Welcome to the

Cornell NanoScale Science & Technology Facility

35^{th} Anniversary Celebration & Annual Meeting

Thursday, July 19, 2012

Cornell University,
Ithaca, New York

The Secretary of Energy
Washington, D.C. 20585

July 2012

Dear Friends and Esteemed Colleagues at the Cornell Nanoscale Facility (CNF):

It is my pleasure to congratulate you on 35 years of outstanding science. Since the earliest days of the CNF, researchers from across the country and around the globe have been coming to facilities such as the CNF to advance their work in engineering, the physical sciences, and the life sciences.

Thousands of scientific projects have been validated, new fields have been opened, and new possibilities created. But there is so much more to do in the field of nanoscale science and technology. The research techniques and interdisciplinary efforts you have employed will be even more essential in future scientific and engineering advances.

I wish you an enjoyable and well-earned day of celebration, and I look forward to your achievements in the years to come.

Sincerely,

Steven Chu

Steven Chu

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Cornell NanoScale Science and Technology Facility
Cornell University
Ithaca, NY 14850

To all my Friends at Cornell:

On behalf of the State of New York, and the 125th Assembly District, I would like to offer my congratulations to you on this very significant anniversary - your facility has been in operation for 35 years!

The Cornell NanoScale and Technology Facility has made available state-of-the-art resources to hundreds of users every year and has provided them with expert staff support. Your users, many of whom come from outside of Cornell, encompass individuals doing research in engineering and physical and life sciences.

Thank you for giving users from academia, industry and government laboratories the opportunity to learn and use the tools available in your facility. The research that they do advances the scientific community and will impact research for years to come.

Sincerely,

Barbara S. Lifton

Barbara Lifton
Member of Assembly
125th District

BSL/cme

ALBANY OFFICE: Room 555, Legislative Office Building, Albany, New York 12248 • 518-455-5444
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July 19, 2012

Dear Friends:

Please accept my warmest greetings and congratulations as you gather for Cornell University's 35th Anniversary as a national user facility and symposium. I am grateful for the opportunity to recognize the groundbreaking work of Cornell University's NanoScale Science and Technology Facility and today's speakers on this noteworthy milestone.

Since its founding in 1977, the Cornell NanoScale Science and Technology Facility, (CNF) has demonstrated an impeccable record of serving consumers from around the world and domestically with access to state-of-the-art nanofabrication and characterization tools. With the introduction of new technology and the success of its projects, CNF has been able to broaden the boundaries of the fields of science and engineering. Successful projects and other multi-disciplinary national user facility initiatives have created an environment for researchers from around the world, to work on innovative projects. With a strong record of training and educating talented students, Cornell University has helped individuals in their pursuit and attainment of educational excellence. I applaud Cornell University and Cornell NanoScale Science and Technology Facility for their dedication and commitment to this important and noble endeavor.

At this time, I would like to take this opportunity to recognize Dr. William Brinkman, Director of the Office of Science, US Department of Energy, for his dedication and hard work to further the cause of nanoscience and technology. In addition, I would like to acknowledge this events distinguished speakers; Professor Neil Gercshenfeld, Director, The Center for Bits and Atoms, MIT; Professor Roger Howe, NNIN Director, Stanford University; Dr. Jordan A. Katine, HGST; Professor Michal Lipson, PhD, Electrical and Computer Engineering, Cornell University; Professor Celeste Nelson, PhD., Chemical and Biological Engineering, Princeton University; and Professor John Rogers, Professor, University of Illinois, Urbana-Champaign, for their commitment to continue to be innovative in the field of nanoscience. Their commitment and devotion to Cornell University and the science industry inspires us all.

Again, on behalf of all New Yorkers, congratulations and thank you for your dedication and hard work. I know that Cornell University and Cornell NanoScale Science and Technology Facility will continue to serve as one of our nation's foremost institutions of educational excellence for years to come. Best wishes on a wonderful event.

Sincerely,

Charles Schumer

Charles E. Schumer
United States Senator

Cornell University

David J. Skorton
President

July 2012

Congratulations to the Cornell NanoScale Science and Technology Facility on its 35th anniversary as a national user facility. Offering advanced equipment and expert staff support, CNF continues to facilitate a wide range of valuable projects, many of them interdisciplinary, involving the physical sciences, life sciences, and engineering. With about half its users coming from outside Cornell, CNF helps users from academia, industry, and government laboratories to pursue their research with state-of-the-art tools.

With support from the National Science Foundation and the New York State Office of Science, Technology and Academic Research, as well as industry partners, Cornell University is proud to offer this important service to the scientific community. My thanks to our CNF colleagues and best wishes for continued success.

David J. Skorton

300 Day Hall Ithaca, NY 14853-2801 **Telephone:** (607) 255-5201 **Fax:** (607) 255-9924 **E-mail:** president@cornell.edu

:•: CNF 35th Anniversary Celebration & Annual Meeting :•:
Thursday, July 19th, 2012

Overview & Locations

8:00 a.m. - 4:15 p.m.; Registration and Presentations, Alice Statler Auditorium, Statler Hall, Cornell Campus
12:30 p.m. - 2:00 p.m.; Lunch, Statler Hotel Ballroom
5:00 p.m. - 7:00 p.m.; Poster Session & Corporate Soiree, Duffield Hall Atria

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Detailed Schedule

8:00-8:45 a.m. Registration & Breakfast Buffet (Alice Statler Auditorium Atrium)

8:45-9:00 Welcoming Remarks (Alice Statler Auditorium)

9:00-10:00 a.m.; Keynote Speaker, Dr. William Brinkman
(Director of the Office of Science, United States Department of Energy)

10:00-10:15 a.m.; break

10:15-11:00 a.m.; Roger Howe (NNIN Director, Electrical Engineering, Stanford University)

11:00-11:45 a.m.; Neil Gershenfeld (Director, MIT Center for Bits and Atoms)

11:45-12:30 p.m.; Celeste Nelson (Chemical & Biological Engineering, Princeton University)

12:30-2:00 p.m.; Lunch (Statler Hotel Ballroom)

2:00-2:45 p.m.; John Rogers (University of Illinois Urbana-Champaign)

2:45-3:30 p.m.; Jordan Katine (HGST, San Jose Research Center)

3:30-4:15 p.m.; Michal Lipson (Electrical & Computer Engineering, Cornell University)

(Short break for setting up posters and company displays)

Evening Session

5:00-7:00 p.m., Poster Session & Corporate Soirée
Duffield Hall Atria

User Poster Awards and the Nellie Yeh-Poh Lin Whetten Memorial Award will be given out at 6:30 p.m.

The Cornell NanoScale Facility is grateful to the following 35th Anniversary Corporate Sponsors

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Presentation Abstracts

in order of

Schedule

Daniel Ralph, CNF Lester B. Knight Director
Donald Tennant, CNF Director of Operations

250 Duffield Hall CNF
Ithaca, NY 14853-2700
General Phone: 607-255-2329
http://www.cnf.cornell.edu/

Daniel Ralph (left above) is the Lester B. Knight Directorship at the Cornell NanoScale Facility (CNF).

Profile:

B.S., 1986, Physics and Mathematics, Vanderbilt University
Ph.D., 1993, Physics, Cornell University
Postdoctoral Research Associate, Harvard University, 1993-96
Assistant Professor, Physics, Cornell University, 1996-2000
Associate Professor, Physics, Cornell University, 2000-2004
Professor, Physics, Cornell University, 2004-present
Lester B. Knight Director, Cornell NanoScale Science & Technology Facility (CNF) 2010-present
Alfred P. Sloan Fellow, 1996-99
David and Lucile Packard Foundation Fellow, 1997-2002
William L. McMillan Award, 1997
Research Corporation Research Innovation Award, 1997
ONR Young Investigators Award, 1997-2000.

Research:

New nanofabrication techniques; electronic properties on molecular length scales; spin transport and high-speed dynamics in magnetic devices; correlated-electron states in magnets and superconductors; quantum properties of defects and impurities. Our group's research focuses on the electronic and magnetic properties of nm-scale samples. The work in the group consists of making nm-size devices using equipment at the CNF, and then performing measurements in Clark Hall (usually) at low temperatures. Students and postdocs in the group are pursuing a wide variety of projects.

Donald M. Tennant (right above) is the Director of Operations at the Cornell NanoScale Facility (CNF).

During Don's 27 year career at Bell Labs, he was a Distinguished Member of Technical Staff where he managed the Advanced Lithography Group in the Nanofabrication Research Department. Since 1979 he worked at Bell in the area of high resolution electron beam lithography and related nanostructure technology. His work has had significant impact on a wide range of disciplines, including: soft x-ray imaging and extreme ultraviolet lithography (EUVL), high precision grating production for DWDM (dense wavelength division multiplexing), and gate technology for both high performance circuit applications and the exploration of the practical limits of silicon technology. His collaborative efforts with SUNY Stonybrook and Brookhaven National Laboratories have resulted in important advances in the field of x-ray optics and microscopy. He has authored or co-authored over 200 articles in these fields, organized major international conferences on the subjects, presented numerous invited technical talks and posters, and has been awarded eleven U.S. patents. He currently serves on the Advisory Committee and is the Financial Trustee for the International Conference of Electron, Ion, and Photon Beams and Nanotechnology (EIPBN). He has served on a number of scientific review panels for the National Labs. He is a Past Chairman of the Nanoscale Science and Technology Division of the AVS, is currently serving a three year term on the JVST Editorial Board and has served as a panelist for the National Research Council of the National Academies.

The focus of his efforts at Cornell's CNF are to lead this comprehensive nanofabrication and characterization facility into new and expanded areas of expertise and to offer frontier capabilities to researchers for interdisciplinary projects and education.

Keynote Speaker:

Dr. William Brinkman

Director of the Office of Science, US Department of Energy

"Whither Nanoscience?"

Solving the problems that are involved in climate change and the sustainability of this planet is perhaps the biggest challenge that civilization has ever faced. In order to make progress on this challenge we need to use all our available resources and nanoscience and technology are in the forefront of creating solutions to many of the issues involved. From batteries whose cathodes and anodes are fabricated at the nanoscale to advanced high strength steels, to catalysts whose very mechanism is defined at the nanoscale level and to electronic devices that are being made ever smaller, we are finding major improvements in our use of energy. Driving toward to the use of renewals, electric cars, small modular reactors etc are all being driven to some extent by inventions and discoveries at the nanoscale.

This talk will review some of these applications and look to the future of the field.

Dr. William F. Brinkman was confirmed by the Senate on June 19, 2009, and sworn in on June 30, 2009, as Director of the Office of Science in the U.S. Department of Energy. He joins the Office of Science at a crucial point in the Nation's history as the country strives toward energy security – a key mission area of the Department of Energy. Dr. Brinkman said during his confirmation hearing that he looked forward to working "tirelessly to advance the revolution in energy technologies, to understand nuclear technologies and to continue basic research in the 21st century."

Dr. Brinkman brings decades of experience in managing scientific research in government, academia, and the private sector to the post. He was born in Washington, Missouri and received his BS and Ph.D. in Physics from the University of Missouri in 1960 and 1965, respectively. Since this time, he has served as a leader of the physics community. He has spent one year as a National Science Foundation postdoctoral fellow at Oxford University. He has served as president of the American Physical Society and on a number of national committees, including chairmanship of the National Academy of Sciences Physics Survey and their Solid-State Sciences Committee. He is a member of the American Philosophical Society, National Academy of Sciences, and the American Academy of Arts and Sciences.

Dr. Brinkman has worked on theories of condensed matter and his early work also involved the theory of spin fluctuations in metals and other highly correlated Fermi liquids. This work resulted in a new approach to highly correlated liquids in terms of almost localized liquids. The explanation of the superfluid phases of one of the isotopes of helium and many properties of these exotic states of matter was a major contribution in the middle seventies. The theoretical explanation of the existence of electron-hole liquids in semiconductors was another important contribution of Brinkman and his colleagues in this period. Subsequent theoretical work on liquid crystals and incommensurate systems are additional important contributions to the theoretical understanding of condensed matter.

In FY 2009, the Office of Science received $4.758 billion in appropriations with an additional $1.6 billion from American Recovery and Reinvestment Act. With these funds, the Office of Science is the single largest supporter of basic research in the physical sciences in the United States, providing more than 40 percent of total funding for this vital area of national importance. It oversees – and is the principal federal funding agency of – the Nation's research programs in high-energy physics, nuclear physics, and fusion energy sciences. In addition, the Office of Science manages fundamental research programs in basic energy sciences, biological and environmental sciences, and computational science. In addition, the Office of Science is the Federal Government's largest single funder of materials and chemical sciences, and it supports unique and vital parts of U.S. research in climate change, geophysics, genomics, life sciences, and science education.

Roger Howe

NNIN Director, Stanford University
Electrical Engineering, Stanford University

“Vacuum Nanosystems for Energy Conversion”

Micro and nano-fabricated sensors (e.g., accelerometers and gyroscopes) and actuators (e.g., light valve chips for projection and cell-phone displays) have become commonplace in recent years. Some of these devices must operate in a hermetically sealed, low-pressure ambient, a need that motivated the development of low-cost, wafer-scale vacuum encapsulation technologies. In this talk, I’ll identify a promising direction for nanotechnology, in which vacuum is more than simply the ambient surrounding a microstructure, but rather is a critical element in device operation.

Thermionic energy converters were conceived in 1915, demonstrated in 1939, and were the focus of astronomical investments during the space race by NASA and the Soviet Union. A 6 kW thermionic converter, fabricated using precision machining and vacuum-tube technology, was flown in the late 1980s by the Soviets. Thermionic converters can be fabricated using extensions of MEMS technology, in which advances in materials, micromachining, and vacuum encapsulation processes can be used to enhance performance and reduce fabrication costs. Potential commercial applications include topping cycles in small-scale co-generation. Recently, a new conversion concept has been demonstrated at Stanford, in which a semiconductor photocathode replaces the conventional metal cathode. This photon-enhanced thermionic energy (PETE) converter harvests photon energies above the bandgap, as well as broad-spectrum radiation through heating of the photocathode. It is attractive as the high-temperature topping cycle for solar-thermal power stations. Micro-and nano-structured, high-temperature materials and micromachining processes are also essential to fabricating wafer-scale, cost-effective PETE converters. I will conclude by summarizing the research directions that are needed to bring thermionic and PETE conversions into the mix of energy conversion options.

Roger T. Howe is the William E. Ayer Professor in the Department of Electrical Engineering at Stanford University, as well as the Faculty Director of the Stanford Nanofabrication Facility. He earned a B.S. degree in physics from Harvey Mudd College, Claremont, California and an M.S. and Ph.D. in electrical engineering from the University of California, Berkeley in 1981 and 1984. After faculty positions at Carnegie-Mellon University in 1984-1985 and the Massachusetts Institute of Technology from 1985-1987, he returned to Berkeley where he was a Professor until 2005.

His research interests include micro electromechanical system (MEMS) design, micro/nanomachining processes, and self-assembly processes. A major focus of his research from the early 1980s until recently was technologies for integrated microsystems, which incorporate both silicon integrated circuits and micromechanical structrures. Recently, his research has shifted to nano electromechanical systems (NEMS), for applications ranging from chemical sensors to relays and logic devices. Prof. Howe has made contributions to the design of MEMS accelerometers, gyroscopes, electrostatic actuators, and microresonators. He was elected an IEEE Fellow in 1996, was co-recipient of the 1998 IEEE Cledo Brunetti Award, and was elected to the U.S. National Academy of Engineering in 2005 for his contributions to MEMS processes, devices, and systems. He was a co-founder of Silicon Clocks, Inc., a start-up company that commercialized poly-SiGe integrated MEMS-on-CMOS for timing applications, which was acquired by Silicon Laboratories, Inc., in April 2010.

In December 2009, he became the Faculty Director of the Stanford Nanofabrication Facility. In February 2011, became the Stanford Site Director of the National Nanotechnology Infrastructure Network (NNIN) and in September 2011, he became Director of the NNIN.

Prof. Neil Gershenfeld

Director, MIT Center for Bits and Atoms

"Computation and Fabrication"

Advances in computation rest on improvements in fabrication, and advances in fabrication rest on improvements in computation, however modeling and making things have historically been distinguishable activities. But they have a deeper connection, through the digitization of fabrication, analogous to the earlier digitization of communication and computation. I will discuss mechanisms for, and implications of, embodying codes and programs in materials.

Prof. Neil Gershenfeld is the Director of MIT's Center for Bits and Atoms. His unique laboratory is breaking down boundaries between the digital and physical worlds, from creating molecular quantum computers to virtuosic musical instruments. Technology from his lab has been seen and used in settings including New York's Museum of Modern Art and rural Indian villages, the White House and the World Economic Forum, inner-city community centers and automobile safety systems, Las Vegas shows and Sami herds. He is the author of numerous technical publications, patents, and books including Fab, When Things Start To Think, The Nature of Mathematical Modeling, and The Physics of Information Technology, and has been featured in media such as The New York Times, The Economist, and the McNeil/Lehrer News Hour. He is a Fellow of the American Physical Society, has been named one of Scientific American's 50 leaders in science and technology, as one of 40 Modern-Day Leonardos by the Museum of Science and Industry, has been selected as a CNN/Time/Fortune Principal Voice, and by Prospect/Foreign Policy as one of the top 100 public intellectuals. Dr. Gershenfeld has a BA in Physics with High Honors and an honorary Doctor of Science from Swarthmore College, a Ph.D. in Applied Physics from Cornell University, was a Junior Fellow of the Harvard University Society of Fellows, and a member of the research staff at Bell Labs.

Research advances by Dr. Gershenfeld and his students and colleagues working at the boundary between physical science and computer science include: one of the first complete quantum computations, using nuclear spins in molecules; microfluidic bubble logic, with bits that transport materials as well as information; physical one-way cryptographic functions , implemented by mesoscopic light scattering; noise-locked loops that entrain on codes, which led to analog logic integrated circuits that use continuous device dynamics to solve digital problems; asynchronous logic automata to align hardware with software; Internet 0 for interdevice internetworking; microslot probes for ultra-small-sample structural studies; integrated 6-axis inertial measurement based on the dynamics of trapped particles; charge source tomography for electric field imaging and intrabody signaling; electropermanent actuators for high torque at low RPM with static holding; and additive assembly of functional digital materials .

He is the originator of the growing global network of field fab labs that provide widespread access to prototype tools for personal fabrication, and directs the Fab Academy, the associated program for distributed research and education in the principles and practices of digital fabrication.

He has done keynote presentations for events including TED, EDUCAUSE, the ACM/IEEE Conference on Supercomputing, IEDM, NSF, the Library of Congress, the White House, Etech, APMM, Nano-Nets, NIP, and PICNIC.

He's played the bassoon, ski patrolled and raced, and swam competitively.

Celeste Nelson

Chemical & Biological Engineering, Princeton University

"Teeny Tiny Tissues: Using Fabrication to Understand and Manipulate Organ Development"

The morphogenetic patterning that generates three-dimensional (3D) tissues requires dynamic concerted rearrangements of individual cells with respect to each other. We have developed fabrication-based 3D culture models that recapitulate the microscale architecture of epithelial ductal trees, enable micrometer-resolution control of tissue geometry and microenvironment, and provide quantitative 4D data in a physiologically relevant context. Incorporating nanoparticles within these tissue models, combined with atomic force microscopy-based spatial mapping of the elasticity of the tissues, has revealed basic design principles used by populations of cells to generate tissue structure. I will discuss how we combine these tiny tissues with computational models to dissect the relative role of tissue mechanics in morphogenesis, and suggest approaches to program tissue development ex vivo.

Celeste Nelson is an Associate Professor in the Departments of Chemical & Biological Engineering and Molecular Biology at Princeton University. She earned S.B. degrees in Chemical Engineering and Biology at MIT in 1998, a Ph.D. in Biomedical Engineering from the Johns Hopkins University School of Medicine in 2003, followed by postdoctoral training in Life Sciences at Lawrence Berkeley National Laboratory until 2007. Her laboratory specializes in using engineered tissues and computational models to understand how mechanical forces direct developmental patterning events during tissue morphogenesis. She is the co-author of over 60 peer-reviewed publications. Dr. Nelson's contributions to the fields of tissue mechanics and morphogenesis have been recognized by a number of awards, including a Burroughs Wellcome Fund Career Award at the Scientific Interface (2007), a Packard Fellowship (2008), a Sloan Fellowship (2010), the MIT TR35 (2010), the Allan P. Colburn Award from the AIChE (2011), and a Dreyfus Teacher-Scholar Award (2012).

John Rogers

University of Illinois Urbana-Champaign

"Semiconductor Nanomaterials for Bio-Integrated Electronics"

Biology is curved, soft and elastic; silicon wafers are not. Semiconductor technologies that can bridge this gap in form and mechanics will create new opportunities in devices that require intimate integration with the human body. This talk describes the development of ideas in semiconductor nanomaterials for electronics, sensors and actuators that offer the performance of state-of-the-art, wafer-based systems but with the mechanical properties of a rubber band. We explain the underlying materials science and mechanics of these approaches, and illustrate their use in bio-integrated, 'tissue-like' devices with unique diagnostic and therapeutic capabilities, when conformally laminated onto the heart, brain or skin. Demonstrations in live animal models and in humans illustrate the functionality offered by these technologies, and suggest several clinically relevant applications.

Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002. He is now the Lee J. Flory-Founder Chair in Engineering at University of Illinois at Urbana/Champaign with a primary appointment in the Department of Materials Science and Engineering. Rogers' research includes fundamental and applied aspects of materials and patterning techniques for unusual electronic and photonic devices, with an emphasis on bio-integrated and bio-inspired systems. He has published more than 300 papers and is inventor on more than 80 patents, more than 50 of which are licensed or in active use. Rogers is a Fellow of the IEEE, APS, MRS and AAAS, and he is a member of the National Academy of Engineering. His research has been recognized with many awards, including a MacArthur Fellowship in 2009 and the Lemelson-MIT Prize in 2011.

Jordan A. Katine

HGST, San Jose Research Center, San Jose, CA 95135

"Nanoscale Magnetic Devices in Technological Applications"

In this talk I will describe the fabrication challenges presented by several current magnetic technologies: spin transfer torque magnetic random access memory (STT-MRAM), magnetic recording head sensors, thermally-assisted magnetic recording heads, and bit patterned media (BPM).

STT-MRAM is generating ever increasing commercial interest as a powerful future memory technology. It is non-volatile, rad-hard, high-endurance, high-speed, CMOS compatible, and scalable to sub-20 nm devices. Although the semiconductor memory community has vast experience in fabricating nanoscale memory elements, the magnetic tunnel junction bits utilized in STT-MRAM present several unique fabrication challenges. In the first part of this talk, I will give a brief introduction to STT-MRAM and discuss the techniques we have developed to fabricate STT-MRAM bits down to 20 nm dimensions.

As the magnetic recording industry is pushing areal densities towards 1 Tbit/in^2, continuous perpendicular media is rapidly reaching its density limit. Thermally-assisted recording techniques should allow the appropriately engineered continuous media to reach areal densities well above 1 Tbit/in^2, but there are many obstacles that need to be overcome before this technology reaches the market. I will describe the design of the plasmonic antenna that allows us to record high-density data using a thermal rather than a magnetic field gradient, and discuss how this near field transducer is integrated into our recording system.

Even if thermally-assisted recording is successful, inevitably bit patterned media will be required if magnetic storage is to extend beyond 5 Tbit/in^2. At even 1 Tbit/in^2, fabrication of a BPM disk is a daunting task. For much less than $1 per disk, we will need to pattern isolated islands of magnetic media with excellent magnetic and lithographic uniformity at a pitch of roughly 25 nm. I will describe the technologies we are developing to make this possible. In addition, I will discuss the synergies realized by combining BPM with thermally-assisted recording.

Of course, writing data at these densities is only half the battle -- we also need to be able to read it. This talk will also describe the magnetic tunnel junction sensor used to read the data off the disk, and discuss the challenges involved in scaling this technology to ever higher densities.

Jordan Katine is a research staff member and manager of the advanced sensor and nanoscale device fabrication group at HGST (a Western Digital subsidiary) in San Jose, CA. He has co-authored over 125 refereed papers and holds a dozen patents related to magnetic recording. He received his Ph.D. in physics from Harvard in 1996, and did post-doctoral research at Cornell from 1996-1999. Prior to joining HGST, he was a research staff member at Hitachi Global Storage Technologies, and at the IBM Almaden Research Center. In 2003, MIT Technology Review named him to their list of 100 innovative young scientists. From 2010-2011, he served as chairman of the IEEE Magnetics Society Technical Committee. In 2006, he was promoted to senior membership in the IEEE, and in 2011 was elected a fellow of the American Physical Society. Dr. Katine's research is primarily focused on nanoscale device physics. He is developing new techniques for fabricating nanoscale devices, and also studies unique phenomena that occur when devices are built at nanoscale dimensions. Most of his recent work has been on nanoscale magnetic devices, where he has studied thermally-assisted magnetic recording and current-driven excitations including the spin transfer effect.

Prof. Michal Lipson

Electrical & Computer Engineering, Cornell University

"Manipulating Light on Chip"

Photonics on-chip could enable a platform for monolithic integration of optics and microelectronics for applications of optical interconnects in which high data streams are required in a small footprint. This approach could alleviate some of the current bottlenecks in traditional microelectronics. In this talk I will review the challenges and achievement in the field of Silicon Nanophotonics and present our recent results. Using highly confined photonic structures, much smaller than the wavelength of light, we have demonstrated ultra-compact passive and active silicon photonic components with very low loss. The highly confined photonic structures enhance the electro-optical and non-linearities properties of Silicon.

We demonstrated several active gigahertz (GHz) components including all-optical and electro-optic low power switches and modulators on silicon. Recently we have also demonstrated the first optical link on chip transmitting Ghz data.

Michal Lipson is an Associate Professor at the School of Electrical and Computer Engineering at Cornell University, Ithaca NY. Her research focuses on novel on-chip Nanophotonics devices. She has pioneered several of the critical building blocks for silicon photonics including the GHz silicon modulators. Professor Lipson's honors and awards include 2010 MacArthur Fellow, NYAS Blavatnik award, OSA Fellow, IBM Faculty Award, and NSF Early Career Award. More information on Professor Lipson can be found at nanophotonics.ece.cornell.edu.

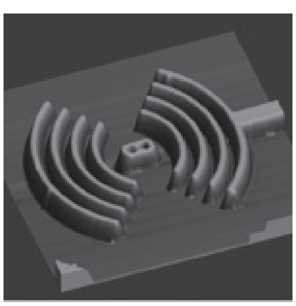

*Figure 1: AFM picture of a photonic device.
The spacing between the periodic regions is ~150 nm.*

Poster Abstracts

in order of

Poster Number

("NE" indicates poster presenters who are not eligible for the poster awards.)

POSTER # 1

Bonding and Packaging Advancements for the Boston Retinal Prosthesis
CNF Project #657-97
Author(s): Shire, D.B., Gingerich, M, McKee, B, et al.
Principal Investigator: D. B. Shire / J. L. Wyatt, MIT
Affiliation(s): Cornell University
Contact: dbs6@cornell.edu

This work is related to the efforts of the Boston Retinal Implant Project to develop a sub-retinal prosthesis to restore vision to the blind. This poster focuses on high density (256+ channel) packaging advancements for the prosthesis, especially hermetic sealing processes for the exterior of the packages. Two-piece custom-machined titanium micro-enclosures 11mm in diameter were sealed using two methods. In the first, the clam shell-like parts were laser welded, and in the second, the parts were sealed by projection welding. Co-fired ceramic structures with Pt signal feedthroughs were also fabricated to mate with these structures, and were gold brazed to the miniature titanium housings. In a subsequent assembly step, flexible stimulating sub-retinal iridium oxide electrode arrays were joined to the feedthrough assemblies by thermo-compression bonding. Tests of the retinal implant assemblies' quality were performed using x-ray analysis, helium leak testing, high pressure burst testing, and precision metallography of the welded joints. Additionally, the thermo-compression bonds to the prosthesis' electrode array had an average shear strength of more than 50 grams force, indicating good quality bonding. Helium leak rates better than 1.0x10E-09 standard cc He / second were obtained.

POSTER # 2

A Three-terminal Spin Transfer Torque Device Utilizing the Giant Spin Hall Effect of Tantalum
CNF Project#: 111-80
Author(s): Chi-Feng Pai, Luqiao Liu, D. C. Ralph and R. A. Buhrman
Principal Investigator: Robert A. Buhrman
Affiliation(s): Applied Physics, Cornell University
Contact: cp389@cornell.edu rab8@cornell.edu

We demonstrate a new three-terminal spintronics device that utilizes the spin Hall effect (SHE) induced spin transfer torque (STT) from tantalum (Ta) to efficiently and reversibly switch the magnetic orientation of a thin free layer electrode of an MgO magnetic tunnel junction having in-plane magnetization. The low write currents (≤ 1mA), large output impedance and good thermal stability (45kBT) that has been achieved with this SHE three-terminal device approach, which separates the write and read operations in a manner that is relatively straightforward to fabricate, demonstrate an attractive candidate for application in next generation STT MRAM and non-volatile spin logic circuits.

[1] S. A. Wolf et al., "Spintronics: A Spin-Based Electronics Vision for the Future", Science 294, 1488 (2001).
[2] D. C. Ralph and M. D. Stiles, "Spin Transfer Torques", Journal of Magnetism and Magnetic Materials 320, 1190 (2008).
[3] L. Q. Liu et al., "Spin-Torque Switching with the Giant Spin Hall Effect of Tantalum", Science 336, 555 (2012).

POSTER # 3

Optomechanical experiments with large area graphene membranes

CNF Project # 76299
Authors: Vivekananda P Adiga, Rob Barton, Isaac Storch, Rob Ilic, Chris Wallin, Paul McEuen, Jeevak M Parpia, Harold Craighead
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Large area, ultra-thin suspended membranes are useful as mechanical resonators whose mechanical degree of freedom can be easily controlled using light due to low spring constants and resonator mass. In this regard, there are advantages associated with using two dimensional materials like graphene, due to its low mass and electrical conductive properties. However, achieving large area suspended devices with high mechanical quality (Q) factors in these high surface-to-volume-ratio resonators has been a challenge. Here we fabricate CVD grown, electrostatically tunable graphene drums of diameter up to 80 µm and measure high quality factors (up to 4000) at room temperature. We then use lasers to control the amplitude of mechanical vibrations using the back action provided by the photothermal effect. We can effectively cool (increase the effective damping) or heat (decrease the effective damping leading to self oscillation) the graphene membrane in a Fabry-Perot cavity formed by the membrane suspended over prefabricated trench, with cavity detuning provided by a highly reflective movable mirror. The strong optomechanical coupling observed in these membranes is due to the low mass and relatively strong absorption in the atomic monolayer.

POSTER # 4

Different Methods and Applications of Patterned Polymer Brushes

CNF Project # 1757-09
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Polymer brushes have many desirable characteristics such as the ability tether molecules to a substrate or change the properties of a surface. Patterning of polymer films has been an area of great interest due to the broad range of applications in the production of integrated circuits, information storage devices, light-emitting displays (LEDs), microfluidic devices, biochips, and in bio-related and medicinal research including the study of cell-surface interactions and tissue engineering. We have investigated different patterning methods and applications for polymer brushes including direct patterning, initiator patterning, and a way to lift off patterned polymer brush membranes from the surface.

POSTER # 5

Optical Properties of Twisted Bilayer Graphene

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2 School of Applied and Engineering Physics, Cornell University;
3 Department of Chemistry and Chemical Biology, Cornell University

Using density functional theory (DFT) and tight binding (TB) calculations, we study the band structure of bilayer graphene as a function of twist angles and compare the results to spectroscopic measurements. To test the accuracy of different exchange-correlation functionals in DFT, we first compare the band structure with DFT and G0W0 approximation for bilayer graphene systems with different twist angles. Our DFT results agree with previous DFT calculations for the weak coupling between the two layers and the band structure.

Calculations of the quasiparticle dispersion using the G0W0 approximation show that DFT underestimates the Fermi velocity of bilayer graphene and the bandgap away from the K point. Scaling of the DFT band structure by an empirical parameter that depends on the twist angle accounts for most of the difference between the DFT and the G0W0 approximation. Based on the G0W0 calculations, we test a set of tight-binding parameters for the interlayer coupling Hamiltonian. Using this tight-binding model and DFT we study the optical matrix elements Mop for the intralayer transition and parallel band transition. Our results reveal that parallel band transition plays an important role in the observed G band resonance in Raman spectroscopy for specific twist angles [1]. We also study the electron-phonon coupling strength using the deformation potential approximation. Combining optical matrix elements with the electron-phonon coupling strength, the Raman intensity curves for various twist bilayer graphene are calculated. The results of these Raman line shapes are consistent with experiment.

[1] R. W. Havener, H. Zhuang, L. Brown, R. G. Hennig, and J. Park, Nano Lett., 2012, 12 (6), pp 3162–3167

POSTER # 6

Slab waveguide photobioreactors for microalgae based biofuel production

CNF Project # 176409

Author(s) Erica Eunjung Jung1, Michael Kalontarov1, Devin F. R. Doud2, Matthew D. Ooms3, Largus T. Angenent2, David Sinton3, and David Erickson1*

Principal Investigator David Erickson

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Microalgae are a promising feedstock for sustainable biofuel production. At present however there are a number of challenges that limit the economic viability of the process. Two of the major challenges are the non-uniform distribution of light in photobioreactors and the inefficiencies associated with traditional biomass processing. To address the latter limitation, a number of studies have demonstrated organisms that directly secrete fuels without requiring organism harvesting. In this study [1] we demonstrate a novel optofluidic photobioreactor that can help address the light distribution challenge while being compatible with these chemical secreting organisms. Our approach is based on light delivery to surface bound photosynthetic organisms through the evanescent field of an optically excited slab waveguide. In addition to characterizing organism growth rates in the system, we show that the photon usage efficiency of evanescent field illumination is comparable to the direct illumination used in traditional photobioreactors. We also show that the stackable nature of the slab waveguide approach could yield a 12 fold improvement in the volumetric productivity.

[1] Jung, E.E., Kalontarov, M., Doud, D.F.R., Ooms, M.D., Angenent, L.T., Sinton, D., Erickson, D., "Slab waveguide photobioreactors for microalgae based biofuel production", Lab on a Chip (accepted 2012)

POSTER # 7

Acousto-Optic Frequency Modulator

CNF Project # 138005

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Optical frequency modulation has been achieved in microstructures using surface acoustic waves to strain self-assembled InAs/GaAs quantum dots. Photon generation at >GHz frequency spacing from a single pump laser has been realised in silicon nitride and silicon dioxide via nonlinear optical processes such as the optical Kerr effect and stimulated Brillouin scattering. Silicon optomechanical resonators operated in resolved sideband regime stand out as strong candidates for optical frequency modulation owing to their strongly coupled mechanical and optical degrees of freedom. Here we present a GHz acousto-optic modulator in silicon with motion excited via electrostatic capacitive actuation. Direct spectroscopy of the modulated laser power shows asymmetric sidebands which indicate coincident amplitude modulation and frequency modulation. We achieve greater than 67X improvement in the optomechanical frequency modulation factor over earlier reported numbers for silicon nanobeams.

POSTER # 8

Juxtamembrane tryptophans of Synaptobrevin 2 clamp the process of membrane fusion
CNF Project # 848-00
Author(s) Qinghua Fang, Ying Zhao, Manfred Lindau
Principal Investigator Manfred Lindau
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Synaptobrevin 2 (syb2), syntaxin (sx1A), and SNAP-25, generate a force to induce fusion pore formation. The v-SNARE syb2 is anchored to the vesicle membrane by a single transmembrane domain. Here we show that 2 tryptophaes (89W90W) located at the juxta-membrane domain of syb2 stabilize the transmembrane (TM) domain postion and control the ratio of spontaneous vs. stimulated membrane fusion events in chromaffin cells. Changing the 2 hydrophobic tryptophans to neutral alanines promotes spontaneous membrane fusion and faster transmitter release kinetics. These results indicate that the two tryptophans act as fusion clamps making fusion stimulus-dependent.

POSTER # 9

Image-based Microfluidic Flow Manipulation for Point-of-care Diagnostics in Low-Resource Settings
CNF Project #: 185810
Authors: Li Jiang, David Erickson
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Today, 5.7 billion people live in developing nations with many unable to access reliable health care. Current technologies cannot solve this problem due to the existing dichotomy between the approaches. On one end, extremely simple devices based on lateral flow assays are cheap, easy to use, but unable to process complex samples. At the other end, sophisticated machines can perform multiple complex functions, but are expensive and difficult to use. Bringing reliable medical diagnostics to the developing world requires novel tools that are both simple in design and able to perform complex functions – goals that have so far been in conflict with each other. We introduce a contact-free light-controlled method to actuate and valve flow in a microfluidic device by grafting poly(N-isopropylacrylamide) (PNIPAAm), a smart polymer that changes its wettability as a function of temperature, onto PDMS. Light shining on the device is converted to heat using a carbon black absorber layer, which changes the surface properties of the channel. We characterize the flow rate as a function of temperature and demonstrate directing the flow into different chambers by using projector images. Such a technique offers user controllability without the expensive machinery, making this ideal for use in resource-limited areas.

POSTER # 10

Sub-frame time resolution in fluorescence imaging reveals delay between SNAP25 conformational change and secretory events in chromaffin cells
CNF project #: 848-00
Authors: Ying Zhao, Qinghua Fang, Adam Drew Herbst, Khajak Berberian, Wolfhard Almers* and Manfred Lindau
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To determine if a direct relation exists between a conformational change in the SNARE complex and the fusion event, we combine Total-Internal Reflection (TIR) Fluorescence Resonce Energy Transfer (FRET) imaging with rapid spatially resolved electrochemical detection of fusion events using ElectroChemical Detector (ECD) arrays (Hafez et al. 2005 PNAS 102:13879). The SNARE Complex Reporter (SCORE) was used, which is based on the SNARE protein SNAP25 with FRET donor CFP and FRET acceptor Venus inserted at the N termini of its SNARE-motifs SN1 and SN2,, respectively (An & Almers 2004 Science 306:1042). The ECD-array consists of four platinum electrodes patterned on a glass coverslip with a space of ~5 µm between them where a bovine chromaffin cell expressing SCORE was placed such that the FRET changes of SCORE could be imaged by TIR-FRET microscopy, while the ECD-array simultaneously records the exocytotic events as amperometric spikes. Based on the oxidation currents recorded by the four electrodes, the locations of the exocytotic events were determined. Our results showed that the FRET change precedes the upstroke of amperometric spikes on average by ~90ms, indicating that the SNAP25 conformational change is associated with fusion pore formation and is not a result of fusion pore expansion.

POSTER # 11

Ultra High Sensitivity Graphene Piezoresistive Pressure Sensor

CNF Project #: 126204

Authors: Hadi Hosseinzadegan, Manoj Pandey, and Amit Lal

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We demonstrate the first-ever pressure sensor utilizing graphene piezoresistors demonstrating the sensitivity as high as 323 µV/V/mmHg. The gauge factor of the piezoresistive resistors, which usually are placed in a Wheatstone bridge configuration, limits the sensitivity of a given sensor. A much higher gauge-factor and transducer sensitivity would enable a much smaller sensor for constant sensitivity, or would enable a much more sensitive sensor for constant membrane area [1]. Given the nm thickness of single or multi-layer graphene films, the overall reduction of the sensor is possible by reducing the membrane sizes to 100s of nm. Hence, graphene films have the potential of realizing nano-scale pressure sensors that are more sensitive than existing polysilicon and silicon technologies, opening the pathways for using pressure sensors within biological cells, or forming high density pressure sensor arrays. Corresponding sensitivity for our device with lateral dimensions of 750µm x 750µm is 323µV/V/mmHg which is two orders of magnitudes higher than the commercial Omega PX140x series and 36 times higher than that of the reported SWCNT transducers [2].

[1] L. Lin, H. Chu, and Y. Lu, "A Simulation Program for the Sensitivity and Linearity of Piezoresistive Pressure Sensors", Journal of Microelectromechanical Systems, 8, 514-522 (1999).

[2] M. Huang, and J. R. Greer, "Measuring Graphene Piezoresistance via in-situ Nanoindentation", ECS Transactions, Vol. 35 (3), pp. 211-216, 2011.

POSTER # 12

Reactivity of Graphene & Graphene Imperfections Studied Using Scanning Electrochemical Microscopy

CNF Project # 128304

Authors: Cen Tan, Joaquín Rodríguez-López, Wan Li, Joshua J. Parks, Michael A. Lowe, Nicole L. Ritzert, Daniel C. Ralph, Héctor D. Abruña

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We are investigating the chemical properties of graphene using electrochemical techniques. We fabricated single layer graphene electrodes derived from both mechanically exfoliated graphene and chemical vapor deposited (CVD) graphene. The rate of heterogeneous electron transfer of graphene was found to be one order of magnitude higher than that of highly oriented pyrolytic graphite. The enhanced electrochemical activity is likely due to the presence of corrugations and imperfections that disrupt the sp2 conjugation of graphene which can alter its electrical, chemical, and mechanical properties. We further examined the rate of heterogeneous electron transfer of single layer CVD graphene using scanning electrochemical microscopy. It was found that the sites with a large concentration of defects are approximately one order of magnitude more reactive, compared to more pristine graphene surfaces, towards electrochemical reactions. In addition, we successfully passivated the activity of graphene defects by carefully controlling the electropolymerization conditions of o-phenylenediamine. The use of spatially resolved scanning electrochemical microscopy for detecting the presence and the "healing" of defects on graphene provides a strategy for in situ characterization and control of this attractive surface, enabling optimization of its properties for application in electronics, sensing, and electrocatalysis.

POSTER # 13 NE

AFM-Assisted Etching and Piezoresistivity Characterization of Graphene
CNF REU 2012
Camille Everhart, Hadi Hosseinzadegan Prof. Amit Lal
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A pressure sensor, consisting of graphene transferred onto Cr/Au electrodes and SixNy 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.

POSTER # 14

Colloidal Self-Assembly-Directed Laser-Induced Non-Close-Packed Crystalline Silicon Nanostructures
CNF Project #: 135605
Authors: Kwan W. Tan, Stacey A. Saba, Hitesh Arora, Michael O. Thompson
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Silicon (Si) nanomaterials have been adapted for many potential applications such as photonic crystals, sensors, and energy conversion and storage. In particular, non-close-packed Si nanostructures with wide photonic bandgap and other surface-enhanced properties further broaden the technology application range. Here we describe a facile and rapid method to fabricate two- and three-dimensional crystalline Si nanostructures with non-close-packed symmetry by coupling colloidal self-assembly structure formation with pulsed laser thermal processing. The resulting pattern transfer yields are high, and long-range order is maintained. This approach is also highly compatible with other semiconducting materials and conventional processing technologies.

POSTER # 15

Graphene Optomechanical Systems
Project number: 900-00
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By virtue of their low mass and stiffness, atomically thin mechanical resonators are attractive candidates for use in optomechanics[1]. Here, we demonstrate photothermal back-action in a graphene mechanical resonator comprising one end of a Fabry-Perot cavity. We have batch fabricated these resonators using graphene grown via chemical vapor deposition[2,3], and a novel post-transfer patterning technique designed to improve yield. To illustrate the utility of optomechanics, we show that a continuous wave laser can be used to

cool a graphene vibrational mode or to power a graphene-based tunable-frequency oscillator[4]. The remarkable sensitivity of graphene optomechanical resonators and their ability to operate over a broad range of wavelengths and mechanical frequencies make them attractive for technological applications and studies of fundamental physics.

[1] C. H. Metzger et al., Nature 432, 1002 (2004)
[2] X.S. Li et al., Science 324, 1312 (2009)
[3] A. M. van der Zande et al., Nano Letters 2010, 10 (12), pp. 4869-4873
[4] R. A. Barton et al., Nano Letters (In Review)

POSTER # 16 NE

A Study of Integrating Societal and Ethical Issues in Nanotechnology Research
CNF REU 2012
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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 so to better the Research Experience for Undergraduates (REU) of the National Nanotechnology Infrastructure Network (NNIN). Interviews of current education coordinators at the 14 NNIN REU sites and also of former REUs from the Cornell Nanoscale Facility (CNF) are used to accumulate and compare SEI training practices. A literature review of the ethics education contributes to a summary report of survey results and best practices in SEI training for NNIN sties to use as a program guide for the future.

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

POSTER # 17

Autonomous Microfluidic Device for Prevention of Traumatic Injury on Battlefield
CNF Project #: 209411
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Wounded soldiers on battlefields are highly vulnerable to hemorrhagic shock (HS), a lethal medical condition caused by a lowered heart output. Due to chaotic nature of battlefields, these patients often lack access to immediate treatment that is often critical to their survival. In remedy, we propose an implementable autonomous device that continuously monitor a warfighter for the presence of late-phase HS and provide a life-extending treatment upon detection. The device comprises a biosensor that detects for a change in vasopressin levels (which have been correlated with late-phase HS by several studies), drug delivery device that releases drug contents and fuel cell unit to power these components. Before attempts at integration, we have tested each miniaturized component independently for successful operation and have shown some success. The biosensor is able to detect 2.6% increase in current when vasopressin concentration is varied from 0 to 20 μM. The drug delivery device based on electrokinetic principles is capable of ejecting contents at 4.19 μl/min with 12 V1 . Lastly, novel non-enzymatic fuel cell can be stacked to provide a power density of 46μWcm¯3 which proved sufficient to operate our biosensor.

[1] A. Chung, Y. Huh and D. Erickson, Biomedical Microdevices, 2009, 11, 861-867.

POSTER # 18 NE

Towards Electrochemical Gating using Transistors
CNF REU 2012
Authors: Sharlin Anwar, Krishna Jayant
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The goal this research project is to develop an electrolyte-oxide-semiconductor (EOS) capacitor to demonstrate (a) the dynamics of the ionic double layer under field effect modulation with varying electrolyte composition and (b) the role of insulator surface groups on the overall capacitance of the double layer. Surface groups are known to get activated (charged) under an applied potential and has been shown to affect double layer formation. This study will help us understand the complex interplay between these concomitant effects through CV measurements. Various EOS capacitor devices will be fabricated, each composed of different insulating oxide layers having different charge properties. The fabrication will be done using GSI PECVD, LPCVD furnace, oxide furnace, n+ polysilicon furnace and ALD for oxide layer deposition. Ellipsometer and profilometer will be used for characterizing the oxide layers. Photolithography will be done using ABM Contact aligner and measurements will be made using Keathley CV meter.

POSTER # 19 NE

Development of an *in vitro* muscle regeneration model using a combination of microfluidics and micropatterning
CNF REU 2012
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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 are using a combination of microfluidics and micropatterning to create an in vitro system to image muscle development of mutant and normal myoblasts. The micropatterning will be used to deposit collagen lines on a non-cell adherent gel on which myotubes can form in precisely controlled geometries. Microfluidic channels will be 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.

POSTER # 20

The potential-dependent growth mechanism of bismuth electrodeposition

CNF project #203611

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We report an in situ X-ray diffraction study of the electrodeposition of Bi on GaAs (110). The experiments were conducted at Cornell High Energy Synchrotron Source. Very briefly, bismuth was electrodeposited at various potentials (-60 to -200 mV) for 30 min, and XRD patterns were collected at 30-second intervals, under various deposition potentials. We give the details of the analysis, the resulting interface structure and the potential dependence of the overlayer structure. From standard crystallographic indexing method, there are at least three different bismuth crystal orientations found on GaAs (110) depending on the applied potentials. At low potential (-60mV), bismuth is orientated to form a lower mismatched interface with GaAs (110). The Bi lattice plane at the interface is (3). At high potential (-200mV), the bismuth lattice plane at interface is (018), forming the interface with shorter repeating units but higher mismatch. At the middle potential (-160mV), both crystal orientations are observed, and a new crystal orientation is also clearly observed, having (0 1 14) Bi interface, which is similar to the crystal orientation in high potential (-200mV).

POSTER # 21 NE

Substrate Conformal Imprint Lithography

CNF REU 2012

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Current photolithography methods are incapable of maintaining Moore's law because their resolution is limited by the wavelength of light used. To achieve features much smaller than the wavelength of light, electron beam lithography must be used, although this is prohibitively expensive. Stamping techniques like Nanoimprint Lithography (NIL) have the potential to both decrease costs and increase throughput while maintaining the same resolution as electron beam lithography. However, because rigid, inflexible stamps are used for NIL, the process is highly sensitive to particulates of any size, making it unreliable and difficult to implement industrially. Substrate Conformal Imprint Lithography (SCIL) uses a soft PDMS stamp instead, providing greater resilience to disorder while maintaining the same resolution. In an effort to test the resolution limits of SCIL, a master stamp was fabricated with features down to 10-20nm in size. Several PDMS stamps molded from this master were used to test the ability of SCIL to replicate such small features and to determine whether SCIL has potential for use in industry.

POSTER # 22

Graphene in the Third Dimension
CNF Project #: 900-00
Author(s): Melina Blees,1 Arthur Barnard,1 Samantha Roberts,1 Joshua Kevek,1 Peijie Ong,1 Aliaksandr Zaretski,2 and Si Ping Wang1
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We have developed a new technique for interacting with single-layer graphene in the third dimension. Using mechanical and optical probes in a liquid environment, we can pick up a graphene sheet and fold it at high angles. We are able to precisely image the shape of the sheet in three dimensions, and can look at graphene on-edge using optical techniques for the first time. Rotational control lets us extract the bending stiffness by observing the graphene's thermal motion at room temperature—a value that, to our knowledge, has never been directly measured for single-layer graphene. And finally, we demonstrate graphene's use as an ideal sheet hinge, in which a single layer of atoms is strong enough to hold panels together yet could be easily scaled down by orders of magnitude. Such sheet hinges require graphene's exceptional strength and flexibility, and may prove to be ideal for applications such as drug delivery boxes.

POSTER # 23

DNA Nanostructures as Novel Scaffolds for CpG Stimulation of the Immune System in the Treatment of Cancer (CNF Project #: NA)
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A major thrust of anticancer research is now focused upon modulating the immune response. Past emphasis on generalized immune stimulation have yielded to newer approaches that focus on specific molecular defects as "targeted therapies". Yet the menu of such therapies remains quite limited and the potential impact of a broad-based immune stimulant would be ground breaking. Legacy efforts using CpG stimulants of the TLR9 receptor have shown theoretical promise, but fall short of practical impact. Problem: A fundamental limitation of previous work is the restriction of a small number of active motifs to relative short linear molecules that cap the potency and degree of contact with the target receptor. Solution: 3D DNA nanostructures that carry up to 24 CpG motifs and serve as a superior scaffold and delivery vehicle for the CpG motifs. The DNA scaffolds are built up from Y-DNA subunits that are fabricated using an empirically designed self-assembly process which results in robust and efficient synthesis of stable, monodisperse materials. Murine model systems have already shown that these molecules are able to achieve a ~170-fold increase in TNF-α and a 17-fold increase in IL-6 stimulation versus their linear counterparts.

POSTER # 24 NE

Selective Atomic Layer Deposition
CNF REU 2012
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Principal Investigator – Professor James Engstrom2 (jre7@cornell.edu)
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I am studying selective deposition of Tantalum Nitride (TaNx) onto copper and SiO_2 surfaces. The technique of atomic layer deposition (ALD) is being used because of the precision control granted by the self-terminating reactions involved. Developing a technique to accomplish selective deposition could be used in semiconductor device interconnects. A layer of TaNx would act as a barrier to stop diffusion of copper into the dielectric. A way to selective deposit TaNx would be required for that. To achieve that goal, I will be studying the effects of varying the reaction temperature during ALD, the number of reaction cycles, and depositing self-assembled monolayers (SAMs) before performing ALD. The SAMS being tested are both highly fluorinated molecules that could create an unreactive surface. The goal of the SAMs would be to only bind to one surface and then block ALD afterwards, creating selective ALD. This poster contains preliminary results of the experiments and data gathered from spectroscopic ellipsometry (SE), atomic force microscopy (AFM), contact angle, and scanning electron microscopy (SEM) within the CNF and x-ray photoelectron spectroscopy (XPS) and low energy ion scattering spectroscopy (LEISS) from outside tools.

POSTER # 25

Twinning and Twisting in bi- and trilayer CVD graphene

CNF Project: 148606

Authors: Lola Brown †, Robert Hovden‡, Pinshane Huang‡, Michal Wojcik†, David A. Muller‡§, and Jiwoong Park†§

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We use Dark-Field transmission electron microscopy (DF-TEM) for rapid and accurate determination of key structural parameters, such as twist angle, stacking order, and interlayer spacing of bilayer (BLG) and trilayer (TLG) graphene grown via chemical vapor deposition [1]. We find that while oriented layers conform exclusively to graphitic stacking, they also form a high density of mirror-stacks, connected by twin boundaries. However, twisted layers lack long range atomic registry, and they continuously stretch and shear independently, forming elaborate Moiré patterns. These results can be understood in terms of an angle-dependent interlayer potential model [2] presented in our work. This imaging technique can facilitate graphene growth optimization and structure-related characterization of any two-dimension crystal for future nanoelectronic and nanomechanic applications.

[1] Brown L. et al, Twinning and Twisting of Tri- and Bilayer Graphene, Nano Lett., 2012, 12 (3), pp 1609–1615

[2] S. Morell, E. et al, Charge redistribution and interlayer coupling in twisted bilayer graphene under electric fields. Phys. Rev. B 2011, 84, 195421

POSTER # 26

Near-field Optical Angular Orientation for the Manipulation of Biological Materials

CNF Project #: 204411

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Near field optical manipulation techniques has demonstrated abilities to trap, transport, and handle micro and nano scale materials. Despite the potential significance in optical manipulation, the angular orientation (1) has not been demonstrated in the near field photonics. To show further capabilities of our near field optical devices (2), we demonstrate the angular orientation with our photonic crystal resonators using biological materials. A single microtubule is rotated by the optical torque resulted from the polarization in the electric field, changing its angular orientation parallel to the direction of the electric field of linearly polarized electromagnetic field that propagates through the silicon nitride photonic crystal resonator. It is also found that the rotational diffusion of the microtubule is decreased by a factor of 6 when the microtubule is subject to the optical torque. Simultaneous application of force and torque on biological materials extends the functionality of our near-field photonic crystal resonators to be more powerful tool in biophysics study and micro- and nanoscale physics.

1. A. Ashkin, J. M. Dziedzic, T. Yamane, Nature 330, 769 (Dec 24, 1987).

2. Y. F. Chen, X. Serey, R. Sarkar, P. Chen, D. Erickson, Nano Lett 12, 1633 (Mar, 2012).

POSTER # 27 NE

Monolayer MoSe2
CNF REU 2012
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We investigate the optical and electrical properties of monolayer MoSe2, a two-dimensional semiconducting material in the family of transition metal dichalcogenides with an expected band gap of ~1.6 eV. While the properties of monolayer MoS2, another semiconducting member of this family (at a band gap of ~1.9 eV), have been widely investigated in the literature, those of monolayer MoSe2 are still largely unexplored. In this poster we examine the band gap of and characterize a transistor based on monolayer MoSe2.

POSTER # 28

Lab-On-A-Syringe Detection of Kaposi's Sarcoma-Associated Herpes Virus (KSHV)
CNF Project #: 1472-06
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Kaposi's sarcoma (KS) is the fourth leading cancer in sub-Saharan Africa. It generally presents as a collection of highly vascular red lesions, especially on the legs, genitals, face and mouth, similar to a number of other diseases, including Bacillary angiomatosis. The cause of KS is Kaposi's sarcoma associated herpesvirus (KSHV, also called HHV-8), a virus that in some nations reaches sero-prevelances of over 40%. Because of its high seroprevalance, the important clinical question isn't whether or not a person is positive for KSHV, but whether or not a specific tumor is. While accurate diagnosis is enabled in first-world hospitals through advanced laboratory medicine such as immunohistochemistry or PCR, developing-world doctors struggle to diagnose KS with high accuracy due to reliance on sub-state-of-the-art techniques. Here we begin to develop easily operated and robust technology for the detection of KSHV in resource limited settings. We aim to solve two of the unique challenges associated with KSHV: 1. it's detection in a biopsy sample, and 2. a multiplexed system to differentiate it from other similarly presenting diseases. Our approach involves the creation of Lab-on-a-Syringe technology with sample in, detection out capability based on gold nanoparticle oligonucleotide colorimetric detection.

POSTER # 29

Non-Enzymatic Single Layer Glucose Fuel Cells for Implantable Devices
CNF Project #: 186310
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There is great interest in developing reliable, long-lasting power sources that offer longer life cycle than lithium batteries for powering implantable medical devices. Such power sources could harness mechanical, thermal or chemical energy from muscle tissue to extend the lifetime of current medical devices and eliminate the need for battery replacement operations. Glucose fuel cells that use non-enzymatic catalysts to convert glucose and oxygen into electricity are attractive because they have much lower power degradation than enzymatic fuel cells, and better power output than thermal and piezoelectric power sources[1]. We have developed a completely novel approach to glucose fuel cell fabrication where both the anode and cathode are patterned using standard semiconductor processing techniques onto a single fused silica substrate. Such single layer fuel cells (SLFC) can be connected to form a fuel cell stack with state of the art power density of 46μWcm¯3 or patterned directly onto implantable devices as a thin coating layer. We demonstrate that by having a co-centric design where the cathode surrounds the anode in a SLFC and by reducing the gap between each SLFC in a fuel cell stack, we can reduce the amount of oxygen reaching the anode and thus improve the performance of the fuel cell.

[1] S. Kerzenmacher, J. Ducree, R. Zengerle, F. von Stetten, Energy harvesting by implantable abiotically catalyzed glucose fuel cells, Journal of Power sources 182 (2008) 1-17

POSTER # 30

Single-Cell Mechanical Phenomena in Cancer Invasion: Micro and Optofluidic Approaches

CNF Project #: 174309

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Cell mechanics is important in many aspects of biology, from development to disease states. In particular, metastasis, the leading cause of cancer related deaths, is intrinsically a mechanical transport phenomenon in which cancer cells must break free from the primary tumor and invade across physiological barriers, from extracellular matrices to vascular networks [1]. While many molecular signals have been identified that drive this process, the effects of the mechanical microenvironment and behavior of cells during the invasion cascade are not well known. Additionally, the need for single-cell analysis has become increasingly important in cancer research, since the heterogeneity in tumor populations has been speculated to drive cancer progression, metastasis, and chemotherapeutic resistance [2]. In our work, we develop microfluidic environments with dimensions that mimic highly confined physiological spaces, and we study the mechanical cues and dynamics of single cells during invasion [3]. We also demonstrate nearfield optical forces as a tool to probe adherent and suspended cells.

1) Chambers AF, Groom AC, and MacDonald IC, Nature reviews, 2002.
2) Gerlinger M, Rowan AJ, Horswell S, et al, The New England Journal of Medicine, 2012.
3) Mak M, Reinhart-King CA, and Erickson D, PLoS ONE, 2011.

POSTER # 31

Separation of Mycobacteria using Insulative Dielectrophoretic Devices to aid in Tuberculosis research

CNF Project no.: 136005

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We present the separation of Mycobacteria using an insulative dielectrophoretic (DEP) device. The device relies on a curved constriction in channel depth to generate electric field gradients for the separation of cells by staggering their transverse position at the exit channels based on their DEP response. The DEP response of a cell depends both on its shape as well as its dielectric properties and those of its hosting medium1. In Mycobacteria, this is a strong function of membrane capacitance2. We have previously shown that this device is capable of separating polystyrene particles of different sizes which have different DEP responses3. In this work, we present the use of this device to separate Mycobacteria based on membrane mutations and/or antibiotic treatment. We expect that the separation of mycobacterial mutants will aid researchers in studying the mechanisms leading to pathogenicity and drug resistance in Mycobacterium tuberculosis.

1) Pohl, H.A., Dielectrophoresis, 1978. 2) Hawkins, B.G., Huang, C., Arasanipalai, S. and Kirby, B.J., "Automated dielectrophoretic characterization of Mycobacterium smegmatis", Anal.Chem., 2011. 3) Hawkins, B.G., Smith, A.E., Syed, Y.A. and Kirby, B.J., "Continuous-flow particle separation by 3D insulative dielectrophoresis using coherently shaped, DC-biased, AC electric fields", Anal.Chem., 2007.

POSTER # 32

Nano/Micro Scale Systems Engineering Education
CNF Project # 1341-05
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The need for expensive, state-of-the-art facilities and experienced support staff is a significant obstacle for the development of young, talented students in the field of nano/micro-scale engineering from small and geographically remote institutions. This impediment may seriously limit the flow of quality talent from these institutions into the high-tech U.S. workplace since they lack the hands-on experience desired by these employers. This poster highlights a model Nanotechnology Undergraduate Education (NUE) program geared toward overcoming this hindrance by providing the students at Clarkson University (CU) the opportunity to receive hands-on design, fabrication, and characterization experience at Cornell University›s NanoScale Science & Technology Facility (CNF), an NSF-supported National Nanotechnology Infrastructure Network (NNIN) facility. Implementation details of the portable model are presented and shared, as well as the personal experiences of one of its participating graduate students. Specifically, the role of CNF on the success of this program will also be discussed.

POSTER # 33

Dynamics of Micro-Rotational Disk Mass Sensor Structures: Characterization and Sensitivity Analysis
CNF project Number is: 1341-05
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In this poster presentation the sensitivity analysis for the motion of a micro-scale in-plane rotational disk sensor along with supporting experimental and computational studies is presented. This novel sensor consists of a free-standing central disk suspended by a set of beam elements excited by an electrostatic comb drive. The key advantage of the proposed architecture over the traditional cantilever beam-based mass sensor design is that a rotational disk operates in the in-plane mode, so the complications associated with out-of-plane deflection of a cantilever beam sensor and resulting reduction in its Q (quality)-factor, are minimized. Based on Hamiltonian's principle, a set of equations of motion for the presented disk sensor structure are derived, and simulated. In addition, the dynamics of the sensor structure is experimentally studied by exciting the micro-structure with a broadband base excitation source. Based on the sensitivity analysis it is predicted that, with a frequency shift of 1.86 Hz, the mass detection sensitivity of the rotational disk sensor can be as low as 0.30ng/cm2. This sensitivity level indicates that the proposed sensing mechanism has the potential of offering up to two orders of magnitude higher mass-sensing resolution than a typical quartz crystal micro balance (QCM) instrument.

POSTER # 34

Mass Production of Patterned Micro- and Nanowires Via Electroplate And Lift (E&L) Lithography
CNF Project # 2079-11
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Electroplate-and-Lift (E&L) lithography1 has been developed as a fast, simple, scalable technique for the controlled, solution-based, electrochemical synthesis of patterned metallic and semiconducting nanowires. E&L employs a reusable, non-sacrificial template, made from alternating layers of insulating and conductive ultrananocrystalline diamond (UNCD)TM. The UNCD is lithographically patterned to expose only edges of the conductive layer, to nucleate nanowire growth. The nanowire diameter can be controlled by increasing the deposition time.2 In alloy systems, the composition of the wires can be controlled by varying the solution composition.3 Following electrodeposition, the nanowires are mechanically removed, to regenerate the template surface for subsequent depositions. A fully automated, roll-to-roll E&L production system is currently under development. Patterned wires with diameters of 100 nm to 10 microns will be produced at a rate of 8 grams per day. Individual wires less than 1 micron in diameter may be produced at a rate of ~ 1 km per day.

(1) Seley, D.B. et. al., ACS Appl. Mater. Interfaces, 2011, 3 (4), pp 925–930 (April 2011 cover)
(2) Jones, D. et. al. Proc. Mater. Res. Soc. doi: 10.1557/opl.2012.664, 30 March 2012
(3) Grodek, C., et. al. Proc. Mater. Res. Soc. doi: 10.1557/opl.2012.247, 13 February 2012

POSTER # 35 NE

Inorganic Nanoparticle Resist
CNF REU 2012
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As feature sizes continue to decrease, the need for high resistance photoresist becomes more apparent. In order to achieve quality distinction with such fine features, thin films of resist must be used for etching. However, due to poor etch resistance this has proven difficult in the past. A promising potential solution lies in inorganic resists. This study looks at one such resist, a zirconium oxide nanoparticle based resist. These zirconium oxide particles are surrounded by an organic ligand, with the inorganic crystal providing the high etch resistance. In particular, the studies being done looks at the effects of different lengths of exposure oxygen plasma before etching to see its effects on etch resistance in CF4 gas. This data can provide information about the optimal conditions for etching, improving the quality of the resist.

POSTER # 36

Fool›s Gold Footprinting: a microfluidic device that generates hydroxyl radicals to probe the solvent accessible surface of nucleic acids

CNF Project #: 692-98
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We describe a microfluidic device containing a mineral matrix capable of rapidly generating hydroxyl radicals that enables high-resolution structural studies of nucleic acids. Hydroxyl radicals cleave the solvent accessible backbone of DNA and RNA; the cleavage products can be detected with as fine as single nucleotide resolution. Protection from hydroxyl radical cleavage (footprinting) can identify sites of protein binding or the presence of tertiary structure. Here we report preparation of micron sized particles of iron sulfide (pyrite) and fabrication of a microfluidic prototype that together generate enough hydroxyl radicals within 20 ms to cleave DNA sufficiently for a footprinting analysis to be conducted. This prototype enables the development of high-throughput and/or rapid reaction devices with which to probe nucleic acid folding dynamics and ligand binding.

POSTER # 37

Fabrication Methods for a Phonon Spectrometer Designed to Spectrally Resolve Hypersonic Phonon Transport through Nanostructures

CNF Project # 174609
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Phonons are the dominant heat carriers in semiconductor and insulators; therefore, the understanding of their behavior at the nanoscale is important for the realization of efficient thermoelectric devices for waste heat recovery. In this work we show how acoustic phonon transport can be directly probed by the generation and detection of non-equilibrium phonons in microscale and nanoscale structures. Our technique employs a scalable method of fabricating phonon generators and detectors on silicon mesas. In the line-of-sight path along the width of these mesas, phonons with frequency ~100 to ~700 GHz can propagate ballistically. Phonons are generated through the decay of quasiparticles injected into one superconducting film of the generator. This process excites phonons in a tunable, non-thermal spectral distribution. The phonons radiate into the mesa and are observed by the detector after passing through the mesa. By utilizing electron-beam lithography and plasma etching, we fabricated high aspect ratio silicon nanosheets of width 100 to 300 nm along the ballistic path and observed surface scattering effects on phonon transmission, which occurs when the characteristic length scale of a material is less than the phonon mean free path. We compare our results to predictions of the Casimir-Ziman theory.

POSTER # 38

Hafnium and Zirconium oxide nanoparticles as novel photoresist materials
CNF project number: 386-90
Authors: Markos Trikeriotisa, Marie Krysaka, Yeon Sook Chunga, Christopher K. Obera, Emannuel P. Giannelisa and Mark Neisserb
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Performance requirements for next generation lithography will necessitate the development of entirely new resist platforms. The new resists for Extreme Ultra-Violet (EUV) lithography must show high etch resistance and high sensitivity. We have developed a novel inorganic photoresist platform to be applied in advanced lithography. These inorganic photoresists are made of metal oxide nanoparticles stabilized with organic ligands and have shown etch resistance that is 25 times higher than polymer resists. This will enable the processing of very thin films (< 40 nm) and will push the resolution limits below 20 nm without pattern collapse.

1. Trikeriotis, M., Krysak, M., Chung, Y. S., Ouyang, C. Y., Cardineau, B., Brainard, R. L., Ober, C. K., Giannelis, E. P., Cho, K. Y., A new inorganic EUV resist with high etch resistance, Proc. SPIE 2012, 8322, 83220U
2. Krysak, M., Trikeriotis, M., Schwartz, E., Lafferty, N., Xie, P., Smith, B., Zimmerman, P. A., Montgomery, W., Giannelis, E. P., Ober, C. K., Development of an inorganic nanoparticle photoresist for EUV, e-beam, and 193nm lithography, Proc. SPIE 2011, 7972, 79721C.

POSTER # 39

High-Efficiency Ordered Silicon Nano-Conical-Frustum Array Solar Cells by Self-Powered Parallel Electron Lithography
CNF Project #: 126204
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Nanostructured silicon thin film solar cells are promising, due to the strongly enhanced light trapping, high carrier collection efficiency, and potential low cost. Ordered nanostructure arrays, with large-area controllable spacing, orientation, and size, are critical for reliable light-trapping and high-efficiency solar cells. Available top-down lithography approaches to fabricate large-area ordered nanostructure arrays are challenging due to the requirement of both high lithography resolution and high throughput. Here, a novel ordered silicon nano-conical-frustum array structure, exhibiting an impressive absorbance of 99% (upper bound) over wavelengths 400-1100 nm by a thickness of only 5 μm, is realized by our recently reported technique self-powered parallel electron lithography that has high-throughput and sub-75 nm high resolution. Moreover, high-efficiency (up to 10.8%) solar cells are demonstrated, using these ordered ultrathin silicon nano-conical-frustum arrays. These related fabrication techniques can also be transferred to low-cost substrate solar energy harvesting device applications.

POSTER # 40 NE

Electrically and Optically Obtaining Q from High Stress SiN Devices

CNF REU 2012

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High-stress silicon nitride membranes show extremely high mechanical quality factors (Q of up to 10 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 is transferred onto this suspended membrane so as to create a degenerately doped region that will actuate the capacitive readout of the resonant motion. Amplitude of resonant motion is detected using interferometric means in a custom built laser setup. Electrically active silicon nitride resonators maintain the ultra-high Q and therefore are useful for the above mentioned applications.

POSTER # 41

Developing a novel electrochemiluminescent (ECL) microfluidic biosensor involving liposome based amplification

CNF Project number: 802-99

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A novel electrochemiluminescence (ECL) based microfluidic biosensor featuring liposome amplification is developed to detect RNA from pathogenic organisms, such as Cryptosporidium parvum in field water. Karanis et al. published in Water Research showed that between 2004 and 2010, 60.3% of worldwide waterborne protozoan outbreaks were caused by C. parvum. The resulting infection is often lethal to immunocompromised, the elderly and infants causing significant problems not only in resource-limited countries but also the developed world. ECL-based detection with a simple instrumental setup built from low cost materials such as polymethylmetacrylate (PMMA) through hot embossing and photolithography is highly suitable for field applications. The microfluidic system consists of multiple channels to allow for simple fluid handling, fully integrated electrochemical and luminescence detection and magnetic-capture based bioassays with liposome signal amplification. Magnetic beads are added to a solution containing reporter probe-labeled liposomes encapsulating high concentration of electrochemiluminescent complex (Ru(bpy)32+) and target RNA to undergo hybridization. The solution is injected in the microfluidic system where the hybridized complexes are immobilized over a magnet located adjacent to integrated electrodes. Injection of a detergent solution (octyl glucopyranoside) lyses the liposomes liberating the Ru(bpy)32+ which can then be monitored in an ECL reaction directly within the chip.

POSTER # 42

Z-Axis OptoMechanical Accelerometer
CNF Project#: 138005
Authors: T A Gosavi (presenter), D N Hutchison, S A Bhave
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We demonstrate a z-axis accelerometer which uses waveguided light to sense proof mass displacement. The accelerometer consists of two stacked rings (one fixed and one suspended above it) forming an optical ring resonator. As the upper ring moves due to z-axis acceleration, the effective refractive index changes, changing the optical path length and therefore the resonant frequency of the optical mode. The optical transmission changes with acceleration when the laser is biased on the side of the optical resonance. This silicon nitride "Cavity-enhanced OptoMechanical Accelerometer" (COMA) has a sensitivity of 22 percent-per-g optical modulation for our highest optical quality factor (Qo) devices.

POSTER # 43

Energy dissipation in high-stress silicon nitride membranes
CNF Project #: 762-99
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When used in vibrating mechanical membranes, high-stress silicon nitride displays anomalously high quality factors for glasses (reaching up to 107); it is thus ideal for high-precision mass-sensing applications, optomechanical experiments, and for realizing mesoscopic quantum systems. We have fabricated several circular membranes with varying aspect ratios and measured their quality factors at room temperature. Results are consistent with current models, as dissipation is seen to depend strongly on vibrational mode, device diameter, and thickness. Dissipation dependence on temperature for various modes has also been explored from room temperature down to 5 K. In this range, we have seen a dissipation plateau characteristic of glasses. We are currently constructing devices with evaporated metal pads which will allow for capacitive readout of membrane motion and the study of this glassy behavior at even lower temperatures (~20 mK) in a dilution refrigerator setup.

POSTER # 44

Fabricated Collagen Microtracks Facilitate MMP-Independent Cancer Cell Migration
CNF Projects 185910 & 204011
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Cancer cells can invade the tumor stroma by degrading the extracellular matrix (ECM) with matrix metalloproteinases (MMPs). Although

MMP inhibitors showed early promise in preventing metastasis in animal models, they have largely failed clinically. Recently, studies have shown that some cancer cells use a combination of proteolysis and cellular force to mechanically rearrange their ECM to form tube-like “microtracks” which other cells can follow without using MMPs themselves. We speculate that this mode of migration in the secondary cells may be one example of true protease-independent migration, and may also help explain the failure of clinical MMP inhibitors, if administered after the initial invasion. In this study, we established a novel method for studying microtrack cell migration in vitro using micropatterned 3D collagen channels. We quantified the speed and maximum invasion distance of cells with low and high MMP activity: non-metastatic MCF10A mammary epithelial cells and metastatic MDAMB231 breast cancer cells. We compared migration within fully 3D collagen matrices and patterned 3D collagen channels. Our data indicate that although MCF10A cells are unable to invade a 3D matrix, they persistently and rapidly migrate through patterned channels. Similarly, we found that while MDAMB231 cells could significantly invade fully 3D matrices, the channel microenvironment induced significantly increased speed and invasion distance which were not disrupted by pharmacological MMP inhibition. Together, these data suggest that microtracks within a 3D ECM may facilitate the migration of cells in an MMP-independent fashion, perhaps revealing novel insight into the clinical challenges facing MMP inhibitors.

POSTER # 45 NE

Fabrication of Spin Torque Switching Device

CNF REU 2012

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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.

POSTER # 46

Patterning Polymer Thin Films in Linear Methyl Siloxanes

CNF Project #: 386-90

Authors: Christine Y. Ouyang, Jin-Kyun Lee, Marie E. Krysak, Gregory N. Toepperwein, Juan J. de Pablo, Christopher K. Ober

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Linear methyl siloxanes are a class of non-polar solvents with low molecular weights. They are low in toxicity, not ozone-depleting and can be recycled after usage.1,2 Their solvent strength is less than that of saturated hydrocarbons but can be enhanced by the addition of suitable co-solvents. Besides their environmental friendliness, they also possess unique physical properties such as low viscosity and low surface tension which are advantageous for processing polymer thin films. Pattern collapse, which is related to the surface tension of the processing solvent, is a common issue for ultra-fine patterns3. In this presentation, linear methyl siloxanes are used as processing solvents for high-resolution patterning of polymer thin films.

(1) Williams, D. E., ACS Symp. Ser. 2000, 244-257.
(2) Atkinson, R., Environ. Sci. Technol. 1991, 25, 863-866.
(3) Tanaka, T.; Morigami, M.; Atoda, N., J. Appl. Phys.1993, 6059-6064

POSTER # 47

Water desalination on a microfluidic platform
Project Number : 1872-10
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Principal Investigator: Professor David Erickson
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Lack of clean, fresh water is one of the biggest challenges facing humanity, with even now 1.2 billion people worldwide lacking access to safe drinking water. Desalination, the process of converting the salty sea/brine water into fresh water, is seen as a viable solution to this problem. However, existing desalination techniques, including multistage flash and reverse osmosis, require huge initial infrastructure and/or access to high grade electrical energy for operation – resources which are scantily available in developing or poor regions. In this work we propose an alternative method and preliminary results for solar desalination on a microfluidic platform which can be used for development of small scale or household units for seawater desalination.

POSTER # 48

Microfluidic Isolation and Amplification of mRNA for a Lab-on-a-Chip
CNF Project #: 802-99
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A microTotal Analysis System (µTAS) for the detection of pathogenic organisms is being developed. Specific focus is put on the isolation and amplification of nucleic acids for subsequent detection in an already developed electrochemical microfluidic biosensor. Here, the hsp70 mRNA from Cryptosporidium parvum is used as model analyte. The surface of a polymethylmethacrylate (PMMA) microfluidic device is carboxylated using a UV/ozone treatment followed by the immobiliziation of polyamidoamine (PAMAM) dendrimers on the surface for increased immobilization efficiency of the oligonucleotide, oligo(dT)25. Isolation of the mRNA is achieved through hybridization of the poly-adenosine (poly-A) tail on the mRNA to the thymidine (dT) oligonucleotide. This enables the unwanted cellular debris to be washed away. Amplification of the mRNA is accomplished via nucleic acid sequence-based amplification (NASBA), an isothermal primer-dependent technique. Here, the amplification of mRNA from few C. parvum oocysts is demonstrated directly on chip and compared to bench-top devices. This is the first proof of a successful NASBA-based amplification of mRNA from C. parvum in relevant analytical volumes.

POSTER # 49

A Single Lithography Self-Aligned Vertical NanoRelay
CNF Project #: 804-99
Author(s): Joshua Rubin1, Ravishankar Sundararaman2, Moonkyung Kim1
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We demonstrate the use of torsion in nanorelays to achieve low voltages, high speeds, single lithography step construction, and a form useful for configurability and electronic design enhancements in three-dimensional integrated implementations. The combined bending and torsion of self-aligned nanopillars facilitates the first top-down fabricated vertical three terminal nanoscale relay. Experimental devices, even at 500 nm features, operate at ~10 V and µs. Scaling suggests operation down to unit volts.

POSTER # 50

Effect of interstitial flow on tumor cell migration using a 3D microfluidic in vitro model
CNF Project # 206811
Author(s): Chih-kuan Tung, Oleh Krupa, Elif Apaydin, and Mingming Wu
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Interstitial flow is ubiquitous in mammalian tissue, but its effects on tumor cell invasion and metastasis are not fully understood. We have developed a PDMS-based microfluidic device that generates a pressure-driven fluid flow across type I collagen matrix, entrapped by contact line pinning. Using the Fluorescence Recovery after Photobleaching (FRAP), we demonstrate that our device is capable of providing a steady and slow (4μm/s) flow across the collagen matrix. Using our device, we demonstrate the effects of interstitial flow on cell morphology. With proper co-culture set-up, we will also be able to model cancer cell migration from the primary tumor and into blood/lymphatic vessels. Overall, our device enables more accurate quantitative studies of interstitial flow in vitro.

POSTER # 51

MEMS electrostatic power generators employ variable gap capacitors to harvest energy from mechanical vibrations and have applications in wireless sensors networks. This work investigates the design of an in-plane, gap-closing, electrostatic micro-generator. Devices were fabricated using silicon on insulator (SOI) technology with thick device layers (200μm) in order to accommodate the large out-of-plane stress imposed by additional mass placed on the resonant structure and to increase the total capacitance area. Narrow band vibrations at 100Hz and 0.1-1.0g acceleration were used during tests as they represent the peak fundamental vibration in many ambient environments. External masses between 0.5 and 2 grams were added to the resonant structures in order to increase inertia and lower the primary resonant frequency to 100Hz. Modeling of the device was performed prior to fabrication in order to optimize and predict the device's behavior during excitation. A high speed, high zoom camera was used to verify the motion of the electrodes and to validate the model's predicted minimum gap between electrodes at resonance. Static and dynamic capacitance measurements indicate large parasitics in the device layer which will be addressed in future designs.

[1] Hoffmann, D., Folkmer, B., & Manoli, Y. (2009). Fabrication, characterization and modelling of electrostatic micro-generators. Journal of Micromechanics and Microengineering, 19
[2] Mitcheson, P. D., Sterken, T., He, C., Kiziroglou, M., Yeatman, E., & Puers, R. (2008). Electrostatic microgenerators. Measurement and Control, 41 114-119
[3] Roundy, S., Wright, P. K., & Rabaey, J. (2003). A study of low level vibrations as a power source for wireless sensor nodes. Computer Communications, 26, 1131-1144

POSTER # 52

A Microfabricated, Combination Flexible-Circuit/Electrode Array for a Subretinal Prosthesis
CNF Project #: 65797
Authors: M.D. Gingerich1,2, R. Akhmechet3, S.F. Cogan4, T.D. Plante4, D.B. Shire1,2, J.L. Wyatt5, J.F. Rizzo3.
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This work is related to the efforts of the Boston Retinal Implant Project to develop a subretinal prosthesis to restore vision to the blind. The specific purpose of this presentation is to describe our efforts to develop a polyimide-based, one-piece, combination flexible-circuit and electrode array (flex-array) which interconnects the RF coil with the hermetically encased prosthesis electronics and the sputtered iridium oxide film (SIROF) stimulating electrodes. A flex-array was designed based on the particular requirements of our subretinal prosthesis. A preliminary microfabrication process was designed based upon our past experience in developing polyimide-based electrode arrays, multilayered metallization and SIROF stimulating electrodes. The initial devices were microfabricated on Si carrier substrates by adapting, integrating and optimizing the aforementioned aspects of previous devices, designs, in vitro and in vivo tests, and microfabrication processes. The overall process consisted of a set of microfabrication processes and steps, including spin coating of photoresists and polyimide, microlithography, physical vapor deposition (PVD), wet and dry etching, and electroplating. The initial batch of devices fabricated was carefully monitored and real-time design and process changes were implemented to insure a successful outcome. A set of microfabrication processes was successfully engineered to produce a flex-array with bonding pads on two sides. The flex-arrays were tested in vitro as well as in vivo in a Yucatan minipig for up to five and half months.

POSTER # 53

Tripodal Binding Motifs for Noncovalent Functionalization of Graphene

Project # 188110

Jason A. Mann, Thomas P. Alava, Joaquín Rodríguez-López, Harold G. Craighead, Héctor Abruña, and William Dichtel*

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POSTER # 54

Resonance measurement of nonlocal spin torque in a 3-terminal magnetic device

CNF Project #: 598-96

Author(s): Lin Xue, C. Wang, Y.-T. Cui, L. Liu, A. Swander, J. Z. Sun, R. A. Buhrman and D. C. Ralph

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A pure spin current generated within a nonlocal spin valve can exert a spin transfer torque on a nanomagnet. This nonlocal torque enables new design schemes for magnetic memory devices that do not require the application of large voltages across tunnel barriers that can suffer electrical breakdown. Here we report a quantitative measurement of this nonlocal spin torque using spin-torque-driven ferromagnetic resonance. Our measurement agrees well with the prediction of an effective circuit model for spin transport. Based on this model, we suggest strategies for optimizing the strength of nonlocal torque.

[1] L. Xue et al., Phys. Rev. Lett. 108, 147201 (2012).

POSTER # 55

Near field optical trapping of biomolecules without temperature increase

CNF Project # 185710

Author(s) Xavier Serey, Yih-Fan Chen, David Erickson

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Nanoscale objects are difficult to manipulate in solution because of Brownian motion. The smaller the object the weaker the grasp on its degrees of freedom. We previously introduced photonic crystal resonators for the manipulation of objects in solution. We found that thermophoresis plays an essential role in device operation as the temperature increase is extremely high at 1550 nm. We introduced a formalism to characterize the transport properties in the vicinity of the photonic crystal traps and compare the magnitudes of the different physical effects. With the knowledge of the devices limitations, we fabricated a new generation of devices operating at 1064 nm that overcome the previous generation's weaknesses. We went on to demonstrate the novel trapping of biomolecules (Wilson Disease Molecule). Last, we added a new component to the possibilities offered by these devices: optical torque wrenching.

[1] Mandal, S., Serey, X., Erickson, D., "Nanomanipulation using Silicon Photonic Crystal Resonators" Nano Letters 10, 99-104 (2010).
[2] Serey, X., Mandal, S., Chen, Y.-F., Erickson, D., "DNA Delivery and Transport in Thermal gradients near optofluidic resonators" Physical Review Letters 108, 048102 (2012).
[3] Chen Y.-F., Serey, X., Sarkar, R., Chen, P., Erickson, D., "Controlled photonic manipulation of proteins and other nanomaterials" Nano Letters 12 (3), 1633-1637 (2012).

POSTER # 56

Tunable Graphene Plasmonic Devices for Terahertz Applications

CNF Project #: 136305

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Graphene, a two-dimensional atomic layer of carbon atoms, is particularly promising for plasmonics, compared to metal plasmonic materials, as it offers frequency tunability, lower losses, and terahertz frequency operation [1-3]. I will present experimental results on some graphene terahertz plasmonic devices. Graphene was grown on copper foil using chemical vapor deposition and transferred onto a silicon substrate. Photolithography was used to define the microstructures. Patterned graphene was doped by exposing to Nitric acid. Measurements were performed using a far-IR FTIR with a silicon bolometer detector. Measurements on graphene strips show that when the incident radiation is polarized perpendicular to the strips, the confined plasmon resonance is excited and appears as a strong narrow peak in the absorption spectrum. We have developed an electromagnetic FDTD model that captures the frequency-dependent graphene conductivity to simulate the fabricated plasmonic structures. Fabricated micron scale wide graphene strips exhibit plasmon resonances in the 4-5 THz range. Comparison of simulations and measurements enables us to extract the scattering time and mobility of 50-75 fs and 1700-2800 sq-cm/V-s at room temperature. These values agree well with the reported values for CVD graphene.

[1] Nature Nanotech., 6, 630-634 (2011);
[2] Nature Nanotech., 7, 330-334 (2012);
[3] Nature Nanotech., 6, 611–612(2011)

POSTER # 57

Directed Nano Assembly of Materials Using Silicon Photonics

CNF Project #: 1857-10

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Principal Investigator: Professor David Erickson
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Photonic manipulation is one area of particular promise for nanoscopic particle manipulation because of the directed assembly approach and the potential for use in highly parallel systems. This project attempts to make progress towards this type of assembly system specifically by using silicon photonic resonators to trap small particles and then fuse them into structures not easily fabricated by presently available methods. Highly concentrated light inside photonic devices is used to transfer the momentum from incident photons to a particle. This transfer of momentum can be utilized to manipulate nanoparticles extremely precisely via near-field optical trapping forces and radiation pressure. This lab has demonstrated reliably repeatable particle trapping using silicon photonic ring resonators. We expect to build structures with these and other resonator designs from nanoscale particles, for example, by using biochemistry and the binding affinities of avidin and biotin to bind functionalized particles to each other. Other possibilities include fusing particles thermally on the resonator and incorporating plasmonic structures to increase trapping forces. The promise of this field of research is the ability to build, from the nanoscopic level, any material, naturally occurring or otherwise, in any configuration, for example, high efficiency photovoltaic materials.

POSTER # 58

Spin Injection into Graphene by Spin Hall Effect
CNF Project #: 598-96

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Graphene is a promising material for micro-scale spin transport because of its long spin-flip length and spin relaxation time up to room temperature.1,2 Previous studies used magnetic tunnel junctions to inject spin current into graphene.1,2 In our study, we explore the possibility to inject spin current into graphene with spin Hall effect. Devices used in our study are fabricated by contacting patterned CVD graphene with Pt wires and magnetic tunnel electrodes. Here, thin Pt wires, which are found to have relatively strong spin Hall effect,3 are used as spin injectors and the ferromagnetic tunnel electrodes are used as spin detectors.

1. Nikolaos Tombros, et al. Electronic spin transport and spin precession in single graphene layers at room temperature. Nature 448, 571-575 (2007).
2. Wei Han, et al. Tunneling Spin Injection into Single Layer Graphene. Physical Review Letters 105, 167202 (2010).
3. L. Liu, O. J. Lee, T. J. Gudmundsen, D. C. Ralph, and R. A. Buhrman. Magnetic switching by spin torque from the spin Hall effect. arXiv:1110.6846 (2011).

POSTER # 59

Getting a Handle on Single Wall Carbon Nanotubes
CNF Project #: 900-00

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We are developing a single walled carbon nanotube (NT) force probe which would utilize an optical trap to manipulate NTs fitted with micron scale dielectric handles. With its nanometer diameter and micron length a NT harnessed in this way may eventually allow us to probe a cell's membrane and interior. In pursuit of this goal we have developed a method to create parallel arrays of aligned NT cantilevers. In this process we transfer highly aligned NTs to a substrate composed of alternating regions of Si separated by SiO_2. Patterning the NTs and etching away the oxide leaves behind ridges supporting arrays of NT cantilevers 0.7nm x 2nm in diameter and up to 700nm in length with densities of over one cantilever per micron. We will discuss our work modifying this technique to pattern and release micron scale NT cantilever probes into solution. We have designed and optically tested lithographically patterned SiO_2 and SU-8 handles, shaped such that they can be manipulated with an optical trap in predictable orientations. We will focus on our current efforts in attaching these optically trappable dielectric handles to individual nanotubes so they can be implemented to make direct force measurements.

POSTER # 60

On Chip Porous Polymer Membranes for Integration of Gastrointestinal Tract Epithelium with Microfluidic 'Body-on-a-Chip' Devices

CNF project number #731-98

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We describe a novel fabrication method that creates microporous, polymeric membranes that are either flat or contain controllable 3-dimensional shapes that, when populated with Caco-2 cells, mimic key aspects of the intestinal epithelium such as intestinal villi and tight junctions. The developed membranes can be integrated with microfluidic, multi-organ cell culture systems, providing access to both sides, apical and basolateral, of the 3D epithelial cell culture. Partial exposure of photoresist (SU-8) spun on silicon substrates creates flat membranes with micrometer-sized pores (0.5 – 4.0 μm) that – supported by posts - span across 50 μm deep microfluidic chambers that were 8 mm wide and 10 long. To create three-dimensional shapes the membranes were air dried over silicon pillars with aspect ratios of up to 4:1. Space that provides access to the underside of the membranes with three-dimensional structures can be created by isotropically etching the silicon with xenon difluoride. Depending on the size of the supporting posts and the pore sizes the overall porosity of the membranes ranged from 4.4% to 25.3%. The microfabricated membranes can be used for integrating barrier tissues such as the gastrointestinal tract epithelium, the lung epithelium, or other barrier tissues with "body-on-a-chip" devices.

POSTER # 61

Miniaturized Spectrometers On-chip Using Photonic Crystal Structures

CNF Project #: 186210

Authors: Zhimin Shi1, Boshen Gao1, Andreas Liapis1, Yiming Lai2, Antonio Badolato2, and Robert W. Boyd1,2

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We show that using slow light can greatly enhance the spectral performance of on-chip interferometers. We propose various optimized photonic crystal structures to improve the performance of various types of integrated spectrometers. The devices are fabricated on Silicon-on-Insulator (SOI) platform, and preliminary results are presented.

POSTER # 62

Study of Liquid Water under Tension with Free-Standing Porous Silicon

CNF Project #: 111903

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Water is vital for all forms of life on earth. Due to its important roles, water is one of the most substantially and extensively studied

molecules; however, water exhibits a number of anomalous properties, which become more apparent in metastable liquid states, and the origins to these anomalies have not been elucidated. In our laboratory, we study water at negative pressure, where water is stretched and metastable with respect to its vapor phase. Several experimental studies reported the measurements of tensile strength of water using various techniques, but there exists large discrepancy among the data. Additionally, all but one experiments failed to reach the theoretically predicted cavitation limit. In our experiment, we place water under tension by trapping a bulk volume of liquid water in cavities etched in glass. The glass is anodically bonded with porous silicon membrane, and the sample is placed in an environmental chamber with a controlled activity of sub-saturated water vapor phase. Upon equilibrium, we can predict the pressure of the liquid phase by extrapolating equation of state, $P(T,\mu)$. In this presentation, we report on 1) cavitation limit of water measured in our system compared with other reported values and 2) using our system to investigate nucleation phenomena in water under tension. We will end our presentation with discussion on our work on developing application for liquid water under tension.

POSTER # 63

The structural effects of photoresist on millisecond post exposure bake

CNF Project: 386-90

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The line width roughness (LWR), one of the greatest challenges when the critical dimension is close to 16nm, degrades the performance of the device. The acid diffusion during the post-exposure bake is the main source of LWR. Our group use laser spike annealing to replace the hotplate as an approach to solve the problem. Since the annealing temperature would be even higher than the melting temperature of the photoresist, it expands the range of reaction that does not happen in conventional baking method. Our study found a method to calibrate the temperature of laser peak temperature and explore the effects of leaving group during laser spike annealing.

CENTER POSTER NE

KAUST-CU

David Jung, dj59@cornell.edu, Cornell University

We will present results of research and applications about Nanoparticle Ionic Materials (NIMs) by KAUST-CU members. These applications include: Desalination and advanced water purification, Photovoltaics and energy storage systems, Nanomaterials for oil and gas exploration and production, and CO2 Capture and Conversion (C3).

CENTER POSTER NE

Nanobiotechnology Center: Facility Capabilities & Techniques

CNF Project # 1108-03

Author(s) Teresa Porri, Brian Bowman, Penny Burke, Carol Bayles, Graham Kerslick

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Nanobiotechnology is by its nature interdisciplinary and requires a diversity of equipment and capabilities not easily accessible or affordable on an individual research group level. One of the NBTC's goals is to provide a multidisciplinary environment that allow users to perform a wide range of research experiments, along with materials fabrication & characterization. Here we discuss some of the recent instrumental acquisitions and other facilities projects in the NBTC facilities, which are available to all facility users.

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