uses high-speed microchips that squeeze more power and performance into even smaller packages. This leads to excess heat generation within the semiconductor component which causes the chip to fail over time. Thermal Interface Materials (TIMs) are an integral part of overall electronic product design. TIMs are used to eliminate the air gaps within the component by conforming to the rough and uneven surfaces of the different parts and consequently remove the heat from the component package surface via a heat sink and heat spreader. The goal of this research is to develop a hybrid material that combines the high thermal conductivity of carbon nanotubes (CNTs) and exceptional mechanical compliance of polythiophene (PTh). We used the low-pressure chemical vapor deposition (LPCVD) technique to fabricate the CNT arrays on silicon wafers. Then a thin layer of PTh was electrochemically deposited on these arrays, examined with scanning electron microscope (SEM) and tested for enhanced heat conduction at the interfaces. Future work will include a detailed study on thermal, electrical and mechanical performance of these polymer CNT hybrid materials.

Oxidation of CVD Grown Carbon Nanotubes for Applying Magnetic Complexes for Spin Transport Measurements

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Due to their high aspect ratio and few nuclear spins, carbon nanotubes (CNTs) can be used as one-dimensional models to observe fundamental spin transport. Polarizing electron spins have been done on CNTs by attaching individual magnetic complexes. Different magnetic complexes and attachment mechanisms have been used, but the one of interest here are tetramanganese(II) complexes with manganese as the metal, which is paramagnetic. Cobalt complexes on the other hand are ferromagnetic and due to this, other interesting properties can be observed with cobalt as the metal. Regardless of the complex however, functional groups need to be introduced to the CNTs in order to chemically attach the complexes.

For this aim, the CNT networks were oxidized at 420ºC in air, pure O_2, and a ~50/50 mix of N_2/O_2 to control the oxidation rate. To measure the degree of oxidation, Raman spectroscopy and resistance measurements across CNT networks were done. An increase in oxidation is expected to show an increase in resistance and defects in the tubes. At 420ºC, the results showed that there was no significant effect on the tubes. A higher temperature might be needed or longer oxidation times may be required.

A microfluidic gradient generating device integrated with nanopatterned matrices for studying cell migration in response to matrix topography and diffusible guidance cues

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Migrating cells are inherently sensitive to a plethora of diffusible and immobilized cues which are integrated to coordinate their directional migration in various contexts of organisational development, physiology and disease *in vivo*. However, the combined effects of these complex guidance cues on directional cell migration remains poorly understood, partly due to complete neglect of these combinational factors in most *in vitro* experimentation. Here we developed a novel microfluidic platform with a nanostructured surface interface, allowing integrative stimulus delivery of chemoattractant factors and topographical cues to migrating cells. We combined nano-grooved substrates with open well microfluidic chambers to study the effects of chemoattractant factors and matrix topography on directional cell migration. Co-current and countercurrent flows of stromal derived factor-1 alpha (SDF-1a) alongside bovine serum albumin (BSA) labeled with fluorescent Rhodamine were used to study microfluidic gradient generation and the subsequent cell homing response. Using this platform, in a single experiment we could simultaneously characterize cell migration and associated cell shape changes under well-defined variations in chemoattractant factors and matrix topography.

Synthesis of CdSe Quantum Dots by Aerosol Reactor

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Nanometer sized semiconductors, or Quantum Dots (QDs) are sought after for their size-dependent photo luminescent properties. The synthesis of QDs in the past has been achieved by the hot solvent injection approach which is difficult to maintain as a continuous process and to operate on a large scale. One of the alternatives to the hot solvent injection is aerosol route formation, having the potential to be a continuous and easy-to-scale-up QD production method. The objectives of this study focus on; (a) the aerosol route formation of CdSe QDs, and (b) the investigation of the effect of the ratio between the cadmium and selenium precursors. The first part of the study was primarily to synthesize CdSe QDs of various sizes with emission wavelengths ranging from blue (465 nm) to red (608 nm) using an aerosol based synthesis. The second part of this study explored the effects of the molar ratio of cadmium acetate to selenium on particle growth rate and the photo luminescent properties. Various molar ratios of Cd:Se were tested, 1:5, 1:2, 1:1, 2:1, and 5:1.

Atomic Layer Deposition Process Optimization and Characterization of Amorphous Metal-Oxide Films

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Atomic Layer Deposition (ALD) is used to create conformal thin films that have many applications due to the wide range of available materials and precisely-controlled film thicknesses. Amorphous metal-oxide thin films are good candidate materials for dielectric gates, diffusion barriers and biocompatible coatings, among many others. ALD processes that have not been optimized and fully characterized result in wasted precursor, longer fabrication times and incomplete understandings of the films themselves. In this work, the processes for hafnia and zirconia films were optimized for uniformity by varying precursor pulse and carrier gas purge times to create the most uniform films. The temperature dependence of various film characteristics was explored for titania, zirconia and silica. Differences between thermal and plasma-enhanced processes were also investigated for titania and alumina films. Uniformity was determined by comparing thickness measured by an ellipsometer at different points across two 100 mm simultaneously-run wafers. Etch rate was determined by comparing the thickness of films before and after set times in 2% HF and 20:1 buffered oxide etch. Metal-Oxide-Silicon capacitors were made with the films to determine breakdown voltage and capacitance with respect to high and low frequency sweeping voltages. This project yielded ALD metal-oxide processes optimized for uniformity and a better understanding of film characteristics.

Top-Gated Graphene-Based Ultrafast Electro-Optic Modulators

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Graphene's universal linear optical absorption, extraordinary carrier mobility, and zero-gap band structure motivate its use as an electro-optic modulator. Via electrostatic doping, the optical absorption of graphene can be modulated by changing the carrier type and density. This electrostatic doping is achieved by applying a gate voltage between graphene and a gate electrode in a thin film structure. Improving on a previously achieved back-gated model, a top-gated geometry was investigated due to its ability to accommodate applications requiring both transmissive and reflective modulators, including utilization in low-loss Bragg reflectors and monolithic fiber lasers. In return for this enhanced effectiveness, the top-gated device requires overcoming additional complications, including depositing dielectric material on graphene, which can lead to destruction of the device. We explored dielectric mediums that can be deposited on graphene with minimal damage, including alumina and silicon monoxide. In this work, we successfully fabricated a top-gated modulator using alumina as a gate dielectric. Alumina was effective in preserving graphene while also exhibiting strong dielectric properties.

Monolayer Molybdenum Diselenide ($MoSe_2$)

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We fabricate a device based on few-layer molybdenum diselenide ($MoSe_2$), a unique two-dimensional semiconducting material in the family of transition metal dichalcogenides. Unlike its sister material, molybdenum disulfide, monolayer $MoSe_2$ is largely unexplored [1]. Here we employ the same exfoliation technique developed by the winners of the 2010 Nobel Prize in Physics for their work with graphene [2]. In this method, scotch tape is used to exfoliate $MoSe_2$ crystals. These crystals are then deposited on the surface of a silicon dioxide/silicon chip. Using an optical microscope, few-layer $MoSe_2$ pieces are identified. A precise measurement of the thickness of each $MoSe_2$ piece is determined using atomic force microscopy. By combining these methods with electron-beam lithography to create a transistor, we can ultimately examine the unexplored optical and electronic properties of monolayer $MoSe_2$.

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Etch Study of Zirconium Oxide Nanoparticle Photoresist

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As feature sizes continue to decrease, the need for high etch-resistance photoresist becomes more apparent. Using thin films leads to lower aspect ratio patterns preventing pattern collapse and providing better pattern transfer. However, due to poor etch-resistance, achieving deep trenches on thin films can be difficult, as one will often etch through the photoresist before completing the etch on the substrate. A promising potential solution lies in inorganic resists. This study looks at one such resist, a zirconium oxide nanoparticle based resist. These zirconium oxide nanoparticles are surrounded by methacrylic acid ligands, where the inorganic core has high etch-resistance and the photochemical reactions can occur at the organic ligands. This presentation looks at the effects of different lengths of oxygen plasma cleaning before etching to see its effects on etch-resistance in CF_4 and SF_6 gases. The oxygen clean appears to have little effect on the etch-resistance of the film, but they do induce the formation of an oxide layer, providing the film with even more protection from etching.

Uptake of Nanoparticles in the Olfactory System and Transport to the Brain in Locust

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Nanoparticles have been gaining increasing interest in consumer products and industrial processes owing to their unique characteristics. The toxicity of nanoparticles via the respiratory route has been well established. Studies confirm that nanoparticles less than 10 nm in diameter deposit efficiently in the nasal, pharyngeal and laryngeal region of the respiratory tract. However, the fate of these particles is not well understood. This presents a unique problem and opportunity as nanoparticles have been reported traveling via the olfactory nerve, the shortest route to the brain. While the olfactory route could be another entry point for environmental toxins, it could also provide a way to circumvent the blood-brain barrier, often a difficult feat in drug delivery. This project aimed to examine nanoparticle transport and activity in the antennae lobe of locust (Schistocerca americana), analogous to the olfactory lobe of mammals. Electrophysiology recordings, which measure neuron activity, were taken before and after injection of a gold nanoparticle suspension. The brain was recovered for transmission electron microscopy (TEM) analysis to determine the cellular localization of nanoparticles. Recordings showed reduced neuron activity and TEM showed particles crossing neuron synapses. Attempts were also made at elucidating possible mechanisms by which nanoparticles could enter the brain via the olfactory system.

Volume Nano-Structured Optics for 3D Superresolution Imaging

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Superresolution microscopy is an imaging technique capable of resolution beyond the diffraction limit. One way to overcome the diffraction limit is by imaging a sparse group of fluorescent molecules at any given time so that no neighboring molecules emit photons simultaneously. By repeating this process, an image can then be generated by precisely localizing all the molecules seen up to a given instant. Superresolution is now limited by the ability to localize a single molecule. In this paper, we present a phase mask that can be inserted in the Fourier plane of a microscope between the object and the camera. The phase mask modifies the transfer function of the imaging system in a way that information about a molecule's position can be extracted more effectively than with a clear aperture. The phase mask was etched into quartz using four binary masks to achieve 16 distinct heights, with the addition of an anti-reflective coating. An accelerated image template matching algorithm is described to retrieve the molecules' location from the captured images.

Engineering Carbon Nanotube Microdrops Using Microfluidic Devices

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Since the discovery of carbon nanotubes (CNTs) by Sumio Iijima in 1991, they have been of great interest to the nanotechnology community. However, progress in CNT technology is slowed down by a lack of methods to control their assembly and organization. In this work, we explored microfluidic drop generators to fabricate CNT microdrops with a controlled geometry and fast throughput. The new CNT morphologies developed in this research are believed to impact a wide variety of applications including CNT based filters, batteries and other energy applications. On the one hand, CNT microdrops were assembled using CNTs water suspensions in polydimethylsiloxane (PDMS). These microdrops were dried out to form solid CNT spheres and characterized using scanning electron microscopy. On the other hand, we explored the fabrication of hollow CNT spheres according to the pickering emulsion principle. In this case, carboxyl functionalized nanotube droplets assemble at the water – cyclohexane interface. This approach was first validated using shear mixing in vials and then transferred to microfluidic drop generators. The latter however still suffers from coalescence and is the subject of further research.

Progress Towards Electrical Interface Chips for BioMEMS

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The conjunction of biology and nanolithography has allowed for the development of many unusual devices—unique hybrids of biological cells and man-made structures. Here, we describe the development of one such device, designed to characterize the contraction force of a skeletal muscle cell. Shimizu et al. measured the force of a single C_2C1_2 myotube by anchoring it to a silicon cantilever and base, electrically stimulating the cell, observing the cantilever movement using an optical microscope, and calculating the resulting force of contraction. Building upon their work, we fabricated micron-scale cantilevers made of the non-cytotoxic photoresist SU-8. In addition to developing the fabrication process for the SU-8 cantilevers, we characterized them using optical microscopy and profilometry. Currently, we are investigating optical frequency domain reflectometry (OFDR) as a method for more accurately measuring the movement of the cantilevers. Accurate characterization of cantilever movement as the cell contracts will allow for a more precise measurement of the force exerted by an individual skeletal muscle cell.

Fabrication of a Spin Torque Ferromagnetic Resonance (ST-FMR) Device

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The goal of this REU project is to measure the material and film thickness dependence of spin-torque ferromagnetic resonance (ST-FMR) induced by the spin Hall effect. The spin Hall effect occurs when a current is sent through a conducting, nonmagnetic material and spin-up and spin-down electrons are separated on either side of the material. This creates what is called a spin current, transverse to the electron current. In this research, the spin Hall effect is used as a source for spin injection in a nonmagnetic, conducting metal to create magnetic precession in an adjacent ferromagnetic film. These experiments will help attain a better understanding of the spin Hall effect in various materials and the dynamics of spin Hall induced ST-FMR. Photolithography, ion milling and sputter deposition will be used to define bilayer structures with contact pads. With these devices, we will measure the ferromagnetic resonance signal to quantitatively determine the spin current injection and spin Hall angle.

Heteroepitaxial Growth of Diamond on SiC Substrates

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The high carrier mobility and thermal conductivity of diamond make it a promising candidate to succeed silicon in electronic device applications and take us beyond current operating speed limitations. Growth of thin, high quality diamond films has been consistently achievable since the 1980's by chemical vapor deposition (CVD) and works best on diamond substrates; however, as diamond substrates are expensive and cannot be commercially grown large enough for mass production, this project explores SiC as an alternative growth substrate. Diamond films have been grown using a hot filament CVD (HFCVD) under two filament configurations, with differing growth times and carbon to hydrogen ratios. Quality of the diamond films was characterized by Raman spectroscopy, scanning electron microscopy (SEM), and energy-dispersive x-ray spectroscopy (EDS). Hall measurements were performed on selected samples to determine the electrical properties of the films. Fabrication of Schottky diodes is planned to assess the potential of these diamond films for electronic devices.

Characterization of Polymer-Modified Silicon Nanophotonic Biosensors

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Silicon photonic microring resonators are label-free biosensors that are able to detect very small changes in bound mass on the surface of a nanophotonic waveguide in real-time, while requiring only a few microliters of sample. However, prior to realizing the full potential of this biosensing technology, it's necessary to address the significant challenge of surface fouling and biocompatibility when performing in complex biological matrices (e.g. blood, plasma, serum). Due to high interfacial energy at the surface, proteins irreversibly adsorb to the microrings upon contact. This non-specific fouling of the sensor surface inhibits its ability to sense specific binding interactions. One strategy used to prevent this non-specific adsorption is to use a controlled polymerization of thin zwitterionic polymer that can be grown from the silicon substrate of the sensor, producing a hydrophilic, non-fouling coating. In this study, carboxybetaine acrylamide was polymerized from microring resonators using atom transfer radical polymerization (ATRP). Sensors were exposed to undiluted human plasma to determine the extent of fouling. The polymer film was characterized using atomic force microscopy (AFM) and scanning electron microscopy (SEM). AFM, SEM, and plasma binding data were used to refine the ATRP process in order to establish a polymerization procedure that enables a microring resonator biosensor to be used in real-world applications.

$CuInSe_2$ nanocrystals with inorganic ligands for photovoltaic devices

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Copper Indium Diselenide ($CuInSe_2$, or CIS) nanocrystals capped with inorganic ligands were explored as the light-absorber layer in photovoltaic devices (PVs) or solar cells. These materials were processed without vacuum or high temperature and deposited using solution-based methods that have the potential for very low cost and high throughput manufacturing. CIS nanocrystal were synthesized by colloidal arrested precipitation with oleylamine capping ligands. Inorganic metal chalcogenide complex (MCC) ligands were exchanged with oleylamine. Typically, the MCC ligand-capped nanocrystals require hydrazine as a solvent, which make processing a challenge. We developed a way to use MCC-capped nanocrystals with more environmentally-responsible solvents, like dimethyl sulfoxide (DMSO), which allowed the nanocrystals to be spray-coated under ambient conditions. The MCC-capped nanocrystal films could then be sintered without resorting to typical high temperature (> 500°C) selenization with selenium (Se) vapor. Sintering the nanocrystal layers helps improve the efficiency of devices based on CIGS nanocrystal inks.

A 3D circuit QED Architecture with Separate Read-out and Coupling Cavities

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This work presents the development of a 3D circuit quantum electrodynamical (QED) architecture with separate cavities for inter-quantum bit (qubit) coupling and for qubit readout. Such a separation allows for optimisation of the cavities for their separate tasks, as opposed to the compromise necessary in single-cavity architectures. The device designed is a 3D analogue of a working multi-resonator, multi-transmon qubit device in standard, planar circuit QED. By switching from coplanar waveguide (CPW) resonators to 3D cavity resonators, we expect to attain significantly higher qubit and resonator coherence times (tens of microseconds), allowing realization of complex quantum computing algorithms while retaining the virtue of physical scalability. The architecture pursued also includes local flux tuning of qubit transition frequencies, necessary for control of qubit-qubit interactions on nanosecond timescales. We present here the design, simulation and initial characterization of the first prototype.

Optimization of inkjet-printed ITO electrodes for fabrication of sub-micron gate length transistors using surface chemistry manipulation

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Ink-jet printed inorganic thin-film transistors (TFT) are critical components for low cost, large area circuits. Since the channel length of the transistor modulates conductance and cutoff frequency by an inverse relation, printing sub-micron gate length transistors will open the door for high performance printable circuits. In this project we explore the treatment of inkjet-printed indium tin oxide (ITO) electrodes with hydrophobic self-assembled monolayers (SAMs) to repel away a second printed ITO electrode, yielding sub-micron electrode gaps. By combining this process with a solution-processed semiconductor such as zinc tin oxide, a cost-effective short channel TFT can be made. In this project, we refine inkjet printing of ITO nanoparticle ink to obtain neatly patterned electrodes of uniform dimensions. Annealing conditions are optimized to obtain minimum resistance for the printed electrodes. We then use SAMs to selectively manipulate the wettability of the ink to the existing electrode versus to various substrates. The effect of SAMs is quantified by contact angle measurements. Work is ongoing to use this technique to fabricate sub-micro scale gaps between electrodes.

High Fidelity Method For Microfabricating In Vitro Neural Networks

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Functional *in vitro* models of neural networks are essential for uncovering the underlying cellular mechanisms by which mechanical stress induces traumatic brain injury. However, current models do not capture the connectivity and organization of the brain's axonal tracts, limiting our ability to study how cellular dysfunction may be transmitted between distant regions of the brain. These models are inadequate due to insufficient fabrication techniques for consistently and accurately placing neurons in a network. Here, we propose a novel method for neural network fabrication that incorporates microfluidic cell placement onto micropatterned substrates. We fabricated a microfluidic device featuring cell traps that capture cells in an organized array, placing them in contact with a fibronectin-coated surface that provides guidance cues for network self-organization. As proof of concept, we used 3T3 fibroblasts to assess the efficiency of this technique. Compared to standard microcontact printing, microfluidic delivery of cells resulted in more consistent, uniform adherence of cells to patterned substrates. Development of this technique may allow fabrication of more authentic neural networks and provide a platform by which we may further investigate the role of diffuse axonal injury in the pathophysiological response to traumatic brain injury.

Development of Air Spaced VIPA's for Use in Optical Coherence Tomography

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Optical Coherence Tomography (OCT) is a high resolution, non-invasive technique for imaging scattering media (e.g., biological tissue). Similarly to ultrasound, OCT nominally produces one-dimensional cross-sectional images called A-scans. The number of data points acquirable in an A scan and consequently imaging depth is related to the spectral resolution of the detector being used. To increase the number data points in the A scan we fabricated a low cost cross dispersing spectrometer based on an air-space Virtually Imaged Phased Array (VIPA). A VIPA is a slightly tilted etalon which allows for high angular dispersion of the broadband incident light by wavelength. The performance of a VIPA depends heavily on surface reflectivity as well as cavity dimensions, and the index of refraction of the cavity medium. VIPA's of various reflectivities were constructed via metal deposition on glass slides, and optical flats; the reflectivities were measured via the Hitachi 4001 Spectrophotometer. Their finesse, FSR, and spectral dispersion characteristics were measured via photodetector. We show that sufficiently capable VIPA's can be constructed far more cheaply than commercial varieties, and will enable the development of high performance, affordable OCT systems.

Enhancing the Luminescence Efficiency of GaSb-Based Dilute-Nitrides by Rapid Thermal Annealing

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It has been shown that GaSb-based dilute-nitrides display improved photoluminescence (PL) with *in situ* annealing in the molecular beam epitaxy (MBE) growth chamber. This improvement in luminescence efficiency translates into improved performance of optoelectronic devices, such as lasers where this will lead to a reduction in threshold current densities. However, similar improvement in luminescence efficiency was not observed during *ex situ* annealing in a rapid thermal annealing (RTA) furnace. The ability to recreate similar annealing performance in the RTA would allow for increasingly efficient annealing. Upon further study, we determined that the degradation in PL resulted from over-annealing of the sample. Attributing this issue to the silicon carrier wafer, which has a higher band gap than the GaSb sample, infrared radiation was heating the sample more than indicated by the carrier wafer pyrometer measurement. We mitigated this issue by integrating a low bandgap InAs layer into the carrier wafer and were able to ensure that our sample was below the temperature indicated by the pyrometer. This optimization allowed us to pinpoint the optimal annealing temperature more accurately and achieve PL performance similar to that of *in situ* annealing.

Effects of Membrane Surface Modification on Calcium Carbonate Fouling and Membrane Efficiency for Desalination

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Reverse osmosis (RO) is a technique that is currently used to desalinate brackish water and seawater through semi-permeable membranes. However, one of the main problems with this RO technique is that the membrane is highly susceptible to fouling which can clog the membrane and reduce water flux and salt rejection. Generally, fouling occurs due to hydrophobic interactions between the solutes and the membrane surface. Thus, in our study we grafted a hydrophilic monomer (polyethylene glycol) to help resist membrane fouling of calcium carbonate, a common mineral foulant. We utilized commercially available thin-film composite (TFC) membranes and modified them by hydrophilic monomer grafting and studied calcium carbonate fouling in sodium chloride solutions. The membrane surface was analyzed using contact angle, force mode atomic force microscopy, and scanning electron microscopy measurements. After characterization, we tested water flux and salt rejection through the unmodified and grafted membranes to measure their efficiency and determine if this membrane modification is a viable option for improving anti-fouling conditions. By improving desalination membranes, this study could assist in reducing water pretreatment costs and the frequency of membrane cleaning.

Carbon Doping on (10-11) GaN by Plasma-Assisted Molecular Beam Epitaxy

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Magnesium (Mg) is the most commonly acceptor used in Gallium Nitride (GaN) devices; however, because it is a deep acceptor it introduces electrical and optical complications. Carbon has been demonstrated to be a possible alternative acceptor dopant atom with a lower activation energy [1], which could alleviate many of the issues surrounding Mg doping. Carbon-doped GaN (GaN:C) samples were homoepitaxially grown on (10-11) and (10-1-1) planes using plasma-assisted molecular beam epitaxy (PAMBE). Un-intentionally doped (UID) GaN and GaN:Mg samples were also grown using PAMBE. Surface roughness of 0.113 was achieved as verified by atomic force microscopy (AFM). There was no crystal degradation from carbon doping as demonstrated by full width half max calculations of x-ray diffraction (XRD) rocking curves. The samples were electrically characterized by taking Hall measurements on mesa-isolated photolithographically-defined contacts placed in a Van der Pauw pattern.

References: [1] Hikosaka et al., phys. stat. sol. (c) 3, No. 6, 1425 (2006)

Electrically and Optically Obtaining *Q* of High Stress SiN Devices

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High-stress silicon nitride membranes show extremely high mechanical quality factors (*Q* of up to 1 million) and are useful for applications in resonant sensors, oscillators and optomechanical experiments. Here we fabricate high *Q* stoichiometric silicon nitride membranes by depositing silicon nitride using LPCVD process followed by back etching of a pre-patterned silicon wafer. Monolayer graphene and thin gold pads are deposited onto this suspended membrane so as to create a conductive region that will enable the capacitive readout of the resonant motion. Amplitude of motion in resonance is usually detected using interferometric means in a custom built laser setup. The optical readout is to be compared to the electrical readout where the amplitude of resonant motion is detected by passing a source-drain current through the graphene via wire-bonded gold pads. The resonant motion should modulate the resistance of the graphene. The readouts display *Q* factors of the composite resonator as high as 100,000. We conclude that electrically active silicon nitride resonators maintain the ultra-high *Q* and therefore are useful for the above mentioned applications.

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Eight NNIN iREU interns spent 12 weeks at the National Institute for Materials Science in Tsukuba, Japan. Research topics included silicon nanoparticles for DNA drug delivery, high-κ dielectrics for future CMOS, polymer biosurface design, GaAs integrated circuits for high-speed ring oscillators, optical characterization and solar cell application of $GaAs/Al_{0.8}Ga_{0.2}As$ quantum well solar cells, hydrogen sensing in SnO_2 thin films, performance limitations of organic transistors and thixotropic gels with mechanoresponsive colors. They traveled the country extensively and enjoyed the enriching culture. One highlight was conquering Mt. Fuji. It was an incredible experience, and they left Japan as international researchers.

Dr. Lawrence S. Goldberg

Senior Engineering Advisor, National Science Foundation

Dr. Lawrence Goldberg is a Senior Engineering Advisor in the Engineering Division at the National Science Foundation. He has been the NSF program manager responsible for the National Nanotechnology Infrastructure Network since before NNIN's inception in 1994.

Dr. Goldberg received his B.S. degree in Engineering Physics from Washington University in 1961, and his Ph.D. degree in Solid State Physics from Cornell University in 1966. From 1966-67, he spent a postdoctoral year as research assistant at the Physikalisches Institut, Universität Frankfurt, Germany. From 1967-1985, he was with the Naval Research Laboratory as research physicist in the Optical Sciences Division. During 1976-1977, he was on sabbatical leave at Imperial College, London, England. Dr. Goldberg's research interests have been in lasers, nonlinear optics, optical parametric devices, ultrashort pulse lasers and spectroscopy, liquid crystals, and radiation defects in crystals.

Dr. Goldberg came to the National Science Foundation in 1985 as Program Director for the Quantum Electronics, Waves, and Beams Program, in the Division of Electrical and Communications Systems, Directorate for Engineering. In the summer of 1989, he served as Acting Head of the NSF Office in Tokyo, Japan. His program responsibilities at NSF covered research areas of quantum electronics, optics, plasmas, and electromagnetics. He served also as Senior Staff Advisor and as Acting Division Director. In 1994, Dr. Goldberg was appointed Director of the Division of Electrical and Communications Systems and served until January 1998. Dr. Goldberg holds the position of Senior Engineering Advisor in the Division of Electrical, Communications and Cyber Systems. In September 2008, Dr. Goldberg was appointed to serve as Acting Director of the Division of Electrical, Communications and Cyber Systems.

Dr. Goldberg served under appointment by the President's Science Advisor as NSF member of the Joint Management Committee for the U.S.-Japan Joint Optoelectronics Project. He helped develop and coordinate the NSF-wide initiative in Optical Science and Engineering, the NSF/DoE Partnership in Basic Plasma Science and Engineering, and the NSF/NIH Scholar-in-Residence at NIH. He provided oversight for the National Nanofabrication Users Network (NNUN), and served five-years as chair of the NSF coordinating committee for the Integrative Graduate Education and Research Traineeship (IGERT) program.

Dr. Goldberg guided the competition and now provides oversight for the National Nanotechnology Infrastructure Network (NNIN). He also provides oversight for the NSF Science and Technology Center on Nanobiotechnology at Cornell University, the NSF Engineering Research Center on Integrated Access Networks (CIAN) at the University of Arizona, and the NSF/DARPA Photonics Technology Access Program (PTAP). Dr. Goldberg coordinates joint activities on nanoelectronics with the Semiconductor Research Corporation and the Silicon Industry Association, conducted under NSF's emphasis on Nanoscale Science and Engineering. He also coordinates the Major Research Instrumentation program for the Engineering Directorate.

Dr. Goldberg served in early 2005 as U.S. Embassy Science Fellow in Chisinau, Moldova, where he worked in close cooperation in an advisory role with the President of the Academy of Sciences of Moldova. He has since participated in government-level science studies in Ukraine, Kazakhstan, and Romania.

Dr. Goldberg is Fellow of the Optical Society of America, and Fellow of the Institute of Electrical and Electronic Engineers.

Dr. Mihail C. Roco
Senior Advisor for Nanotechnology, National Science Foundation

Dr. Roco is the founding chair of the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET), and is the Senior Advisor for Nanotechnology at the National Science Foundation. He also coordinated the programs on academic liaison with industry (GOALI). Prior to joining National Science Foundation, he was Professor of Mechanical Engineering at the University of Kentucky (1981-1995), and held visiting professorships at the California Institute of Technology (1988-89), Johns Hopkins University (1993-1995), Tohoku University (1989), and Delft University of Technology (1997-98).

Dr. Roco initiated the first Federal Government program with focused on nanoscale science and engineering (on Synthesis and Processing of Nanoparticles) at NSF in 1991. He formally proposed NNI in a presentation at White House/OSTP, Committee on Technology, on March 11, 1999. He is a key architect of the National Nanotechnology Initiative, and coordinated the preparation of the U.S. National Science and Technology Council reports on "Nanotechnology Research Directions" (NSTC, 1999) and "National Nanotechnology Initiative" (NSTC, 2000).

Dr. Roco is a Correspondent Member of the Swiss Academy of Engineering Sciences, a Fellow of the American Society of Mechanical Engineers, a Fellow of the Institute of Physics, and a Fellow of the American Institute of Chemical Engineers. He has been co-founder and Chair of the AIChE Particle Technology Forum and of the International Multiphase Flow Council. He has served as editor for Journal of Fluids Engineering and Journal of Measurement Science and Technology, and is Editor-in-chief of the Journal of Nanoparticle Research. He has been member in the several research boards in Americas, Europe and Asia including the S&T Council of the International Risk Governance Council in Geneva.

He was honored as recipient of the Carl Duisberg Award in Germany, "Burgers Professorship Award" in Netherlands and the "University Research Professorship" award in U.S. He was named the "Engineer of the Year" in 1999 and again in 2004 by the U.S. National Society of Professional Engineers and NSF. In 2002, he received the "Best of Small Tech Awards" ("Leader of the American nanotech revolution"). Forbes magazine recognized him in 2003 as the first among "Nanotechnology's Power Brokers" and Scientific American named him one of 2004's top 50 Technology Leaders. Dr. Roco is the 2005 recipient of the AIChE Forum Award "for leadership and service to the national science and engineering community through initiating and bringing to fruition the National Nanotechnology Initiative". He received the National Materials Advancement Award from the Federation of Materials Societies at the National Press Club in 2007 for NNI leadership and "as the individual most responsible for support and investment in nanotechnology by government, industry, and academia.

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Practice

Nicole offers clients wide-ranging experience with patent infringement actions in several significant patent jurisdictions, including Delaware, Texas, Massachusetts, California, and the International Trade Commission. With a degree in electrical engineering, Nicole's litigation experience includes matters relating to electronics and consumer products, computers, semiconductors, telematics, software, Internet-based technology, and telecommunications. Her litigation experience includes Markman hearings, summary judgment hearings, and ITC investigations.

Nicole is also a registered patent attorney and has experience filing reexaminations on behalf of her clients. Some of Nicole's recent successes include her representation of Motorola in both District Court and the ITC in its smartphone litigation against RIM and her representation of PerkinElmer against Intema, Ltd., which resulted in summary judgment of invalidity of Intema's patent.

Representative Clients and Matters

- ***Motorola Mobility, Inc.*** *v. Microsoft Corporation*: Represents Motorola against Microsoft in multi-district patent litigation (including ITC) directed to, inter alia, the Motorola Droid and Microsoft's Xbox 360, Windows 7 and Internet Explorer 9.
- ***Motorola, Inc.*** *v. VTech Communications, Inc. et al.*(E.D. Tex.): Involved in a litigation relating to five patents covering telecommunication products and features, including a design patent that relates to Motorola's Razr phone design.
- Certain Wireless Communication System Server Software, Wireless Handheld Devices and Battery Packs: Represented **Motorola** in an ITC litigation against RIM relating to five patents directed to features of wireless devices. RIM settled with Motorola shortly before the Markman hearing as part of a global settlement of all litigation between Motorola and RIM.
- Certain Digital Televisions and Certain Products Containing Same and

Education

- JD, 2002, The George Washington University Law School, Student Intellectual Property Society
- BSEE (Electrical Engineering), *cum laude*, 1999, Binghamton University, T.J. Watson Excellence Award; Tau Beta Pi; Eta Kappa Nu; President, Institute for Electronic and Electrical Engineers

Bar Admissions

- District of Columbia, 2004
- New York, 2003
- U.S. Patent and Trademark Office, 2002

Courts

- U.S. District Court for the District of Columbia, 2011
- U.S. District Court for the Southern District of New York, 2003
- U.S. District Court for the Eastern District of New York, 2003
- U.S. Court of Appeals for the Federal

Matt Kennedy, Ph.D.

Postdoctoral Research Associate

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Matt Kennedy completed a B.S. in Physics at UCLA in 2004 and a Ph.D. in Electrical and Computer Engineering at Cornell University in 2010. Dissertation work involved the development of microfluidic biosensors.

He presently works full-time as a postdoctoral research associate at the Naval Research Laboratory in Washington, DC, where he studies fluid dynamics at surfaces and interfaces. Matt will discuss the pros and cons of attending graduate school and pursuing a research career through continued postdoctoral research.

He will provide some tips for how to succeed in different research environments, how to choose good scientific advisers, and how to have fun along the way.

Graham M. Pugh

Director, International Climate Change Policy and Technology

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Graham Pugh leads an office focused on clean energy and climate change within DOE's Office of Policy and International Affairs. Much of his work is focused on the 23-government Clean Energy Ministerial process (www.cleanenergyministerial.org), for which his office serves as Secretariat. He is also responsible for planning and implementing the work of the U.S.-led initiatives in that effort.

Graham's prior international work includes coordinating the international efforts of the DOE Office of Energy Efficiency and Renewable Energy and serving in the Office of Global Change at the Department of State, where he was a member of the U.S. delegation to meetings of the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change.

In the domestic context, Graham served as Deputy Associate Director for Climate and Energy at the Council on Environmental Quality in the Executive Office of the President, where he focused on energy resources, technology commercialization and financing. His prior domestic work in DOE involved leading analytical efforts to plan and coordinate Federal actions to develop and commercialize technologies to address climate change.

Before coming to Washington, Graham was employed by Intel Corporation for eleven years, where he focused on new technology development, international technology cooperation, and strategic investment. He made the transition to government service in 2004 as a recipient of a Diplomacy Fellowship from the American Association for the Advancement of Science.

Graham holds bachelors and masters degrees in physics and engineering, both from Cornell University. He was a Peace Corps Volunteer in Kenya, teaching science and mathematics in rural secondary schools.

Mrs. Sarah Rickman-Yapp

Department/Sector: Program Management/Defense & Aerospace

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Sarah Rickman-Yapp graduated from Patrick Henry High School in Ashland, VA in 2000. She began her engineering career at Lehigh University and participated in the NNIN (NNUN) REU Program in 2003 at Stanford University. Sarah worked for Professor Paul McIntyre conducting research on ferroelectric materials being considered for use in non-volatile Random Access Memory (RAM).

She graduated from Lehigh University with a B.S. in Chemical Engineering in 2004 but based on her experience at Stanford, decided to switch fields and move to Materials Science from Chemical Engineering. She obtained her M.S.in Materials Science and Engineering from the University of Delaware in 2006 where her thesis focused on thin film materials for photovoltaics. She then spent a year at Carnegie Mellon University performing research on the structure and electrical properties of SiC for high power devices before moving on to industry.

Sarah joined Saft America Inc. in Cockeysville, MD, in September 2007 as a Research Scientist. Saft Cockeysville specializes in the manufacture and development of li-ion batteries for military and space applications. She worked in the R&D group for three years conducting studies on the aging of li-ion batteries and new materials for improved safety. Sarah then moved into the management group as a Program Engineer and is a manager of programs related to space applications and aviation.

Gina Eosco

Ph.D. Student

Risk Communication Research Group

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Gina graduated from Cornell University in 2008 with an Master of Science degree in Communication. She returned to Cornell in the fall of 2011 to complete her Ph.D.

Gina's research interests include the application of risk, science, and visual communication theories to weather, climate, and natural hazards, as well as the intersection between science communication and action (i.e., policy decisions, evacuation decisions, etc.) Her MS thesis was part of a larger goal focusing on scientific translation through visuals — that is, looking at how the scientific objective of a graphic may or may not translate to public understanding. In particular, her thesis uses hurricane track graphics as a case study to see how forecasters prioritize and convey weather information for visuals. Her next steps include how the public interprets these graphics, followed by an analysis of the forecasters' objectives compared to public understanding.

Her other research includes newspaper use of scientific uncertainty and preparedness frames while covering seasonal hurricane forecasts. She is also involved in a project sponsored by the Dept. of Communication and the Center for Life Science Enterprise that focuses on scientists' engagement with the public.

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Benton, Rachel • BUS # 2 • PS# 2, Ohio

Bjarnason, Elsie • BUS # 2 • PS# 2, Ohio

Blonsky, Adam • BUS # 2 • PS# 2, Ohio

Bodington, Dashiell • BUS # 2 • PS# 2, Ohio

Brady, Merrill • BUS # 1 • PS# 1, Ohio

Bryant, Alex • BUS # 1 • PS# 1, Ohio

Buck, Alexander • BUS # 2 • PS# 2, Ohio

Burns-Heffner, Colin • BUS # 2 • PS# 2, Ohio

Butera, Patrick • BUS # 1 • PS# 1, Ohio

Calderon Jr., Isidro • BUS # 2 • PS# 2, Ohio

Chew, Annabel • BUS # 1 • PS# 1, Ohio

Cosgriff, Lauren • BUS # 2 • PS# 2, Ohio

Davydovich, Dmitriy • BUS # 2 • PS# 2, Ohio

Dean, Leon • BUS # 2 • PS# 2, Ohio

Deng, Donna • BUS # 2 • PS# 2, Ohio

Do, Duy • BUS # 1 • PS# 1, Ohio

Echeverria, Marcos • BUS # 2 • PS# 2, Ohio

Ellison, Amanda • BUS # 1 • PS# 1, Ohio

Everhart, Camille • BUS # 1 • PS# 1, Ohio

Gaudreau, Ryan • BUS # 1 • PS# 1, Ohio

Gaviria, William • BUS # 2 • PS# 2, Ohio

Gilpin, William • BUS # 1 • PS# 1, Ohio

Goldfeld, David • BUS # 1 • PS# 1, Ohio

Gosse, Melissa • BUS # 1 • PS# 1, Ohio

Guess, Kyle • BUS # 2 • PS# 2, Ohio

Gupta, Sonali • BUS # 1 • PS# 1, Ohio

Hamstra, Lee • BUS # 2 • PS# 2, Ohio

Hayes, Anderson • BUS # 1 • PS# 1, Ohio

Henderson, Codey • BUS # 2 • PS# 2, Ohio

Hirokawa, Soichi • BUS # 2 • PS# 2, Ohio

Hirotsu, Kelsey • BUS # 2 • PS# 2, Ohio

Holmes, Ian • BUS # 1 • PS# 1, Ohio

Hood, Keevin • BUS # 1 • PS# 1, Ohio

Hovish, Michael • BUS # 1 • PS# 1, Ohio

Hummel, Gwendolyn • BUS # 2 • PS# 2, Ohio

James, Briana • BUS # 1 • PS# 1, Ohio

Johnson, Camryn • BUS # 1 • PS# 1, Ohio

Jue, Melinda • BUS # 1 • PS# 1, Ohio

Kiok, Matthew • BUS # 1 • PS# 1, Ohio

Klemme, Daniel • BUS # 2 • PS# 2, Ohio

Knight, Andrew • BUS # 1 • PS# 1, Ohio

Lambdin, Olivia • BUS # 1 • PS# 1, Ohio

Lampe, Corinne • BUS # 2 • PS# 2, Ohio

Lee, Alexander • BUS # 2 • PS# 2, Ohio

Lee, Jia • BUS # 2 • PS# 2, Minnesota

Lee, Jonathan • BUS # 2 • PS# 2, Minnesota

Llinas, Juan • BUS # 2 • PS# 2, Minnesota

Long, Clay • BUS # 1 • PS# 1, Minnesota

Luo, Peter • BUS # 1 • PS# 1, Minnesota

MacKenzie, Ian • BUS # 1 • PS# 1, Minnesota

Makhnejia, Kamil • BUS # 2 • PS# 2, Minnesota

Margita, Kaleigh • BUS # 1 • PS# 1, Minnesota

McArthur, Donnita • BUS # 1 • PS# 1, Minnesota

McMorris, Ryan • BUS # 2 • PS# 2, Minnesota

McMullen, Adam • BUS # 2 • PS# 2, Minnesota

Meyerhofer, Phillip • BUS # 2 • PS# 2, Minnesota

Michael, Maria • BUS # 2 • PS# 2, Minnesota

Mori, Isao • BUS # 2 • PS# 2, Minnesota

Mork, Frazier • BUS # 1 • PS# 1, Minnesota

Murphy, Ryan • BUS # 1 • PS# 1, Minnesota

Nakamoto, Christopher • BUS # 2 • PS# 2, Minnesota

Newton, Jared • BUS # 1 • PS# 1, Minnesota

Norman, Justin • BUS # 2 • PS# 2, Minnesota

Nygren, Katherine • BUS # 2 • PS# 2, Minnesota

Occena, Jordan • BUS # 2 • PS# 2, Minnesota

Olson, Stephen • BUS # 2 • PS# 2, Minnesota

Otto, Lauren • BUS # 1 • PS# 1, Minnesota

Overvig, Adam • BUS # 1 • PS# 1, Minnesota

Parry, Ryan • BUS # 1 • PS# 1, Minnesota

Pelaez, III, Francisco • BUS # 1 • PS# 1, Minnesota

Pozo, Jorge • BUS # 1 • PS# 1, Minnesota

Reit, Radu • BUS # 2 • PS# 2, Minnesota

Roberge, Adam • BUS # 1 • PS# 1, Minnesota

Ross, Emily • BUS # 2 • PS# 2, Minnesota

Rothenberg, Jacob • BUS # 2 • PS# 2, Minnesota

Russo, Elisa • BUS # 1 • PS# 1, Minnesota

Sakakibara, Reyu • BUS # 1 • PS# 1, Minnesota

Sanville, Andrew • BUS # 1 • PS# 1, Minnesota

Scheideler, William • BUS # 1 • PS# 1, Minnesota

Schliep, Karl • BUS # 1 • PS# 1, Minnesota

Schoening, Jonathan • BUS # 1 • PS# 1, Minnesota

Shapero, Aubrey Michael • BUS # 2 • PS# 2, Minnesota

Shim, YooSun • BUS # 1 • PS# 1, Minnesota

Swartz, Stephanie • BUS # 2 • PS# 2, Minnesota

Switzer, Oliver • BUS # 1 • PS# 1, Minnesota

Tam, Andrew • BUS # 1 • PS# 1, Minnesota

Thielen, Brianna • BUS # 2 • PS# 2, Minnesota

Thomas, Cherrelle • BUS # 2 • PS# 2, Minnesota

Truxal, Ashley • BUS # 2 • PS# 2, Minnesota

Vrla, Geoffrey • BUS # 2 • PS# 2, Minnesota

Vulis, Daryl • BUS # 1 • PS# 1, Minnesota

Welsh, Timothy • BUS # 2 • PS# 2, Minnesota

Wendt, Nathaniel • BUS # 2 • PS# 2, Minnesota

Wong, Whitney • BUS # 1 • PS# 1, Minnesota

Yu, Caroline • BUS # 2 • PS# 2, Minnesota

Yu, Patrick • BUS # 1 • PS# 1, Minnesota