PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 10147

, "Front Matter: Volume 10147," Proc. SPIE 10147, Optical Microlithography
XXX, 1014701 (12 April 2017); doi: 10.1117/12.2277795

SPIE.

Event: SPIE Advanced Lithography, 2017, San Jose, California, United States

PROCEEDINGS OF SPIE

Optical Microlithography XXX

Andreas Erdmann

Jongwook Kye

Editors

28 February – 2 March 2017

San Jose, California, United States

Sponsored by
SPIE

Cosponsored by
Cymer, an ASML company (United States)

Published by
SPIE

Volume 10147

Proceedings of SPIE 0277-786X, V. 10147

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

Optical Microlithography XXX, edited by Andreas Erdmann, Jongwook Kye,
Proc. of SPIE Vol. 10147, 1014701 · © 2017 SPIE · CCC code:
0277-786X/17/\$18 · doi: 10.1117/12.2277795

Proc. of SPIE Vol. 10147 1014701-1

The papers 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. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers 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 these proceedings:

Author(s), "Title of Paper," in *Optical Microlithography XXX*, edited by Andreas Erdmann, Jongwook Kye, Proceedings of SPIE Vol. 10147 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510607453

ISBN: 9781510607460 (electronic)

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 © 2017, 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/17/\$18.00.

Printed in the United States of America.

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

**SPIE. DIGITAL
LIBRARY**

SPIEDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five 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.

Contents

vii	<i>Authors</i>
xi	<i>Conference Committee</i>

PUSHING OPTICAL LIMITS

10147 06	Using heuristic optimization to set SRAF rules [10147-5]
----------	---

IMAGE AND PROCESS CONTROL

10147 09	Process margin improvement through finger-print removal based on scanner leveling data [10147-8]
10147 0A	Scanner-to-scanner CD analysis and control in an HVM environment [10147-9]
10147 0C	450mm lithography status for high volume manufacturing [10147-11]

3D RESIST EFFECTS AND MODELING: JOINT SESSION WITH CONFERENCES 10146 AND 10147

10147 0F	Experimental characterization of NTD resist shrinkage [10147-14]
10147 0G	Investigation of 3D photoresist profile effect in self-aligned patterning through virtual fabrication [10147-15]

LITHO ETCH PROCESS INTERACTION: JOINT SESSION WITH CONFERENCES 10147 AND 10149

10147 0H	Reducing the impact of etch-induced pattern shift on overlay by using lithography and etch tool corrections [10147-16]
10147 0I	Optimal structure sampling for etch model calibration [10147-17]
10147 0J	Interlayer verification methodology for multi-patterning processes [10147-18]

COMPUTATIONAL LITHOGRAPHY I

10147 0L	Full chip hierarchical inverse lithography: a solution with perfect symmetry [10147-20]
10147 0M	Source defect impact on pattern shift [10147-21]
10147 0O	Automated detection and classification of printing sub-resolution assist features using machine learning algorithms [10147-23]

DESIGN INTERACTIONS WITH LITHOGRAPHY: JOINT SESSION WITH CONFERENCES 10147 AND 10148

- 10147 0Q **Resist 3D aware mask solution with ILT for hotspot repair** [10147-25]
- 10147 0R **Enhanced OPC recipe coverage and early hotspot detection through automated layout generation and analysis** [10147-26]

NON-IC APPLICATIONS

- 10147 0T **A physical model for innovative laser direct write lithography** [10147-28]
- 10147 0U **Performance analyses of plasmonic lithography** [10147-29]
- 10147 0W **Neuroelectronic device process development and challenge** [10147-31]

COMPUTATIONAL LITHOGRAPHY II

- 10147 0Y **Effective use of aerial image metrology for calibration of OPC models** [10147-33]
- 10147 0Z **Accurate characterization of 2D etch bias by capturing surrounding effects from resist and trench areas** [10147-34]
- 10147 11 **Si-photonics waveguides manufacturability using advanced RET solutions** [10147-36]

OVERLAY OPTIMIZATION

- 10147 12 **Overlay statistics for multiple exposure patterning** [10147-37]
- 10147 13 **Experimental verification of on-product overlay improvement by intra-lot overlay control using metrology based grouping** [10147-38]
- 10147 15 **FinFET-induced anisotropy in printing of implantation shapes** [10147-40]

TOOLINGS

- 10147 16 **On-product overlay improvement with an enhanced alignment system** [10147-41]
- 10147 17 **Reticle heating feed-forward control (RHC2) on NXT:1980Di immersion scanner for enhanced on-product overlay** [10147-42]
- 10147 19 **The ArF laser for the next generation multiple-patterning immersion lithography supporting green operations and leading edge processes** [10147-44]
- 10147 1A **Layout independent leveling (LIL) on NXT:1980Di immersion scanners for enhanced productivity** [10147-45]

LATEST NEWS

- 10147 1B **Immersion lithography scanner resolution performance demonstration on 450mm substrates** [10147-46]

POSTER SESSION

- 10147 1E **Improving the topography performance of ion implantation resist** [10147-48]
- 10147 1G **Eliminate the vibration defect for laser interference lithography using an optical chopper system** [10147-51]
- 10147 1H **The pattern-matching based OPC approach for preemptively fixing the weak points** [10147-53]
- 10147 1J **Lithography and OPC friendly triple patterning decomposition method for VIA** [10147-55]
- 10147 1L **The ultra-violet partial coherence modulation transfer function for lithography** [10147-57]
- 10147 1M **Constructing freeform source through the combination of neural network and binary ant colony optimization** [10147-58]
- 10147 1N **Development of the next-generation ArF excimer laser with ultra-narrow stable spectral bandwidth for multiple patterning immersion lithography** [10147-59]
- 10147 1O **Excimer laser gas usage reduction technology for semiconductor manufacturing** [10147-60]
- 10147 1P **The thermal aberration analysis of a lithography projection lens** [10147-61]
- 10147 1Q **Application of optical similarity in OPC model calibration** [10147-62]
- 10147 1R **Compact modeling for the negative tone development processes** [10147-63]
- 10147 1S **Addressing optical proximity correction challenges from highly nonlinear models** [10147-64]
- 10147 1T **Alignment solutions on FBEO layers using ASML scanners** [10147-65]
- 10147 1U **Novel methodology to optimize wafer alignment to enhance 14nm on product overlay** [10147-66]
- 10147 1V **Process of opto-mechanical design and assembly for reflective mirror subsystem of lithographic projection lens** [10147-68]
- 10147 1W **Advanced application of pattern-aware OPC** [10147-70]

- 10147 1Z **Study of aging behaviour on 193nm phase-shift masks** [10147-74]
- 10147 20 **Image acquisition and motion positioning system design based on the projection lens wavefront aberration measurement** [10147-75]

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

Adam, Kostas, 0Y	Duan, Lifeng, 1P
Akbulut, Mustafa B., 0G	Dufaye, Félix, 1Z
Ali, Hussein, 0R	Dunn, Shannon, 0C, 1B
Allampalli, Vasanth, 0G	Dusa, Mircea, 0H
Armeanu, Ana-Maria, 15	Dzeng, Yu-Hua, 1G
Aung, Nyan, 1T, 1U	Elbattay, Khalid, 09, 0A
Bahnas, Mohamed, 0R	Elistratov, Nikolay, 15
Beak, Du Hyun, 0A	Erdmann, Andreas, 0T
Black, Russell A., 0C, 1B	Ervin, Joseph, 0G
Böcker, Paul, 13	Faken, Daniel, 0G
Bontekoe, Marcel, 09	Fan, Yongfa, 0Z
Boogaarts, Maarten, 09	Farys, V., 11
Brown, Jay, 16	Felix, Nelson M., 12
Bu, Yang, 1P	Feng, Mu, 0Z
Burbine, Andrew, 0Y	Foong, Yee Mei, 0Y
Bushida, Satoru, 19	Fried, David, 0G
Buttgereit, Ute, 0Y	Fu, Chien-Chung, 1G
Cai, Howard, 1S	Furusato, Hiroshi, 1N
Carr, Christopher R., 0C, 1B	Gabor, Allen H., 12
Cecil, Tom, 1S	Galbiati, Andrea, 1Z
Chahine, Charlotte, 0H	Gao, Haiyong, 1T, 1U
Chang, Chansam, 1A	Gao, Weimin, 0F
Chang, Shenq-Tsong, 1V	Gommers, Ralf, 1A
Chen, Ao, 0R, 0Y	Goossens, Ronald, 0A
Chen, James, 1W	Granik, Yuri, 15
Chen, Norman, 06	Graur, Ioana, 0O, 0R
Chen, Wenhui, 1E	Greiner, Ken, 0G
Chen, Xi, 0U	Gronlund, Keith, 0Z
Chen, Xiao, 1J	Grozev, Grozdan, 0F
Chen, Yen-Jen, 1T	Gu, Jiangjiang, 0G
Choi, Jin Phil, 09, 0A	Guntuka, Anand, 0A
Choi, Junghwan, 15	Guo, L. Jay, 0U
Chung, Angeline, 0Y	Hamouda, Ayman, 0R
Chung, Chien-Kai, 1V	Han, Dong Kyung, 09, 0A
Chung, Woong Jae, 1T, 1U	Han, Hank, 13
Clifford, Chris, 0Y	Han, Sangjun, 13
Cottaar, Jeroen, 09, 1A	Han, Xiaoquan, 20
Crawford, Charles, 1Z	Hart, Gregory, 1T
Cremer, S., 11	Hauptmann, Marc, 13
Crupe, Preston A., 0C, 1B	Hellin, David, 0H
Dam, Thuc, 0Q	Heres, Pieter, 1T
DeBisschop, Peter, 0Y	Hikida, Yujiro, 16
de Graaf, Roelof, 17, 1A	Holscher, Arjan, 1A
Delvigne, Erik, 1U	Hooker, Kevin, 0Q
Dong, Lisong, 1E	Hoppe, Wolfgang, 0Q
Donkerbroek, Arjan, 09	Howell, Rafael, 0Z
Dosho, Tomonori, 16	Hsu, Fan-Hsuan, 1W
Droste, Richard, 17, 1A	Huang, Hsin-Hui, 0C, 1B
Du, Yaojun, 1H	Huang, Jason, 1R

Huang, Jiun-Woei, 1L
 Hutchinson, Trent, 1Z
 Hwang, Hyunwoo, 17, 1A
 Ichinose, Go, 16
 Isoyan, Artak, 0M
 Jaenen, Patrick, 0H
 Jang, Jong Hoon, 17, 1A
 Jang, Se-Yeon, 09, 0A, 17
 Jang, Stephen, 1S
 Jehoul, Christiane, 0H
 Jobes, Mark, 0O
 Jongen, Joris, 17
 Jung, Sunwook, 0J
 Kallingal, Chidam, 06
 Kamimura, Sou, 0F
 Kang, Young Seog, 09, 0A, 17, 1A
 Kerrien, G., 11
 Khalek, Samah, 1A
 Khikhlovskiy, Seva, 1T
 Kim, Chung-Yong, 09, 0A
 Kim, HyoungKook, 0C, 1B
 Kim, Jinhee, 0J
 Kim, Jungmin, 0J
 Kim, Young Ha, 17, 1A
 Kim, Young Jun, 09
 Klostermann, Ulrich, 0F
 Kohli, Kirti K., 0O
 Kong, Jeong-Heung, 09, 0A, 17, 1A
 Kou, Weitian, 13
 Kubis, Michael, 0H
 Küchler, Bernd, 0F
 Kumazaki, Takahito, 19, 1N
 Kuo, Fred, 1R
 Kuo, Hung-Fei, 1M
 Kupers, Michiel, 13
 Kuroda, Takuya, 0C, 1B
 Kurosu, Akihiko, 19, 1N, 1O
 Lafferty, Neal, 0R
 Lai, Nelson, 1W
 Lecarpentier, Laurent, 1Z
 Lee, Byeong Soo, 17, 1A
 Lee, Honggoo, 13
 Lee, Shawn, 1U
 Leray, Philippe, 0H
 Leslie, Alan, 06
 Li, Bing, 20
 Li, Liang, 1J
 Li, Sikun, 1P
 Li, Waikin, 0F
 Li, Zhao-Ze, 0A
 Liang, Gaofeng, 0U
 Lie, Frederick, 1M
 Lin, Lawrence, 1W
 Lin, Te-Hsun, 1G
 Lin, Wei-Cheng, 1V
 Lin, Yu-Chuan, 1V
 Liu, Guangyi, 20
 Liu, Jian, 06
 Liu, Qingwei, 1J
 Liubich, V., 11
 Lutich, Andrey, 0I
 Madkour, Kareem, 0R
 Mai, Hsuan-Ying, 1G
 Mai, Yung-Ching, 1W
 Mali, Rajan, 1T
 Mao, Yanjie, 1P
 Matsunaga, Takashi, 19, 1N, 1O
 McGinty, Chris, 0R
 Meiring, Jason, 0R
 Melvin, Lawrence S., III, 0M, 1R
 Minghetti, Blandine, 1T, 1U
 Miyamoto, Hirotaka, 19
 Mizoguchi, Hakaru, 19, 1N, 1O
 Moe, Andrew, 09, 0A
 Moest, Barry, 17
 Moon, Junghwan, 13
 Morita, Masahiro, 16
 Mülders, Thomas, 0F
 Munson, Jasper P., 0C, 1B
 Nam, Youngsun, 17, 1A
 Nikolsky, Peter, 0A
 Oh, Seung Chul, 1U
 Ohta, Takeshi, 19, 1N, 1O
 Okamoto, Takanobu, 16
 Onanuga, Temitope, 0T
 Oouchi, Takuma, 1O
 Orlando, B., 11
 Oti, Elliot, 1A
 Ouyang, Ruiyue, 09
 Paarhuis, Bart, 17
 Pap, Andras, 0G
 Park, Noh-Kyoung, 0A
 Park, Sejin, 0J
 Park, Tony, 09, 0A
 Peng, Austin, 0A
 Perez, Victor A., 0C, 1B
 Pogliani, Carlo, 1Z
 Poonawala, Aryn, 1S
 Qi, Yuejing, 20
 Raas, Marcel, 1A
 Rangarajan, Balaji, 09
 Robinson, Matthew, 0W
 Rumler, Maximilian, 0T
 Rutten, Jeroen, 09
 Ryu, Machi, 0A
 Samudrala, Pavan, 1T, 1U
 Sawh, Chander, 0M
 Schatz, Jirka, 0I
 Schmoeller, Thomas, 0Q
 Schumacher, Dan, 0R
 Selinidis, Kosta, 0Q
 Shiba, Yuji, 16
 Shibasaki, Yuichi, 16
 Shin, Jangho, 0A
 Shin, Ju Hee, 0A
 Shirakawa, Michihiro, 0F
 Simons, Geert, 0H
 Slaughter, Gymama, 0W
 Slotboom, Daan, 13
 Sobieski, Daniel, 0H

Song, Changrock, 13	Zhu, Alan, 1W
St. John, Matt, 1S	Zuniga, Christian, 15
Stavenga, Marco, 17	
Strolenberg, Chris, 0A	
Sturtevant, John, 0J, 0Y	
Su, Xiaojing, 1E	
Subramany, Lokesh, 1T, 1U	
Sun, Gang, 1P	
Sundermann, Frank, 1Z	
Sung, Yun-A, 0A	
Taaka, Hironobu, 0F	
Tejnil, Edita, 1Q	
Thaler, Thomas, 0Y	
Thivolle, Nicolas, 1Z	
Tomasello, Vito, 0A	
Tritchkov, A., 1I	
Tseng, Shih-Feng, 1V	
Tsushima, Hiroaki, 19, 1N, 1O	
Tu, Yuanying, 1J	
Tyson, Joel, 0W	
Ur-Rehman, Samee, 0H	
van Delft, Jan-Pieter, 09	
van der Wielen, Jeroen, 17	
van Hoof, Bram, 1A	
van Kemenade, Jan, 1A	
Verbeek, Niek, 17	
Viatkina, Katja, 0H	
von Sydow, Axel, 09	
Voncken, Maarten, 1A	
Wang, ChangAn, 06	
Wang, Jen-Shiang, 0Z	
Wang, Jian, 1P	
Wang, Jinze, 0Z	
Wang, Xiangzhao, 1P	
Wang, Xiren, 15	
Wei, Yayi, 1E	
Weichselbaum, Stefan, 17, 1A	
Weisbuch, François, 0I	
Wilkinson, William, 06	
Wise, Rich, 0H	
Woo, Jaesun, 13	
Woo, Youngseok, 15	
Xiao, Guangming, 0Q	
Yamamoto, Hajime, 16	
Yan, Guanyong, 1J	
Yang, Yin-Kuang, 1G	
Yashiro, Masanori, 1O	
Ye, Jun,	
Yeh, Shin-Shing, 1W	
Yenikaya, Bayram, 0L, 1W	
Yesilada, E., 1I	
Yoshidome, Masahiro, 0F	
Ypma, Alexander, 13	
Yu, Hyun-Woo, 13	
Zeggaoui, N., 1I	
Zhang, Chen J., 0W	
Zhang, Wenzhe, 0H	
Zhang, Yunqiang, 1S	
Zhao, Qiao, 0Z	
Zheng, Leiwu, 0Z	

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

Andreas Erdmann, Fraunhofer-Institut für Integrierte Systeme und Bauelementetechnologie IISB (Germany)

Conference Co-chair

Jongwook Kye, GLOBALFOUNDRIES Inc. (United States)

Conference Program Committee

Pary Baluswamy, Micron Technology, Inc. (United States)

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

Jo Finders, ASML Netherlands B.V. (Netherlands)

Carlos Fonseca, Tokyo Electron America, Inc. (United States)

Tsai-Sheng Gau, Taiwan Semiconductor Manufacturing Company Ltd. (Taiwan)

Bernd Geh, Carl Zeiss SMT Inc. (United States)

Yuri Granik, Mentor Graphics Corporation (United States)

Harsha Grunes, Intel Corporation (United States)

Young Seog Kang, SAMSUNG Electronics Company, Ltd. (Korea, Republic of)

Sachiko Kobayashi, Toshiba Corporation (Japan)

Kafai Lai, IBM Corporation (United States)

Michael Liehr, SUNY CNSE/SUNYIT (United States)

Soichi Owa, Nikon Corporation (Japan)

Ryan Pearman, D2S, Inc. (United States)

John S. Petersen, Periodic Structures, Inc. (United States)

Mark C. Phillips, Intel Corporation (United States)

Daniel Sarlette, Infineon Technologies Dresden (Germany)

Xuelong Shi, Semiconductor Manufacturing International Corporation (China)

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

Kazuhiro Takahashi, Canon Inc. (Japan)

Geert Vandenberghe, IMEC (Belgium)

Reinhard Voelkel, SUSS MicroOptics SA (Switzerland)
Uwe D. Zeitner, Fraunhofer-Institut für Angewandte Optik und
Feinmechanik (Germany)

Session Chairs

- 1 Keynote Session
Andreas Erdmann, Fraunhofer-Institut für Integrierte Systeme und
Bauelementetechnologie IISB (Germany)
Jongwook Kye, GLOBALFOUNDRIES Inc. (United States)
- 2 Pushing Optical Limits
Geert Vandenbergh, IMEC (Belgium)
Young Seog Kang, SAMSUNG Electronics Company, Ltd.
(Korea, Republic of)
- 3 Image and Process Control
Soichi Owa, Nikon Corp. (Japan)
Andreas Erdmann, Fraunhofer-Institut für Integrierte Systeme und
Bauelementetechnologie IISB (Germany)
- 4 3D Resist Effects and Modeling: Joint Session with Conferences 10146
and 10147
Carlos Fonseca, Tokyo Electron America, Inc. (United States)
Rick Uchida, Tokyo Ohka Kogyo America, Inc. (United States)
- 5 Litho Etch Process Interaction: Joint Session with Conferences 10147
and 10149
Richard J. Wise, Lam Research Corporation (United States)
Yuri Granik, Mentor Graphics Corporation (United States)
- 6 Computational Lithography I
John S. Petersen, Periodic Structures, Inc. (United States)
Kafai Lai, IBM Corporation (United States)
- 7 Design Interactions with Lithography: Joint Session with Conferences
10147 and 10148
Daniel Sarlette, Infineon Technologies Dresden (Germany)
Luigi Capodieci, KnotPrime Inc. (United States)
- 8 Non-IC Applications
Reinhard Voelkel, SUSS MicroOptics SA (Switzerland)
Andreas Erdmann, Fraunhofer-Institut für Integrierte Systeme und
Bauelementetechnologie IISB (Germany)

- 9 Computational Lithography II
Ryan Pearman, D2S, Inc. (United States)
Harsha Grunes, Intel Corporation (United States)
- 10 Overlay Optimization
Sachiko Kobayashi, Toshiba Corporation (Japan)
Xuelong Shi, Semiconductor Manufacturing International Corporation (China)
- 11 Toolings
Bernd Geh, Carl Zeiss SMT Inc. (United States)
Kazuhiro Takahashi, Canon Inc. (Japan)
- 12 Latest News
Mark C. Phillips, Intel Corporation (United States)
Bernd Geh, Carl Zeiss SMT Inc. (United States)