## PROCEEDINGS OF SPIE

# Photomask Technology 2022

Bryan S. Kasprowicz Editor

26-29 September 2022 Monterey, California, United States

Sponsored by



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



Published by SPIE

Volume 12293

Proceedings of SPIE 0277-786X, V. 12293

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

Photomask Technology 2022, edited by Bryan S. Kasprowicz, Proc. of SPIE Vol. 12293, 1229301 · © 2022 SPIE · 0277-786X · doi: 10.1117/12.2667057

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 *Photomask Technology 2022*, edited by Bryan S. Kasprowicz, Proc. of SPIE 12293, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

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

ISBN: 9781510656413 ISBN: 9781510656420 (electronic)

Published by **SPIE** P.O. Box 10, Bellingham, Washington 98227-0010 USA Telephone +1 360 676 3290 (Pacific Time) SPIE.org Copyright © 2022 Society of Photo-Optical Instrumentation Engineers (SPIE).

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 fees. To obtain permission to use and share articles in this volume, visit Copyright Clearance Center 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.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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



**Paper Numbering:** A unique citation identifier (CID) number is assigned to each article in the Proceedings of SPIE 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 Conference Committee

#### INSPECTION/REPAIR

12293 06	Mask inspection technologies for expanding EUV lithography (Invited Paper) [12293-7]
12293 07	Introduction of new visual analysis program using defect image segmentation for EUV mask mass product at modern load port [12293-8]
12293 08	AFM clean and nanomachining repair technology for future mask nodes [12293-9]
12293 0A	Towards improving challenging stochastic defect detection in SEM images based on improved YOLOv5 [12293-11]
	CURVILINEAR MASKS
12293 OC	A study of ILT-based curvilinear SRAF with a constant width [12293-2]
12293 OD	You don't need 1nm contours for curvilinear shapes: pixel-based computing is the answer [12293-3]
12293 OE	Assessment of contour modeling readiness for curvilinear masks [12293-4]
12293 OF	A method for calibrating a curvature-based pre-bias model for advanced mask process correction applications [12293-5]
	ADVANCED CLEANING
12293 OH	In-situ cavitation measurements with a wireless sensor array: applications in megasonic photomask cleaning [12293-18]
12293 OI	Removal behavior of Sn and Pb contaminants on EUV mask after EUV exposure [12293-19]
	PSM MASK: JOINT SESSION WITH PHOTOMASK AND EUV CONFERENCES
12293 0M	A study of patterning 36nm-pitch logic contact holes in a metal oxide resist using a

12293 0M A study of patterning 36nm-pitch logic contact holes in a metal oxide resist using a high-reflectance phase-shifting mask that results in image reversal [12293-23]

### RESIST MATERIALS AND PROCESS I: JOINT SESSION WITH PHOTOMASK AND EUV CONFERENCES

12293 ON	Robust and reliable actinic ptychographic imaging of highly periodic structures in EUV photomasks [12293-50]
	ALTERNATIVE APPLICATIONS
12293 OP	Nanoimprint performance improvements for high volume semiconductor device manufacturing [12293-13]
12293 OQ	Characteristics of fine feature hole templates for nanoimprint lithography toward 2nm and beyond [12293-14]
	MASK PROCESS CORRECTION
12293 OU	Benefits of SEM field-of-view contour averaging for contour-based MPC modeling [12293-24]
12293 OV	A neural network assisted etch model for mask process correction [12293-26]
12293 OW	Mask process correction for laser writers [12293-27]
	MASK METROLOGY
12293 OZ	Investigation of stochastic roughness effects for nanoscale grating characterization with a stand-alone EUV spectrometer [12293-30]
12293 10	Direct correlation between mask registration and on-wafer measurements for individual logic device features [12293-31]
12293 12	Extreme ultraviolet lithography reticle local CD uniformity correlation to wafer local CD uniformity [12293-33]
	WRITE AND PROCESS
12293 14	Study of EB resist dissolution contrast and chemical blur impact on the ultimate resolution [12293-34]
12293 17	Multibeam mask requirements for advanced EUV patterning [12293-38]

	POSTER SESSION
12293 1	9 Bayesian optimization-based estimation of effective reaction radius of chemically amplified resist in acid catalyzed deprotection reaction [12293-39]
12293 1	A Single-pass frame generation for multi-layer 3D circuits [12293-40]
12293 1	C Aerial image metrology (AIMS) based mask-model accuracy improvement for computational lithography [12293-42]
12293 1	D The feasibility of alternative blank substrate materials for large-scale FPD mask process and manufacturing [12293-43]
12293 1	A study of rare contamination defects come in a vacuum chamber [12293-44]
12293 1	F Data preparation for digital scanner [12293-45]
12293 1	G Depth of focus in high-NA EUV lithography: a simulation study [12293-46]
12293 1	H Haze classification based on location for COG mask [12293-49]
12293 1	J Research of high-transmission phase-shift mask on critical dimension uniformity in ArF

12293 1K Precise optical constants: determination and impact on metrology, simulation, and development of EUV masks [12293-53]

lithography [12293-52]

### **Conference Committee**

Conference Chair

Bryan S. Kasprowicz, HOYA Corporation (United States)

Conference Co-chair

Ted Liang, Intel Corporation (United States)

#### Conference Program Committee

Frank E. Abboud, Intel Corporation (United States) **Uwe F.W. Behringer**, UBC Microelectronics (Germany) Aki Fujimura, D2S, Inc. (United States) Emily E. Gallagher, imec (Belgium) Naoya Hayashi, Dai Nippon Printing Co., Ltd. (Japan) Henry H. Kamberian, Photronics, Inc. (United States) Byung Gook Kim, ESOL, Inc. (Korea, Republic of) Romain Lallement, IBM Thomas J. Watson Research Center (United States) Lawrence S. Melvin III, Synopsys, Inc. (United States) Kent H. Nakagawa, Toppan Photomasks, Inc. (United States) Dong-Seok Nam, ASML (United States) Takahiro Onoue, HOYA Corporation (Japan) Thomas Franz Karl Scheruebl, Carl Zeiss SMS Ltd. (Israel) Yuyang Sun, Mentor Graphics Corporation (United States) Jed H. Rankin, GLOBALFOUNDRIES Inc. (United States) Douglas J. Resnick, Canon Nanotechnologies, Inc. (United States) Anna Tchikoulaeva, Lasertec U.S.A., Inc. Zweigniederlassung Deutschland (Germany) Claire van Lare, ASML Netherlands B.V. (Netherlands) Yongan Xu, Applied Materials, Inc. (United States) Kei Yamamoto, FUJIFILM Corporation (Japan) Shusuke Yoshitake, NuFlare Technology, Inc. (Japan) Larry S. Zurbrick, Keysight Technologies, Inc. (United States)