2016 International Workshop on EUV Lithography

June 13-16, 2016

CXRO, LBNL ▪ Berkeley, CA

Workshop Agenda
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Organized by

EUREKA

CXRO
THE CENTER FOR X-RAY OPTICS

EUV
LITHO, INC.

Vivek Bakshi (EUV Litho, Inc.), Chair
Patrick Naulleau (CXRO), Co-Chair
Monday, June 13, 2016

**EUVL Short Course: 8:30 AM to 5 PM**
Building name: Building 66
Room Number: 66-316
Coffee served during AM and PM breaks. Shuttle from Building 66 to Café for lunch.

Tuesday, June 14, 2016

**CXRO Tour: 3 PM to 5:00 PM**
Building name: CXRO (4th Floor lobby)
Meet in the lobby at 3 PM (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 15, 2016

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: 7:30 AM – 8:30 AM**
**Workshop Presentations: 8:30 AM – 4:30 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.

**4:30 PM: Adjourn for the day for Networking**
(Option of a shuttle for area tour will be provided. Details to be announced.)
**Thursday, June 16, 2016**

Building name: Building 66 (317)

**Continental Breakfast:** 7:30 AM – 8:30 AM

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

**Lunch:** 12:00 PM – 1:30 PM

**EUVL Workshop Steering Committee Meeting (Closed working lunch meeting)**  
11:20 AM to 12:50 PM  
Building name: Building 66  
Room Number: 66-316 (Located next door to the main auditorium #317)

**Poster Session and Reception:** 5:50 PM to 7:00 PM  
Building name: Building 54  
(Bay View Cafeteria. *Shuttle will be provided to take attendees from the auditorium to the poster session location.*)

**Depart for Dinner:** 7:15 PM (from Poster Session Location)  
Dinner Location: Hotel Claremont (off-site, Berkeley, CA)  
*Shuttle will be available for pickup and drop-off for off-site dinner*

**Workshop Adjourned:** 9:30 PM

**Shuttle Bus Services and Parking Information**

Updated information is available on the website [www.euvlitho.com](http://www.euvlitho.com)
2016 International Workshop on EUV Lithography

CXRO, LBNL, Berkeley, CA, USA
June 13-16, 2016

Workshop Agenda

Monday, June 13, 2016

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 14, 2016

Registration and Reception

3:30 PM- 5:00 PM  CXRO Tour (Building # 2, Fourth floor)

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

Welcome to LBL
Mike Witherell, Director, LBL

Introduction to Agenda (Intro-1)
Vivek Bakshi
EUV Litho, Inc., Austin, TX, USA

Session 1: Keynote – 1

Session Chair: Patrick Naulleau (CXRO)

EUV Lithography’s Present and Future (P1)
Harry J. Levinson
GLOBALFOUNDRIES

EUVL Readiness for High Volume Manufacturing (P3)
Britt Turkot
Intel Corporation

Break (20 minutes)

Session 2: EUV Sources

Session Co-chairs: H. Mizoguchi (Gigaphoton) and Padraig Dunne (UCD)

Development of 250 W EUV Light Source For HVM Lithography (P34) (Invited)
Gigaphoton Inc. Hiratsuka facility, JAPAN

CO2 Amplifiers to Generate > 20 kW Laser Power for Stable > 250 W Extreme Ultraviolet (EUV) Power (P33) (Invited)
Koji Yasui1, Naoyuki Nakamura2, Jun-ichi Nishimae2, Masashi Naruse3, and Masato Matsubara3
1Mitsubishi Electric Corporation, Head quarter, Tokyo, Japan
2Mitsubishi Electric Corporation, Advanced technology R&D center, Hyogo, Japan
3Mitsubishi Electric Corporation, Nagoya works, Nagoya, Japan

New Concepts for a High Brightness LPP EUV Source (P35)
Konstantin Koshelev, Alexander Vinokhodov, Mikhail Krivokoritov, Oleg Yakushev, Samir Ellwi, Denis Glushkov, Pavel Seroglazov
RnD-Isan, Moscow, Russia and ISTEQ B.V., Eindhoven, the Netherlands
Laboratory Soft X-ray Tomography with a Simple Robust Laser Plasma Light Source (P32) (Invited)
F. O'Reilly1,2, G. Wielgoszewski2, J. Howard2, F. McGrath2, R. Byrne2, A. Mahon2, O. Hammad2, T. McEnroe2, T. McCormack1, G. O'Sullivan1, E. Sokell1, P. Dunne1, N. Kennedy1, K. Fahy2, P. Sheridan2
1 University College Dublin, School of Physics, Dublin, Ireland
2 SiriusXT Ltd, Science Centre North, Belfield, Ireland

Lunch 11:50 AM – 1:00 PM

Session 3: FEL based EUV Sources

Session Chairs: Alex Murokh (Radiabeam) and Erik R. Hosler (GLOBALFOUNDRIES)

Free-electron Lasers: Beyond EUV Lithography Insertion (P41) (Invited)
Erik R. Hosler, Obert R. Wood II
GLOBALFOUNDRIES, 400 Stone Break Road Extension, Malta, NY 12020

High Efficiency Free Electron Lasers (P44) (Invited)
Alex Murokh
Radiabeam

Design and Development of a 10-kW Class EUV-FEL Project in Japan (P43) (Invited)
Ryukou Kato
High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, 305-0801 Japan

Break and Group Photograph 2:00 PM (30 Minutes)

Session 4: EUV Optics

Session Chair: Regina Soufl (LLNL) and Ladislav Pina (Rigaku)

EUV Lithography High-NA Scanner for Sub 8 nm Resolution (P61) (Invited)
Jan van Schoot1, Eelco van Setten1, Gerardo Bottiglieri1, Kars Troost1, Sascha Migura2, Jens-Timo Neumann2, Bernhard Kneer2, Winfried Kaiser2
1ASML, De Run 6501, 5504 DR Veldhoven, Netherlands
2Carl Zeiss SMT GmbH, Rudolf-Eber-Straße 2, 73447 Oberkochen, Germany

Multilayer coatings for the first Micro-Exposure Tools with NA=0.5 (P64) (Invited)
Regina Soufl1, Jeff Robinson1, Eberhard Spiller2, Monica Fernández-Pereia1, Eric Gullikson3, Luc Girard4, Lou Marchetti4, John Kincaede4
1Lawrence Livermore National Laboratory, Livermore, CA 94550
2Spiller X-ray Optics, Livermore, CA 94550
3Lawrence Berkeley National Laboratory, Berkeley, CA 94720
Atomic-scale investigations of formation and aging processes of EUV optics (P66) (Invited)
Joost W.M. Frenken
Advanced Research Center for Nanolithography (ARCNL)
Science Park 110, 1098 XG, Amsterdam, The Netherlands

Diffractive Optics for EUV Applications (P67)
Ryan Miyakawa, Henry Wang, Weilun Chao, and Patrick Naulleau
Center for X-ray Optics, Lawrence Berkeley National Lab, 1 Cyclotron Rd, Berkeley, CA 94720

Fabrication of EUVL Micro-field Exposure Tools with 0.5 NA (P68)
Luc Girard¹, Lou Marchetti¹, Jim Kennon², Bob Kestner², Regina Souffli³, Eric Gullickson⁴
¹Zygo Corporation, Extreme Precision Optics (EPO), Richmond, CA 94806, USA
²Akumen Engineering, LLC. (former employees of Zygo EPO)
³Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550
⁴Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720

Multilayer EUV Optics with Integrated IR Suppression Gratings (P69)
Torsten Feigl¹, Marco Perske¹, Hagen Pauer¹, Tobias Fiedler¹, Uwe Zeitner², Robert Leitel², Hans-Christoph Eckstein², Philipp Schleicher², Sven Schröder², Marcus Trost², Stefan Risse², Christian Laubis³, Frank Scholze³
¹ optiX fab GmbH, Hans-Knöll-Str. 6, 07745 Jena, Germany
² Fraunhofer IOF, Albert-Einstein-Str. 7, 07745 Jena, Germany
³ PTB Berlin, Abbeestr. 2-12, 10587 Berlin, Germany

Adjourn: Time off for Networking
End Day 1
Thursday, June 16, 2016

Welcome and Announcements (Intro-2)
Vivek Bakshi
EUV Litho, Inc.

Session 5: Keynote-2

Session Chair: Patrick Naulleau (CXRO)

EUVL Exposure Tools for HVM: Status and Outlook (P2)
Igor Fomenkov
Cymer LLC, An ASML Company, San Diego, CA 92127, USA

Session 6: Mask-1

Session Co-Chairs: Ted Liang (Intel)

Eigenmode Analysis of Electromagnetic Fields in Binary EUV Masks (P51)
Michael Yeung¹, Eytan Barouch² and Hye-Keun Oh³
¹Fastlitho, 123 E. San Carlos Street, #251, San Jose, CA 95112
²Boston University, 15 St. Mary’s Street, Boston, MA 02215
³Hanyang University, Ansan, Gyeonggi 426-791, Republic of Korea

Challenges for Predictive EUV Mask Modeling (P82) (Invited)
P. Evanschitzky, A. Erdmann
Fraunhofer IISB, Schottkystrasse 10, 91058 Erlangen, Germany

Break 10:00 AM (20 Minutes)

Session 7: Mask -2

Session Chair: Ken Goldberg (LBNL)

Actinic Mask Inspection System Using Coherent Scattreometry Microscope (P84) (Invited)
H. Kinoshita, T. Harada, Y. Nagata, T. Watanabe and K. Midorikawa
University of Hyogo, Japan

Near Wavelength Limited, 15nm Spatial Resolution, Ptychographic Imaging using a 13.5nm Tabletop High Harmonic Light Source (P59) (Invited)
Henry Kapteyn
KMLabs Inc., 1855 S. 57th Court, Boulder, CO 80301 USA
Improvement of Coherent Scattering Microscopy by applying Ptychographical Iterative Engine (P55)
Dong Gon Woo¹, Seongchul Hong¹, Hoon Jo², Whoi-Yul Kim², and Jinho Ahn¹
¹Department of Materials Science and Engineering
²Department of Electronics and Computer Engineering
Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 133-791, Korea

Lunch 11:20 PM (90 Minutes)

Steering Committee working lunch meeting (Closed meeting)

12:50 PM Session 8: Mask -3

Session Chair: Jim Wiley (ASML)

Extreme Ultraviolet Mask Manufacturing: Challenges and Opportunities (P52) (Invited)
Bryan Kasprowicz¹, Henry Kamberian²
¹Photronics Inc., Allen, Texas, USA
²Photronics Boise nanoFab, Boise, Idaho, USA

Progress and Opportunities in EUV Mask Development (P53) (Invited)
Ted Liang
Intel Mask Operations, 3065 Bowers Avenue, Santa Clara, CA USA

Title TBA (P67) (Invited)
Patrick Naulleau
CXRO

Extending CO₂ Cryogenic Aerosol Cleaning for EUV Mask Cleaning (P57) (Invited)
Ivin Varghese and Charles W. Bowers
Eco-Snow Systems, RAVE N.P. Inc., 4935A Southfront Rd., Livermore, CA, USA 94551

Break 2:10 PM (20 Minutes)

Session 9: Resist -1

Session Co-Chairs: Stephen Meyers (Inpria) and Yoshi Hishiro (JSR)

EUV Radiation Chemistry Fundamentals: Novel Probing Techniques (P72)
Oleg Kostko, B. Xu, D. S. Slaughter, K. D. Closser, S. Bhattarai, B. Hinsberg,
Chemical Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkley, CA 94720, USA
Mechanisms of Exposure of Resists to EUV Light: Photons, Electrons and Holes (P76) (Invited)
Amrit Narasimhan, Steven Grzeskowiak, Greg Denbeaux, Robert Brainard
SUNY Polytechnic Institute, Albany NY 12203

Fundamentals of X-Ray Excitation and Relaxation in EUV Resists (P78) (Invited)
D. Frank Ogletree
Molecular Foundry, Materials Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720 USA

Session 10: Resist -2

Session Co-Chairs: Robert Brainard (SUNY) and Frank Ogletree (LBNL)

Fundamental Aspect of Photosensitized Chemically Amplified Resist: How to overcome RLS trade-off (P73) (Invited)
Seiichi Tagawa¹,² and PSCAR Collaboration Members
¹Graduate School of Engineering, Osaka University, Ibaraki, Osaka 567-0047, Japan,
²Institute of Scientific and Industrial Research, Osaka University, Ibaraki, Osaka 567-0047, Japan

Molecular Resist Materials for Extreme Ultraviolet Lithography (P74) (Invited)
Hiroki Yamamoto¹, Hiroto Kudo², and Takahiro Kozawa¹
¹The Institute of Scientific and Industrial Research, Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan (Osaka Univ.)
²Department of Chemistry and Materials Engineering, Faculty of Chemistry, Materials and Bioengineering, Kansai University, 3-3-35, Yamate-cho, Suita-shi, Osaka 564-8680, Japan

Metal Oxide EUV Photoresist for N7 Relevant Patterns (P79) (Invited)
Stephen T. Meyers, Andrew Grenville
Inpria Corporation, 2001 NW Monroe Avenue, Corvallis, OR, USA 97330

Title TBA (P91) (Invited)
Yoshi Hishiro
JSR

EUVL Workshop Summary (P90)
Vivek Bakshi
EUV Litho, Inc.

5:50- 7:00 PM Poster Session
7:30 -9:30 PM Dinner
Session 11: Poster Session (5:50 PM - 7:00 PM)

Session Chairs: Vivek Bakshi (EUV Litho Inc.) and Patrick Naulleau (CXRO)

1. Inspection Efficiency Comparison between Phase Contrast and Dark Field Microscopy for EUV Actinic Blank Inspection (P86)
   Yow-Gwo Wang* a,b, Andy Neureuther a,b, Patrick Naulleau b
   aDepartment of Electrical Engineering and Computer Sciences, University of California, Berkeley, CA USA 94720; bCenter for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA USA 94720

2. Off-axis Aberration Estimation in an EUV Microscope using Natural Speckle (P54)
   Aamod Shanker 1, Antoine Wojdyla 2, Gautam Gunjala 1, Jonathan Dong 3, Markus Benk 2, Andy Neureuther 1, Kenneth Goldberg 2, Laura Waller 1
   1Dept of Electrical Engineering and Computer Sciences, UC Berkeley, CA
   2Center for X-Ray Optics, Lawrence Berkeley National Lab, Berkeley, CA
   3D epartement de Physique, Ecole Normale Sup érieure, Paris 75005, France

3. Improving SRAF margin and imaging performance by using PSM in EUVL (P56)
   Yong Ju Jang 1, Jung Sik Kim 1, Seongchul Hong 2, Jinho Ahn 1,2
   1Department of Nanoscale Semiconductor Engineering
   2Department of Materials Science and Engineering
   Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea

4. CSM with Ptychography
   Dong Gon Woo 1, Seongchul Hong 1, Hoon Jo 2, Whoi-Yul Kim 2, and Jinho Ahn 1
   1Department of Materials Science and Engineering
   2Department of Electronics and Computer Engineering
   Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 133-791, Korea

5. Multilayer Development for EUV Lithography in CIOMP (P62)
   Bo Yu 1, Chunshui Jin 1, Chun Li 1, Shun Yao 1
   1Changchun Institute of Optical, Fine Mechanics and Physics, Chinese Academy of Sciences, 3888 Dong Nanhu Road, Changchun, China, 130033

6. Realization of EBL2, an EUV exposure facility for EUV induced contamination research (P65)
   Norbert Koster, Edwin te Sligte, Freek Molkenboer, Alex Deutz, Peter van der Walle, Pim Mulwij, Wouter Mulchuyse, Bastiaan Oostdijck, Christiaan Hollemans, Björn Nijland, Peter Kerkhof, Michel van Putten
   TNO, Stieltjesweg 1, 2628 CK Delft, The Netherlands

7. Modeling the Interaction of EUV radiation with Photoresist Materials (P71)
   Kristina D. Closser 1, David Prendergast 3, Musa Ahmed 1, Paul D. Ashby 2, Oleg Kostko 1, D. Frank Ogletree 1, Deirdre L. Olynick 2, D. Slaughter 2, Bo Xu 3, Patrick Naulleau 1
   1Molecular Foundry, Lawrence Berkeley National Laboratory
   2Chemical Sciences Division, Lawrence Berkeley National Laboratory
   3Center for X-ray Optics (CXRO), Lawrence Berkeley National Laboratory
8. Tin Cage Photoresists for EUV Lithography (P75)
Jarich Haitjema
Nano photochemistry Group, Advanced Research Center for Nanolithography (ARCNL), The Netherlands

Suchit Bhattaratia, Andrew R. Neureutheria, Patrick P. Nauleaub
aDepartment of EECS, Univ. of California, Berkeley, CA, USA 94720
bCenter for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA, USA 94720

10. Advances in EUV Resists 2010-2016
Robert Brainard, Gregg Gallatin, and Mark Neisser
aSUNY Polytechnic Institute
bApplied Math Solutions, LLC
cWhitehouse Station, NJ

11. Influence of Pulse Duration on CO2 Laser Produced tin Plasma by 1D Plasma Modeling (P31)
Wang Xinbing, Yao Liwei and Zuo Dulu
Wuhan National Laboratory for Optoelectronics, Huazhong University of Science Technolo
technology, Wuhan, 430074, China

12. Stable Droplet Generator for High brightness LPP EUV Source (P36)
Konstantin Koshelev, Alexander Vinokhodov, Mikhail Krivokorytov, Yuri Sidelnikov, Oleg Yakushev, Denis Glushkov, Pavel Seroglav, Samir Ellwi
1RnD-ISAN/EUV Labs, Troitsk, 142190 Russia
2Institute for Spectroscopy RAS, Troitsk, 142090 Russia
3ISTEQ, 5656 AG Eindhoven

13. Laboratory Cryo Soft X-ray Tomography: Progress in the Development of a Commercial Microscope (P37)
Kenneth Fahy, Fergal O’Reilly, Tony McEnroe, Felicity McGrath, Jason Howard, Aoife Mahon, Ronan Byrne, Osama Hammad, and Paul Sheridan
1SiriusXT Ltd., Science Centre North, UCD, Belfield, Dublin 4, Ireland
2School of Physics, UCD, Belfield, Dublin 4, Ireland

14. Light Source Development at Energetiq (P38)
Stephen F. Horne, Donald K Smith, Matthew M Besen, Paul A Blackborow, Deborah S Gustafson, Matthew J. Partlow, Huiling Zhu
Energetiq Technology, Inc.

15. Commercial Poster – Sponsor Product Description
Arnd Baurichter
Research-Instruments, Germany