

PROCEEDINGS OF SPIE

# ***Advanced Etch Technology and Process Integration for Nanopatterning XV***

**Efrain Altamirano-Sánchez  
John Hoang**  
*Editors*

**24–26 February 2026  
San Jose, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 13984**

Proceedings of SPIE 0277-786X, V. 13984

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

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 *Advanced Etch Technology and Process Integration for Nanopatterning XV*, edited by Efrain Altamirano-Sánchez, Proc. of SPIE 13984, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

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

ISBN: 9781510699144  
ISBN: 9781510699151 (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 © 2026 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*

---

## ADVANCED MATERIALS AND ETCH PATTERNING INTEGRATION I

---

- 13984 02 **Cryogenic plasma etching for SiO<sub>2</sub>/SiN dielectric films: a mini review (Invited Paper)** [13984-1]
- 13984 03 **Plasma etching process tailoring for different polysilicon microstructures used in 10nm FD-SOI metal gate stacks** [13984-3]
- 13984 04 **Optimization of pitch walking for Ti-based spacer integration in semi-damascene double patterning at MP18** [13984-5]

---

## ADVANCED MATERIALS AND ETCH PATTERNING INTEGRATION II

---

- 13984 05 **Cryogenic etching and halogens (Invited Paper)** [13984-6]
- 13984 06 **Atomic layer etching pitch splitting (APST<sup>™</sup>) for nanoimprint lithography: combining simplicity, precision, and sustainability** [13984-7]
- 13984 07 **Self-aligned quadruple patterning made simple: extending the applications of atomic layer etch-induced pitch splitting (APST<sup>™</sup>)** [13984-9]

---

## HETEROGENEOUS/3D INTEGRATION

---

- 13984 08 **Etch performance and substrate-dependent selectivity of a polytelluoxane-based EUV photoresist** [13984-10]
- 13984 09 **Integration and process strategies for post-bond lithographic overlay control for advanced node (Invited Paper)** [13984-11]
- 13984 0A **Die warpage and overlay control using die stress management (DSM)** [13984-12]
- 13984 0B **Advanced patterning techniques enhancing 3D circuit architectures** [13984-13]

---

## COMPUTATIONAL PATTERNING AND PROCESS CONTROL

---

- 13984 0C **Knowledge-enhanced embedding for virtual metrology with uncertainty quantification in the Bosch etching process** [13984-17]

13984 0D **Laser absorption spectroscopy: a breakthrough in plasma etch endpoint detection for EUV and ALE patterning process** [13984-18]

---

**NOVEL PATTERNING PROCESSES: DIRECTIONAL PATTERNING, ALE/ALD, ISOTROPIC AND BEYOND I**

---

13984 0E **Highly selective silicon etch for high-NA EUV patterning** [13984-22]

---

**NOVEL PATTERNING PROCESSES: DIRECTIONAL PATTERNING, ALE/ALD, ISOTROPIC AND BEYOND II**

---

13984 0F **Application of ALD and isotropic etch to 3D patterning of advanced logic and memory devices (Invited Paper)** [13984-23]

13984 0G **AI-native equipment design for atomic precision etching** [13984-24]

13984 0H **Low-damage gas cluster ion beam polishing of the C-face of 4H-SiC** [13984-25]

13984 0I **Novel wet process to improve channel hole profile towards 3D-NAND flash memory** [13984-26]

---

**NOVEL PATTERNING PROCESSES: DIRECTIONAL PATTERNING, ALE/ALD, ISOTROPIC AND BEYOND III**

---

13984 0J **Transforming EUV patterned P34nm circular CH structures into oval CHs through directional etch (Invited Paper)** [13984-27]

13984 0K **P20 High-NA enablement through pattern shaping technology: tip-to-tip engineering, roughness, and defectivity improvement (Invited Paper)** [13984-28]

13984 0L **Transient assisted processing (TAP): a novel plasma approach for precise, sustainable, and scalable patterning** [13984-29]

---

**SUSTAINABLE PATTERNING**

---

13984 0M **Advancing sustainable semiconductor manufacturing: synergistic innovations in etch gas development and abatement technologies (Invited Paper)** [13984-31]

13984 0N **Sustainable plasma processes for the cleaning of etching reactors** [13984-32]

13984 0O **Dry etch patterning, sustainability, performance: how can they all fit together?** [13984-33]

---

## **EUV PATTERNING AND ETCH**

---

- 13984 0P **Local CD uniformity improvements for random logic via thorough dry etch process optimizations** [13984-35]
- 13984 0Q **Dry etch patterning properties of organic underlayer used on EUV metal oxide resist platform** [13984-36]

---

## **POSTER SESSION**

---

- 13984 0R **Overcoming DRAM BCAT patterning defects by reducing bending and wiggling** [13984-40]
- 13984 0S **Cap film damage suppression during EUV mask process** [13984-41]
- 13984 0T **Integrated lith-to-etch protocols for indigenous resists technology enabling high-fidelity device fabrication** [13984-42]
- 13984 0U **A hybrid physics-machine learning framework for fast, predictive low-pressure plasma etching models** [13984-45]
- 13984 0V **Multistage dielectric structure controls ion angular distributions in dual-frequency capacitively coupled plasmas** [13984-46]
- 13984 0W **Electron incidence angle distributions during sheath collapse phase in high-frequency capacitively coupled plasmas** [13984-47]