PROCEEDINGS OF SPIE

[SPIDigitalLibrary.org/conference-proceedings-of-spie](https://spiedigitallibrary.org/conference-proceedings-of-spie)

Front Matter: Volume 7970

, "Front Matter: Volume 7970," Proc. SPIE 7970, Alternative Lithographic Technologies III, 797001 (27 April 2011); doi: 10.1117/12.897034

SPIE.

Event: SPIE Advanced Lithography, 2011, San Jose, California, United States

PROCEEDINGS OF SPIE

Alternative Lithographic Technologies III

Daniel J. C. Herr
Editor

1–3 March 2011
San Jose, California, United States

Sponsored and Published by
SPIE

Volume 7970

Proceedings of SPIE, 0277-786X, v. 7970

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Alternative Lithographic Technologies III*, edited by Daniel J. C. Herr, Proceedings of SPIE Vol. 7970 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X

ISBN 9780819485298

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445

SPIE.org

Copyright © 2011, Society of Photo-Optical Instrumentation Engineers

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/11/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

ix	Conference Committee
xiii	Introduction

SESSION 1 KEYNOTE SESSION

7970 03	Nanoimprint lithography for semiconductor devices and future patterning innovation (Keynote Paper) [7970-02] T. Higashiki, T. Nakasugi, I. Yoneda, Toshiba Corp. (Japan)
---------	--

SESSION 2 NANOIMPRINT LITHOGRAPHY I: CMOS

7970 05	The comparison of NGLs from a tool vendor's view (Invited Paper) [7970-04] A. Suzuki, Canon Inc. (Japan)
7970 06	Jet and flash imprint defectivity: assessment and reduction for semiconductor applications [7970-05] M. Malloy, SEMATECH (United States); L. C. Litt, SEMATECH (United States) and GLOBALFOUNDRIES (United States); S. Johnson, D. J. Resnick, Molecular Imprints, Inc. (United States); D. Lovell, College of Nanoscale Science and Engineering (United States)
7970 07	Defect reduction of high-density full-field patterns in jet and flash imprint lithography [7970-06] L. Singh, K. Luo, Z. Ye, F. Xu, G. Haase, D. Curran, D. LaBrake, D. Resnick, S. V. Sreenivasan, Molecular Imprints, Inc. (United States)
7970 09	Progress in mask replication using jet and flash imprint lithography [7970-08] K. S. Selinidis, C. B. Brooks, G. F. Doyle, L. Brown, C. Jones, J. Imhof, D. L. LaBrake, D. J. Resnick, S. V. Sreenivasan, Molecular Imprints, Inc. (United States)

SESSION 3 MASKLESS LITHOGRAPHY I

7970 0B	Position accuracy evaluation of multi-column e-beam exposure system [7970-10] M. Takizawa, H. Komami, M. Kurokawa, A. Yamada, Advantest Corp. (Japan)
7970 0C	eMET: 50 keV electron multibeam mask exposure tool [7970-11] C. Klein, J. Klikovits, H. Loeschner, E. Platzgummer, IMS Nanofabrication AG (Austria)
7970 0D	Scanning exposures with a MAPPER multibeam system [7970-12] C. van den Berg, G. de Boer, S. Boschker, MAPPER Lithography (Netherlands); E. A. Hakkennes, Technolution B.V. (Netherlands); G. Holgate, MAPPER Lithography (Netherlands); M. Hoving, Technolution B.V. (Netherlands); R. Jager, J. J. Koning, V. Kuiper, Y. Ma, I. L. van Mil, H. W. Mook, T. Ooms, T. van de Peut, MAPPER Lithography (Netherlands); S. Postma, DEMCON (Netherlands); M. Sanderse, P. Scheffers, E. Slot, A. Tudorie, A. M. C. Valkering, MAPPER Lithography (Netherlands); N. Venema, Technolution B.V. (Netherlands); N. Vergeer, MAPPER Lithography (Netherlands); A. Weirisma, S. Woutersen, Technolution B.V. (Netherlands); M. J. Wieland, B. J. Kampherbeek, MAPPER Lithography (Netherlands)

- 7970 OE **Multi-shaped beam: development status and update on lithography results** [7970-13]
M. Slodowski, H.-J. Doering, W. Dorl, I. A. Stolberg, Vistec Electron Beam GmbH (Germany)

SESSION 4 DIRECTED SELF-ASSEMBLY I: SELECTED SEMICONDUCTOR APPLICATIONS: JOINT SESSION WITH CONFERENCE 7972

- 7970 OF **Self-assembly patterning for sub-15nm half-pitch: a transition from lab to fab (Invited Paper)** [7970-14]
C. Bencher, J. Smith, L. Miao, C. Cai, Y. Chen, Applied Materials, Inc. (United States);
J. Y. Cheng, D. P. Sanders, M. Tjio, H. D. Truong, IBM Almaden Research Ctr. (United States);
S. Holmes, IBM Albany Nanotech (United States); W. D. Hinsberg, IBM Almaden Research Ctr. (United States)

SESSION 5 NOVEL APPLICATIONS I

- 7970 OK **Nanoimprint process for 2.5Tb/in² bit patterned media fabricated by self-assembling method** [7970-19]
Y. Ootera, A. Yuzawa, T. Shimada, R. Yamamoto, Y. Kamata, N. Kihara, A. Kikitsu, Toshiba Corp. (Japan)
- 7970 OL **High-density patterned media fabrication using jet and flash imprint lithography** [7970-20]
Z. Ye, R. Ramos, C. Brooks, L. Simpson, J. Fretwell, S. Carden, P. Hellebrekers, D. LaBrake, D. J. Resnick, S. V. Sreenivasan, Molecular Imprints, Inc. (United States)

SESSION 6 DIRECTED SELF-ASSEMBLY II: PROCESSING AND FUNDAMENTALS

- 7970 ON **Development of realistic potentials for the simulation of directed self-assembly of PS-PMMA di-block copolymers** [7970-22]
R. A. Lawson, P. J. Ludovice, C. L. Henderson, Georgia Institute of Technology (United States)
- 7970 OP **Guided self-assembly of block-copolymer for CMOS technology: a comparative study between grapho-epitaxy and surface chemical modification** [7970-24]
L. Oria, Microelectronic Institute of Barcelona (Spain); A. Ruiz de Luzuriaga, CIDETEC (Spain);
X. Chevalier, CEA-LETI (France); J. A. Alduncin, D. Mecerreyes, CIDETEC (Spain); R. Tiron, S. Gaugiran, CEA-LETI (France); F. Perez-Murano, Microelectronic Institute of Barcelona (Spain)
- 7970 OQ **Study and optimization of the parameters governing the block copolymer self-assembly: toward a future integration in lithographic process** [7970-25]
X. Chevalier, CEA-LETI, MINATEC (France) and Lab. de Chimie des Polymères Organiques ENSCPB-IPB (France); R. Tiron, T. Upreti, S. Gaugiran, CEA-LETI, MINATEC (France); C. Navarro, S. Magnet, Arkema S.A. (France); T. Chevolleau, G. Cunge, Lab. des Technologies de la Microélectronique, CNRS, CEA-LETI (France); G. Fleury, G. Hadzioannou, Lab. de Chimie des Polymères Organiques, ENSCPB-IPB (France)

SESSION 7 NANOIMPRINT LITHOGRAPHY II: PROCESSES AND MATERIALS

- 7970 OS **Approaches to rapid resist spreading on dispensing based UV-NIL** [7970-27]
K. Usuki, S. Wakamatsu, T. Oomatsu, K. Kodama, K. Kodama, FUJIFILM Corp. (Japan)

- 7970 OT **Reactive fluorinated surfactant for step and flash imprint lithography** [7970-28]
T. Ogawa, The Univ. of Texas at Austin (United States) and Central Glass Co., Ltd. (Japan);
D. J. Hellebusch, M. W. Lin, B. M. Jacobsson, W. Bell, C. G. Willson, The Univ. of Texas at Austin
(United States)
- 7970 OU **A new releasing material and continuous nano-imprinting in mold replication for patterned media** [7970-29]
K. Suzuki, H. Kobayashi, T. Sato, H. Yamashita, T. Watanabe, HOYA Corp. (Japan)

SESSION 8 MASKLESS LITHOGRAPHY II

- 7970 OX **Fast mask writers: technology options and considerations (Invited Paper)** [7970-32]
L. C. Litt, T. Groves, G. Hughes, SEMATECH (United States)
- 7970 OY **IMAGINE: an open consortium to boost maskless lithography take off: first assessment results on MAPPER technology** [7970-33]
L. Pain, B. Icard, M. Martin, C. Constancias, S. Tedesco, CEA-LETI, MINATEC (France);
P. Wiedeman, A. Farah, B. J. Kampherbeek, MAPPER Lithography B.V. (Netherlands);
C. Pieczulewski, SOKUDO Co., Ltd. (Japan); H. Kandrashov, Dai nippon SCREEN Deutschland GmbH (Germany)
- 7970 OZ **Influence of massively parallel e-beam direct-write pixel size on electron proximity correction** [7970-34]
S. J. Lin, P. S. Chen, J. J. Shin, W. C. Wang, B. J. Lin, Taiwan Semiconductor Manufacturing Co. Ltd. (Taiwan)
- 7970 10 **Data path development for multiple electron beam maskless lithography** [7970-35]
F. Krecinic, S.-J. Lin, J. J. H. Chen, Taiwan Semiconductor Manufacturing Co. Ltd. (Taiwan)
- 7970 11 **E-beam to complement optical lithography for 1D layouts** [7970-36]
D. K. Lam, E. D. Liu, Multibeam Corp. (United States); M. C. Smayling, Tela Innovations, Inc. (United States); T. Prescop, Multibeam Corp. (United States)
- 7970 12 **Model-based mask data preparation (MB-MDP) and its impact on resist heating** [7970-37]
A. Fujimura, D2S, Inc. (United States); T. Kamikubo, NuFlare Technology, Inc. (Japan); I. Bork, D2S, Inc. (United States)

SESSION 9 NANOIMPRINT LITHOGRAPHY III: NOVEL NIL APPLICATIONS

- 7970 14 **Wafer-level fabrication of distributed feedback laser diodes by utilizing UV nanoimprint lithography** [7970-39]
M. Yanagisawa, Y. Tsuji, H. Yoshinaga, N. Kouno, K. Hiratsuka, Sumitomo Electric Industries, Ltd. (Japan)
- 7970 15 **Fabrication of hole pattern for position-controlled MOVPE-grown GaN nanorods with highly precise nanoimprint technology** [7970-40]
T. Eriksson, K. D. Lee, B. Heidari, Obducat Technologies AB (Sweden); P. Rode, W. Bergbauer, M. Mandl, C. Kölper, M. Strassburg, Osram Opto Semiconductors GmbH (Germany)
- 7970 16 **Adaptation of roll-to-roll imprint lithography: from flexible electronics to structural templates** [7970-41]
E. R. Holland, A. Jeans, P. Mei, C. P. Taussig, R. E. Elder, Hewlett-Packard Co. (United States);
C. Bell, E. Howard, J. Stowell, Arizona State Univ. (United States)

- 7970 17 **Development and characterization of carbon nanotube processes for NRAM technology** [7970-42]
G. Amblard, Nantero, Inc. (United States)

SESSION 10 MASKLESS LITHOGRAPHY III

- 7970 18 **New advances with REBL for maskless high-throughput EBDW lithography (Invited Paper)** [7970-43]
P. Petric, C. Bevis, M. McCord, A. Carroll, A. Brodie, U. Ummethala, L. Grella, A. Cheung, R. Freed, KLA-Tencor Corp. (United States)
- 7970 19 **Data preparation solution for e-beam multiple pass exposure: reaching sub-22nm nodes with a tool dedicated to 45 nm** [7970-44]
L. Martin, S. Manakli, S. Bayle, ASELT Nanographics (France); K.-H. Choi, M. Gutsch, Fraunhofer Ctr. Nanoelectronic Technologies (Germany); J. Pradelles, CEA-LETI, MINATEC (France); J. Bustos, STMicroelectronics (United States)
- 7970 1A **Demonstration of real-time pattern correction for high-throughput maskless lithography** [7970-45]
E. A. Hakkenes, A. D. Wiersma, M. Hoving, N. Venema, S. Woutersen, Technolution B.V. (Netherlands); T. van de Peut, M. Sanderse, M. J. Wieland, MAPPER Lithography B.V. (Netherlands)
- 7970 1B **EBPC for multi-beams low kV electron projection lithography** [7970-46]
J. Belledent, S. Soulan, L. Pain, CEA-LETI, MINATEC (France)
- 7970 1C **Fast characterization of line-end shortening and application of novel correction algorithms in e-beam direct write** [7970-47]
M. Freitag, K.-H. Choi, M. Gutsch, C. Hohle, Fraunhofer Ctr. Nanoelectronic Technologies (Germany); R. Galler, M. Krueger, EQUIcon Software GmbH Jena (Germany); U. Weidenmueller, Vistec Electron Beam GmbH (Germany)

SESSION 11 NOVEL APPLICATIONS II

- 7970 1F **Nanopatterning of diblock copolymer directed self-assembly lithography with wet development** [7970-50]
M. Muramatsu, M. Iwashita, T. Kitano, T. Toshima, Tokyo Electron Kyushu Ltd. (Japan); Y. Seino, D. Kawamura, M. Kanno, K. Kobayashi, T. Azuma, Toshiba Corp. (Japan)
- 7970 1H **Double and triple exposure with image reversal in a single photoresist layer** [7970-52]
C. Ndoye, M. Orlowski, Virginia Polytechnic Institute and State Univ. (United States)

SESSION 12 CROSS-CUTTING TECHNOLOGIES

- 7970 1K **Tunable two-mirror laser interference lithography system for large-area nano-patterning** [7970-54]
W. Mao, I. Wathuthanthri, C.-H. Choi, Stevens Institute of Technology (United States)
- 7970 1L **Solid-immersion Lloyd's mirror as a testbed for plasmon-enhanced high-NA lithography** [7970-55]
P. Mehrotra, C. W. Holzwarth, R. J. Blaikie, Univ. of Canterbury (New Zealand)

- 7970 1M **Soft UV-NIL at the 12.5 nm scale** [7970-57]
G. Kreindl, M. Kast, D. Treiblmayr, T. Glinsner, EV Group, E. Thallner GmbH (Austria);
E. Platzgummer, H. Loeschner, P. Joechl, S. Eder-Kapl, T. Nartz, IMS Nanofabrication AG
(Austria); M. Muehlberger, I. Bergmair, M. Boehm, R. Schoeftner, PROFACTOR GmbH (Austria)

POSTER SESSION

- 7970 1N **Scatterometry sensitivity for NIL process** [7970-56]
T. Miyakawa, K. Sato, K. Sentoku, H. Ina, Canon Inc. (Japan)
- 7970 1R **Fast and large-field electron-beam exposure by CSEL** [7970-61]
A. Kojima, Crestec Corp. (Japan) and Tokyo Univ. of Agriculture and Technology (Japan);
T. Ohta, Tokyo Univ. of Agriculture and Technology (Japan); H. Ohya, Crestec Corp. (Japan);
N. Koshida, Tokyo Univ. of Agriculture and Technology (Japan)
- 7970 1S **Optimization of e-beam landing energy for EBDW** [7970-63]
E. D. Liu, T. Prescop, Multibeam Corp. (United States)
- 7970 1T **Demonstration of lithography patterns using reflective e-beam direct write** [7970-64]
R. Freed, J. Sun, A. Brodie, P. Petric, M. McCord, KLA-Tencor Corp. (United States); K. Ronse,
L. Haspeslagh, B. Vereecke, IMEC (Belgium)
- 7970 1U **A lossless circuit layout image compression algorithm for electron beam direct write lithography systems** [7970-65]
J. Yang, Univ. of Michigan (United States); S. A. Savari, Texas A&M Univ. (United States)
- 7970 1V **Electron beam induced freezing of positive tone, EUV resists for directed self assembly applications** [7970-66]
H.-H. Cheng, I. Keen, A. Yu, Y.-M. Chuang, I. Blakey, K. S. Jack, The Univ. of Queensland
(Australia); M. J. Leeson, T. R. Younkin, Intel Corp. (United States); A. K. Whittaker, The Univ. of
Queensland (Australia)

Author Index

Conference Committee

Symposium Chairs

Donis G. Flagello, Nikon Research Corporation of America (United States)

Harry J. Levinson, GLOBALFOUNDRIES Inc. (United States)

Conference Chair

Daniel J. C. Herr, Semiconductor Research Corporation (United States)

Conference Cochair

William M. Tong, KLA-Tencor Corporation (United States)

Program Committee

Joy Y. Cheng, IBM Almaden Research Center (United States)

Juan J. de Pablo, University of Wisconsin-Madison (United States)

Elizabeth A. Dobisz, Hitachi Global Storage Technologies, Inc. (United States)

Benjamin G. Eynon, Jr., Molecular Imprints, Inc. (United States)

Timothy R. Groves, University at Albany (United States)

Cynthia Hanson, Space and Naval Warfare Systems Center Pacific (United States)

Tatsuhiko Higashiki, Toshiba Corporation (Japan)

William D. Hinsberg, IBM Almaden Research Center (United States)

Bert Jan Kampherbeek, MAPPER Lithography (Netherlands)

Ryan J. Kershner, University of Wisconsin-Madison (United States)

Sung-Woo Lee, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)

J. Alexander Liddle, National Institute of Standards and Technology (United States)

Lloyd C. Litt, SEMATECH North (United States) and GLOBALFOUNDRIES Inc. (United States)

Hans Loeschner, IMS Nanofabrication AG (Austria)

R. Scott Mackay, Petersen Advanced Lithography, Inc. (United States)

Osamu Nagarekawa, HOYA Corporation (Japan)

Laurent Pain, CEA-LETI (France)

Benjamin M. Rathsack, Tokyo Electron America, Inc. (United States)

Douglas J. Resnick, Molecular Imprints, Inc. (United States)

Frank M. Schellenberg, Consultant (United States)

Ines A. Stolberg, Vistec Electron Beam GmbH (Germany)

Kevin T. Turner, University of Wisconsin-Madison (United States)

James J. Watkins, University of Massachusetts Amherst (United States)

Wei Wu, Hewlett-Packard Laboratories (United States)
Masaki Yamabe, Association of Super-Advanced Electronics
Technologies (Japan)

Session Chairs

- 1 Keynote Session
Daniel J. C. Herr, Semiconductor Research Corporation (United States)
William M. Tong, KLA-Tencor Corporation (United States)
- 2 Nanoimprint Lithography I: CMOS
William M. Tong, KLA-Tencor Corporation (United States)
Douglas J. Resnick, Molecular Imprints, Inc. (United States)
- 3 Maskless Lithography I
Hans Loeschner, IMS Nanofabrication AG (Austria)
Timothy R. Groves, University at Albany (United States)
- 4 Directed Self-Assembly I: Selected Semiconductor Applications: Joint
Session with Conference 7972
Elizabeth A. Dobisz, Hitachi Global Storage Technologies, Inc. (United
States)
Daniel P. Sanders, IBM Almaden Research Center (United States)
- 5 Novel Applications I
Douglas J. Resnick, Molecular Imprints, Inc. (United States)
Gregg M. Gallatin, National Institute of Standards and Technology
(United States)
- 6 Directed Self-Assembly II: Processing and Fundamentals
Matt Malloy, SEMATECH Inc. (United States)
Joy Y. Cheng, IBM Almaden Research Center (United States)
- 7 Nanoimprint Lithography II: Processes and Materials
Elizabeth A. Dobisz, Hitachi Global Storage Technologies, Inc. (United
States)
Douglas J. Resnick, Molecular Imprints, Inc. (United States)
- 8 Maskless Lithography II
Lloyd C. Litt, SEMATECH North (United States) and GLOBALFOUNDRIES
Inc. (United States)
Laurent Pain, CEA-LETI (France)
- 9 Nanoimprint Lithography III: Novel NIL Applications
Kevin T. Turner, University of Wisconsin-Madison (United States)
Tatsuhiko Higashiki, Toshiba Corporation (Japan)

- 10 Maskless Lithography III
Lloyd C. Litt, SEMATECH North (United States) and GLOBALFOUNDRIES Inc. (United States)
Hans Loeschner, IMS Nanofabrication AG (Austria)
- 11 Novel Applications II
Cynthia Hanson, Space and Naval Warfare Systems Center Pacific (United States)
Kevin T. Turner, University of Wisconsin-Madison (United States)
- 12 Cross-Cutting Technologies
Daniel J. C. Herr, Semiconductor Research Corporation (United States)
Cynthia Hanson, Space and Naval Warfare Systems Center Pacific (United States)

Introduction

This year's Alternative Lithographic Technologies III conference built on last year's momentum and opened to a standing room only audience of more than 420 colleagues. While challenges remain, each NGL appears to be moving forward toward their niche applications. There seems to be growing support for extensible patterning options to leverage the integration of more than one tool exposure tool option, as suggested by Yan Borodovsky. For example, EUV, 193i double patterning, or imprint may be used to define large arrays of regular features that are selectively cut into desired feature shapes by another imaging process, such as maskless patterning.

The community's sustained support for directed self assembly appears to be gaining traction within the patterning community. Chris Bencher, of AMAT, and Joy Cheng, of IBM, gave a linked pair of talks, which suggested that directed self assembly technology's demonstrated performance, defectivity and process window adds credibility to DSA's position as a potential patterning solution option on the ITRS roadmap. The AMAT study reports the first rather rigorous analysis of DSA related defect levels on 300-mm wafers, in a near manufacturing environment. This study found no DSA related defects on the patterned areas considered, which places an upper limit on DSA defectivity at <25 defects/cm². The follow-up IBM presentation suggests that the status of current DSA technology appears to be similar to that of 193i, at a similar phase of its development. The following EE Times article provides an independent perspective on the status of the emerging alternative lithographic technology:

Dylan McGrath, "Momentum builds for directed self-assembly."
EE Times News and Analysis (March 2, 2011). Accessed April 4, 2011.
<http://www.eetimes.com/electronics-news/4213705/Momentum-builds-for-directed-self-assembly>

SANTA CLARA, Calif.—Directed self-assembly (DSA)—a technology based on a concept that was virtually unknown outside of research labs a few years ago—has emerged as a legitimate contender for use in future semiconductor manufacturing.

"Directed self-assembly cannot be ignored," said Christopher Bencher, a member of the technical staff at Applied Materials Inc., at the SPIE Advanced Lithography conference here Tuesday (March 1). Bencher further suggested that DSA should be moved from the list of emerging lithography technologies to the "current" technologies list.

At SPIE, Bencher presented data on self-assembly patterning for cells with a half-pitch of less than 15-nm that was collected through a joint project with IBM Research. Bencher noted that while lithographers have been enthusiastic about DSA, the biggest concern has been defect density. Bencher said his project demonstrated the use of DSA to build 12-nm line/space structures across an entire 300-mm wafer with a very low rate of less than 1 percent of "dislocation" defects.

Hundreds of particle defects were also measured during the project, but, according to Bencher, particle defects introduced through the use of DSA are no different than particle defects encountered during the use of any new process technology material and will be reduced through better filtration in the fab. Bencher's project was concerned mainly with dislocation defects because, he said, this is a new type of defect inherent to DSA. "This clearly puts us on a trajectory to make DSA feasible, with fairly good defect control," Bencher said.

In DSA, a block copolymer or polymer blend is deposited on a substrate, usually by spin coating, and subjected to an annealing process that "directs" it to form ordered structures. Researchers say DSA is compatible with conventional 193-nm lithography equipment and would eliminate the need for dual exposure steps.

DSA first landed on the International Technology Roadmap for Semiconductors (ITRS) as a potential solution for leading-edge, critical layer lithography in 2007 and remained part of 2009 ITRS. The technology is also considered complementary to next-generation lithography candidates such as extreme ultraviolet (EUV) lithography and nano-imprint lithography. But even the most enthusiastic supporters of DSA acknowledge that the technology is years away from being used in CMOS production, even in a best case scenario. Defect density is only one of a number of technical hurdles DSA must overcome to be viable in volume production. Yoshi Hishiro, director of R&D at materials supplier JSR Micro Inc., estimated that DSA was at least two to three years away from being used in niche CMOS production.

Attendees at SPIE are nervous about the prospects for EUV, long considered the front runner to replace optical lithography. Intel Corp. hopes to put EUV into production at the 10-nm node, but this week its lithography director said EUV is running late for 10-nm design rule definition. Development of power sources for EUV lithography tools remains behind schedule, and several SPIE attendees expressed concern that EUV was still dealing with "basic physics" issues."

On 2 March, the 2011 Alternative Lithographic Technologies III conference also hosted a panel discussion entitled "Economics of Lithography for Alternative Applications." Historically, cutting-edge lithography has been tailored to projected IC industry requirements. However, these requirements are diverging from those of other emerging application opportunities, such as in the optics, biotechnology, or even the hard disk areas, which are driven by very different economic models. This panel discussion provided a forum to illuminate this blind spot and clarify the projected patterning requirements for these emerging application spaces.

Have we passed the tipping point for one or more of these emerging patterning technologies? That question may best be answered at next year's conference, which promises to deliver new breakthroughs in these alternative technologies and their emerging application opportunities.

Daniel J. C. Herr