

2019 EUVL Workshop

June 10-13, 2019

CXRO, LBL ▪ Berkeley, CA

Workshop Agenda



2019 EUVL Workshop Sponsors



Organized by



Vivek Bakshi (EUV Litho, Inc.), Chair

Patrick Naulleau (CXRO), Co-Chair

2019 EUVL Workshop

CXRO, LBL, Berkeley, CA, USA

June 10-13, 2019

Workshop Agenda Outline

Monday, June 10, 2019

EUVL Short Course: 8:30 AM to 5:00 PM

Building name: 54-130

Room Number: 54-130

Coffee served during AM and PM breaks. Café (Building 54) for lunch.

Tuesday, June 11, 2019

CXRO EUVL Program Showcase: 11:30 PM to 4:30 PM

Presentations on Technology, facilities, services and research from CXRO, LBL

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

Room Number: 130

Introductions: 11:30 AM – 11:45 AM

Lunch: 11:045 AM to 1:00 PM

Presentations: 1:00 PM – 2:40 PM

Coffee Break: 2:40 -3:10 PM

Presentations: 3:10 – 4:30 PM

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 12, 2019

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: 8:00 AM – 8:30 AM

Workshop Presentations: 8:30 AM – 5:10 PM

2019 EUVL Workshop

Lunch: 1:00 PM – 2:00 PM

Continental Breakfast, morning registration and coffee during breaks will be served outside the auditorium. Seating also available next door in room # 316. Group can also walk together for Lunch to patio of Building 67.

Poster Session and Reception: 5:30 to 6:30 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 13, 2019

Building name: Building 66 (317)

Continental Breakfast: 8:00 AM – 8:30 AM

Workshop Presentations: 8:30 AM – 5:10 PM

Lunch: 12:20 PM – 1:40 PM

Steering Committee Meeting (Closed working lunch meeting) 12:30 to 1:30 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

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Monday, June 10, 2019

Short Courses

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

8:30 AM -5:00 PM

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Room Number: 130

SESSION 1 – Recent Progress by the CXRO Team

Session Chair: Patrick Naulleau

11:30 AM – 11:45 AM Introductory Remarks (Patrick Naulleau)

11:45 AM – 01:00 PM Networking Lunch

01:00 PM – 03:10 PM Presentations

Achieving Diffraction-limited Performance on the Berkeley MET5 (P61)

Ryan Miyakawa

CXRO

A SHARP tool for current and future nodes of EUV lithography (P62)

Markus Benk, Ryan Miyakawa, Patrick Naulleau

CXRO

Measuring chemical image in photoresist (P63)

Luke Long

CXRO

Quantitative Phase Imaging for EUV Photomasks (P64)

Stuart Sherwin

CXRO

Photoemission study on EUV materials (P65)

Jonathan Ma, Andrew Neureuther, Patrick Naulleau

CXRO

2:40 pm – 3:10 pm COFFEE BREAK

SESSION 2 – Facilities and Research at LBNL

Session Chair: Isvar Cordova

3:10 – 4:30 PM Presentations

Measurement of electron blur (P66)

Oleg Kostko, Jonathan Ma, and Patrick Naulleau

Chemical Sciences/Advanced Light Source, LBL

Assessing the Impact of Latent Imaging of Resists via Grazing Incidence Resonant X-ray Scattering (P67)

Isvar. A. Cordova^{1,2}, Guillaume. Freychet^{1,4}, Scott. D. Dhuey³, Alex Hexemer¹, Cheng Wang¹, Patrick Naulleau³

¹*Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

²*Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

³*Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

⁴*NSLS-II, Brookhaven National Laboratory, Berkeley, CA 94720 USA*

Gentle High Speed Atomic Force Microscopy using Encased Cantilevers and Spiral Scanning (P68)

Paul Ashby

Molecular Foundry

Fundamental dynamics of bond-selective chemistry initiated by low-energy electrons (P69)

Dan Slaughter¹, Ali Belkacem¹ and Tom Rescigno¹, Cynthia Trevisan², C. William McCurdy³

¹*Chemical Sciences Division, LBNL*

²*Department of Sciences and Mathematics, California Maritime Academy*

³*Chemical Sciences Division, LBNL, and Department of Chemistry, University of California*

2019 EUVL Workshop

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 12, 2019

8:30 AM Welcome and Introduction

Welcome to 2019 EUVL Workshop (Intro-1A)

Vivek Bakshi, *EUV Litho, Inc.*

Welcome to LBL

Speaker TBA, *LBL*

Announcements (Intro-1B)

Patrick Naulleau, *LBL*

Introductions

All

Session 1: Keynote – 1

Session Chair: Patrick Naulleau (LBL)

**Canonical Phase Measurement in Quantum Mechanics (P1)
(Keynote Presentation)**

Irfan Siddiqi

University of California Berkeley and Lawrence Berkeley National Lab

**EUV lithography Today and Extension for the Next Generation (P2)
(Keynote Presentation)**

Britt Turkot

Intel Corporation

10:40 AM Break (20 minutes)

Session 2: EUV Masks

Session Co-chairs: Jane P. Chang (UCLA) and Jinho Ahn (Hanyang)

Ion Beam Technology Roadmap for EUV Mask Deposition and Absorber Etch Processes (Invited) (P14)

Sandeep Kohli, Meng Lee, Boris Druz, Adrian Devasahayam

Veeco Instruments, 1 Terminal Drive, Plainview, NY 11803

Next Generation EUV Mask Blank Absorber Development (Invited) (P16)

Vibhu Jindal, Shuwei Liu, Kan Fu, Weimin Li, Wen Xiao, Khor Wui,

Madhavi Chandrathood

Applied Materials

Selective and Directional Patterning of Ni for EUV Masks Application (Invited) (P11)

Jane P. Chang

Department of Chemical and Biomolecular Engineering, University of California, Los Angeles (UCLA), Los Angeles, CA 90095

Fabrication and Evaluation of SiN-based EUV Pellicle (Invited) (P12)

Ha Neul Kim¹, Yong Ju Jang², Seong Ju Wi¹, Juhee Hong³, Chang Hoon Lee³, Kee Soo Nam³ and Jinho Ahn^{1,2}

¹*Division of Materials Science and Engineering*

²*Division of Nanoscale Semiconductor Engineering*

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

³*S&S tech Co. Ltd., 42, Hosandong-ro, Dalseo-gu, Daegu, Republic of Korea*

Stochastic Failure Risk (Invited) (P13)

Kevin Lucas

Synopsys, Austin, TX

Stochastic Investigation of the Impact of Absorber Variations on Wafer Patterns (Invited) (P15)

Derren Dunn¹, Lawrence S. Melvin III², Tim Fühner²

¹*IBM Research, 257 Fuller Rd, Albany, NY 12203, USA*

²*Synopsys, Inc. 2025 NW Cornelius Pass Road, Hillsboro, OR 97124, USA*

Lunch 1:00 PM – 2:00 PM

Session 3: EUV Resist

Session Co-chairs: Anna Lio (Intel Corporation) and Alex Robinson (Irresistible Materials)

EUV Resists: Can We Move Fast and Light? (Invited) (P34)

Anna Lio

Intel Corporation

Multi-Trigger Resist (Invited) (P33)

G. O'Callaghan^{a,b}, C. Popescu^b, Y. Vesters^{c,d}, A. McClelland^b, J. Roth^e, W. Theis^f, A.P.G. Robinson^{a,b}

^a*Irresistible Materials, Birmingham Research Park, Birmingham, UK*

^b*School of Chemical Engineering, University of Birmingham, UK.*

^c*IMEC, Kapeldreef 75, 3001 Leuven, BE*

^d*KU Leuven, Chemistry Department, Celestijnenlaan 200F, 3001 Leuven, BE*

^e*Nano-C, 33 Southwest Park, Westwood, MA, USA.*

^f*School of Physics and Astronomy, University of Birmingham, UK.*

Role of Ambient Conditions on Organotin Cluster Based Extreme Ultraviolet Resist Chemistries (P35)

Gregory S. Herman, J. Trey Diulus, Ryan T. Frederick, Rafik Addou
School of Chemical, Biological, and Environmental Engineering, Oregon State University, Corvallis, OR, 97331, USA

Break and Group Photograph 3:00 PM (30 Minutes)

Session 4: EUV Optics and Patterning

Session Chair: Sascha Migura (Carl Zeiss) and Ladislav Pina (CTU)

Optics for EUV Lithography (Invited) (P24)

Sascha Migura
Carl Zeiss SMT GmbH, Germany

Defectivity Improvements Enabling HVM for EUV Scanners (P23)

Mark van de Kerkhof, Christian Cloin, Andrei Yakunin, Ferdi van de Wetering,
Andrey Nikipelov, Fabio Sbrizzai
ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

Update on EUV Optics Calibration (P21)

Eric Gullikson
CXRO

Maskless, High-NA EUV Scanner (P22)

Kenneth C. Johnson
KJ Innovation, 2502 Robertson Rd., Santa Clara, CA 95051

Overview, Status and Performance of the 0.5-NA EUV Microfield Exposure Tool at Berkeley Lab (P25)

Chris Anderson
Berkeley Lab, 1 Cyclotron Road Mail Stop 2R0400, Berkeley, CA 94720 USA

Break: 5:10 PM

Session 5: Poster Session 5:30 6:30 PM

Assessing the Impact of Latent Imaging of Resists via Grazing Incidence Resonant X-ray Scattering (P31)

Isvar. A. Cordova^{1,2}, Guillaume Freychet^{1,4}, Scott. D. Dhuey³, Alex Hexemer¹, Cheng Wang¹, Patrick Naulleau³

¹*Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

²*Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

³*Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA*

⁴*NSLS-II, Brookhaven National Laboratory, Berkeley, CA 94720 USA*

Progress in EUV Resists Towards High-NA EUV Lithography (P32)

Xiaolong Wang¹, Zuhail Tasdemir¹, Michaela Vockenhuber¹, Iacopo Mochi¹, Lidia van Lent-Protasova², Marieke Meeuwissen², Rolf Custers², Gijsbert Rispens², Rik Hoefnagels², Yasin Ekinci¹

¹*Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland*

²*ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands*

Development of EUV-ptychography Microscope: EUV Scanning Lensless Imaging (ESLI) (P17)

Dong Gon Woo¹, Young Woong Kim¹, Yong Ju Jang², Seong Ju Wi¹, Seung Hyuk Shin³, Whoi-Yul Kim³ and Jinho Ahn^{1,2}

¹ *Division of Materials Science and Engineering*

² *Division of Nanoscale Semiconductor Engineering*

³ *Department of Electronics and Computer Engineering*

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

Study of the Reflection-field Features of EUV Mask Blank with Defects in Multilayers (P18)

Guannan Li^{1,2}, Lituo Liu¹, Weihu Zhou¹, Xiaobin Wu¹, Xiaomei Chen¹, Yu Wang¹, Dongbin Mei¹

¹*Institute of Micro-electronics of the Chinese Academy of Sciences, Beijing 100029, China*

²*University of Chinese Academy of Sciences, Beijing 100049, China*

Thermo-mechanical Characteristics of EUV Pellicle with Particle Contamination (P19)

Ha Neul Kim¹, Yong Ju Jang², Seong Ju Wi¹, and Jinho Ahn^{1, 2}

¹*Division of Materials Science and Engineering*

²*Division of Nanoscale Semiconductor Engineering*

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

Study of Feature Extraction and Classification of Defects from EUV Mask with Arbitrary Pattern Using Convolutional Neural Network (P20)

Lituo Liu¹, Guannan Li^{1,2}, Weihu Zhou¹, Xiaobin Wu¹, Dongbin Mei¹, Yu Wang¹

¹*Institute of Micro-electronics, Chinese Academy of Science, Beijing, 100029, China*

²*University of Chinese Academy of Sciences, Beijing, 100049, China*

Adaptive piezoelectric optics for XUV wavelengths (P26)

Muharrem Bayraktar¹, Mohammadreza Nematollahi¹, Philip Lucke¹, Andrey Yakshin¹, Eric Louis¹, Guus Rijnders² and Fred Bijkerk¹

¹*Industrial Focus Group XUV Optics, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands*

²*Inorganic Materials Science Group, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands*

Measuring chemical image in photoresist (P63)

Luke Long

CXRO

Quantitative Phase Imaging for EUV Photomasks (P64)

Stuart Sherwin

CXRO

Photoemission study on EUV materials (P65)

Jonathan Ma, Andrew Neureuther, Patrick Naulleau

CXRO

Alkyltin Keggin clusters as photoresist material for EUV lithography (P70)

Rebecca Stern

UC-Berkeley

End Day 1

Thursday, June 13, 2019

8:30 AM Announcements (Intro-2)

Patrick Naulleau, LBL

Session 6: Keynote-2

Session Chair: Eric Panning (Intel)

EUV Lithography Research and Development Activities in Japan (Keynote Presentation) (P4)

Takeo Watanabe

University of Hyogo

Enabling the Semiconductor Roadmap from a Multi-Angled Approach (Keynote Presentation) (P3)

Steven Welch

Applied Materials

Break (20 Minutes)

Session 7: EUV Sources

Session Co-Chairs: Hakaru Mizoguchi (Gigaphoton) and Fariba Abhari (Adlyte Corporation)

Challenge of High Power LPP-EUV Source with Long Collector Mirror Lifetime for Semiconductor HVM (Invited) (P44)

Hakaru Mizoguchi, Hiroaki Nakarai, Tamotsu Abe, Hiroshi Tanaka, Yukio Watanabe, Tsukasa Hori, Yutaka Shiraishi, Tatsuya Yanagida, Georg Soumagne, Tsuyoshi Yamada and Takashi Saitou

Gigaphoton Inc. Hiratsuka facility, 3-25-1 Shinomiya Hiratsuka Kanagawa, 254-8567, JAPAN

Lithography Machine In-line Broadband Spectrum Metrology and Feedback-control System (P43)

Fei Liu¹, Dries Smeets¹, Sjoerd Huang¹, Andrei Yakunin¹, Peter Havermans¹, Rene Oosterholt¹, Muharrem Bayraktar², Fred Bijkerk²

¹ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

² Industrial Focus Group XUV Optics, MESA + Institute for Nanotechnology, University of Twente, The Netherlands

Energetiq Source Update (Tentative Title) (Invited) (P46)

Toru Fujinami

Energetiq

Adlyte Corporation – Source Update (Tentative Title) (Invited) (P42)

Fariba Abhari

Adlyte Corporation, Switzerland

EUV Metrology with a Compact Accelerator-based Source (Invited) (P41)

Yasin Ekinici

Paul Scherrer Institut, Switzerland

High Repetition Rate (81.25MHz) FEL Project Based on cERL (P45)

Hiroshi Kawata, Hiroshi Sakai, Norio Nakamura, and Ryukou Kato

High Energy Accelerator Research organization (KEK)

Lunch 12:20 PM (80 Minutes)

Steering Committee working lunch meeting (Closed meeting)

Session 8: Blue-X I

Session Co-Chairs: Craig Siders (LLNL) and Tatyana Sizyuk (Purdue University)

Blue-X: the New Frontier (P58)

Vivek Bakshi

EUV Litho, Inc.

Thulium-based EUV Drive Lasers Scalable to Near-MW Average Powers (Invited) (P51)

C. W. Siders, S. Langer, A.C. Erlandson, T.C. Galvin, B.A. Reagan, E.F. Sistrunk, T.M. Spinka, and C. L. Haefner

Advanced Photon Technologies, Lawrence Livermore National Laboratory, NIF & Photon Science Directorate, 7000 East Avenue, Livermore CA 94550

An Optimization Study of EUV Sources driven by Lasers of Different Wavelengths (Invited) (P53)

Steven Langer, Howard Scott, and Craig Siders

Lawrence Livermore National Laboratory

Effect of Laser Wavelength on EUV Plasma Dynamics, Source Efficiency, and Ionic Debris Evolution (Invited) (P56)

Tatyana Sizyuk

Center for Materials under Extreme Environment (CMUXE)

College of Engineering, Purdue University, West Lafayette, IN, 47907

Break 2:50 PM (20 Minutes)

Session 9: Blue-X II

Session Co-chairs: Regina Soufli (LLNL) and Frank Delmotte (Universite Paris-Saclay)

Advanced Multilayer Development for the Water-Window Spectral Region (Invited) (P52)

F. Delmotte, C. Burcklen**, E. Meltchakov, J. Rebellato, S. de Rossi
Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Universite Paris-Saclay, 91127 Palaiseau Cedex, France

*** current affiliation: Lawrence Livermore National Laboratory, Livermore, California, USA*

Refractive index measurements with improved accuracy around EUV/x-ray absorption edges and impact in multilayer modeling (Invited) (P54)

Regina Soufli¹, Franck Delmotte², Farhad Salmassi³, Julia Meyer-Ilse³, Catherine Burcklen¹, Jennifer Rebellato², Nicolai Brejnholt¹, Sonny Massahi⁴, David Girou⁴, Finn Christensen⁴, Eric M. Gullikson³

¹*Lawrence Livermore National Laboratory, Livermore, California*

²*Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, Palaiseau, France*

³*Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, California*

⁴*Danish Technical University (DTU)-Space, Lyngby, Denmark*

Adaptation of the Reflectance of Bragg Mirrors to Wide Source Spectra (Invited) (P57)

R. Meisels and F. Kuchar

Institute of Physics, Montanuniversitaet, 8700 Leoben, Austria

Characterization of laser-produced plasmas in the 1-6 nm region using cryogenic Xe targets (P55)

S. C. Bott-Suzuki¹, A. Bykanov², O. Khodykin², M. Tillack¹, S. Cordaro¹

¹*University of California San Diego, 9500 Gilman Drive #0417, La Jolla, CA 92093-0417, USA*

²*KLA-Tencor Corporation, Milipitas, CA, USA*

Announcements

Vivek Bakshi
EUV Litho, Inc.

Depart for Dinner

6:00 -9:00 PM Dinner Cruise

