TUESDAY, May 26, 2015

7:00 am – 7:00 pm Conference Registration
Seaport Ballroom Foyer

8:00 am – 3:00 pm **Short Course: State-of-the-Art Nanofabrication – Fundamentals and Applications**
Grand Ballroom C
This course is intended to bring researchers new to the field of nanofabrication up to speed on the fundamentals of techniques such as atomic layer deposition, plasma etching, block copolymer and e-beam lithography as well as characterization. A detailed discussion of advanced applications of complex nanofabrication will also be presented.

Speakers:
Deirdre Olynick, Staff Scientist, Lawrence Berkeley National Laboratory
Annika Peter, ALD Technologist, Oxford Instruments
Tom Tiwald, Applications Engineer, J.A. Woollam Co.
Thomas Mueller, Director, AFM Development Applications
Leonidas Ocola, Argonne National Laboratory

3:00 pm – 6:00 pm Commercial Exhibit Session
Seaport Ballroom D/E/F/G/H

7:00 pm – 9:30 pm Welcome Reception
Kin Oasis Pool

WEDNESDAY, May 27, 2015

7:30 am – 5:00 pm
Conference Registration

10:00 am – 4:30 pm
Commercial Exhibit Session - Seaport Ballroom D/E/F/G/H

10:30 am – 12:00 pm
Poster Session - Seaport Ballroom D/E/F/G/H

12:00 pm – 1:15 pm
Women in Nanofabrication Networking lunch- Balboa A/B/C

5:30 pm – 7:00 pm
Poster Session, Seaport Ballroom D/E/F/G/H

WEDNESDAY MORNING, May 27, 2015

Plenary Session

Seaport Ballroom A/B/C
Session Chairs:
J. Todd Hastings, University of Kentucky
Michael Guillorn, IBM Research

8:00am
Welcome

8:15 am - 8:55 am Plenary-1
Materials by Design: 3-Dimensional Architected Nanostructured Meta-Materials, J. R.Greer, California Institute of Technology

Creation of extremely strong yet ultra-light materials can be achieved by capitalizing on the hierarchical design of 3-dimensional nano-architectures. Such structural meta- materials exhibit superior thermomechanical properties at extremely low mass densities (lighter than aerogels), making these solid foams ideal for many scientific and technological applications.

8:55 am - 9:35 am Plenary-2
Advances in scaling of genomic assays: The role of nanofabrication in the past, present, and future evolution of genome technology, Kevin Gunderson, illumina

In this talk, the history of scaling genomic assays and the associated technical innovations will be explored, as well as the ever increasing role of both top-down and bottom-up nanofabrication in further scaling of NGS technologies. The talk will conclude with an exploration of current scaling challenges, and how future innovation in nanofabrication will enable the continued evolution of NGS to provide cheaper and more complete genomes

9:35 am - 10:15 am Plenary-3
3D Printing of Advanced Biocomposites on Earth and Beyond, Lynn Rothschild, NASA Ames Research Center

Human exploration is limited by the cost of launching materials to space. Biology can solve these problems with self-replication and repair,and producing materials. Synthetic biology expands life's repertoire. Using organisms as feedstock for additive manufacturing could make possible the dream of producing tools, smart fabrics and replacement organs on demand.

WEDNESDAY AFTERNOON, May 27, 2015

Session 1A - Directed Self Assembly 1

Seaport Ballroom A
Session Chairs:
Karl Bergrenn, MIT
Alex Liddle, NIST

1:15 pm - 1:45 pm 1A1 (Invited)
Directed Self-Assembly Via Shrink Process with Lamella-forming Block Copolymers, Chi-Chun Liu, Joy Cheng**, Cheng Chi, Yongan Xu, Daiji Kawamura*, Lovejeet Singh*, Kota Nishino*, Martha Sanchez**, Kristin Schmidt**, Jed Pitera**, Eugene Delenia**, Leslie Thompson**, Richard Farrell***, Nihar Mohanty***, Hongyun Cottle***, Luciana Meli, Kaushik Vemareddy****, Ryota Harukawa****, Venkat Nagaswami****, Kafai Lai#, Tsuyoshi Furukawa*, Ken Maruyama*, David Hetzer***, Daniel Sanders**, Nelson Felix, Sean Burns, and Matthew Colburn, IBM Albany NanoTechnology Center, *JSR Micro Inc, **IBM Research-Almaden, ***TEL Technology Center, America, LLC, ****KLA-Tencor Ltd., and #IBM Semiconductor Research and Development Center

DSA of lamella-forming BCP was evaluated as a candidate for forming Self-aligned via, process window and pattern transfer were investigated. The profile and the thickness of the residual PS layer were studied using Monte Carlo simulation and FIB cross-section SEM. Preliminary defectivity study using the lamellar system will be presented.

1:45 pm - 2:05 pm 1A2
Electrical Yield Verification of Half Pitch 15 nm Patterns using Directed Self-assembly of PS-b-PMMA, Tsukasa Azuma, Yuriko Seino, Hironobu Sato, Yusuke Kasahara, Katsutoshi Kobayashi, Hitoshi Kubota, Hideki Kanai, Katsuyoshi Kodera, Naoko Kihara, Yoshiaki Kawamonzen, Satoshi Nomura, Ken Miyagi, Shinya Minegishi, Toshikatsu Tobana and Masayuki Shiraishi, EUVL Infrastructure Development Center, Inc

We demonstrated electrical yield verification for half pitch 15 nm patterns across 300 mm wafer using directed self-assembly of PS-b-PMMA. The electrical open and short yield test could reveal our process viability from the perspective of total performance for practical semiconductor device manufacturing.

2:05 pm - 2:25 pm 1A3
Selective neutralization for neutral last grapho-epitaxy directed self-assembly, H. Tsai, S. Engelmann, C.-C. Liu, J. Cheng, J. Pitera, D. Sanders, M. Colburn, and M. A. Guillorn, IBM

A neutral last grapho-epitaxy process decouples template formation from the DSA processes and enables the use of more processes and materials. In this paper, we show that a neutral brush with a grafting density determined by process temperature and substrate property exhibits superior neutral last DSA results than conventional brushes.

2:25 pm - 2:45 pm 1A4
Selective Laser Ablation in Resists and Block Copolymers for High Resolution Lithographic Patterning, Pradeep Perera, Prashant Kulshreshtha, Dimas G. D. Oteyza, Adam Schwartzberg, Deirdre L. Olynick, Nathan Jarnagin*, Cliff Henderson*, Zhiwei Sun**, Ilja Gunkel**, Thomas Russell**, Matthias Budden***, and Ivo W. Rangelow***, Lawrence Berkeley National Laboratory, *Georgia Institute of Technology, **University of Massachusetts Amherst and Lawrence Berkeley National Laboratory, and ***Ilmenau University of Technology

We demonstrated a dry, selective laser ablation development in calixarene (MAC6) which produced high resolution, high aspect ratio features not achievable with wet development. In this paper, we demonstrate selective ablation in block copolymer systems. This offers an alternative to block removal using plasma etching when selectivity cannot be achieved.

2:45 pm - 3:15 pm 1A5 (Invited)
Directed Self-Assembly Process Integration – Fin Patterning Approaches and Challenges, Safak Sayan, Taisir Marzook, Intel Corporation, BT Chan, Nadia Vandenbroeck, Roel Gronheid, IMEC

In this contribution, we will present/propose fin patterning approaches and challenges for sub-10 nm CMOS technology nodes, which includes demonstration of DSA integration to CMOS process flows with front-end-of-line device film stacks.

Session 1B - Nano- and Micro- Electromechanical Systems

Seaport Ballroom B
Session Chairs:
Maxim Zalalutdinov, NRL
Enrico Mastropaolo, Univ. Edinburgh

1:15 pm - 1:45 pm 1B1 (Invited)
Solid State RF NEMS-CMOS Resonators, D. Weinstein, MIT

Resonant Body Transistors can be integrated into a standard CMOS process for low power clock generation and high-Q tank circuits. I will discuss our work on the first hybrid RF MEMS-CMOS Si resonators at the transistor level of a CMOS baseline process, without the need for any post-processing or packaging.

1:45 pm - 2:05 pm 1B2
Free-standing Nanostructures in Single-crystal Quartz, Y.-I. Sohn and Marko Lončar, Harvard University

We demonstrat the fabrication of free-standing nanostructures made in single-crystal quartz. Fabrication is done by combining the traditional RIE etch of silicon dioxide and the angled-etching technique. Nano-cantilevers are made as exemplary structures of free-standing device, which are essential elements in nanomechanics and nanooptics

2:05 pm - 2:25 pm 1B3
Determination of Mechanical, Electrical and Surface Properties of an Individual Carbon Nanotube by Single Measurement, P. Neuzil, V. Svatoš, J. Drbohlavová, and J. Hubálek, Brno University of Technology

We probed vertically aligned CNTs were probed by electrically biased tipless AFM cantilevers. We have extracted Young's modulus and electrical conductivity of a single CNT by processing force and current spectra. We had also information about number of CNT in contact with the cantilever at any point of time.

2:25 pm - 2:45 pm 1B4
High performance lithium niobate surface acoustic wave transducers exceeding 10 GHz resonant frequency, X. Chen, M. A. Mohammad, J. W. Conway*, B. Liu, Y. Yang, T.-L. Ren, Tsinghua University, *Stanford University

A systematic study of SAW transducers in the 4-12 GHz range is reported. Various designs, EBL nanofabrication, and performance metrics will be discussed in detail. This is the first report of lithium niobate SAW transducers exceeding 10 GHz, which can benefit high speed, short range communications or high selectivity sensors.

2:45 pm - 3:15 pm 1B5 (Invited)
Advances in fabrication and electrical transduction of silicon nanowire mechanical resonators, F. Perez-Murano. IMB-CNM. CSIC. Barcelona.

Silicon nanowire mechanical resonators are excellent building blocks for ultra-high sensitivity mass sensors. We will present recent development for their fabrication, based on top-down and bottom-up methods. It will also be shown that suspended silicon nano-beams present exceptional electronic and electromechanical properties, from single electron behavior to enhanced piezoresistive transduction

Session 1C - Beam Induced Deposition and Etching 1

Seaport Ballroom C
Session Chairs:
Philip Rack, Univ. Tennessee
Dieter Kern, Tuebingen

1:15 pm - 1:45 pm 1C1 (Invited)
Recent advances in gas-assisted electron and ion beam induced surface processing techniques, M. Toth, University of Technology, Sydney

Gas-assisted charged particle beam processing enables direct-write nanofabrication using electron and ion beams. Recent applications of these techniques will be reviewed with an emphasis on damage-free etching, surface functionalization and the role of self-assembly structure formation.

1:45 pm - 2:05 pm 1C2
Laser Assisted Electron Beam Induced Deposition: Towards a Nanoscale Atomic Layer Deposition Process, Michael G. Stanford*, Brett B. Lewis*, Joo Hyon Noh*, Harald Plank**, Jason D. Fowlkes*,***, Nicholas A. Roberts*, Philip D. Rack*,***, *University of Tennessee, **Graz University of Technology, ***Oak Ridge National Laboratory

While recently EBID deposits have been used as selective atomic layer deposition (ALD) catalyst, here we demonstrate an in-situ ALD-like process driven by electron and laser-induced thermal half reactions. We have developed a reactive gas-assisted laser anneal process to enhance the purity of patterns deposited using $MeCpPtIVMe_3$ precursor gas.

2:05 pm - 2:25 pm 1C3
Focused Ion Beam Processing of Polymers: Pushing the Limits by Alternative Patterning Strategies, R. Schmied, A. Orthacker, B. Chernev, C. Mayrhofer, J. Kraxner, R. Winkler, J. Hobisch*, G. Trimmel*, H. Plank*, Centre for Electron Microscopy, *Graz University of Technology

This presentation summarizes latest advances in the field of focused ion beam processing (Ga+) of polymers. A simulation / calculation model is presented which identifies a technical heat component induced by classical patterning strategies. A counterstrategy is sucessfully introduced which minimizes chemical degradation and maximizes morphological stability beyond current limits.

2:25 pm - 2:45 pm 1C4
Evaluating Process Parameters for Liquid Phase Electron Beam Induced Etching of Copper, L. Boehme and J. T. Hastings, University of Kentucky

The selective, and site-specific, electron beam induced etching of a copper thin film on silicon, with aqueous sulfuric acid as the etchant, is presented. To better understand the etching process, the effects of liquid thickness, sulfuric acid concentration, dose, and refresh time were studied.

2:45 pm - 3:05 pm 1C5
Designing Precursors for the Deposition Technique: CVD vs. EBID, L. McElwee-White, J.A. Brannaka, Y.-C. Wu and D.H. Fairbrother*, University of Florida and Johns Hopkins University*

Electron beam induced deposition (EBID) often involves precursors developed for chemical vapor deposition (CVD). However, the different decomposition chemistry in the two techniques often makes CVD precursors unsuitable for EBID. Mechanism-based design of precursors for CVD and EBID will be presented in case studies for comparison and contrast.

Session 2A - Nanoimprint Lithography 1

Seaport Ballroom A
Session Chairs:
Stefano Cabrini, LBL
Hella-Christin Scheer, Univ. Wuppertal

3:30 pm - 4:00 pm 2A1 (Invited)
Tunable mesoscale magnetic structures by nanoimprint lithography, Kannan M. Krishnan*, Byung-Seok Kwon*, Zheng Li* and Wei Zhang**, University of Washington, **Argonne National laboratory

We describe a versatile, defect-free, nanoimprint lithography process for the large-area patterning of magnetic structures of metals, oxides and multilayers including examples of (a) Competing anisotropies and temperature dependence of exchange-biased, epitaxial arrays (b) Sombrero-shaped synthetic antiferromagnet (Fe_3O_4/Ti)n nanoelements and their direct release and (c) Large-area L10 FePt bit-patterned media.

4:00 pm - 4:20 pm 2A2
Printable Integrated Photonic Devices with a high refractive index, C. Pina-Hernandez, C. Mejia Prada, G. Calafiore, C. Peroz, Q. Fillot*, S. Dhuey*, A. Koshelev**, and A. Goltsov**, aBeam Technologies, Inc., *Lawrence Berkeley National Lab. and **NanoOptics Devices

We present here a powerful route to fabricate the first printable photonic integrated circuits (PIC) with high refractive index.

4:20 pm - 4:40 pm 2A3
Combining UV-nanoimprint lithography and inkjet printing for the fabrication of monolithic micro-optical components, L. Jacot-Descombes, V.J. Cadarso*, A. Schleunitz, S. Grützner, J. Brugger**, H. Schift*, and G. Grützner, micro resist technology GmbH, *Paul Scherrer Institute and **Ecole Polytechnique Federale de Lausanne

This paper presents for the first time the combination of inkjet-printed microlenses arrays, containing lenses with individual characteristics, and their UV-nanoimprint lithography high-throughput replication into commercially available optical polymers. Fabricated and replicated microlens arrays into PDMS and Ormocomp as well as optical characterization is also presented.

4:40 pm - 5:00 pm 2A4
Molecular Dynamics Study of Line Edge Roughness in Nanoimprint Lithography, N. Iwata, M. Yasuda, H. Kawata, Y. Hirai, Osaka Prefecture University

The line edge roughness (LER) of the resist pattern formed by nanoimprint lithograhpy (NIL) is studied with molecular dynamics simulation. The LER increases as the interaction between the mold and resist becomes large. The LER of the pattern is closely related to the demolding force even in the atomic-scale NIL.

5:00 pm - 5:20 pm 2A5
Volume-expansion polymerization for UV-curable nanoimprint, Zengju Fan, Ziping Li, Yanqing Tian and Xing Cheng, South University of Science and Technology of China

In this work, we report a nanoimprint resist formula that utilizes volume-expansion polymerization.Zero volume expansion is expected to reduce residual stress in cured resist and lower separation energy during demolding.

Session 2B - Nanophotonics 1

Seaport Ballroom B
Session Chairs:
Wei Wu, USC
Rick Bojko, Univ. Washington

3:30 pm - 4:00 pm 2B1 (Invited)
Chip-scale Cavity Electro-optomechanics with Aluminum Nitride, L. Fan and H. Tang, Yale University

Aluminum nitride is the ideal material to realize electro-optomechanical systems. We will review our recent progress in developing integrated AlN optomechanical devices including optomechanical crystal, micro-disk, and micro-wheel, as well as their applications.

4:00 pm - 4:20 pm 2B2
Nano Cost Nano Patterned Template for Surface Enhanced Raman Scattering, H.- C. Hou, J. Kim, K. Kanakamedla, S. Basu, T. Daniels-Race, and M. Feldman, Louisiana State University

Etched aluminum foil is coated with a thin gold layer and used as a template for Surface Enhanced Raman Scattering. Patterns are imprinted in epoxy, and the aluminum is removed by etching. Strong signals have been observed in transmission, as required for clinical applications.

4:20 pm - 4:40 pm 2B3
Breaking Malus' Law: Enhancing Asymmetric Light Transmission with Metasurfaces, Cheng Zhang, Carl Pfeiffer, Taehee Jang, Vishva Ray, Anthony Grbic and L. Jay Guo, The University of Michigan

A structure providing broadband asymmetric light transmission at 1.5 μm with a suppression ratio of 24:1 is achieved with a metasurface consisting of three cascaded layers of gold nano-wires, with a total thickness of λ/5.

4:40 pm - 5:00 pm 2B4
Scatterometry of a 50-nm Half Pitch Wire Grid Polarizer, Ruichao Zhu, Alexander R. Munoz, S.R.J Brueck, Sharwan Singhan*, S. V. Sreenivasan*, University of New Mexico and *University of Texas at Austin,

We have carried out scatterometry studies of a 50nm half-pitch wire-grid polarizer fabricated by nano-imprint lithography and anisotropic etching. In particular, the limits of scatterometry as both the pitch and the CD become << the scatterometry wavelength are explored.

5:00 pm - 5:20 pm 2B5
Visible subwavelength dielectric grating reflector fabricated using focused ion beam, M. S. Alias, H-.Y. Liao, T. K. Ng, B. S. Ooi, King Abdullah University of Science & Technology (KAUST)

Here we propose subwavelength grating reflector fabrication using focused ion beam technique on dielectric multilayers (Si_3N_4/SiO_2) using GaN-sapphire substrate at visible wavelength. We spin-coated electron dissipation polymer (ESPACER 300Z) on the sample surface to reduce the charging effect of the dielectrics, GaN and sapphire during milling.

WEDNESDAY AFTERNOON, May 27, 2015

Session 2C - Focused Ion Beam Technology 1

Seaport Ballroom C
Session Chairs:
Sven Bauerdeick, RAITH
Adam Steele, zeroK

3:30 pm - 4:00 pm 2C1 (Invited)
Exploring Neon GFIS Nano-Machining Applications in Circuit Edit, Shida Tan, Roy Hallstein, Rick Livengood, Haripriya Prakasam, Laxa Patel, Octavian Nastasescu, and Chris Scheffler, Intel Corporation

In this paper, the general approach employed, challenges encountered, and early results acquired in neon application development using Zeiss NanoFAB (noble GFIS) platform for circuit edit will be presented. The merits and limitations of applying a Ne+ beam in high precision circuit edit applications will be shared with the audience.

4:00 pm - 4:20 pm 2C2
Three-dimensional Nanofabrication on Hydrogen Silsesquioxane Using Focused Helium Ion Beam Lithography, J. Cai and W. D. Li, The University of Hong Kong

We propose and demonstrate 3-D fabrication of HSQ structures using focused helium ion beam by controlling the volumetric energy deposition profile of focused helium ions. Sub-100 nm embedded hollow channels in crosslinked HSQ resist and suspended HSQ beams are fabricated by exposing thick HSQ with specially designed dose profiles.

4:20 pm - 4:40 pm 2C3
3D Nanofabrication by Geometrically-Confined Helium Ions in Diamond Nanostructures, C.S. Kim, R.G. Hobbs, V.R. Manfrinato, K.K. Berggren, Massachusetts Institute of Technology

We have studied the distribution of helium ions deposited in single-crystal diamond membranes using a combination of focused gallium ion beam and transmission electron microscopy, and expanded this study (defect formation) to include building novel 3D nanostructures defined by the geometrically-confined helium ion distribution on nanostructured geometries.

4:40 pm - 5:00 pm 2C4
FIB Milling and Replica Molding of Complex Surfaces with Atomic-Scale Precision, K.-T. Liao*,**, J. Schumacher**, H. J. Lezec**, S. M. Stavis**, *University of Maryland and **NIST

We advance and integrate focused ion beam (FIB) milling and silicone replica molding, for prototyping and manufacturing with atomic-scale precision. We investigate the FIB bombardment of a silicon surface over five orders of magnitude of dose variation, and we mill and mold complex surfaces with atomic-scale heights and depths.

5:00 pm - 5:20 pm 2C5
Post Fabrication of Foundry-Fabricated CMOS Serpentine Nanowire Biosensor with Focused Ion Beam, Pengyuan Zang, Honglei Wang, Liuxi Qian, Dian Zhou, Walter Hu, Jun Tao*, Yang Liu*, Wenbin Li*, Xuan Zeng*, University of Texas at Dallas and *Fudan University

We developed a post fabrication process with focused ion beam (FIB) followed with buffered oxide etch (BOE) to expose the Si nanowire FET biosensors, which were fabricated by semiconductor foundry with standard CMOS processes, for the detection of chemical and biological analytes.

Session 3A - Nanobiotechnology 1

Seaport Ballroom A
Session Chairs:
Regina Luttge, TU Delft
Shalom Wind, Columbia

8:00 am - 8:30 am 3A1 (Invited)
Studies of bacterial cells and cellular assemblies using lab-on-a-chip platform, D. Yang, C.M. Greer, A. Jennings, S. Retterer* and J. Mannik, University of Tennessee and *Oak Ridge National Laboratory

Lab-on-a-chip technology offers new tools to grow, manipulate, and observe cells and cellular assemblies. The technological advances in this area have enabled us to study how bacteria penetrate small pores and channels, elucidate their mechanical properties, and characterize molecular mechanisms that are involved in cell division.

8:30 am - 8:50 am 3A2
Microwell arrays for high-throughput investigation of microbial interactions, R.R. Hansen, C.M. Timm, M.L. Simpson, S.T. Retterer, Oak Ridge National Laboratory

In this work, a micro and nanostructured interface containing arrays of wells is developed to isolate thousands of unique bacterial populations in a controlled physical and chemical microenvironment. This allows for a high-throughput screening approach to identify bacterial populations and environments that promote colonization or decay.

8:50 am - 9:10 am 3A3
Probing Immune Cell Response to Heterogeneous Rigidity at the Nanoscale, J. Liao, M. Biggs*, R. Cooper, C. Dahlberg, J. Kysar, S. J. Wind, Columbia University and *National University of Ireland-Galway

Elastomeric surfaces presenting regions of heterogeneous ridigity are created by exposure to an electron beam. T-cell adhesion and polarization on the rigid features are a function of feature size. T-cell functional response is also affected. These surfaces have potential for application in adoptive immunotherapy.

9:10 am - 9:30 am 3A4
Dielectrophoresis-assisted 3D nanochannel electroporation for high-throughput cell transfection with dosage control, Lingqian Chang, Paul Bertani, Daniel Gallego-Perez, Xi Zhao, Veysi Malkoc, L .James Lee, Wu Lu, Ohio State University

Precise transfection of large cell populations could not be achievable by any of the existing non-viral methods. Using projection photolithography and deep reactive ion-etch, we herein reported a unique silicon 3D nanochannel electroporation system for precisely control the dosage when delivering exotic molecules into living cells with negligible cell damage.

9:30 am - 10:00 am 3A5 (Invited)
Single Molecule Bioelectronics using Carbon Nanotube Circuits, P.G. Collins, University of California at Irvine

Nanoscale electronic devices like field-effect transistors have long promised to provide sensitive, label-free detection of biomolecules. Recent measurements have demonstrated dynamic, single-molecule monitoring of enzymatic activity using single-walled carbon nanotube transistors. This presentation will describe design rules for building effective nanocircuits from a wide range of enzymes or proteins.

Session 3B - Advanced Pattern Transfer

Seaport Ballroom B
Session Chairs:
Skip Berry, LAM Research
Deirdre Olynick, LBL

8:00 am - 8:30 am 3B1 (Invited)
Directed Ribbon Beam Processing, A. Renau and S. Ruffell, Applied Materials Inc.

We review a new processing technology that uses a ribbon ion beam for materials engineering. We show how this technology is very well suited to 2D and 3D structures because it allows processing to be varied depending on surface orientation and/or position on the wafer.

8:30 am - 8:50 am 3B2
Massively Parallel Silicon Micro-Patterning and Thin Slicing by Magnetically Guided Etching, T. K. Kim, D. Chun, C. Choi, C. S. Rustomji, Y. J. Kim, C.-H. Liu, G. Kim, R. Chen, S. Jin, University of California at San Diego

The effect of resistivity, annealing in Ar, and doping type on etching was studied with magnetically guided electroless etching method. 3-layer of Fe/Au/Fe and Fe-embedded Au layer were fabricated to protect the magnetic layer from corrosion by etchant. High-aspect-ratio, vertical micro hole array has also been successfully prepared.

8:50 am - 9:10 am 3B3
Fabrication of high aspect ratio tungsten nanostructures on large area ultrathin c-Si membranes for X rays applications, F. Delachat, J. Margot, C. Constancias*, C. Cadoux*, P. Gergaud*, B. Le Drogoff**, S. Delprat**, and M. Chaker**, University of Montréal, *CEA-LETI – Univ. Grenoble Alpes, and **Institut National de la Recherche Scientifique.

In this work, we demonstrate a full fabrication process of high aspect ratio (up to 8.5) diffraction gratings made of tungsten on flat (planarity <10nm), ultrathin (100 nm and 50 nm) and large area (1 x 1 mm2) silicon membranes using pseudo-Bosch etching innovatively applied to tungsten.

9:10 am - 9:30 am 3B4
Precise measurement of chromium dry etching rate at low temperatures for ultimate profile control, D. Staaks*,**, X. Yang***, S. Dallorto*, S. Dhuey*, S. Sassolini*, K. Y. Lee***, I. W. Rangelow**, and D. L. Olynick*, *Lawrence Berkeley National Laboratory, **Ilmenau University of Technology, and ***Seagate Technology

Investigation of chromium dry etching of Cl_2/O_2 plasma at different conditions and chemistry for profile controle of patterned features.

9:30 am - 10:00 am 3B5 (Invited)
Wafer-Scale Etching of Nanometer-Scale Features With Low Energy Electron Enhanced Etching (LE4), S. Sando, Systine, Inc.

Sestina's Low Energy Electron Enhanced Etching (LE4) technology operates in a wafer-scale DC plasma platform. Material including silcon, oxides, low-k dielectrics, GaAs, GaN and other III-V's have been etched to dimensions much smaller than 10nm with damage-free surfaces that approach atomic smoothness and preserve the stoichiometry.

Session 3C - Beam Induced Deposition and Etching 2

Seaport Ballroom C
Session Chairs:
Paul Alkemade, TU Delft
Jason Fowlkes, ORNL

8:00 am - 8:30 am 3C1 (Invited)
Focused Electron Beam Induced Processing: An Application Perspective, H. Plank, Graz University of Technology

The contribution sheds light on the Focused Electron Beam Induced Processing as emerging additive, diret-write method with respect to applications. After briefly discussing the state-of-the-art and recent concepts, ongoing research is presented by means of plasmoninc, sensing and photovoltaic FEBIP applications.

8:30 am - 8:50 am 3C2
Focused Electron Beam Induced Deposition of Copper from Aqueous Solutions in Micro-wells, S. Esfandiarpour, A. Noubani and J. T. Hastings, University of Kentucky

We have proposed microwells to increase control over the liquid layer for liquid phase FEBID. Proposed microwells have been used to evaluate copper deposition from two aqueous solutions containing CuSO4. X-ray spectroscopy is used to estimate the thickness in the target region and to quantify the purity of deposits.

8:50 am - 9:10 am 3C3
Gas Cluster Ion Beam Stimulated Reaction with Adsorbed Molecules on Metal Surface, N. Toyoda, I. Yamada, University of Hyogo

Gas cluster ion beam stimulated reactions with adsorbed molecules on metal was used for novel etching. By GCIB irradiation with acetic acid, etching depths of Pt, Ru, Ta, CoFe showed 1.8 – 16.1x deeper than those without acetic acid. Dense energy deposition enhanced reactions between adsorbed gas and target surface.

9:10 am - 9:30 am 3C4
Hydrogen-beam induced deposition of platinum and tungsten microstructures, A. Botman, S. J. Randolph and J. J. L. Mulders, FEI Company

We report on the use of a focused hydrogen beam for deposition of platinum and tungsten microstructures from MeCpPtMe3 and W(CO)6 precursor gases respectively. Examples of typical deposition morphologies will be presented as well as cross-sectional and compositional analysis. Strategies for obtaining microstructures with highly pure platinum will be discussed.

9:30 am - 9:50 am 3C5
Focused Neon Ion Beam Induced Sputtering of Copper: Monte Carlo Simulations, R. Timilsina*, S. Tan**, R. Livengood** and P.D. Rack*,***, *University of Tennessee, **Intel Corporation and ***Oak Ridge National Laboratory

Session 4A - Plasmonics

Seaport Ballroom A
Session Chairs:
Steve Brueck, Univ. New Mexico
Dan Pickard, National University of Singapore

10:15 am - 10:45 am 4A1 (Invited)
Lithographic engineering of volume plasmons, V. R. Manfrinato, R. Hobbs, Y. Yang, L. Zhang*, D. Su*, S. A. Goodman, E. A. Stach*, and K. K. Berggren, MIT and *BNL

Here we present the engineering of volume plasmons and surface plasmons by nanolithography and characterization by electron energy loss spectroscopy.

10:45 am - 11:05 am 4A2
Spatial-Mapping of Photoemission from Plasmonic Nanoparticle Arrays, R. G. Hobbs, W. P. Putnam, A. Fallahi*, Y. Yang, F. X. Kärtner*, and K. K. Berggren, Massachusetts Institute of Technology and *University of Hamburg

In this work, we have used poly(methyl methacrylate) to map electron emission from plasmonic Au nanorods excited by ultrafast, ten femtosecond pulses of infrared light. Mapping electron emission from these materials on the nanometer scale will aid the development of ultrafast vacuum electronics.

11:05 am - 11:25 am 4A3
Ultra-thin, Smooth and Low loss Al-doped Ag Film and its Application in Plasmonic Interconnects, Cheng Zhang, Nathaniel Kinsey*, Long Chen, Vladimir M. Shalaev*, Alexandra Boltasseva* and L. Jay Guo, University of Michigan and *Purdue University

We report an effective approach to achieve wetting-layer free, ultra-thin and smooth Ag films by co-depositing Al during the film deposition. Long range surface plasmon interconnects based on Al-doped Ag are demonstrated. This Ag-like, ultra-thin and smooth film contributes to low loss propagation of the plasmon mode.

11:25 am - 11:45 am 4A4
Solid Immersion Optics for Surface Plasmon Excitation in a Transmission Mode Photoemission Electron Microscope, V.Viswanathan, A.S. Yusuf, N. R. Shami, H. Hao and D.S. Pickard, National University of Singapore

We present our efforts on modifying the illumination optics on a transmission PEEM for controlled excitation of surface plasmons under normal and oblique incidence. Complex field distributions and interference patterns around holes on aluminium films are observed under different illumination conditions. Further work on lithographically patterned devices will be presented.

11:45 am - 12:15 pm 4A5 (Invited)
Digital metamaterials & micro-optics for photonics & imaging, Rajesh Menon, Dept. of Electrical & Computer Engineering, University of Utah

We apply fabrication-constrained numerical optimization to design metamaterials-based photonic devices comprised of discrete spatial pixels, which we refer to as digital metamaterials.

Session 4B - Nanostructures for Quantum Computing

Seaport Ballroom B
Session Chairs:
Dave Pappas, NIST
Lisa Edge, HRL

10:15 am - 10:40 am 4B1 (Invited)
Superconducting Resonators: The Canary in the Coherence Coalmine, A. Megrant, University of California Santa Barbara

In recent years, superconducting qubits have seen a dramatic improvement in their ability to retain quantum information for a longer time. I will discuss how we have systematically improved this coherence time in our Xmon style superconducting qubits using superconducting resonators as a simpler test bed.

10:40 am - 11:00 am 4B2
Deterministic Creation of Closely-Spaced Single NV Centers in Diamond, Diego Scarabelli, Matt Trusheim*, Ophir Gaathon**, Dirk Englund*, Shalom J. Wind, Columbia University, *MIT, **Diamond Nanotechnologies, Inc.

We describe a process for the creation of single nitrogen vacancy centers in diamond, spaced sufficiently close together to enable quantum coupling between their spin states.

11:00 am - 11:25 am 4B3 (Invited)
Nanofabrication of singlet-triplet qubit in Si/SiGe quantum dots with integrated micromagnets, Xian Wu, D.R.Ward, J.R.Prance*,Dohun Kim, John King Gamble, R.T.Mohr, Zhan Shi, D.E.Savage, M.G.Lagally, Mark Friesen, S.N.Coppersmith, M.A.Eriksson, University of Wisconsin-Madison, Lancaster University*

Electron beam lithography is used to pattern gates that can electrically confine a small number of electrons to within less than a hundred nanometers with controlled electron tunneling rates.I will present the operation and nanofabrication of the singlet-triplet spin qubit in quantum dots with integrated micromagnet in a Si/SiGe heterostructure.

11:25 am - 11:50 am 4B4 (Invited)
Taking Superconducting Qubits to the Next Generation, Matthias Steffen, IBM

Quantum computing is a potentially game-changing technology capable of performing calculations that are intractable on conventional computers. Lithographically defined superconducting qubits are a promising candidate to build a quantum computer. A 4-qubit circuit is demonstrated which detects both types of quantum errors. Steps towards future integration challenges are discussed.

11:50 am - 12:15 pm 4B5 (Invited)
Exchange-only Qubits in Si/SiGe Quantum Dots Patterned Using Electron-Beam Lithography, M. Borselli, HRL Laboratories

The first part of this talk will be an overview of how electrostatically-defined quantum dots in silicon have evolved, with an emphasis on the advances enabled by better electron-beam lithography. The second part of this talk will focus on a specific HRL demonstration of an exchange-only qubit in isotopically-enriched silicon.

Session 4C - Electron Beam Lithography 1

Seaport Ballroom C
Session Chairs:
Richard Tiberio, Stanford
John Hartley, SUNY CNSE

10:15 am - 10:45 am 4C1 (Invited)
DNA Origami as Molecular Circuit Boards: Attachment, Patterning, and Stability, M. A. Pillers, K. N. Kim, K. Sarverswaran, B. Gao, M. Lieberman, University of Notre Dame

DNA origami can bind and organize nanoelectronic components, but problems could occur when the soft matter of the origami is subjected to lithographic processes. We describe the "molecular liftoff" technique to pattern DNA origami on functionalized silicon and the effect of thermal and solvent processing on origami structure and functionality.

10:45 am - 11:05 am 4C2
Teflon AF Patterning using Variable Pressure Electron-Beam Lithography, M. Sultan, J. T. Hastings, University of Kentucky
Teflon AF, an amorphous fluoropolymer, is shown to function as a positive electron-beam resist when exposed in a variable-pressure, water-vapor ambient and developed in ethanol. This marked change in behavior from exposure under high-vacuum conditions provides a means to pattern the material while minimally altering its desirable properties.

11:05 am - 11:25 am 4C3
Progress in electron-beam-lithography-fabricated Fresnel zone plates on diamond membranes for hard X-ray focusing, Nicolaie Moldovan, Hongjun Zeng, Leonidas E. Ocola*, Ralu Divan*, and Alex B. Martinson*, Advanced Diamond Technologies, Inc. and *Argonne National Laboratory

Fresnel zone plates structures were obtained at wafer scale by electron beam patterning of hydrogen silsesquioxane resist and transfer in diamond by reactive ion etching, followed by diamond membranes formation and iridium atomic layer deposition. The composite zone plates design was implemented along with branching buttresses, for avoiding zones tearing.

11:25 am - 11:45 am 4C4
Fabrication of metal nano-antennas with sub-10nm gap by using electron-beam induced deposition etch masks, I.G.C. Weppelman, P.C. Post, C.T.H. Heerkens, C.W. Hagen, J.P. Hoogenboom, TU Delft

Nanostructures with a small, sub-10 nm, gap spacing are important, e.g., for application as optical antennas. We use EBID etch masks in combination with a Cr sacrificial layer to fabricate gold nanostructures with a small gap spacing on ITO and Si substrates.

11:45 am - 12:05 pm 4C5
Fabrication and Characterization of Membrane Nano-gratings for Electron Diffraction, Y. Yang, R. Hobbs, V. Manfrinato, C. Kim, O. Celiker, A. Agarwal, K. Berggren, Massachusetts Institute of Technology

Nanofabricated transmission gratings are of interest for a variety of applications including electron interferometry and holography as well as vortex beam generation. Here, We report ~10-nm-thick membrane silicon nitride nano-gratings fabricated with electron beam lithography and characterized with electron diffraction in a transmission electron microscope.

Session 5A - Optical and Extreme UV (EUV) Lithography

Seaport Ballroom A
Session Chairs:
Martin Feldman, LSU
Mark L. Schattenburg, MIT

1:30 pm - 2:00 pm 5A1 (Invited)
EUV Lithography: Separating Fact from Fiction, W. Arnold, ASML

EUV Lithography has been developed to succeed DUV lithography for high volume IC production. Recent advances in source power bring the technology to a competitive level with DUV immersion multipatterning.

2:00 pm - 2:20 pm 5A2
Parallel near field optical lithography with sub wavelength resolution using a massive array of bowtie antennas, A. Datta*, X. Wen*,**, L. M. Traverso*, X. Xu*, and E. E. Moon***, *Purdue University, **University of Science and Technology of China and ***Massachusetts Institute of Technology

We describe parallel optical lithography process using bowtie antennas with nano meter level gap control where we can achieve sub wavelength resolution.

2:20 pm - 2:40 pm 5A3
Demonstration of below 30-nm half pitch resolution at the SHARP microscope, M. P. Benk, K. A. Goldberg, A. Wojdyla, C. N. Anderson, P. Naulleau and, M. Kocsis*, Lawrence Berkeley National Laboratory and *Inpria Corporation

We fabricated a test mask with lines and spaces down to 20-nm half pitch exposing a silicon wafer coated with a multilayer and photoresist in the Berkeley Microfield Exposure Tool. With this mask we demonstrate real-space imaging resolution well below 30 nm half-pitch at the Berkeley SHARP microscope.

2:40 pm - 3:00 pm 5A4
Planar interference lithography by exploiting high-k modes, Xi Chen, Fan Yang, Cheng Zhang, L. Jay Guo, University of Michigan

By using a new plasmonic optical nanolithography approach, we aim to achieve high aspect ratio subwavelength patterns with pitch equal to one-half the period of the specially designed photomasks. Deep subwavelength 1D periodic structures were obtained with the half pitch less than 1/6 of the light wavelength.

3:00 pm - 3:30 pm 5A5 (Invited)
Principles and Promise of Multicolor, Visible-Light Nanolithography, J. T. Fourkas, University of Maryland

Multicolor approaches have led to a renaissance in optical fluorescence microscopy, enabling resolution that is far below that predicted by the Abbe criterion. Similar approaches are beginning to be employed in projection lithography. In the presentation we will present the fundamental principles of multicolor, visible-light nanolithography and discuss its prospects.

Session 5B - Atomic Layer Deposition

Seaport Ballroom B
Session Chairs:
Ageeth Bol, TU Eindhoven
Alan Brodie, KLA-Tencor

1:30 pm - 2:00 pm 5B1 (Invited)
Selective Growth and Self-Alignment Requirements for Advanced Patterning Applications, C.H. Wallace, Intel Corporation

The introduction of new lithography methods may improve resolution; however, the issue of edge-placement error will be a problem regardless of the lithography exposure technique. This presentation will discuss past, current and future methods of improving overlay and critical dimension errors using self-alignment and selectivity.

2:00 pm - 2:20 pm 5B2
Photoluminescence of Sequential Infiltration Synthesized ZnO nanostructures, Leonidas E. Ocola, David Gosztola, and Kyle Chen*, Argonne National Laboratory and *Illinois Mathematics and Science Academy

In this paper we present an alternative method of creating ZnO nanostructures that can be used for both plasmonic and photonic applications by combining lithography and a modified ALD process named Sequential Infiltration Synthesis. Optical properties of these structures will be discussed.

2:20 pm - 2:40 pm 5B3
Fabrication of Thin Metallic Nanostructures Using Atomic Layer Deposition, J.-H. Min, A. Bagal, J. Z. Mundy, C. J. Oldham, G. N. Parsons and C.-H. Chang, North Carolina State University

In this work, we report the fabrication of thin metallic nanostructures by conformal atomic layer deposition coating on one-dimensional grating layer patterned by interference lithography. Detailed optical, electrical, and mechanical characterizations of the thin metallic nanostructure will be performed using different substrate materials and grating geometries.

2:40 pm - 3:00 pm 5B4
Fabrication of Stretchable Transparent Conductors Using Nano-Accordion Structures, Abhijeet Bagal, Erinn C. Dandley, Junjie Zhao, Xu A. Zhang, Christopher J. Oldham, Gregory N. Parsons, and Chih-Hao Chang, North Carolina State University.

We present a fabrication technique for making a novel nano-material for stretchable transparent conductor based on nanolithography and atomic layer deposition. This approach involves improving the stretchability of Al-doped-ZnO (AZO)/ZnO thin films facilitated by accordion-fold geometry. We also present detailed analysis and characterization of its mechanical, electrical and optical properties.

3:00 pm - 3:30 pm 5B5 (Invited)
Strategies for selective deposition and selective etching of metal oxide materials on patterned substrates, Fatemeh S. M. Hashemi*, Stacey F. Bent**, *Department of Materials Science and Engineering, Stanford University, ** Department of Chemical Engineering, Stanford University

Invited talk on strategies for selective deposition and selective etching of metal oxide materials on patterned substrates

Session 5C - Beam Induced Deposition and Etching 3

Seaport Ballroom C
Session Chairs:
Aurelien Botman, FEI
Jabez McClelland, NIST

1:30 pm - 2:00 pm 5C1 (Invited)
Growth of functional magnetic and superconducting materials by Focused Beam Induced Deposition techniques, J. M. De Teresa, CSIC-Universidad de Zaragoza

The use of $Co_2(CO)_8$ and $Fe_2(CO)_9$ precursors has allowed us to grow a large variety of magnetic nanostructures with high magnetic metal content (80-100%). Such functional magnetic deposits can be applicable in memories, logic and sensors. Superconducting deposits using the $W(CO)_6$ precursor have been created for studies of nanosuperconductivity.

2:00 pm - 2:20 pm 5C2
Nano Pattern Transfer into Si and ITO using masks made by Electron Beam Induced Deposition, M.Scotuzzi, M.J. Kamerbeek, C.W. Hagen, A. Goodyear*, and M. Cooke*, Delft University of Technology and *Oxford Instruments Plasma Technology

Nano Imprint Lithography (NIL) requires high resolution stamps. We report on the pattern transfer of sub-20-nm features, made by Electron Beam Induced Deposition, into underlying Silicon and ITO. This could be an attractive technique for the fabrication of NIL stamps.

2:20 pm - 2:40 pm 5C3
Helium-ion-beam-induced growth of 3-dimensional AFM probes, Gaurav Nanda, Paul Alkemade, Emile van Veldhoven*, Diederik Maas*, Rodolf Herfst*, and Hamed Sadeghian*, Delft University of Technology and *TNO Delft

We use helium-ion-beam-induced deposition to grow an AFM probe with a hammer-head shape on top of a conventional AFM tip. For this purpose, we move the focused ion beam laterally in 2 dimensions during deposition. We test the hammer-head AFM probe on the sidewall of trenches in resist.

2:40 pm - 3:00 pm 5C4
Expanding nanomagnetic logic into the third dimension - new pathways via FEBID, H.D. Wanzenboeck, M.M. Shawrav, S. Wachter, M. Gavagnin, E. Bertagnolli, Vienna University of Technology

Focused electron beam induced deposition (FEBID) is a direct write lithography that allows to deposit magnetic single-domain nanostructures by local decomposition of an iron penatacarbonyl precursor. By controlling the pixel spacing and dwell time during deposition we could fabricate single-domain magnetic in-plane nanostructures that directly transform into out-of-plane (3D) nanostructures.

3:00 pm - 3:20 pm 5C5
Focused Electron Beam Induced Processing Via Multi-Mode Energized Micro/Nano-Jets To Enable Advances In Graphene Nanoelectronics, M. Henry, J. Fisher, S. Kim, P. A. Kottke, A. G. Fedorov, Georgia Institute of Technology

Fundamentals of new methods of FEBIP enabled by multi-mode energized micro/nano-jets will be discussed, including enabling application to carbon nanoelectronics and graphene devices.

Session 6A - Nanoimprint Lithography 2

Seaport Ballroom A
Session Chairs:
Bo Cui, Univ. Waterloo
Pat Watson, Princeton

3:45 pm - 4:15 pm 6A1 (Invited)
Precision Overlay in UV Nanoimprint Lithography, S.V. Sreenivasan, The University of Texas at Austin

4:15 pm - 4:35 pm 6A2
Novel Structuring Process for Injection Molding Inserts By Free-Form Reverse Nanoimprint Lithography, Ariadna Fernández*, Juan Medina*, Achille Francone*, Clivia M. Sotomayor Torres*,**, Nikolaos Kehagias*, Christian Benkel***, Markus Guttmann***, Lasse H.Thamdrup****, Brian Bilenberg****, and Theodor Nielsen****, *Catalan Institute of Nanoscience and Nanotechnology, 2**ICREA, Institució Catalana de Recerca i Estudis Avançats, ***Karlsruhe Institute of Technology (KIT), and ****NIL Technology ApS

In this paper we demonstrate the use of flexible reversal nanoimprint lithography to fabricate residual layer free structures over free form surfaces and material (steel) substrates. Water repellent structures have been realized on injection molding inserts while a novel up-plating process has been developed to create fully metallic patterned inserts.

4:35 pm - 4:55 pm 6A3
Thermal wrinkling of nanoimprinted SU-8 with masked UV-exposure, C. Steinberg, M. Belgouzi, K. Dhima, M. Papenheim, S. Wang, H.-C. Scheer, University of Wuppertal

Thermal wrinkling of SU-8 is studied after local masked UV-exposure and a UV-ozone flood exposure. The impact of geometries and the impact of a pre-pattern will be investigated. The pre-pattern is realized by nanoimprint. The type of pre-pattern influences the wrinkling obtained.

4:55 pm - 5:15 pm 6A4
High Aspect Nanopore Array Fabrication by Nanoimprint Employing Novel Demolding Process, M. Mamuro, K. Shimomukai, H. Kawata, M. Yasuda, Y. Hirai, Osaka Prefecture University

High aspect nanopore array is fabricated by the thermal nanopmprint employing novel demolding process. Polystyrene (PS) nanopores, whose aspect ratio exceeds 6, can be obtained without pattern defects.

5:15 pm - 5:35 pm 6A5
High contrast gratings for 3D additive manufacture, Y. Li, X. Song, H Liu, Y. Yao, Y. Wang, B. Song, Y. Chen, Wei Wu, and Ming Hsieh, University of Southern California

We proposed an approach to spatially modulate light beam in a UV curable resin based 3D additive manufacture system by using high contrast gratings. As a result, light beams of different wavelengths in a single curing tool can have different pixel size.

Session 6B - Nanoelectronics 1

Seaport Ballroom B
Session Chairs:
Bill Mitchell, UCSB
Josephine Chang, IBM Research

3:45 pm - 4:15 pm 6B1 (Invited)
Nanoelectronic Devices with Layered Semiconductors: Challenges, and advances in Fabrication and Performance, Debdeep Jena, Cornell University

The promise and challenges of nanoelectronic devices with layered semiconductor materials will be described in the talk.

4:15 pm - 4:35 pm 6B2
Encapsulated Delamination Transfer and Nanofabrication of Silicene Field-Effect Transistors, Li Tao, Eugenio Cinquanta*, Carlo Grazianetti*, Alessandro Molle* and Deji Akinwande, University of Texas at Austin, Dallas and *IMM-CNR

We report our recent progress addressing the air-stability issue by a unique growth-transfer-fabrication process named silicene encapsulated delamination with native electrodes (SEDNE). SEDNE enabled the first silicene field-effect transistor, corroborating theoretical expectations on ambipolar Dirac charge transport with extracted mobility of ~100 cm^2/V-s.

4:35 pm - 4:55 pm 6B3
Fabrication of Nanodamascene Metallic Single Electron Transistor, G. Karbasian, A. Orlov, G. Snider, University of Notre Dame

We present experimental demonstration of metallic single electron transistor (SET) fabricated using a nanodamascene process and atomic layer deposition (ALD) to form a 1nm Al_2O_3 tunnel barrier.This is the first fabricated nanodamascene SET showing metallic behavior with well-defined metallic island and tunnel junctions.

4:55 pm - 5:15 pm 6B4
Lithography-free fabrication of graphene devices, N.F.W. Thissen, J.W. Weber, A.J.M. Mackus, W.M.M. Kessels, A.A. Bol and J.J.L. Mulders*, Eindhoven University of Technology and *FEI Company

This work demonstrates the fabrication of graphene devices using a novel resist-free fabrication technique based on ion beam patterning of the graphene, followed by graphene contacting using a combination of electron beam induced deposition and selective atomic layer deposition. This results in graphene devices with very low contact resistance (40ohm).

5:15 pm - 5:40 pm 6B5 (Invited)
Honeycomb Lattice Patterned on GaAs Quantum Well: Artificial Graphene, D. Scarabelli, S. Wang, A. L. Levy, L. N. Pfeiffer*, V. Pellegrini**, M. J. Manfra**, A. Pinczuk, S. J. Wind, Columbia University,, *Princeton University, **Italian Institute of Technology

Precision electron beam lithography and reactive ion etching are combined to create a tunable system in a two dimensional electron gas that aims to replicate the massless Dirac fermion physics that is a hallmark of graphene.

THURSDAY AFTERNOON, May 28, 2015

Session 6C - Electron Beam Lithography 2

Seaport Ballroom C
Session Chairs:
Uli Hoffmann, Genisys
Ernst Kratschmer, IBM Research

3:45 pm - 4:15 pm 6C1 (Invited)
Multiple e-beam direct write enters pre-production mode, J. Pradelles, J. Reche, Y. Blancquaert, C. Constancias, L. Lattard, N. Vergeer*, Y. Ma*, P. Wiedemann*, G. de Boer*, and M. Wieland*, CEA-Leti and *Mapper Lithography

The Mapper pre-production platform (FLX-1200) is installed in the CEA-Leti clean room and interfaced with Sokudo duo track. It is targeting CMOS 28/20/14 nodes on 300mm wafer with a 1wph throughput . We will review the lithographic performances and explain our comparison study between in-line metrology and on wafer measurements.

4:15 pm - 4:35 pm 6C2
Development of a column using permanent magnet lens for a multi-axis maskless E-beam lithography system, H. Yasuda, A. Ito, Y. Oae, T. Haraguchi, K. Takahata, H. Yabara ,PARAM Corporation

One column with five stage lenses using permanent magnet was developed. The diameters of the lenses are smaller than 27mm so that the column element can be used for multi-axis and multi-beam lithography system presented by PARAM.

4:35 pm - 4:55 pm 6C3
Patterning of ≤ 16 nm defect arrays with electron beam lithography which are used to develop a high throughput electron beam defect inspection tool, K. Cummings, B. Bunday, M. Malloy, J. Hartley*, L. Banu*, M. Mellish*, and Weilun Chao**, SEMATECH, *SUNY Polytechnic Institute and **Lawrence Berkeley Laboratories,

SEMATECH has established an infrastructure development program to ensure needed metrology tools and techniques are available for leading edge semiconductor processes and devices. The primary goal of this program is identify,evaluate and develop disruptive technologies to enable multibeam-electron beam inspection as a high throughput replacement for bright field optical inspection.

4:55 pm - 5:15 pm 6C4
Corner2-EPC: A Layout Image Compression Algorithm for Electron Beam Lithography, N. Chaudhary, Y. Luo and S. A. Savari, Texas A&M University

We propose Corner2-EPC, a lossless layout image compression algorithm for electron beam proximity corrected layout images. Corner2-EPC is unique among such algorithms because it was motivated by the GDSII format. It considerably outperforms Block C4 in encoding/decoding times and in memory requirements; it mostly outperforms Block C4 in compression ratios.

5:15 pm - 5:35 pm 6C5
Experimental Beam Blur characterization in CAR resist for E-beam lithography at 5kV and 100kV using spectral analysis, C. Constancias, J. Jussot, J. Reche, B. Dal'Zotto, J. Pradelles, M. Fouchier*, L. Lattard, CEA-Leti and *University Grenoble Alpes

FRIDAY MORNING, May 29, 2015

Session 7A - Nanophotonics 2

Seaport Ballroom A
Session Chairs:
Rajesh Menon, Univ. Utah
Shane Palmer, Nikon Research

8:00 am - 8:30 am 7A1 (Invited)
Controlling excitons in semiconductor quantum dots for nanophotonic applications, Jiye Lee, Keiko Munechika, Dimitrios Simatos, Stephen Whitelam, and Alexander Weber-Bargioni, Lawrence Berkeley National Laboratory

This talk presents our study on nanoscale energy flow through quantum dot arrays and electrical switching of individual quantum dot emission.

8:30 am - 8:50 am 7A2
Micro-optics at the diffraction limit: design for manufacture, Kenneth A. Goldberg and J. Alexander Liddle, Lawrence Berkeley National Lab and *National Institute of Standards and Technology

Reductions in image sensor pixel size have lead to concomitant reductions in the size of the microlenses used to focus light on the pixels' active area. We have developed a simple binary structure, taking into account diffractive effects, that performs better and is easier to fabricate.

8:50 am - 9:10 am 7A3
Fabrication of high quality factor optical nanocavities in bulk single-crystal diamond, M.J. Burek, Y. Chu, M.S.Z. Liddy**, P. Patel**, J. Rochman**, M.D. Lukin*, and M.Lončar, *Harvard University and **University of Waterloo

Optical nanocavities (racetrack resonators and nanobeam photonic crystal cavities) are fabricated in bulk single-crystal diamond via a recently demonstrated “angled-etching” nanofabrication method. Devices operating in the telecom band exhibited Q-factors exceeding 10^5, while devices in the visible yielded Q-factors greater than 10^4.

9:10 am - 9:30 am 7A4
Significantly-Enhanced Light Extraction and Power Efficiency of Red Organic Light- Emitting Diode by Nano-Mesh Fabricated by Large-Area Nanoimprint, J. Qi, W. Ding, Y. Wang, Q. Zhang, H. Chen and S. Y. Chou, Princeton University

We report a new red OLED structure that uses a nano-mesh configuration which not only enhances the light extraction but also lowers the driving voltage, hence significantly enhancing quantum and power efficiencies.

9:30 am - 9:50 am 7A5
Fabrication of Silicon-on-Insulator Blazed-Grating Optical Couplers using a Thermal Scanning Probe System, S. Ristic, M. Nannini, P. Grütter, P. Paul*, and F. Holzner*, McGill University and *SwissLitho AG

McGill University has recently purchased the world’s first commercial Thermal Scanning Probe Lithography prototyping tool, “NanoFrazor Explore,” made by SwissLitho AG. We demonstrate the technology by fabricating nanophotonic devices, namely fiber-to-chip optical grating couplers based on regular 2D gratings as well as highly directional, multilevel-blazed 3D gratings.

Session 7B - Nanoelectronics 2

Seaport Ballroom B
Session Chairs:
Patrick Braganca, HGST
Stella Pang, Univ. Hong Kong

8:00 am - 8:30 am 7B1 (Invited)
All-optical control of magnetization in various metallic magnetic systems, Rajasekhar Medapalli, Y. Takahashi*, Y. Quessab**, D. K. Kim, C. H. Lambert**, S. Mangin**, K. Hono*, Y. Fainman***, and E. Fullerton, Center of Magnetic Recording Research, University of California San Diego, USA, *2Magnetic Materials Unit, National Institute for Materials Science, Tsukuba 305-0047, Japan, **Institut Jean Lamour UMR CNRS 7198– Université de Lorraine, -Nancy, France, ***Electrical and Computer Engineering, University of California San Diego, USA.

8:30 am - 8:50 am 7B2
Hafnium oxide resistive memory based on cross-bar structures down to sub-20 nm dimensions, M. A. Mohammad, H. Tian, X. Chen, Y. Yang, and T.-L. Ren, Tsinghua University

Numerous applications require low-power resistive switching devices. In this regard, a systematic study of cross-bar RRAM devices from 500 nm down to sub-20 nm widths, and various HfOx thicknesses is reported. The design, nanofabrication, testing, and performance will be discussed.

8:50 am - 9:10 am 7B3
Highly Reliable Resistive Switching Devices Based on Tantalum-doped Silicon Oxide, H. Jiang, C. Li, Q. Xia, Nanodevices and Integrated Systems Laboratory, Department of Electrical and Computer Engineering, University of Massachusetts, Amherst

Silicon oxide is one of the most promising switching materials because it is fully compatible with CMOS. Here, we reported reliable bipolar RS from Ta:SiO_2 with record high endurance (3E8 cycles) among SiO2 based devices. We further adopted a 3-dimensional vertical structure and studied the scaling of the Ta:SiO_2 devices.

9:10 am - 9:30 am 7B4
Fabrication of Consistent MoS_2 Biosensors for Quantifying Cancer-Related Biomarker Molecules with Femtomolar-Level Detection Limit, H. Nam, B.R. Oh, P. Chen, M. Chen, S. Wi, K. Kurabayashi, X. Liang, University of Michigan

We fabricated multiple sets of MoS_2-based transistor biosensors and demonstrated that these devices can be synergistically utilized to measure the concentrations of cancer-related biomarker molecules with very low abundance (e.g., fM-level TNF-α cytokine samples) as well as quantify the affinity and kinetic properties of the biomarker-receptor pairs.

9:30 am - 9:50 am 7B5
Fabrication of Transition Metal Dichalcogenide Photovoltaic Devices Using Surface-Charge Transfer (SCT) Doping Mechanism, S. Wi, M. Chen, H. Nam, X. Liang, University of Michigan

We report a new upscalable doping technique capable of forming permanently stable built-in p-n junctions in pristine WSe_2 photoactive layers and resulting in excellent PV performance.

Session 7C - Focused Ion Beam Technology 2

Seaport Ballroom C
Session Chairs:
Shida Tan, Intel
John Melngailis, Univ. Maryland

8:00 am - 8:30 am 7C1 (Invited)
A new Liquid Metal Ion Source configuration for improving Focused Ion Beams machines., J. Gierak, E. Bourhis, R. Jede* and L. Bruchhaus*, LPN-CNRS and *Raith GmbH

In this presentation we will summarize our recent efforts aiming at optimizing a Ga-LMIS “needle type” configuration within a dedicated environment for stable operation below the 1µA regime. The setup, we will detail, that has been integrated in our FIB nanowriter now allows important performance gains.

8:30 am - 8:50 am 7C2
Application of laser-cooling and compression to create a high resolution focused ion beam, S. H. W. Wouters, G. ten Haaf, P. H. A. Mutsaers, O. J. Luiten, E. J. D. Vredenbregt, Eindhoven University of Technology

Ultra-low temperature (1 mK) ion beams can be created by photo-ionization of a laser cooled and compressed thermal atomic beam. Full device simulations show that for rubidium ions, spot sizes down to 1 nm can be achieved at a current of 1 pA.

8:50 am - 9:10 am 7C3
A New In-situ Broad Ion Beam, With Energy Range 1 – 500 eV, J.J.L. Mulders, P.H.F Trompenaars, E.G.T. Bosch,and R.T.J.P. Geurts, FEI Company

A new broad ion beam source has been developed for sample modification at very low energy. This in-situ source, mounted on a FIB or SEM can be used for sample milling at energies between 50 and 500 Volt and for local deposition with ion enrgies even below 20 Volts.

9:10 am - 9:30 am 7C4
Improved Instrumentation and Patterning Strategies for Extended and Continuous FIB Nanofabrication, S. Bauerdick, A. Nadzeyka, B. Wittmann, M. Kahl, J. Fridmann*, and J. Klingfus*, Raith GmbH and *Raith America Inc.

We used write field stitching and truly continuous writing for FIB nanofabrication. A pattern generator is synchronized to the stage and optimal patterns are calculated to prevent re-deposition. Moreover continuous stripe-like patterning with sophisticated beam movements will be shown for applications using Ga and new ions like Au or Si.

9:30 am - 10:00 am 7C5 (Invited)
Imaging Nanophotonic Modes of Microresonators using a Focused Lithium Ion Beam, Kevin A. Twedt*,**, Jie Zou*,**, Marcelo Davanco*, Kartik Srinivasan*, Jabez J. McClelland*, and Vladimir A. Aksyuk*, *NIST and **University of Maryland

We present in-situ measurements of the response of a silicon microdisk cavity to a lithium FIB probe. An optomechanical interaction induced by the FIB allows us to map the spatial distribution of the nanophotonic modes with both high spatial and spectral resolution, and with minimal perturbation to the high-Q modes.

Session 8A - Resists and Lithography Materials

Seaport Ballroom A
Session Chairs:
Cliff Henderson, Georgia Tech
Tony Novembre, Princeton

10:15 am - 10:45 am 8A1 (Invited)
Novel EUV resist development for sub-14 nm half pitch, Yoshi Hishiro, JSR Micro Inc.

In this paper, we will report the recent progress of resolution and sensitivity improvement of JSR novel EUV resist.

10:45 am - 11:05 am 8A2
Cross Section of Photo Acid Generators (PAGs) in EUV Photoresists vs. Electron Beam Energies, S. Grzeskowiak, A. Narasimhan, J. Ostrander,J. Schad, W. Earley, R. Brainard, G. Denbeaux, L. Ocula*, SUNY Polytechnic Institute and *Argonne National Laboratories

To study the photoelectrons generated by the EUV absorption and measure their effect within the resist, photoresists were exposed to incident electrons as a function of electron energy. These incident electrons interacted with photo acid generators in a photoresist, and the cross section was determined experimentally.

11:05 am - 11:25 am 8A3
Electron beam lithography on irregular surface using grafted PMMA brush, R. Dey and B. Cui, Waterloo Institute for Nanotechnology (WIN)

Nanofabrication on irregular surfaces is always challenging. Here we demonstrate that a mono-layer PMMA brush can be reliably grafted on irregular surface and can be used to pattern a non-flat AFM cantilever by electron beam lithography and pattern transfer. High resolution down to 30 nm was achieved.

11:25 am - 11:45 am 8A4
Lithographic Evaluation of gL-2000: A High-Resolution Resist for Electron-Beam Lithography, R. G. Hobbs, M. K. Mondol, N. Honda*, R. Hardman*, and K. K. Berggren, Massachusetts Institute of Technology and *MicroChem Corp.

We have evaluated the lithographic performance of gL-2000, a high-resolution, positive-tone resist for electron-beam lithography. 'gL-2000' is chemically similar to ZEP and has demonstrated similar lithographic performance to ZEP during our evaluation.

11:45 am - 12:05 pm 8A5
Development Characteristics of Polymethyl Methacrylate in Alcohol/Water Mixtures, Leonidas E. Ocola, David Gosztola and Maya Costales*, Argonne National Laboratory and *Illinois Mathematics and Science Academy

This paper reports on the study of development characteristics of PMMA in methanol, ethanol and isopropanol mixtures with water as developers. We have found that ethanol/water mixtures at a 4:1 volume ratio are an excellent, high resolution, non-toxic, developer for exposed PMMA.

Session 8B - Special Session: Nanoscience User Facilities

Seaport Ballroom B
Session Chairs:
Aaron Stein, BNL
Rob Ilic, NIST

10:15 am - 10:40 am 8B1 (Invited)
Nanoscale Science Research Centers (NSRCs): User facilities for nanoscience and nanotechnology, Stefano Cabrini, Lawrence Berkeley National Laboratory

The Department of Energy's Office of Science supports five NSRCs that are strategically located across the U.S, colocated with other major user facilities.The mission is: to enable the external scientific community to carry out high-impact nanoscience projects through a peer-reviewed user program, and to conduct in-house research for society's benefit.

10:40 am - 11:05 am 8B2 (Invited)
Encased Cantilevers for Low-Noise Force and Mass Sensing in Liquids, Dominik Ziegler, Paul Ashby *, Scuba Probe Technologies LLC, *Lawrence Berkeley National Laboratory

High damping in liquids makes atomic force microcopy (AFM) imaging of biological samples very challenging. Encased cantilevers are a solution where significantly lower damping is achieved by keeping the resonator dry. Along with various AFM images of challenging samples, we also demonstrate the quantitative mass sensing in liquids.

11:05 am - 11:30 am 8B3 (Invited)
Realization of 2D and 3D All-Dielectric Optical Metamaterials, Yuanmu Yang, Parikshit Moitra, Ivan I. Kravchenko*, Dayrl P. Briggs*, Jason Valentine, Vanderbilt University, *Oak Ridge National Laboratory

In this talk, I will discuss our recent efforts to develop purely dielectric metamaterials which exhibit low absorption loss at optical frequencies. These metamaterials are formed from silicon-based unit cells that exhibit both electric and magnetic Mie resonances, allowing us to manipulate the optical properties of the composite.

11:30 am - 11:55 am 8B4 (Invited)
The Center for Nanoscale Science and Technology: NIST's Nanotechnology User Facility, J. Alexander Liddle

The NIST Center for Nanoscale Science and Technology supports the U.S. nanotechnology enterprise from discovery to production by providing access to world-class nanoscale measurement and fabrication methods and technology. I will describe CNST's capabilities, explain how users interact with CNST, and give examples of work carried out in the Center.

11:55 am - 12:20 pm 8B5 (Invited)
Three weeks at CNST of NIST, P. Neuzil, V,. Svatos, Brno University of Technology

We will present our users' experience with CNST (NIST) fabrication facility, where we spent three weeks this February. We were able to fabricate a number of different devices, such as bolometers, electrochemical chips and mold for gecko lizard mimicking structure.

Session 8C - Charged Particle Optics and Sources

Seaport Ballroom C
Session Chairs:
Dan Meisburger, Keysight
Mark McCord, KLA Tencor

10:15 am - 10:45 am 8C1 (Invited)
Use of HfC(210) as High Brightness Electron Sources, W.A. Mackie, J.M. Lovell, and G.G. Magera
Applied Physics Technologies, Inc.

We continue to demonstrate a new high brightness electrons source operating in the extended Schottky regime. These sources have advantages over commercial ZrO/W Schottky sources in that they are capable of higher brightness and much higher angular intensity. Comparisons will be given and operation in a XL40 FEG SEM.

10:45 am - 11:05 am 8C2
A novel electron monochromator for high resolution imaging and spectroscopy, M. Mankos and K. Shadman, Electron Optica, Inc.

A novel monochromator design that reduces the energy spread of commonly used electron sources from the characteristic range of 0.2-0.5 eV into the 10-50 meV range has been developed.

11:05 am - 11:25 am 8C3
Laser triggered microfabricated Ultrafast Beam Blanker, I.G.C. Weppelman, R.F.C. van Tol, C.T.H. Heerkens, R.J. Moerland, J.P. Hoogenboom, P.Kruit, TU Delft

We discuss a micron sized blanker integrated with a photoconductive switch for Ultrafast Electron Microscopy. The photoconductive switch is illuminated with femtosecond laser pulses, hence the beam blanker is jitter free locked to the laser and is capable of blanking an electron beam at ultrafast timescales.

11:25 am - 11:45 am 8C4
Microstructure-Induced Laser Acceleration of Free Electrons, Ken Leedle, James Harris, Robert Byer, and Fabian Pease, Stanford University

We describe acceleration, deflection and deceleration of free electrons using the interaction between a 100KeV electrons beam, a silicon microstructure and a 907nm pulsed laser beam.

11:45 am - 12:05 pm 8C5
A Colored Cesium Iodide Photocathode Excited by 405 nm Irradiation, Yao-Te Cheng, Juan R. Maldonado, Piero Pianetta, R. Fabian Pease, Lambertus Hesselink, Department of Electrical Engineering, Stanford University

Session 9A - Nanobiotechnology 2

Seaport Ballroom A
Session Chairs:
Boyan Boyanov, illumina
Scott Retterer, ORNL

1:30 pm - 2:00 pm 9A1 (Invited)
Molecular Occupancy of Nanodot Arrays, H. Cai, H. Wolfenson, M. Sheetz, S. J. Wind, Columbia University

Nanoscale bioarrays, in which a given biomolecular species is presented on a surface in different geometric arrangements, require precise determination of the stoichiometry at each site. We demonstrate assessment and control of the number of molecules on metallic nanodot anchors as a function of nanodot size and linker chemistry.

2:00 pm - 2:20 pm 9A2
Translocation of Single Stranded DNA through Nano-Cylindrical PEO Passage Self-Assembled by Amphiphilic Block Copolymer, Hiroshi Yoshida, Rena Akahori and Yusuke Goto, Hitachi Ltd.

One of the major issues to achieve label-free DNA sequencing with nanopore sensors is to reduce translocation speed of DNA molecules. In this paper, we report a novel approach for slowing the translocation by applying a hydrophilic nano-cylinders self-assembled by amphiphilic block copolymer as a DNA transport channel.

2:20 pm - 2:40 pm 9A3
Fabrication of Free-standing Casein Microstructures with Bioimprinted Cellular Surface Features, A. Hashemi, I. Mutreja, M. A. Ali*, M. M. Alkaisi and V. Nock, University of Canterbury and *University of Otago

In this paper we demonstrate the transfer of positive and negative cellular bioimprints, with combined micro- and nanoscale features into biodegradable protein devices. To achieve this a two-step fabrication procedure was developed. Protein cross-linking, bioimprint replication and the effect of the imprinted surface features on secondary cells will be discussed.

2:40 pm - 3:00 pm 9A4
Advances in 3D neuronal cell culture, J.P. Frimat*, S. Xie*, A.J. Bastiaens*, B. Schurink*, F. Wolbers*, **, J.M.J de Toonder* and R, Luttge*,**,*Eindhoven University of Technology and **University of Twente

In this contribution, we present the latest advances for a fully functional hybrid bioreactor coupled to commercially available microelectrode arrays (MEAs) to study 3D neuronal networks in controlled environments for analysis of cellular physiological and pathological responses.

3:00 pm - 3:30 pm 9A5 (Invited)
Carbon nanotube membranes as the active element in remotely programmable transdermal addiction treatment device, B.J. Hinds, University of Washington

Carbon nanotube membranes show near perfect slip flow properties supporting pressure flow enhancements of 10^4 but offer no chemical selectivity/application. Recently we have found that using electrically driven ions act as selective pumps for 10^2 improvements in power efficiency allowing incorporation into transdermal drug delivery devices coupled to smart phone.

Session 9B - Emerging Technologies

Seaport Ballroom B
Session Chairs:
David Tanenbaum Pomona
Rebecca Cheung, University of Edinburgh

1:30 pm - 2:00 pm 9B1 (Invited)
Integrated On-Chip Energy Storage Using Porous-Silicon Electrochemical Capacitors, D. S. Gardner, C. W. Holzwarth III, Y. Liu, S. B. Clendenning, W. Jin, B. K. Moon, C. Pint*,**, Z. Chen*, E. Hannah*, R. Chen*, C. P. Wang***, C. Chen***, Ermei Mäkilä****, and J. L. Gustafson**,*****, Intel Labs, *former Intel Corp., **Vanderbilt University, ***Florida Intl. University, ****University of Turku, and *****Ceranovo

Integrated energy storage is increasingly important in the field of internet of things and energy harvesting with capacitors being ideal for devices requiring higher powers, low voltages, or thousands of cycles. This work demonstrates electrochemical capacitors fabricated using ALD-coated porous silicon nanostructures with ultra-high surface-to-volume ratios and an electrolyte.

2:00 pm - 2:20 pm 9B2
Quantitative Analysis of Digital STM Lithography Precision, J. H. G. Owen, J. Ballard, E. Fuchs, J. Alexander, C. Delgado, J. N. Randall and J. R. Von Ehr, Zyvex Labs LLC

We have developed an STM lithography system with real time positioning corrections to achieve atomic-precision patterning. Comparing test patterns written on H:Si(001) with and without these corrections, we show that the errors are reduced more than 90%. We present design rules for ultra-precise 2D and 3D nanostructures.

2:20 pm - 2:40 pm 9B3
Stand-alone Piezoeletronic Transistor, J. B. Chang, H. Miyazoe, M. Copel, P. M. Solomon, X.-H. Liu, T. M. Shaw, A. G. Schrott, G. J. Martyna, and D. M. Newns, IBM T.J. Watson Research Center

We report on the first physical realization of a stand-alone, monolithically integrated PiezoElectronic Transistor. In this device, a gate voltage expands a piezoelectric element, compressing a piezoresistive element to turn the switch “on”. This experimental demonstration is an important early step in towards a fast, low-power VLSI technology.

2:40 pm - 3:00 pm 9B4
Multilayer Transition Metal Dichalcogenide Device Arrays Fabricated Using Nanoimprint-Assisted Shear Exfoliation (NASE), M. Chen, H. Nam, S. Wi, and X. Liang, University of Michigan

We developed a new nanoimprint-based approach capable of producing pristine multilayer MoS_2 fake arrays over large areas and demonstrated working FETs and biosensors made from as-produced MoS2 flakes. These demonstrated functional devices exhibited consistent performance and held a significant potential for enabling future scale-up applications of TMDC-based electronic devices.

3:00 pm - 3:20 pm 9B5
Nanometer precise overlay for sub-20nm thermal scanning probe lithography, Colin Rawlings, Heiko Wolf, Philipp Mensch, Siegfried Karg James Hedrick*, Dan Coady*, Urs Duerig, Armin W. Knoll, IBM Research - Zurich, *IBM Research - Almaden.

We have recently demonstrated transfer of sub-20nm features written using thermal Scanning Probe Lithography (tSPL) into a silicon substrate. To exploit these high resolution capabilities in the fabrication of devices nanometer precise overlay is required. Here we will describe the nanometer accurate detection of features buried beneath the resist layer.

Session 9C - Novel Imaging and Characterization Techniques

Seaport Ballroom C
Session Chairs:
Larry Muray, Keysight
John Randall, Zyvex Labs

1:30 pm - 2:00 pm 9C1 (Invited)
Atomic Resolution Electron Tomography, Jianwei Miao, M. C. Scott, Chien-Chun Chen, Rui Xu, University of California, Los Angeles, Peter Ercius, Ulrich Dahmen, Lawrence Berkeley National Laboratory

2:00 pm - 2:20 pm 9C2
Design, technology and application of piezoresistive scanning thermal probe for nanoscale investigations, Paweł Janus, Andrzej Sierakowski, Piotr Grabiec, Bin Yang*, Michel Lenczner*, Maciej Rudek**, Teodor** Gotszalk**, Instytut Technologii Elektronowej, Warszawa 02-688, Poland, *FEMTO-ST, University of Technology at Belfort-Montbeliard, France and **Wroclaw University of Technology

In this paper, a novel micromachined, piezoresistive scanning probe microscopy (SPM) micro-cantilevers with conductive platinum tips are presented. The design, measurements methodology as well as the results of thermal scans of the surfaces will be presented and discussed.

2:20 pm - 2:40 pm 9C3
A Computational Fluorescent Microscopy Through a Glass Needle, G. Kim, N. Nagarajan, A. Meiri, S. Merrill, R. Menon, University of Utah

We propose a computational method to capture fluorescent images through a single glass cannula for minimally invasive in-vivo imaging. We experimentally demonstrate high-fidelity images with 1um resolution. Such device could allow imaging of hard-to-reach places with a high resolution and a great versatility.

2:40 pm - 3:00 pm 9C4
1.5 nm fabrication of test patterns for characterization of metrological systems, S. Babin, G. Calafiore, C. Peroz, N. Bouet*, S. Cabrini**, E. Chan**, I. Lacey**, W. R. McKinney**, V. V. Yashchuk**, R. Conley***, and A. Vladar#, aBeam Technologies, Inc., * Brookhaven National Laboratory, **Lawrence Berkeley National Laboratory, ***Argonne National Laboratory, and #National Institute of Standards and Technology

The characterization of metrology systems requires test patterns at a scale one order smaller than the measured features. The fabrication of test patterns with linewidths down to 1.5 nm is described. The test pattern contains thousands alternating lines of silicon and silicon-tungsten, each according to its designed width.

3:00 pm - 3:30 pm 9C5 (Invited)
Hybrid Nanoscale X-ray Imaging, A. Sakdinawat, S. Oh, C. Chang, R.C. Tiberio*, M.J. Rooks**, E.A. Dobisz***, J.Park, SLAC National Accelerator Laboratory, *Stanford University, **Yale University

Hybrid imaging methods combine direct methods, which include fabrication and optimization of optical components, and computational methods, which include reconstruction capabilities and encoding algorithms, to create high performance imaging techniques. We describe x-ray optics fabrication using metal assisted chemical etching and specialized diffractive optics design for hybrid imaging schemes.

Session 10A - Directed Self Assembly 2

Seaport Ballroom A
Session Chairs:
Andres Torres, Mentor Graphics
Hsinyu Tsai, IBM Research

3:45 pm - 4:15 pm 10A1 (Invited)
High Chi Block Co-polymers for Lithography, G. WIllson, C. WIlison, M. Maher, W. Durand, G. Blachut, Y. Asano,and M. Carlson, The University of Texas

A number of high chi block co-polymers have been synthesized, characterized and evaluated for use in patterning for microelectronic devices and bit patterned media for hard disk drives.

4:15 pm - 4:35 pm 10A2
Directed Assembly of Multiple Pattern Morphologies Using Block Copolymer Blends, A. Stein, G. Wright, K.G. Yager, C.T. Black, Brookhaven National Laboratory

We expand the traditional DSA patterning approach to enforce the coexistence of multiple, aligned BCP morphologies (lines and dots) in a single step. By carefully designing the template, we can preprogram desired spatial arrangements of different morphologies assembled from a single blend.

4:35 pm - 4:55 pm 10A3
Post-Directed-Self-Assembly Membrane Fabrication for In-situ Analysis of Block Copolymer Structures, J. Ren, T. Segal-Peretz, P. Nealey L. E. Ocola*, R. Divan*, and D. A. Czaplewski*, University of Chicago and *Argonne National Lab

Complex structures formed by directed self-assembly of block copolymers require through-film analysis and membrane sample fabrication. We developed a full-wafer process to back etch the silicon substrate after directed self-assembly to prepare block copolymer thin films on silicon nitride membranes. Results from TEM and X-ray scattering are presented.

4:55 pm - 5:15 pm 10A4
Laser Induced Liquid Phase Instabilities: Transition From Single Particle Coalescence To Multi-Particle Breakup of Nickel Nano-Rivulets and Programming Instabilities, C. Hartnett, P. Rack, J. Fowlkes*, K. Mahady**, S. Afkhami**, L. Kondic**, University of Tennessee, *Oak Ridge National Laboratory, **New Jersey Institute of Technology

Liquid rivulets below critical dimensions collapse to form single particles rather than break into multiple particles. We focus on the unique spatial and temporal transition region between the two competing regimes. And selectively harnessing specific perturbations imposed by nanofabrication conditions (programming) it is possible to access different spatial particle-array outcomes.

5:15 pm - 5:35 pm 10A5
Implementation of Surface Energy Modification in Grapho-Epitaxy Directed Self-Assembly for Hole Multiplication, J. Doise, R. Gronheid*, J. Bekaert*, B. Chan*, Y. Cao**, G. Lin**, KU Leuven/Imec, *Imec, **EMD Performance Materials Corp.

In this work a dedicated surface energy modification step is implemented in imec's grapho-epitaxy directed self-assembly flow for hole multiplication. Experimental findings are presented concerning the influence of surface energy on the DSA cylinder profile, hole placement accuracy and transfer of the pattern into an underlying stack.

Session 10B - Micro- and Nanofluidics

Seaport Ballroom B
Session Chairs:
Saba Ghassemi , U Penn
Leonidas Ocala, ANL

3:45 pm - 4:15 pm 10B1 (Invited)
Node-Pore Sensing: A Label-Free Method for Cell Screening, L. L. Sohn, University of California, Berkeley

We have developed a unique, label-free, multi-parametric method to screen single cells for size, multiple cell-surface markers, and deformability. This versatile method—Node-Pore Sensing—is based on measuring the current pulse caused by a cell transiting a microchannel that has been segmented by a series of inserted nodes.

4:15 pm - 4:35 pm 10B2
Microfluidic Exchange Devices for Cell-free Reactions, A. Timm, P. Shankles, S. Retterer, M.J. Doktycz, Oak Ridge National Lab

We have designed microfluidic reactors for the production of protein therapeutics using cell-free protein synthesis. Our reactors are designed with parallel, serpentine reactor and feeder channels separated by a nanoporous membrane created using electron-beam lithography, allowing exchange of metabolites and inhibitory molecules, increasing reaction times and yields.

4:35 pm - 4:55 pm 10B3
Nanomedicine of isolated axons - Electrical activity of individual neurites growing in a microfluidic channel, J. Mika, H.D. Wanzenboeck, P. Schuller, E. Bertagnolli, K. Schwarz, and P. Scholze*, Vienna University of Technology and *Medical University Vienna

Microchannels act as guidance tubes for neurites and can model neurite regeneration. Microfluidic channels were fabricated by nanoimprinting and exclude the neuron's somata while neurites grow into channels. Microelectrodes in the microchannel record neuronal activity real-time during growth of neurites. The influence of physiological factors on neurite growth was investigated.

4:55 pm - 5:15 pm 10B4
Multiscale fluidic architectures for chemical manipulations of biological domains across length scales, L.J. Millet, S.T. Retterer, M.J. Doktycz, Oak Ridge National Laboratory

Chemical signatures in biological systems are dynamic and span intra- and inter-cellular domains with length-scales from nanometers to meters. Resolving spatiotemporal dynamics of biochemical signals is a grand challenge that can be met through the development of micro- and nano-fluidic probes that advance chemical measurement and detection strategies.

5:15 pm - 5:35 pm 10B5
Electronic Quantification of Protein Biomarkers Based on Bead Aggregate Sizing, Z. Lin, P. Xie, X. Cao, M. Javanmard, Rutgers University

Current microbiological techniques applied for protein biomarker detection, involved time consuming methods based on sandwich immunoassays. Here, we use our electronic biochip for the rapid detection and quantification of protein biomarkers electronically. We successfully demonstrate proof of concept based on detection of streptavidin-biotin binding.

Session 10C - High Throughput Electron Microscopy

Seaport Ballroom C
Session Chairs:
Kevin Cummings, SEMATECH
Kale Beckwitt, Intel

3:45 pm - 4:15 pm 10C1 (Invited)
A single-column, multi-beam SEM for high-resolution, high-throughput imaging, Tomasz Garbowski, Thomas Kemen, Matt Malloy*, Brad Thiel**, Ben Bunday*, Richard Schalek***, Jeff W. Lichtman***, Dirk Zeidler, Carl Zeiss Microscopy GmbH, *SEMATECH, **SUNY Polytechnic Institute, ***Harvard University

An increasing need for imaging large sample areas at nm resolution calls for SEMs that achieve the required resolution and sufficient throughput. We report on a multi-beam SEM that enables a considerable increase of total imaging speed compared to single beam SEMs and its application to a variety of samples.

4:15 pm - 4:35 pm 10C2
Simulation technique for pattern inspection using projection electron microscope, S. Iida, R. Hirano, T. Amano, H. Watanabe, EIDEC

We developed an Monte Carlo software for pattern inspection, that has the capabilities to take into account electron scattering in 3D patterns, charging and discharging, aperture stop, and imaging electron optics . Sensitivity of defect detection was affected by the image contrast and the pattern edge profile.

4:35 pm - 4:55 pm 10C3
Proposed Architecture of a Multi-Column Electron-Beam Wafer Inspection System for High Volume Manufacturing, D. Meisburger, J. Spallas, K. Werder, L. Muray, Keysight Technologies

Recent advances in the performance of miniature column SEMs now make it theoretically possible to use hundreds of these to inspect semiconductor wafers for defects at extremely high speed. We will cover the specialized requirements and tradeoffs for multi-column inspection, the column design requirements, and the expected system performance.

4:55 pm - 5:15 pm 10C4
A High-Current Miniature Column for a High Volume Manufacturing Multi-Column Wafer Inspection System, James Spallas, Dan Meisburger, Kurt Werder and Lawrence Muray, Keysight Technologies, Inc.

We have investigated the development of a high performance multi-column wafer inspection system capable of detecting small defects at speeds compatible with high volume manufacturing based on the design and performance of columns currently in production.

5:15 pm - 5:35 pm 10C5
Parallel Secondary Electron Imaging in a Multi-Beam SEM, Y. Ren, C.W. Hagen and P. Kruit, Delft University of Technology

To increase the imaging throughput of Scanning Electron Microscope(SEM), imaging systems are designed for our Multi-Beam SEM(MBSEM), for parallel detection of Transmitted Electrons (TE), Secondary Electrons (SE) and Backscattered Electrons (BSE). Here we present the SE imaging result and update TE imaging result .

WEDNESDAY POSTER SESSION, May 27, 2015

Seaport Ballroom, E/F/G/H
10:30 am – 12:00 pm
5:30 pm – 7:00 pm

Advanted Pattern Transfer
P01-01
Fabrication of Topography-Free Samples for Thermal Spatial Resolution Measurement of Scanning Thermal Microscopy, *Y. Ge, Y. Zhang, J.M.R. Weaver, P.S. Dobson, University of Glasgow*

We present a novel fabrication technique to produce multi-material, lithographically defined, topography-free samples. This uses a sacrificial substrate that is deleted in the final fabrication step, leaving an exposed, flat surface. A Scanning Thermal Microscopy (SThM) sample was produced and used as a thermal-spatial resolution test exhibiting minimal topographic artifacts.

P01-02
Low DC-Bias Silicon Nitride Anisotropic Etching, *Y.F. Wang, H. Liu, W. Wu, University of Southern California*

This paper presents a research on low DC-bias silicon nitride anisotropic etching technology. Four factors are considered: reactive ion etch (RIE) power, ICP Power, pressure in the etching chamber, and the carbon-to-fluorine ratio (C/F). We successfully achieved low DC-bias silicon nitride anisotropic etching, with DC-bias 34V and etching rate 40nm/min.

P01-03 (Invited)
Directed patterning of arbitrary metal oxide nanostructures using polymer template nanoreactors, *C-Y. Nam, A. Stein, K. Kisslinger, Center for Functional Nanomaterials, Brookhaven National Laboratory*

We demonstrate a nanofabrication technique that can pattern functioning metal oxide nanostructures with arbitrarily-chosen designs/morphologies, high aspect ratios, and controlled dimensions/spatial registrations by utilizing lithographically patterned, topographical polymer templates as localized chemical reactors in which gaseous organometallic precursors and water are sequentially perfused and react to form target metal oxides.

P01-04
Ion-dose controlled etching of Nanoimprint stamps for the fabrication of Fresnell lenses, *H. Wanzeboeck, S. Waid, E. Bertagnolli, Vienna University of Technology, Institute for Solid State Electronics*

Dose-controlled Ga-implantation with a focused ion beam was used to implant a etch-resistant hardmask into a silicon substrate. Depending on the Ga-dose and the gas composition the reactive ion etching is delayed. This process allowed to fabricate a 3-dimensional NIL-stamp of a Fresnel lens and to successfully imprint the pattern.

P01-05
Faraday Cage Reactive Ion Etching: Simulation and Experiments, *P. Latawiec, Y. -I. Sohn, M. Burek, M. Loncar, School of Engineering and Applied Science, Harvard University*

The physics of Faraday cage reactive ion etching is investigated through simulation and experiments. Simulations reveal that larger mesh pitches used during ion etching may create a secondary ion sheath at the sample due to the leakage of ions past the Faraday cage.

P01-06
Line Edge Roughness Frequency Analysis during Pattern Transfer in Semiconductor Fabrication, *Lei Sun, Wenhui Wang, Genevieve Beique, Min Gyu Sung, Obert R. Wood, Yulu Chen, Ryoung-Han Kim, GLOBALFOUNDRIES*

A frequency analysis based 3 sigma LER characterization methodology is proposed. The LER transfer during etch processing will be discussed in this paper. With the new methodology, residual wiggling effect can be detected and process optimization to reduce residual wiggling becomes possible.

P01-07 (Invited)
Ultra high aspect ratio sub-50 nm deep silicon trenches by photo-assisted electrochemical etching, *Ferhat Aydinoglu, Celal Con and Bo Cui*

Photo-assisted electrochemical etching of silicon was carried out using an electrolyte containing HF. As etching preferably occurs at sharp tips where electric field is highest, the etching is directional towards wafer backside. Ultra high aspect ratio trenches and holes were obtained, with diameter/width 50-100 nm and depth 33-45 µm.

Beam Induced Deposition and Etching

P02-01

Electron Stimulated Purification of Platinum Nanostructures Grown Via Focused Electron Beam Induced Deposition, *Brett B. Lewis*, Michael G. Stanford*, Jason D. Fowlkes**, Joo Hyon Noh*, Kevin Lester**, Harald Plank***, and Philip D. Rack**, *University of Tennessee, **Oak Ridge National Laboratory, ***Graz University of Technology*

Here we introduce a room temperature purification process via the electron stimulated reaction of oxygen adsorbed and permeated into an electron beam induced deposit composed of a platinum carbon matrix. Importantly, the fidelity of the deposit is maintained and even enhanced during the purification process.

P02-02

Nanopore perforation in various membrane material by focused electron beam in transmission electron microscope, *Hyun-Mi Kim, Seong-Yong Cho, Ki-Bum Kim, Seoul National University*

We investigated the nanopore evolution on nitride and metal membranes through focused e-beam in transmission electron microscopy. We have reviewed a mechanism on the scattering between electron and mater: elsastic and inelastic. Based on theoretical calculation, it is believe that nanopore drilling is governed by direct atomic displacement by elastic scattering.

P02-03

In situ observation of Au nanoparticles behavior on different substrate during e-beam irradiation, *Hyun-Mi Kim, Nong-moon Hwang, Ki-Bum Kim, Seoul National University*

We observed the behavior of Au nanoparticles on pure carbon and SiO membrane under the e-beam irradiation. Average diameter of Au nanoparticles was about 3 nm.The behavior of Au nanoparticles on pure carbon and SiO as e-beam irradiation time was extremely different. Au on SiO travels and aggregate during irradiation.

P02-04

High-Fidelity Shapes and Disruption Mechanism during Focused Electron Beam Induced Deposition, *R. Winkler, G. Arnold, J.D. Fowlkes*, R. Timilsina**, A. Szkudlarek***, R. Schmied, A. Orthacker, G. Kothleitner****, I. Utke***, P.D. Rack**, H. Plank****, Centre for Electron Microscopy, *Oak Ridge National Laboratory, **University of Tennessee, ***EMPA, ****Graz Uiversity of Technology*

The contribution gives an overview about latest achievements in the field of focused electron beam induced deposition concerning the fabrication of high-fidelity shapes as crucial element for real applications. Fundamental broadening and proximity effects are discussed together with technical aspects required for the fabrication of sharpest edges and ultraflat surfaces.

P02-05

Towards high purity FEBID gold nanostructures – a comparison of purification approaches, *M.M.Shawrav, P.Taus, H.D. Wanzenboeck, Z.G.Goekdeniz, E.Bertagnolli, Institute of Solid State Electronics, Vienna University of Technology*

This work presents various purification approaches for FEBID gold nanostructures fabricated using organometallic precursors. The chemical composition and height of the structures will be compared for i)e-beam curing ii)oxidation with (oxygen and water) and iii) combination of e-beam curing and oxidation. The applications of purified structures will be discussed.

P02-06

Combined Electron Beam Induced Deposition and Etching for 3D shape control, *S. Hari, C. W. Hagen, P. Kruit, J. J. L. Mulders*, P. H. F. Trompenaars*, Delft University of Tehcnology, *FEI Company*

Electron Beam Induced Deposition (EBID) is an attractive high resolution patterning technique, albeit with limited control over the shapes of structures. We present the application of Electron Beam Induced Etching (EBIE) to modify the 3D profile of EBID structures while retaining all the advantages of electron beam induced processing.

P02-07 (Invited)

Focused Electron Beam Induced Etching - Advantages, Features and Limitations of FEBIE with Chlorine, *H.D. Wanzenboeck, M.M. Shawrav, J. Mika, S. Waid, Z. Goekdeniz, P. Roediger, E. Bertagnolli, Vienna University of Technology*

P02-08

In Situ Transport Properties Measurements of FEBID Cu(II)(hfa)2 During Annealing, *Alfredo R. Vaz*,*,Yucheng Zhang*,Aleksandra Szkudlarek***Ivo Utke*, *EMPA, Laboratory for Mechanics of Materials and Nanostructures, Thun, Switzerland. **UNICAMP, State University of Campinas, Center for Semiconductor Components (CCS), Brazil.***AGH University of Science and Technology, Academic Centre for Materials and Nanotechnology, Krakow, Poland.*

FEBID using organometallic precursors often results in large carbon / low metal content deposit material. In this work, in-situ conventional annealing was applied successfully to improve upon the metal content in FEBID deposits and it was used also to decrease the resistance of Cu-C lines deposited from Cu(hfac)2 precursor.

P02-09
Low-leakage current and damage-free silicon nitride deposition at 30oC by inductively coupled plasma with neutral beams by neutralization grid plate, *H. Zhou, X. Li, University of Glasgow*

Low-leakage current and damage-free silicon nitride deposition at 30oC by inductively coupled plasma with neutral beams by neutralization grid plate. Scanning Auger microscope is used to analyze chemical compositions of both surface and depth profile of SiNx films deposited by different neutral beam processes without exposing the films to air.

P02-10 (Invited)
Electron beam induced oxidation of direct–write deposits: a simulation, *J. Fowlkes*,** B. Lewis**, M. Stanford**, H. Plank***,****, R. Winkler***, B. Geier***, P. Rack*,*** Oak Ridge National Laboratory, ** The University of Tennessee, Knoxville, *** Graz Centre for Electron Microscopy, **** Graz University of Technology*

Electron beam direct–write has recently taken a large step forward with the discovery of techniques to purify deposits in–situ. This development has opened the door for future direct–write device prototyping and editing. A simulation is reported here that suggests aspects of the physical chemistry taking place during the reaction.

Nanoelectronics, CNT and Graphene-Related Nanofabrication

P03-01
Patterned freestanding Carbon Nanomembranes and Graphene via Extreme UV interference Lithography, *A. Winter, A. Gölzhäuser, Bielefeld University, Germany, A. Turchanin, Friederich Schiller University Jena, Germany, Y. Ekinci, M. Vockenhuber, Paul Scherrer Institut, Switzerland*

Carbon nanomembranes (CNMs) are thin (~1.0 nm), two-dimensional sheets with tailored physical or chemical function. We present the fabrication of nanopore arrays in freestanding CNMs and graphene using extreme ultraviolet interference lithography (EUV-IL), a high resolution and high throughput nanopatterning technique. The nanostructures are analyzed with helium ion microscopy (HIM).

P03-02 (Invited)
ZnO Functionalization of Multi-walled Carbon Nanotubes for Methane Sensing at Single PPM Concentration Levels, *Md Humayun, R. Divan*, L. Stan*, A. Gupta**, D. Rosenmann*, L. Gundel***, P. A. Solomon****, I. Paprotny, University of Illinois at Chicago, *Center for Nanoscale Materials, Argonne National Laboratory, **Illinois Mathematics and Science Academy, ***Lawrence Berkeley National Laboratory, ****U. S. Environmental Protection Agency*

The abstract presents oxygen plasma and UV ozone based effective surface pre-treatment techniques to enhance ZnO functionalization of multiwalled carbon nanotubes for methane sensing applications. Atomic layer deposition temperature dependence of the crystal quality of functionalizing ZnO nanoparticles is analyzed. The ZnO-MWCNT chemiresistors detect methane at single ppm concentration levels.

P03-03
Carbon nanotube field effect transistor apatasensors for estrogen detection in liquids, *H. Y. Zheng, Cameron S. Wood, Omar A. Alsager, Justin M. Hodgkiss, N. O. V. Plank, Victoria University of Wellington*

We investigate how the ionic strength of the liquid environment (water or buffer at various strengths) alters the electric double layer and the subsequent detection sensitivity of estrogen molecules in carbon nanotube thin film transistor platforms.

P03-04
Stencil lithography for damage free fabrication of short channel photo conductive devices in graphene, *Junjie Li,, Jinhai Shao, Jianpeng Liu, Bingrui Lu, Chialin Tsou, Yifang Chen ,Nanolithography and Application Research Group, State key lab of Asic and System, School of Information Science and Engineering, Fudan University, Lin Hao, National Physical Lab, UK*

Use SL combined with optical lithography to fabricate 200 nm interdigitated electrodes on graphene for short channel devices in ballistic transport regime at room temperature thanks to the high mobility of the carriers. This will allow us to investigate the quantum transport of graphene at room temperature for novel nanodevices.

P03-05
O_2 and H_2O mediated FEBIE for fabrication of sub-10-nm diameter nanopores in few layer graphene, *Lex Pillatsch, Alfredo R. Vaz, A. Szkudlarek , Ivo Utke,*A.V. Alaferdov, *S. Moshkalev, EMPA, Swiss Federal Institute of Materials Testing and Research, Switzerland, *UNICAMP, State University of Campinas, Center for Semiconductor Compo-nents (CCS), Brazil*

Sub-10-nm diameter nanopores in few layer of graphene have been etched by FEBIE. The formation of FEBIE holes in carbon membranes as function of the precursor regime governed by the residence time and so deduced lower limit of nanopore diameters which can be obtained, are discussed.

P03-06
Protection of graphene against helium-ion-induced damage by h-BN encapsulation, *G. Nanda, S. Goswami, P. F. A. Alkemade, Kavli Institute of Nanoscience, TU Delft, The Netherlands*

We investigate helium-ion-induced defects in graphene that is encapsulated between h-BN flakes. Raman spectroscopy measurements reveal a high tolerance of the h-BN encapsulated graphene to the helium ion beam. In addition, we fabricate a graphene device with one-dimensional contacts to study the charge transport.

P03-07
Transferring Graphene Nanostructures onto a Transparent Flexible Substrate, *J. Ding, K. Du*, F. T. Fisher, E.-H. Yang, Stevens Institute of Technology, * University of California, Berkeley*

Transparent flexible substrates have been ideal substrates for graphene in the application of photovoltaics and flexible electronics. Here we introduce a facile and reliable method of patterning graphene directly on a copper substrate, followed by transferring onto a PMDS substrate, while maintaining the geometrical nature of a patterned graphene.

P03-08
Gated Si Tip Field Electron Emitter with Integrated Nano-Conduction-Channel, *Zhijun Huang, Shaozhi Deng, Ningsheng Xu, Juncong She, State Key Laboratory of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Material and Technology, School of Physics and Engineering, Sun Yat-sen University, China*

We report a featured Si tip structure with an integrated nano-conduction-channel as a current limiter, which has improved reliability while maintaining a low driving voltage. The channel limits both the electric and thermal conduction. Both the thermal enhanced field emission and the current-limited effect result in a linear F-N plot.

P03-09
Effects of Programming Current and Environment on the Resistive Switching of a Nanoscale Memristive Device, *S. Pi, Q. Xia, University of Massachusetts*

Recently we implemented a novel radiofrequency switch with excellent RF performance based on a memristive device. Here, the dependency of the switching behavior on the programming current and environment were studied and used for improving device's ON state conductance and reducing programming voltages.

P03-10
Koops-GranMat, a Bose-Einstein Condensate material working at room temperature being capable to replace superconductors in many applications, *H. Koops, HaWilKo GmbH, Germany*

Giant current density is observed at room temperature in Koops-GranMat. FEBIP builds the material. The current density is > 1.5 GA/cm². The electron-conduction is by Bose Einstein condensate at 300 K. The material replaces HTC materials as photo detector in X, Vis and IR, and electron emitters of high brightness.

Directed Assembly
P04-01
High-χ Bio-Based Block Copolymers for Self-Assembled Nano-Lithography, *D. Ouhab*, S. Halila*, R. Tiron** and R. Borsali*, *CERMAV-CNRS, **LETI-CEA*

Combining the knowledge of CERMAV-CNRS in the design of high resolution thin films obtained by self-assembly of biobased block copolymers and the expertise of LETI-CEA on innovative lithography processes, the project is to evaluate new bio-based copolymers as an alternative for tomorrows nano lithography.

P04-02 (Invited)
Laser-induced self-assembly of noble metal nanoparticles and EELS characterization, *Yueying Wu*, Guoliang Li, Charles Cherqui**, Jon P. Camden, David J. Masiello**, Jason D. Fowlkes***, Philip D. Rack*&***, University of Notre Dame, *University of Tennessee, **University of Washington, ***Oak Ridge National Laboratory*

We present self and directed assembly of highly ordered nanoparticles via pulsed laser induced dewetting of thin films of various shapes and sizes. Specifically, nanoparticles of noble metals and alloys were synthesized on TEM membranes and a comprehensive plasmonic study using EELS and e-DDA simulation was performed

P04-03 (Invited)
A simulation study on defect annihilation dynamics in directed self-assembly lithography, *Katsuyoshi Kodera, Hideki Kanai, Hironobu Sato, Yuriko Seino, Katsutoshi Kobayashi, Yuusuke Kasahara, Hitoshi Kubota, Naoko Kihara, Yoshiaki Kawamonzen, Shinya Minegishi, Ken Miyagi, Masayuki Shiraishi, Toshikatsu Tobana, Satoshi Nomura, Tsukasa Azuma, EUVL Infrastructure Development Center, Inc.*

We have investigated defect annihilation dynamics in directed self-assembly lithography using simulation method based on self-consistent field theory and dissipative particle dynamics. In the presentation, we will also discuss some comparison results with our wafer experimental results.

P04-04
Rapid growth in 30 seconds of thermally induced microphase-separation of PS-b-PMMA for directed self-assembly lithography, *Nobuya Hiroshiba, Ryo Okubo, Masaru Nakagawa, Azusa N. Hattori*, Hidekazu Tanaka*, IMRAM Tohoku Univ., *ISIR Osaka Univ.*

We investigated the annealing period necessary for the highly ordered microphase-separated cylindrical structure of single-layer PS-b-PMMA by AFM measurement. The result revealed that the well-ordered microphase-separated structure on a Si wafer was formed within 30 sec by annealing at 200^{o}C on a conventional hot plate.

P04-05
Nano Mesh Patterns by BCP Self-Templating, *A. Tavakkoli K. G., S. M. Nicaise, K. Gadelrab , A. Alexander-Katz, C. A. Ross, K. K. Berggren, Massachusetts Institute of Technology*

This abstract describes the fabrication of a nanomesh rectangular array by block copolymer self-direction. An initial layer of BCP cylinders was used as a topographical template for a second-layer of cylindrical BCP. The top-layer oriented perpendicular to the bottom-layer to form a mesh. Applications include bit-patterned media and integrated circuits.

P04-06
Templated Self-Assembly of Block Copolymer Thin Films under Lithographic Confinement, *H. Do, H. K. Choi, J. Chang, C. A. Ross, K. K. Berggren, Massachusetts Institute of Technology*

We describe how physical confinement affects the self-assembly of cylindrical morphology polystyrene-b-polydimethylsiloxane (PS-b-PDMS) block copolymer thin films. We observed bar-shaped PDMS structures inside square and rectangular grid templates. Alignment direction of these structures was controlled by the template shape.

P04-07
Optimization of Peanut-Shaped Template Geometry for Block Copolymer Directed Self-Assembly, *M. C. Tung, H. Yi, H.-S. P. Wong, Stanford University*

We demonstrate that there exists an optimum critical dimension for peanut-shaped templates to produce two-hole pairs. This critical dimension is nearly the same regardless of the geometry of the template neck.

P04-08
Ultra-high resolution nanofabrication using self assembly of salt-polymer nanocomposite film, *C. Con, F. Aydinoglu, B. Cui, University of Waterloo*

We developed a simple, low cost, and high resolution (20nm) self-assembly method. Metal salt and PMMA were dissolved in DMF (Dimethylformamide). Thermal annealing the film induced phase separation. After oxygen plasma etching of PMMA, salt islands were formed that can be used as hard mask to etch the substrate.

P04-09
Neutral surface prepared by vapor phase coating for PS-b-PMMA self assembly, *Babak Shokouhi, Wadha Alyalak, Mustafa Yavuz and Bo Cui*

Neutral surface is needed for symmetric PMMA-b-polystyrene self assembly. Here we achieved neutral surface by a self-assembled mono-layer with the right surface energy. Silicon was treated with silane surfactant by putting it together with a drop of the surfactant. Vertical lamellae were obtained with characteristic fingerprint pattern.

P04-10
300mm DSA process qualification and stability, *M. Argoud, A. Gharbi, P. Pimenta-Barros, G. Chamiot-Maitral, I. Servin, R. Tiron, X. Chevalier*, C. Nicolet*, C. Navarro*, G. Fleury**, G. Hadziioannou**, M. Asai***, C. Pieczulewski***, CEA-LETI, *ARKEMA FRANCE, **LCPO, ***DAINIPPON SCREEN MFG.*

DSA potential must be confirmed viable for high volume manufacturing. Developments are especially necessary to transfer this technology on 300mm-wafers to demonstrate semiconductor fab-compatibility. The challenges of this paper concern the stability, both uniformity and defectivity, of the entire process, including tools, Block Co-Polymers and Neural Layer materials.

Electron Beam Lithography
P05-01
Fabrication of a high-resolution mask based on enhanced techniques for line edge roughness improvement with a non-chemically amplified resist and a post-exposure bake, *H.Miyoshi, J.Taniguchi, Tokyo University of Science*

In our researches, the use of PEB with a non-CAR resist helps to suppress the proximity effect, improving LER, and causes an annealing effect, permitting us to demonstrate an advanced fabrication technique for high resolution masks of the order of 20 nm.

P05-02
A novel PMMA/NEB bilayer process for sub-20 nm metallic nanoslits by electron beam lithography and dry etch, *Chialin Tsou, Sichao Zhang, Jinhai Shao, Yaqi Ma, Bingrui Lu, Yifang Chen*

We have developed a novel PMMA/NEB process for the fabrications of sub-20 nm nanoslits in 100 nm thick Au film. This success enables us to produce highly sensitive sensors with either LSPRs or SERS configurations.

P05-03
Gray scale electron beam lithography for photon-nanojet based nanolens with super resolution lithography prospect, *Chen Xu, Sichao Zhang, Jinhai Shao, Bing-Rui Lu and Yifang Chen, Nit Taksatorn*, Fudan University, *GenISys GmbH*

3D nanolens with semi-cylindrical shape, which is proved the focusing behavior of a dielectric nanoshpere with the resolution of sub diffraction limit by FDTD, is fabricated in PDMS by grayscale EBL, assisted by Monte Carlo method. This work shows the promising step forward in developing novel nanolithography by white lights.

P05-04
Multilayer on-chip stacked zone plates with high aspect ratio for hard X-ray nanoscale imaging, *Kenan Li, Michael Wojcik*, Chris Jacobsen*, Northwestern University, *Argonne National Lab*

We fabricated a double layer on-chip stacked zone plate made of gold which measures 1.14 μm thick and has 100 nm finest zone period (aspect ratio up to 23:1). The process is a multi-step process which involves the combination of high resolution e-beam lithography, development, RIE, electroplating and multilayer alignment.

P05-05
Fabrication of X-ray reflection sinusoidal grating using fast electron beam direct writing, *Xiaoli Zhu*, Changqing Xie*,Leifeng Cao**, Lai Wei**, Yilei Hua*,Peixiong Shi***, Jiebin Niu*, Bailing Shi*, Ming Liu*, *Institute of Microelectronics, CAS, **Research Center of Laser Fusion, CAEP,***Technical University of Denmark*

A novel X-ray reflection sinusoidal grating which can suppress high-order diffraction was fabricated using fast electron beam direct writing and Au-Au bonding techniques. In experiment, several critical techniques have been investigated to achieve sinusoidal grating patterns with nanoscale critical dimension and large area on standard bulk silicon substrate.

P05-06
20 nm Flip Blazed Fresnel zone plates by a PMMA/ZEP bilayer technique, *Jianpeng Liu, Jinhai Shao, Sichao Zhang, Yaqi Ma,Yifang Chen, *Biao Deng, *Tiqiao Xiao, Fudan University*

By summary, in this work we has successfully innovated a new method to generate shaped profiles of zone plate by using PMMA/ZEP bilayer. This technique has the advantages of high reliability and high controllability in the process for higher efficiency and high resolution.

P05-07
Analytic Derivation and Minimization of Line Edge Roughness in Electron-beam Lithography, *R. Guo, S.-Y. Lee, J. Choi*, S.-H. Park*, I.-K. Shin* and C.-U. Jeon*, Auburn University, *Samsung Electronics*

In efforts to minimize the LER, it is essential to have an efficient and accurate method to estimate it. In this study, a new approach to the analytic derivation of LER is taken to make the derivation procedure simpler and the LER expression more applicable.

P05-08
Effects of thermal treatment on the transfer characteristics of sub-100 nm SnS_2 thin-film transistor arrays, *Jeongsu Lee, Gunwoo Lee, Onejae Sul*, Seung-Beck Lee**, Department of Nanoscale Semiconductor Engineering, Institute of Nano Science and Technology, Department of Electronic Engineering*

Here, we demonstrate the fabrication of a sub100 nm SnS2 thin-film transistor (TFT) array and also investigate the effects of thermal treatment on its transfer characteristics.

P05-09 (Invited)
A study of characteristics of a microcolumn based on CNT emitters, *Hyung Woo Kim, Young Bok Lee, Sung Woong Choi, Dae Wook Kim, Seung Joon Ahn, Tae Sik Oh, Ho Seob Kim, Young Chul Kim*, Sun Moon University, *Eulji University*

Using the microcolumn adopting 2D-CNT emitter, we obtained both a normal SEM image and an overlapped SEM image. We performed a simulation study to investigate the origin of the overlapped SEM image on the assumption that multiple CNT emitters are activated simultaneously and contribute the overlapped image formation.

P05-10
A Practical Approach to Modeling Scanning Electron Microscope Images for Minimization of Line Edge Roughness and Critical Dimension Error, *S.-Y. Lee, X. Zhao, R. Guo, J Choi*, S.-H. Park*, I.-K. Shin*, C.-U. Jeon*, Auburn University, *Samsung Electronics*

In this study, a practical approach to modeling the e-beam lithographic process directly from SEM images for minimization of the CD error and LER has been developed for line/space patterns. This approach does not require a point spread function.

P05-11
Automated Geometry assisted PEC for electron beam direct write nanolithography, *Leonidas E. Ocola, David Gosztola, Argonne National Laboratory, Gerald Lopez, GenISys, Inc.,*

In this paper we present the implementation of nanoscale proximity effect correction (NanoPEC) by using scripts in a commercially available PEC software (Layout Beamer, GenIsys GmbH). We will present optimized methodology for isolated and arrays of structures that are used in plasmonic applications.

P05-12
Enhanced adhesion of electron beam resist by grafted monolayer PMMA brush, *F. N. Viscomi* **, R. Dey**, R. Caputo*, B. Cui**, *University of Calabria, **Waterloo Institute for Nanotechnology (WIN)*

Inadequate adhesion of resist to substrate is a seriously issue since resist patterns may detach due to capillary force during liquid drying. Here we modified silicon substrate by grafting a monolayer PMMA brush that led to a remarkable improvement in adhesion and thus higher resolution for ZEP and polystyrene resist.

P05-13
PMMA resist containing metal salt for enhanced dry etching resistance, *C. Con, B. Cui, University of Waterloo*

We obtained metal containing resist by dissolving metal salt such as aluminum nitride or nickel chloride and PMMA in DMF (Dimethylformamide) solvent followed by spin coating. The dry etching resistance was increased by 4 times compared to pure PMMA, and the mixture behaved as electron beam resist.

P05-14
Electron Beam Induced High Resolution Biofunctionalised Nanopatterns, *Sangeetha Hari, Christian Floris, Miranda Vaandrager, Jeroen Rozendaal, Jacob Hoogenboom and Cornelis Hagen*

Biofunctionalised nano scale arrays are an important tool in the study of several biological processes, especially to monitor interactions between single molecules. We present IgG-Alexa488- functionalised high resolution fluorescent nanopatterns fabricated on a PEG silane-coated Glass/ITO substrate in a Scanning Electron Microscope by resist free electron beam patterning.

P05-15
Direct Writing of Silver Nanostructures and Painting on Phosphate Glass with Electron Beam Irradiation, *K. Jacobs, P. M. Ferreira, University of Illinois at Urbana Champaign*

A simple process for direct writing of silver nanoparticles on, and direct coloring the surface of, ionically conductive and transparent $AgIAgPO_3$ glass using an electron beam is presented. Through selection of the electron beam parameters and total fluence, control of the specific colors produced and film thickness is demonstrated.

Emerging Technologies

P06-01
Computational study on 3-Dimensional Imaging by Advanced Built-in Lens Mask (BILM) Lithography, *N. Ueda, T. Tanaka, H. Kikuta, M. Yasuda, H. Kawata, M. Sasago, Yoshihiko Hirai, Osaka Prefectuer Univ.*

We newly propose novel photolithographic method for 3-dimensional imaging by advanced built-in lens mask (BILM) lithography to realize multiple focusing without hard lens systems. The performance is examined by computational lithographic work. 3-dimensional imaging of the H shaped structure is succsesfully demonstrated using single mask without lens systems.

P06-02
A single protein resolution mapping of DNA-ZFP interaction using solid-state nanopores, *Jae-Seok Yu, Min-Cheol Lim*, Huynh Thi Ngoc Duyen*, Hyung-Jun Kim, Hyun-Mi Kim, Young-Rok Kim*, Ki-Bum Kim, Seoul National University, *Kyung Hee University*

We demonstrated a rapid mapping of ZFP bound to dsDNA using solid-state nanopores. When ZFP labeled DNAs were driven through a nanopore by an electric field, characteristic ionic current signals arising from the passage of DNA/ZFP complex were detected, which enabled us to identify the locations of ZFP binding site.

P06-03
Fabrication and Mechanical Properties of Porous 3D Nanostructures, *Abhijeet Bagal, Xu Zhang, Rahnuma Shahrin, Erinn Dandley, Junjie Zhao, Christopher Oldham, Gregory Parsons, Christopher Bobko and Chih-Hao Chang*

We present a novel fabrication technique combining colloidal lithography and atomic layer deposition to make ordered ZnO porous nanostructures. Mechanical properties of these nanostructures are tested using nanoindentation method. The effect of porosity of ZnO 3D structures on the scaling factor for elastic modulus will be presented.

P06-04 (Invited)
A thiol-ene / acrylate thermoset polymer as flexible substrate for implantable electronics, *David E. Arreaga-Salas, Adrian Avendaño-Bolívar, Dustin Simon, Radu Reit, Aldo Garcia-Sandoval, Alexandra Joshi-Imre, and Walter E. Voit, The University of Texas at Dallas*

We will present successful integration of high charge-injection capacity materials onto thiol-ene / acrylate thermoset polymer substrates, we will also summarize the limitations of shape memory polymer substrates for applications in flexible electronics in general.

Focused Ion Beam Technology
P07-01
Lithography and in situ elucidation of conductivity in graphene structures using scanning helium ion microscopy, *A. Rondinone, V. Iberi, B. Matola, A. Lynn, D. Joy, Oak Ridge National Laboratory*

We discuss the utility of helium ion lithography for fabricating conducting graphene structures supported by silicon oxide. We demonstrate that ion beams may be used in conjunction with the graphene work function and secondary electron yield to observe the conductivity of graphene-based nanoelectronic devices in situ.

P07-02
Backside circuit edit with gas assisted etching on a platform with multiple focused ion beams, *Deying Xia, John Notte, Bernhard Goetze, Carl Zeiss Microscopy*

XeF_2-assisted gallium focused ion beam was used to enhance etching the thick Si for backside circuit edit and endpoint was detected to stop in some metal layer while helium ion beam was used to get imaging in multiple ion beam system.

P07-03
Proton beam writing on polyvinylidene difluoride films for high-aspect-ratio micro-structuring, *H. Matsuoka, H. Hayashi, H. Nishikawa, H. Koshikawa, Y. Maekawa*, Shibaura Institute of Technology, *Japan Atomic Energy Agency*

In this study, we have proposed a mask-less approach to micro-structuring of polyvinylidene difluoride (PVDF) films with piezoelectricity using proton beam writing (PBW), which is suitable for high-aspect-ratio, micro-structuring. Combined with a wet etching technique, we were able to obtain high-aspect-ratio microstructuring of PVDF with a depth of 15 micrometers.

P07-04
Characterization of mechanical properties of the carbon mechanical nanostructure fabricated from SU-8 resist by FIB/EB dual-beam lithography, *R. Kometnai, Y. Miyata, E. Maeda, The University of Tokyo*

Characterization of the mechanical properties of carbon mechanical structure fabricated from SU-8 by FIB/EB dual-beam lithography and annealing treatment was carried out in order to enable fabrication of functional nanomechanical devices. Relationship between fabrication, material characteristics such as Young's modulus and density and resonant properties will be reported in details.

P07-05
Controllable Synthesis of Single Conducting Polymer Nanowire on electrodes Fabricated by Focused Ion Beam Milling, *B. G. Quan, J. J. Li, C. Z. Gu,W. J. Zou*, Z. X. Wei* Institute of Physics,CAS, *National Center for Nanoscience and Technology*

This abstract is about the application of Focused Ion Beam technique on directed self-assembly of single conducting polymer nanowire. By combination of top-down and bottom-up techniques, this work provides a facile stratigy for fabrication single nanowire based sensor device.

P07-06
Research on three-dimension current density distribution of a 30kV focused ion beam with Coulomb interactions, *Li Wenping, Li Qian, Liu Junbiao*,Beihang University, *Institute of Electrical Engineering*

Three-dimension focused ion beam(FIB) current density distribution is obtained through N-body Monte Carlo method with Coulomb interactions being considered. Spatial ion trajectory is traced with an optimum N(the number of particles per bunch).The three-dimension beam current density of the whole column can lay foundation for the FIB mechanical design.

Novel Imaging and Characterization Techniques
P08-01
Modeling of Local Dielectric Charging-up during SEM Observation, *Zh. H. Cheng, H. Koyama, Y. Kimura, and H. Shinada, Central Research Lab., Hitachi, Ltd.,O. Komuro, Hitachi High Technologies America, Inc.*

We propose an analytical model and derive the intrinsic parameters that govern the collecting efficiency of the secondary electrons escaped from dielectrics during SEM observation. Our model provides a convenient way to suppress the variation in image contrast within the field of view during SEM observation.

P08-02
Development of head-scanning atomic force microscope in scanning electron microscope, *Dal-Hyun Kim, Hyunung Yu, Byong Chon Park, Korea Research Institute of Standards & Science*

A beam bounce type head-scanning atomic force microscope (HSAFM) in SEM is developed that enables a large sample to be imaged. The head of HSAFM is so small and light that a good image can be acquired at a line scan rate of 1.8 Hz without loss of image sharpness.

P08-03
Variation in phase defect volume on extreme ultraviolet mask before and after coating reflective multilayer, *T. Amano, T. Abe*, EIDEC, *Dai Nippon Printing Co., Ltd.*

Influence of the phase defect volume on the defect detection signals of the at-wavelength dark-field inspection tool was investigated. The defect volumes on EUV blank were measured using scanning prove microscope with two types of tips (silicone-type and carbon-nanofiber-type). Both of them could measure the defect volume with highly accuracy.

P08-04
Improvement of Xe Plasma FIB Resolution and its Integration with Electron and Photon Beams, *J. Jiruše, M. Havelka, J. Polster, T. Hrnčíř, TESCAN Brno, s.r.o.*

We present latest advances of Xe plasma FIB improving lateral resolution more than two times. SEM is upgraded using recently developed immersion electron optics for better resolution at low beam energies. TOF-SIMS and Raman analysers are also integrated thus providing electron, ion and photon beams in one instrument.

P08-05
Focused ion beam fabrication of planar probes for high resolution shear force microscopy, *P. Kunicki, M. Moczała, D. Kopiec, W. Majstrzyk, K. Orłowska, G. Jóźwiak and T. Gotszalk, Wrocław University of Technology, A. Sierakowski*, M. Płuska*, P. Grabiec*, P. Janus*, *Institute of Electron Technology*

In this paper fabrication process of microprobes for the shear force microscopy using focused ion beam technology will be presented. The microtip protrudes out of piezoresistive cantilever, whose deflection is thermally actuated. The FIB milling proces is monitored by the cantilever resonance frequency measurement and regularized blind tip reconstruction calculation.

P08-06
Electron-Beam Induced Atomic-Scale Defects in 2D Materials at Elevated Temperatures using In Situ Transmission Electron Microscopy, *A. Gibb [1, 2;] M. Gilbert [1;] T. Pham [1,3;] C. Song [2,3;] A. Zettl [1,3]; [1]University of California, Berkeley, [2]National Center for Electron Microsocpy, [3]Lawrence Berkeley National Lab*

In this study, we report on the structure of defects in hexagonal boron nitride at elevated temperature using in situ aberration corrected transmission electron microscopy. By changing the temperature during electron beam irradiation, we both induce and image atomic-scale defects with a variety of geometries.

Micro- and Nano- Fluidics

P09-01
High-efficiency Water Electrolysis based on Nanoelectrodes, *Y.F. Wang, W. Wu, University of Southern California*

Water electrolysis for hydrogen generation has low efficiency due to Ohmic loss from water resistivity between two electrodes. We reduce the distance between two electrodes to nanometer scale (even shorter than Debye length), to reduce the total Ohmic loss and achieve a much higher efficiency for hydrogen generation.

P09-02
Air-Stable Droplet Interface Bilayers, *Andy Sarles*, Jonathan Boreyko**, Chris Richards***, C. Patrick Collier, Oak Ridge National Laboratory, * University of Tennessee, ** Virginia Polytechnic Institute and State University, *** University of Kentucky*

Droplet interface bilayers (DIBs) are versatile model membranes useful for synthetic biology and biosensing; however, to date they have been for the most part confined to fluid reservoirs. When two or more water droplets meet on an oil-infused nanostructured substrate, air-stable droplet interface bilayers ("air-DIBs") form between noncoalescing water droplets.

P09-03
Fabrication of Nanoporous Membranes for Tuning Microbial Interactions and Biochemical Reactions, *P.G. Shankles(*,**), A.C. Timm**, S.T. Retterer(*,**), M.J. Doktycz(*,**), *University of Tennessee, **Oak Ridge National Lab*

Multi-scale fluidic platforms combine photo- and soft- lithographic techniques with high-resolution patterning and etching to address the full range of functional scales seen in complex biological and chemical systems. We implement these techniques to produce nanoporous membranes that control species transport while maintaining satisfactory throughput and cost.

P09-04
Impedance Cytometry Based on Multi-fingered Interdigitated Electrodes, *P. Xie, Z. Lin, N. Talukder, X. Cao, Rutgers University, S. Emaminejad, University of California Berkeley*
M. Javanmard, Rutgers University

We present a novel method of achieving high SNR electrical impedance measurements using multi-fingered interdigitated electrodes in conjunction with a matched filter resulting in processing gain.

P09-05
Sensitivity of Thermo-Moisture Responsive Shape Memory Polymer Controlled by Imprinted Nano-Micro Patterns, *G. Kim, Y. J. Kim, C. Choi, K. J. Hwang, Y. Zhong, R. Chen, S. Jin, University of California San Diego*

We have developed a thermo-moisture responsive polymer(TMP) which consists of two components of hydrophobic material and hydrophilic material, and controlled the sensitivity of TMP to water by imprinting nano-micro patterns on the surface of the polymer.

P09-06
Characterization of QSil 216 and QSil 218 for Microfluidic and Biomedical Applications, *J.K. Mika, R.M. Mayer, H.D. Wanzenboeck, E. Bertagnolli, Vienna University of Technology*

For the first time the two alternative materials QSil 216 and QSil 218 were compared with Sylgard 184 by using them for the fabrication of a neurite-isolation microfluidic device. Microfluidic devices for PC12 nerve cells were fabricated and differences in the fabrication process and material properties were investigated.

P09-07
Characterization of Electrophysiological Properties of Neurites using a Microfluidic-Microelectronic Platform, *J.K. Mika, K. Schwarz*, P. Scholze*, H.D. Wanzenboeck, E. Bertagnolli,Vienna University of Technology, 'Medical University of Vienna*

The understanding how the electric transmission of neuronal activity occurs and is propagated plays an important role in neurobiology. We developed a microfluidic-microelectrode platform to determine the shape and the propagation speed which depend on the characteristics of the cell.

Nano- and Micro- electromechanical Systems
P10-01
Metallic Nanostructures Controlled by Dewetting Thin Film on Patterned Ceramic Surface, *Keisuke Nagato, Lei Wang, Shiko Iwasaki, Tetsuya Hamaguchi, Masayuki Nakao, The University of Tokyo*

The method of dewetting thin metallic film on ceramic surface can be used to obtain triple phase boundaries (TPBs) of metal, ceramic and air. We researched dewetting thin metallic film on patterned ceramic surface in order to obtain more TPBs.

P10-02
Graphene-derived Materials for NEMS, *M.K. Zalalutdinov, J.T Robinson, C.D. Cress, J.C. Culbertson, A.L. Friedman, E.S. Snow, B.H. Houston, Naval Research Laboratory*

We demonstrate that for ultra-thin films comprised of a few monolayers of 2D materials (graphene, BN) a wide range tunability of mechanical properties (stress, stiffness) is attainable through engineering the defect state. We compare experimental results for heterostructures prepared by layer transfer versus multilayer graphene films deposited by spin cast and discuss applications for tunable materials in nanomechanics.

P10-03
Modelling and analysis of MEMS capacitive microphone with compliant diaphragm, *Robin Singh, S M Kulkarni, Department of Mechanical Engineering, National Institute of Technology, India*

A novel compliant diaphragm has been proposed for MEMS capacitive microphone. The performance is found to be greatly improved in terms of characteristics parameters. The sensitivity increased from 1mV/Pa to 5.4 mV/Pa. Operating frequency is 15KHz with frequency-rolloff of 1200Hz and reduced thermal noise of 16dB from 20dB.

Nanoimprint Lithography
P11-01
Surface Patterning of Protein Matrix Basement, *H. Mekaru, National Institute of Advanced Industrial Science and Technology (AIST)*

As a method of processing a grid mesh on the surface of a basement membrane matrix, we investigated on a possibility that thermal imprinting is applied to a protein. Although a pattern transfer at 75 ^{0}C could not be observed, a thermal imprinting at 100 ^{0}C or more was effective.

P11-02
Novel Method for Fabrication of Sub-50nm Multi-tier Nanoimprint Lithography Templates, *P. Joseph, S.V. Sreenivasan, The University of Texas at Austin*

In this work, we describe a novel fabrication process to make high resolution (sub-50nm) multi-tier nanoimprint templates, while eliminating the need for any alignment or overlay. These templates are planned to be used for patterning high resolution devices on rigid and flexible substrates by nanoimprint lithography.

P11-03
Temperature dependence of molecular orientation of liquid crystalline polymer induced by nanoimprint-graphoepitaxy, *Makoto Okada,Yuichi Haruyama,Shinji Matsui, Risa Hosoda*, Yusuke Taniguchi*, Nobuhiro Kawatsuki*, Hiroshi Ono**, LASTI,University of Hyogo, *Graduate School of Engineering, University of Hyogo, **Nagaoka University of Technology*

We carried out nanoimprint-graphoepitaxy on liquid crystalline polymer (LCP) and observed the imprinted LCP patterns by polarized optical micrography (POM) under crossed Nicols. We confirmed that the contrast of POM images were changed depending on nanoimprint temperature.

P11-04
Numerical method using modified squeeze model for NIL, *J.H. Ryu, G.H. Kim*, H.J. Lim*, J.J. Lee*, S.H. Lee**, University of Science and Technology, *Korea Institute of Machinery and Materials, **Wonkwang University*

A modified squeeze model was presented and used for investigating the effect of a stamp geometry, polymer thickness, and temperature. It was confirmed that this model was in good agreement with experimental results. A filling ratio increased with the increases of cavity size and the dcreases of pressure variation rate.

P11-05
Large-scale formation of three-dimensional plasmonic nanodishes using nanoimprint lithography, *Jung-Sub Wi, Tae Geol Lee, Jin Gyeong Son*, Sang Woo Han*, Korea Research Institute of Standards and Science, *Korea Advanced Institute of Science and Technology*

There are increasing demands for the development of a reliable and straightforward method to fabricate plasmonic nanostructures which allow us to localize light for various purposes such as localized surface plasmon based bio-chemical sensor. The authors will present a wafer-scale formation of three-dimensional gold nanodishes using nanoimprint lithography and oblique-angle-deposition.

P11-06
Fabrication of the flexible metallic master using LTIL process for roll nanoimprint lithography, *S. Park, M. Kim, M. Jeong*, J. Lee*Gwangju Institute of Science and Technology, *Korea Institute of Machinery and Materials*

To overcome the fabrication process difficulty for the roll NIL master, the flexible and metallic type master is proposed. The nano patterns are fabricated by LTIL ad aluminum lift-off process, and PDMS sheet is bonded on the opposite surface of the nano patterned.

P11-07
Stress and Deformation Behaviors in Polymer Resist during Demolding Process of Hot Embossing via Finite Element Method, *Q. Wang, R. Zhang, Shandong University of Science and Technology*

In hot embossing, the process of demolding plays an important role to determine the success of imprinting fine patterns. In this report, the authors studied the stress and the deformation behaviors in polymer resist during demolding process of hot embossing via finite element method.

P11-08
Residual layer less nano-transfer by roll press and liquid transfer imprint lithography, *T. Hayashi, J. Taniguchi, M. Moro, Tokyo University of Science*

The roll press motion was used for thinning the transfer resin and for the transfer to the substrate. The thinning process does not require other coating equipment such as an applicator or spin-coater. thereby patterns were transferred to a silicon substrate without residual layer.

P11-09
Impact of side wall angle of mold pattern on release force in nanoimprint lithography, *K. Uemura*, K. Fujii*, M. Michalowski**, T. Tochino*, K. Shimomukai* N. Nakamura*, M. Yasuda*, H. Kawata*, Z. Rymuza**, and Y. Hirai*, *Osaka Pref. Univ. , **Warsaw Univ. of Technology*

Impact of the side wall slope angle on mold release force is studied by experimental and computational works in nanoimprint lithography. The release force decreases as the slope angle decreases until critical angle. The reason is confirmed by computational work.

P11-10
Fabrication of super-lyophobic surface on thermoplastic substrates with hybrid micro/nano-scale overhang structures, *H. Feng, W. Shu, J. Pang, B. Zhang, X. Chen and Y. Chen, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, China*

We propose a simple, versatile, and low-cost approach to create super-lyophobic surfaces with hybrid micro/nano-scale overhang structures on highly transparent thermoplastic substrates such as COC or COP.

P11-11
Procedure for high temperature nanoimprint of organic semi-conducting polymer, *S Si Wang, K. Dhima, C. Steinberg, M. Papenheim, H.-C. Scheer, University of Wuppertal*

High temperature nanoimprint of organic semi-conducting polymers is limited as in general the organic material degrades at high temperature under oxygen contact. We propose a novel procedure for imprinting – heating under pressure – to avoid degradation during high-temperature T-NIL without the need for an imprint under controlled atmosphere.

P11-12
A flexible hybrid stamp for T-NIL based on OrmoStamp, *M. Papenheim, C. Steinberg, K. Dhima, S. Wang, H.-C. Scheer, University of Wuppertal*

Thin hybrid stamps (<100µm thickness) consisting of a structured top-layer from OrmoStamp and different backplane materials are investigated for low pressure NIL. Calculations of the pressure reduction provided with the hybrid stamps are given, compared to a 500µm thick stamp from Si.

P11-13
Fiber-facet SERS Probes Fabricated Using Double-Transfer Nanoimprint Lithography, *Shijie Li, S. Li, Z. Zhu, W.D. Li, The University of Hong Kong*

Double-transfer UV-NIL is used to transfer metallic nanostructures from a cyclic olefin copolymer mold to the fiber facet to fabricate fiber-facet surface-enhanced Raman sensors. Electric field distribution and enhancement are estimated using FDTD simulation. Different configurations and geometric parameters are investigated to further improve the device performance.

P11-14
Cost-effective and Solution Processed Fabrication for Metal Mesh Based Flexible Transparent Conducting Electrodes, *A. Khan, W.D. Li, The University of Hong Kong*

We propose and demonstrate a cost-effective approach for fabricating flexible transparent metal mesh electrodes via simple solution processed steps involving lithography, electroplating and thermal imprint transfer. The fabricated Cu mesh electrode exhibited an optical transmittance of 70% at 550 nm, 1.5 Ω/sq sheet resistance and superior bending durability.

P11-15
Fabrication of passive polarization-dependent asymmetric optical devices using nanoimprint lithography, *Yuhan Yao, He Liu, Richard P. Wang*, Michelle L. Povinelli, Wei Wu, University of Southern California, *Lawrenceville School*

We report of our progress on fabricating the optical asymmetric device consisting of two cascaded gratings. In this work, we used nanoimprint lithography and reactive ion etching to fabricate large-area gratings. The asymmetric transmittance was experimentally observed for TE polarization.

P11-16
Studies on the fully automated printing/imprint process using a double-side patterned soft stamp, *J. He, S. Howitz, F. Baudisch, GeSiM*

The author present in this work a double-side patterned (DSP) soft membrane stamp consisted of PDMS with a glass background to reduce the soft stamp deformation and to confine the UV-curing only in nano patterns area.

P11-17
Damascene of metallic wires on imprinted flexible substrate, *J. Wang, K. Nagato, K. Takahashi, T. Hamaguchi, M. Nakao, University of Tokyo*

To obtain the micro wires on flexible substrate, we improve the printing process by nanoimprinting and damascene technology. We obtain the fine wire with the width of 20 µm on PEN film and evaluate the wires by measuring their resistance.

P11-18
A Study of Nanoimprinted Color Filter with Ultra High Resolution, *Bing-Rui Lu, Chen Xu, Jinhai Shao, Sichao Zhang and Yifang Chen*Nanolithography and Application Research Group, State key lab of Asic and System, School of Information Science and Engineering, Fudan University*

In our work, Nanoimprint Lithography (NIL) is used in association with a one-layer metal deposition to achieve a RGB color filter in ultrahigh resolution of 25,000 DPI. This simple fabrication method can produce ultra high resolution color filter with high throughput and low cost for color display, sensing and imaging.

P11-19
Fabrication of Nano-Sized MTJ Array for MRAM Devices, *Young jin Kim*, Gunwoo Kim*, Chulmin Choi**, Kyung-Jun Hwang**, Chin-Hung Liu*, Dong Won Chun*, Cihan Kuru*, Renkun Chen*,** and Sungho Jin*,*** Materials Science & Engineering, University of California at San Diego.,** Mechanical & Aerospace Engineer*

Isolated Si nanopillar arrays are first fabricated by lithography or self-assembly such as by electron beam lithography or nano imprinting lithography. The diameter regime of the nano-patterned islands can be in the range of 20 – 100 nm.

Nanostructures for Biology and Nanomedicine
P12-01
Fabrication and characterization of zinc oxide nanoneedles for medical/biological applications, *Atif Syed*, Vasileios Koutsos*, Enrico Mastropaolo*, Monika Warzecha**, Dimitrios Lamprou**, *The University of Edinburgh, **University of Strathclyde*

Zinc oxide (ZnO) nanoneedles (NNs) have been fabricated, synthesized and characterized for its potential application in drug delivery and nanomedicine. Preliminary results indicate that ZnO NNs are chemically and morphologically stable at 50 degrees C for 2 weeks and at PBS solution (pH=7.4) hereby showing feasibility in drug delivery applications.

P12-02
Thin-film electrode patterning for encapsulated and air-stable droplet interface bilayers, *M. Nguyen, S.A. Sarles, S. T. Retterer*, University of Tennessee, *Oak Ridge National Laboratory*

Our current objective is to design and fabricate thin-film surface electrodes to enable electrical measurement of droplet interface bilayers to characterize bilayer formation along with collective images to examine droplet wetting on the patterned surfaces.

P12-03
Cell Migration Direction Switched by Angular Gratings, *S.F. Zhou, S. Gopalakrishnan, Y.H. Xu, Y.W. Lam, S.W. Pang, City University of Hong Kong*

Directional changes of MC3T3 osteoblast cells on angular gratings fabricated on PDMS substrates were investigated. Cell migration direction is found to depend on bending angles and segment lengths of patterns. Designs with short grating segments and 135° bending corners can provide good directional control for cells to move forward.

P12-04
Effect of Iron-Doped Apatite Nanoparticles on a Eukaryotic Host-Virus System, *J.M. Andriolo*, C.A. McConnell**, B.I. Connors**, M.L. Pedulla**, K. Hailer**, J.L. Skinner**, *University of Montana and the Montana Tech of the University of Montana, **Montana Tech of the University of Montana*

Iron-doped apatite nanoparticles have been shown to increase phage infections of both gram-positive and gram-negative bacterial cells. Despite many replications of these results, specific mechanisms remain elusive. To further understand influence of IDANPs on viral infections, experiments have been replicated in eukaryotic cells Chlorella NC64A, and its virus PBCV-1.

P12-05
Focused Microwave Cancer Therapy Using Lithographically Defined Nanoparticles, *M. Yu , Y.F. Wang, J. Stang, M. Moghaddam, Y.R. Li, W. Wu, University of Southern California*

This study presents lithographically defined nanoparticles to achieve enhanced absorption at microwave frequencies for caner therapy. Temperature distribution in blood with particles inside was explored to demonstrate the suitable heating performance. Those particles can be fabricated at large volume and low cost using roll-to-roll nanoimprint lithography.

P12-06
Tip-Enhanced Surface Enhanced Raman Scattering on Gold Nanoparticle Decorated Silicon Microcone Array Substrate for DNA Sensing, *Junjie Li, Baogang Quan, Yujin wang and Changzhi Gu, Institute of Physics, Chinese Academy of Sciences*

Au nanoparticles (AuNPs) decorated silicon microcone has a superior SERS property over that on flat silicon. The AuNPs decorated Si microcone is employed as a hairpin DNA sensor with an enhancement factor about 5×10^7. Our results indicate that AuNPs on Si microcone array with nano-tip is a promising bio-analytical platform.

P12-07
Injection-Compression Molding of Nanostructures for Three-Dimensional Cell-Culturing, *K. Nagato, M. Oike*, Y. Kimura**, T. Kakinuma*, M. Nakao, The University of Tokyo,*SEIKOH GIKEN Co., Ltd., **tella, Inc.*

Three-dimensional cell culturing on patterned surface is increasingly developed and expected as a new method. The nanostructured cell-culturing dishes were fabricated by injection compression molding and the homogeneity of the spheroid sizes cultured in the dishes were investigated.

P12-08
Assembly of Superparamagnetic Iron Oxide Nanoparticles on DNA Nanostructures, *Daniel Schiffels* **, J. Alexander Liddle**National Institute of Standards and Technology, **University of Maryland*

We present a method to position Superparamagnetic Iron Oxide Nanoparticles (SPIONs) on DNA nanostructures, enabling the production of constructs with precisely engineered magnetic properties from simple components. We also investigate a novel strategy to purify the constructs with high yield.

P12-09
Direct Electron Transfer From Single Enzymes to Single Wall Carbon Nanotubes, *A. Aslam, A. Kanwal, G. A. Thomas, Y. Ying*, Z. Iqbal*, E. Farinas*, R. C. Farrow, Department of Physics, New Jersey Institute of Technology,*Department of Chemistry and Environmental Science, New Jersey Institute of Technology*

Direct electron transfer from single enzymes is demonstrated using measurements from an addressable array of individual vertical single wall carbon nanotubes functionalized with the enzymes. The origin of variation in electron transfer rates is discussed. The nature of the immobilization of enzymes on this platform impacts future nanofabricated enzyme sensors.

P12-10
Microfluidic platform for studies of self-organizing processes in a bacterial cell, *D. Yang, C.M. Greer, A. Jennings, S. Retterer*, J. Mannik, University of Tennessee,*Oak Ridge National Laboratory*

We describe two novel microfluidic platforms that enable to study fast cellular responses to mechanical and chemical stimuli in a fluorescence microscope. The platforms are designed for bacterial cells but can be also useful in studies of yeast and other single-celled organisms.

Novel Optical Lithography
P13-01
Scalable and high-throughput 2D nanopatterning via sequential combination of continuous 1D patterning strokes, *J. G. Ok, M. K. Kwak*, A. Panday**, T. Lee**, L. J. Guo**, Seoul National University of Science and Technology, *Kyungpook National University, **University of Michigan*

We present a simple and high-throughput 2D nanopatterning methodology via sequential continuous 1D nanopatterning strokes enabled by Dynamic Nano-Inscribing (DNI) and Vibrational Indentation Patterning (VIP). DNI inscribes and VIP indents 1D micro/nano-grating patterns continuously, which can be combined for scalable fabrication of various 2D patterns.

P13-02
Two Photon Lithography Written Defects in 3D Holographic Lithography Structures and Conversion to Higher Index Materials, *S. Kooi, Institute for Solider Nanotechnologies, MIT*

3D photonic structures are produced via holographic lithography. Engineered defects are then introduced into these structures with direct write two photon lithography techniques. Optical properties are calculated and measured before and after the introduction of the defect. Conversion to higher index materials and mechanically tunable structures are explored.

P13-03
Subwavelength NanoPatterning via Selective Dissolution of One-Photoisomer, *P. Cantu, R. Menon, B. Pollock*, T.L. Andrew*, University of Utah, *University of Wisconsin-Madison*

We report that the diffraction limit of conventional optical lithography can be overcome by exploiting the transitions of organic photochromic derivatives induced by their photoisomerization at low light intensities. We define this novel method as Patterning via Optical Saturable Transformations (POST).

P13-04
The soft X-ray Interference Lithography Beamline(XIL, BL08U1B) at SSRF, *Yanqing Wu, Jun Zhao, Shumin Yang, Liansheng Wang, Chaofan Xue, Renzhong Tai,Shanghai Institute of Applied Physics, Chinese Academy of Sciences*

P13-05
Towards sub-10 nm node by EUV lithography, *T. S. Kulmala, M. Vockenhuber, R. Fallica, E. Buitrago, Y. Ekinci, Paul Scherrer Institute, Switzerland*

EUV interference lithography has recently attracted growing interest as a powerful tool in academic and industrial research. One main challenge is development of resists fulfilling strict sensitivity, resolution and line-edge roughness requirements. We present a detailed analysis of the most promising materials when moving towards 10 nm HP resolution.

P13-06
Super-resolution Optical Nanolithography using two approaches of Absorbance Modulation, *A. Majumder, F. Masid, B. Pollock*, T. L. Andrew*, R. Menon, University of Utah, *University of Wisconsin-Madison*

We report on the most recent developments in AMOL that demonstrate two new approaches to the technique involving a top-down barrier-layer-free method and a method to separate the AML from the rest of the sample stack, thereby allowing it to be reused for multiple exposures like a programmable mask.

Nanophotonics and Plasmonics
P14-01
Plasmonic Effect of Process Parameters on 10-nm Patterning in Computational Lithography, *S.-K. Kim, Hanyang University, Hongik University*

Maskless plasmonic lithography (MPL)process is modeled and simulated for 15-nm critical dimension (CD). The near-field intensity with the plasmonic phenomena of aperture shapes is described due to aperture parameters by using the rigorous coupled-wave analysis (RCWA) method and the finite difference time domain (FDTD) method.

P14-02 (Invited)
Optical Transmission Via Elliptically Patterned Grooves on Pyramidal Nano-aperture, *Seong Soo Choi, Myoung Jin Park, Chul-Hee Han, SunMoon University, Sung In Kim, Jung Ho Yoo, Kyoung Jin Park, National Nanofabrication Center, Korea, Yong Sang Kim, School of Electronic and Electrical Engineering, Korea, Sang Hoon Han, Nam Kyou Park*
School of Electrical Engineering, Seoul National University

The nano-apertures surrounded with periodic elliptic groove patterns on pyramid were fabricated by FIB. The optical characteristics of the fabricated nano-apertures with elliptic groove patterns on pyramids were investigated. Huge enhancement of the transmitted optical power was observed from a pyramidal

P14-03
Reusable Moth-Eye nano-patterned PDMS sticker as a versatile function of coating for photovoltaics., *Yong H. Kihm, Doo-Hyun Ko, Il Ki Han, Hyungduk Ko, Korea Institute of Science and Technology*

In this work, the moth-eye nano patterned PDMS sticker which are protuberant, aspect ratio >1 long and truncated corn-like shape are studied as anti-reflection coating (ARC) for the solar photovoltaic system.

P14-04
Narrowband Photonic Absorber with Nano-Fins in Near-Infrared Region for Wavelength Detection with Mechanical Resonator, *E. Maeda, R. Kometani, The University of Tokyo*

In this report, new narrowband photonic absorber for wavelength detection in NIR region is presented. Our photonic absorber can absorb almost 100% light wave in NIR region. The structure consists of separated nano-fins which show narrowband absorption.

P14-05
Nano-scale intra-cavity defects in photonic crystal microcavity filter for enhancing transmission, *A. S. Jugessur, University of Iowa*

Features of about 60-90 nm in size are added within the microcavity of the PhC microcavity filters and fabricated on GaAs/AlGaAs epitaxial substrate using Electron Beam Lithography and Reactive Ion Etching. An increase in optical transmission by a factor of 2.5 is obtained by the addition of the nano-scale defects.

Resists and Lithography Materials
P15-01
Origin of insoluble residual in ZEP520 electron-beam resist development, *Ming Lu, Xiao Tong, M. Lu, X. Tong, M. Liu, Z. Fu*, Brookhaven National Laboratory, *Stony Brook University*

Following-up to our discovery of insoluable ZEP520 resist residual, FTIR, photo-emission spectroscopy and X-ray absorption near edge structure spectroscopy are used to identify its origin. It was revealed that C-O bridge is formed at the resist-substrate interface which bonds short polymer chain onto silicon surface.

P15-02
Novel UV-curable Hybrid Polymers with Elevated Refractive Index and Improved PDMS-compatibility, *J. J. Klein, M.-M. Russew, A. Schleunitz, M. Vogler, G. Grützner, M. Foerthner*, M. Rommel*, micro resist technology GmbH, *Fraunhofer Institute for Integrated Systems and Device Technology*

We report on the development of hybrid polymer prototypes with enhanced curing behavior and PDMS compatibility as well as on a high refractive index prototype. Both materials not only meet the anticipated material's optical performance, but also exhibit an improved adaptability to patterning technologies and advanced micro- and nano-optical applications.

P15-03
Computational Study of Resist Pattern Shrinkage under CD-SEM Observation, *Y. Furukawa, M. Yasuda, H. Kawata, Y. Hirai, Osaka Prefecture University*

The resist pattern shrinkage by electron irradiation is simulated. The absorbed energy distribution in the resist is calculated with the Monte Carlo simulation of electron scattering. The shrinkage of the resist corresponding the absorbed energy is estimated from the molecular dynamics (MD) simulation.

P15-04
Towards a Novel Positive Tone Resist mr-PosEBR for High Resolution Electron Beam Lithography, *S. Pfirrmann*, A. Voigt*, G. Grützner*, I. Harder**, O. Lohse**, *micro resist technology GmbH, **Max Planck Institute for the Science of Light*

Herein, we present early lithographic results obtained with a newly developed positive tone electron beam resist mr-PosEBR. The resist material was specifically tailored to meet the needs for high resolution, sensitivity and etch resistance. Under the conditions tested it performs comparably to the high resolution resist ZEP-520A.

P15-05
Direct photo-patterning of thiol-ene thermoset polymer thin film structures by DLP lithography, *Jim Amato, Matthew Di Prima*, Alexandra Joshi-Imre**, Walter E. Voit**, Syzygy Memory Plastics, *Food and Drug Administration, **Advanced Polymer Research Lab, The University of Texas at Dallas*

We are presenting first results on direct photo-patterning of thiol-ene and thiol-ene / acrylate thin films by projection lithography

P15-06
Novel Resist for Electron Beam Lithography on Insulating Substrates, *F. Hasan, A.P.G. Robinson, University of Birmingham, UK.*

Electron beam lithography (EBL) has the capability for extremely high-resolution patterning, and is used for mask making, low-volume high-value manufacturing, prototyping and other nanotechnology research. Due to increased process complexity and poor resolution with such approaches, we are developing an electron beam resist which is inherently conductive.

Charged Particle Optics and Sources
P16-01
Low Energy Performance of a SEM Using a New Monochromator with Double Offset Cylindrical Lenses, *T.Ogawa,B.Cho,S.Ahn,Korea Research Institute of Standards and Science*

We've proposed a new MC with double offset cylindrical lenses. The energy resolution is better than 10 meV for 4 keV. The MC improves the beam diameter down to 4.4 nm from 19.7 nm at 100eV, 1 pA. This MC is effective to improve SEM performance in low energy region.

P16-02
Electron sources and applications for electron beams in air, *G.G. Magera and W.A. Mackie, Applied Physics Technologies, Inc.*

There are many applications for electrons emitted into ambient air. These can be for direct electron injection into semiconductor laser materials, cross-linking of polymers to facilitate curing, sterilization, particle detection and analysis to name a few. We will present results using various electron transparent windows, beam voltages and emission currents.

P16-03
Photoionization of a laser-intensified atomic beam: prospects for high resolution focused ion beams, *G. ten Haaf, S.H.W. Wouters, O.J. Luiten, E.J.D. Vredenbregt, P.H.A. Mutsaers, Eindhoven University of Technology*

Photoionization of a laser cooled and compressed thermal atomic beam is a promising technique to produce high brightness ion beams. Here the results of particle tracing simulations and analytical calculations will be presented which show that a spot size of 1 nm is possi