

2015 International Workshop on EUV Lithography

June 15-19, 2015

Makena Beach & Golf Resort ▪ Maui, Hawaii

Workshop Proceedings



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Makena Beach & Golf Resort, Maui, Hawaii, USA

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Workshop Sponsors



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Workshop Agenda Outline

Monday, June 15, 2015

8:30 AM -5:00 PM
EUV Lithography Short Course (Makena Salon)

Tuesday, June 16, 2015

3:00 PM - 5:00 PM
Registration (Kaeo Ballroom Foyer)
Speaker Prep (Wailea Salon)

6:00 PM - 7:30 PM
Reception (Pacific Lawn)

Wednesday, June 17, 2015

7:30 AM – 8:30 AM Breakfast (Café Kiowai)
8:30 AM – 11:40 AM Oral Presentations (Wailea Salon)
11:40 AM – 1:00 PM Lunch (Molokini Room)
1:00 PM – 4:00 PM Oral Presentations (Wailea Salon)
4:00 PM Afternoon off for Networking

Thursday, June 18, 2015

7:30 AM – 8:30 AM Breakfast (Café Kiowai)
8:30 AM – 12:00 PM Oral Presentations (Wailea Salon)
12:00 PM – 1:00 PM Lunch (Molokini Room)
1:00 PM – 5:00 PM Oral Presentations (Wailea Salon)
5:00 PM - 6:00 PM Poster Session (Wailea Salon Foyer)
6:30 PM – 8:00 PM Dinner (Pacific Lawn)

Friday, June 19, 2015

8:30 AM – 10:00 AM EUVL Workshop Steering Committee Meeting (Café Kiowai)

Workshop Proceedings

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2015 International Workshop on EUV Lithography

Makena Beach & Golf Resort, Maui, Hawaii, USA
June 15-19, 2015

Wednesday, June 17, 2015

8:30 AM **Welcome and Introduction**

Introductions (Intro-1)

Vivek Bakshi
EUV Litho, Inc., Austin, TX, USA

Session 1: Keynote – 1

Session Chair: Hakaru Mizoguchi (Gigaphoton)

EUVL for HVM: Progress Update (P1)

Mark Phillips
Intel Corporation, Hillsboro, OR 97124, USA

Challenges of EUV Lithography for HVM (P2)

Takayuki Uchiyama
Lithography Process Development Department, Center for Semiconductor Research and Development, Toshiba Corporation, Japan

Break (20 minutes)

Session 2: Optics and Contamination

Session Co-chairs: Yuriy Platonov (Rigaku) and David Ruzic (UIUC)

Progress with Capping Layer and Optics Refurbishment Development at RIT (Invited Talk) (P72)

Yuriy Platonov^a, Michael Kriese^a, Vladimir Martynov^a, Raymond Crucet^a, Yang Li^a, Steven Grantham^b, Charles Tarrio^b, John Curry^b, Shannon Hill^b, Thomas Lucatorto^b

^a*Rigaku Innovative Technologies, 1900 Taylor Rd., Auburn Hills, MI 48326, USA*

^b*Institute for Standards and Technology, Gaithersburg, MD 20899, USA*

Issues in the Testing of Non-CAR Materials in Hydrogen Atmospheres (Invited Talk) (P73)

C. Tarrio, R. F. Berg, S. B. Hill, and T. B. Lucatorto

Sensor Science Division, National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA

Collector Cleaning and EUV Extendability (Invited Talk) (P74)

David N. Ruzic, Daniel T. Elg, Gianluca A. Panici, Shailendra N. Srivastava

Center for Plasma Material Interactions, Department of Nuclear, Plasma, and Radiological Engineering, University of Illinois at Urbana-Champaign

Scintillators and Imaging in EUV/XR Spectral Region (Invited Talk) (P71)

Ladislav Pina

Czech Technical University in Prague, Prague, Czech Republic

Lunch 11:40 AM – 1:00 PM

Session 3: EUV Resists

Session Co-chairs: Toru Fujimori (EIDEC) and Yoshi Hishiro (JSR)

Recent Progresses in Negative-tone Imaging using EUV Exposure (Invited Talk) (P62)

Toru Fujimori, Toru Tsuchihashi and Toshiro Itani

EUVL Infrastructure Development Center, Inc. (EIDEC), 16-1 Onogawa, Tsukuba-shi, Ibaraki 305-8569, Japan

Novel EUV Resist Development for sub-14 nm Half pitch (Invited Talk) (P64)

Yoshi Hishiro

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

Dissolution Dynamics of Chemically Amplified Resists for Extreme Ultraviolet Lithography Studied by Quartz Crystal Microbalance (Invited Talk) (P65)

Masaki Mitsuyasu, [Hiroki Yamamoto](#) and Takahiro Kozawa
The Institute of Scientific and Industrial Research, Osaka University, Address: 8-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

Characterization of Inorganic Resists Using Temperature Programmed and Electron Stimulated Desorption (P61)

[Gregory S. Herman](#) and Ryan Frederick
*Oregon State University, School of Chemical, Biological and Environmental Engineering
102 Gleeson Hall, Corvallis, OR USA*

EUV Patterning Improvement Toward High-volume Manufacturing (Invited Talk) (P63)

[Yuhei Kuwahara](#)¹, [Koichi Matsunaga](#)¹, [Shinichiro Kawakami](#)¹, [Kathleen Nafus](#)¹, [Philippe Foubert](#)², [Anne-Marie Goethals](#)²
¹ *Tokyo Electron Kyushu Ltd., 1-1 Fukuhara, Koshi city, Kumamoto, 861-1116, Japan*
² *IMEC, Kapeldreef 75, B-3001, Leuven, Belgium*

Break 2:40 PM (20 Minutes)

Session 4: EUVL Regional Reviews

Session Chair: Vivek Bakshi (Vivek Bakshi, EUV Litho, Inc.)

[Wang Xiangzhao \(SIOM, China\) \(P21\)](#)

[Bob Rollinger \(ETHZ, Europe\) \(P22\)](#)

[Jinho Ahn \(Hanyang University, Korea\) \(P23\)](#)

[Takayuki UCHIYAMA \(TOSHIBA, Japan\) \(P24\)](#)

[Patrick Naulleau \(CXRO, USA\) \(P25\)](#)

Adjourn: Time off for Networking

End Day 1

Thursday, June 18, 2015

Welcome and Announcements (Intro-2)

Vivek Bakshi
EUV Litho, Inc.

Session 5: Keynote-2

Status and outlook of LPP light sources for HVM EUVL (P3)

Igor Fomenkov, ASML, Cymer, San Diego, USA

Session 6: EUV Sources

Session Co-Chairs: Rainer Lebert (RI) and Debbie Gustafson (Energetiq)

Update of One Hundred Watt HVM LPP-EUV Source (Invited Talk) (P33)

Hakaru Mizoguchi, Hiroaki Nakarai, Tamotsu Abe, Takeshi Ohta, Krzysztof M Nowak, Yasufumi Kawasuji, Hiroshi Tanaka, Yukio Watanabe, Tsukasa Hori, Takeshi Kodama, Yutaka Shiraishi, Tatsuya Yanagida, Georg Soumagne, Tsuyoshi Yamada, Taku Yamazaki, Shinji Okazaki and Takashi Saitou
Gigaphoton Inc. Hiratsuka facility: 3-25-1 Shinomiya Hiratsuka Kanagawa,254-8567, JAPAN

States and Prospects of Laser Drivers for 250W and Toward > 500W Extreme ultraviolet (EUV) Generation (Invited Talk) (P35)

Koji Yasui¹ and Jun-ichi Nishimae²
¹*Mitsubishi Electric Corporation, Head quarter, Tokyo, Japan*
²*Mitsubishi Electric Corporation, Advanced technology R&D center, Hyogo, Japan*

XUV Research with Compact DPP and LPP Laboratory Sources: Complementary to Beamlines and Large Scale Industrial Tools (Invited Talk) (P31)

Rainer Lebert¹, Christoph Phiesel¹, Thomas Mißalla¹, Christian Piel¹, Klaus Bergmann², Alexander von Wezyk², Jochen Vieker², Serhiy Danylyuk³, Lukas Bahrenberg³, Stefan Herbert³, Larissa Juschkina⁴, Aleksey Maryasov⁴
¹ *RI Research Instruments GmbH (RI), 51429 Bergisch-Gladbach, Germany*
² *Fraunhofer Institute for Laser Technology (FhG-ILT)*
³ *Chair for the Technology of Optical Systems*
⁴ *Chair for the Experimental Physics of EUV*
^{3, 4} *at RWTH Aachen University;*
^{2,3,4} *at 52074, Aachen, Germany*

Plasma Design of the EQ-10 EUV Source (Invited Talk) (P34)

Stephen F. Horne, Matthew J. Partlow, Deborah S. Gustafson, Matthew M. Besen, Donald K. Smith, Paul A. Blackborow
Energetiq Technology Inc., 7 Constitution Way, Woburn MA 01801 USA

High Brightness LPP Light Sources for High Volume Inspection (Invited Talk) (P36)

Bob Rollinger
Swiss Federal Institute of Technology, Laboratory for Energy Conversion, ETH Zurich, ML J23, Sonneggstrasse 3, 8092 Zürich, Switzerland

Break (20 Minutes)

Session 7: Panel Discussion (40 Minutes)

Lunch 12:00 PM (60 Minutes)

Session 8: FEL based Sources for EUVL

Session Co-chairs: Alex Murokh (RadiaBeam) and Norio Nakamura (KEK)

LCLS-II and Free Electron Laser Drivers for EUV Lithography (Invited Talk) (P44)

Aaron Tremaine
SLAC, 2575 Sand Hill Road, Menlo Park, 94025, USA

An ERL-Based High-Power Free-Electron Laser for EUV Lithography (Invited Talk) (P42)

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

EUV Radiation from a Microbunched Storage Ring (Invited Talk) (P41)

Daniel Ratner, Alex Chao
SLAC, 2575 Sand Hill Road, Menlo Park, 94025, USA

TESSA – a Novel High Efficiency EUV Source (Invited Talk) (P43)

A. Murokh¹, J. Duris², P. Musumeci²
¹*RadiaBeam Technologies, USA*
²*UCLA, USA*

Simulation of an Electron Gun for ERL-FEL Based EUV Lithography System (Invited Talk) (P45)

Taisuke Kawasaki¹, Makoto Takemura¹, Haruo Miyadera¹, Tsukasa Miyajima², Masahiro Yamamoto², Yosuke Honda², Takashi Uchiyama², Xiuguang Jin², Yukihide Kamiya², Hiroshi Kawata², Yukinori Kobayashi², Nobuyuki Nishimori³, Ryoichi Hajima³

¹TOSHIBA Corporation: 8, Shinsugita-Cho, Isogo-Ku, Yokohama 235-8523, Japan

²High Energy Accelerator Research Organization (KEK): 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

³Japan Atomic Energy Agency (JAEA): 4-49 Muramatsu, Tokai-mura, Naka-gun, Ibaraki 319-1184, Japan

Break 2:40 PM (20 Minutes)

Session 9: EUV Masks

Session Co-Chairs: Takashi Kamo (Toshiba) and Jinho Ahn (Hanyang University)

Current Status and Outlook for EUV Mask (Invited Talk) (P52)

Takashi Kamo

Lithography Process Development Department,

Center for Semiconductor Research & Development, TOSHIBA Corporation, Kanagawa 212-8583, Japan

Progress Towards Actinic Patterned Mask Inspection (Invited Talk) (P51)

Oleg Khodykin

RAPID, KLA-Tencor Inc., USA

Critical Defect Size on the Extreme Ultraviolet (EUV) Mask and Cleaning Process for its Removal (Invited Talk) (P54)

Min-Su Kim^a, Hye-Rim Ji^b, In-Seon Kim^b, Hye-Keun Oh^b, Jin-Ho Ahn^c and Jin-Goo Park^{a†}

^aDepartment of Materials Engineering and Bio-Nano Technology, Hanyang University, Ansan, Korea,

^bDepartment of Applied Physics, Hanyang University, Ansan, Korea,

^cDepartment of Materials Science and Engineering, Hanyang University, Seoul, Korea

Tabletop-Scale EUV Coherent Phase-And-Amplitude Imaging Using High Harmonics (P55)

Daniel E. Adams, Dennis F. Gardner, Elisabeth R. Shanblatt, Christina L. Porter, Robert M. Karl, Michael D. Tanksalvala, Henry C. Kapteyn, Margaret M. Murnane
JILA, University of Colorado, 440 UCB, Boulder, Colorado 80309-0440, USA

Multilayer Mask Roughness: the Relative Importance of Phase and Amplitude (Invited Talk) (P56)

Patrick P. Naulleau¹, Kenneth A. Goldberg¹, Eric Gullikson¹, Rene Claus², Henry Wang², Andy Neureuther²

¹Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720

²University of California at Berkeley, Berkeley, CA 94720

EUVL Workshop Summary (Summary)

Vivek Bakshi, *EUV Litho, Inc.*

5 PM: Session 10: Poster Session

XUV, EUV and Soft-X-Ray Solutions with Compact Laboratory-Sources (P32)

Rainer Lebert¹, Christoph Phiesel¹, Thomas Mißalla¹, Christian Piel¹, Klaus Bergmann², Alexander von Wezyk², Jochen Vieker², Serhiy Danylyuk³, Lukas Bahrenberg³, Stefan Herbert³

¹ RI Research Instruments GmbH (RI), 51429 Bergisch-Gladbach, Germany

²Fraunhofer Institute for Laser Technology (FhG-ILT)

³ Chair for the Technology of Optical Systems at RWTH Aachen University

^{2,3} at 52074, Aachen, Germany

Optimal Shift of Pattern Shifting for Mitigation of Mask Defects in EUV Lithography (P53)

Sikun Li, Xiangzhao Wang, Xiaolei Liu, Heng Zhang

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

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EUV/SXR/XR Optics and Imaging Detectors

Ladislav Pena

Rigaku Innovative Technologies Europe, Prague, Czech Republic

Low Readout-noise CCD-cameras for VUV, EUV and X-Ray Imaging and Spectroscopy

Martin Regehly, Katharina Mangold, Roman Kemmler

greateyes GmbH, Rudower Chaussee 29, 12489 Berlin, Germany

Ultrahigh Brightness and Broadband Laser-Driven Light Sources

H. Zhu, G. Hill, M. Besen, D. Smith, P. Blackborow

Energetiq Technology, Inc., Woburn, MA 01801, USA

