

# 2017 International Workshop on EUV Lithography

June 12-15, 2017

CXRO, LBNL ▪ Berkeley, CA

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## Workshop Agenda

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**

# **2017 International Workshop on EUV Lithography**

CXRO, LBNL, Berkeley, CA, USA

June 12-15, 2017

## **Workshop Agenda Outline**

### **Monday, June 12, 2017**

#### **EUVL Short Course: 8:30 AM to 5 PM**

Building name: Building 66

Room Number: 66-316

Coffee served during AM and PM breaks. Walk from Building 66 to Café for lunch.

### **Tuesday, June 13, 2017**

#### **Lab Tour: 3 PM to 5:00 PM (Molecular Foundry at LBL [link](#))**

Please meet at the CXRO -4<sup>th</sup> Floor lobby at 3 PM (Building 2, Across the street from Bay View Cafeteria or Building 54) to take a shuttle for the tour. Tour Guide: Patrick Naulleau

#### **Registration, Speaker prep and Reception: 5:00 PM - 6:30 PM**

Building name: Building 54 (Also known as Bay View Cafeteria – name not shown on the building)

Room Number: Main hall

### **Wednesday, June 14, 2017**

Building name: Building 66

Room Number: Auditorium (317). Building entrance is from the second floor. Stairs are directly to the left after entering the building.

#### **Continental Breakfast and Registration: 7:00 AM – 8:00 AM**

#### **Workshop Presentations: 8:00 AM – 4:20 PM**

#### **Lunch: 12:20 PM – 1:20 PM**

Continental Breakfast, morning registration and coffee during breaks will be served outside the auditorium. Seating also available next door in room # 316.

Group will walk together for Lunch to patio of Building 67. We also have inside room (67-3111, Chemla room) reserved for those who will prefer to eat inside.

**Poster Session and Reception: 5:30 to 7:00 PM**

Building name: Building 54 (Bay View Cafeteria - Name not shown on the building)  
(Shuttle will be provided to take attendees from the auditorium to the poster session location.)

**Thursday, June 15, 2017**

Building name: Building 66 (317)

**Continental Breakfast: 7:00 AM – 8:00 AM**

**Workshop Presentations: 8:00 AM – 4:40 PM**

**Lunch: 12:00 PM – 1:00 PM**

**Steering Committee Meeting (Closed working lunch meeting) 12:00 to 1:00 PM**

Building name: Building 66  
Room Number: 66-316 (Located next door to the main auditorium #317)

**Depart for Dinner: 4:50 PM**

Dinner Cruise Location: Berkeley Mariana, Empress Hornblower Upper Deck  
Shuttle will be available for pickup for off-site dinner and drop-off after dinner

**Workshop Adjourned: 9:00 PM**

**Shuttle Bus Services and Parking Information to be available at the website**  
[www.euvlitho.com](http://www.euvlitho.com)

# **2017 International Workshop on EUV Lithography**

**(2017 EUVL Workshop)**

*CXRO, LBNL, Berkeley, CA, USA*

*June 12-15, 2017*

## **Workshop Agenda**

### **Monday, June 12, 2017**

#### **Short Courses**

EUV Lithography

by Vivek Bakshi (EUV Litho, Inc.), Patrick Naulleau (LBNL) and Jinho Ahn (Hanyang University)

8:30 AM -5:00 PM (Building 66 – Room 316)

### **Tuesday, June 13, 2017**

#### **Facility Tour, Registration and Reception**

3:00 PM- 5:00 PM      Molecular Foundry Tour (Meet at Building # 2, Fourth floor at 3 PM)

5:00 PM- 6:30 PM      Registration, reception & Speaker Prep (Building 54, Bay View Cafeteria)

**Wednesday, June 14, 2017**

**8:00 AM Welcome and Introduction**

Introductions (Intro-1)  
Vivek Bakshi  
*EUV Litho, Inc., Austin, TX, USA*

**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. Kasprovicz<sup>1</sup> and Michael Lercel<sup>2</sup>  
<sup>1</sup>*Photronics, Inc.*  
<sup>2</sup>*ASML, 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<sup>a</sup>, Iacopo Mochi<sup>a</sup>, Rajeev Rajendran<sup>a</sup>, Istvan Mohacsi<sup>a</sup>, Yoshitake Shusuke<sup>b</sup>, Yasin Ekinci<sup>a</sup>

<sup>a</sup>*Paul Scherrer Institute, Villigen PSI, Villigen, CH-5232, Switzerland*

<sup>b</sup>*NuFlare 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<sup>a</sup>, Thomas V. Pistor, Andrew Neureuther<sup>a</sup>, and Patrick Naulleau<sup>b</sup>

<sup>a</sup>*University of California, Berkeley, Department of Electrical Engineering and Computer Sciences, Berkeley, California, United States, 94720*

<sup>b</sup>*Lawrence 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 Endo<sup>1</sup>, Martin Smrž<sup>1</sup>, Jiří Mužík<sup>1,2</sup>, Ondřej Novák<sup>1</sup>, Michal Chyla<sup>1</sup>, Tomáš Mocek<sup>1</sup>

<sup>1</sup> *HiLASE Centre, Institute of Physics AS CR, Za Radnicí 828, 252 41 Dolní Břežany, Czech Republic*

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

**Scalability of CO<sub>2</sub> Amplifiers to Generate Stable > 500W Extreme Ultraviolet (EUV) Beams (P12) (Invited Paper)**

Koji Yasui<sup>1</sup>, Naoyuki Nakamura<sup>2</sup>, Jun-ichi Nishimae<sup>2</sup>, Masashi Naruse<sup>3</sup>, Kazuo Sugihara<sup>3</sup>, and Masato Matsubara<sup>3</sup>

<sup>1</sup>*Mitsubishi Electric Corporation, Head quarter, Factory Automation Systems Group, Tokyo, Japan*

<sup>2</sup>*Mitsubishi Electric Corporation, Advanced technology R&D center, Hyogo, Japan*

<sup>3</sup>*Mitsubishi 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,<sup>a,b,\*</sup> Andrew R. Neureuther,<sup>a,b</sup> Patrick P. Naulleau<sup>b</sup>

<sup>a</sup>*University of California, Berkeley, Department of Electrical Engineering and Computer Sciences, Berkeley, California, United States, 94720*

<sup>b</sup>*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<sup>\*</sup>, 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)**

Young Woong Kim<sup>1</sup>, Dong Gon Woo<sup>1</sup>, Seung Hyuk Shin<sup>2</sup>, Hoon Jo<sup>2</sup>, Whoi-Yul Kim<sup>2</sup> and Jinho Ahn<sup>1</sup>

<sup>1</sup>*Division of Materials Science and Engineering*

<sup>2</sup>*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<sup>1,2</sup>, Michal Odstrcil<sup>1,3</sup>, Raoul Bresenitz<sup>1</sup>, Yusuke Teramoto<sup>4</sup>, Marco Perske<sup>5</sup>, Torsten Feigl<sup>5</sup>, William S. Brocklesby<sup>3</sup>, Larissa Juschkin<sup>1,2</sup>

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

<sup>2</sup>*Peter Grünberg Institute 9, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*

<sup>3</sup>*Optoelectronics Research Center, University of Southampton, SO17 1BJ, United Kingdom*

<sup>4</sup>*BLV Licht- und Vakuumtechnik GmbH, Steinbachstraße 15, Aachen, Germany*

<sup>5</sup>*OptiXfab. GmbH, Hans-Knoell-Str. 6, 07745 Jena, Germany*

### **Achromatic Talbot lithography with partially coherent EUV radiation (P62)**

Sascha Brose<sup>1</sup>, Jenny Tempeler<sup>1</sup>, Hyun-su Kim<sup>2,3</sup>, Serhiy Danylyuk<sup>1</sup>, Peter Loosen<sup>1</sup>, Larissa Juschkin<sup>2,3</sup>

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

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

<sup>3</sup> Peter Grünberg Institute 9, JARA-FIT, Forschungszentrum Jülich GmbH, Germany

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

Maksym Tryus<sup>1</sup>, Serhiy Danylyuk<sup>2</sup>, Daniel Wilson<sup>3</sup>, Stefan Herbert<sup>2</sup>, Lukas Bahrenberg<sup>2</sup>, Angelo Giglia<sup>4</sup>, Piergiorgio Nicolosi<sup>5</sup>, and Larissa Juschkin<sup>1,3</sup>

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

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

<sup>3</sup> Peter Grünberg Institut 9, JARA-FIT, Forschungszentrum Jülich GmbH, Germany

<sup>4</sup> CNR - Istituto Officina Materiali, Trieste, Italy

<sup>5</sup> 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<sup>1,2</sup>, Christian Laubis<sup>2</sup>, Mewael Sertsu<sup>1,3</sup>, Frank Scholze<sup>2</sup>, Larissa Juschkin<sup>1,4</sup>

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

<sup>2</sup> Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2-12, 10587 Berlin, Germany

<sup>3</sup> Dipartimento di Ingegneria dell'Informazione, Universita' degli Studi di Padova, Italy

<sup>4</sup> Peter Grünberg Institute 9, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

### **Estimation of Lithographically-relevant Secondary Electron Blur (P51)**

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

**Additional Poster Papers to be Announced Soon**

**End Day 1**

**Thursday, June 15, 2017**

**Welcome and Announcements (Intro-2)**

Vivek Bakshi  
*EUV Litho, Inc.*

**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,<sup>a</sup> Amrit Narasimhan,<sup>a</sup> Michael Murphy,<sup>a</sup> Lee Napolitano,<sup>b</sup> Daniel A. Freedman,<sup>b</sup> Robert L. Brainard,<sup>a</sup> and Greg Denbeaux<sup>a</sup>  
<sup>a</sup> *State University of New York Polytechnic Institute - CNSE, 257 Fuller Rd. Albany, NY 12203*  
<sup>b</sup> *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) (Tentative Title) (Invited Paper)**

Seiichi Tagawa<sup>1,2</sup>  
<sup>1</sup>*Graduate School of Engineering, Osaka University, Ibaraki, Osaka 567-0047, Japan,*  
<sup>2</sup>*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<sup>a</sup>, Y. Zhang<sup>a</sup>, J. Haitjema<sup>a</sup>, L. Wu<sup>a</sup>, O. Luigier<sup>a</sup>, D. Kazazis<sup>b</sup>, M. Vockenhuber<sup>b</sup>, T. R. Fallica<sup>b</sup>, Y. Ekinici<sup>b</sup>, A.M. Brouwer<sup>a</sup>.*

*<sup>a</sup> Advanced Research Center for Nanolithography, Science Park 110, 1098XG Amsterdam, The Netherlands*

*<sup>b</sup> Paul Scherrer Institute, 5232 Villigen PSI, Switzerland*

**Fundamentals of X-Ray Excitation and Relaxation in EUV Resists** (*Tentative Title*) (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*

## **Announcements**

Vivek Bakshi

*EUV Litho, Inc.*

## **Depart for Dinner**

**6:00 -9:00 PM    Dinner Cruise**

