



Final Report

Report #: DOE-NJIT-0015555-1

Grant: DE-SC0015555

Date: January 26, 2017

Title: Student Support for EIPBN 2016 Conference - Final Report

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I. Introduction

The 60th International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN) was held in Pittsburgh, PA, from May 31st to June 3rd, 2016. The conference received technical co-sponsorship from the American Vacuum Society (AVS) in cooperation with the Optical Society of America (OSA), and the American Physical Society (APS).

EIPBN, or the “three beams meeting”, is the premier conference for the early dissemination of high-impact and high-quality information on the science and technology of nano-patterning. The conference consistently brings together hundreds of engineers and scientists in industry, academia, and government from all over the world to discuss interdisciplinary issues at the forefront of these areas.

Three plenary talks discussed applications of micro- and nano-scale devices to the search for answers to fundamental questions about our world. These talks touched on the 3 aspects of the ultimate question that the science fiction author Douglas Adams described as “Life, the Universe, Everything!”. Prof. Robert Austin discussed nanoscale structures used to understand DNA; Prof. Jonas Zmuidzinas described devices used to characterize radiation that tells the story of the origin of the universe; Dr. Alessandro Marchioro talked about the devices used to measure the particle tracks at the CERN accelerator that recently confirmed the existence of the Higgs particle.

Besides sessions on our foundation topics of electron, ion and photon lithography and characterization, the important “beamless” technologies of nanoimprinting and tip-based lithography were strongly represented. Applications of these techniques in photonics, electronics, quantum computing, and biology continue to play an ever increasing role at our meeting. There were 2 sessions on the fundamental complement of lithography technology - pattern transfer. Invited presentations on metal assisted chemical etching, atomic layer etching, and cryo-etching led the way.

The 2016 Conference Chairman is Dr. John Hartley of NuFlare Technology America, Inc. and the Program Chairman is Dr. George (Pat) Watson of Princeton University. The Conference is organized and managed by a Steering Committee, which is incorporated in the state of New Jersey, and fully protected by liability insurance. In addition to the Conference Chair and Program Chair the members of the Steering Committee at the time of the conference were:

Lawrence Muray, Keysight Technology
Stefano Cabrini, Lawrence Berkeley National Laboratory
Todd Hastings, University of Kentucky
Michael Guillorn, IBM
Theodore Fedynyshyn, MIT Lincoln Labs
Karl K. Berggren, MIT
Shida Tan, Intel
Cliff Henderson, Georgia Tech

Students are the lifeblood of the EIPBN conference, in that they both provide a fresh and exciting perspective, and also become the future scientists attending the conference in the future on a regular basis. Financial support provided for their travel came from a mixture of government agencies and corporate donors. The Department of Energy Office of Basic Energy Sciences provided \$5,000 to support student travel from US universities to participate at EIPBN 2016 through grant DE-SC0015555.

II. EIPBN 2016 Student Participation

Student presentations are a vital part of the EIPBN Conference. They contain new, innovative approaches to the topics of the conference that are of great interest to the technical community at large. Furthermore, once the students graduate and launch their careers in the field, they become the regular attendees of the conference for years to come. If they become professors, they advise students in turn on projects that address future problems in the field of the conference, and the cycle continues. In this regard, maintaining strong student participation is a requirement for the long-term viability of the conference. Thanks to travel support from EIPBN in combination with a reasonable reduced conference registration rate for students, 127 students attended EIPBN 2016. Students were 30% of the conference attendance, a very strong participation. Of those students that attended 61 were offered travel support with 59 accepting. Support from EIPBN is provided through sponsors such as the DOE Office of Science. Students were presenting authors on either an oral or poster presentation. This is not surprising, since the time and expense for a student to attend the conference is usually justified only if a paper is to be presented.

This year, as in previous years, the students were offered discounted registration for the conference. The advance student registration rate was set to \$275, with the on-site student registration set to \$325 (compared to \$700 and \$750 for regular attendees).

Student Financial Support

As in years past, financial support for student travel was provided. The amount funded was chosen to approximately offset air travel. Each supported student receives \$500. As part of the conditions for receiving funds, students were:

- 1) Required to register for the conference, and
- 2) Asked to volunteer for various tasks that may be available for students.

The tasks we usually ask students to perform at the conference are assisting the session chairs in managing their room, usually helping questioners be heard by running microphones to them. Students are also asked to help at the set up time the physical posters, putting banners on the poster boards to identify the locations where individual posters are to be placed.

III. Awarding Student Funds

A detailed process was used to decide which student should receive financial support. These steps were listed in detail on the conference website.

Acceptance of Abstract: First, it was required that students have their name on an accepted abstract to be considered for travel reimbursement. The decisions about student support were therefore made after the Program Chair had prepared the initial Program.

Request by Professor: Second, the student's *Professor* needed to send a request for financial support to either the Conference Chair or the Program Chair. Requests from students themselves were returned and the students asked to have their professor provide a request. All requests were forwarded to the Conference Chair for final disposition.

Granting: At a predetermined cutoff date all requests for support received for students who were the presenting authors on papers were granted. For EIPBN 2016, awards were offered to 61 students, an increase of 9 relative to 2015. 50 students accepted the awards and attended the conference.

A variety of universities, countries, and topics were represented among the students receiving support. Students from 8 countries (including the US) and 35 universities were among the recipients of student travel financial support. The students receiving EIPBN 2016 financial support are listed in Table I.

Last name	First name	School/Institute
Liao	Jinyu	Columbia University
Cai	Haogang	Columbia University
Scarabelli	Diego	Columbia University
Ng	Ray	Singapore UTD
Nam*	Hongsuk	University Michigan
Chen	Mikai	University Michigan
Li	Da	University Michigan
Dallarto*	Stefano	LBNL
Rangnekar	Sonal	LBNL
Colon*	Albert	University of Illinois at Chicago
Zhu*	Ruichao	University of New Mexico
Zhang*	Rui	University of Edinburgh
Shakarisaz	David	Central University of Houston
Syam	Amjad	University of Kentucky
Esfandiarpour	Samaneh	University of Kentucky
Scotuzzi	Marijke	TU Delft
Papenheim*	Marc	University of Wuppertal
Cho	Joon Hyong	University of Texas at Austin
Kim	Jin-Sung	Princeton University
Beisel*	Joshua	Montana Tech
Murphy	John	Montana Tech
Zhang	Xu	NC State
Bagal	Abhijeet	NC State
Min	Joong Hee	NC State
Tippens	Jared	NC State
Nagai	Hero	NC State

Nicaise	Sam	MIT
Bedewy	Mostafa	MIT
Dreser	Christopher	University Tübingen
Wang	Honglei	University of Texas at Dallas
Haroldson	Ross	University of Texas at Dallas
Aydinoglu*	Ferhat	University of Waterloo
Con	Celal	University of Waterloo
Zheng*	Shuo	University of Waterloo
Lauffer	Philipp	TU Dresden
Nanda	Gaurav	TU Delft
Chen	Sihan	University of Illinois Urbana-Champaign
Pan*	Yanbiao	Rutgers University
Zu*	Fangzhou	Rutgers University
Syed	Atif	University Edinburgh
Li	Dehua	Auburn University
Guo*	Rui	Auburn University
Xie	Pengfei	Rutgers University
Azam	Gholizadeh	Rutgers University
Lin	Zhongtian	Rutgers University
Tu	Fan	Universität Erlangen
Lin	Peng	University of Massachusetts
Jiang	Hao	University of Massachusetts
Stanford	Michael	University of Tennessee
Wood	Steven	University of Pennsylvania
Zhouyang	Zhu	University of Hong Kong
Jingxuan*	Cai	University of Hong Kong
Cuiping	Zhang	University of Hong Kong
Shijie*	Li	University of Hong Kong
Chang	Lingqian	Ohio State University
Hou*	Huili	Penn State University
Perez-Martinez	Carla	MIT
Chaudhary	Narendra	Texas A&M University
Bonam*	Ravi	CNSE/IBM
Hou	Sean	Louisiana State University
Matruglio	Alessia	University of Trieste, IOM-CNR
Quetz	Abdiel	Brookhaven National Lab

Table I: Students receiving EIPBN 2016 Student Travel Support. *Students that published papers in the special conference issue of JVST B.

Student Support Grants

Student support was provided from government and corporate sources as shown in Table II. The remainder required to support all first author requests was provided by undesignated sponsorships.

Sponsor	Contribution
Department of Energy	\$5,000
NuFlare	\$3,000
Raith America, Inc	\$2,300
Total	\$10,300

Table II: Sponsors of EIPBN 2016 Student Travel Support.

Prof. Reginald Farrow at the New Jersey Institute of Technology solicited funds from the DOE Office of Science. NJIT dispersed the full granted funds to EIPBN 2016 and waived any facilities and administration costs.

IV. Peer-Reviewed Publications from EIPBN 2016

Extended abstracts of papers presented at the conference are available online: <http://eipbn.omnibooksonline.com/>. All participants that presented papers at the EIPBN 2016 Conference had the opportunity to submit journal articles to a special publication of the Journal of Vacuum Science and Technology B (JVSTB). JVSTB generally publishes those submitted articles that are accepted after peer review in the Nov/Dec issue of the same year as the conference. See JVSTB Vol. 34, No. 6 (<http://avs.scitation.org/toc/jvb/34/6?expanded=34>) for the EIPBN 2016 published articles. The final count for published manuscripts are 62 papers from the conference submitted, with 51 accepted. There were 23 papers from students published in the special volume and are listed in the Appendix.

V. Conclusion

The 60th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication, 2016, held at the Wyndham Grand Hotel in Pittsburgh, PA from May 31 to June 3, 2016 was a great success in large part because financial support allowed robust participation from students. The students gave oral and poster presentations of their research and many published peer-reviewed articles in a special conference issue of the Journal of Vacuum Science and Technology B. The Department of Energy Office of Basic Energy Sciences supported 10 students from US universities with a \$5,000 grant (DE-SC0015555). On behalf of the Steering Committee of EIPBN I would like to thank DoE for its support of student participation at this very worthwhile conference.

Reginald C. Farrow, Ph.D.

APPENDIX

Publications by EIPBN 2016 Student Travel Award Recipients

Design, fabrication, and characterization of polymer-based cantilever probes for atomic force microscopes

Fangzhou Yu, Jiangbo Liu, Xiao Zhang, Ai-Lian Lin, Nabeela Khan, Yanbiao Pan, Nan Gao, Qingze Zou, Jaeseok Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena 34, 06KI01 (2016); <http://doi.org/10.1116/1.4960726>

Nanofluidic flow assisted assembly of dispersed plasmonic nanostructures into shallow nanochannel sensors

Hongsuk Nam, Jeong Seop Yoon, Hiroto Izuoka, Bo-Ram Oh, Katsuo Kurabayashi, Wenjie Wan, Xiaogan Liang

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena 34, 06KM04 (2016); <http://doi.org/10.1116/1.4967748>

Nanoimprint-assisted shear exfoliation plus transfer printing for producing transition metal dichalcogenide heterostructures

Da Li, Sungjin Wi, Mikai Chen, Byunghoon Ryu, Xiaogan Liang

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena 34, 06KA01 (2016); <http://doi.org/10.1116/1.4961384>

Pattern-generation and pattern-transfer for single-digit nano devices

Ivo W. Rangelow, Ahmad Ahmad, Tzvetan Ivanov, Marcus Kaestner, Yana Krivoshapkina, Tihomir Angelov, Steve Lenk, Claudia Lenk, Valentyn Ishchuk, Martin Hofmann, Diana Nechepurenko, Ivaylo Atanasov, Burkhard Volland, Elshad Guliyev, Zahid Durrani, Mervyn Jones, Chen Wang, Duxi Liu, Alexander Reum, Mathias Holz, Nikolay Nikolov, Wojciech Majstrzyk, Teodor Gotszalk, Daniel Staaks, Stefano Dallorto, Deirdre L. Olynick

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena 34, 06K202 (2016); <http://doi.org/10.1116/1.4966556>

Investigating compositional effects of atomic layer deposition ternary dielectric Ti-Al-O on metal-insulator-semiconductor heterojunction capacitor structure for gate insulation of InAlN/GaN and AlGaN/GaN

Albert Colon, Liliana Stan, Ralu Divan, Junxia Shi

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena 34, 06K901 (2016); <http://doi.org/10.1116/1.4964693>

Scatterometry for nanoimprint lithography

Ruichao Zhu, Steven R. J. Brueck, Noel Dawson, Tito Busani, Praveen Joseph, Shrawan Singhal, S. V. Sreenivasan

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K503 (2016); <http://doi.org/10.1116/1.4967933>

Effects of contact states on polymer pattern deformation during demolding process in nanoimprint lithography

Lijun Ma, Qing Wang, Rui Zhang, Xu Zheng, Tong Zheng

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K409 (2016); <http://doi.org/10.1116/1.4968531>

Nanoimprint-induced orientation of localized wrinkles with SU-8

Christian Steinberg, Manuel Runkel, Marc Papenheim, Si Wang, Andre Mayer, Hella-Christin Scheer

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K402 (2016); <http://doi.org/10.1116/1.4962162>

Lithography via electrospun fibers with quantitative morphology analysis

Joshua D. Beisel, John P. Murphy, Jessica M. Andriolo, Emily A. Kooistra-Manning, Sean Nicolaysen, Orrin Boese, Jake Fleming, Wataru Nakagawa, Jack L. Skinner

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KG02 (2016); <http://doi.org/10.1116/1.4964636>

Mixture of ZEP and PMMA with varying ratios for tunable sensitivity as a lift-off resist with controllable undercut

Shuo Zheng, Ripon Kumar Dey, Ferhat Aydinoglu, Bo Cui

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K603 (2016); <http://doi.org/10.1116/1.4967932>

Silicon nanostructures with very large negatively tapered profile by inductively coupled plasma-RIE

Asma Ayari-Kanoun, Ferhat Aydinoglu, Bo Cui, Faycal Saffih

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KD01 (2016); <http://doi.org/10.1116/1.4964402>

Design, fabrication, and characterization of polymer-based cantilever probes for atomic force microscopes

Fangzhou Yu, Jiangbo Liu, Xiao Zhang, Ai-Lian Lin, Nabeela Khan, Yanbiao Pan, Nan Gao, Qingze Zou, Jaeseok Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KI01 (2016); <http://doi.org/10.1116/1.4960726>

Design, fabrication, and characterization of polymer-based cantilever probes for atomic force microscopes

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Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KI01 (2016); <http://doi.org/10.1116/1.4960726>

Noise filtering for accurate measurement of line edge roughness and critical dimension from SEM images

Dehua Li, Rui Guo, Soo-Young Lee, Jin Choi, Seom-Beom Kim, Sung-Hoon Park, In-Kyun Shin, Chan-Uk Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K604 (2016); <http://doi.org/10.1116/1.4968184>

Analytic estimation of line edge roughness for large-scale uniform patterns in electron-beam lithography

Rui Guo, Soo-Young Lee, Jin Choi, Seom-Beom Kim, Sung-Hoon Park, In-Kyun Shin, Chan-Uk Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K605 (2016); <http://doi.org/10.1116/1.4968186>

Noise filtering for accurate measurement of line edge roughness and critical dimension from SEM images

Dehua Li, Rui Guo, Soo-Young Lee, Jin Choi, Seom-Beom Kim, Sung-Hoon Park, In-Kyun Shin, Chan-Uk Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K604 (2016); <http://doi.org/10.1116/1.4968184>

Practical approach to modeling e-beam lithographic process from SEM images for minimization of line edge roughness and critical dimension error

Rui Guo, Soo-Young Lee, Jin Choi, Sung-Hoon Park, In-Kyun Shin, Chan-Uk Jeon

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 011601 (2016); <http://doi.org/10.1116/1.4937740>

Induction-heated nanoimprint on soda-lime glass using sapphire molds

Jingxuan Cai, Shijie Li, Xu Guo, Haixong Ge, Wen-Di Li

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K408 (2016); <http://doi.org/10.1116/1.4966557>

Induction-heated nanoimprint on soda-lime glass using sapphire molds

Jingxuan Cai, Shijie Li, Xu Guo, Haixong Ge, Wen-Di Li

Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K408 (2016); <http://doi.org/10.1116/1.4966557>

Crystallization of nanoscale NiTi alloy thin films using rapid thermal annealing

Huiliang Hou, Reginald F. Hamilton, Mark W. Horn
Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KK01 (2016); <http://doi.org/10.1116/1.4963375>

Impact of parallelism on data volumes for a multibeam mask writer

Narendra Chaudhary, Yao Luo, Serap A. Savari
Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KF01 (2016); <http://doi.org/10.1116/1.4963151>

Materials characterization for multilayer electron beam lithography

Ravi K. Bonam, John G. Hartley
Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06KG04 (2016); <http://doi.org/10.1116/1.4968536>

Large area three dimensional structure fabrication using multilayer electron beam lithography

Ravi K. Bonam, John G. Hartley
Journal of Vacuum Science & Technology B, Nanotechnology and Microelectronics: Materials, Processing, Measurement, and Phenomena **34**, 06K606 (2016); <http://doi.org/10.1116/1.4966961>