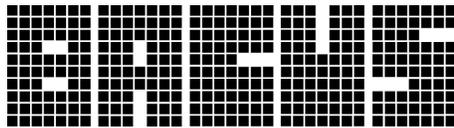# *Photomask Technology 2017*

Peter D. Buck
Emily E. Gallagher
Editors

11–14 September 2017
Monterey, California, United States

Sponsored by

BACUS

The international technical group of SPIE dedicated
to the advancement of photomask technology

SPIE.

Published by
SPIE

Volume 10451

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

Contents

iv

METROLOGY

PHOTOMASK LITHOGRAPHY, AND MASK PROCESS & REPAIR

NANO IMPRINT LITHOGRAPHY

POSTER SESSION: EUV INSPECTION

POSTER SESSION: MATERIALS AND NOVEL APPLICATIONS

POSTER SESSION: OPC

v

POSTER SESSION: OPC/MASK INTERACTIONS

POSTER SESSION: PROCESS AND REPAIR

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.

viii

Conference Committee

Conference Chairs

Peter D. Buck, Mentor Graphics Corporation (United States)
Emily E. Gallagher, IMEC (Belgium)

BACUS Steering Committee

Frank E. Abboud, Intel Corporation (United States)
Paul W. Ackmann, GLOBALFOUNDRIES Inc. (United States)
Michael D. Archuletta, RAVE LLC (United States)
Artur P. Balasinski, Cypress Semiconductor Corporation
    (United States)
Uwe F. W. Behringer, UBC Microelectronics (Germany)
Peter D. Buck, Mentor Graphics Corporation (United States)
Brian Cha, SAMSUNG Electronics Company, Ltd.
    (Korea, Republic of)
Jerry Cullins, Hoya Corporation (United States)
Derren Dunn, IBM Corporation (United States)
Thomas B. Faure, GLOBALFOUNDRIES Inc. (United States)
Aki Fujimura, D2S Inc. (Japan)
Brian J. Grenon, Grenon Consulting (United States)
Jon Haines, Micron Technology, Inc. (United States)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)
Bryan S. Kasprowicz, Photronics, Inc. (United States)
Patrick M. Martin, Applied Materials, Inc. (United States)
Shane Palmer, Nikon Research Corporation of America
    (United States)
Jan Hendrik Peters, bmbg consulting(Germany)
Moshe Preil, KLA-Tencor Corporation (United States)
Douglas J. Resnick, Canon Nanotechnologies, Inc. (United States)
Thomas Scheruebl, Zeiss SMT GmbH (Germany)
Thomas Struck, Infineon Technologies AG (Germany)
Bala Thumma, Synopsys, Inc. (United States)
Anthony Vacca, AVI-Photomask (United States)
Michael Watt, Shin-Etsu MicroSi, Inc. (United States)
Jim N. Wiley, ASML US, Inc. (United States)
Larry S. Zurbrick, Keysight Technologies, Inc. (United States)

Conference Program Committee

Frank E. Abboud, Intel Corporation (United States)
Paul W. Ackmann, GLOBALFOUNDRIES Inc. (United States)
Artur P. Balasinski, Cypress Semiconductor Corporation
　(United States)
Lucien Bouchard, Photronics Inc. (United States)
Byungcheol Cha, SAMSUNG Electronics Company, Ltd.
　(Korea, Republic of)
Uwe Dietze, SUSS MicroTec Inc. (United States)
Thomas B. Faure, GLOBALFOUNDRIES Inc. (United States)
Aki Fujimura, D2S, Inc. (United States)
Brian J. Grenon, RAVE LLC (United States)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)
Izak Kapilevich, Applied Materials, Inc. (United States)
Bryan S. Kasprowicz, Photronics, Inc. (United States)
Byung-Gook Kim, SAMSUNG Electronics Company, Ltd.
　(Korea, Republic of)
Lloyd C. Litt, GLOBALFOUNDRIES Inc. (United States)
Paul F. Morgan, Micron Technology, Inc. (United States)
Takahiro Onoue, HOYA Corporation (Japan)
Shane R. Palmer, Nikon Research Corporation of America
　(United States)
Moshe E. Preil, KLA-Tencor Corporation (United States)
Douglas J. Resnick, Canon Nanotechnologies, Inc. (United States)
Thomas Scheruebl, Carl Zeiss SMT GmbH (Germany)
Yuyang Sun, Mentor Graphics Corporation (United States)
Banqiu Wu, Applied Materials, Inc. (United States)
Shusuke Yoshitake, NuFlare Technology, Inc. (Japan)

Session Chairs

Opening Remarks
Peter D. Buck, Mentor Graphics Corporation (United States)
Emily E. Gallagher, IMEC (Belgium)

Keynote and Invited Session
Peter D. Buck, Mentor Graphics Corporation (United States)
Emily E. Gallagher, IMEC (Belgium)

Mask Data Preparation I
Paul W. Ackmann, GLOBALFOUNDRIES Inc. (United States)
Peter D. Buck, Mentor Graphics Corporation (United States)

Mask Data Preparation II
Paul W. Ackmann, GLOBALFOUNDRIES Inc. (United States)
Peter D. Buck, Mentor Graphics Corporation (United States)

Machine Learning
Aki Fujimura, D2S, Inc. (United States)
Bryan S. Kasprowicz, Photronics, Inc. (United States)

Photomask Japan 2017
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)
Takahiro Onoue, HOYA Corporation (Japan)

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. Kasprowicz, 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)

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

Mask/OPC Interactions
Paul A. Morgan, Micron Technology, Inc. (United States)
Byungcheol Cha, SAMSUNG Electronics Company, Ltd. (Korea,
  Republic of)

Metrology
Moshe E. Preil, KLA-Tencor Corporation (United States)
Thomas Scheruebl, Carl Zeiss SMT GmbH (Germany)

Student Session: Joint session with conferences 10451 and 10450
Yuyang Sun, Mentor Graphics Corporation (United States)
Shinji Okazaki, ALITECS Company, Ltd. (Japan)

Photomask Lithography, and Mask Process & Repair
Brian J. Grenon, RAVE LLC (United States)
Uwe Dietze, SUSS MicroTec Inc. (United States)

Nano Imprint Lithography
Douglas J. Resnick, Canon Nanotechnologies, Inc. (United States)
Naoya Hayashi, Dai Nippon Printing Company, Ltd. (Japan)

Panel Discussion: Joint with conferences 10451 and 10450
Byung-Gook Kim, SAMSUNG Electronics Company, Ltd.
   (Korea, Republic of)
Fei Wang, Hermes-Microvision Inc., USA (United States)
Jed H. Rankin, GLOBALFOUNDRIES Inc. (United States)
Jeff Farnsworth, Intel Corporation (United States)
Shusuke Yoshitake, NuFlare Technology, Inc. (Japan)
Weston L. Sousa, KLA-Tencor Corporation (United States)

Introduction

The 2017 SPIE Photomask Technology Conference was held September 11-14 in Monterey, California, co-located for the first time with the EUV Lithography Conference. The organizers of these two conferences recognized their synergy and thought that a united conference would have value greater than the two held separately. Indeed, the combined conference integrated naturally and the increased attendance gave the conference a momentum not experienced in years. Since their first date went so well, these two conferences are expected to remain together for the foreseeable future.

EUV lithography readiness for high volume production was the overriding theme of the conference with joint sessions on EUV readiness, pellicles, and inspection/metrology. A joint panel discussion explored options and strategies for early EUVL insertion without initial actinic inspection availability. The general consensus of the panelists and attendees was that this was not a technical barrier but did have a large impact on complexity, cost, and cycle time.

Machine Learning is gaining more and more attention as organizations attempt to make sense of the huge amount of data collected in the process of manufacturing masks and integrated circuits. This year, for the first time, Photomask Technology included a Machine Learning session that explored use models and applications for this exciting emerging data analysis technology. Papers from the conference, covering the latest progress in all areas related to photomasks, follow in this proceedings.

Peter D. Buck
Emily E. Gallagher