PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 9231

, "Front Matter: Volume 9231," Proc. SPIE 9231, 30th European Mask and Lithography Conference, 923101 (17 October 2014); doi: 10.1117/12.2083409

SPIE.

Event: 30th European Mask and Lithography Conference, 2014, Dresden, Germany

PROCEEDINGS OF SPIE

30th European Mask and Lithography Conference

Uwe F.W. Behringer

Editor

24–25 June 2014

Dresden, Germany

Organized by

VDE/VDI GMM—The Society for Microelectronics,
Micro- and Precision Engineering (Germany)

Published by

SPIE

Volume 9231

Proceedings of SPIE 0277-786X, V. 9231

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

30th European Mask and Lithography Conference, edited by Uwe F.W. Behringer, Proc. of SPIE Vol. 9231,
923101 · © 2014 SPIE · CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2083409

Proc. of SPIE Vol. 9231 923101-1

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 *30th European Mask and Lithography Conference*, edited by Uwe F.W. Behringer, Proceedings of SPIE Vol. 9231 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X
ISBN: 9781628412857

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 © 2014, 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/14/\$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

vii	<i>Authors</i>
ix	<i>Conference Committee</i>
xiii	<i>Foreword</i>
xv	<i>Sponsors and Cooperating Partners</i>
xvii	<i>High performance mask fabrication process for the next-generation mask production (Best Paper of PMJ 2014) [9256-21]</i>

PLENARY SESSION I

9231 02	Black border, mask 3D effects: covering challenges of EUV mask architecture for 22nm node and beyond (Best Poster BACUS 2013) [9231-19]
---------	--

PLENARY SESSION II

9231 03	EUV lithography: progress, challenges, and outlook (Keynote Paper) [9231-35]
9231 04	28nm node process optimization: a lithography centric view (Invited Paper) [9231-26]

MASK WRITING TIME OPTIMIZATION

9231 06	Reticles, write time, and the need for speed (Invited Paper) [9231-36]
9231 07	Writing time estimation of EB mask writer EBM-9000 for hp16nm/logic11nm node generation [9231-8]

EUV LITHOGRAPHY

9231 08	Imaging performance and challenges of 10nm and 7nm logic nodes with 0.33 NA EUV [9231-18]
9231 09	Scanner arc illumination and impact on EUV photomasks and scanner imaging [9231-24]

EUV MASK TECHNOLOGY

- 9231 OB **High-throughput parallel SPM for metrology, defect, and mask inspection** [9231-14]

E-BEAM TECHNOLOGIES

- 9231 OD **New LEEPL technology (Invited Paper)** [9231-34]
- 9231 OE **Multi-stencil character projection e-beam lithography: a fast and flexible way for high quality optical metamaterials** [9231-17]
- 9231 OF **Integration of e-beam direct write in BEOL processes of 28nm SRAM technology node using mix and match** [9231-25]

TEMPLATES TECHNOLOGIES

- 9231 OH **Replicating micro-optical structures using soft embossing technique** [9231-13]

SIMULATION

- 9231 OI **14-nm photomask simulation sensitivity** [9231-20]
- 9231 OJ **Aerial image simulation for partial coherent system with programming development in MATLAB** [9231-11]

METROLOGY

- 9231 OL **Photomask CD and LER characterization using Mueller matrix spectroscopic ellipsometry** [9231-10]
- 9231 OM **Determination of line profiles on photomasks using DUV, EUV, and x-ray scattering** [9231-16]

WAFER PROCESSING

- 9231 OO **Overlay leaves litho: impact of non-litho processes on overlay and compensation** [9231-29]
- 9231 OP **Lithography with infrared illumination alignment for advanced BiCMOS backside processing** [9231-5]

DSA TECHNOLOGY AND ALTERNATIVE LITHOGRAPHY

- 9231 0Q **Compact model experimental validation for grapho-epitaxy hole processes and its impact in mask making tolerances** [9231-12]
- 9231 0R **Contact hole multiplication using grapho-epitaxy directed self-assembly: process choices, template optimization, and placement accuracy (Best Paper of EMLC 2014)** [9231-21]
- 9231 0S **Impact of mask absorber and quartz over-etch on mask 3D induced best focus shifts** [9231-28]
- 9231 0T **Challenges and opportunities in applying grapho-epitaxy DSA lithography to metal cut and contact/via applications** [9231-7]

PROCESSES AND SPECIAL TECHNOLOGIES

- 9231 0U **Innovative and water based stripping approach for thick and bulk photoresists** [9231-500]
- 9231 0V **How holistic process control translates into high mix logic fab APC?** [9231-4]

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.

Ackmann, Paul W., 06, 0I	Haase, A., 0M
Adam, Kostas, 0I	Hagihara, Kazuki, xvii
Armeanu, Ana, 0I	Hanisch, Norbert, 0F
Banasch, Michael, 0E	Hasan, Md. Nazmul, 0J
Behrendt, U., 0P	Hattori, Kiyoshi, 07
Bekaert, Joost, 0R, 0T	Heinrich, A., 0L
Belledent, Jérôme, 0Q	Her, YoungJun, 0R
Beraud, B., 0V	Herfst, R. W., 0B
Bischoff, J., 0L	Hertzsch, Tino, 0O
Bodermann, B., 0M	Hohle, Christoph, 0F, 0U
Bouma, Anita, 0S	Huebner, Uwe, 0E
Buck, Peter, 0I	Imoto, Tomohiro, 02
Buergel, Christian, 0I	Islamaj, Esma, 0H
Burger, S., 0M	Itoh, Masamitsu, xvii
Cao, Yi, 0R	Jaganatharaja, Ramasubramanian
Capelli, Renzo, 09	Kottumakulal, 02
Chan, Boon Teik, 0R	Joshi, Pankaj, 0H
Choi, Kang-Hoon, 0F	Kalk, Franklin, 0I
Clifford, Chris, 0I	Kamikubo, Takashi, 07
Connolly, Brid, 02	Kaynak, M., 0P
Cotte, Eric, 0O	Ketelsen, H., 0L
Crowcombe, W. E., 0B	Kley, Ernst-Bernhard, 0E
Cuypers, Dieter, 0H	Kobayashi, Yoshihito, xvii
Davydova, Natalia, 02, 08	Kodera, Yutaka, 02
Decaunes, J., 0V	Kondo, Shinpei, 02
de Kruif, Robert, 02	Kotani, Jun, 02
Depre, Laurent, 08	Kramer, G. F. I. J., 0B
De Smet, Herbert, 0H	Krasnova, Polina, 0Q
De Smet, Jelle, 0H	Krumrey, M., 0M
Dietrich, Kay, 0E	Kulse, P., 0P
Dirnstorfer, I., 0L	Lam, A., 0V
Doise, Jan, 0R	Lam, Michael, 0I
Ducotè, J., 0V	Lammers, Ad, 02
Endres, J., 0M	Lapeyre, C., 0V
Esche, Silvio, 0U	Laubis, C., 0M
Falkner, Matthias, 0E	Le-Gratiet, B., 0V
Farys, Vincent, 08	Litt, Lloyd C., 06
Fenger, Germain, 0Q, 0T	Ma, Yuansheng, 0Q, 0T
Finders, Jo, 08, 0S	Magnusson, Krister, 09
Fouquet, Antoine, 0Q	Man, Cheuk-Wah, 02
Fryer, David, 0I	Marschmeyer, S., 0P
Fukugami, Norihito, 02	Meiner, K., 0L
Gans, Fritz, 0I	Mikolajczak, M., 0V
Garetto, Anthony, 09	Mikolajick, T., 0L
Gatefait, M., 0V	Miyazaki, Junji, 0S
Gharbi, Ahmed, 0Q	Morimoto, Hiroaki, 02
Granik, Yuri, 0Q, 0T	Motokawa, Takeharu, xvii
Gronheid, Roel, 0R	Murugesan Kuppuswamy, Vijaya-Kumar, 0R
Gutsch, Manuela, 0F	Nakagawa, Kent, 0I

Ning, Guo Xiang, 06, 0I
 Ogasawara, Munehiro, 07
 Oliver, Mike, 0I
 Oorschot, Dorothe, 02, 08
 Orlando, B., 0V
 Ostrovsky, A., 0V
 Pelletier, A., 0V
 Psara, Eleni, 08
 Rahman, Md. Momtazur, 0J
 Richter, U., 0L
 Rolff, Haiko, 02
 Rudolph, Matthias, 0U
 Ruhm, Matthias, 0O
 Ryckaert, Julien, 0T
 Sadeghian, H., 0B
 Saito, Masato, xvii
 Sakata, Yo, 02
 Scherübl, Thomas, 09
 Schiffelers, Guido, 02, 08
 Scholze, F., 0M
 Schulz, Bernd, 0O
 Schulz, K., 0P
 Schulze, Steffen, 0I
 Schumann, Dirk, 0U
 Seidel, Robert, 0F
 Seltmann, Rolf, 04, 0O
 Shang, Xiaobing, 0H
 Soltwisch, V., 0M
 Steidel, Katja, 0F
 Sturtevant, John, 0I
 Suenaga, Machiko, xvii
 Sundermann, F., 0V
 Takekoshi, Hidekazu, 07
 Tan, Jin-Yi, 0H
 Tejnil, Edita, 0I
 Thienpont, Hugo, 0H
 Thrun, Xaver, 0F, 0U
 Tillack, B., 0P
 Tiron, Raluca, 0Q
 Torres, J. Andres, 0Q, 0T
 Udoy, Ariful Banna, 0J
 Ugajin, Kunihiro, xvii
 Ullrich, Albrecht, 02, 0M
 Utsumi, Takao, 0D
 Vandenberghe, Geert, 0R, 0T
 van den Dool, T. C., 0B
 van Dijk, Joep, 02
 Van Erps, Jurgen, 0H
 van Setten, Eelco, 02, 08
 van Veen, Marieke, 0S
 Vervaeke, Michael, 0H
 Wernecke, J., 0M
 Werner, Thomas, 0F
 Wietstruck, M., 0P
 Winters, J., 0B
 Word, James, 0T
 Wurm, S., 03
 Yagawa, Keisuke, xvii
 Yamada, Hirokazu, 07
 Zeitner, Uwe D., 0E

Conference Committee

Conference Chair

Uwe F.W. Behringer, UBC Microelectronics (Germany)

Conference Co-chairs

B. Connolly, Toppan Photomasks GmbH (Germany)

C. Gale, Applied Materials Dresden (Germany)

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

Program Chairs

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

D. Sarlette, Infineon Technologies AG (Germany)

R. Selmann, GLOBALFOUNDRIES (Germany)

Members

M. Arnz, Carl Zeiss SMT AG (Germany)

C. Blaesing, Carl Zeiss SMS GmbH (Germany)

P. Chen, Taiwan Mask Corporation (Taiwan)

N. Davydova, ASML Netherlands B.V. (Netherlands)

R. Jonckheere, IMEC (Belgium)

K. Kimmel, SEMATECH Inc. (United States)

B. Lauche, Photronics MZD GmbH (Germany)

H. Levinson, GLOBALFOUNDRIES Inc. (United States)

H. Löschner, IMS Nanofabrication AG (Austria)

W. Maurer, Infineon Technologies AG (Germany)

C. Progler, Photronics Inc. (United States)

E. Rausa, Plasma-Therm LLC (United States)

D. J. Resnick, Molecular Imprints (United States)

C. Romeo, Numonyx (Italy)

K.-D. Röth, KLA-Tencor MIE GmbH (Germany)

H. Scheer, Bergische Universität Wuppertal (Germany)

T. Scheruebl, Carl Zeiss SMS GmbH (Germany)

R. Schnabel, VDE/VDI-GMM (Germany)

S. Schulze, Mentor Graphics Corporation (United States)

M. Staples, GLOBALFOUNDRIES (Germany)

I. Stolberg, Vistec Electron Beam GmbH Jena (Germany)

S. Tedesco, CEA-LETI (France)

J. Waelpoel, ASML Netherlands B.V. (Netherlands)

G. Wenz, Wenz Consulting (Germany)

H. Wolf, Photronics MZD GmbH (Germany)
S. Wurm, SEMATECH Inc. (United States)
L. Zurbrick, Agilent Technologies (United States)

Session Chairs

- 1 Plenary Session I
J. Finders, ASML Netherlands B.V. (Netherlands)
R. Selmann, GLOBALFOUNDRIES (Germany)
- 2 Plenary Session II
B. Connolly, Toppan Photomasks GmbH (Germany)
C. Gale, Applied Materials Dresden (Germany)
- 3 Mask Writing Time Optimization
J. H. Peters, Carl Zeiss SMS GmbH (Germany)
H. Morimoto, Toppan Printing Company (Japan)
- 4 EUV Lithography
S. Wurm, SEMATECH Inc. (United States)
N. Davydova, ASML Netherlands B.V. (Netherlands)
- 5 EUV Mask Technology
D. Farrar, Hoya Corporation (United Kingdom)
M. Arnz, Carl Zeiss SMT AG (Germany)
- 6 News from Other Conferences
Uwe F.W. Behringer, UBC Microelectronics (Germany)
- 7 E-Beam Technologies
I. Stolberg, Vistec Electron Beam GmbH Jena (Germany)
Uwe F.W. Behringer, UBC Microelectronics (Germany)
- 8 Templates Technologies
I. Stolberg, Vistec Electron Beam GmbH Jena (Germany)
Uwe F.W. Behringer, UBC Microelectronics (Germany)
- 9 Simulation
H. Wolf, Photronics (Germany)
Uwe F.W. Behringer, UBC Microelectronics (Germany)
- 10 Metrology
K.-D. Röth, KLA-Tencor MIE GmbH (Germany)
J. Jaehnert, Infineon Technologies AG (Germany)
- 11 Wafer Processing
B. Connolly, Toppan Photomasks GmbH (Germany)
C. Gale, Applied Materials Dresden (Germany)

- 12 DSA Technology and Alternative Lithography
N. Hayashi, Dai Nippon Printing Company Ltd. (Japan)
R. Selmann, GLOBALFOUNDRIES (Germany)
- 13 Processes and Special Technologies
J. Finders, ASML Netherlands B.V. (Netherlands)
Uwe F.W. Behringer, UBC Microelectronics (Germany)

Foreword

On behalf of VDE/VDI-GMM, the sponsors, and the organizing committee, we welcome you to the proceedings volume from the 30th European Mask and Lithography Conference, EMLC2014 at the Hilton Hotel in Dresden, Germany.

The conference has annually brought together scientists, researchers, engineers, and technologists from research institutes and companies from around the world to present innovations at the forefront of mask lithography and mask technology. The two-day conference was dedicated to the science, technology, engineering, and application of mask and lithography technologies and associated processes, giving an overview of the present status in mask and lithography technologies and the future strategy where mask producers and users have the opportunity of becoming acquainted with new developments and results. This year's sessions included: Mask Writing Time Optimization; EUV Lithography; EUV Mask Technology; E-Beam Technologies; Templates Technologies; Simulation; Metrology; Wafer Processing; DSA Technology and Alternative Lithography, and Processes and Special Technologies.

Heinz Martin Esser, CEO of Roth & Rau – Ortnor GmbH was the welcome speaker. His presentation introduced European's largest Cluster in the ICT (Information & Communication Technology) and explained the impressive development with the main success factors. Another highlight of his talk described the efforts to build up a strong European Cooperation beginning initially with a partnership with Grenoble (Minalogic) which could be extended with other important European High-Tech Clusters (Silicon Europa) to establish a new mutual European Identity in the global competition.

Our first keynote speaker was Jan Hendrik Peters from Carl Zeiss, SMS GmbH, Jena, Germany. His talk was "EUV mask infrastructure: Are we ready to meet the demands for the consumer electronics market?"

Our second keynote speaker was Stefan Wurm from SEMATECH. His talk was entitled "EUV lithography: process, challenges and outlook."

Keeping our tradition, we invited the Best Paper of PMJ 2014 (the paper will be announced by the PMJ Committee), and the Best Poster from BACUS2013 which was "Black border, mask 3D effects: covering challenges of EUV mask architecture for 22nm node and beyond," and was presented by Natalia Davydova from ASML.

Also a tradition we invited V. Jindal from SEMATECH to present information regarding the yearly "Mask Industry Survey."

Technical Exhibition

Parallel to the Conference Presentations, the Technical Exhibition took place on Tuesday and Wednesday where companies (mask suppliers, material suppliers, and equipment suppliers) exhibited their companies and products. To foster the exchange between the conference attendees and the exhibitors, the exhibition area was also the place for all coffee and lunch breaks.

Uwe F.W. Behringer
EMLC2014 Conference Chair

Cooperating Partners and Sponsors of the EMLC 2014