THE 57th INTERNATIONAL CONFERENCE on ELECTRON, ION, and PHOTON BEAM TECHNOLOGY & NANOFABRICATION

Gaylord Opryland Resort
Nashville, TN
May 28 – May 31, 2013

Sponsored Topical Conference of
The American Vacuum Society

Endorsed by:
American Physical Society

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Optical Society of America

and

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Institute of Electrical and Electronic Engineers

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COMMERCIAL SESSION
Todd Hastings, University of Kentucky

Mentorship Program
Leonidas E. Ocola, Argonne National Laboratory

PROGRAM COMMITTEE & SECTION HEADS

Directed Self Assembly
Joy Cheng, Elizabeth Dobisz, Euclid Moon, Paul Nealey, Martin Peckerar, Caroline Ross, Ricardo Ruiz, Hiroshi Yoshida

Electron or Ion Beam Lithography
John Hartley, Todd Hastings, Uli Hoffmann, Hans Loeschner, Juan Maldonado, John Melngailis, Steve Rishton, Don Tennant

Electron or Ion Sources and Systems
Alan Brodie, Nick Economou, Lloyd Harriott, Pieter Kruit, Juan Maldonado

Emerging Technologies
Charles Black, Mike Fritze, Cindy Hanson, Dieter Kern, Shinji Matsui, Paul Nealey, R. Fabian Pease, Martin Peckerar, John Randall, Hank Smith, David Tanenbaum, Grant Willson

Extreme UV Lithography
Uwe Behringer, Marty Feldman, Kenneth Goldberg, Eric Hendrickx, Patrick Naulleau, Takeo Watanabe

Maskless Lithography
Steve Brueck, David Joy, Juan Maldonado, Rajesh Menon, Dan Pickard, Mordechai Rothschild, Mark Schattenburg

Metrology, Imaging and Alignment
Eric Anderson, Leili Baghai Rad, Ralf Heilmann, David Joy, Euclid Moon, Phillip Russell

Nanobiology
Reginald Farrow, James Grote, Francis Ligler, Regina Luttge, Shalom Wind

Nanoelectronics
Karl Berggren, Andrew Dzurak, Peter Grutter, Stella Pang, Phil Wong, Qiangfei Xia

Nanoimprint and soft lithography
Steve Chou, Dan Kercher, Shinji Matsui, Deirdre Olynick, Stella Pang, Minghao Qi, Douglas Resnick, Helmut Schift, Grant Willson

Nano-MEMS
Uwe Behringer, Richard Blaikie, Rebecca Cheung, Julia Greer, Leonidas E. Ocola

Nanophotonics and Plasmonics
Richard Blaikie, Steven Brueck, Mark Horn, Alex Liddle, Rajesh Menon, Daniel Pickard

Nanostructures and Pattern Transfer
Evangelos Gogolides, Ralf Heilmann, Mark Horn, Derrick Mancini, Raghunath Murali, Deirdre Olynick, Stella Pang, Minghao Qi, Richard Tiberio, Joel Wendt

Optical Lithography
Steve Brueck, Tim Brunner, Michael Fritze, Tim Groves, Shinji Okazaki, Shane Palmer, Mordechai Rothschild, Henry Smith, Bruce Smith

Patterned Media and Data Storage
S. Assefa, Elizabeth Dobisz, Kim Lee, Caroline Ross, Shuaigang Xiao

Resists
Karl Berggren, R Brainard, Theodore Fedynyshyn, F Houle, Chris Soles, Gregory Wallraff

Simulation and Modelling
Tim Brunner, Roxann Engelstad, Chris Mack, David Melville, Lawrence Melvin, Martin Peckerar, Frank Schellenberg, Kevin Turner

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Sergey Zaitsev

CONFERENCE INFORMATION

HOTEL LOCATION: The 2013 conference will be held in Gaylord Opryland Resort, Nashville, Tennessee

Gaylord Opryland Resort
2800 Opryland Drive
Nashville, TN 37214

REGISTRATION: The conference registration desk at the Opryland Resort will be open during the hours listed below. Please check in upon arrival. Badges are required to attend the technical sessions.

ONSITE REGISTRATION HOURS
Registration Desk – Tennessee Ballroom Foyer

Tuesday, May 28	2:00 p.m. - 7:00 p.m.
Wednesday, May 29	7:30 a.m. - 3:30 p.m.
Thursday, May 30	7:30 a.m. - 5:00 p.m.
Friday, May 31	7:30 a.m. - 12:00 p.m.

CONFERENCE SCOPE: EIPBN, the "3-Beams", Conference**,** is the premier conference on the science and technology of nanopatterning. Traditionally focused on electron, ion, and photon beams, (the 3 beams), the technology of nanofabrication covered in this conference has grown to include nanoimprint and molecular self-assembly as well. This conference is the place to hear the newest techniques and the latest advances in patterning and device fabrication technology.

CONFERENCE FORMAT: The Conference opens on Tuesday afternoon with a special Commercial session, which features vendors of materials and equipment which are relevant to the conference. Here is your opportunity to meet with vendors who are eager to discuss their latest lithography systems, materials, and characterization instruments and related products. The Commercial Session begins on Tuesday at 3:00 pm in the Ryman Exhibit Hall with a reception followed by the Welcome Reception at 7:00 pm at the Waters Edge. The Plenary session begins on Wednesday morning. The rest of the conference has three parallel sessions from Wednesday afternoon through Friday afternoon. Dress for the conference is casual.

COMMERCIAL SESSION: The commercial exhibition schedule is:

Tuesday, May 28, 3:00 pm to 6:00 pm
Wednesday, May 29, 10:00 am – 4:30 pm
Thursday, May 30, 10:00 am – 1:00 pm

Participating companies include system suppliers for lithography, metrology, inspection, processing, nanofabrication, and characterization. They also include suppliers of simulation tools, data management, materials, services and subsystems. It is a complete cross section of our industry. Representatives from all suppliers are available to give information about their companies and products and to answer your questions. The suppliers especially welcome students who wish to learn more about industry and its opportunities. The setting is informal, and light refreshments are available on Tuesday from 3:00 pm to 6:00 pm.

Participants in this year's commercial session include: A&D Company Limited, aBeam Technologies, Inc., Angstrom Scientfic, Inc., Applied Physics Technologies, Carl Zeiss Microscoy, LLC, Electron Optica/MEBS, GenISys, Heidelberg Instruments Inc., Hitachi High Technologies America, Inc, JEOL USA, INC, Lumarray Inc, MicroChem Corp, NanoAndMore, Nanonex Corporation, Nanoscribe GmbH, National Institute for Nanotechnology, National Nanotechnology Infrastructure Network (NNIN), NIST/CNST, NuFlare Technology, Inc., Oxford Instruments, Raith USA, Inc., Specialty Coating Systems, STS-ELIONIX, Tescan USA, TMC Ametek, Trion Technology, University of Louisville-Speed School of Engineering, Vanderbilt University, Vistec Electron Beam GmbH, Vistec Gaussian Beam Lithography, VSG - Visualization Sciences Group,

Mentorship Program: EIPBN 2013 will introduce a Mentorship Hour where any of the attending members of the EIPBN community can participate. The concept is to allow more senior members of the community share their experiences and stories with those who are looking for guidance. Any attendee can be a mentoree.

MICROGRAPH CONTEST: On the lighter side, for the 19th year, the conference will sponsor a micrograph contest. Here is your chance to share those strange or beautiful micrographs that you have taken in the course of your work! John Randall, the 1995 conference chairman, has agreed to preside over this annual event. See the EIPBN website for details.

BANQUET AND SOCIAL EVENTS: There will be an informal welcome reception for all registered attendees (extra tickets may be purchased for guests) on Tuesday evening, May 28 from 7:00 until 9:30 pm at the Water's Edge on Delta Island section of the hotel.

Thursday's banquet and show cruise will be held on the General Jackson Riverboat. Tickets cost $80.00 each. Enjoy the Nashville music show. The Micrograph Contest awards will be announced at the banquet. There will be plenty of opportunity to socialize with colleagues, renew old acquaintances, discover new ones, and to discuss the conference, all in a fun, social setting. EIPBN attendees and their guests are encouraged to book their tickets in advance. Shuttle service to the General Jackson Riverboat will pick up guests at the Presidential Portico, starting at 6:00 pm. The Riverboat leaves dock at 7:00 pm.

PUBLICATION: The proceedings of this conference will be published in the November/December 2013 issue of the Journal of Vacuum Science and Technology (JVST). Accepted papers will have publication charges waived and all of the authors receive free AVS membership.

CONFERENCE INFORMATION ON THE WEB: You can find up-to-date information on all aspects of EIPBN at http://www.eipbn.org and on the EIPBN app.

TUESDAY AFTERNOON, May 28, 2013

2:00 pm – 7:00 pm Conference Registration
Tennessee Ballroom Foyer

3:00 pm – 6:00 pm Commercial Exhibit Session
Ryman Exhibit Hall

7:00 pm – 9:30 pm Welcome Reception
Water's Edge on Delta Island section of the hotel.

WEDNESDAY MORNING, May 29, 2013

7:30 am – 3:30 pm Conference Registration

10:00 am – 4:30 pm Commercial Exhibit Session
Ryman Exhibit Hall

12:00 pm – 2:30 pm Poster Session
Ryman Exhibit Hall

Plenary Session

Tennessee Ballroom
Session Chairs:
Rebecca Cheung, University of Edinburgh
Leonidas E. Ocola, Argonne National Laboratory

8:00 AM
Welcome

8:30am 01-Plenary 1
Breaking through the scaling boundaries, key for a sustainable society, *Luc Van den hove, CEO and President, Jo De Boeck, CTO, imec*

Several key societal challenges in domains such as healthcare, energy, urbanization and mobility call for sustainable solutions that can be enabled by combining various technologies. These solutions will be backboned by wireless sensor systems, smart mobile devices and huge data centers and servers, the key constituents of a new information universe. They will require extreme computation and storage capabilities, bound by (ultra)low-power or heat dissipation constraints, depending on the application. This drives the need to keep on scaling transistor technologies by tuning the three technology knobs: power/performance, area and cost. To get to ultra-small dimensions, advanced patterning integration, new materials, and new device architectures are being introduced. This comes along with an increasing need for process complexity reduction and variability control. Equally important are the continued R&D efforts in scaling memory technologies. NAND Flash, DRAM and SRAM memories are now approaching

the point where new scaling constraints force exploration of new materials, cell architectures and even new memory concepts. This opens opportunities for resistance based memories such as resistive RAM, phase-change RAM or spin-torque transfer magnetoresistive RAM.

9:15am 01-Plenary 2
Nanotechnology Convergence for IT, ET, and BTs, Jongmin Kim, University of Oxford

We present the current and future nanotechnology, especially focusing on the convergence of nano with electronics, photonics, energy, and bio areas. Nano-electronics will cover the graphene and carbon nanotubes, and their applications in nano vacuum electronics. These will also cover flexible and transparent electrodes, and transistors. Nano-photonics will include quantum-dot displays and other applications with field enhanced structure. Nano energy areas will be covered with energy generation and storage. New types of nano bio medical imaging system such as multi beam X-rays and teraherz imaging system will be specially covered.

10:00AM BREAK

10:30am 01-Plenary 3
Designing Bio-inorganic Nanomaterials for Ultrasensitive Biosensing, M. M. Stevens, Imperial College London

This talk will provide an overview of our recent developments in the design of nanomaterials for ultrasensitive biosensing. Our recent simple conceptually novel approaches to real-time monitoring of protease, lipase and kinase enzyme action using modular peptide functionalized gold nanoparticles and quantum dots will be presented.

11:15am 01-Plenary 4
Single Molecule and Single Cell Sensing with Nanomechanical Systems, Michael Roukes, California Institute of Technology

Nanoelectromechanical systems (NEMS) resonators can detect inertial mass with exceptional sensitivity. We have used NEMS devices to realize a new method for single-molecule mass spectrometry. In our first-generation approach, mass spectra from several hundred adsorption events were assembled into mass spectra using statistical analysis. Our second-generation approach now enables NEMS based mass spectrometry (MS) in real time: as each molecule in the sample adsorbs upon the NEMS resonator, its mass and position-of-adsorption are determined by continuously tracking two driven vibrational modes of the device. We demonstrate the potential of this method by analyzing individual IgM antibody complexes and other biological analytes in real-time. NEMS-MS is a unique and promising new form of mass spectrometry: it can resolve neutral species, provides resolving power that increases markedly for very large masses, is readily scalable to millions of channels, and is and producible en masse by methods from the semiconductor industry for very-large-scale integration. The talk will conclude with projections about exciting applications for this methodology.

WEDNESDAY AFTERNOON, May 29, 2013

Poster Session and Lunch

Ryman Hall
Wednesday, 12:00pm – 2:30pm
Posters are available for viewing on Thursday until 1:00 pm

Focused Ion Beam or Maskless Lithography

P01-01
Plasmonic Nanogap Arrays Fabricated via Moiré Holographic Lithography, Ishan Wathuthanthri, Ke Du, Chang-Hwan Choi, Stevens Institute of Technology

In this work, we demonstrate the use of simple two-beam holographic lithography systems (operating with a 325 nm HeCd laser) regulated with multiple exposures (i.e. superimposition of Moiré gratings) and manipulation of the lithographic process conditions to produce plasmonic nanogap arrays well below the diffraction limit of the irradiation source.

P01-02
Application of Proton Beam Writing to a Direct Etching of PTFE for PDMS Replica Molding, Hiroyuki Nishikawa, Takashi Hozumi, Shibaura Institute of Technology

We studied the capability of proton beam writing (PBW) in the direct etching of PTFE. The proton microbeam at 1.0 MeV was scanned on a PTFE film. With increasing PB fluence, the depth of micromachining increased up to 30 micrometers. Replica molding of the PTFE was successfully made using PDMS.

P01-03
Ga+ Focused Ion Beam Micromachining of Thermoplastic Polymers, Ka Wong, Alan Batchelor, Dieter Griffis, Charles Balik, North Carolina State University

The interrelationships between four different thermoplastic polymers (PE, PS, and PA6) with variable processing parameters and process efficiency of Ga+ FIB milling phenomena are examined. The roles of beam current, pixel spacing (i.e. pitch size) and pixel dwell time are considered as applied to FIB nanomachining of these materials.

P01-04
Prototype Active-Matrix Nanocrystalline Silicon Electron Emitter Array for Massively Parallel Direct-Write Electron Beam Lithography, Naokatsu Ikegami, Nobuyoshi Koshida, Tokyo University of Agriculture and Technology, Takashi Yoshida, Masayoshi Esashi, Tohoku University, Akira Kojima, Hideyuki Ohyi, Crestec Corporation

This paper presents our latest achievements on the prototype active-matrix nanocrystalline Si electron emitter array for massively parallel Direct-Write EB lithography. Electron emissions from the fabricated structure array worked as intended, indicating that the designed function of switching on and off the beamlets is properly performed by changing the CMOS-compatible voltage.

P01-05
Advanced Maskless Grayscale Lithography using a new writing strategy to increase the number of grayscale levels, Dominique Colle, Diez Steffen, Niels Wijnaendts, Heidelberg Instruments Mikrotechnik GmbH

Maskless Grayscale Lithography is the state of the art technology for rapid prototyping of micro optics, but currently limited by the number of grayscale levels. In this work we compare the grayscale performance of a standard grayscale method and the new advanced grayscale principle with 10 times more grayscale levels.

P01-06
Maskless Subwavelength Nanopatterning Using Vortex Phase Plates and Absorbance Modulation, Apratim Majumder, Rajesh Menon, The University of Utah, Trisha Andrew, University of Wisconsin-Madison

Absorbnce modulation optical lithography (AMOL) is a type of maskless lithographic technique that provides a means of fabricating sub wavelength nano-scale structures using a photochromic layer and dual-wavelength illumination schemes. Here we report the use optical vortex arrays with AMOL to fabricate arbitrary two-dimensional patterns in a dot-matrix fashion.

P01-07
Ion and Electron Beam Lithography in a Multifunctional Tool FIB/SEM with in-situ SPM, Jaroslav Jiruše, Rudolf Miroslav, TESCAN, a.s., Kvapil Michal, Brno University of Technology, Lišková Zuzana, Neuman Jan, Tomáš Šikola, Brno University of Technology

Combined FIB/SEM/SPM tool was used for ion and electron beam lithography and consequent investigation by in-situ SPM. Selective growth of metallic (Co, Au) nanostructures was optimized. Arrays of gold plasmonic antennas for near and middle infrared light were fabricated on substrates with a layer of nano-crystalline diamond using EBL.

P01-08
Direct Ga and Si Ion Beam Lithography for Nanopore Fabrication with High Resolution and Reproducibility, Sven Bauerdick, Achim Nadzeyka, Paul Mazarov, Lars Bruchhaus, Raith, Joel Fridmann, Raith, Jason Elliot Sanabia, Raith

DNA sequencing requires <20 nm nanopores with repeatable shape and minimal contamination. Here we used direct IBL to fabricate high resolution nanopores at wafer-scale. We investigated the diameter for different sub-10 nm ion beams and achieved 20-10 nm nanopores with excellent reproducibility for Gallium, Silicon and other ion species.

P01-09
Lloyd's Mirror Interferometer Using a Single-Mode Fiber Spatial Filter, Kuo-Chun Tseng, David Mikolas, En-Chiang Chang, Pao-Te Lin, De-Shiun Lin, Tzer-Bin Huang, Yin-Kuang Yang, Chien-Chung Fu, National Tsing-Hua University

An ultraviolet single-mode fiber (SMF) is used for beam transport, spatial filtering, and beam expansion for a Lloyd's mirror interferometer for laser interference lithography (LIL). By illuminating a Lloyd's Mirror interferometer with the beam produced by a single fiber, line/space photoresist patterns with a pitch of 220 nm were demonstrated.

MEMS

P02-01
Control of stress in sputtered tantalum films for MEMS applications, Enrico Mastropaolo, Eldad Grady, Rebecca Cheung, University of Edinburgh, Rhonira Latif, Technical University of Malaysia Malacca

The influence of sputtering conditions on tantalum (Ta) film deposition has been investigated for MEMS beams fabrication. Film stress gradually increases towards compressive values as a function of time when exposed to atmospheric conditions. Flat or buckled structures have been fabricated by controlling and fixing the as-deposited residual stress magnitude.

P02-02
Improvement of Bonding Strength in Room Temperature Wafer Bonding using Surface Smoothing by Ne Beam, Yuichi Kurashima, Atsuhiko Maeda, Hideki Takagi, National Institute of Advanced Industrial Science and Technology (AIST)

Surface activated room temperature wafer bonding is a powerful technology for heterogeneous integration of ICs, micro electro-mechanical systems (MEMS) and so on. The bonding process is based on inter-atomic bonds formation between two sufficiently smooth surfaces. In this report, we improved the bonding strength using surface smoothing by Ne beam.

P02-03
Optical microlithography on oblique surfaces via a novel diffractive phase mask, Peng Wang, Rajesh Menon, University of Utah

Here, we propose a novel approach employing computer-generated diffractive optics to project complex 3D light fields into space. Such a technique can enable patterning of 3D structures or planar microstructures on extremely oblique surfaces by a single exposure and hence, circumvent constraints in traditional methods.

Novel imaging

P03-01
A method for dynamic parameterized shape reconstruction. Application to scatterometry, Sebastien Soulan, Maxime Besacier, LTM/CNRS, Patrick Schiavone, Aselta Nanographics, Mohamed El Kodadi, ASML

Extremely high performances in real-time metrology techniques are now required for nano-manufacturing. Among these, scatterometry is the most promising: non-destructive, non-invasive and fast. Here we show a novel solution for real-time scatterometry: with incomplete ellipsometry data acquired at a sufficient frequency, we reconstruct a perfectly precise and accurate diffracting structure.

P03-02
Investigating effects of aerial image averaging and pupil plane filtering on line edge roughness (LER), Burak Baylav, Bruce Smith, Rochester Institute of Technology

This paper investigates effect of aerial image averaging on LER PSD. It also explores pupil phase amplitude/phase filtering as a way to mitigate LER transferred from mask to wafer.

P03-03
Active-illumination parallel Raman/SERS imaging, Ji Qi, Wei-Chuan Shih, University of Houston

Raman imaging is a powerful technique for material analysis, for example, stress and temperature measurement in silicon and compositional analysis of polymer micro particles. Recently, we have developed a novel parallel Raman imaging scheme for simultaneously collecting Raman spectra from multiple points using active illumination.

Modeling

P04-01
Theoretical study of the effects of substrate material refractive index on the optical transmission of nano-hole arrays, Mehrdad Irannejad, Bo Cui, University of Waterloo, Waterloo, ON,Canada

The linewidth of the resonance peaks in NHAs are decreased on increasing the index of the substrate.However,they are increased on increasing the hole diameter and as a result,using high index substrate and smaller hole diameter in the NHAs could increase the sensitivity which is promising new approaches in sensing application.

P04-02
Multi-Source, Complex Beamline Modeling Development in MICHELLE eBEAM, Serguei Ovtchinnikov, Masis Mkrtchyan, Roman Shtokhammer, John Petillo, SAIC, Simon Cooke, Alexander Vlasov, Baruch Levush, NRL

We report on developing new capabilities in MICHELLE-eBEAM code for simulations of high-current electron beam lithography devices that contain counter-streaming regions and include optical components and electron sources that are both aligned with, and oblique to, the main device axis. The achieved accuracy and performance of the code are discussed.

P04-03
Fluctuation Control of Measurement Interferometers: Application of algorithms to correct for local stage-motion induced pressure surges, Shane R. Palmer, Nikon Research Corp. of America

A method to correct for local fluctuations created by stage motions in an enclosure is used in a feed-forward algorithm. The algorithm is based on the reduced Navier-Stokes equations and represented in a 6-term model. Experimental results will be presented that show a reduction of interferometer fluctuation by over 40%.

P04-04
Detailed Molecular Dynamics Studies of Block Copolymer Directed Self-Assembly: Effect of Guiding Layer Properties on Block Copolymer Directed Self-Assembly, Andrew Peters, Richard Lawson, Peter Ludovice, Clifford L. Henderson, Georgia Institute of Technology

Detailed molecular dynamics simulations have been performed to explore the effect of guiding layer properties and errors on resulting DSA pattern properties. Furthermore, the effect of using block copolymers whose blocks have large differences in cohesive energy densities are explored.

P04-05
Pattern-integrated interference lithography: vector modeling of the single-exposure recording of integrated photonic-crystal structures, Matthieu Leibovici, Thomas K. Gaylord, Georgia Institute of Technology

Pattern-integrated interference lithography (PIIL) has been recently proposed as a rapid, cost-effective, and wafer-scale fabrication technique for dense integrated photonic-crystal devices. In this work, a new PIIL vector modeling is presented. The response of a positive photoresist during exposure is simulated as well.

Nanometrology

P05-01
Parallel Auger Electron Analysis inside Scanning Electron Microscopes, K. H. Cheong, A. Khursheed, National University of Singapore

This paper presents developments of a high performance parallel energy spectrometer that can be used inside SEM chambers as an add-on attachment. Predicted to have over two orders of magnitude better signal-to-noise characteristics than previous designs. This paper will present further developments in the design and preliminary experimental results.

P05-02
Measuring Field-Stitch Boundary Error of Electron Beam Lithography With X-ray Diffraction, Aaron Stein, Kenneth Evans-Lutterodt, Brookhaven National Laboratory

We use synchrotron-based x-ray diffraction to measure field-stitch boundary errors and evaluate which schemes for minimizing the error are most effective.

P05-03
CD Matching between CD-SEM and Scatterometry Metrology, Yi Song, Anne-Laure Charley, Philippe Leray, Imec

We will investigate the performance of optical scatterometry and compare with the CD-SEM. CD-SEM is implemented as a reference to optimize the recipe of scatterometry.

P05-04
Reconstructing Cross-Sectional Profiles from Top-View SEM Images Using Edge Fluctuation Characteristics, Hiroshi Fukuda, Hitachi High-Technologies Corporation

LER is decomposed into two components, parallel shift and deformation of averaged cross-sectional profile, and a local slope of the pattern surface is estimated from the latter. Cross-sectional profiles are reconstructed by scanning this procedure across top-view SEM images, and results agreed well with the real cross-sections.

P05-05
Liquid-Immersion Lloyd's Mirror Interference Lithography, Abhijeet Bagal, Chih-Hao Chang, North Carolina State University

We present an all-liquid immersion scheme to fabricate subwavelength periodic structures using Lloyd's mirror interference lithography, by taking advantage of high refractive index of immersion fluids. We also discuss the effect of light absorption in the immersion fluid on the quality of the structure produced.

P05-06
EUVL Aberration Metrology using Resist Images from a Strong Phase Shifting Mask, Germain Fenger, Bruce Smith, Rochester Institute of Technology, Obert Wood, Sudharshanan Raghunathan, Lei Sun, Thomas Wallow, Deniz Civay, Pawitter Mangat, Haiko Rolff, Markus Bender, Thorsten Schedel, GLOBALFOUNDRIES, Iacopo Mochi, Kenneth Goldberg, Chri Anderson, Paul Denham, Eric Gullikson, Lawrence Berkeley National Labs

In this paper we will present results from our experiments using these phase shifting masks and report on our attempt to combine these experimental results with dense lithography simulations to determine corresponding pupil aberration levels.

P05-07
Defect-tracking For Nanoimprint Lithography Using Optical Surface Analyzer and Scanning Electron Microscope, Zhaoning Yu, Nobuo Kurataka, Hieu Tran, Gene Gauzner, Seagate Technology

In this paper, we discuss a method for effectively tracking defects by combining the functions of an optical surface analyzer with SEM. Our studies show that the particles found on substrates are predominantly hard particles such as metal oxides, which tend to cause permanent template damage during imprint.

P05-08
Abrasion Test for Antisticking Layer by Scanning Probe Microscopy, Makoto Okada, Yuichi Haruyama, Shinji Matsui, Univ. of Hyogo

We evaluated the abrasion of antisticking layer (ASL) by contact mode-scanning probe microscopy (SPM) because the cantilever is in direct contact with the ASL surface at contact mode-SPM. As the results, the adhesion and frictional forces are different before and after contact mode-SPM.

P05-09
Atom-based Pitch and Length Standards, Kai Li, Namboodiri Pradeep, Joseph Fu, Richard Silver, NIST

The main focus of this work is developing methods to fabricate structures on the near atomic scale whose dimensions can be traced directly to the intrinsic crystal lattice. The technique uses scanning tunneling microscope to produce atomically-resolved patterns and subsequently transferred into the substrate that serve as stable, atom-based standards.

Patterned media

P06-01
Magnetic domain wall motion in permalloy wires with nanometer-scaled notches, T. C. Chen, C. Y. Kuo, A. K. Mishra, J. C. Wu, National Changhua University of Education

P06-02
Magnetic patterning by oxygen reduction using low energy Helium irradiation, Zhen Zheng, Long Chang, Paul Ruchhoeft, University Of Houston, Houston, Sakhrat Khizroev, University Of California, Dmitri Litvinov, University Of Houston

We introduce a technique of patterning magnetic nanostructure using low energy heilum irradiation. The approach uses low mas and energy helium ions to strike a non-magnetic oxidized metal layer, kicking oxygen out of the layer to turn particular area back to magnetic.

Nanophotonics

P07-01
Exploiting extreme coupling to realize a metamaterial perfect absorber (Invited), Uwe Huebner, Mario Ziegler, Institute of Photonic Technology (IPHT), Ekaterina Pshenay-Severin, Rasoul Alaee, Christoph Menzel, Carsten Rockstuhl, Thomas Pertsch, Friedrich-Schiller-Universität Jena

An optical metamaterial which uses the effect of extreme coupling between closely spaced nanostructured gold metal plates and a planar gold substrate was realized. The metamaterial shows the predicted effect of nearly perfect absorption with multiple resonances in the spectral range from 100 THz to 600 THz.

P07-02
Pronounced Effects of Anisotropy on Plasmonic Properties of Nanorings Fabricated by Electron Beam Lithography, Rachel Near, Georgia Institute of Technology, Christopher Tabor, Jinsong Duan, Ruth Pachter, Air Force Research Laboratory, Mostafa El-Sayed, Georgia Institute of Technology

Gold nanoring dimers were fabricated via EBL. The coupling between the inner and outer surfaces of a single nanoring renders it very sensitive to any anisotropy. We found that anisotropy in the particle geometry and anisotropy introduced by the substrate combine to create very unique spectral features in this system.

P07-03
Plasmonic Conductors for Organic Solar Cells, Fernando E. Camino, Chang-Yong Nam, Matthew Sfeir, Charles T. Black, Center for Functional Nanomaterials

Using FIB milling, we fabricated metal hole arrays (MHAs) on silver films with sub-wavelength hole sizes, and incorporated them as semi-transparent electrodes in P3HT:PCBM-based solar

cells. We observe increased light absorption and short-circuit current under illumination when the enhanced transmission peaks of the MHA match the organic blend's absorption range.

P07-04
SPR-based Surface-enhanced Raman Scattering for the Detection of Organophosphorus Pesticide, Jie-Hui Li, Tao Huang, Hong-Yan Dou, Xin-Ming Ji, The State Key Lab of ASIC and System

A novel surface plasmon resonance (SPR)-based SERS is proposed for OPs detection. The gold-plated photonic crystals (PCs) present the appealing characteristics of wide spectrum across visible and IR wave band are highly SERS sensitivity, while it barely requires sample and sample preparation.

P07-05
Nano-Rough Gold for Enhanced Raman Scattering, Jeonghwan Kim, Kyung-Nam Kang, Anirban Sarkar, Dooyoung Hah, Theda Daniels-Race, Martin Feldman, Louisiana State University

Conventional Raman scattering is a workhorse technique for detecting and identifying complex molecular samples. The presence of a nano-rough metallic surface enhances the scattered Raman light signal enormously. This paper reports a technique for obtaining nano-rough gold surfaces using simple apparatus and no lithographic steps.

P07-06
Surface-enhanced Raman Spectroscopy with monolithic, hierarchical nanoporous gold disk substrates, Ji Qi, Pratik Motwani, Mufaddal Gheewala, John Wolfe, Wei-Chuan Shih, University of Houston

We present monolithic, hierarchical nanoporous gold thin films and disks as surface-enhanced Raman scattering (SERS) substrates for molecular sensing. Localized surface plasmon resonance (LSPR) effect can boost the Raman scattering, resulting in an enhancement factor of ~0.5 million and 100 million for thin films and disks, respectively.

P07-07
Infrared nanophotonics based on indium-tin-oxide nanorod array, Shi-Qiang Li, Peijun Guo, Robert Chang, Northwestern University, Leonidas Ocola, Argonne National Laboratory

Nanofabrication, along with simulation, was used to study ITO nanorod array with different lattices. The arrays were optimized so that the coupling of photonic and plasmonic modes was observed. This has demonstrated a versatile platform to design and fabricate desired structures for nanophotonics.

P07-08
Triggering and monitoring plasmon enhanced reactions by optical nanoantennas coupled to photocatalytic beads, Adam Schwartzberg, Wei Bao, Alexander Weber-Bargioni, Stefano Cabrini, Lawrence Berkeley National Labs, Marco Salmistraro, Laura Depero, Ivano Alessandri, University of Brescia

Plasmonic Bow-tie antennas have been fabricated onto micron-sized beads with catalytic activity. Strong plasmon enhancement of photodegredation has been observed by using the plasmon enhanced Raman signal from the analyte.

P07-09
2D and 3D Plasmonic Nanostars for Bio-sensing Applications - Single Molecule Detection, M. Chirumamilla[a,b*], A. Toma[a], G. Das[a], A. Gopalakrishnan[a,b], R. Proetti Zaccaria[a], F. De Angelis[a] and E. Di Fabrizio[a,] [a]Istituto Italiano di Tecnologia, [b]Università degli Studi di Genova,

Nanostars are complex plasmonics nanostructures, where the central core and petal parameters are the main factors which determine the LSPR in the nanostar. Plasmonic Au nanostars offer great potential for biomedical application due to their biocompatibility and plasmon tunability over visible and near IR region.

P07-10
Tapered hyperbolic metamaterials for broadband absorption, Alex Kaplan, Jing Zhou, Lingjie Guo, University of Michigan

Structured hyperbolic metamaterials can lead to a variety of interesting applications such as hyperlensing due to their unique and broadband optical properties. This work demonstrates the fabrication and analysis of tapered hyperbolic metamaterial nanostructures in order to achieve strong absorption over a broad range of wavelengths.

P07-11
Advances on e-beam fabrication of photonic crystal membranes, Jon Olav Grepstad, NTNU, MiNaLab, Thomas Reisinger, and Bodil Holst, UiB, Norway

A new fabrication technique is presented for making free-standing dielectric 2D photonic crystal membranes. E-beam lithography was done directly on free-standing membranes, to form a quadratic 490 nm lattice of 220 nm diameter through holes. Fabricated membranes were investigated with SEM and optically characterized for light in the visible range.

P07-12
Enhanced up-conversion luminescence in a microtubular optical resonator, Jing Zhang, Jiao Wang, Yangfu Fang, Jian Zhong, Gaoshan Huang, Xugao Cui, Yongfeng Mei, Fudan University

Considering the weak efficiency of up-conversion in thin films and the optical resonance modes in microtubes,in this work, we focus on the realization of up-conversion in thin Y2O3:Er3+/Yb3+ films and enhance the luminescence intensity by coupling Y2O3:Er3+/Yb3+ fluorescence with optical resonance modes in microtubes.

P07-13
A Light-driven Micro-motor Based on Angular Momentum Transfer through Subwavelength Grating Waveplates, Zhouyang Zhu, Wen-Di Li, The University of Hong Kong, Haixiong Ge, Nanjing Univ., Wei Wu, Univ. of Southern California,

We propose a light-driven micro-motor by using subwavelength gratings to convert angular momentum from incident light into mechanic torque on a rotor. Fabrication and characterization is ongoing to demonstrate such a device. Applications in micro/nanofluidic study and bio-medical devices can be explored using this device.

Directed Self Assembly/Self Assembly

P08-01
Defectivity and uniformity evaluation of block copolymer directed self-assembly for contact hole shrink 300mm-process, Maxime Argoud, Raluca Tiron, Ahmed Gharbi, Patricia Pimenta-Barros, Marc Sanche, Sebastien Barnola, Laurent Pain, CEA-LETI, Xavier Chevalier, Christophe Navarro, Arkema, Guillaume Fleury, Georges Hadziioannou, LCPO UMR 5629

The main goal of this paper is to investigate the defectivity and the uniformity related with a contact hole shrink 300mm-process. Using the 300mm pilot line available in LETI and Arkema's materials, our approach is based on the graphoepitaxy of PS-b-PMMA block copolymers.

P08-02
Patterning of Nanoparticles Using Electric Field Assisted Coffee Ring Effect, Jinhua Mu, Qiangfei Xia, University of Massachusetts, Amherst

We report the patterning of concentric rings of metal, dielectric, and polymer nanoparticles using electric field modulated coffee ring effect.

P08-03
PS-b-PHEMA: A Promising High χ Polymer for Directed Self-Assembly Lithography, Jing Cheng, Richard Lawson, Wei-Ming Yeh, Nathan Jarnagin, Laren M. Tolbert, Clifford L. Henderson, Georgia Institute of Technology

In this paper, poly(styrene)-b-poly(hydroxyethylmethacrylate), PS-b-PHEMA, will be discussed as a candidate for replacing PS-b-PMMA in DSA lithography. It will be shown that PS-b-PHEMA possesses a χ value greater than 0.35, can be thermally annealed, and is easily capable of producing grating patterns with pitches on the order of 10nm.

P08-04
Controlling the Morphology of Silver Nanoparticle Films formed by Laser-induced Deposition from Liquids, Carlos A. Jarro, Matthew Bresin, J. Todd Hastings, University of Kentucky

A thin coating of APTES dramatically improves the density of silver nanoparticle films deposited on glass by laser induced deposition from liquids. Additionally the deposit's structure varies dramatically with illumination intensity. Increased density and structural control could be important for direct material patterning, deposition of Ag seeds, SPR, and SERS.

P08-05
Pattern Transfer from Directed PS-b-PMMA Films with Sub-25 nm Full Pitch, Lei Wan, Ricardo Ruiz, Yves-Andre Chapuis, He Gao, Kanaiyalal Patel, Thomas Albrecht, HGST-a Western Digital Company, Yi Cao, Jian Yin, SungEun Hong, Guanyang Lin, AZ Electronic Materials

We explore different pattern transfer methods from lamellae-forming PS-b-PMMA block copolymers with sub-25 nm full pitch. Regular lift-off, dry lift-off, atomic layer deposition (ALD), and direct etching using hard mask have been investigated and compared. Our results suggest that pattern transfer is the most critical step for pattern perfection.

P08-06
Directly-Photodefinable Guiding Layers: Enabling Simple 3-Step DSA Processes for Lithographic Patterning, Jing Cheng, Richard Lawson, Wei-Ming Yeh, Nathan Jarnagin, Laren Tolbert, Clifford L. Henderson, Georgia Institute of Technology

In this paper, recent progress in designing and optimizing photodefinable guiding layers for directed self-assembly lithography will be reviewed. The properties of layers designed for guiding PS-b-PMMA in particular will be reviewed and the prospects for such designs in other block copolymers will be discussed.

Electron Beams

P09-01
Mm^2 size arrays of metal nano-particles for solar cell applications fabricated by Electron Beam Lithography (EBL), Martin Greve, Bodil Holst, University of Bergen, Phil Denby, EnSol A/S

We have fabricated large arrays of metal nanoparticles using electron beam lithography for investigating the optical properties for solar cell applications.

P09-02
Print based estimation of probe size distribution in electron beam lithography, Ananthan Raghunathan, John Hartley, State University of New York at Albany

A new method of characterizing the probe shape in electron beam lithography is presented by analyzing features printed on resist. By accurately modeling the point spread function in the sub-100 nm regime including secondary electrons, the spot size distribution can be de-convolved from the experimental data.

P09-03
Low line edge roughness patterning with Character Projection EB Lithography for Photonic Devices, Masaki Kurokawa, Masahiro Takizawa, Shin-ichi Hamaguchi, Akio Yamada, Kiichi Sakamoto, Takayuki Nakamura, Advantest Corp.

In this paper we introduce a comprehensive data processing system of Character Projection electron beam writer for low Line Edge Roughness patterning of Photonic devices. And some optical parameters of photonic devices fabricated by this method will be reported.

P09-04
A Multiple electron beam wafer inspection system design using permanent magnetic lens arrays, Tao Luo, Consultant, Anjam Khursheed, National University of Singapore

This paper presents a multiple-electron-beam inspection technique using permanent magnetic lens arrays for wafer inspection purposes. It provides high resolution capability (~3nm), uniform performance across the whole wafer, symmetric field of each lens system, and focusing adjustability for a wide range of landing energy and extraction field.

P09-05
Small-Pitch Electron Diffraction Holograms Patterned on Inorganic Resist with Electron Beam Lithography, Tyler Harvey, Benjamin McMorran, Gii Brougher, Kurt Langworthy, University of Oregon

We demonstrate electron diffraction through 20 nanometer pitch gratings. To produce intense, well-separated, nanometer-sized beams for novel electron microscopy techniques, large, efficient, small-pitch gratings are necessary. We show that scaleable, efficient electron diffraction grating structures may be produced by electron beam lithography with negative inorganic resist on silicon nitride.

P09-06
Dependency Analysis of Line Edge Roughness in Electron-beam Lithography, Xinyu Zhao, Soo-Young Lee, Auburn University, Sanghee Lee, Byung-Gook Kim, Chan-Uk Jeon, Han-Ku Cho, Samsung

One of the major factors which contribute to line edge roughness (LER) in electron-beam (e-beam) lithography is the stochastic fluctuation of exposure (energy deposited in the resist). In this study, a 3-D model of substrate system is employed to thoroughly analyze the dependency of LER on various e-beam lithographic parameters.

P09-07
Analytic Model of Line Edge Roughness from Stochastic Exposure Distribution in Electron-beam Lithography, Rui Guo, S.-Y. Lee, Auburn University, S.-H. Lee, B.-G. Kim, C.-U. Jeon, H.-K. Cho, Samsung

While the simulation approach to estimating line edge roughness (LER) is flexible, it is computationally intensive. The objective of this study is to develop an analytic method for estimating the LER caused by the stochastic exposure distribution in the resist to avoid the repetitive time-consuming simulation.

P09-08
Synthesis of metal nanoparticles in polymeric films induced by electron beam, Hiroki Yamamoto, Takahiro Kozawa, Seiichi Tagawa, Osaka university, Jean-Louis Marignier, Mehran Mostafavi, Jacqueline Belloni, Université Paris-Sud

We succeeded in the formation of metal nanoparticles embedded in a polymeric film without additives using electron beam. Also, the elucidation of formation mechanism in polymeric films was investigated. Conditions have been found to radiolytically synthesize stable metal nanoparticles of silver or gold embedded in polymeric films.

P09-09
A Fast Path-based Method for 3-D Resist Development Simulation in Electron-beam Lithography, Qing Dai, Rui Guo, Soo-Young Lee, Auburn University, Sanghee Lee, Byung-Guk Kim, Chan-Uk Jeon, Han-Ku Cho, Samsung

A common drawback of the existing methods for simulating resist development process is a long computation time required especially for 3-D simulation. A fast path-based method for 3-D resist development simulation which avoids the time-consuming iterative computation required in the cell-removal method without sacrificing the simulation accuracy is proposed.

P09-10
Influence of EUV mask structure on electron trajectories, Susumu Iida, Tsuyoshi Amano, Ryoichi Hirano, Tsuneo Terasawa, Hidehiro Watanabe, EUVL Infrastructure Development Center,Inc.

Electrons injected in EUV reflective multi-layers (MLs) spread laterally along Si layer. This results in the spread of a generating area of secondary electrons as the injected energy increase. This result suggests that MLs can leads to the degradation of the image resolutions in electron microscopy technique.

P09-11
Fabrication of Gold Bowtie Nano-antenna by E-beam Lithography on Si3N4 Membrane for SERS, Jian Zhang, Mehrdad Irannejad, Bo Cui, University of Waterloo

Bowtie array with nano-gap is an ideal structure for SERS. It is challenging to fabricate nano-gap in EBL because of proximity effect. Here proximity effect is completely eliminated by coating the resist on a thin membrane. Gap with 6 nm was achieved, and SERS signal increased significantly for smaller gaps.

P09-12
Electron beam optimization using self-developing resist for large write-field electron beam lithography, Ripon Kumar Dey, Bo Cui, University Of Waterloo

Large write-field allows fast writing in electron beam lithography, but pattern at field corners is often poorly defined. Here we use self-developing resist to examine the pattern right after exposure for electron beam optimization, in order to achieve uniformly well-defined pattern across a large write-field of 1 mm^2.

P09-13
Write-field alignment optimization using self-developing electron beam resist, Ripon Kumar Dey, Bo Cui, University Of Waterloo

Large write-field allows fast writing in electron beam lithography, but write-field alignment accuracy decreases. Here we use self-developing resist to examine the alignment accuracy right after exposure and adjust the zoom factor and rotation accordingly, in order to minimize stitching error when using a large write-field of 1 mm^2.

P09-14
Dot-Matrix Marks for Dynamic Overlay Measurements in Electron Beam Lithography, Ernst Kratschmer, IBM Rsearch, James J. Bucchignano, David P. Klaus, Michael A. Guillorn, IBM Research

This presentation introduces a high resolution dot-matrix mark to measure spatially and time-resolved overlay in electron beam lithography. Mark design and analysis will be discussed along with sample applications.

P09-15
Hexagonal three-dimensional plasmonic nanoantenna arrays, X. X. Xia, Z. Liu, B. G. Quan, C. Z. Gu, J. J. Li, Institute of Physics.CAS

A series of hexagonal three dimensional gold nanoantenna arrays were fabricated. The optical responses of such nanoantenna arrays were systematic studied by varying the incidence polarization, geometry parameters of nanoantenna structure and dielectric-loads. It would improve the manipulation ability of nanoantenna metamaterials with more freedom and flexibility.

Emerging Technologies

P10-01
Impact of pattern profile on surface plasmon polaritons in computational lithography, Sang-Kon Kim, Hanyang University

For the plasmonic nanolithography, the extraordinary optical transmission beyond the conventional diffraction limitations is observed in a metal film. In this study, plasmonic phenomenon is described in simulation with the basis of experiment. SPP effects on pattern formation inside resist will be discussed on basis of simulation results.

P10-02
Enhanced purity via laser assisted electron beam induced deposition of tungsten, Nicholas A. Roberts, Omniprobe, Inc. and University of Tennessee, Carlos M. Gonzalez, University of Tennessee, Jason D. Fowlkes, Oak Ridge National Lab, Cheryl. D. Hartfield, Omniprobe, Inc. and Oxford Instruments Company, Tom M. Moore, Omniprobe, Inc. and P.D. Rack, University of Tennessee, Oak Ridge National Laboratory

We demonstrate laser assisted electron beam induced deposition of tungsten. The laser assist method thermally desorbs non-volatile reaction by-products therefore producing a higher purity deposit. We show a resistivity improvement of four orders of magnitude with the best case being less than one order of magnitude higher than pure tungsten.

P10-03
Forward sputtering of thin films using focused helium ion beam, Peiyan Yang, Wen-Di Li, University of Hong Kong, Wei Wu, Univ. of Southern California

We numerically studied the forward sputtering behavior on thin films of typical materials under helium ion irradiation. These results will be useful for developing new techniques in high-resolution nanofabrication and material modification applications.

P10-04
In-situ Microfluidics using a Liquid Injector for the Study of Beam Induced and Dynamic Processes, Aurelien Botman, Steven Randolph, FEI Company

Using our Liquid Injector System, we are able to deliver, position and perform experiments with micron-sized drops of liquid in vacuum environments while scanning with the electron beam. This allows the study of beam induced and dynamic processes in situ.

P10-05
Changing to TiOx Based Nanostructured Catalyst Support Materials for PEM Fuel Cells Utilizing ALD and PEALD, Richard Phillips, Robin Hansen, Alexander O'Toole, Xiaoli He, Robert Geer, Eric Eisenbraun, University at Albany

The utilization of high aspect ratio nanostructures as catalyst supports for fuel cells. Materials are manufactured using atomic layer deposition (ALD) and plasma enhanced ALD over anodic aluminum oxide (AAO) and silicon nanowire templates.

Carbon-based devices/systems

P11-01
Analysis and understanding the regrowth of Multi-walled carbon nanotube forests, Daewoong Jung, Donghyun Kim, Gil Sik Lee, The University of Texas at Dallas

Here we show how MWCNT forests grow on the spin-capable forest substrate in a regrowth process. the diameter and chirality of a CNT forest are preserved when a secondary CNT forest is grown on the same substrate in a regrowth process.

P11-02
Effect of thickness of the catalyst film and the hydrogen gas on the spin-capability of a MWCNT forest, Daewoong Jung, Donghyun Kim, Gil Sik Lee, The University of Texas at Dallas

The growth of spin-capable MWCNT forests will be achieved through the understanding of the important factors affecting the forest growth: the catalyst thickness and the hydrogen, since the precise conditions necessary for effective spin-capability are extremely sensitive. These factors were investigated in order to develop reliable spin-capable MWCNT growth process.

P11-03
Tracking the Movement of Carbon Nanotubes during Dielectrophoretic Deposition, Ali Kashefian Naieni, Alireza Nojeh, University of British Columbia

Dielectrophoresis is a powerful method for the fabrication of a wide variety of carbon nanotube devices. Using particle-tracing simulations, we study the movement of semiconducting and metallic CNTs in aqueous solutions with low conductivity for various situations during dielectrophoresis.

P11-04
Correlation between Electron-Irradiation Effect and Stress in Carbon Nanotubes: Molecular Dynamics Study, Yoshinori Chihara, Masaaki Yasuda, Hiroaki Kawata, Yoshihiko Hirai, Osaka Prefecture University, Kazuhiro Tada, Toyama National College of Technology

We study the electron-irradiation effects in carbon nanotubes under tension or torsion stress with a molecular dynamics simulation. From the present study, it is found that the applied stress is one of the important parameters to control the structural change in carbon nanotubes by electron irradiation.

P11-05
Control of carbon nanofibers configuration on glassy carbon by two-step ion beam irradiation method, Jun Taniguchi, Yuki Konno, Tokyo University of Science

Carbon nano-fibers were formed using a two-step ion beam irradiation method at room temperature. First, oxygen ion beam irradiates to glassy carbon (GC) substrate and making the

nano-scale conical structures. After that, argon ion beam irradiates to this sample by oblique angle, and then, CNFs are formed on GC surface.

P11-06
Laser Induced Structural Damage to Multi-walled Carbon Nanotubes in a Controlled-Pressure Environment, Amir Khoshaman, Mike Chang, Alireza Nojeh, University of British Columbia

Carbon nanotubes (CNT) are among one of the most prominent candidates for electron sources. To use CNT-based electron sources in practice, their structural stability during emission must be studied. In this work, the issue of stability of CNTs and their structural integrity in the thermionic emission regime is investigated.

P11-07
Fabrication of hundreds of field effect transistors on a single carbon nanotube for basic studies and molecular devices, X. Zhang, D. Chenet, B. Kim, J. Yu, C. Nuckolls, J. Hone, Columbia University

P11-08
High Temperature Gradient in a Conductor: Carbon Nanotube Forest under the "Heat Trap" Condition, Mike Chang, Mehran Vahdani Moghaddam, Amir Khoshaman, Masoud Dahmardeh, Kenichi Takahata, Alireza Nojeh, University of British Columbia, Mohamed Sultan Mohamed Ali, Universiti Teknologi Malaysia

A large temperature gradient(1200 K/mm) is achieved along the sidewall of carbon nanotube (CNT) forest by visible-line laser irradiation with intensity of 19.1 W/mm^2. This "Heat Trap" effect observed on CNT forests suggests an potential alternative for thermoelectric devices other than PGEC materials.

P11-09
Nano-structure Modified Thin-Film Paper Energy Storage Device, Naga Korivi, Manisha Vangari, Li Jiang, Tuskegee University

A novel paper thin-film supercapacitor is reported here with electrodes made of carbon paper surfaces modified by a unique combination of active nano-structered materials. The developed device is an improvement over similar devices which show comparable electrical performance, but have larger total weight and thickness than our device.

P11-10
Study of optical anisotropy property to rapidly characterize structural qualities of CVD prepared graphene films, Yu-Lun Liu, Chen-Chieh Yu, Cheng-Yi Fang, Tai-Chi Yang, Hsuen-Li Chen, Cheng-Kai Chang, Li-Chyong Chen, Kuei-Hsien Chen, National Taiwan University

In this study, we find that the optical anisotropy of graphene films could be used as an alternative quality factor for the rapid characterization of large-area graphene films prepared through chemical vapor deposition (CVD).

P11-11
Graphene-based Broadband THz Modulators, Haidong Zhang, Ye Shao, The Ohio State University, Hyowook Kim, K. Santhakumar, Gwangju Institute of Science and Technology, Charles Tu, Gwangju Institute of Science and Technology; University of California at San Diego, Wu Lu, The Ohio State University;

We demonstrate electrically controlled graphene-based optical wide band modulators from 100 GHz to 1.5 THz at room temperature. The modulation depth, or relative transmission change, reached about ~ 20% for single layer graphene devices.

P11-12
High yield fabrication of graphene resonators array with poly-Si sacrificial layer, Tao Chen, Enrico Mastropaolo, Andrew Bunting, Rebecca Cheung, University of Edinburgh

This paper demonstrates the possibility of using poly-Si as a sacrificial layer for graphene resonator fabrication, giving a yield of over 95%, since poly-Si can be removed in gaseous phase by XeF_2, which avoids the surface tension induced damage during the drying period of wet release

P11-13
A Model for Nano-manufactured Electrodes utilizing Vertical Carbon Nanotubes, Alokik Kanwal*, Ross Cohen*, Ali Mustafa*, Stephanie Milczarski*, Gordon Thomas*, Zafer Iqbal*,**, Reginald Farrow*, *New Jersey Institute of Technology, **Carbomet

Devices based on vertical nanotubes and fabricated by electrophoresis have shown great promise as single cell bio probes. The devices exploit vertical nanotube (1.2nm diameter) inside 30-40nm windows. Here we present a model for this unique geometry to help explain the conduction and operation of the bio probe devices.

Nanoelectronics

P12-01
Fabrication of Electronic Fabry-Perot Interferometer in the Quantum Hall Regime, Sanghun An, Simas Glinskis, Woowon Kang, Leonidas E. Ocola, Loren Pfeiffer, Ken West, Kirk Baldwin, Princeton University

Fabrication and experimental study of Fabry-Perot interferometer in the quantum Hall regime is reported. High quality Fabry-Perot interferometers are fabricated via e-beam lithography, dry etching, and metallization. The data demonstrates quantum interference of electrons in the quantum Hall regime.

P12-02
Structural properties and electroforming-free resistive switching characteristics of Nd_2O_3, Dy_2O_3 and Er_2O_3 memory devices fabricated in full room temperature, Ching-Hao Chueh, Chih-Hung Lu, Jim-Long Her, Tung-Ming Pan, Chang Gung University, Yasuhiro H. Matsuda, The University of Tokyo

In this study, we reported the electroforming-free resistive switching behavior in the $Ru/RE_2O_3/TaN$ (RE=Nd, Dy and Er) memory devices using thin Nd_2O_3, Dy_2O_3 and Er_2O_3 films

fabricated with full room temperature process. The dominant conduction mechanisms of the Ru/RE2O3/TaN devices in the low-resistance state and high-resistance state are Ohmic behavior.

P12-03
Fabrication of p-type Silicon Nanowires for 3D FETs Using Focused Ion Beam, Marcos Vinicius Puydinger dos Santos, José Alexandre Diniz, José Godoy Filho, University of Campinas

Focused Ion Beam (FIB) system have been used for sub-32 nm and 3D devices, such as FinFETs and Si nanowire. In this work, a FEI Nova 200 NanoLab FIB system was used for local Gallium doping and Silicon nanowire (SiNW) fabrication on SOI wafer for 3D FETs.

P12-04
Crossbar Arrays of Sub-10 nm Memristive Devices Fabricated with Nanoimprint Lithography, Shuang Pi, Peng Lin, Qiangfei Xia, University of Massachusetts

We present crossbar arrays of memristive devices with sub-10 nm feature sizes fabricated by using NIL. Operation current of 600 pA with low power consumption was demonstrated with 8 nm device, which also displayed fast switching speed and improved performance repeatability. Smaller devices are also promised with this method.

P12-05
Continuous and Scalable Fabrication of Functional films via Vibrational Indentation Patterning and Photo Roll Lithography, Jong G. Ok, Kyu-Tae Lee, Chad Huard, Jae Yong Lee, L. Jay Guo, University of Michigan, Se Hyun Ahn, Molecular Imprints, Inc., Moon Kyu Kwak, Kyungpook National University

We utilize the template-free and continuous patterning techniques named Vibrational Indentation-driven Patterning (VIP) and Photo-Roll Lithography (PRL) to the high-throughput fabrication of functional nanoelectronics films. First we demonstrate flexible metal wire-grid polarizers using VIP-fabricated blazed gratings. Then we present transparent conductors by PRL patterning of metal meshes on transparent substrates.

P12-06
Low Temperature Electrical and Optical Characterization of Lithographically-Defined Au Microchannels on an Elastomeric Substrate, Firouzeh Sabri, R. Wilson, University of Memphis

The low temperature behavior of Au-PDMS bilayer system with lithographically-defined channels has been investigated. both the optical and electrical behavior of the system was monitored as the substrate temeprature was lowered and the non-linearity of the electrical reposnse calibrated. The interference pattern of the surface layer was also investigated.

P12-07
Electromagnetically Induced Transparency in Au:VO2 Nanoparticles, Christina McGahan, Kannatassen Appavoo, Richard Haglund, Vanderbilt University, Ethan Shapera, Cambridge University

Lithographically prepared Au nanoparticles on a phase-changing material (VO_2) demonstrate tunable electromagnetically induced transparency.

P12-08
Low-power Resistive Switching in Ultra-smooth Native AlOx Thin Films Fabricated by Template Stripping, Hao Jiang, Peng Lin, Qiangfei Xia, University of Massachusetts

Memristive devices based on ultra-smooth native AlOx were fabricated by template stripping. The fabrication process had high device yield nearly 100%. The devices exhibited repeatable switching behavior with high ON/OFF ratio (10E7) and low power consumption.

P12-09
Ultralow Voltage Resistive Switching in Ultrathin Silicon Oxide, Can Li, Hao Jiang, Qiangfei Xia, University of Massachusetts

We report SiOx based nonvolatile memristive devices that exhibited with ultralow programming voltages (<0.5 V) and ultra-high ON/OFF conductance ratio (>108). Each device consists of a heavily doped silicon bottom electrode, a ~1 nm thick SiOx switching layer that was produced in wet chemical processes and a top metal electrode.

P12-10
Fabrication of organic MESFET device by dual-layer thermal nanoimprint, Yunbum Jung, Xing Cheng, Texas A&M University

We present the patterning of spatially self-aligned two-metal patterns on top of organic semiconductor based on dual-layer thermal nanoimprint. This technique enables non-destructive high-resolution metal patterning on top of organic semiconductors without shadow masks. The technique is ideal for fabricating high-performance short-channel organic MESFET devices for organic integrated circuits.

Nanobiology

P13-01
The five whys (and one h) of super hydrophobic surfaces in medicine (Invited), Francesco Gentile, Enzo Di Fabrizio, University Magna Graecia of Catanzaro

Super hydrophobic surfaces (SHSs) are artificial, micro- or nano- fabricated surfaces, with a texture given by a regular lattice of cylindrical pillars. The most practical property of SHSs is a reduced friction coefficient. Here we show how this property can be utilized for the detection of few bio molecules.

P13-02
Approach to an on-chip 3D neural-network in a hydrogel based bioreactor, Bart Schurink, Regina Luttge, University of Twente

A novel biomimetic based brain analog for in-vivo like neural cell culture with electrophysiological and biochemical read-outs is presented. We propose a PDMS-hydrogel bioreactor for 3D cell culture on top of a MEMS fabricated multi-electrode array as a solution to advanced brain models.

P13-03
Electro-Active Single Mode Integrated Optical Waveguide Application in Spectroelectrochemistry, Xue Han, Sergio Mendes, University of Louisville

Electro-active single mode integrated optical waveguide was applied for spectroelectrochemistry. Because it has extreme high sensitivity and doesn't affected by double layer capacitance, like current signal, sub-monolayer surface coverage of redox species can be detected easily.

P13-04
Roll-to-Roll Hot Embossing of Micron and Nanoscale Structures for the Fabrication of Plastic Devices, G.Kreindl, M. Chouiki, C. Thanner, C.A de Coulomb, EVGroup, J.Dumond, Hong Yee Low, Ong Kian Soo, Institute of Materials Research & Engineering

P13-05
Cryogenic imaging of biological specimens using Helium Ion Microscope, Jing Gu, D.S. Pickard, National University Of Singapore

This paper introduces the recent imaging result of biological specimen using cryostage-installed Helium Ion Microscope(HIM) while their hydrated state is maintained. The advantages of HIM including high resolution and charge neutralization are therefore applicable to produce reliable and faithful images of biological ultrastructures.

P13-06
An Innovative EBL Writing Strategy for High Speed and Precision Lithography of Large Circle Arrays for Microfiltration and Photonics in Solar Cells, Kevin E. Burcham, Jason E. Sanabia, Michael Kahl, Axel Rudzinski, Raith, Markus Fleger, Oliver Humbach, temicon GmbH

Nanosieves for microfiltration and photonics in solar cells both require large circle arrays covering several square inches. We present and discuss the differences between two EBL patterning modes: conventional stitching EBL and a new and unique “stitch-error-free” EBL writing strategy called MBMS.

P13-07
Bifunctional Nanoarrays for Probing the Immune Response at the Single-Molecule Level, Haogang Cai, Matteo Palma, Haguy Wolfenson, Michael Sheetz, Michael Dustin, Shalom Wind, Columbia University, David Depoil, New York University

To probe the geometric factors that affect T-cell response, we have created bifunctional nanoarrays created by molecular-scale nanolithography and site-selective biochemical assembly. T-lymphocytes are presented with individual T-cell receptor ligands surrounded by costimulatory adhesion molecules. Cellular response is shown to be a function of the geometric arrangement of these ligands.

P13-08
Large scale fabrication scheme for all-polymer multilevel nano-microfluidic Lab-on-Chip (LoC) systems: the PolyNano approach, Marco Matteucci, Simone Tanzi, Peter F. Østergaard, Simon T. Larsen, Rafael Taboryski, Technical University of Denmark

We here present an all-polymer Lab-on-Chip fabrication method that involves silicon dry etching, electroplating, injection molding and thermal bonding. Such methodology is the base of

the PolyNano initiative at DTU Nanotech. Applications in the fields of cell and DNA analysis based on such methodology will also be presented.

P13-09
Influence of Engineered Surface on Cell Motility and Directionality, Q. Y. Tang, W. Y. Tong, Y. W. Lam, P. Shi, S. W. Pang, City University of Hong Kong

In this paper, patterned structure polydimethylsiloxane (PDMS) was applied as the engineered substrate for cell culturing. The effects of groove width, depth, shapes, and surface energy on cell motility and directionality were investigated. Cells seeded on the patterned area moved faster and changed their positions along the patterns.

P13-10
Application of EBL fabricated nanostructured substrates for SERS detection of protein A in aqueous solution, Luis Gutierrez-Rivera, Robert F. Peters, Steven K. Dew, Maria Stepanova, University of Alberta, National Institute for Nanotechnology NRC.

Surface enhanced Raman spectroscopy (SERS) allows capturing of vibration signatures of molecules adsorbed on metal nanostructures. Arrays of gold nano-dots with pitches from 50 nm and different inter-dot gaps were fabricated on dielectric substrates by electron-beam lithography. These arrays were bio-functionalized and used to obtain SERS spectra of protein A.

P13-11
Microfilters with Nanotopography for Isolation of Circulating Tumor Cell from Blood, Olga Makarova, Daniel Adams, Peixuan Zhu, Shuhong Li, Platte Amstutz, Cha-Mei Tang, Creatv MicroTech Inc., Ralu Divan, Daniel Rosenmann, Argonne National Laboratory

The efficiency of cancer cell capture can be increased by introducing nanoscale topography. AAO is fabricated directly on the filter and serves as an etching template to create surface reliefs using reactive ion etching. The utility of the microfilters is evaluated using cancer cell lines spiked into normal human blood.

Nanoimprint

P14-01
Fabrication of Polymer Structures with Undercuts by Reverse Imprint Lithography (Invited), Andreas Finn, Andreas Jahn, Sebastian Killge, Carsten Werner, Wolf-Joachim Fischer, Technische Universität Dresden, René Hensel, Leibniz Institute of Polymer Research Dresden, Institute of Semiconductors and Microsystems,

We produced polymer membranes to mimic the omniphobic wetting resistance of collembola springtails.

P14-02
The Effect of Improved Hardness using Polyurethane Acrylate in Replica Mold for Substrate Conformal Imprint Lithography, Geehong Kim, Hyungjun Lim, Jaejong Lee, Keebong Choi, SungWhi Lee, Korea Institute of Machinery and Materials

This paper shows an alternative replica fabrication method for substrate conformal imprint lithography. It uses polyurethane acrylate for the first pattern layer and controls the solidification state of polyurethane acrylate by adjusting exposure time. We can expect better results by using this harder replica mold in SCIL process.

P14-03
Evaluation of fluorine additive segregation in UV nanoimprint resin by X-ray photoelectron spectroscopy, Takahiro Oyama, Makoto Okada, Shuso Iyoshi, Yuichi Haruyama, Shinji Matsui, Univ. of Hyogo, JST-CREST, Hiroto Miyake, Tomoya Mizuta, Daicel Co., LTD

Recently, it has been shown that the additive of fluorine compounds to UV nanoimprint resin maintains the low surface energy. This phenomenon is induced by fluorine compounds segregation. In this work, we evaluated the fluorine additive segregation in UV nanoimprint resin by X-ray photoelectron spectroscopy.

P14-04
Replication of NIL Stamps by Metal-Assisted Chemical Etching of Silicon, Mohammad Tarequzzaman, Mariusz Graczyk, Anders Kvennefors, Ivan Maximov, Lund University

We report application of a metal-assisted chemical etching of Si for fabrication of nanoimprint stamps. The process is used for replication of "master" stamps with high fidelity.

P14-05
Au split-ring resonator arrays responsive to a magnetic field in a visible frequency region fabricated by UV nanoimprint lithography, Masaru Nakagawa, Takuya Uehara, Tatsuya Tomioka, Shoichi Kubo, Masaru Nakagawa Tohoku Univ., Morihisa Hoga, DNP

We fabricated Au split-ring resonator (SRR) arrays by UV nanoimprint lithography. Au-plated substrates modified with the hydroxyl-terminus monolayer allowed the coating of thin UV-curable resin film containing hydroxyl groups. We demonstrate optical properties of the SRR arrays in a visible frequency region and the multiple patterning in a step-and-repeat manner.

P14-06
Planarized Ag Nanopattern Array for Plasmonic Resonance-driven Electroluminescence Enhancement, Chul-Hyun Kim, Sang-Kuen Sung, Joo-Yeon Jung, Ji-Hye Lee, Jun-Ho Jeong, Jun-Hyuk Choi, Eung-Sug Lee, KIMM

This work will present cost-effective advanced fabrication strategies to realize the planarized plasmonic nanopattern array via (1) bilayer resist system and hybrid nanoimprint approach, and (2) Imprint transfer lithography for the emission enhancement in optoelectronic applications.

P14-07
Polymer filling behaviors with imprinting velocity in NIL, JiHyeong Ryu, University of Science and Technology, Sang-Ho Lee, Wonkwang University, HyungJun Lim, JaeJong Lee, Korea Institute of Machinery and Materials

As the imprint velocity increases, maximum polymer height increases by squeezing flow. Also, single or double peak shapes are remarkably appeared by changing the flow direction from the side to the center of the stamp. From the results of this study, it can be applied to analyze the flow characteristics.

P14-08
High-Throughput Transfer Imprinting for Organic Semiconductor, Xing Cheng, Gihoon Choo, Texas A&M

Nanoimprint-based transfer imprinting of organic semiconductor is reported in this work. This technique enables residual-layer-free patterning of organic semiconductors without mold contamination. The transfer imprinting technique is amenable to roll-to-roll process for high-throughput patterning of organic semiconductors for low-cost organic electronic applications.

P14-09
A novel route for fabricating Printable Photonic Devices with a high refractive index, Carlos Pina Hernandez, Giuseppe Calafiore, Christophe Peroz, aBeam Tech, Alexander Polyakov, Valeria Lacatena, Scott Dhuey, Stefano Cabrini, LBNL

A novel process for printing sub-10 nm photonic structures with high refractive index. The technology is suitable for fabricating printable photonic devices.

P14-10
Exceptional Thermal Stability of Thermoplastic Polymer Nanostructures Patterned by Nanoimprint, Xing Cheng, Youwei Jiang, Texas A&M University

Thermoplastic polymer micro- and nanostructures patterned by nanoimprint suffer pattern decay when heated to a temperature close to or above the polymer's glass transition temperature. In this work, we report the observation of unexpected thermal stability of polycarbonate nanostructures at temperatures well above its glass transition temperature.

P14-11
Free-standing filaments in thermal nanoimprint induced by pre-filling, Andre Mayer, Marc Papenheim, Khalid Dhima, Si Wang, Saskia Möllenbeck, Hella-Christin Scheer, University of Wuppertal, Konrad Vogelsang, Christian Spreu, Helmut Schift, Paul Scherrer Institut

Typically, a gap between the polymer and the stamp during nanoimprint leads to physical self-assembly. Within this work we present a way how to create free standing filaments under such conditions. The physics as well as the impact of different equipment and different materials will be discussed.

P14-12
Reflow minimization via viscosity control by exposure, Khalid Dhima, Andre Mayer, Si Wang, Hella-Christin Scheer, University of Wuppertal

Our goal is to perform hybrid lithography with alignment, which ultimately requires the conventional order hybrid lithography process. Therefore this study focuses on the optimization of the post exposure bake to minimize standing wave effects and also to avoid reflow. This is performed by viscosity control via exposure.

P14-13
Underestimated impact of instabilities with nanoimprint, Andre Mayer, Khalid Dhima, Si Wang, Christian Steinberg, Marc Papenheim, Hella-Christin Scheer, University of Wuppertal

In nanoimprint, instabilities give rise to a strong re-arrangement of the polymeric layer under the action of surface tension. When such effects occur before the actual imprint, the imprint suffers

from an initially non-uniform polymer supply, though starting from spin-coated layers. The results suggest a re-consideration of the imprint procedure.

P14-14
Selective Patterning of Fluorinated Self-assembled Monolayer by UV Nanoimprinting for Directed Self-Assembly, Hitomi Wakaba, Makoto Okada, Syuso Iyoshi, Yuichi Haruyama, Shinji Matsui, University of Hyogo,JST-CREST

We proposed the new fabrication method of chemically pre-patterned fluorinated self-assembled monolayer (F-SAM) by lift-off process using UV nanoimprint. And, we observed F-SAM pattern in the topographic and friction images. The result indicates that selective patterning of F-SAM by UV nanoimprinting was succeeded.

P14-15
Effect of toluene treatment on PDMS molding into nanoholes, Celal Con, Jian Zhang, Bo Cui, University of Waterloo

Previous studies show that filling PDMS into patterns on anti-adhesion treated master mold was improved by diluting PDMS with toluene, and this was attributed to the reduction of viscosity. Here we show that toluene facilitates PMDS filling because it modifies the surface energy and wetting properties of the master mold.

P14-16
Dual scale controlled surface roughness by wrinkling of polymer imprints, Hyun Wook Ro, Jung-Hyun Lee, Lemaillet Paul, Germer Thomas, Christopher Soles, Christopher Stafford, NIST, Huang Rui, University of Texas

Duak length scale hierarchical surface patterns are demonstrated utilizing surface wrinkling of nanoscale 1-D grating polymer patterns. The precise control of the characteristics of the dual length scale patterns and a quantitative description of the observed wrinkling behavior using a composite model will be presented in a great detail.

P14-17
Selective Edge Lithography for Fabricating Imprint Mold with Nano Size and Large Size Mixed Patterns, Hayato Noma, Jyunji Sakamoto, Hiroaki Kawata, Masaaki Yasuda, Yoshihiko Hirai, Osaka Prefecture University/JST CREST

The selective edge lithography process for fabricating nano size and large size mixed patterns is developed. It is shown that both the micron size and nano size mixed patterns and the submicron size and nano size mixed patterns are successfully fabricated by using the new edge lithography process.

P14-18
Nanopatterned micromechanical elements by polymer injection molding with hybrid molds, Helmut Schift, Paul Scherrer Institut (PSI), Prabitha Urwyler, University of Basel

We present two examples of polymer micromechanical elements with integrated surface structures, in which hybrid molds for injection molding were used. They exhibit combinations of optical or biological functionalities combined with mechanical properties.

P14-19
Three dimensional hologram-ROM duplication by UV-NIL, Noriyuki Unno, Shuhei Yoshida, Hideki Akamatsu, Manabu Yamamoto, Shin-ichi Satake, Jun Taniguchi, Tokyo University of Science

Since the data size of pictures and videos has been increasing every year, a strong need exists for high speed and large capacity read only memory (ROM). We demonstrate computer generated hologram ROM duplication by ultra violet NIL via a three-dimensional master mold, which is fabricated by electron beam lithography.

P14-20
Novel nanofabrication method to achieve high aspect ratio metallic patterns by thermal nanoimprint lithography, Nerea Alayo, Jordi Llobet, IMB-CNM.CSIC, Xavier Borrisé, ICN-CIN2, Francesc Perez-Murano, IMB-CNM.CSIC

A novel fabrication process is presented to obtain high aspect ratio metallic nanostructures by thermal-NIL. This method overcomes the current difficulties related to residual layer removal and the lift-off after the nanoimprint lithography. The method will enable the fabrication of multilayer stacks consisting of customized materials deposited by sputtering.

P14-21
An investigation into the role of self-assembled monolayers of silane in UV nano-imprint lithography, Alborz Amirsadeghi, Sunggook Park, Louisiana State University, Jae Jong Lee, Korea Institute of Machinery and Materials

On a flat surface application of silane reduces the de-bonding energy in nano-imprint lithography due to a decreased surface energy. When vertical sidewalls are present, silane is significantly more effective to reduce de-bonding energy due to also a decreased friction coefficient. Longer silanes reduce surface energy and friction coefficient more.

P14-22
Pre-hardening Ultraviolet nanoimprint lithography using opaque mold, Jun Taniguchi, Tokyo Yuya Kaichi, Tokyo University of Science

We have established novel NIL technique of pre-hardening UV-NIL. As a result, nano-scale patterns were successfully transferred without defects. This process is effective for opaque mold and substrate such as silicon mold. Usually, silicon mold uses for thermal cycle NIL, but pre-hardening UV-NIL is enable to use silicon mold.

P14-23
DWDM laser arrays fabricated using thermal nanoimprint lithography on Indium Phosphide substrates, Kristian Smistrup, Jesper Nørregaard, Andrej Mironov, Tobias Hedegaard Bro, Brian Bilenberg, Theodor Nielsen, NIL Technology ApS, Anders Kristensen, Ole Hansen, Technical University of Denmark, S Rishton, F Khan, M Emanuel, Y Ma, Y Zhang, Neophotonics Corpo

DWDM lasers play a major role in long-haul broadband communication. Lasers are made single mode by including a lambda quarter shift at the center of the grating. Typically, these lasers are produced EBL. We present a production method based on nanoimprint lithography, which is potentially less costly and faster.

P14-24
2D Azobenzene Liquid-crystalline Polymer-based Switchable Photonic Crystals via Nanoimprint, Xinming Ji, Jie Hui Li, Hongyan Dou, Yanlei Yu, Fudan University

A novel two-dimensional photonic crystal (PC) contained azobenzene crosslinked liquid-crystalline polymers (CLCPs) was fabricated by using the nanoimprinting technique.On/off switch characteristics were observed by alternate irradiation with UV and visible light. A transmittance contrast of more than 75% was realized under the excitation of 1.5 mW/cm2 intensity.

P14-25
Durability assessment of mold release agents for ultraviolet nanoimprint lithography, Kota Funakoshi, Syo Shirato, Jun Taniguchi, Ryo Tsuboi, Shinya Sasaki, Tokyo University of Science Kudankita,

The durability enhancement of the release agent in UV-NIL is in great demand. The development of an evaluation under accelerated condition is needed. By applying a release agent on the Silicon surface, we performed a sliding test, and analyzed the wear trace by means of AFM and FT-IR.

P14-26
Novel template releasing process Novel template releasing process by multi-axis controlled systems in nanoimprint lithography, Tomoki Nishino, Honoka Fujita, Takuya Kitagawa, Takahiro Shiotsu, Hiroaki Kawata, Yoshihiko Hirai, Osaka Prefectuer University

We newly propose 3-axis controlled template releasing method in nanoimprint lithography. Screw releasing method, where the template is liftted by three poiints and they altanatively lifted up the template, is effective for voluntary layout patterns for defect elimination in nanoimprint lithography.

P14-27
Nanoimprint-Based Lift-off Process for a Large-Scale Epitaxial Growth of Nanowires, Mariusz Graczyk, Jesper Wallentin, Magnus Heurlin, Magnus T. Borgström, Ivan Maximov, Lund University, Gang Luo, Babak Heidari, Obducat AB

We demonstrate a large-area nanoimprint process for a controllable growth of InP nanowires. The nanoimprint process details are described and discussed. The reported opmimized NIL process was used to produce nanowire-based solar cells with high efficiency.

P14-28
Reorientation Evaluation of Photoinduced Liquid Crystalline Polymer Pattern Fabricated by Hybrid Nanoimprinting with Linearly Polarized Ultra Violet Irradiation, Makoto Okada, Emi Nishioka, Mizuho Kondo, Yuichi Haruyama, Tomoyuki Sasaki, Nobuhiro Kawatsuki, Shinji Matsui, Univ. of Hyogo, Hiroshi Ono, Nagaoka University of Technology

P6CAM is the photoinduced liquid crystalline polymer. The P6CAM molecules are aligned by linearly polarized ultra violet (LPUV) irradiation or thermal nanoimprinting. To induce the bidirectional molecular orientation on the identical P6CAM pattern, we performed thermal nanoimprinting with LPUV irradiation.

P14-29
2D- visualization of imprint-induced flow by means of crystallizing polymers, Si Wang, Andre Mayer, Khalid Dhima, Hella-Christin Scheer, University of Wuppertal

A new method for 2D-visualization of flow by means of flow-induced optical anisotropy is proposed. For demonstration the imprint is performed in materials of high and low tendency towards crystallization, e.g. P3HT, an organic polymer available as ‚regular' (high) and ‚random' (low) polymer. Only regular P3HT shows flow-induced anisotropy.

P14-30
Sub-10nm nanofabrication by step-and-repeat UV nanoimprint lithography, Scott Dhuey, Giuseppe Calafiore, David Gosselin, Deirdre Olynick, Stefano Cabrini, Lawrence Berkeley National Lab, Christophe Peroz, aBeam Technologies, Nerea Alayo, Centro Nacional Microelectronica Barcelona

We describe work done in the area of high resolution step-and-repeat UV nanoimprint lithography. We first demonstrate template resolution enhancement techniques enabled by atomic layer deposition where we are able to print 6nm features and 20nm pitch features. We also demonstrate fabrication of 14nm metallic structures by imprint and lift-off.

P14-31
Magnetic field assisted micro contact printing: a new concept of fully automated and calibrated process, Jean-Christophe Cau, Ludovic Lafforgue, Vincent Paveau, innopsys

In this work, we propose a new concept of microcontact printing : the magnetic field assisted micro contact printing. For that, we integrated on the upper side of a stamp a quantity of iron powder (25% weight). The stamp became sensitive to a magnetic field.

P14-32
Functional Nano Patterns realized by Thermal and UV Nano Imprint Lithography, Mario Baum, Jan Besser, Maik Wiemer and Thomas Gessner, Fraunhofer Institute for Electronic Nano Systems

Within this paper a typically used process flow for pattern transfer via UV-NIL and thermal NIL is described. This process flow includes the NIL processes and the dry etching for pattern transfer. Certain application examples in optical/photonic components, medical/biological surfaces and microfluidics fields will be demonstrated.

Resists

P15-01
Contrast curve engineering by using multi-layer polystyrene electron beam resist, Manal Alhazmi, Mustafa Yavuz, Bo Cui, University of Waterloo

Here we use multi-layer polystyrene resist with very different molecular weights and thus very different sensitivities, in order to tailor the contrast curve with great freedom. Moreover, each layer with a target molecular weight can be “simulated” by mixing two polystyrenes having very different molecular weights.

P15-02
Line width roughness reduction strategies for resist patterns printed via electron beam lithography, Julien Jussot, UJF, Erwine Pargon, CNRS-LTM, Beatrice Icard, Laurent Pain, CEA-LETI, Jessy Bustos, STMicroelectronics

In this study several techniques to decrease the LWR of Line & Space patterns printed via electron beam (50kV) lithography are investigated. The following techniques are discussed: thermal treatments, plasma treatments, surfactant rinse and use of under-layers.

P15-03
Polycarbonate as an ideal grayscale electron beam resist using diluted cyclopentanone developer, Arwa Abbas, Mustafa Yavuz, Bo Cui, The University of Waterloo

Grayscale lithography is commonly used to generate 3D structures. Resist having low contrast is preferred in order to have a broad process window for reproducible results. We show that using diluted cyclopentanone developer, polycarbonate can achieve very low contrast that makes it a promising resist for grayscale electron beam lithography.

P15-04
Exposure Strategy: Investigation of the Relationship between Exposure Speed and Ultra High Resolution in electron beam lithography, Scott Lewis, Damien Jeanmaire, Lucio Piccirillo, The University of Manchester, Guy DeRose, Bophan Chhim, Axel Scherer, California Institute of Technology

Complementing optical with electron beam lithography provides a route towards the next generation microprocessors. Optimizing writing factors to produce the smallest features in SML100 resist while minimizing proximity effects are investigated and discussed. Statistical models suggest that approximately 32% smaller structures would be achieved using 100pA vs 10nA writing current.

P15-05
Process Dependence of Line Width Roughness in Electron Beam Resists, Tomoharu Yamazaki, Hiroki Yamamoto, Takahiro Kozawa, Osaka university

In this work, the stochastic effect of incident electrons was investigated by changing process conditions. A non-chemically amplified resist was used to eliminate the effect of chemical reaction. The formation mechanism of LWR is discussed based on radiation chemistry.

P15-06
WITHDRAWN - Optical Hybrid Polymers with Tunable Refractive Index for Nanoimprint Technology

P15-07
Hard resist masks prepared with sequential infiltration synthesis process for high-resolution deep etch, Xianghai Meng, Stony Brook University, Ming Lu, Brookhaven National Laboratory

Several popular electron-beam and photo- resists treated with alumina sequential-infiltration-synthesis process are examined under plasma etch processes dominated by chemical reaction, week and modest physical bombardments respectively. The etching rates along different

infiltration depths reveal a path to further improve their etching resistance for high-resolution deep etch.

P15-08
Investigation into Shot Noise Effects of Direct Write Electron Beam Lithography Using High Energy Electron Beams, Alan Brodie, Luca Grella, Mark McCord, Mark Smith, KLA-Tencor, Peter Ercius, NCEM, Greg Wallraff, Martha Sanchez, IBM

The purpose of this work is to assist in resist optimization for high voltage EBDW by investigating the effect of shot noise on line edge roughness (LER) and critical dimension uniformity (CDU), when the MFP of the electron beam is greater than or equal to the thickness of the resist.

P15-09
Pattern exposure order dependence in hydrogen silsequioxane, Devin Brown, Georgia Institute of Technology

Pattern order dependence is observed and characterized in electron beam lithography exposed hydrogen silsesquioxane resist. The observed effect is sensitive to exposure order and location, is repeatable over time, and is not a function of delay time.

P15-10
Point-spread function of energy deposition by an electron-beam determined by using energy-filtered TEM, Vitor Manfrinato, Bowen Baker, Karl Berggren, MIT, Lihua Zhang, Dong Su, Eric Stach, Brookhaven National Lab, Huigao Duan, Hunan University

We measured the energy deposited in the resist at the nanometer scale and the effects of delocalized energy deposition in the resist by using energy-filtered transmission electron microscopy and electron energy loss spectroscopy.

P15-11
Chemical Composition and Pattern Development in Inorganic Photoresist Materials Deposited from Aqueous Solution, Rose Ruther, Richard Oleksak, Jennie Amador, Shawn Decker, Gregory Herman, Douglas Keszler, Oregon State University, Szu-Ying Wang, Eric Garfunkel, Rutgers University, William Stickle, Hewlett-Packard Co

Metal oxide-sulfates (MSOx) are promising high resolution, high sensitivity inorganic resists for e-beam or EUV lithography. Quartz crystal microbalance, electron microscopy, ion scattering, and x-ray spectroscopy are used to characterize the composition of MSOx films and further our understanding of the thermal, radiation, and dissolution chemistries involved in pattern development.

P15-12
An in situ analysis of EUV resist dissolution characteristics by high speed AFM, Julius Joseph Santillan, Toshiro Itani, EIDEC, Inc.

The first in situ dissolution characterization results of extreme ultraviolet (EUV) exposed patterns on a negative tone development (NTD) resist utilizing an organic solvent developer is presented. A detailed explanation of the results obtained with 32 nm half pitch lines and spaces patterns will be discussed.

Nanostructures and Pattern Transfer

P16-01
Sub-10nm Resolution after Lift-Off using HSQ/PMMA Double Layer Resist (Invited), Marcus Rommel, Jürgen Weis, Max Planck Institute for Solid State Research, Bengt Nilsson, Piotr Jedrasik, Valentina Bonanni, Alexandre Dmitriev, Chalmers University of Technology,

For working on silicon dioxide covered or bare silicon substrates we developed an EBL process utilizing poly-methyl-methacrylate (PMMA) as a sacrificial layer beneath the pattern defining hydrogen-silesquioxan (HSQ) layer. This process allows us to create quasi-films, consisting of sub-10 nm separated metal structures, using lift-off avoiding HF containing etchants.

P16-02
Wafer Scale Fabrication of High-Aspect Ratio Gold Nanostructures using Ar+ - Ion Beam Etching, Richard Kasica, Gerard Henein, NIST

We present results of fabricating high aspect ratio gold nano-holes and nano-gratings with controlled sidewall angle and wafer scale uniformity for use in nanocalorimetry and nanoplasmonic devices.

P16-03
Fabrication of Nano-Bowl Arrays via Simple Holographic Patterning and Lift-Off Process, Yuyang Liu, Ke Du, Ishan Wathuthanthri, Chang-Hwan Choi, Stevens Institute of Technology

In this work, we report a new and simple way to fabricate uniform nano-bowl arrays of metal (e.g., gold) with well-controlled pattern periodicity and shapes over a large substrate area (e.g., on a full wafer scale), based on holographic nanopatterning and lift-off process.

P16-04
High accuracy dual side overlay with KOH through wafer etching, Henk Van Zeijl, Delft University of Technology, Keith Best, Simax Lithography

This work describes the use of a dual side 2 mask process used in combination with an advanced front to back side alignment (FTBA) system to characterize the precision of KOH through wafer etch processes.

P16-05
Development of a Mask-less Nanofabrication Process for SnO2 Periodic Nanostructure, Debabrot Borgohain, Sachin D Kshirsagar, Raj Kishora Dash, M Ghanashyam Krishna, University of Hyderabad

P16-06
Inductively Coupled Plasma Etching of Through-Cell Vias in Indium-Bearing III-V Solar Cells Using SiCl4/Ar plasma, Yuning Zhao, Patrick Fay, University of Notre Dame, Andree Wibowo, Chris Youtsey, MicroLink Devices, Inc.

A wafer-scale SiCl4-based ICP-RIE etch process for fabricating dense arrays of small-area through-cell vias in In-bearing III-V heterostructures for advanced triple-junction photovoltaic cells is demonstrated. Smooth sidewalls are obtained; the etch rate and profile uniformity are evaluated, and optical emission spectroscopy is used to monitor the etch process.

P16-07
Polymeric Sidewall Transfer Lithography, Yi-Chen Lo, Xing Cheng, Texas A&M University

Polymeric sidewall transfer lithography technique presents a facile route towards the creation of sub-50 nm structures without the need of advanced lithography equipments. We describe the process details and optimization schemes in this report. The polymeric sidewall transfer lithography is expected to be a fast nanostructure prototyping technique.

P16-08
Thermal dewetting of gold particles on a template surface, Zhaoqian Liu, Gaoshan Huang, Hui Li, Yongfeng Mei, Ran Liu, Fudan University

Noble metallic nanoparticles have attracted intensive interest for promising applications in optics,chemical and biological sensing. Here, a novel technique to arrange nanospheres induced by thermal dewetting process is introduced. Nanoparticles dispersed in a circular array around nanopores can be well fabricated by introducing a pre-patterned anodic aluminum oxide template.

P16-09
Patterning of Light-Extraction Nanostructures on Sapphire Substrates Using Nanoimprint, SiO_2 Masking and ICP Dry Etching, Hao Chen, Qi Zhang, Stephen Chou, Princeton University

We developed a fabrication process based on nanoimprint and ICP dry etching with SiO_2 mask that allows nanopillars (200 nm pitch and sub-150 nm diameter) etched into sapphire with much deeper depth and steeper sidewall over the previous wet-etching and dry-etching. The process is scalable to large volume LED manufacturing.

P16-10
KOH Polishing of Nanoscale Deep Reactive-Ion Etched Ultra-High Aspect Ratio Gratings, Alexander Bruccoleri, Dong Guan, Pran Mukherjee, Ralf Heilmann, Mark Schattenburg, Massachusetts Institute of Technology

We have developed the worlds first process to polish nanoscale ultra-high aspect ratio structures via wet KOH etching. We present a novel technique to align the gratings to the <111> silicon planes, enabling us to reduce sidewall roughness by at least an order of magnitude without destroying the grating bars.

P16-11
Fabrication of transparent superoleophobic surfaces by multiple shrinking mask etching and layer-by-layer coating, Hyungryul Choi, Kyoo-Chul Park, Hyomin Lee, Jeong-Gil Kim, Robert Cohen, Gareth McKinley, George Barbastathis, Massachusetts Institute of Technology

We propose a re-entrant subwavelength nanocone surface structure for enhanced transparency and superoloephobicity. The re-entrant texture is created using a square array of silica nanocones coated uniformly with silica nanoparticles using top-down and bottom-up fabrication processes: interference lithography and multiple shrinking mask etching; and layer-by-layer assembly.

P16-12
Dipole-Coupled Nanomagnet Chains Fabricated on Silicon Nitride Membranes for Time-Resolved X-Ray Microscopy Experiments, David Carlton, Weilun Chao, Erik Anderson, Mi Young Im, Lawrence, Peter Fischer, Patrick Naulleau, Berkeley National Labs, Zheng Gu, Brian Lambson, Jeffrey Bokor, University of California Berkeley

We develop a process to fabricate chains of single domain nanomagnets fabricated on Silicon Nitride membranes integrated with Copper wires and perform X-ray microscopy measurements on them. The results show the nanomagnets in the chain couple antiferromagnetically and can be reset using electrical pulses through the Copper wires.

P16-13
Lithographically-Defined ZnO Nanowire Growth, Samuel Nicaise, Amirreza Kiani, Sehoon Chang, Jian Wei Jayce Cheng, Caroline Ross, Silvija Gradecak, Karl Berggren, Massachusetts Institute of Technology

ZnO NWs with varying sizes, orientations and pitch were grown perpendicular to a ZnO seed-layer thin film via a low-temperature hydrothermal process (mixture of zinc nitrate hexahydrate and hexamethylenetetramine solution). The spatial distribution of growth was directed by PMMA resist and PS-b-PDMS block copolymer growth masks on the surface.

P16-14
Metal-Assisted Etching of Silicon Molds for Electroforming, Ralu Divan, Argonne National Laboratory, Daniel Rosenthal, Illinois Mathematics and Science Academy, Karim Ogando, Centro Atomico Bariloche and Instituto Balseiro, Leonidas E. Ocola, Daniel Rosenmann, Argonne National Laboratory, N. Moldovan Advanced Diamond Technologies

Template based metal-assisted chemical etching enables fabrication of Si nanostructures with controlled diameter, shape, length, and packing density. We present the results on Si nanostructure fabrication by metal-assisted chemical etching where the metal patterning was done with e-beam lithography, or interference lithography, and lift-off.

P16-15
Fabrication of Patterned Interference-Based and Absorption-Based Polarizers, Wei-Liang Hsu, Graham Myhre, Kaushik Balakrishnan, Stanley Pau, University of Arizona

The chemistry, fabrication process, spatial resolution and optical properties of arbitrarily patterned circular polarizers and infrared polarizers are presented. Patterned circular polarizers can be fabricated using cholesteric liquid crystal polymers. Patterned IR polarizers can be fabricated using infrared dichroic dye as a guest in liquid crystal polymer host.

P16-16
Comparison of Au feature formation using two Au-calixarene resists, electron beam lithography, and low temperature organic removal, Pradeep Perera, Dimas Garcia De Oteyza, Scott Dhuey, Bruce Harteneck, Adam Schwartzberg, Stefano Cabrini, Deirdre Olynick, Molecular Foundry, Micheal Nigra, Alexander Katz, UC Berkeley

We study directed nanoparticle formation using electron beam lithography of Au-calixarene resists. Two Au bound calixarene resists are compared. Organic/inorganic ratio is same but Au is bound as single atoms or in 11 atom clusters. Particle formation is studied post-exposure and after plasma treatment.

TECHNICAL SESSIONS

WEDNESDAY AFTERNOON, May 29, 2013

Session 1A: Electron Beam 1

Tennessee A/B
Session Chairs:
John Melngailis, University of Maryland
Steve Rishton, Neophotonics

2:30pm 1A-1 (Invited)
Proof of 50keV Electron Multi-Beam Writing at 0.1nm Address Grid (Invited), Hans Loeschner, Elmar Platzgummer, IMS Nanofabrication AG

A proof-of-concept 50keV electron multi-beam mask writer with a 200x reduction column provides 262,144 programmable 20nm beams. 24nm HP resolution demonstrated. 50nm lines printed with pitch from 100.0nm in steps of 0.1nm to 109.9nm. CD-SEM measurements show pitch deviations as low as 0.23nm 3sigma and CD deviations of 1.6nm 3sigma.

3:00pm 1A-2
Optically Actuated Nanostructured Electron-Emitter Arrays, Richard Hobbs, Yujia Yang, Phillip Keathley, William Graves, Franz Kärtner, Michael Swanwick, Luis Velásquez-García, Karl Berggren, Massachusetts Institute of Technology

Here, we outline the design, fabrication and testing of nanostructured, plasmonic, Au electron emitter arrays, and sub-10 nm Si electron emitter arrays. Electron emission from the nanostructure arrays is actuated by femtosecond pulses of 800 nm wavelength light. Multiphoton, and strong field photoelectron emission has been observed.

3:20pm 1A-3
Image distortion in REBL system: the correctable and the residual, Sameet Shriyan, Mark McCord, Paul Petric, Shinichi Kojima, Alan Brodie, Allen Carroll, KLA-Tencor Corp., Masis Mkrtchyan, SAIC, Simon Cooke, NRL

This paper examines the details of image distortion caused by electron optical lenses as the image traverses through the latest generation of the REBL electron-optical column. The magnitude and the source of distortion have been identified and the impact on the feature placement and blur is discussed with correction strategies.

3:40pm 1A-4
Low-Energy Electron Diffractive Imaging Based on a Single-Atom Electron Source, Ing-Shouh Hwang, Wei-Tse Chang, Chun-Yueh Lin, Wei-Hao Hsu, Mu-Tung Chang, Yi-Sheng Chen, Tien-Tzou Tsong, Academia Sinica

A single-atom tip can be a high-brightness and high-coherence electron field emitter. The point projection images and diffractive images of graphene will be presented. A new design of a low-

energy electron diffraction microscope based on a single-atom electron gun and a focusing lens is proposed for imaging thin nano-objects.

4:00pm 1A-5
Shaped and multiple electron beams from a single thermionic cathode, Mehran Vahdani Moghaddam, Alireza Nojeh, University of British Columbia

Low throughout remains the single biggest problem of electron-beam lithography. Here, we demonstrate shaped and multiple thermionic electron emission spots from a single cathode. The cathode consists of an array of vertically aligned carbon nanotubes (carbon nanotube forest) and is heated to thermionic temperature with a low power continues laser.

4:20pm 1A-6
High throughput scanning electron microscopes with MEMS-based multi-beam optics, Pieter Kruit, Yan Ren, Takashi Ichimura, Delft University of Technology

We present two novel designs for high throughput scanning electron microscopes with MEMS-based multi-beam optics. Both are based on traditional SEMs in which the beam is split into 196 sub beams. First experimental results of the separate detection of the secondary electrons from the sub beams will be presented.

5:15pm - 6:15pm - Mentorship Program
Exhibit Hall

Session 1B: Nanophotonics 1

Tennessee Ballroom C
Session Chairs:
Richard Blaikie, University of Otago
Jack Skinner, University of Montana

2:30pm 1B-1 (Invited)
Multifunctional Nanostructured Materials: Blurring the Lines between Optical Interfaces (Invited), Chih-Hao Chang, North Carolina State University

Bio-inspired nanostructured materials have received significant interest across many research disciplines. However, the design of such materials should not be limited to biology. Enabled by the recently advances in nanofabrication, nanostructured materials can be engineered to have better performance, more functionality, and increased complexity as compared to their biological counterparts.

3:00pm 1B-2
Hydrogen Silsesquioxane As A Resist And Material Of Choice In Fabricating Plasmonic Antennas, Joel Yang, Michel Bosman, Karthik Kumar, Xiao Ming Goh, Shawn Tan, Institute of Materials Research and Engineering, Singapore, Huigao Duan, Hunan University

HSQ is used as an imaging layer for a single-use nanostencil for creating sub-10-nm gaps in plasmonic nanostructures. It is also used as a coating to preserve the shape and sizes of polycrystalline structures while annealing was applied to increase its internal grain sizes.

3:20pm 1B-3
Reaching theoretical resonance quality factor limit in coaxial plasmonic nano resonators fabricated by Helium Ion Microscope, Mauro Melli, Aleksandr Polyakov, Daniel Gargas, D. Frank Ogletree, P. Jim Schuck, Stefano Cabrini, Alex Weber-Bargioni, LBNL, Chuong Huynh, Larry Scipioni, Carl Zeiss Microscopy LLC

In this work, we present an experimental demonstration of maximum theoretical performance of HIM-made coaxial apertures in a thin gold film on a glass substrate. The measured EOT signal in the visible spectrum reaches the theoretically predicted optical response for a perfect model coaxial structure.

3:40pm 1B-4
Moving Towards Structural Color Display: Angle Insensitive Structural Colors Based on Metallic Gratings and Color Pixels beyond the Diffraction Limit, Cheng Zhang, Yi-Kuei Wu, Andrew E. Hollowell, L. Jay Guo, The University of Michigan

We have theoretically and experimentally studied a vertical nano cavity for highly efficient, angle robust/insensitive color filtering. Moreover, this structure has demonstrated color pixel size beyond the diffraction limit and wide color tunability throughout the entire visible spectrum.

4:00pm 1B-5
Double External Quantum Efficiency/Light Extraction and Widen Viewing Angle of Organic Light-Emitting Diodes with New Plasmonic Cavity with Subwavelength Hole Array (PlaCSH), Wei Ding, Yuxuan Wang, Hao Chen, Stephen Chou, Princeton University

This is first demonstration of new LED structure fabricated by NIL with subwavelength plasmonic cavity, compared to reference LEDs of same structure except no plasmonic cavity, (a) increases total EQE 93%, (b) has widen viewing angle by 7%, and (c) replaces ITO using thin transmissive metallic-mesh electrode of subwavelength holes.

4:20pm 1B-6 (Invited)
Direct write and nanoprinting for plasmon resonance color filters (Invited), David Cumming, Iain McCrindle, Chris Martin, Qin Chen, Glasgow University

We present direct write and nano-imprinted colour filter technologies based on the phenomenon of lateral surface plasmon resonance in a thin aluminium film. Rich colour spectra are obtained, and we show how the method can be applied to colour functionalisation of digital image sensors.

5:15pm - 6:15pm - Mentorship Program
Exhibit Hall

Session 1C: EUV 1

Tennessee Ballroom D/E
Session Chairs:
John Hartley, University at Albany SUNY
John Randall, Zyvex Labs

2:30pm 1C-1 (Invited)
NGL for NGL: Next Generation Lithography for Next Generation Logic (Invited), Yan Borodovsky, Intel Corporation

EUVL, EBDW and DSA are all under consideration to complement optical lithography. Defectivity and required corresponding wafer metrology, sampling and disposition methodology needed for introduction of EUVL, DSA and EBDW in HVM is yet to be developed. Presentation focus on defectivity specific to stated NGLs, and means to address those.

3:00pm 1C-2
Efficient Packaged Zoneplates for EUV Instruments, Erik Anderson, Eric Gullikson, Weilun Chao, Senajith Rekawa, Nord Andresen, Lawrence Berkeley National Laboratory

We have developed two approaches to improving zoneplate efficiency. First we use the phase shifting property of Si3N4 for phase zoneplates and secondly, we improved our freestanding etching in which the support membrane is completely removed. Finally, we have exploited the kinematic approach to produce a robust package.

3:20pm 1C-3
Continuous and Stochastic effects for 2D structures in EUV Lithography, Alessandro Vaglio Pret, Peter De Bisschop, Imec

In EUV-lithography Shot-Noise effects influence the pattern fidelity of printed features.In optical-lithography the discreteness of light is negligible and the pattern can be optically corrected in a continuous fashion.However, EUV-lithography requires stochastic modeling.In this paper we try to discriminate pattern failures due to poor image quality from stochastic phenomena.

3:40pm 1C-4
Phase Defect Characterization on an EUV Blank Mask using Micro Coherent EUV Scatterometry Microscope, Tetsuo Harada, Yusuke Tanaka, Takeo Watanabe, Hiroo Kinoshita, Univ. of Hyogo, Youichi Usui, Tsuyoshi Amano, EIDEC

We have developed a new EUV defect-characterizing tool of micro coherent EUV scatterometry microscope (micro-CSM), which exposed focused coherent EUV to defect. Micro-CSM recorded scattering signal of ellipsoidal defects, which were corresponded to AFM results. Micro-CSM can evaluates the actinic phase, which will become essential tool for EUV mask fabrication.

4:00pm 1C-5
EUV Bessel beam lithography, Li Wang, Mohamad Hojeij, Nassir Mojarad, Michaela Vochenhuber, Jens Gobrecht, Yasin Ekinci, LMN PSI

In this paper we show the application of non-diffracting beams for high-resolution lithography, alternative to electron beam lithography (EBL) for providing arbitrary patterns. This technique

also holds advantages such as, no depth of focus, no proximity effect, massively parallel writing and no need of complex electron focusing lenses and columns.

4:20pm 1C-6 (Invited)
EUV Lithography and 3D IC (Invited), Banqiu Wu, Ajay Kumar, Applied Materials, Inc.

Challenge and future of EUV lithography and 3D IC were reviewed and discussed. IC scaling enhanced by EUVL or 3D IC stacking technologies can improve device performance, but the final adoption will depend on the system rather than device performance, throughput, productivity, and costs.

5:15pm - 6:15pm - Mentorship Program
Exhibit Hall

THURSDAY MORNING, May 30, 2013

Posters are available for viewing on Thursday until 1:00 pm

Session 2A: Nanostructures 1

Tennessee Ballroom A/B
Session Chairs:
Martin Feldman, Louisiana State University
Karl Berggren, Massachusetts Institute of Technology

8:10am 2A-1 (Invited)
Nanofabricated Silicon Devices: From Nanosensors to Medical Implants (Invited), Axel Scherer, Sameer Walavalkar, William Fegadolli, Andrew Homyk, Muhammad Rahman, Akram Sadek, Caltech

We show 3-dimensionally etched silicon nanostructures with lateral dimensions below 10nm. This control enables "geometric bandgap engineering", leading to many interesting devices with optical, electrical and mechanical opportunities. We discuss applications in medical diagnostic systems.

8:40am 2A-2
Soft- and near-field lithography on glass hemisphere surface for spherical zone plates, Bingrui Lu, Ya-Qi Ma, Ai-Guo Yang, Xin-Ping Qu, Ran Liu, Yifang Chen, Fudan University

We developed a novel concept of micro-imaging system with innovative lenses – zone plates built on glass balls. A soft- and near-field lithography is developed which is generally applicable for replications on uneven surfaces. It has great potentials in life science, medical care, material sciences and micro X-ray optics system.

9:00am 2A-3
Fabrication of hierarchical nanostructures using free-standing tri-layer membrane, Ke Du, Yuyang Liu, Ishan Wathuthanthri, Chang-Hwan Choi, Stevens Institute of Technology

In this work, we report a new fabrication method which can make hierarchical nanostructures even on high-aspect-ratio pre-patterns, using a free-standing tri-layer membrane comprised of metal and resist films as a versatile mask and stencil for robust and uniform pattern transfer including etching and deposition processes.

9:20am 2A-4
Out-of-plane nanofabrication using evaporated electron beam resist, Sondos Alqarni, Celal Con Bo Cui, Institute for Nanotechnology

We coat by thermal evaporation polystyrene resist on the sides of high aspect ratio and thin silicon nano-wall. By electron beam lithography to pattern the resist on the nano-wall, followed by etching through the nano-wall laterally using isotropic RIE with the resist as mask, out-of-plane nanostructures were achieved.

9:40am 2A-5
Free-standing nanoscale mechanical and photonic devices fabricated in single-crystal diamond, Michael Burek, Daniel Ramos, Nathalie de Leon, Brendan Shields, Birgit Hausmann, Yiwen Chu, Qimin Quan, Alexander Zibrov, Hongkun Park, Mikhail Lukin, Marko Loncar, Harvard University

A novel nanofabrication technique to realize suspended mechanical and photonic nanostructures in single-crystal diamond substrates is presented. The developed methodology employs oxygen plasma etching and yields free-standing nanobeam mechanical resonators, waveguides and photonic crystal cavities. Initial characterization of single-crystal diamond nanobeam mechanical resonators and photonic crystal cavities are presented.

Coffee break 10:00am - 10:20am

Session 2B: Focused Ion Beam or Sources 1

Tennessee Ballroom C
Session Chairs:
Reginald Farrow, New Jersey Institute of Technology
Shida Tan, Intel Corporation

8:10am 2B-1 (Invited)
HfC(310) high brightness sources for advanced imaging applications (Invited), Willilam Mackie, Josh Lovell, Todd Curtis, Gerald Magera, Applied Physics Technologies

CFEs are the brightest cathodes but with inherent noise. Zr/O/W(100) Schottky sources use flow of Zr/O, limiting operation range of T, F, and P; hence limit I' and operation to UHV.

HfC(310) Schottkys show promise because of operation without limitations on T or F and possible operation at higher pressures.

8:40am 2B-2
Fabrication and Modification of Carbon Nanomembranes (CNMs) by Helium Ion Lithography, Xianghui Zhang, Henning Vieker, Daniel Emmrich, André Beyer, Armin Gölzhäuser, Universität Bielefeld

A helium-ion microscope (HIM) is used to laterally cross-link aromatic self-assembled monolayers(SAMs)into carbon nanomembranes (CNMs). We determine the resolution limit (<5nm) and we used the He+ beam to mill nanopores with well defined size and shape in CNMs as well as in graphene.

9:00am 2B-3
Understanding Nanomachining in Gold Substrates, Kate L. Klein, Eva M. Mutunga, University of the District of Columbia, Andras E. Vladar, National Institute of Standards and Technology, Lewis A. Stern, Carl Zeiss Microscopy LLC

The Orion helium ion microscope offers a novel method for nanofabrication at a scale currently unattainable with conventional Ga-based FIB. In this paper we investigate mill rates for Au as a function of feature size and substrate thickness to better understand the machining process in thin films and bulk substrates.

9:20am 2B-4
Development of a low energy neutral particle printer for atomically precise patterning of desorption resists, Hong-Jie Guo, Mufaddal Gheewala, Apeshka Awale, Pratik Motwani, S.S. Pei, Jack Wolfe, University of Houston

Our goal is to develop a high-throughput, parallel exposure technique for atomically-precise patterning of desorption resists based on neutral atom proximity lithography. Our paper will report virtual source size, brightness, and energy spread of a xenon atom source operating the energy range 50-100 eV.

9:40am 2B-5
Visualizing the Interaction Volume of Helium Ions in Hydrogen Silsesquioxane, Jingxuan Cai, Zhou-Yang Zhu, Wen-Di Li, The University of Hong Kong, Paul F. A. Alkemade, Delft University of Technology, Emile van Veldhoven, TNO, Delft

We demonstrate visualization of the scattering volume of helium ions in thick HSQ layer by exposing thick HSQ resist through a thin SiN membrane using focused helium ion beam. The exposed HSQ layer shows a bubble-like shape which can provide information on the ion scattering and crosslinking processes.

Coffee break 10:00am - 10:20am

Session 2C: Modeling

Tennessee Ballroom D/E
Session Chairs:
Tim Brunner, IBM
Frank Schellenberg, TBD Technologies

8:10am 2C-1 (Invited)
Non Equilibrium Block Copolymer Directed Self Assembly. Multiblocks, Solvents, and Thick Films (Invited), Juan de Pablo, University of Chicago

This presentation will provide an overview of state-of-the-art theoretical and computational approaches for simulation of block copolymer directed assembly, along with a discussion of their ability to describe experimental data of direct relevance to lithographic patterning.

8:40am 2C-2
Study of multilayer systems in electron beam lithography, Robert F. Peters, Taras Fito, Luis Gutierrez-Rivera, Steven K. Dew, Maria Stepanova, University of Alberta, National Institute for Nanotechnology (NRC)

We investigate the influence of anti-charging conductive layers on electron beam lithography (EBL) nano-patterning both experimentally and numerically. We extend our EBL simulation tool by incorporating the effects of various anti-charging coating layers on top of PMMA resist and compare the predicted and fabricated nano-patterns on dielectric and semiconductor substrates.

9:00am 2C-3
Off Axis Modeling and Measurement of Emission Parameters for the Schottky Emitter, Sean Kellogg, Kun Liu, Gregory Schwind, Lynwood Swanson, FEI Company

An investigation has been carried out involving both computer modeling and experimental data of the off axis emission parameters for a ZrO/W Schottky electron source. The critical source parameters will be presented as function of emission angle, these include the source brightness, energy spread, field factor, and work function.

9:20am 2C-4
Simulation of dose variation and charging due to fogging in electron beam lithography, Sergey Babin, Sergey Borisov, Elena Patjukova, aBeam Technologies, Inc.

Fogging in electron beam lithography effects placement accuracy and critical dimensions. The effect was simulated using Monte Carlo method: absorbed dose and charge deposition in resist due to fogging were modeled. Setup parameters of EBL system were varied.

9:40am 2C-5
Simulation Study on Template Releasing Process in Nanoimprint Lithography, Takahiro Shiotsu, Naoki Nishikura, Masaaki Yasuda, Hiroaki Kawata, Yoshihiko Hirai, Osaka Prefectuer University

Simulation study was done for template releasing process in nanoimprint lithography. Lift off, peeling and roll to roll processes are investigated in typical configulations. The stress

distribusions are studied. The results show that the stress becomes maximun just before the template is detached from resist.

Coffee break 10:00am - 10:20am

Session 3A: Novel imaging/metrology

Tennessee Ballroom A/B
Session Chairs:
Alex Liddle, NIST
Ralf Heilmann, Massachusetts Institute of Technology

10:20am 3A-1 (Invited)
Infrared nanospectroscopy meets FIB and TEM (Invited), Rainer Hillenbrand, CIC nanoGUNE

Light scattering at atomic force microscope tips is employed for infrared-spectroscopic imaging with 20nm spatial resolution. Chemical identification of polymer nanostructures and free-carrier mapping in ZnO nanowires will be presented. The technique's capabilities are enhanced by FIB fabrication of infrared-resonant tips and by correlating the infrared images with TEM images.

10:50am 3A-2
Modulus Mapping in High Resolution Patterned Features, Prashant Kulshreshtha, Dominik Ziegler, Deirdre Olynick, Paul D. Ashby, Lawrence Berkeley National Laboratory, Ken Maruyama, JSR Micro INC, James Blackwell, Intel Corporation,

In this study, we have extensively evaluated various AFM based methods towards quantitative mechanical measurements in patterned materials. Utility and limits of each technique will be discussed in the context of high-resolution lithographic and plasma patterning. Improvements in modulus, adhesion and topography of structures result in a collapse-free pattern.

11:10am 3A-3
Combined SIMS-SPM instrument for high sensitivity and high resolution elemental 3D analysis, Yves Fleming, Tom Wirtz, David Dowsett, Mathieu Gerard, Centre de Recherche Public – Gabriel Lippmann, Urs Gysin, Thilo Glatzel, Department of Physics, Ernst Meyer, Department of Physics, University of Basel, Urs Maier, Urs Wegmann, Ferrova

We present an integrated SIMS-SPM instrument, based on the Cameca NanoSIMS50, combining sequential high resolution Scanning Probe Microscopy and high sensitivity SIMS, allowing topographical images of the sample surface to be recorded in-situ before, in between and after SIMS analysis. Examples of high-sensitivity high-resolution 3D chemical reconstructions will be presented.

11:30am 3A-4
Process Monitoring of an Electron Beam Lithography Process for Silicon Photonics in a University Facility, Richard Bojko, Kristopher Lawler, University of Washington

We have developed simple yet accurate process monitoring of overlay and CD using ordinary optical microscope and SEM images, with custom image analysis software. We use this to monitor our e-beam fabrication process for silicon photonics.

11:50am 3A-5
Towards SIMS on the Helium Ion Microscope: detection limits and experimental results on the ORION, David Dowsett, Lex Pillatsch, Nico Vanhove, Tom Wirtz, Centre de Recherche Public – Gabriel Lippmann, Sybren Sijbrandij, John Notte, Carl Zeiss Microscopy LLC

We present an overview of our progress towards adding SIMS capability to the Helium Ion Microscope, including, potential useful yields and detection limits for metal and semiconductor samples, achievable lateral resolution and first experimental results from a prototype extraction and detection system for secondary ions.

LUNCH ON YOUR OWN

Session 3B: Resists

Tennessee Ballroom C
Session Chairs:
Chris Mack, Lithoguru
Guy DeRose, California Institute of Technology

10:20am 3B-1 (Invited)
Nanochemistry in Chemically Amplified Resists Used for Extreme Ultraviolet Lithography (Invited), Takahiro Kozawa, Osaka University

The chemical reactions play an important role in not only image formation but also LER formation of chemically amplified resists. The chemistry induced in nanoscale regions is discussed. Also, the design strategy for the resist materials used for 16 nm node and beyond is discussed on the basis of nanochemistry.

10:50am 3B-2
Contamination Mitigation from Salty HSQ Development for Nanoscale CMOS Device Patterning, Markus Brink, Isaac Lauer, Sebastian U. Engelmann, Ernst Kratschmer, Michael A. Guillorn, IBM Research

CMOS scaling has sparked interest in silicon devices with sub-30nm pitch. This isn't easily achieved even with EBL due to resist limitations. Salty developed HSQ has demonstrated high spatial resolution. Contamination concerns, however, have prevented its use in CMOS integration. We show contamination reduction suitable for a CMOS research line.

11:10am - 3B-3
Methods for Controlled Polymerization in Negative Tone Resists, Richard A. Lawson, Ameneh Cheshmekhani, Laren M. Tolbert, Clifford L. Henderson, Georgia Institute of Technology

Classical positive tone resists have a number of limitations for sub-20 nm patterning. Negative tone resists offer a promising alternative, but methods for controlling the polymerization front in cross-linking systems must be utilized. This paper will discuss and compare methods we have explored for controlling polymerization in cationic resists.

11:30am 3B-4
Negative-Tone Chemically-Amplified for Sub-20nm Lithography, Prashant Kulshreshtha, Scott Dhuey, Paul D. Ashby, Deirdre Olynick, Lawrence Berkeley National Laboratory, Ken Maruyama, JSR Micro INC, James Blackwell, Intel Corporation

Here, we report 20 nm half-pitch (HP) patterning using a negative-tone chemically amplified (CA) molecular resist for E-beam or EUV exposure systems. Cross-linkable resists shows simultaneous improvements in surface energy, modulus, structural integrity, and swelling to ensure collapse free sub-20nm HP patterns and line-edge roughness (LER) down to 2.7 nm.

11:50am 3B-5 (Invited)
Nanoparticle Photoresists: Highly Sensitive EUV Resists with a New Patterning Mechanism (Invited), Marie Krysak, Christine Ouyang, Markos Trikeriotis, Emmanuel Giannelis, Christopher Ober, Cornell University

In this study we present a new photoresist material based on hybrid organic/hafnium oxide or zirconium oxide nanoparticles composed of an oxide core surrounded by organic ligands. These studies have shown that the highly sensitive photoresists are not chemically amplified. This presentation will describe the patterning mechanism in detail.

LUNCH ON YOUR OWN

Session 3C: Nanoelectronics 1

Tennessee Ballroom D/E
Session Chairs:
Stella Pang, City University of Hong Kong
Natalie Plank, Victoria University of Wellington

10:20am 3C-1
Memristive Nanodevices: Mechanisms, Promises and Challenges (Invited), J. Joshua Yang, Hewlett Packard Laboratories

Memristive devices are two terminal electrical resistance switches that can retain a state of internal resistance based on the history of applied voltage and current, which can be used to store and process information. The device working mechanisms, promises and challenges will be discussed in this presentation.

10:50am 3C-2
Integration of Planar Memristors with CMOS for Hybrid Circuits, Peng Lin, Shuang Pi, Qiangfei Xia, University of Massachusetts

Planar resistive switching devices were integrated with a foundry-built CMOS substrate, serving as memory and data routing network for the CMOS logic gates underneath. The forming and programming voltages of the planar device were greatly lowered down, making them compatible with low-voltage CMOS circuitry.

11:10am 3C-3
Fabrication of 18 nm split-gate charge trap memories by hybrid lithography (e-beam/DUV), Sebastien Pauliac-Vaujour, Gabriel Molas, Lia Masoero, Marc Gely, Christelle Charpin, CEA, LETI, Corinne Comboroure, ST microelectronics

In this work, we present the fabrication of split-gate charge trap memories with silicon nanocrystal, silicon nitride and Si-nc/SiN charge trapping layers. By using an hybrid lithography (e-beam/DUV) process, we have demonstrated that it was possible to perform split-gate charge trap memories with electrical gate lengths down to 18 nm.

11:30am 3C-4
Improved Switching Uniformity for TiO2/HfO2 Bi-layer Memristive Devices, Hao Jiang, Qiangfei Xia, University of Massachusetts

By introducing a thin HfO2 layer into the Pt/TiO2/Pt device geometry, the device performance uniformity was greatly improved. The reduced variations have been attributed to fewer filaments in the bilayer structure.

11:50am 3C-5 (Invited)
Si MOSFET with a Nanoscale Void Channel (Invited), Hong Koo Kim, Siwapon Srisonphan, Yun Suk Jung, University of Pittsburgh

We report low-voltage (~1V) emission of 2D electron gas into a nanoscale air channel that was vertically etched into a silicon MOS. The low-voltage emission is enabled by Coulombic repulsion of electrons. We developed a FET structure that demonstrates an on/off ratio of 500, and a turn-on gate voltage of 0.5 V under ambient conditions.

LUNCH ON YOUR OWN

Session 4A: Nanoimprint 1

Tennessee Ballroom A/B
Session Chairs:
Helmut Schift, Paul Scherrer Institut
Lei Wan, HGST

1:30pm 4A-1
Substrate Conformal Imprint Lithography for nanophotonics in applications (Invited), Marc Verschuuren, Philips Research Laboratories, Gabriel Lozano, Said Rodríguez, Center for Nanophotonics, FOM Institute AMOLF

The efficiency of Solid State Lighting applications can be enhanced by using nano-patterns to control the emission direction and spectral shape. We use a robust, defect tolerant nanoimprint method (SCIL) to fabricate photonic crystal patterns on separate LED chips and use plasmonic nano-antennas to strongly modify emission from phosphors.

2:00pm 4A-2
Fabrication of Plasmonic-enhanced Nanostructured Electron Source (PNE) Using Epitaxial Lift-off and Nanoimprint Lithography, Yixing Liang, Yuxuan Wang, Weihua Zhang, Loren Pfeiffer, Stephen Chou, Princeton University

We have proposed, fabricated and tested a new innovative photocathode, termed Plasmonic-enhanced Nanostructured Electron-source (PNE), that offers many advantages over the conventional photocathodes, including sub-picosecond electron pocket pulse width, ultra-high quantum efficiency, small longitude and transverse emittance, sub-diffraction limit spot size, and long photocathode life-time.

2:20pm 4A-3
Thermally-Modulated Alignment for Nanoimprinting, Euclid Moon, Massachusetts Institute of Technology, Saurabh Chandorkar, Intel, R. Fabian Pease, Stanford University

Simultaneous alignment throughout multiple fields is desirable for high-throughput imprint lithography. Here we describe a method to minimize alignment errors at multiple sites via application of few-K thermal gradients to a template and a wafer. Initial results in a 1D array show improvement of field-to-field alignment to 1 nm.

2:40pm 4A-4
Effects of Fluorosurfactants on Antisticking Layer Resistance in Repeated UV Nanoimprint, Shuso Iyoshi, Makoto Okada, Yuichi Haruyama, Shinji Matsui, University of Hyogo, Kei Kobayashi, Shu Kaneko, Masaru Nakagawa, Tohoku University, Hiroshi Hiroshima, National Institute of Advanced Industrial Science and Technology (AIST)

The effort is being made for achieving more than 10000 steps of repeated UV nanoimprint with a single mold. This work revealed that fluorosurfactant additives may play an important role for enhancing the resistance of antisticking layer against repeated UV nanoimprints.

3:00pm 4A-5
Sub-30 nm Roller Nanoimprint Lithography Using Flexible Hybrid Molds and Applications to Large-Area High-Performance Nanoplasmonic Sensors and Solar Cells, Qi Zhang, Hao Chen, Stephen Chou, Princeton University

We report (a) a roller nanoimprint machine we built, (b) fabrication of large area (4" width) flexible hybrid molds with either with PDMS or PFPE front surface for the roller nanoimprint, and (c) their applications in fabrication of nanoplasmonics (e.g. solar cells, LEDs, and sensors) of sub -30 nm features.

Coffee Break 3:20pm - 3:40pm

Session 4B: Carbon-based devices/systems

Tennessee Ballroom C
Session Chairs:
David Cumming, University of Glasgow
Mike Guillorn, IBM Yorktown

1:30pm 4B-1 (Invited)
Diamond based Micro and Nano Systems (Invited), Anirudha Sumant, Argonne National Laboratory

I will discuss some of the recent results on the fabrication of MEMS and NEMS devices based on ultrananocrystalline diamond (UNCD)films. We believe that these results will open-up new opportunities for the fabrication of NEMS devices and sensors with increased sensitivity and new functionalities for a variety of applications.

2:00pm 4B-2
Analog and digital flexible nanoelectronics fabricated from advanced 2D nanomaterials, Li Tao, Hsiao-Yu Chang, Jongho Lee, Huifeng Li, Richard Piner, Rodney Ruoff, Deji Akinwande, The University of Texas at Austin

We report our recent efforts on integrating 2D material (graphene and MoS_2) to enable high performance nanoelectronics on flexible plastics. With recent progress in material synthesis, device configuration and fabrication, our flexible RF or digital devices exhibited comparable performance to counterparts on conventional Si or quartz substrates.

2:20pm 4B-3
Morphological characterization of metallic nano-structures evaporated through stencil on graphene, Veronica Savu, University of Basel/EPFL, Cornelia Nef, Wangyang Fu, Christian Schönenberger, University of Basel, Valentin Flauraud, Jürgen Brugger, EPFL

Metals and organic impurities can influence the doping of graphene. In order to avoid organic residues, we deposit metallic nanostructures through stencils. We characterize the morphology

of the metal on graphene vs. insulating substrates. The results provide a solution to graphene electronics for smart engineering of electrodes with nanogaps.

2:40pm 4B-4
Graphene Field-Effect Transistors with Gigahertz-Frequency Power Gain on Flexible Substrates, Nicholas Petrone, Inanc Meric, Kenneth Shepard, James Hone, Columbia University

We fabricate field-effect transistors on flexible substrates utilizing graphene synthesized by chemical vapor deposition as the channel material. Our devices demonstrate unity-current-gain and unity-power-gain frequencies up to 10.7 and 3.7 GHz, respectively, with strain limits of 1.75%, representing the only technology to achieve gigahertz-frequency power gain at strains above 0.5%.

3:00pm 4B-5
High-resolution Nanopatterning of Graphene Using Direct Helium Ion Beam Milling, Ahmad Abbas, He Liu, Yuhand Yao, Gang Liu, Chongwu Zhou, Wei Wu, University of Southern California, Douglas Ohlberg, R. Stanley Williams, Hewlett-Packard Co.

Here, we report our progress of patterning Graphene nanoribbons (GNRs) with half-pitch down to 5 nm using direct He ion beam milling. The line edge roughness was characterized using Raman spectroscopy.

Coffee Break 3:20pm - 3:40pm

Session 4C: Focused Ion Beam or Sources 2

Tennessee Ballroom D/E
Session Chairs:
Shane Palmer, Nikon Research Corporation
Mike Fritze, University of Southern California

1:30pm 4C-1 (Invited)
Chemical Assisted Etching with Ne+ & He+ Ion Microscope (Invited), Richard Livengood, Shida Tan, Paul Hack, Intel, Kate Klein, Andras Vladar, NIST, David Ferranti, Lewis Stern, Carl Zeiss

Since 2009, Intel and Zeiss have been collaboratively studying the properties of Helium and Neon for microscopy and nanomachining applications. In this talk we will present nanomachining properties of neon and helium in bulk substrate semiconductor materials and present recent Intel/Zeiss/NIST experimental results for ion beam induced Gas Assisted Etching.

2:00pm 4C-2
First focused ion beam images using a novel electron impact gas ion source, David Jun, Leon van Kouwen, Pieter Kruit, TU Delft

We are developing a high performance gas ion source suitable for high resolution focused ion beam applications. Electron impact ionization inside a sub-micron size gas chamber is used to obtain monochromatic (<1ev) bright beams (> $1x10^6$ A/m^2srV) of various ion species.

2:20pm 4C-3
A laser-cooled atomic beam for application in high resolution FIB, Steinar Wouters, S. B. van der Geer, B. Jansen, G. ten Haaf, P. H. A. Mutsaers, O. J. Luiten, E. J. D. Vredenbregt, Eindhoven University of Technology

A new type of high-brightness ion source is under development which employs transverse laser cooling and compression of a thermal atomic Rubidium beam, followed by infield photo-ionization. This has the advantage of supplying a higher current in a smaller spot, thus increasing the resolution and the speed of the FIB.

2:40pm 4C-4
Progress Report on the Multi-Species Focused Ion Beam Lithography System and Its Applications, Sven Bauerdick, Paul Mazarov, Ralf Jede, Joel Fridmann, Jason Elliot Sanabia, Raith, Brent Gila, Bill Ray Appleton, University of Florida,

A Gallium IBL tool with lithography architecture and an ion column and source for high resolution, large area and long-term patterning enables challenging nanofabrication applications. Here we developed the stable high resolution delivery of ion species such as Silicon, Gold and others. We present capabilities and applications of multiple-species IBL.

3:00pm 4C-5
Metal Depositions Induced by Helium and Neon Ion Beams, Huimeng Wu, L.A. Stern, D. Ferranti, K. Klein, D. Xia, B. Thompson, Carl Zeiss Microscopy LLC, G.M. Gonzalez, P.D. Rack, University of Tennessee

We will present the beam chemistry with He and Ne ion beams to induce metal deposition. We will discuss the differences between the dimensions and resistivities of metal lines deposited by various ion beams.

Coffee Break 3:20pm - 3:40pm

Session 5A: Directed Self Assembly (DSA)/Self Assembly (SA) 1

Tennessee Ballroom A/B
Session Chairs:
Aaron Stein, Brookhaven National Laboratory
Paul Nealey, University of Chicago

3:40pm 5A-1 (Invited)
Directed Self-Assembling Lithography Process for High-Density Bit Patterned Magnetic Recording Media (Invited), Akira Kikitsu, Masahiro Kanamaru, Tomoyuki Maeda, Norikatsu Sasao, Naoko Kihara, Takeshi Okino, Ryosuke Yamamoto, Yoshiyuki Kamata, Toshiba Corp.

Achievement of high-density Bit patterned magnetic recording media fabricated by directed self assembly lithography is reviewed. PS-PDMS diblock copolymer with feature size of 12nm-pitch is used for an etching mask. Discussion on the switching field distribution of damaged magnetic dots and precise pattern alignment process is presented.

4:10pm 5A-2
Rule-Based Directed Self-Assembly of Circuit-Like Block-Copolymer Patterns, Jae-Byum Chang, Hong Kyoon Choi, Adam F. Hannon, Alfredo Alexander-Katz, Caroline A. Ross, Karl K. Berggren, Massachusetts Institute of Technology

Templated self-assembly of block copolymers is one of candidates of next-generation nanolithography, but fabricating a complex pattern has been difficult due to the complexity of the required template. Here, we demonstrate a new approach that uses a limited number of features that considerably reduces the complexity of the template.

4:40pm 5A-3
Directed Self-Assembly of Ternary Blends of Block Copolymer and Homopolymers on Chemical Patterns, Ling-Shu Wan, Paulina A. Rincon Delgadillo, Paul F. Nealey, University of Chicago, Roel Gronheid, IMEC

We investigated the directed self-assembly of ternary blends on chemical patterns produced on 300-mm wafers. We found that the best assembly occurs under conditions in which Lo of the blend falls within a narrow range of being half Ls, and the range depends on the widths of the guiding stripes.

5:00pm 5A-4
Sacrificial Post Templating Method for Block Copolymer Self-Assembly, Amir Tavakkoli K. G., Sam Nicaise, Adam Hannon, Kevin Gotrik, Caroline Ross, Karl Berggren, Massachusetts Institute of Technology

A sacrificial-post templating method for directing block copolymer (BCP) self-assembly is introduced. The physical post-template is removed along with the majority block, and therefore the post template is not incorporated into the final pattern. This method fabricated nanoscale features in different shapes, lattices, and sizes from one BCP.

5:20pm 5A-5
Fabrication of Hierarchical Three-Dimensional Nanostructures Using Template-Directed Assembly of Colloidal Particles, Jonathan Elek, Xu Zhang, Chih-Hao Chang, North Carolina State University

The technique of using templates to direct the self-assembly of colloidal nanospheres allows for the inexpensive fabrication of complex hierarchical patterns which can be achieved over a large area. In this work, template-directed self-assembly of colloidal particles is used for the “top-down” patterning of hierarchical 3D structures.

Session 5B: Nanobiology/Fluidics

Tennessee Ballroom C
Session Chairs:
S. Wind, Columbia University
R. Luttge, University of Twente

3:40pm 5B-1 (Invited)
Label-Free Cell Screening (Invited), Lydia Sohn, University of California, Berkeley

We have developed a label-free method of cell screening based on measuring a current pulse when a cell transits a microchannel. With this simple DC measurement, it is possible to characterize cells for size, shape, and specific cell-surface markers. I will discuss our method's application to screening rare stem cells.

4:10pm 5B-2
Fabrication and Demonstration of Ultra-sensitive and Fast Immunoassay Platform With 3D Nanoplasmonic Cavity Antenna and Microfluidics Using Nanoimprint, Ruoming Peng, Chao Wang, Liangcheng Zhou, Qi Zhang, Weihua Zhang, Stephen Chou, Princeton University

We report (a) a new immunoassay platform that increase the detection sensitivity by 106 fold using novel plasmonic nanostructures, and reduce the total assay time by 5 times through microfluidic channles; and (b) its fabrication using high-precision and high-throughput nanoimprint.

4:40pm 5B-3
Nanowire-Based Electrode for Neural Recordings in the Brain, Dmitry Suyatin, Lars Wallman, Jonas Thelin, Christelle Prinz, Henrik Jorntell, Lars Samuelson, Lars Montelius, Lund University, Jens Schouenborg, Lund University

Research on implantable neural interfaces may enable new possibilities for basic research and clinical applications. Here we report fabrication and functional testing of GaP nanowire-based electrode with a controllable nanomorphology. This type of electrode can be used as a model system for analysis of nanostructured neuronal interfaces in vivo.

5:00pm 5B-4
Ionic Transportation through DNA-based Nanochannels, Paul Bertani, Corey Beck, Xi Zhao, L. James Lee, Sherwin Singer, Wu Lu, The Ohio State University,

We present a polymer-based nanochannel array for ionic transport study at the nanometer scale. The nanometer scale channels are fabricated via a DNA stretching technique utilizing Polydimethylsiloxane (PDMS) stamps. Electrical measurements are used to verify ion translocation and are compared with modeling and simulation data.

5:20pm 5B-5 (Invited)
Targeted nanopatterning for medical applications (Invited), Nikolaj Gadegaard, University of Glasgow

Nanofabrication has opened up an exciting new field of nanobiology. The use of lithographic techniques commonly used for semiconductor fabrication is now extensively used to study

biological systems with such engineered materials. This presentation will give an overview of how blue-sky research can be taken to application.

Session 5C: Microelectromechanical Systems (MEMS) 1

Tennessee Ballroom D/E
Session Chairs:
Phillip Russell, Appalachian State University
Veronica Savu, EPFL, Switzerland

3:40pm 5C-1 (Invited)
Silicon Carbide Nanoelectromechanical Systems and Nanomechanical Logic (Invited), Philip Feng, Mehran Mehregany, Case Western Reserve University

We present our recent efforts and latest results in advancing SiC nanoelectromechanical systems (NEMS) toward a scalable nanomechanical logic technology, and we demonstrate some clear advantages of SiC for enabling NEMS logic switches with robust nanoscale contacts and long lifetimes (in contrast to many other NEMS switches).

4:10pm 5C-2
Design and Fabrication of Ultrananocrystalline Diamond Based Nanoelectromechanical Switches, Kenneth J Perez Quintero, David Czaplewski, Anirudha Sumant, Argonne National Laboratory

We fabricated ultranocrystalline diamond nanowire-based nanoelectromechanical (NEMS) switches. The nanowires were patterned by electron beam lithography, and processed using lift-off and reactive ion etching. The nanowires are 10 microns in length and 100nm in width. We aim to fabricate NEMS switches with fast switching times and low actuation voltages.

4:40pm 5C-3
Towards an RF Planar Waveguide Electron LINAC, JuneHo Hwang, Yue Shi, Amit Lal, Cornell University

This abstract presents planar silicon-based charged particle electrostatic accelerators to miniaturize electron beam systems. It describes a design and initial experimental data from a LINAC that utilizes a co-planar waveguide resonator to achieve accelerating voltages across the accelerating electrodes.

5:00pm 5C-4
Tunability of silicon carbide resonators with electrothermal actuation and piezoelectric readout, Enrico Mastropaolo, Rebecca Cheung, University of Edinburgh, Boris Svilicic, University of Rijeka

Silicon carbide MEMS resonators with electrothermal actuation and piezoelectric sensing are presented. By varying the d.c. input bias from 1V to 7V the devices' frequency can be tuned to 300,000ppm and Q-factor improved by 130%. The influence of structures' dimension on frequency shift, Q-factor and energy dissipation is discussed.

5:20pm 5C-5
Micromachined stylus ion traps through high aspect ratio lithography and electrochemical deposition, Christian Arrington, Ehren Baca, Johnathan Coleman, Patrick Finnegan, Andrew Hollowell, Adam Rowen, Sandia National Laboratories, Kyle McKay, John Jost, Ulrich Warring, Yves Colombe, Robert Jordens, Martin Weides, Andrew Wilson, Dietrich Leibfried, Dustin Hite, David Pappas, David Wineland, NIST

Electrochemical fabrication offers unique advantages for nano/microfabrication. Precise control of deposition sites and thicknesses in addition to 3-D stacking of materials allows significant challenges to be solved through electrodeposition that are beyond the capabilities of standard silicon methods or conventional machining techniques. We have successfully electroformed 3-D stylus ion traps.

FRIDAY MORNING, May 31, 2013

Session 6A: Electron Beam 2

Tennessee Ballroom A/B
Session Chairs:
Alan Brodie, KLA Tencor
Uli Hofmann, GenISys GmbH

8:10am 6A-1 (Invited)
Determining the range and intensity of backscattered electrons from the substrate density and atomic number (Invited), David Czaplewski, Martin Holt, Leonidas Ocola, Argonne National Laboratory

We present a model to predict the range and intensity of backscattered electrons from the density and atomic number of the substrate. We also present our experimental method that combines hybridization of direct write dose and backscatter dose and amplification of backscatter dose contribution using a self-reinforcing pattern geometry.

8:40am 6A-2
Design of ring-cathode focused electron beam columns, Anjam Khursheed, National University of Singapore

This paper presents focused electron beam columns designed for ring-cathodes. The probe current is expected to be in the micro-ampere range with predicted probe diameters less than twenty nano-meters.

9:00am 6A-3
Dual Layer Negative Tone Metal Liftoff Electron Beam Lithography process for nanometer scale Plasmonic and Photonic devices, Yao-Te Cheng, James W Conway, Nancy Latta, Richard Tiberio, Stanford University

We investigate a dual layer negative tone resist process for metal lift-off using electron beam lithography employing HSQ as the imaging layer above PMMA. We employ RIE using oxygen to clear exposed areas of PMMA to generate precision reentrant profiles beneath the HSQ enhancing the metal lift-off patterning result.

9:20am 6A-4
Fabrication of a rotation corrector for electron multi beam array micro-lenses, Aernout Christiaan Zonnevylle, Carel Heerkens, Kees Hagen, Pieter Kruit, TU Delft

Fabrication of MEMS multi beam array rotation correction device. This device is capable of correction rotation errors between multi beam array lens block with an electric field. We will show the tools we have used to built this device, the concept, fabrication results and validation experiments.

9:40am 6A-5
Liquid-phase electron-beam-induced-deposition on bulk substrates without liquid cells, Matthew Bresin, Neha Nehru, J. Todd Hastings, University of Kentucky

Cell-less deposition of highly pure silver nanostructures has been performed using liquid-phase electron-beam-induced-deposition (LP-EBID). Previous work using this technique has relied on commercial liquid cells, which fundamentally limit substrate choice for advanced patterning applications. Here we demonstrate in-situ liquid precursor generation and control, for patterning on bulk substrates.

Coffee break 10:00am - 10:20am

Session 6B: Tip-based Processing

Tennessee Ballroom C
Session Chairs:
Fabian Pease, Stanford University
Todd Hastings, University of Kentucky

8:10am 6B-1 (Invited)
Active Cantilever-free Scanning Probe Lithography (Invited), Keith A. Brown, Xing Liao, Daniel J. Eichelsdoerfer, Wooyoung Shim, Chad A. Mirkin, Northwestern University,

Cantilever-free scanning probe lithography (SPL) represents a powerful method for rapidly printing arrays of nanoscale molecular features, but can only create duplicates of a pattern. Here, we report the development of actuation schemes for cantilever-free SPL that allows one to print arbitrary arrangements of features by depositing materials or energy.

8:40am 6B-2
Fabricating arbitrary silicon nanostructures using thermal dip pen nanolithography (tDPN), Huan Hu, Parsian Mohseni, Mark Shannon, Xiuling Li, William King, University of Illinois at Urbana and Champaign

This paper presents progress of using thermal Dip Pen Lithography (tDPN) to fabricate arbitrary solid nanostructures such as silicon and silicon oxide. Moreover, we show aligned high aspect ratio vertical silicon nanowire arrays fabricated using tDPN and metal-assisted chemical etching (MacEtch).

9:00am 6B-3
Mix&Match Electron Beam and Scanning Probe Lithography for sub-5 nm Patterning, Marcus Kaestner, Manuel Hofer, Ivo Rangelow, Ilmenau University of Technology

In this paper we demonstrate proof of concept combining Electron beam lithograpghy with the outstanding capabilities of closed-loop scanning proximal probe nanolithography on ultra-high resolution molecular resist calixarene. The symbiosis between EBL & SPL expands the process window of nanopatterning and enables excellent patterning resolution and overlay and placement accuracy.

9:20am 6B-4
Multi-spot-size vector writing approach to atomically precise H depassivation lithography, James Owen, Justin Alexander, Joshua Ballard, Ehud Fuchs, William Owen, John Randall, Jim Von Ehr, Zyvex Labs LLC

Our goal is to develop STM-based depassivation lithography into an Atomically Precise manufacturing process. We describe our vector writing process, used to draw shapes, such as 3 nm boxes, with errors of 0.01 -0.1 nm. Multiple spot sizes are used to draw large shapes quickly, while maintaining Atomic Precision edges.

9:40am 6B-5
Mesoscopic Electronic Devices Fabricated using Atomic Force Lithography, Rudzani Nemutudi, iThemba LABS, National Research Foundation, Masaya Kataoka, National Physical Laboratory, Chi-Te Liang, National Taiwan University, Geb Jones, Dave Ritchie, Univesity of Cambridge

The miniaturisation of electronic devices relies on the ability of lithographic techniques to pattern ultra-fine features. AFM lithography is a fabrication technique which utilizes a conducting tip to pattern a surface. We show a range of mesoscopic devices fabricated with an AFM to demonstrate its versatility as a lithographic tool.

Coffee break 10:00am - 10:20am

Session 6C: Nanophotonics 2

Tennessee Ballroom D/E
Session Chairs:
Steve Brueck, University of New Mexico
Daniel Pickard, National University of Singapore

8:10am 6C-1 (Invited)
All-angle Negative Refraction and Active Flat Lensing in the Ultraviolet (Invited), Henri Lezec, NIST, Ting Xu, NIST, Amit Agrawal, Syracuse University, Kenneth Chau, University of British Columbia

We report the first experimental implementation of a metamaterial with a broad-angle, negative refractive index in the ultraviolet (UV). The metamaterial, based on stacked plasmonic waveguides, is used to achieve Veselago flat lensing in three dimensions and all-optical switching, at a free-space wavelength of 364 nm.

8:40am 6C-2
Ultrathin, High-Efficiency, Broad-Band, Omni-Acceptance Organic Solar Cells Using New Plasmonic Cavity with Subwavelength Hole Array, Stephen Chou, Wei Ding, Princeton University

We present fabrication and demonstration of a new ultra-thin high-efficiency solar cell (SC) structure, termed “Plasmonic cavity with subwavelength hole-array (PlaCSH) SC”, which offers solutions to three central issues in SC: light absorption, light trapping, and ITO replacement, leading to doubling (normal incident) and tripling (cloudy day) power conversion efficiency.

9:00am 6C-3
Freestanding Photonic Crystals in Lithium Niobate, Reinhard Geiss, Holger Hartung, Michael Steinert, Séverine Diziain, Frank Schrempel, Ernst-Bernhard Kley, Thomas Pertsch, Andreas Tünnermann, Friedrich-Schiller-Universität

The fabrication of freestanding photonic crystal cavities in lithium niobate is presented. The patterning combines ion-beam enhanced etching and focused ion-beam (FIB) milling. The effect of gallium contamination by FIB and how to circumvent it by subsequent wet etching in hydrofluoric acid is discussed.

9:20am 6C-4
Optimization of Electron Beam Patterned HSQ Mask Edge Roughness for Low-Loss Silicon Waveguides, Michael Wood, Li Chen, Justin Burr, Ronald Reano, Ohio State University

HSQ resist line edge roughness is reduced by simultaneously maximizing electron beam spot overlap and development contrast. Measured optical propagation losses from fabricated silicon strip waveguides show a 7 dB/cm reduction with the reduced line edge roughness HSQ mask.

9:40am 6C-5
A lab-on-a-chip with 30 nm nanochannels and plasmonic bowtie nanoantenna, Irene Fernandez-Cuesta, Corrado Carbone, Scott Dhuey, Andrew Taber, Daniel Gargas, Jim Schuck, Stefano Cabrini, The Molecular Foundry (LBNL)

An integrated device, based on sub-30 nm nanochannels and plasmonic bowtie nanoantenna is presented here. A summary of the fabrication process (all wafer-scale, based on nanoimprint lithography) as well as details on the device performance for sensing will be shown.

Coffee break 10:00am - 10:20am

Session 7A: Emerging Technologies

Tennessee Ballroom A/B
Session Chairs:
Dieter Kern, University of Tuebingen
Don Tennant, Cornell University

10:20am 7A-1 (Invited)
Controlled bottom-up assembly of functional molecules: From wires to networks (Invited), Christophe Nacci, Leonhard Grill, Fritz-Haber-Institute of Max-Planck-Society

The talk will be an overview of our achievements in assembling functional molecules into controlled and predefined covalently bound molecular architectures by on-surface synthesis technique. Conductance measurements through individual molecular wires grown in a bottom-up fashion have been realized by using a low-temperature scanning tunnelling microscope.

10:50am 7A-2
3 D Nanostructures via Aligned Stacking of Pre-patterned Membranes, Corey Fucetola, Lin Lee Cheong, Euclid Moon, Henry Smith, Massachusetts Institute of Technology

Previously, we described efforts to develop a broadly-applicable technology for fabricating three-dimensional nanostructures based on aligning and stacking pre-patterned membranes. Alignment of the membranes relative to one another, with nanometer-level precision, is our focus because conventional mask-substrate alignment processes do not extend to stacking multiple membrane layers.

11:10am 7A-3
Nanograting–Mediated Growth of Bismuth Selenide Topological Insulator Nanoribbons, Sungjin Wi, Eljon Elezi, Amy Liu, Vishva Ray, Kai Sun, Xiaogan Liang, University of Michigan

We present a nanostructure-mediated growth process specifically for producing bismuth selenide (Bi2Se3) topological insulator nanoribbons with a high yield.This work could serve as an important foundation for nanomanufacturing topological insulator nanoribbons with controllable feature size, large-area uniformity and ordering suitable for future applications in low-dissipation nanoelectronics and magnetoelectronic sensors.

11:30am 7A-4
Optoelectronic Devices on-Fiber Enabled by Micro-Assembly Process Using Polydimethylsiloxane Probes, Xiaolong Hu, Prashanta Kharel, Xiang Mao, Luozhou Li, Dirk Englund, Columbia University

We present a novel micro-assembly process using Polydimethylsiloxane probes. This process permits us to assemble different membrane optoelectronic devices into a system, with sub-micrometer alignment accuracy and robust electrical contact. In particular, we show examples of assembling devices directly on facets of standard optical fiber to functionalize the fiber.

11:50am 7A-5 (Invited)
The nano-optics of plasmonic optical tweezers, SERS substrates and multi-colored silicon nanowires (Invited), Kenneth Crozier, Harvard University

We demonstrate the use of surface plasmon nanostructures to trap and manipulate micro- and nanoparticles. We fabricate optical antennas for surface-enhanced Raman scattering (SERS), with gaps down to 3 nm. We demonstrate that silicon nanowires take on a surprising variety of colors covering the visible spectrum.

LUNCH ON YOUR OWN

Session 7B: Maskless Lithography

Tennessee Ballroom C
Session Chairs:
Tim Groves, University at Albany
Mark Schattenburg, Massachusetts Institute of Technology

10:20am 7B-1 (Invited)
MAPPER progress towards a High Volume Manufacturing EBDW system (Invited), G. de Boer, M.P. Dansberg, R. Jager, J.J.M. Peijster, E. Slot, S.W.H.K. Steenbrink, M.J. Wieland, MAPPER Lithography, P. Kruit, Delft University of Technology

MAPPER Lithography is developing a maskless lithography technology based on massively-parallel electron-beam writing with high speed optical data transport for switching the electron beams. The progress towards a High Volume Manufacturing EBDW system will be presented.

10:50am 7B-2
Nanoengineered charge-drain film for electron-optical MEMS in the REBL E-beam column, William Tong, Alan Brodie, Françoise Kidwingira, Mark McCord, KLA-Tencor Corp., Anil Mane, Jeffrey Elam, Argonne National Laboratory

We have engineered a new class of material consisting of nanoclusters of conductive oxides encapsulated in a high dielectric strength insulator. Its resistivity can be tailored by changing the density of the nanoclusters. We have successfully applied it as a coating to overcome the severe charging the REBL's electron-optical MEMS.

11:10am 7B-3
Patterning via Optical Saturable Transformations via Solubility Rate Difference, Precious Cantu, Rajesh Menon, University of Utah, Trisha Andrews, University of Wisconsin-Madison

In POST, the recording medium is comprised of photo-switchable molecules that undergo reversible transitions between two isomeric forms A and B. By incorporating an additional

irreversible transformation, we can show that deep sub-wavelength nanopatterning may be achieved at low light intensities and with simple optical systems.

11:30am 7B-4
Optical patterning of features with spacing below the far-field diffraction limit using absorbance modulation, Farhana Masid, Rajesh Menon, University of Utah, Trisha. L Andrew, University of Wisconsin-Madison,

Here we demonstrate a new benign technique of absorbance modulation, which enables patterning of isolated lines of width 60nm for an exposure wavelength of 325nm. Furthermore, by moving the optical pattern relative to the sample, we demonstrate patterning of closely-spaced lines, whose spacing is as small as 119nm.

11:50am 7B-5 (Invited)
Direct laser writing: Finer, faster and more flexible (Invited), Erik Waller, Michael Renner, Georg von Freymann, University of Kaiserslautern, Michael Thiel, André Radke, Nanoscribe GmbH

SLM based three-dimensional laser lithography reduces the voxel's axial elongation from about 3.0 down to 1.9 by amplitude and phase modulation, allowing for smaller axial feature separation. Multiple voxels reduce writing times by one order of magnitude, scanning the beam gains potentially another two orders.

LUNCH ON YOUR OWN

Session 7C: Nanostructures 2

Tennessee Ballroom D/E
Session Chairs:
Hank Smith, Massachusetts Institute of Technology
Deirdre Olynick, Lawrence Berkeley National Laboratory

10:20am 7C-1 (Invited)
Field Effect Transistor Performance of Hydrothermal ZnO Nanowires (Invited), Cameron Wood, Conor Burke, Hannah Zheng, Natalie Plank, The MacDiarmid Institute, Victoria University of Wellington

Fabrication routes for ZnO nanowire FETs where morphology of the nanowires can be controlled by the chemical composition of the growth mixture and by confinement of the available growth area will be presented. The resulting FET behaviour and performance will be discussed and the potential for nanowire device platforms.

10:50am 7C-2
Fabrication of Periodic Hollow-Shell Nano-Volcano Arrays for Particle Trapping, Xu Zhang, Chih-Hao Chang, NC State University

We demonstrate the fabrication of periodic hollow-shell nano-volcano arrays using light scattering from a hexagonal non-close-packed monolayer of particles. The structure will be designed and optimized to load and release particles precisely for drug delivery application.

11:10am 7C-3
Fabrication of single-crystal diamond nano-slabs for photonic applications, Luozhou Li, Edward Chen, Matthew Trusheim, Jonathan Hodges, Dirk Englund, Columbia University, Ming Lu, Brookhaven National Laboratory

We present a method for mass fabrication of high-purity diamond nanoscale slabs by alternating between plasma etching and mask deposition steps. The material properties of nano-slabs are indistinguishable from the parent bulk diamond. These nanoslabs are suitable for a range of nano-photonic devices based on high-quality diamond membranes.

11:30am 7C-4
Nanofabrication of high aspect ratio structures using evaporated polystyrene resist containing metal, Celal Con, Bo Cui, University of Waterloo

We show that polystyrene electron beam resist can become a superior dry-etch mask by incorporating metal into it, which can be done simply by thermally co-evaporation of polystyrene and metal. After electron beam lithography using this metal-containing resist of 220 nm thickness, we etched silicon to 2.2 μm deep.

11:50am 7C-5 (Invited)
Enabling High Performance Detectors and Optics for Astronomy and Planetary Exploration with PEALD (Invited), April Jewell, John Hennessy, Frank Greer, Michael Hoenk, Shouleh Nikzad, Jet Propulsion Laboratory, Erika Hamden, Columbia University

Here we describe the use plasma enhanced atomic layer deposition for the development of antireflection coatings and pass band filters for silicon-based detectors, reflective coatings for optics, as well as surface passivation layers for a variety of semiconductor-based technologies.

LUNCH ON YOUR OWN

Session 8A: EUV 2

Tennessee Ballroom A/B
Session Chairs:
Eric Anderson, Lawrence Berkeley National Laboratory
Banqiu Wu, Applied Materials Inc.

1:30pm 8A-1 (Invited)
Defect Management of EUV Masks: Progress and Outlook (Invited), Anthony Yen, TSMC

This presentation aims to provide an overview of progress and challenges in the management of defects on EUV masks, including inspection, repair, cleaning, transportation, and storage, to enable development and initial manufacturing of semiconductor devices using EUV lithgoraphy.

2:00pm 8A-2
Single-digit patterning using EUV light, Li Wang, Mohamad Hojeij, Nassir Mojarad, Michaela Vockenhuber, Yasin Ekinci, Jens Gobrecht, LMN Paul Scherrer Institute

We show the capability of EUV-IL as a powerful tool for providing development of photoresist and etching processes at sub-10 nm nodes for industry and academic. There are also various other applications at such size range, just as some examples, templated self-assembly, quantum physics, photonic devices.

2:20pm 8A-3
Stochastic Exposure Kinetics of EUV Photoresists: A Simulation Study, Chris Mack, Lithoguru.com, John Biafore, Mark Smith, KLA-Tencor

A physics-based stochastic simulator models EUV exposure as an electron captured event. The goal of this work will be to explore the stochastic implications of this mechanism as compared to the more common continuous slowing down approximation to energy transfer by photoelectrons.

2:40pm 8A-4
Periodic metallic structures fabricated by coherent Talbot lithography in a table top system, Wei Li, Dinesh Patel, Lukasz Urbanski, Carmen Menoni, Mario Marconi, Colorado State University, Aaron Stein, Brookhaven National Lab

We present a defect tolerant Extreme Ultraviolet (EUV) lithography technique based on the utilization of the Talbot effect. The method renders error-free prints, regardless of existence of defects in the mask. The technique combined with coherent illumination from a compact EUV laser constitutes a compact lithography tool for nanopatterning.

3:00pm 8A-5
Unveiling success rate of defect mitigation by experiment with EUV Actinic Blank Inspection Prototype for 16 nm hp, Tetsunori Murachi, Tsuyoshi Amano, EUVL infrastructure Development Center, Inc., Hiroki Miyai, Lasertec Corp.

We fabricated Fiducial Marks (FMs), inspected FMs with EUV Actinic full-field mask Blank Inspection Prototype developed by EIDEC-LaserTec, and estimated FM registration accuracy. We also evaluated location accuracy of natural defects on mask. We will discuss success rate of defect mitigation schemes by considering previous study and above experimental results.

Coffee Break 3:20pm - 3:40pm

Session 8B: Nanoimprint 2

Tennessee Ballroom C
Session Chairs:
Steve Chou, Princeton University
Shinji Matsui, University of Hyogo

1:30pm 8B-1 (Invited)
8" and 12" wafer scale Nano Imprint Lithography: from process control to optical functions (Invited), Stefan Landis, Vincent Reboud, CEA-LETI

In this paper we present the development of the 8" and 12" wafer scale Nano Imprint Lithography. Starting from the understanding of some process issues, we will demonstrate how the process became mature and how new approaches to manufacture complex 3D shapes with various optical functions could be proposed.

2:00pm 8B-2
Polymer filling behaviors with imprinting velocity in NIL, JiHyeong Ryu, University of Science and Technology, Sang-Ho Lee, Wonkwang University, HyungJun Lim, JaeJong Lee, Korea Institute of Machinery and Materials

As the imprint velocity increases, maximum polymer height increases by squeezing flow. Also, single or double peak shapes are remarkably appeared by changing the flow direction from the side to the center of the stamp. From the results of this study, it can be applied to analyze the flow characteristics.

2:20pm 8B-3
Novel Ordered Hetero Junction Organic Photovoltaics (OHJ-OPV) Novel Ordered Hetero Junction Organic Photovoltaics (OHJ-OPV) by multi-layered direct nanoimprint using buli-in electrode mold, Kohei Tomohiro, Naoki Nishikura, Hiroaki Kawata, Yoshihiko Hirai, Osaka Prefecture University, Kazuhiro Tada, Manabu Ishikawa, Toyama National College of Technology

Novel ordered hetero junction for organic photovoltaics is proposed by multi-layred direct nanoimprint using built-in electrode mold. The process also provides self-sealing during direct nanoimprint without de-molding process. The electric characteristics show increment of photo current by expanded junction area using proposed process.

2:40pm 8B-4
Fabrication of Large-area Flexible Roll-to-Roll Nanoimprint Molds with Sub-100nm Features Using Step-and-Repeat Duplication, Bonding and Lift-off, Hao Chen, Qi Zhang, Stephen Chou, Princeton University

We developed a fast and low-cost method to fabricate large-area flexible roll-to-roll molds with sub-100 nm features by step-and-repeat duplication (with a small-area master mold) and bonding and lift-off of the duplication. We achieved a high fidelity (<3% deviation) in the mold duplication.

3:00pm - 8B-5
Accuracy of Wafer Level Alignment with Substrate Conformal Imprint Lithography, Robert Fader, Maximilian Rumler, Mathias Rommel, Anton Bauer, Lothar Frey, Fraunhofer IISB, Marc Verschuuren, Robert van de Laar, Philips Research, Ran Ji, Michael Hornung, SUSS MicroTec Lithography GmbH

In this work stamp distortions, local alignment accuracy, and the overlay alignment accuracy of the Substrate Conformal Imprint Lithography (SCIL) process on SUSS mask aligners are investigated systematically. The aligment accuracy of the process is determined using high contrast box in box patterns as well as Moiré patterns.

Coffee Break 3:20pm - 3:40pm

Session 8C: Nanoelectronics 2

Tennessee Balroom D/E
Session Chairs:
Rich Tiberio, Stanford University
Bo Cui, University of Waterloo

1:30pm 8C-1 (Invited)
Ionic memory and the future of the semiconductor industry (Invited), Michael Kozicki, Arizona State University

Ionic resistance-change devices have been shown to be ideal for low power memory arrays but have the potential for much wider impact. This talk will cover the state-of-the-art in nanoionic memory and will also highlight emergent applications of the technology in reconfigurable systems and interconnect.

2:00pm 8C-2
Transfer-Printing of Prepatterned Semiconducting Few-Layer-Molybdenum Disulfide Structures for Electronic Applications, Hongsuk Nam, Sungjin Wi, Xiaogan Liang, University of Michigan

We systematically studied transfer-printing approaches for creating ordered MoS2 micro- and nanostructures over large areas and demonstrated field-effect transistors made from printed MoS2 flakes with excellent performance. This research also identified the key processing

conditions affecting the printing uniformity, morphology of MoS_2 structures, and ultimate transport properties of MoS_2-based FETs.

2:20pm 8C-3
Voltage Dependent Electroforming of TiO2-based Memristive Devices, Hao Jiang, Qiangfei Xia, University of Massachusetts

The voltage dependence of electroforming process of TiO_2 based memristive devices was systematically studied. The devices could be formed to either ON or OFF state using voltages of the same polarity but with different amplitudes. The initial forming step also affected the subsequent switching behavior.

2:40pm 8C-4
GaN/AlN Double Barrier Nanowire Resonant Tunneling Diodes, Ye Shao, A.T.M. Sarwar, Santino Carnevale, Roberto Myers, Wu Lu, The Ohio State University

We demonstrate GaN/AlN Double Barrier Nanowire Resonant Tunneling Diodes with high tunneling current density and peak-to-valley current ratio. The performance of NW RTDs with different AlN barrier was compared. Also, PVCR was further enhanced using a Ni/Au Schottky metal contact at one end of the nanowire RTD.

3:00pm 8C-5 (Invited)
Oxide Nanoelectronics on Demand (Invited), Guanglei Cheng, University of Pittsburgh

We introduce a conductive AFM lithography technique for producing electronic nanostructures at the interface between two normally insulating oxides, $LaAlO_3$ and $SrTiO_3$. The electronic and optical properties of the nano-devices will be discussed also.

Coffee Break 3:20pm - 3:40pm

Session 9A: Focused Ion Beam or Sources 3

Tennessee Ballroom A/B
Session Chairs:
Nick Economou, PointSpectrum LLC
Carla Perez Martinez, Massachusetts Institute of Technology

3:40pm 9A-1 (Invited)
Extendability of LPP EUV source technology in kW average power and 6.x nm wavelength operation (Invited), Akira Endo, HiLase

Evaluation of the established LPP EUV source technology is given to indicate further technical path to 1kW average power operation at 13.5nm, and reduction down to 6.x nm. Technical improvements are required in driving laser (pulsed CO_2 laser at 100kW average power), stable beam delivery, and higher conversion efficiency.

4:10pm 9A-2
Monte Carlo Simulations of Helium and Neon Ions Beam Induced Deposition, Rajendra Timilsina, Daryl Smith, University of Tennessee Knoxville, Philip Rack, University of Tennessee Knoxville and Oak Ridge National Laboratory

4:40pm 9A-3
Patterning Plasmonic Nanostructures - Regimes of the Gallium Focused Ion Beam and Helium Ion Microscope, Hanfang Hao, Vignesh Viswanathan, Yue Wang, Daniel Pickard, National University Of Singapore

Direct patterning using focused gallium ion beam and helium ion microscope has been employed to fabricate plasmonic devices down to the nano-meter scale. In this work, we aim to determine the regimes that these two tools operate optimally and identify fundamental and engineering limitations.

5:00pm 9A-4
Advances in Ion Beam micromachining for complex 3D microfluidics, Leonidas E. Ocola, Argonne National Laboratory

This paper present work that shows that a Dual-beam FIB tool can be used for practical microfluidic applications. The bottom of a microfluidic mixer is texturized in a complex manner. Pros and cons of different patterning strategies regarding pattern boundaries, redeposition control, and pattern data organization, will be discussed.

5:20pm 9A-5
Mechanical characteristics of the ultra-long horizontal free-space-nanowire grown by real-time feedback control on focused-ion-beam chemical vapor deposition, Dengji Guo, Shin'ichi Warisawa, Sunao Ishihara, Reo Kometani, The University of Tokyo

Real-time feedback control on FIB-CVD was proposed and demonstrated to be enabling the fabrication of horizontal free-space-nanowire with a length more than 30 micrometers. Furthermore, the mechanical characteristics of free-space-nanowire grown by real-time feedback control on FIB-CVD, were investigated.

Session 9B: Directed Self Assembly / Self Assembly 2

Tennessee Ballroom C
Session Chairs:
Theodore Fedynyshyn, MIT Lincoln Laboratory
Liz Dobisz, HGST

3:40pm 9B-1 (Invited)
Sub-10 nm silicon nano-structures based on block copolymer lithography and high selectivity, cryogenic temperature dry etching (Invited), Deirdre Olynick, Molecular Foundry, Zuwei Liu, Oxford Instruments, Xiaodan Gu, Thomas Russell, U. Mass Amherst, Justin Hwu, Seagate, Valentyn Ishchuk, Ivo Rangelow, Imenau University of Technology

We studied cryogenic plasma etching down to sub-10 nm scale towards production of densely packed silicon features from various block copolymer defined masks. For example, using PS-

PDMS block copolymer lithography, sub-10 nm silicon wires were produced. Selectivity mechanisms are revealed and simulation work is shown.

4:10pm 9B-2
Thermodynamic origin of placement errors for contact holes created by directed self-assembly, Sander Wuister, Tamara Druzhinina, Eddy Van der heijden, Davide Ambesi, Jo Finders, ASML, Emiel Peeters, Chris Van Heesch, Henk Boots, Philips Research

The pitch of staggered CHs, formed by DSA, shows an intrinsic Gaussian distribution that originates from thermodynamic broadening. Absolute overlay between staggered CHs formed by DSA and NAND_WL will be shown. Ultimate confinement is found in CH shrink. Experimental placement errors will be reported and compared to mean field simulations.

4:40pm 9B-3
Block Copolymer Directed Self-Assembly Two-Hole Pattern inside Peanut-Shaped Templates, He Yi, H.-S. Philip Wong, Stanford University

Previously we demonstrated using topographical templates to flexibly control DSA for contact hole patterning. Among all templates, peanut-shapes are important as they represent that two separate circular templates merge due to limited resolution of lithography. We explore the design space of the peanut-shaped templates for the DSA 2-hole pair pattern.

5:00pm 9B-4
DNA Origami: Prospects for Nanomanufacturing, James Liddle, Andrew Berglund, Gregg Gallatin, National Institute of Standards and Technology, Kan Du, Seung Hyeon Ko, National Institute of Standards and Technology/Maryland Nanocenter, University of Maryland, /Maryland Nanocenter, University of Maryland

Design rules for the assembly of heterogeneous nanoparticles (quantum dots and Au nanoparticles)on DNA origami are determined using measurements of the fluorescence response of the quantum dots to the size, number and placement of Au nanoparticles. This is combined with reaction rate data to understand the manufacturability of such structures.

5:20pm 9B-5
Ordered arrays of carbon nanotube segments by directed assembly, Erika Penzo, Matteo Palma, Risheng Wang, Shalom Wind, Columbia University

We describe two directed assembly techniques, based upon the combination of precise lithographic patterning and selective modulation of surface chemistry and surface energy, for the arrangement of single wall carbon nanotube segments, with control over position and orientation.

Session 9C: MEMS 2

Tennessee Ballroom D/E
Session Chairs:
Enrico Mastropaolo, University of Edinburgh
David Tanenbaum, Pomona College

3:40pm 9C-1 (Invited)
Triboelectric Generators for Self-Powered Electronics (Invited), Guang Zhu and Zhong Lin Wang, Georgia Institute Of Technology

Here, we introduce a fundamentally innovative technology called triboelectric generators for harvesting ambient mechanical energy. It is based on the coupling between triboelectric effect and electrostatic induction. Diverse forms of mechanical energy can be harvested by the triboeletric generator, making it a universal, scalable, and practical technology.

4:10pm 9C-2
Optomechanical resonator fabrication with the surface plasmon antenna for the wavelength detection, Reo Kometani, Hui Liu, Shin'ichi Warisawa, Sunao Ishihara, The University of Tokyo

In this study, an optomechanical resonator with a plasmon antenna was fabricated in order to achieve the high accuracy wavelwngth detection, and its performance was investigated. As a result, We found that an optomechanical resonator has the wavelength detection resolution of 0.024 nm.

4:40pm 9C-3
Planar Electronic Picosecond Electron Pulser, JuneHo Hwang, Serhan Ardanuc, Amit Lal, Cornell University

Generation of picosecond electron packets without using a high-speed laser is one technology approach towards realizing a compact electron pulser. This paper presents a design and initial results on an electron pulser that uses a swept voltage and beam blanking pillars to generate short electron packets without using high-speed laser.

5:00pm 9C-4
Fabrication of neural probes for simultaneous in vivo optical stimulation and electrical recording in the brain, Mufaddal Gheewala, Wei-Chuan Shih, John Wolfe, University of Houston, Gopathy Purushothaman, Vanderbilt University, John Dani, Neuroscience, Baylor College of Medicine, Houston

The goal of this paper is to report the design and fabrication of implantable neural probes, optrodes, for simultaneous optical stimulation and electrical recording in the deeper regions of the brain. 2-channel prototypes have been fabricated and used in preliminary experiments.

5:20pm 9C-5
Fabrication of Complex Three-Dimensional Multilevel Silicon Micro- and Nano-Structures using High Energy Ion Irradiation, Sara Azimi, Dang Zhiya, Mark Breese, University of Singapore

We have developed a new process to fabricate arbitrary-shaped, multilevel, three-dimensional free-standing micro- and nano-structures on bulk silicon using focused high energy proton beam irradiation, followed by electrochemical anodization. This is the only technique capable of making such complex free-standing structures on bulk silicon after a single-step etching.

Program at a Glance

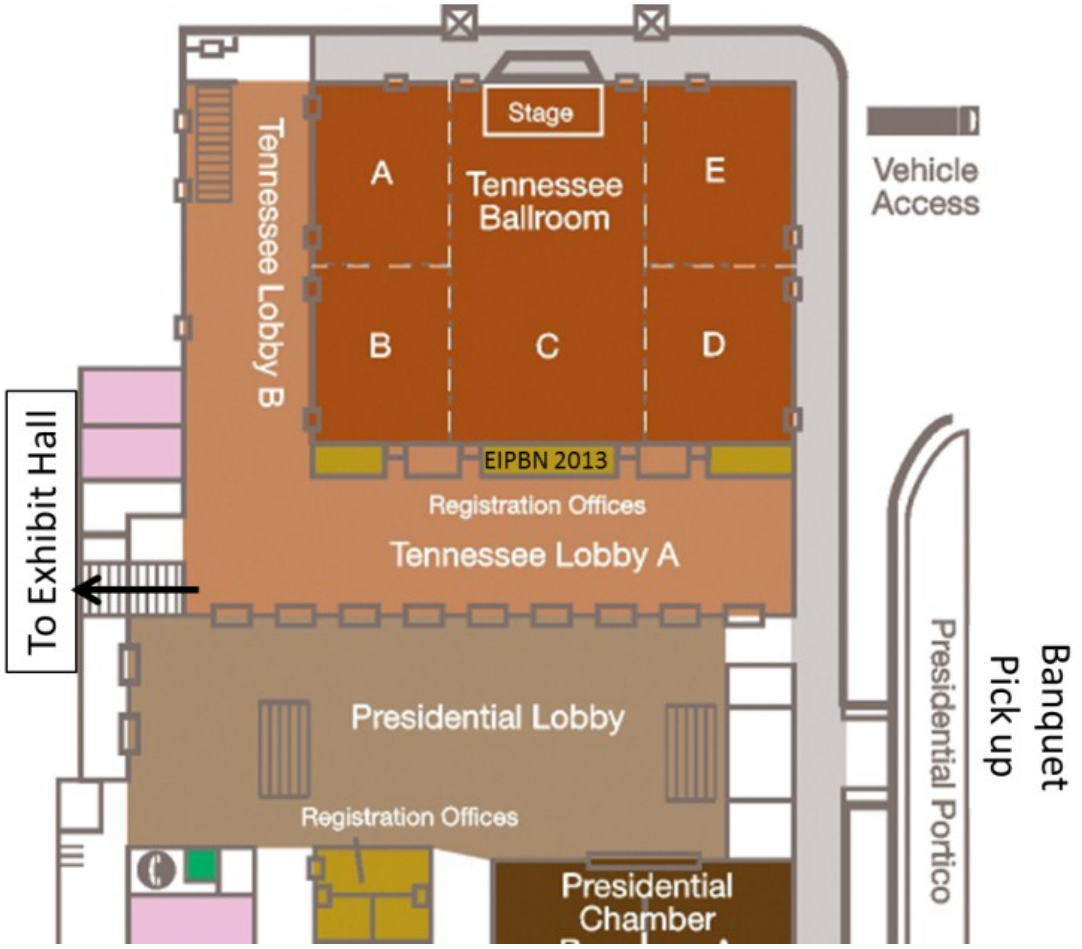
Tuesday May 28th, 2013			
Time Start	**Time End**	**Session**	**Venue**
2:00 PM	7:00 PM	Onsite Registration and Material Pick up	Tennessee Lobby
3:00 PM	6:00 PM	Commercial Exhibit	Ryman Exhibit Hall
7:00 PM	10:00 PM	Welcome Reception	The Water's Edge on Delta Island
Wednesday May 29th, 2013			
Time Start	**Time End**	**Session**	**Venue**
7:30 AM	3:30 PM	Onsite Registration and Material Pick up	Tennessee Lobby
10:00 AM	4:30 PM	Commercial Exhibit	Ryman Exhibit Hall
8:30 AM	12:00 PM	Plenary Session	Tennessee Ballroom
12:00 PM	1:00 PM	Poster Lunch	Ryman Exhibit Hall
12:00 PM	2:30 PM	Poster Session	Ryman Exhibit Hall
2:30 PM	4:50 PM	Session 1A - Electron Beam 1	Tennessee Ballroom A/B
		Session 1B - Nanophotonics 1	Tennessee Ballroom C
		Session 1C - EUV 1	Tennessee Ballroom D/E
4:50 PM	5:30 PM	Poster Session	Ryman Exhibit Hall
5:15 PM	6:15 PM	Mentorship Hour	Ryman Exhibit Hall
Thursday May 30th, 2013			
Time Start	**Time End**	**Session**	**Venue**
7:30 AM	5:00 PM	Onsite Registration and Material Pick up	Tennessee Lobby
10:00 AM	1:00 PM	Commercial Exhibit	Ryman Exhibit Hall
10:00 AM	1:00 PM	Poster Session	Ryman Exhibit Hall
8:10 AM	10:00 AM	Session 2A - Nanostructures 1	Tennessee Ballroom A/B
		Session 2B - Focused Ion Beam or Sources 1	Tennessee Ballroom C
		Session 2C - Modeling	Tennessee Ballroom D/E
10:00 AM	10:20 AM	Break	Ryman Exhibit Hall
10:20 AM	12:20 PM	Session 3A - Novel imaging/metrology	Tennessee Ballroom A/B
		Session 3B - Resists	Tennessee Ballroom C
		Session 3C - Nanoelectronics 1	Tennessee Ballroom D/E
12:20 PM	1:30 PM	Lunch	
1:30 PM	3:20 PM	Session 4A - Nanoimprint 1	Tennessee Ballroom A/B
		Session 4B - Carbon-based devices/systems	Tennessee Ballroom C
		Session 4C - Focused Ion Beam or Sources 2	Tennessee Ballroom D/E
3:20 PM	3:40 PM	Break	Tennessee Lobby
3:40 PM	5:50 PM	Session 5A - Directed Self Assembly (DSA)/Self Assembly (SA) 1	Tennessee Ballroom A/B
		Session 5B - Nanobiology/fluidic	Tennessee Ballroom C
		Session 5C - Microelectromechanical Systems (MEMS) 1	Tennessee Ballroom D/E
6:00 PM	6:30 PM	Leave for Banquet	Presidential Portico
7:00 PM	10:00 PM	Banquet	General Jackson Riverboat

Program at a Glance

Friday May 31st, 2013			
Time Start	**Time End**	**Session**	**Venue**
7:30 AM	12:00 PM	Onsite Registration and Material Pick up	Tennessee Lobby
8:10 AM	10:00 AM	Session 6A - Electron Beam 2	Tennessee Ballroom A/B
		Session 6B - Tip-based Processing	Tennessee Ballroom C
		Session 6C - Nanophotonics 2	Tennessee Ballroom D/E
10:00 AM	10:20 AM	Break	Tennessee Lobby
10:20 AM	12:20 PM	Session 7A - Emerging Technologies	Tennessee Ballroom A/B
		Session 7B - Maskless Lithography	Tennessee Ballroom C
		Session 7C - Nanostructures 2	Tennessee Ballroom D/E
12:20 PM	1:30 PM	Lunch	
1:30 PM	3:30 PM	Session 8A - EUV 2	Tennessee Ballroom A/B
		Session 8B - Nanoimprint 2	Tennessee Ballroom C
		Session 8C - Nanoelectronics 2	Tennessee Ballroom D/E
3:20 PM	3:40 PM	Break	Tennessee Lobby
3:40 PM	5:40 PM	Session 9A - Focused Ion Beam or Sources 3	Tennessee Ballroom A/B
		Session 9B - Directed Self Assembly/Self Assembly 2	Tennessee Ballroom C
		Session 9C - MEMS 2	Tennessee Ballroom D/E

Gaylord Opryland Floor Plans

Main Floor Plan



Lower Floor Plan

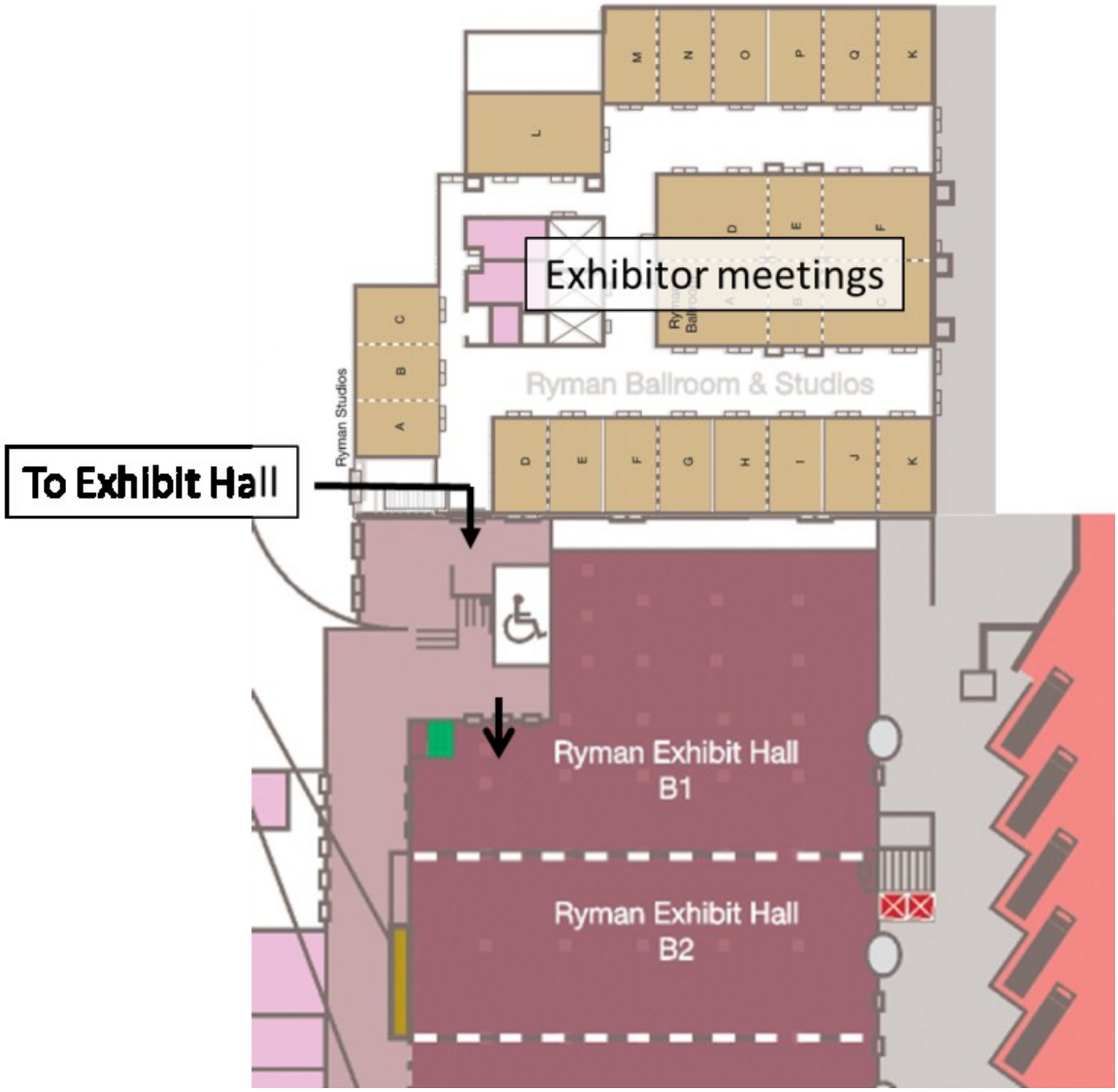
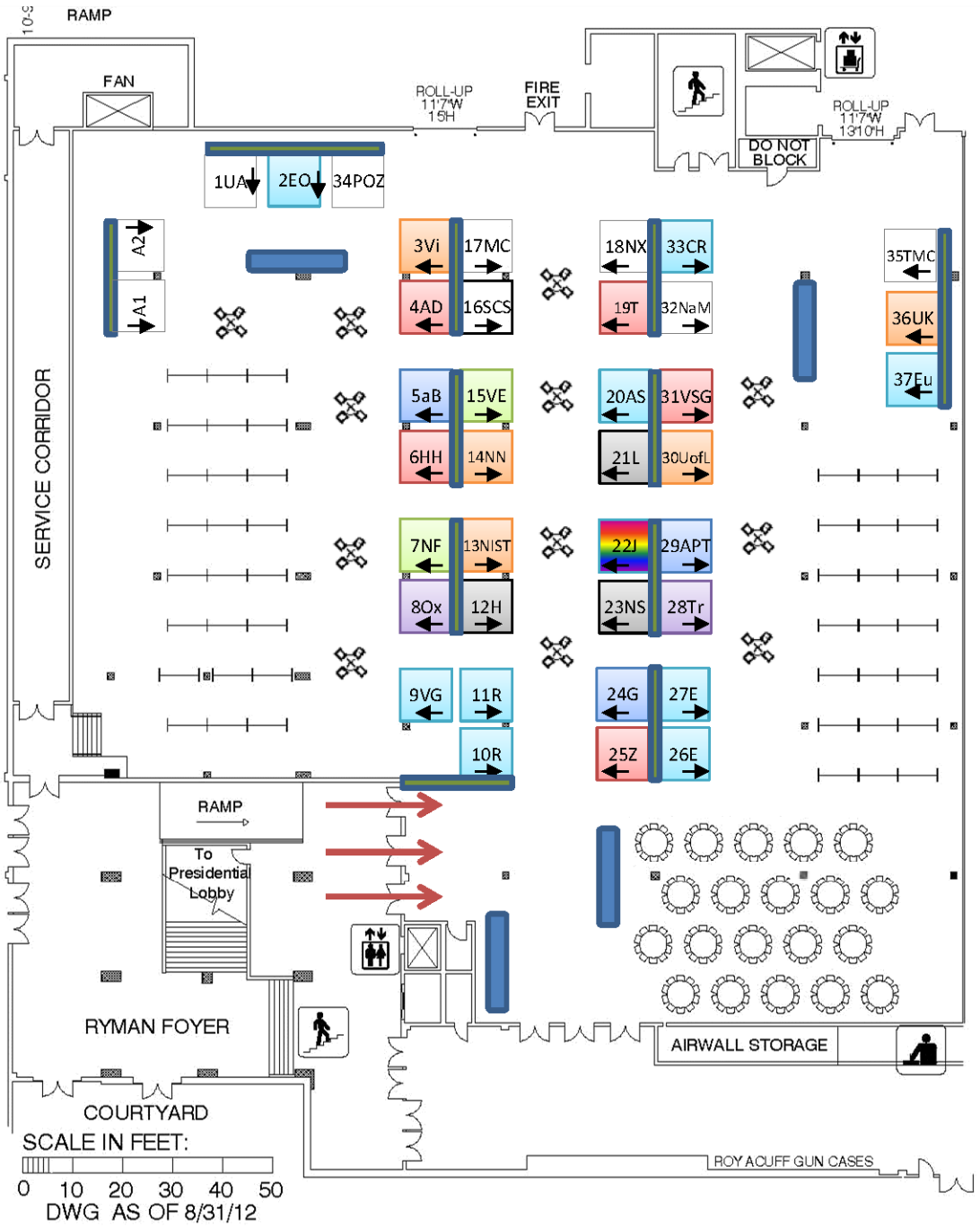


Exhibit Layout

Company Name	Booth	Code
National Institute for Nanotechnology	1	UA
Electron Optica/MEBS	2	EO
Vanderbilt Institute of Nanoscale Science and Engineering	3	Vi
A&D Company Limited	4	AD
aBeam Technologies, Inc.	5	aB
Hitachi High Technologies America, Inc	6	HH
NuFlare Technology, Inc.	7	NF
Oxford Instruments	8	Ox
Vistec Gaussian Beam Lithography	9	VG
Heidelberg Instruments Inc.	12	H
NIST/CNST	13	NIST
National Nanotechnology Infrastructure Network (NNIN)	14	NN
Vistec Electron Beam GmbH	15	VE
Specialty Coating Systems	16	SCS
MicroChem Corp	17	MC
Nanonex Corporation	18	NX
Tescan USA	19	T
Angstrom Scientfic, Inc.	20	AS
Lumarray Inc	21	L
JEOL USA, INC	22	J
Nanoscribe GmbH	23	NS
GenISys	24	G
Carl Zeiss Microscopy, LLC	25	Z
Trion Technology	28	Tr
Applied Physics Technologies	29	APT
University of Louisville-Speed School of Engineering	30	UofL
VSG - Visualization Sciences Group	31	VSG
NanoAndMore	32	NaM
CRESTEC CORPORATION	33	CR
Pozzetta	34	Poz
TMC Ametek	35	TMC
University of Kentucky - CeNSE	36	UK
Eulitha	37	Eu
Raith USA, Inc.	10,11	R
STS-ELIONIX	26,27	E

SEM | Gaussian Beam | Etch | Sources/ accessories | optical | Mask writers | User facilities | Other



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