

PROCEEDINGS OF SPIE

Photomask and Next-Generation Lithography Mask Technology XX

Kokoro Kato

Editor

16–18 April 2013

Yokohama, Japan

Sponsored by

PMJ Photomask Japan

BACUS

SPIE

Published by

SPIE

Volume 8701

Proceedings of SPIE 0277-786X, V. 8701

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

Photomask and Next-Generation Lithography Mask Technology XX,
edited by Kokoro Kato, Proc. of SPIE Vol. 8701, 870101 · © 2013 SPIE
CCC code: 0277-786X/13/\$18 · doi: 10.1117/12.2032560

Proc. of SPIE Vol. 8701 870101-1

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 *Photomask and Next-Generation Lithography Mask Technology XX*, edited by Kokoro Kato, Proceedings of SPIE Vol. 8701 (SPIE, Bellingham, WA, 2013) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819494917

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 © 2013, 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/13/\$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 as 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*

WRITING TECHNOLOGIES

- 8701 02 **Modeling of resist surface charging effect on EBM-8000 and its comparison with EBM-6000** [8701-34]
N. Nakayamada, T. Kamikubo, H. Anze, M. Ogasawara, NuFlare Technology, Inc. (Japan)
- 8701 03 **Next generation electron beam lithography system F7000 for wide range applications** [8701-29]
H. Hayakawa, M. Takizawa, M. Kurokawa, A. Tsuda, M. Takigawa, S. Hamaguchi, A. Yamada, K. Sakamoto, T. Nakamura, Advantest Corp. (Japan)

MATERIAL AND PROCESS

- 8701 04 **Effect of cleaning chemistry on MegaSonic damage** [8701-13]
S. Singh, U. Dietze, SUSS MicroTec Inc. (United States); P. Dress, SUSS MicroTec Photomask Equipment GmbH & Co. KG (Germany)
- 8701 05 **Megasonic cleaning: effect of dissolved gas properties on cleaning** [8701-33]
H. Shende, MP Mask Technology Ctr., LLC (United States); S. Singh, SUSS MicroTec Inc. (United States); J. Baugh, MP Mask Technology Ctr., LLC (United States); U. Dietze, SUSS MicroTec Inc. (United States); P. Dress, SUSS MicroTec Photomask Equipment GmbH & Co. KG (Germany)
- 8701 06 **Physical force optimization for advanced photomask cleaning** [8701-24]
C. W. Shen, K. W. Lin, C. L. Lu, L. Hsu, A. Chin, A. Yen, Taiwan Semiconductor Manufacturing Co., Ltd. (Taiwan)
- 8701 07 **Progressive defects caused by crosstalk between mask fabrication processes** [8701-53]
J. Oh, J. Choi, J. Choi, H. Lee, H. Koh, B. Kim, C. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)

REPAIR

- 8701 08 **In-situ repair qualification by applying Computational Metrology and Inspection (CMI) technologies** [8701-41]
C. Y. Chen, I. Wei, L. Tuo, C. S. Yoo, Taiwan Semiconductor Manufacturing Co. (Taiwan); D. Chen, D. Peng, M. Satake, B. Su, L. Pang, Luminescent Technologies, Inc. (United States)

- 8701 09 **A method of utilizing AIMS to quantify substrate/attenuator over-etch or under-etch during mask repair** [8701-10]
V. Sargsyan, K. Olson, Carl Zeiss SBE, LLC, SMS Division (United States); D. Uzzel, J. Morgan, M. Ma, Photronics, Inc. (United States); G. Tabbone, Carl Zeiss SMS GmbH (Germany); A. Garetto, Carl Zeiss SBE, LLC, SMS Division (Germany)

INSPECTION AND METROLOGY I

- 8701 0A **Photomask quality evaluation using lithography simulation and multi-detector MVM-SEM** [8701-3]
K. Ito, T. Murakawa, N. Fukuda, S. Shida, T. Iwai, J. Matsumoto, T. Nakamura, Advantest Corp. (Japan); S. Matsushita, K. Hagiwara, D. Hara, D2S K.K. (Japan)
- 8701 0B **Mask degradation monitoring with aerial mask inspector** [8701-16]
W.-J. Tseng, Y.-Y. Fu, S.-P. Lu, M.-S. Jiang, Rexchip Corp. (Taiwan); J. Lin, C. Wu, Applied Materials (Taiwan); S. Lifschitz, A. Tam, Applied Materials (Israel)

MDP AND EDA

- 8701 0C **Fuzzy pattern matching techniques for photomask layout data** [8701-9]
K. Kato, Y. Taniguchi, K. Nishizawa, Hitachi High-Tech Science Corp. (Japan)
- 8701 0D **Using a mask rule checker as an electrical rule checker** [8701-27]
P. Morey-Chaisemartin, E. Beisser, XYALIS (France)
- 8701 0E **Verification: an enabler for model based data preparation** [8701-50]
P. Schiavone, A. Chagoya, L. Martin, V. Annezo, A. Blanchemain, Aselta Nanographics (France)
- 8701 0F **Comparison techniques for VSB fractured vs. unfractured data** [8701-7]
D. Salazar, J. Valadez, Synopsys, Inc. (United States)
- 8701 0G **Circle pattern detector & VSB shot count estimator** [8701-26]
S. Munoz, Synopsys Chile R&D Ctr. (Chile); R. Kondepudy, Synopsys, Inc. (United States)
- 8701 0H **Better numerical model for shape-dependent dose margin correction using model-based mask data preparation** [8701-22]
Y. Kimura, T. Kubota, K. Kouno, HOYA Corp. (Japan); K. Hagiwara, S. Matsushita, D. Hara, D2S K.K. (Japan)

FPD PHOTOMASKS

- 8701 0I **High resolution technology for FPD lithography tools** [8701-17]
N. Yabu, Y. Nagai, S. Tomura, T. Yoshikawa, Canon Inc. (Japan)
- 8701 0J **Development of the CLIOS G821 system for inspection of LSPM for high-definition FPDs** [8701-28]
M. Takano, M. Hamakawa, M. Toriguchi, S. Kuroda, A. Tajima, Lasertec Corp. (Japan)

MDP

- 8701 0K **In collaboration with mask suppliers for change management enhancement** [8701-18]
E. Deng, C. D. Lee, R. Lee, United Microelectronics Corp. (Taiwan)
- 8701 0L **Quality enhancement of parallel MDP flows with mask suppliers** [8701-19]
E. Deng, R. Lee, C. D. Lee, United Microelectronics Corp. (Taiwan)
- 8701 0M **Layout finishing of a 28nm, 3 billions transistors, multi-core processor** [8701-20]
P. Morey-Chaisemartin, E. Beisser, XYALIS (France)
- 8701 0N **A novel algorithm for notch detection** [8701-23]
C. Acosta, D. Salazar, D. Morales, Synopsys Chile R&D Ctr. (Chile)
- 8701 0O **Advancements in automatic marking with range pattern matching** [8701-6]
D. Salazar, J. Valadez, Synopsys, Inc. (United States)
- 8701 0P **A study of applications scribe frame data verifications using design rule check** [8701-21]
S. Saito, M. Miyazaki, M. Sakurai, T. Itoh, K. Doi, N. Sakurai, T. Okada, Fujitsu Semiconductor Ltd. (Japan)

EUVL MASKS I

- 8701 0Q **Exploring probability of shallow ML defect impact to defect assurance** [8701-48]
K. Matsui, Toppan Printing Co., Ltd. (Japan); N. Takagi, EUVL Infrastructure Development Ctr., Inc. (Japan); S. Takahashi, Y. Kodera, Y. Sakata, S. Akima, Toppan Printing Co., Ltd. (Japan)
- 8701 0R **Challenge for under 40nm size pattern making for EUV mask** [8701-36]
T. Abe, Y. Inazuki, Y. Kobayashi, Y. Morikawa, H. Mohri, N. Hayashi, Dai Nippon Printing Co., Ltd. (Japan)
- 8701 0S **Development of optical system on novel Projection Electron Microscopy (PEM) for EUV masks and its basic performance evaluation** [8701-38]
M. Hatakeyama, T. Murakami, K. Terao, K. Watanabe, Y. Naito, EBARA Corp. (Japan); T. Amano, R. Hirano, S. Iida, T. Terasawa, H. Watanabe, EUVL Infrastructure Development Ctr., Inc. (Japan)
- 8701 0T **EUV scanner throughput considerations for the higher mask magnification** [8701-2]
K. Takehisa, Lasertec Corp. (Japan)

LITHOGRAPHY RELATED TECHNOLOGIES

- 8701 0U **Projection exposure using a projector with highly minute liquid crystal display panels** [8701-8]
S. Koyama, K. Saito, T. Horiuchi, Tokyo Denki Univ. (Japan)

INSPECTION AND METROLOGY II

- 8701 0V **Improvement of a DUV mask inspection tool to hand over the baton for next-generation tool smoothly** [8701-30]
H. Hashimoto, N. Kikuri, E. Matsumoto, H. Tsuchiya, R. Ogawa, I. Isomura, M. Isobe, K. Takahara, NuFlare Technology, Inc. (Japan)
- 8701 0W **EUV reticle inspection with a 193nm reticle inspector** [8701-51]
W. Broadbent, G. Inderhees, T. Yamamoto, I. Lee, P. Lim, KLA-Tencor Corp. (United States)

EUVL MASKS II

- 8701 0X **Investigation of cleaning process induced CD shift at EUV mask** [8701-14]
P. Nesladek, F. Schunke, S. Rümmelin, Advanced Mask Technology Ctr. GmbH & Co. KG (Germany); K. Dittmar, GLOBALFOUNDRIES Dresden Module One, LLC & Co. KG (Germany)
- 8701 0Z **E-beam resist outgassing for study of correlation between resist sensitivity and e-beam optic contamination** [8701-54]
S.-I. Lee, Y. S. Jeong, C. H. Park, H. B. Kim, I. Shin, C.-U. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)

EUVL MASKS III

- 8701 10 **A study of phase defect measurement on EUV mask by multiple detectors CD-SEM (Best Student Paper)** [8701-49]
I. Yonekura, H. Hakii, S. Morisaki, Toppan Printing Co., Ltd. (Japan); T. Murakawa, S. Shida, M. Kuribara, T. Iwai, J. Matsumoto, T. Nakamura, Advantest Corp. (Japan)
- 8701 11 **Defect printability studies at SEMATECH** [8701-15]
I.-Y. Jang, R. Teki, V. Jindal, F. Goodwin, SEMATECH North (United States); M. Satake, Y. Li, D. Peng, Luminescent Technologies, Inc. (United States); S. Huh, S.-S. Kim, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)
- 8701 12 **Using pattern shift to avoid blank defects during EUVL mask fabrication** [8701-45]
Y. Negishi, Y. Fujita, K. Seki, T. Konishi, Toppan Photomasks, Inc. (United States); J. Rankin, S. Nash, E. Gallagher, IBM Corp. (United States); A. Wagner, IBM Watson Research Ctr. (United States); P. Thwaite, A. Elayat, Mentor Graphics Corp. (United States)
- 8701 13 **A very fast and accurate rigorous EMF simulator for EUVL masks based on the pseudo-spectral time-domain method** [8701-5]
M. Yeung, Fastlitho Inc. (United States); E. Barouch, Boston Univ. (United States)

EUVL MASKS IV

- 8701 14 **Evaluation of non-actinic EUV mask inspection and defect printability on multiple EUV mask absorbers** [8701-32]
K. Badger, E. Gallagher, IBM Microelectronics (United States); K. Seki, Toppan Photomasks, Inc. (United States); G. McIntyre, IBM Microelectronics (United States); T. Konishi, Toppan Photomasks, Inc. (United States); Y. Kodera, Toppan Printing Co., Ltd. (Japan); V. Redding, KLA-Tencor Corp. (United States)
- 8701 15 **Extending DUV mask inspection tool for inspecting 2xnm HP and beyond** [8701-55]
J. Na, S. H. Han, G. Yoon, D. H. Chung, B.-G. Kim, C. Jeon, SAMSUNG Electronics Co., Ltd. (Korea, Republic of); D. Bernstein, L. Shoval, I. Dolev, O. Shopen, Applied Materials (Israel); J. S. Lee, C. Lyu, S. R. Bae, Applied Materials (Korea, Republic of)

EUVL MASKS V

- 8701 16 **Pattern inspection performance of novel Projection Electron Microscopy (PEM) on EUV masks** [8701-39]
R. Hirano, S. Iida, T. Amano, T. Terasawa, H. Watanabe, EUVL Infrastructure Development Ctr., Inc. (Japan); M. Hatakeyama, T. Murakami, K. Terao, EBARA Corp. (Japan)
- 8701 18 **The capability of high magnification review function for EUV actinic blank inspection tool** [8701-42]
H. Miyai, T. Suzuki, K. Takehisa, H. Kusunose, Lasertec Corp. (Japan); T. Yamane, T. Terasawa, H. Watanabe, I. Mori, EUVL Infrastructure Development Ctr., Inc. (Japan)
- 8701 19 **Phase imaging of EUV masks using a lensless EUV microscope** [8701-4]
T. Harada, M. Nakasuji, Univ. of Hyogo (Japan) and CREST, Japan Science and Technology Agency (Japan); Y. Nagata, RIKEN (Japan) and CREST, Japan Science and Technology Agency (Japan); T. Watanabe, H. Kinoshita, Univ. of Hyogo (Japan) and CREST, Japan Science and Technology Agency (Japan)

Author Index

Conference Committees

Symposium Chair

Toshiyuki Horiuchi, Tokyo Denki University (Japan)

Symposium Vice-chair

Masato Shibuya, Tokyo Polytechnic University (Japan)

Advisory Committee Chair

Yasuo Tarui, Tokyo University of Agriculture and Technology (Japan)

Advisory Committee

Morihisa Hoga, Dai Nippon Printing Company, Ltd. (Japan)

Masanori Komuro, New Energy and Industrial Technology
Development Organization (Japan)

Masao Otaki, Toppan Printing Company, Ltd. (Japan)

Norio Saito, Nippon Institute of Technology (Japan)

Yoshio Tanaka, Luminescent Technologies, Inc. (Japan)

Organizing Committee Chair

Toshiyuki Horiuchi, Tokyo Denki University (Japan)

Organizing Committee Vice-chair

Masato Shibuya, Tokyo Polytechnic University (Japan)

Organizing Committee

Uwe Behringer, UBC Microelectronics (Germany)

Parkson Chen, Taiwan Mask Corporation (Taiwan)

Han-ku Cho, Samsung Electronics Company, Ltd. (Korea, Republic of)

Junko Collins, SEMI Japan (Japan)

Brian J. Grenon, Advanced Technical Instruments (United States)

Takehiko Gunji, Sony Corporation (Japan)

Hideaki Hamada, HTL Company Japan Ltd. (Japan)

Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)

Eiichi Hoshino, Nikon Corporation (Japan)

Kunihiro Hosono, Renesas Electronics Corporation (Japan)

Gregory Hughes, SEMATECH (United States)

Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)

Hideaki Mitsui, HOYA Corporation (Japan)
Warren Montgomery, CNSE (United States)
Ichiro Mori, EUVL Infrastructure Development Center, Inc. (Japan)
Hiroaki Morimoto, Toppan Printing Company, Ltd. (Japan)
Yoshiki Suzuki, KLA-Tencor Japan Ltd. (Japan)
Tadahiro Takigawa, ASML Japan Company, Ltd. (Japan)
Koichiro Tsujita, Canon Inc. (Japan)
Anto Yasaka, SII NanoTechnology Inc. (Japan)

Steering Committee Chair

Hiroaki Morimoto, Toppan Printing Company, Ltd. (Japan)

Steering Committee Vice-chairs

Kunihiro Hosono, Renesas Electronics Corporation (Japan)
Hidehiro Watanabe, EUVL Infrastructure Development Center, Inc.
(Japan)

Steering Committee

Takayuki Abe, NuFlare Technology Inc. (Japan)
Shinji Akima, Toppan Printing Company, Ltd. (Japan)
Kazuko Jochi, KLA-Tencor Japan Ltd. (Japan)
Ichiro Kagami, Sony Corporation (Japan)
Takashi Kamo, Toshiba Corporation Corporate Research and
Development Center (Japan)
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)
Yasutaka Morikawa, Dai Nippon Printing Company, Ltd. (Japan)
Yasushi Ohkubo, HOYA Corporation (Japan)
Tomoyuki Okada, FUJITSU SEMICONDUCTOR LTD. (Japan)
Toshiyuki Takahashi, JEOL Ltd. (Japan)
Kiwamu Takehisa, Lasertec Corporation (Japan)
Hiroyoshi Tanabe, Intel K.K. (Japan)

Program Committee Chair

Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)

Program Committee Vice-chairs

Shinji Akima, Toppan Printing Company, Ltd. (Japan)
Ichiro Kagami, Sony Semiconductor Corporation (Japan)

Program Committee

Tsukasa Abe, Dai Nippon Printing Company, Ltd. (Japan)
Akihiko Ando, Renesas Electronics Corporation (Japan)
Tadashi Arai, Canon Inc. (Japan)
Jeff Farnsworth, Intel Corporation Technology and Manufacturing Group (United States)
Thomas B. Faure, IBM Corporation (United States)
Kazuyuki Hagiwara, D2S, K.K. (Japan)
Shigeru Hirukawa, Nikon Corporation (Japan)
Koji Hosono, FUJITSU SEMICONDUCTOR LTD. (Japan)
Hidemichi Imai, Dai Nippon Printing Company, Ltd. (Japan)
Gregg Inderhees, KLA-Tencor Corporation (United States)
Franklin Kalk, Toppan Photomask, Inc. (Japan)
Byung-Gook Kim, Samsung Electronics Company, Ltd. (Korea, Republic of)
Jun Kotani, Toppan Printing Company, Ltd. (Japan)
John Lin, Taiwan Semiconductor Manufacturing Company, Ltd. (Taiwan)
Mark Ma, Photronics, Inc. (United States)
Koji Murano, Toshiba Corporation (Japan)
Yoshinori Nagaoka, KLA-Tencor Japan Ltd. (Japan)
Yasutoshi Nakagawa, JEOL Ltd. (Japan)
Noriaki Nakayamada, NuFlare Technology Inc. (Japan)
Yuji Nonami, Panasonic Corporation (Japan)
Steffen Schulze, Mentor Graphics Corporation (United States)
Yasunari Sohda, Hitachi, Ltd. (Japan)
Osamu Suga, EUVL Infrastructure Development Center, Inc. (Japan)
Yoji Takagi, Applied Materials Japan, Inc. (Japan)
Kiwamu Takehisa, Lasertec Corporation (Japan)
Hironobu Taoka, Renesas Electronics Corporation (Japan)
Richard Tseng, Taiwan Mask Corporation (Taiwan)
Yoichi Usui, HOYA Corporation (Japan)

Session Chairs

Opening Session

Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)

Writing Technologies

Jun Kotani, Toppan Printing Company, Ltd. (Japan)

Uwe Behringer, UBC Microelectronics (Japan)

Material and Process

Koji Murano, Toshiba Corporation (Japan)

Thomas B. Faure, IBM Corporation (Taiwan)

Invited Session

Naoki Nishida, HOYA Corporation (Japan)
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)
Richard Tseng, Taiwan Mask Corporation (Taiwan)

Repair

Naoki Nishida, HOYA Corporation (Japan)
Kokoro Kato, Hitachi High-Tech Science Corporation (Japan)
Richard Tseng, Taiwan Mask Corporation (Taiwan)

Inspection and Metrology

Akihiko Ando, Renesas Electronics Corporation (Japan)
Anna Tchikoulaeva, Lasertec U.S.A., Inc. (United States)

MDP and EDA

Koji Hosono, FUJITSU SEMICONDUCTOR LIMITED (Japan)
Steffen Schulze, Mentor Graphics Corporation (United States)

FPD Photomasks

Ichiro Kagami, Sony Semiconductor Corporation (Japan)
Tor Sandstrom, Micronic Mydata (Sweden)

EUVL Masks I

Tsukasa Abe, Dai Nippon Printing Company, Ltd. (Japan)
Inkyun Shin, Samsung Electronics (Korea)

EUVL Masks II

Jun Kotani, Toppan Printing Company, Ltd. (Japan)
Jeff Farnsworth, Intel Corporation Technology and Manufacturing
Group (United States)

EUVL Masks III

Kiwamu Takehisa, Lasertec Corporation (Japan)
Frank Abboud, Intel Corporation (United States)

EUVL Masks IV

Yoshinori Nagaoka, KLA-Tencor Japan Ltd. (Japan)
Emily Gallagher, IBM (United States)