PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 10450

, "Front Matter: Volume 10450," Proc. SPIE 10450, International Conference on Extreme Ultraviolet Lithography 2017, 1045001 (16 November 2017); doi: 10.1117/12.2293159

Event: SPIE Photomask Technology and EUV Lithography, 2017, Monterey, California, United States

PROCEEDINGS OF SPIE

International Conference on Extreme Ultraviolet Lithography 2017

Paolo A. Gargini
Patrick P. Naulleau
Kurt G. Ronse
Toshiro Itani
Editors

11–14 September 2017
Monterey, California, United States

Sponsored by
SPIE

Co-sponsored by
Nikon Inc. (United States) • Gigaphoton Inc. (Japan) • Hitachi (Japan) • Fujifilm (Japan)
ASML (Netherlands) • Lasertec (Japan) • Tokyo Ohka Kogyo Co., Ltd. (Japan) • Screen
Semiconductor Solutions Co., Ltd. (Japan) • EMD Performance Materials Corp. (United States)
Nuflare Technologies, Inc. (Japan) • Tokyo Electron Ltd. (Japan) • Lexel Corp. (United States)
JSR Micro Inc. (United States) • Carl Zeiss SMT GMBH (Germany) • IMEC (Belgium) • Hoya
(Japan)

Published by
SPIE

Volume 10450

Proceedings of SPIE 0277-786X, V. 10450

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

International Conference on Extreme Ultraviolet Lithography 2017, edited by Paolo A. Gargini,
Patrick P. Naulleau, Kurt G. Ronse, Toshiro Itani, Proc. of SPIE Vol. 10450, 1045001
© 2017 SPIE · CCC code: 0277-786X/17/\$18 · doi: 10.1117/12.2293159

Proc. of SPIE Vol. 10450 1045001-1

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 *International Conference on Extreme Ultraviolet Lithography 2017*, edited by Paolo A. Gargini, Patrick P. Naulleau, Kurt G. Ronse, Toshiro Itani, Proceedings of SPIE Vol. 10450 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510613744
ISBN: 9781510613751 (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>
ix	<i>Conference Committee</i>

EUV READINESS: JOINT SESSION WITH CONFERENCES 10450 AND 10451

10450 05	EUV mask manufacturing readiness in the merchant mask industry [10450-4]
----------	---

EUV MASK INSPECTION: JOINT SESSION WITH CONFERENCES 10451 AND 10450

10450 06	Classification and printability of EUV mask defects from SEM images [10450-5]
10450 07	Actinic inspection of EUV reticles with arbitrary pattern design [10450-6]

EUV MASK METROLOGY AND INSPECTION: JOINT SESSION WITH CONFERENCES 10450 AND 10451

10450 08	Measurement of through-focus EUV pattern shifts using the SHARP actinic microscope [10450-7]
----------	---

EUV MASK PELLICLE: JOINT SESSION WITH CONFERENCES 10451 AND 10450

10450 0B	Efficient simulation of EUV pellicles [10450-11]
----------	---

EUV MASK AND IMAGING

10450 0C	EUV source optimization driven by fundamental diffraction considerations [10450-12]
10450 0F	Individual multilayer reflectance and near field image formation in an EUV reticle [10450-16]

EUV RESIST I

10450 0H	Unraveling the role of secondary electrons upon their interaction with photoresist during EUV exposure [10450-17]
----------	--

EUV RESISTS II

10450 0P	Reducing roughness in extreme ultraviolet lithography [10450-25]
----------	---

HIGH-NA EUV LITHOGRAPHY	
10450 0V	Optical proximity correction for anamorphic extreme ultraviolet lithography [10450-31]
EUV SOURCE	
10450 0Z	High-power LPP-EUV source with long collector mirror lifetime for high volume semiconductor manufacturing [10450-35]
EUV PATTERNING AND PROCESS ENHANCEMENT I	
10450 17	EUV local CDU healing performance and modeling capability towards 5nm node [10450-43]
10450 18	Roadmap evolution: from NTRS to ITRS, from ITRS 2.0 to IRDS [10450-44]
EUV PATTERNING AND PROCESS ENHANCEMENT II	
10450 1A	Development of amorphous silicon based EUV hardmasks through physical vapor deposition [10450-46]
POSTER SESSION: EUV SOURCE	
10450 1C	Key components development progress updates of the 250W high power LPP-EUV light source [10450-48]
POSTER SESSION: EUV RESISTS AND PROCESS	
10450 1E	A study on enhancing EUV resist sensitivity (2) [10450-50]
10450 1F	Technology for defectivity improvement in resist coating and developing process in EUV lithography process [10450-51]
10450 1H	Development of the negative-tone molecular resists for EB/EUVL having high EUV absorption capacity and molecular design method [10450-53]
POSTER SESSION: EUV PELLICLES	
10450 1K	Lifetime estimation of extreme-ultraviolet pellicle at 500 W source power by thermal stress analysis [10450-56]
10450 1L	Characterization of pellicle membranes by lab-based spectroscopic reflectance and transmittance measurements in the extreme ultraviolet [10450-57]

- 10450 1M **Search for multi-stack EUV pellicle membrane for EUV non-actinic mask inspection** [10450-58]
- 10450 1N **Thermo-mechanical behavior analysis of extreme-ultraviolet pellicle cooling with H₂ flow** [10450-59]
- 10450 1O **Lifetime impact on residual stress of EUV pellicle** [10450-60]
- 10450 1Q **Wrinkle formation analysis in extreme-ultraviolet pellicle** [10450-62]

POSTER SESSION: EUV PATTERNING AND PROCESS ENHANCEMENT

- 10450 1T **Contrast matching of line gratings obtained with NXE3XXX and EUV- interference lithography** [10450-65]
- 10450 1U **Coater/developer based techniques to improve high-resolution EUV patterning defectivity** [10450-66]

POSTER SESSION: EUV MASK METROLOGY, INSPECTION, AND IMAGING

- 10450 1X **Applications of RCWA on EUV mask optics** [10450-70]

POSTER SESSION: EUV HARDWARE

- 10450 21 **Extreme ultra violet lithographic optical projection system design method using Code V lens module and generalized Gaussian constants** [10450-72]
- 10450 24 **A new objective for EUV lithography, EUV microscopy, and 2D x-ray imaging** [10450-75]
- 10450 27 **Characterization of EBL2 EUV exposure facility** [10450-78]
- 10450 2A **Optimized phase-shifting masks for high-resolution resist patterning by interference lithography** [10450-81]

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.

Abe, Tamotsu, 0Z, 1C	Hetzer, Dave, 1U
Adam, Kostas, 0V	Hill, Kenneth W., 24
Bahrenberg, Lukas, 1L, 2A	Hoefnagels, Rik, 1T
Ban, Chung-Hyun, 1K	Hontake, Koichi, 1U
Benk, Markus, 08	Hori, Tsukasa, 0Z, 1C
Bitter, Manfred L., 24	Hsiao, Li-Jen, 2I
Broman, Par, 0C	Hubbard, Alex, 1U
Brose, Sascha, 1L, 2A	Huli, Lior, 1U
Cao, Yong, 1A	Hur, Su-Mi, 1M
Chen, Alek, 05	Ichinomiya, Hiroshi, 1F
Chen, Yulu, 08	Ishii, Takuya, 1C
Chiou, Tsann-Bim, 05	Isoyan, Artak, 0F
Cho, Wonil, 06	Itou, Noritoshi, 1C
Choi, Peter, 17	Jee, Tae Kwon, 17
Choi, Yohan, 05	Jeong, Hae-Nam, 1Q
Clifford, Chris, 0V	Jiang, Fan, 0V
Custers, Rolf, 1T	Jiang, Jing, 0H
Dai, Huixiong, 1A	Johnson, Richard, 1U
Danylyuk, Serhiy, 1L, 2A	Juschkin, Larissa, 2A
De Silva, Anuja, 1A, 1U	Kamberian, Henry, 05, 08
de Simone, Danilo, 0H	Kamei, Yuya, 1F
Delgado-Aparicio, Luis F., 24	Kandel, Yudhi, 0F
Deutz, Alex F., 27	Kang, Myung-Gi, 1N
DeVries, Scott, 1A	Kasprowicz, Bryan, 08
Diehl, Daniel L., 1A	Kawakami, Shinichiro, 1F, 1U
Dong, Lisong, 1X	Kawasuji, Yasufumi, 0Z, 1C
Echigo, Masatoshi, 1H	Kazazis, Dimitrios, 07
Eftthimion, Philip C., 24	Kerkhof, Peter J., 27
Ekinci, Yasin, 07, 1T	Kim, Guk-Jin, 1M, 1Q
Enomoto, Masashi, 1F	Kim, Min-Woo, 1O
Erdmann, A., 0B	Ko, Akiteru, 1U
Evanschitzky, P., 0B	Kodama, Takeshi, 0Z, 1C
Fallica, Roberto, 1T	Koike, Kyohei, 17
Fan, Taian, 1X	Koster, Norbert B., 27
Felix, Nelson M., 1A, 1U	Kraus, Brian F., 24
Fenger, Germain, 0V	Kudo, Hiroto, 1H
Fernandez, Sara, 07	Lam, Michael, 0V
Finders, Jo, 0C	Lammers, Ad, 05
Fonseca, Carlos, 17	Lebert, Rainer, 2A
Foubert, Philippe, 1F	Lee, Sung-Gyu, 1M, 1N, 1O, 1Q
Gallagher, Emily, 1L	Lemley, Corey, 1U
Gao, Lan, 24	Lin, Hoang-Yan, 2I
Gao, Weimin, 0F	Liu, Eric, 1U
Gargini, Paolo A., 18	Loosen, Peter, 1L, 2A
Goldberg, Kenneth, 08	Lu, Jian, 24
Green, Michael, 05	Mack, Chris A., 0P
Ham, Young, 05	Mangat, Pawitter, 08
Harada, Tetsuo, 1E, 1H	Matsumoto, Yoko, 1E
Hashimoto, Yusaku, 1U	McCord, Jeremy, 08
Helfenstein, Patrick, 07	McNamara, John, 0C

Meeuwissen, Marieke, 1T
 Meli, Luciana, 1A, 1U
 Melvin, Lawrence S., 0F
 Mignot, Yann, 1A
 Miyao, Kenichi, 1C
 Miyazaki, Junji, 05
 Mizoguchi, Hakaru, 0Z, 1C
 Mochi, Iacopo, 07, 1T
 Molkenboer, Freek T., 27
 Morgan, Paul A., 06
 Mulckhuyse, Wouter, 27
 Murray, Cody, 1U
 Nafus, Kathleen, 1F
 Naito, Michiya, 1E
 Nakarai, Hiroaki, 0Z, 1C
 Ngai, Christopher S., 1A
 Nowak, Krzysztof M., 0Z
 Oh, Hye-Keun, 1K, 1M, 1N, 1O, 1Q
 Okamoto, Takeshi, 1C
 Olvera, Karen Garrido, 1T
 Oostdijck, Bastiaan W., 27
 Pablant, Novimir A., 24
 Park, Eun-Sang, 1K, 1N, 1O
 Park, Jae-Hun, 1K
 Petrillo, Karen, 1U
 Phan, Khoi, 1A
 Pollentier, Ivan, 0H, 1L
 Price, Daniel, 06
 Progler, Chris, 05
 Raghunathan, Ananthan, 0V
 Rajeev, Rajendran, 07
 Rio, David, 17
 Rispens, Gijsbert, 1T
 Rost, Daniel, 06
 Saitou, Takashi, 0Z, 1C
 Satake, Masaki, 06
 Sato, Takashi, 1H
 Schoofs, Stijn, 17
 Sekiguchi, Atsushi, 1E
 Seshadri, Indira, 1A
 Shimoaoki, Takeshi, 1U
 Shiozawa, Takahiro, 1F
 Shiraishi, Yutaka, 0Z, 1C
 Soumagne, Georg, 0Z
 Stolfi, Michael, 1A
 Stollenwerk, Jochen, 1L
 Takigawa, Tomoaki, 1H
 Tanaka, Hiroshi, 0Z, 1C
 Tanaka, Koichiro, 1U
 Tasdemir, Zuhdi, 1T
 te Sligte, Edwin, 27
 Timmermans, Marina, 1L
 Timoshkov, Vadim, 17
 Togashi, Yuta, 1H
 Toida, Takumi, 1H
 Tolani, Vikram L., 06
 Tsai, Yu-Cheng, 17
 Tseng, Shih-En, 05
 Utsumi, Yoshiyuki, 1E
 van Adrichem, Paul, 0C
 van der Walle, Peter, 27
 van Putten, Michel, 27
 van Setten, Eelco, 0C
 Vanelderen, Pieter, 0H
 Vesters, Yannick, 0H
 Vockenhuber, Michaela, 1T
 Wallow, Thomas, 08
 Wang, Erik, 0C
 Watanabe, Takeo, 1E, 1H
 Watanabe, Yukio, 0Z, 1C
 Wei, Yayi, 1X
 Westerhout, Jeroen, 27
 Wood, Obert, 08
 Xu, Yongan, 1A, 1U
 Yabu, Takayuki, 1C
 Yaegashi, Hidetami, 17
 Yamada, Tsuyoshi, 0Z
 Yamazaki, Taku, 0Z, 1C
 Yanagida, Tatsuya, 0Z, 1C
 Yildirim, Oktay, 1T
 Yoshitake, Shusuke, 07
 Zeng, Wilson, 1A

Conference Committee

Conference Chairs

Paolo A. Gargini, Stanford University (United States)
Patrick P. Naulleau, Lawrence Berkeley National Laboratory
(United States)
Kurt G. Ronse, IMEC (Belgium)
Toshiro Itani, EUVL Infrastructure Development Center, Inc. (Japan)

Conference Program Committee

Eric M. Panning, Intel Corporation (United States)
Winfried Kaiser, Carl Zeiss SMT GmbH (Germany)
Satoshi Tanaka, EUVL Infrastructure Development Ctr., Inc. (Japan)
Eric Hendrickx, IMEC (Belgium)

Session Chairs

Keynote Session: Joint Session with conferences 10451 and 10450
Eric M. Panning, Intel Corporation (United States)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)

EUV Readiness: Joint session with conferences 10450 and 10451
Eric M. Panning, Intel Corporation (United States)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)

EUV Mask Inspection: Joint session with conferences 10451 and 10450
Paul A. Morgan, Micron Technology, Inc. (United States)

EUV Mask Metrology and Inspection: Joint session with conferences
10450 and 10451
Bryan S. Kasprowitz, Photronics, Inc. (United States)
Thomas Scheruebl, Carl Zeiss SMT GmbH (Germany)

EUV Mask Pellicle: Joint session with conferences 10451 and 10450
Emily E. Gallagher, IMEC (Belgium)
Dario L. Goldfarb, IBM Thomas J. Watson Research Center
(United States)

EUV Mask and Imaging
Peter Evanschitzky, Fraunhofer-Institut für Integrierte Systeme und
Bauelementetechnologie IISB (Germany)
Jin-ho Ahn, Hanyang University (Korea, Republic of)

EUV Resist I

Gregory H. Denbeaux, SUNY Polytechnic Institute (United States)

Takahiro Kozawa, Osaka University (Japan)

EUV Resists II

Eishi Shiobara, EUVL Infrastructure Development Center, Inc. (Japan)

Student Session: Joint session with conferences 10451 and 10450

Yuyang Sun, Mentor Graphics Corporation (United States)

Shinji Okazaki, ALITECS Company, Ltd. (Japan)

High-NA EUV Lithography

Winfried Kaiser, Carl Zeiss SMT GmbH (Germany)

Erik R. Hosler, GLOBALFOUNDRIES Inc. (United States)

EUV Source

Jan van Schoot, ASML Netherlands B.V. (Netherlands)

Sang Hun Lee, Intel Corporation (United States)

EUV Patterning and Process Enhancement I

Ryoung-Han Kim, IMEC (Belgium)

EUV Patterning and Process Enhancement II

Akiyoshi Suzuki, Gigaphoton Inc. (Japan)

Wang Yueh, Intel Corporation (United States)