Contents

v Authors
vii Conference Committee
ix Introduction

PATTERNING TECHNIQUES FOR ADVANCED TECHNOLOGY NODES

10149 08 Self-aligned block technology: a step toward further scaling [10149-7]

PATTERNING CHALLENGES IN NANOPHOTONIC STRUCTURES

10149 0D Silicon photonics and challenges for fabrication (Invited Paper) [10149-13]
10149 0F Reducing Line Edge Roughness in Si and SiN through plasma etch chemistry optimization for photonic waveguide applications [10149-15]

PATTERNING MATERIALS AND ETCH: JOINT SESSION WITH CONFERENCES 10146 AND 10149

10149 0H Plasma-assisted thermal atomic layer etching of Al2O3 [10149-17]
10149 0I Self-aligned quadruple patterning using spacer on spacer integration optimization for N5 [10149-18]
10149 0J Directed self-assembly patterning strategies for phase change memory applications [10149-19]

NOVEL PLASMA PATTERNING TECHNIQUES

10149 0K Nanoimprint, DSA, and multi-beam lithography: patterning technologies with new integration challenges (Invited Paper) [10149-20]
10149 0L Overview of several applications of chemical downstream etching (CDE) for IC manufacturing: advantages and drawbacks versus WET processes (Invited Paper) [10149-21]
10149 0M Study of selective chemical downstream plasma etching of silicon nitride and silicon oxide for advanced patterning applications [10149-22]
Co-optimization of lithographic and patterning processes for improved EPE performance (Invited Paper) [10149-25]

Self-aligned blocking integration demonstration for critical sub-40nm pitch Mx level patterning [10149-26]

Guiding gate-etch process development using 3D surface reaction modeling for 7nm and beyond (Invited Paper) [10149-36]

Plasma processing of III-V materials for energy efficient electronics applications (Invited Paper) [10149-29]

Design and fabrication of resonator-QWIP for SFs gas sensor application [10149-30]

Spin-on metal oxide materials for N7 and beyond patterning applications [10149-8]

Improvement of a block co-polymer (PS-b-PDMS) template etch profile using amorphous carbon layer [10149-24]

A method to accelerate creation of plasma etch recipes using physics and Bayesian statistics [10149-33]

The line roughness improvement with plasma coating and cure treatment for 193nm lithography and beyond [10149-34]

The application of advanced pulsed plasma in Fin etch loading improvement [10149-35]

Facile fabrication of Si-based nanostructures [10149-37]
Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Altamirano-Sanchez, E., 0T
Argoud, M., 0K
Arnold, John C., 0J
Ayala, J., 0D
Bannister, Julie, 0B
Barla, Kathy, 0B
Barnola, S., 0K
Barwicz, Tymon, 0D, 0F
Bekaert, Joost P., 0N
Beral, Christophe, 0N
Besseron, A., 0K
Biesemans, Serge, 0N
Biolsi, Peter, 0I, 0O
Blancquaert, Y., 0K
Boemmels, Jürgen, 08
Boniface, John, 0H
Bonnecaze, Roger T., 0X
Bos, S., 0K
Brianceau, P., 0K
BrightSky, Matt, 0J
Bruce, Robert L., 0J
Campo, Alain, 0L
Chamiot-Maitral, G., 0K
Chang, Josephine, 0F
Chhun, Sonarith, 0L
Cho, J.-Y., 0T
Choi, K. S., 0S
Chopra, Meghali J., 0X
Claveau, G., 0K
Cucci, B., 0D
Cunge, Gilles, 0L, 0M
Dalzotto, B., 0K
Dang, D., 0D
de Buttet, Côme, 0L, 0M
de Loijer, Peter, 0N
Decoster, Stefan, 0B
DeCuir, E. A., 0S
Delachat, F., 0K
Demand, Marc, 0B, 0N
Deshpande, Vaibhav, 0Q
deVilliers, Anton, 0B, 0Q
Di Lorenzo, Paolo, 0N
Doan, T., 0D
Dunn, Derren, 0Q
Engelmann, Sebastian U., 0F, 0J
Essomba, P., 0K
Farrell, Richard A., 0O
Felichenauf, N., 0B, 0D
Felix, Nelson, 0J
Feurprier, Yannick, 0B
Fischer, Andreas, 0H
Fonseca, Carlos, 0B
Franz, Martin, 0J
Fu, R. X., 0S
Fu, Yen-Chun, 0R
Garnier, Philippe, 0L
Gharbi, A., 0K
Ghosal, M., 0D
Giewont, K., 0D
Gill, D., 0D
Gottscho, Richard A., 0H
Green, William M., 0D, 0F
Gull, Ronald, 0Q
Han, Qi-Hua, 0Z
Holmes, Steven, 0F
Hong, S.-E., 0T
Hofp, T., 0T
Huang, Yi, 0Y
Hui, Lior, 0B
Janek, Richard, 0H
Jee, Taekwon, 0N
Kal, Subhadeep, 0I
Kamalapurkar, Swetha, 0F
Kanarik, K. J., 0H
Khatari, Marwan, 0D, 0F
Kiers, Ton, 0N
Kiewra, E., 0D
Kim, Ryan, 0B
Ko, Akiteru, 0I, 0Q
Kumar, Kaushik A., 0B, 0N
Lagrasta, Sebastien, 0M
Lam, Chung H., 0J
Landis, S., 0K
Lane, Austin, 0X
Lapeyre, C., 0K
Larivière, Stefane, 0N
Lazzarino, Frédéric, 0B
Leidy, R., 0D
Leray, Philippe, 0B
Li, Xu, 0R
Lill, Thorsten, 0H
Liu, Chi-Chun, 0J
Liu, Eric, 0I
Lorant, C., 0T
Lung, Hsiang-Lan, 0J
Luong, Vinh, 0B
Mallik, Arindam, 0B
Mannaert, G., 0T
Conference Committee

Symposium Chair

Bruce W. Smith, Rochester Institute of Technology (United States)

Symposium Co-Chair

Will Conley, Cymer, An ASML Company (United States)

Conference Chair

Sebastian U. Engelmann, IBM Thomas J. Watson Research Center (United States)

Conference Co-Chair

Richard S. Wise, Lam Research Corporation (United States)

Conference Program Committee

Efrain Altamirano-Sánchez, IMEC (Belgium)
Julie Bannister, Tokyo Electron America, Inc. (United States)
Sang-Hoon Cho, SK Hynix, Inc. (Korea, Republic of)
Maxime Darnon, LTM CNRS (France)
Eric A. Hudson, Lam Research Corporation (United States)
Catherine B. Labelle, GLOBALFOUNDRIES Inc. (United States)
Nae-Eung Lee, Sungkyunkwan University (Korea, Republic of)
Qinghuang Lin, IBM Thomas J. Watson Research Center (United States)
Gottlieb S. Oehrlein, University of Maryland, College Park (United States)
Erwine Pargon, CNRS/LTM (France)
Nicolas Posseme, CEA-LETI (France)
Ricardo Ruiz, HGST (United States)
Seiji Samukawa, Tohoku University (Japan)
Robert Turkot, Intel Corporation (United States)
Jeff Xu, Qualcomm Technologies Inc. (United States)
Anthony Yen, TSMC Taiwan (Taiwan)
Ying Zhang, Applied Materials, Inc. (United States)
Session Chairs

Opening Remarks
Sebastian U. Engelmann, IBM Thomas J. Watson Research Center
(United States)

1 Keynote Session
Catherine Labelle, GLOBALFOUNDRIES Inc. (United States)
Qinghuang Lin, IBM Thomas J. Watson Research Center
(United States)

2 Patterning Techniques for Advanced Technology Nodes
Ying Zhang, Applied Materials, Inc. (United States)
Efrain Altamirano-Sánchez, IMEC (Belgium)

3 Advanced Plasma Process Control
Eric A. Hudson, Lam Research Corporation (United States)
Julie Bannister, Tokyo Electron America, Inc. (United States)

4 Patterning Challenges in Nanophotonic Structures
Maxime Darnon, CNRS-LN2 (France)
Julie Bannister, Tokyo Electron America, Inc. (United States)

5 Patterning Materials and Etch: Joint Session with Conferences 10146 and 10149
Qinghuang Lin, IBM Thomas J. Watson Research Center
(United States)
Sebastian U. Engelmann, IBM Thomas J. Watson Research Center
(United States)

6 Novel Plasma Patterning Techniques
Efrain Altamirano-Sánchez, IMEC (Belgium)
Eric A. Hudson, Lam Research Corporation (United States)

7 Litho Etch Process Interaction: Joint Session with Conferences 10147 and 10149
Richard S. Wise, Lam Research Corporation (United States)
Yuri Granik, Mentor Graphics Corporation (United States)

8 Patterning Solutions for Emerging Products
Maxime Darnon, CNRS-LN2 (France)
Qinghuang Lin, IBM Thomas J. Watson Research Center
(United States)
Introduction

This proceedings volume contains accepted papers from the SPIE conference on Advanced Etch Technology for Nano-patterning VI (The SPIE Etch conference) held as part of the International Symposium on Advanced Lithography, held 26 February — 2 March 2017, in San Jose, California, United States. These proceedings papers cover the latest advances in the wide field of etch and nano-patterning technology and offer a glimpse at the state-of-the-art developments of this important field of semiconductor technology.

This year’s SPIE Etch conference continued the fine tradition of having a wide international representation and attracted many researchers from related fields. For this year, our conference spanned three days, with the papers divided into eight sessions (listed below) which continued to garner tremendous interest among conference attendees:

- Keynote Session
- Patterning Techniques for Advanced Technology Nodes
- Advanced Plasma Control
- Patterning Challenges in Nanophotonic Structures
- Patterning Materials and Etch: Joint Session with Conferences 10146 and 10149
- Novel Plasma Patterning Techniques
- Litho Etch Process Interaction: Joint Session with Conferences 10147 and 10149
- Patterning Solutions for Emerging Products

The widely recognized challenges in extension of Moore’s Law have driven the industry toward collaboration across process modules. This year, the Etch conference focused on strengthening this collaboration with two well-attended joint sessions on Patterning Materials and Etch with the Advances in Patterning Materials and Processes conference (volume 10146) and on Litho Etch interactions with the Optical Microlithography conference (volume 10147).

The keynote session of the Etch conference again drew very big crowds, where some of the most important fundamental issues faced in the world of nano-patterning and etch, as well as device fabrication in a post-classical scaling world, were discussed. First hints at new directions for patterning applications were presented at the nanophotonic patterning session, where patterning applications for optical devices and features were discussed. We hope that these proceedings proves valuable to the many patterning scientists and engineers working in the fast-moving semiconductor industry. We also hope that it serves as a useful reference for those who are interested in nanofabrication, micro- and

We thank the authors, particularly the invited speakers, for their valuable contributions to the conference and proceedings volume. The SPIE Etch conference is highly regarded among the worldwide patterning community; which recognizes the high quality of our talks and proceedings papers. We also thank members of the organizing committee for their dedication and hard work to help maintain a high quality of this conference. We are also grateful to LAM Research Corporation (United States) for their generous financial support.

Finally, we extend our sincere thanks to the SPIE staff for their tireless efforts and their meticulous organizational skills in helping make this year’s SPIE Etch conference a success and in assembling and publishing this proceedings volume.

Sebastian U. Engelmann
Richard S. Wise