

PROCEEDINGS OF SPIE

# ***Novel Patterning Technologies 2023***

**J. Alexander Liddle  
Ricardo Ruiz**  
*Editors*

**27 February – 2 March 2023  
San Jose, California, United States**

*Sponsored by*  
SPIE

*Cosponsored by*  
Intel Corporation (United States)

*Published by*  
SPIE

**Volume 12497**

Proceedings of SPIE 0277-786X, V. 12497

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

Novel Patterning Technologies 2023, edited by J. Alexander Liddle, Ricardo Ruiz,  
Proc. of SPIE Vol. 12497, 1249701 · © 2023 SPIE  
0277-786X · doi: 10.1117/12.2685105

Proc. of SPIE Vol. 12497 1249701-1

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 [SPIDigitalLibrary.org](http://SPIDigitalLibrary.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 *Novel Patterning Technologies 2023*, edited by J. Alexander Liddle, Ricardo Ruiz, Proc. of SPIE 12497, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

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

ISBN: 9781510661011  
ISBN: 9781510661028 (electronic)

Published by

**SPIE**

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time)

[SPIE.org](http://SPIE.org)

Copyright © 2023 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](http://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.

**SPIE. DIGITAL  
LIBRARY**

[SPIDigitalLibrary.org](http://SPIDigitalLibrary.org)

---

**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*

---

## KEYNOTE SESSION

---

12497 02 **The evolution of heterogeneous integration and packaging for the age of chiplets (Keynote Paper)** [12497-2]

---

## E-BEAM

---

12497 03 **The potential of e-beam lithography for micro- and nano-optics on large areas (Invited Paper)** [12497-4]

12497 04 **Efficient exposure of non-Manhattan layouts using Vistec's shaped beam systems** [12497-5]

12497 05 **High-productivity direct-write e-beam lithography: an enabling patterning technology to augment your lithography toolbox** [12497-7]

12497 06 **E-beam direct write lithography: the versatile ally of optical lithography** [12497-51]

---

## MULTI-BEAM MASK WRITING

---

12497 07 **Multi-beam patterning technology and mask making beyond 5nm (Invited Paper)** [12497-10]

12497 08 **Current performance and future plans on electron multi-beam mask writers toward high-NA EUV era (Invited Paper)** [12497-8]

---

## NANOIMPRINT I

---

12497 09 **Nanoimprint post processing techniques to address edge placement error (Invited Paper)** [12497-13]

12497 0A **Replication of 3D patterns from a grayscale resist master by nanoimprint process** [12497-15]

12497 0B **Next generation imprint equipment for patterning high quality micro-optical elements** [12497-16]

---

## NANOIMPRINT II

---

- 12497 OC **High transfer fidelity via nanoimprint lithography of patterns for bioelectronics applications (Invited Paper)** [12497-17]
- 12497 OD **Advances and applications in nanoimprint lithography (Invited Paper)** [12497-18]
- 12497 OE **Fabrication of dual damascene structure with nanoimprint lithography and dry-etching (Invited Paper)** [12497-19]

---

## NOVEL PATTERNING I

---

- 12497 OF **Novel approach of patterning technologies enabling monolithic micro-optical components** [12497-21]
- 12497 OG **Scalable digital atomic precision lithography** [12497-22]
- 12497 OH **Key ingredients for manufacturing superconducting quantum processors at scale** [12497-25]

---

## DSA I

---

- 12497 OI **Mitigating stochastics in EUV lithography by directed self-assembly (Invited Paper)** [12497-27]
- 12497 OJ **Pattern fidelity improvement of DSA hole patterns (Invited Paper)** [12497-28]
- 12497 OK **EUV lithography line-space pattern rectification using block copolymer directed self-assembly: a roughness and defectivity study** [12497-30]

---

## NOVEL PATTERNING III

---

- 12497 OL **Seamless micro and nanopatterned drum molds based on ultrasonic indentation** [12497-39]
- 12497 OM **Advancing high resolution photolithography with hybrid polymers for wafer-scale manufacture of micro-optics and patterned passivation layers** [12497-40]

---

## GREYSCALE LITHOGRAPHY

---

- 12497 ON **Mask errors impact on grayscale lithography patterning** [12497-42]
- 12497 OO **Ultra-thick positive photoresist layers for maskless grayscale lithography** [12497-43]

12497 OP **Pushing deep greyscale lithography beyond 100- $\mu$ m pattern depth with a novel photoresist**  
[12497-44]

---

**POSTER SESSION**

---

12497 OQ **Overlay performances of wafer scale nanoimprint lithography** [12497-46]

12497 OR **Continuous large area oxide printing from liquid metals** [12497-48]

12497 OS **Application of double exposure technique in plasmonic lithography** [12497-49]

12497 OT **Computational study of 3-dimensional photo lithography on limitations and possibility for novel structures** [12497-50]

12497 OU **Study on the releasing process of tilted grating structure for AR glasses using nanoimprint**  
[12497-53]

12497 OV **Cross-functional photoresists and photopolymers enhancing micro- and nanofabrication**  
[12497-55]

12497 OW **Micro-nanostructuring of ZrO<sub>2</sub> sol-gel by optical and nanoimprint lithography on various substrate for optical applications** [12497-56]

12497 OX **Realization of high-Q Lamb wave resonator with smooth vertical etching profile for thin film lithium niobate (2023 Intel Supply Chain Award for Best Student Paper)** [12497-157]



# Conference Committee

## *Symposium Chair*

**Kafai Lai**, The University of Hong Kong (Hong Kong, China)

## *Symposium Co-chair*

**Qinghuang Lin**, Lam Research Corporation (United States)

## *Conference Chair*

**J. Alexander Liddle**, National Institute of Standards and Technology  
(United States)

## *Conference Co-chair*

**Ricardo Ruiz**, Lawrence Berkeley National Laboratory (United States)

## *Conference Program Committee*

**Alan D. Brodie**, KLA Corporation (United States)

**Tito L. Busani**, The University of New Mexico (United States)

**Richard A. Farrell**, Meta (United States)

**Sandip Halder**, imec (Belgium)

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

**Daniel J. C. Herr**, The University of North Carolina at Greensboro  
(United States)

**Tatsuhiko Higashiki**, KIOXIA Corporation (Japan)

**Erik R. Hosler**, PsiQuantum Corporation (United States)

**Koji Ichimura**, Dai Nippon Printing Company, Ltd. (Japan)

**Stephen M. Kuebler**, University of Central Florida (United States)

**Chi-Chun Liu**, IBM Thomas J. Watson Research Center (United States)

**Hans Loeschner**, IMS Nanofabrication GmbH (Austria)

**Laurent Pain**, CEA-LETI (France)

**Eric M. Panning**, Intel Corporation (United States)

**Ivo W. Rangelow**, Technische Universität Imenau (Germany)

**Douglas J. Resnick**, Canon Nanotechnologies, Inc. (United States)

**Martha I. Sanchez**, Applied Materials, Inc. (United States)

**Chandrasekhar Sarma**, Intel Corporation (United States)

**Gurpreet Singh**, Intel Corporation (United States)

**Ines A. Stolberg**, Vistec Electron Beam GmbH (Germany)

**Mark A. van de Kerkhof**, ASML Netherlands B.V. (Netherlands)  
**Niels Wijnaendts van Resandt**, Heidelberg Instruments Inc.  
(United States)  
**Lovejeet Singh**, JSR Micro, Inc. (United States)