

2017 EUVL Workshop

June 12-15, 2017

CXRO, LBNL ▪ Berkeley, CA

Workshop Proceedings

2017 International Workshop on EUV Lithography
(2017 EUVL Workshop)

June 12-15, 2017, The Center for X-ray Optics (CXRO), Lawrence
Berkeley National Laboratory, Berkeley, CA, USA



Sponsors



Organized by



Vivek Bakshi (EUV Litho, Inc.), Chair
Patrick Naulleau (CXRO), Co-Chair



Group Photograph, June 14, 2017

(Please visit workshop's home page at www.euvlitho.com for additional photographs from the workshop.)

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*CXRO, LBNL, Berkeley, CA, USA
June 12-15, 2017*

Workshop Proceedings

(Please click on links to download or view PDF versions of the presentations)

Wednesday, June 14, 2017

8:00 AM Welcome and Introduction

[Welcome to LBL \(Historical Perspective on EUVL\) \(P0\)](#)

Glen Kubiak, LBL

Welcome to 2017 EUVL Workshop

Vivek Bakshi

EUV Litho, Inc., Austin, TX, USA

Introductions and Announcements (Intro-1)

Patrick Naulleau, LBL

Session 1: Keynote – 1

Session Chair: Anthony Yen (ASML)

[EUVL: Current Status & Remaining Challenges \(P1\) \(Keynote Presentation\)](#)

Obert R Wood II

GLOBALFOUNDRIES, 400 Stone Break Road Extension, Malta, New York 12020, U.S.A.

[EUV Lithography for HVM \(P3\) \(Keynote Presentation\)](#)

Britt Turkot

Intel Corporation

Break (20 minutes)

Session 2: EUV Masks and Mask Metrology

Session Co-chairs: Jim Wiley (ASML) and Bryan Kasprovicz (Photronics)

EUV Mask Economics: Impact of Mask Costs on Patterning Strategy (P33)
(Invited Paper)

Bryan S. Kasprovicz¹ and Michael Lercel²

¹Photronics, Inc.

²ASML, Inc.

Reduction of Large Killer Defects in EUV Mask Blanks (P39) (Invited Paper)

Adrian Devasahayam, Alan V. Hayes, Boris Druz, Sandeep Kohli, Rustam Yevtukhov,
Veeco Instruments Inc (United States)

NewSUBARU EUVL R&D Activities and EUV Mask Defect Inspection (P34)
(Invited Paper)

Takeo Watanabe and Tetsuo Harada

Center for EUVL, Laboratory of Advanced Science and Technology for Industry, University
of Hyogo

**Anamorphic Imaging: Emulating Future Nodes of EUV Lithography on the SHARP
Microscope (P38)**

Markus Benk, Weilun Chao, Ryan Miyakawa, Kenneth Goldberg, Patrick Naulleau
Lawrence Berkeley National Laboratory, Center for X-ray Optics, 1 Cyclotron Road,
Berkeley, California, United States, 94720

Characterization of SiN-based membrane for EUV pellicle application (P60)

Jinho Ahn

Division of Materials Science and Engineering

Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea

RESCAN - A Standalone Tool for EUV Mask Defect Inspection (P32)

Patrick Helfenstein^a, Iacopo Mochi^a, Rajeev Rajendran^a, Istvan Mohacsi^a, Yoshitake
Shusuke^b, Yasin Ekinci^a

^aPaul Scherrer Institute, Villigen PSI, Villigen, CH-5232, Switzerland

^bNuFlare Technology, Inc., 8-1 Shinsugita-cho, Yokohama 235-8522, Japan

**Rigorous 3D Electromagnetic Simulation of Ultrahigh Efficiency EUV Contact-hole
Printing with Chromeless Phase-shift Mask (P37)**

Stuart Sherwin^a, Thomas V. Pistor, Andrew Neureuther^a, and Patrick Naulleau^b

^aUniversity of California, Berkeley, Department of Electrical Engineering and Computer
Sciences, Berkeley, California, United States, 94720

^bLawrence Berkeley National Laboratory, Center for X-ray Optics, 1 Cyclotron Road,
Berkeley, California, United States, 94720

Lunch 12:20 AM – 1:20 PM

Session 3: EUV Sources- I

Session Co-chairs: Akira Endo (HiLASE) and Oscar Versolato (ARCNL)

[kW-class Picosecond Thin-disk Pre-pulse Laser PERLA for Efficient EUV Generation \(P11\) \(Invited Paper\)](#)

Akira Endo¹, Martin Smrž¹, Jiří Mužík^{1,2}, Ondřej Novák¹, Michal Chyla¹,
Tomáš Mocek¹

¹ HiLASE Centre, Institute of Physics AS CR, Za Radnicí 828, 252 41 Dolní Břežany, Czech Republic

² Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Břehová 7, 115 19 Praha 1, Czech Republic

[Scalability of CO₂ Amplifiers to Generate Stable > 500W Extreme Ultraviolet \(EUV\) Beams \(P12\) \(Invited Paper\)](#)

Koji Yasui¹, Naoyuki Nakamura², Jun-ichi Nishimae²,
Masashi Naruse³, Kazuo Sugihara³, and Masato Matsubara³

¹Mitsubishi Electric Corporation, Head quarter, Factory Automation Systems Group, Tokyo, Japan

²Mitsubishi Electric Corporation, Advanced technology R&D center, Hyogo, Japan

³Mitsubishi Electric Corporation, Nagoya works, Nagoya, Japan

[Simulating EUV Production – an Overview of the Underpinnings \(P13\) \(Invited Paper\)](#)

Howard Scott and Steve Langer

Lawrence Livermore National Laboratory, USA

[Short-pulsed Nd:YAG Laser Interaction with Tin Micro-droplets \(P14\) \(Invited Paper\)](#)

Oscar O. Versolato

Advanced Research Center for Nanolithography (ARCNL), Science Park 110, 1098 XG Amsterdam, The Netherlands

Break and Group Photograph 2:20 PM (30 Minutes)

Session 4: EUV Sources - II

Session Chair: Erik R. Hosler (GLOBALFOUNDRIES) and Hiroshi Kawata (KEK)

[Next Generation Source Power Requirements: What will we need at the 3 nm node and beyond? \(P15\) \(Invited Paper\)](#)

Erik R. Hosler

GLOBALFOUNDRIES, 400 Stone Break Road Extension, Malta, NY 12020

[A Compact Linac-Driven EUV Light Source utilizing a Short-Period Microwave-Driven Undulator \(P16\)](#)

Filippos Toufexis*, Cecile Limborg-Deprey, Valery A. Dolgashev, Sami G. Tantawi
SLAC National Accelerator Laboratory, 2575 Sand Hill Rd, Menlo Park, California 94025

* Also at the Department of Electrical Engineering, Stanford University

Concept for 1kW EUV Source for Lithography Based on FEL Emission in Compact Storage Ring (P17) (Invited Paper)

Michael Feser

Lyncean Technologies Inc.

Challenges to Realize the EUV-FEL High Power Light Source - Present Status on the EUV-FEL R&D Activities (P18) (Invited Paper)

Hiroshi Kawata

High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan

Session 5: Poster Session 5:30 7:00 PM

Session Chair: *Gregory Denbeaux (SUNPU Poly)*

Large Collector Mirror Reflectometer for the High Power EUV Light Source Achievement (P25)

Takeo Watanabe and Tetsuo Harada

Center for EUVL, Laboratory of Advanced Science and Technology for Industry, University of Hyogo

Measuring Aberrations with Mask Roughness (P35)

Aamod Shanker

Dept. of Electrical Engineering and Computer Sciences, University of California, Berkeley, CA

Impact of Tool Design on Defect Detection Sensitivity for EUV Actinic Blank Inspection (P36)

Yow-Gwo Wang,^{a,b,*} Andrew R. Neureuther,^{a,b} Patrick P. Naulleau^b

^a*University of California, Berkeley, Department of Electrical Engineering and Computer Sciences, Berkeley, California, United States, 94720*

^b*Lawrence Berkeley National Laboratory, Center for X-ray Optics, 1 Cyclotron Road, Berkeley, California, United States, 94720*

Variable Separation Method for Three-dimensional EUVL Mask Diffraction Simulation (P40)

Xiangzhao Wang^{*}, Heng Zhang, Sikun Li

Laboratory of Information Optics and Opto-electronic Technology, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai, China, 201800

Improved Inspection Ability of Coherent Scattering Microscopy by Applying Ptychography (P31)

Winner of First Place in the Poster Session

Young Woong Kim¹, Dong Gon Woo¹, Seung Hyuk Shin², Hoon Jo², Whoi-Yul Kim² and Jinho Ahn¹

¹*Division of Materials Science and Engineering*

²*Department of Electronics and Computer Engineering*

Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea

Coherent diffraction imaging with partially coherent discharge plasma based EUV sources (P61)

Jan Bußmann^{1,2}, Michal Odstrcil^{1,3}, Raoul Bresenitz¹, Yusuke Teramoto⁴, Marco Perske⁵, Torsten Feigl⁵, William S. Brocklesby³, Larissa Juschkin^{1,2}

¹*Chair for Experimental Physics of EUV, JARA-FIT, RWTH Aachen University, Steinbachstrasse 15, 52074 Aachen, Germany*

²*Peter Grünberg Institute 9, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*

³*Optoelectronics Research Center, University of Southampton, SO17 1BJ, United Kingdom*

⁴*BLV Licht- und Vakuumtechnik GmbH, Steinbachstraße 15, Aachen, Germany*

⁵*OptiXfab. GmbH, Hans-Knoell-Str. 6, 07745 Jena, Germany*

Achromatic Talbot lithography with partially coherent EUV radiation (P62)

Sascha Brose¹, Jenny Tempeler¹, Hyun-su Kim^{2,3}, Serhiy Danylyuk¹, Peter Loosen¹, Larissa Juschkina^{2,3}

¹ Chair for the Technology of Optical Systems, JARA-FIT, RWTH Aachen University, Germany

² Chair for the Experimental Physics of EUV, JARA-FIT, RWTH Aachen University, Germany

³ Peter Grünberg Institute 9, JARA-FIT, Forschungszentrum Jülich GmbH, Germany

Spectroscopic EUV reflectometry for characterization of thin films and layered structures (P63)

Maksym Tryus¹, Serhiy Danylyuk², Daniel Wilson³, Stefan Herbert², Lukas Bahrenberg², Angelo Giglia⁴, Piergiorgio Nicolosi⁵, and Larissa Juschkina^{1,3}

¹ Chair for the Experimental Physics of EUV, JARA-FIT, RWTH Aachen University, Germany

² Chair for the Technology of Optical Systems, JARA-FIT, RWTH Aachen University, Germany

³ Peter Grünberg Institut 9, JARA-FIT, Forschungszentrum Jülich GmbH, Germany

⁴ CNR - Istituto Officina Materiali, Trieste, Italy

⁵ Dipartimento di Ingegneria dell'Informazione, Universita' degli Studi di Padova, Italy

EUV scattering metrology: Benchmarking of discharge plasma source based table-top scatterometry versus PTB synchrotron based EUV radiometry (P64)

Oleksiy Maryasov^{1,2}, Christian Laubis², Mewael Sertsu^{1,3}, Frank Scholze², Larissa Juschkina^{1,4}

¹ Chair for the Experimental Physics of EUV, JARA-FIT, RWTH Aachen University, Steinbachstr. 15, 52074 Aachen, Germany

² Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2-12, 10587 Berlin, Germany

³ Dipartimento di Ingegneria dell'Informazione, Universita' degli Studi di Padova, Italy

⁴ Peter Grünberg Institute 9, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Estimation of Lithographically-relevant Secondary Electron Blur (P51)

Winner of Second Place in the Poster Session

Roberto Fallica and Yasin Ekinci

Paul Scherrer Institute, 5232 Villigen PSI, Switzerland

EUV Lithography Research and Development Activities at University of Hyogo (P52)

Takeo Watanabe and Tetsuo Harada

Center for EUVL, Laboratory of Advanced Science and Technology for Industry, University of Hyogo

EUV Light Source Development at Energetiq (P65) (Commercial Poster)

Matthew Partlow, Energetiq

Laser Driven Light Sources (LDLS) from Energetiq (P66) (Commercial Poster)

Matthew Partlow, Energetiq

Veeco's Technologies Enable High Growth Markets (P67) (Commercial Poster)

Sandeep Kohli, Veeco

End Day 1

Thursday, June 15, 2017

Welcome and Announcements (Intro-2)

Patrick Naulleau, LBL

Session 6: Keynote-2

Session Chair: Patrick Naulleau (LBL)

[Tabletop Coherent EUV Sources and Applications: Full Field Sub-Wavelength Imaging at 13.5nm and Materials Metrology \(P4\) \(Keynote Presentation\)](#)

Margaret Murnane

JILA, University of Colorado at Boulder and KMLabs Inc.

[High Power HVM LPP-EUV Source with Long Collector Mirror Lifetime \(P2\) \(Keynote Presentation\)](#)

Hakaru Mizoguchi

Gigaphoton Inc., Hiratsuka Kanagawa, 254-8567, JAPAN

[EUV Lithography: Progress in LPP Source Power Scaling and Availability \(P5\) \(Keynote Presentation\)](#)

Igor Fomenkov

Cymer LLC, An ASML Company, San Diego, CA 92127, USA

Break (20 Minutes)

Session 7: Optics and Contamination

Session Co-Chairs: Jan van Schoot (ASML) and Ladislav Pina (RITE)

[EUV Optics Life-time Research: Past, Present and Future \(P21\) \(Invited Review paper\)](#)

Norbert Koster, Edwin te Sligte, Arnold Storm, Herman Bekman, Jacques van der Donck, Diederik Maas, Jochem Janssen, Rogier Verberk

TNO, Stieltjesweg 1, 2628 CK Delft, The Netherlands

[The Future of EUV Lithography: Enabling Moore's Law in the Next Decade \(P22\) \(Invited Paper\)](#)

Jan van Schoot, Kars Troost, Alberto Pirati, Rob van Ballegoij, Peter Krabbendam, Judon Stoeldraijer, Erik Loopstra, Jos Benschop, Jo Finders, Hans Meiling, Eelco van Setten, Bernhard Kneer*, Bernd Thuering*, Winfried Kaiser*, Tilmann Heil*, Sascha Migura*
ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

**Carl Zeiss SMT GmbH, Rudolf-Eber-Straße 2, 73447 Oberkochen*

[Latest Developments in EUV Optics \(P23\) \(Invited Paper\)](#)

Jack Liddle, Joerg Zimmermann, Jens Timo Neumann, Matthias Roesch, Ralf Gehrke, Bernhard Kneer, *Eelco van Setten, *Jan van Schoot

Carl Zeiss SMT GmbH, Rudolf-Eber-Straße 2, 73447 Oberkochen

**ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands*

[EUV/SXR Optics and Metrology Development at RITE \(P24\) \(Invited Paper\)](#)

Ladislav Pina

Rigaku Innovative Technologies Europe (RITE), Prague, Czech Republic

Lunch 12:00 PM (60 Minutes)

Steering Committee working lunch meeting (Closed meeting)

Session 8: Resist and Patterning -1

Session Co-Chairs: Greg McIntyre (IMEC) and Yoshi Hishiro (JSR)

[EUVL Developments at Imec \(P47\) \(Invited Paper\)](#)

Greg McIntyre

IMEC

[Reactivity of Metal Oxalate EUV Resists as a Function of the Central Metal \(P41\) \(Invited Paper\)](#)

Steven Grzeskowiak,^a Amrit Narasimhan,^a Michael Murphy,^a Lee Napolitano,^b
Daniel A. Freedman,^b Robert L. Brainard,^a and Greg Denbeaux^a

^a *State University of New York Polytechnic Institute - CNSE, 257 Fuller Rd. Albany, NY 12203*

^b *State University of New York at New Paltz, 1 Hawk Drive New Paltz, NY 12561*

[Novel EUV resist development for sub-7 nm node \(P43\) \(Invited Paper\)](#)

Yoshi Hishiro

JSR Micro INC, 1280 N. Mathilda Ave, Sunnyvale, CA 94089, USA

[Metal Oxide Photoresists: Breaking Paradigms in EUV Lithography \(P50\) \(Invited Paper\)](#)

Jason Stowers

Inpria

[Fundamental Aspect of Photosensitized Chemically Amplified Resist: How to overcome RLS trade-off \(P46\) \(Invited Paper\)](#)

Seiichi Tagawa^{1,2}

¹*Graduate School of Engineering, Osaka University, Ibaraki, Osaka 567-0047, Japan,*

²*Institute of Scientific and Industrial Research, Osaka University, Ibaraki, Osaka 567-0047, Japan*

Break 2:50 PM (20 Minutes)

Session 9: Resist and Patterning -2

Session Co-chairs: Greg Denbeaux (SUNY Poly) and Frank Ogletree (LBL)

[Towards Real-Time Analysis of Morphologies using Scattering \(P42\) \(Invited Paper\)](#)

Alex Hexemer

Lawrence Berkeley National Laboratory, Berkeley, California, United States, 94720

[Extreme ultraviolet Induced Chemical Reactions in Photoresists and Model Systems \(P44\) \(Invited Paper\)](#)

S. Castellanos^a, Y. Zhang^a, J. Haitjema^a, L. Wu^a, O. Luigier^a, D. Kazazis^b, M. Vockenhuber^b, T. R. Fallica^b, Y. Ekinici^b, A.M. Brouwer^a.

^a *Advanced Research Center for Nanolithography, Science Park 110, 1098XG Amsterdam, The Netherlands*

^b *Paul Scherrer Institute, 5232 Villigen PSI, Switzerland*

[Fundamentals of X-Ray Excitation and Relaxation in EUV Resists \(P45\) \(Invited Paper\)](#)

D. Frank Ogletree

Molecular Foundry, Materials Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720 USA

[Fundamental Aspects of Low Energy Electron Driven Chemistry \(P48\) \(Invited Paper\)](#)

Dan Slaughter

Chemical Sciences Division, LBNL

[EUVL Workshop Summary \(P70\)](#)

Vivek Bakshi

EUV Litho, Inc.

Depart for Dinner

6:00 -9:00 PM Dinner Cruise

