

# 2010 International Workshop on EUV Lithography

June 21-25, 2010

Makena Beach Golf Resort ■ Maui, Hawaii

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## Workshop Proceedings





# **2010 International Workshop on EUV Lithography**

**Makena Beach Golf Resort, Maui, Hawaii, USA  
June 21-25, 2010**

## **Workshop Agenda**

### **Short Courses (Makena Room, June 21-22, 2010)**

#### **EUV Lithography**

8:00 AM -5:00 PM, Monday, June 21, 2010

#### **Resist Materials for High Resolution Patterning**

6:00 PM-10:00 PM, Monday, June 21, 2010

#### **EUV Physics**

8:00 AM – 12:00 PM, Tuesday, June 22, 2010

#### **Introduction to Optical Lithography**

1:00 PM – 5:00PM, Tuesday, June 22, 2010

### **EUVL Workshop (June 22-25, 2010)**

#### **Tuesday, June 22, 2010**

|                  |                                                                        |
|------------------|------------------------------------------------------------------------|
| 3:00 PM- 5:00 PM | Registration (Kaeo Ballroom Entry Lanai)<br>Speaker Prep (Wailea Room) |
| 5:00 PM- 7:00 PM | Reception (Pacific Lawn)                                               |



### **Wednesday, June 23, 2010**

|          |   |          |                                            |
|----------|---|----------|--------------------------------------------|
| 7:00 AM  | – | 8:00 AM  | Breakfast                                  |
| 8:00 AM  | – | 12:00 PM | Oral Presentations (Wailea Room)           |
| 12:00 PM | – | 1:00 PM  | Lunch (Holokai Pavilion)                   |
| 1:00 PM  | – | 5:00 PM  | Oral Presentations (Wailea Room)           |
| 5:00 PM  | – | 6:00 PM  | Poster Session and Reception (Makena Room) |
| 7:00 PM  |   |          | Dinner (Pacific Lawn)                      |

### **Thursday, June 24, 2010**

|          |   |          |                                  |
|----------|---|----------|----------------------------------|
| 7:00 AM  | – | 8:00 AM  | Breakfast                        |
| 8:00 AM  | – | 12:00 PM | Oral Presentations (Wailea Room) |
| 12:00 PM | – | 1:00 PM  | Lunch (Holokai Pavilion)         |
| 1:00 PM  | – | 3:00 PM  | Oral Presentations (Wailea Room) |
| 3:00 PM  |   |          | Adjourn                          |

### **Friday, June 25, 2010**

|         |   |          |                                                                         |
|---------|---|----------|-------------------------------------------------------------------------|
| 8:30 AM | – | 10:00 AM | EUVL Workshop Steering Committee Meeting<br>(Kahili Court Private Room) |
|---------|---|----------|-------------------------------------------------------------------------|



# **2010 International Workshop on EUV Lithography**

*Makena Beach Golf Resort, Maui, Hawaii, USA  
June 21-25, 2010*

## **Workshop Proceedings**

### **Monday, June 21, 2010**

#### **Short Courses**

##### **EUV Lithography**

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

8:00 AM -5:00 PM, Monday, June 21, 2010

##### **Resist Materials for High Resolution Patterning**

by Cliff Henderson (Georgia Tech University)

6:00 PM-10:00 PM, Monday, June 21, 2010

### **Tuesday, June 22, 2010**

#### **Short Courses**

##### **EUV Physics**

by David Attwood (LBNL)

8:00 AM – 12:00 PM, Tuesday, June 22, 2010

##### **Introduction to Lithography**

by Chris Mack (Lithoguru.com)

1:00 PM – 5:00 PM, Tuesday, June 22, 2010

#### **Registration and Reception**

3:00 PM- 5:00 PM

5:00 PM- 7:00 PM

Registration & Speaker Prep

Reception



**Wednesday, June 23, 2010**

**8:00 AM** **Welcome and Introduction**

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

**8:10 AM** **Session 1: Keynote -1**

**Session Chair: Sam Sivakumar (Intel)**

**EUV: Status and Challenges Ahead** (Keynote-1)

Jos Benschop  
*ASML, Eindhoven, Netherlands*

**EUV Lithography: Approaching Pilot Production** (Keynote-2)

Obert Wood  
*GlobalFoundries, Albany, New York, USA*

**9: 20 AM** **Award Ceremony**

**9:35 AM** ***Break (20 Minutes)***

**9:55 AM** **Session 2: High Power EUV Sources**

**Session Chairs: David Attwood (University of California at Berkeley)  
and Obert Wood (Global Foundries)**

**Future of High Power EUV Sources** (Source-10, Invited)

Hakaru Mizoguchi  
*Gigaphoton, Tshigi, Japan*

**CO<sub>2</sub> Laser-produced Tin Plasmas as EUVL Sources** (Source-3)

Thomas Cummins, Gerry O'Sullivan, Emma Sokell, Padraig Dunne, Fergal O'Reilly  
and Tony Donnelly  
*University College Dublin, Dublin, Ireland*



**Improving Efficiency of MOPA Laser System for LPP EUV Source** (Source-1, Invited)

Krzysztof M. Nowak, Takashi Suganuma, Toshio Yokotsuka, Koji Fujitaka, Hideo Hoshino, Masato Moriya, Takeshi Ohta, Akira Sumitani, Akira Endo  
*EUVA (Extreme Ultraviolet Lithography System Development Association), Hiratsuka, Kanagawa, Japan*

**Modelling of High Intensity EUV Light Sources Based on Laser & Discharge Produced Plasmas** (Source-6)

S. V. Zakharov<sup>1,2,3</sup>, P. Choi<sup>1,2</sup>, V. S. Zakharov<sup>2</sup>

<sup>1</sup> NANO-UV sas, Villebon/Yvette 91140, France

<sup>2</sup> EPPRA sas, Villebon/Yvette 91140, France

<sup>3</sup> also with RRC Kurchatov Institute, Moscow, Russia

**Status and Future of High Power EUV Source Technology** (Source-11)

Vivek Bakshi

*EUVL Litho, Inc., Austin, TX, USA*

**11:20 Session 3: Next Generation EUV Sources**

***Session Chair: Jos Benschop (ASML)***

**Laser-produced terbium & gadolinium Plasmas as EUVL Sources at 6.5 – 6.7 nm** (Source-7, Invited)

Padraig Dunne<sup>1</sup>, Thomas Cummins<sup>1</sup>, John White<sup>1</sup>, Deirdre Kilbane<sup>1</sup>, Rebekah D'Arcy<sup>1</sup>, Emma Sokell<sup>1</sup>, Thomas McCormack<sup>1</sup>, Imam Kambali<sup>1</sup>, Takamitsu Otsuka<sup>2</sup>, Colm O'Gorman<sup>1</sup>, Enda Scally<sup>1</sup>, Fergal O'Reilly<sup>1</sup>, Tony Donnelly<sup>1</sup> and Gerry O'Sullivan<sup>1</sup>.

<sup>1</sup>University College Dublin, Dublin, Ireland

<sup>2</sup>Utsunomiya University, Tochigi, Japan

**Atomic Processes in Plasma EUV Sources at  $\lambda=6.5\text{nm}$**  (Source-2)

Akira Sasaki

*Japan Atomic Energy Agency, Kyoto, Japan*

**11:55 AM Lunch (Holokai Pavilion)**



## **1:00 PM                      Session 4: EUV Sources for Metrology**

**Session Chairs: Padraig Dunne (University College Dublin) and Sergey Zakharov (EPPRA)**

### **EUV Source Development for AIMS and Blank Inspection** (Source-4)

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

### **High Brightness EUV Light Source System Development for Actinic Mask Metrology** (Source-5)

Sergey V. Zakharov <sup>1,2,5</sup>, Peter Choi <sup>1,2</sup>, Raul Aliaga-Rossel <sup>1</sup>, Adrice Bakouboula <sup>1</sup>, Otman Benali <sup>1</sup>, Philippe Bove <sup>1</sup>, Michele Cau <sup>1</sup>, Grainne Duffy <sup>1</sup>, Carlo Fanara <sup>2</sup>, Wafa Kezzar <sup>1</sup>, Blair Lebert <sup>2</sup>, Keith Powell <sup>1</sup>, Ouassima Sarroukh <sup>2</sup>, Luc Tantart <sup>1</sup>, Clement Zaepffel <sup>2</sup>, Vasily S. Zakharov <sup>2</sup>, Alan Michette <sup>3</sup>, Edmund Wyndham <sup>4</sup>

<sup>1</sup> NANO-UV sas, Villebon/Yvette 91140, France

<sup>2</sup> EPPRA sas, Villebon/Yvette 91140, France

<sup>3</sup> Dept of Physics, King's College, London WC2R 2LS UK

<sup>4</sup> Pontificia Universidad Catolica de Chile, Santiago, Chile

<sup>5</sup> RRC Kurchatov Institute, Moscow, Russia

### **High Brightness EUV Source Using a DC High Voltage Generator** (Source-8)

John Madey, Luis Elias and Eric Szarmes  
*University of Hawai'i at Manoa, Manoa, Hawaii, USA*

### **Status of EUV Sources for Mask Metrology** (Source-12)

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

## **2:00 PM                      Session 5: EUV Optics**

**Session Chair: Yuriy Platonov (Rigaku Innovative Technologies)**

### **Virtual Sputter Chamber - Multiphysics Simulation of Magnetron Sputter & Deposition of EUV/X-ray Thin Films** (Optics-1, Invited)

Chris Walton  
*Lawrence Livermore National Laboratory, Livermore, CA, USA*

### **Growth, Microstructure and Stress Evolution of Sputtered Thin Films for EUV/X-ray Applications** (Optics-2, Invited)

Regina Soufli  
*Lawrence Livermore National Laboratory, Livermore, CA, USA*



**2:40 PM**

**Break (20 Minutes)**

**3:00 PM**

**Session 6: Contamination**

**Session Chairs: Iwao Nishiyama (SELETE) and Greg Denbeaux (University of Albany)**

**Novel Ozone-based Cleaning Technique for EUV Optics Carbon Contamination** (Contamination-2, Invited)

Iwao Nishiyama, Toshihisa Anazawa, Noriaki Takagi, Osamu Suga  
MIRAI-Semiconductor Leading Edge Technologies, Inc., Ibaraki, Japan

**Carbon Contamination of EUV Masks and its Effect on Imaging**

(Contamination- 4)

Greg Denbeaux<sup>1</sup>, Yu-Jen Fan<sup>1</sup>, Leonid Yankulin<sup>1</sup>, Petros Thomas<sup>1</sup>, Chimaobi Mbanaso<sup>1</sup>, Alin Antohe<sup>1</sup>, Rashi Garg<sup>1</sup>, Andrea Wüest<sup>2</sup>, Patrick Naulleau<sup>3</sup>, Kenneth Goldberg<sup>3</sup>, Iacopo Mochi<sup>3</sup>

<sup>1</sup>College of Nanoscale Science and Engineering, University at Albany, NY

<sup>2</sup>SEMATECH, Albany, NY

<sup>3</sup>CXRO, Lawrence Berkeley National Lab, Berkeley, CA

**Analysis of Carbon Contamination on EUV Mask using CSM / ICS** (Mask-1)

Jae Uk Lee<sup>1</sup>, Chang Young Jeong<sup>1</sup>, Sangsul Lee<sup>1</sup>, Jong Gul Doh<sup>1</sup>, Dong Geun Lee<sup>2</sup>, Seong-Sue Kim<sup>2</sup>, Han-Ku Cho<sup>2</sup>, Seung-yu Rah<sup>3</sup> and Jinho Ahn<sup>1</sup>

<sup>1</sup> Department of Materials Science and Engineering, Hanyang University, Korea

<sup>2</sup> Photomask Team, Memory Division, Semiconductor Business, Samsung Electronics Co., LTD, Korea

<sup>3</sup> Pohang Accelerator Laboratory, Korea

**Outgassing and Extreme-ultraviolet Photochemistry of Photoresist and Underlayer Materials** (Contamination-1)

Grace H. Ho, Fu-H. Kang, Chih-H. Shao, Wei-L. Hung, Chih-B. Kao, and Yu-L. Chou  
Department of Applied Chemistry, National University of Kaohsiung, Kaohsiung, Taiwan

**Nanoparticle Contamination Control and Metrology for the Extreme Ultraviolet Lithography (EUVL) Systems** (Contamination-3)

David Y.H. Pui

University of Minnesota, Minneapolis, MN, USA

**4:20 PM**

**Break (40 Minutes)**



## **5:00 PM – 6:00 PM      Poster Session and Reception**

### **5:00 PM                      Session 7: Poster Session**

***Session Chair: Ken Goldberg (LBNL)***

#### **Chemical Vapor Composite Silicon Carbide (CVC SiC™) Mirror Substrates**

(Optics-3)

Clifford T. Tanaka

*Trex Enterprises Corporation, Kauai, HI, USA*

#### **Production of High Purity Functional Water at Point-of-Use for Advanced Mask Cleaning Processes** (Mask-3)

Annie Xia

*Entegris, Inc., Billerica, MA, USA*

#### **EUV Laser for Applications in EUVL Mask Metrology** (Source-9)

Davide Bleiner<sup>1</sup>, Christoph Imesch<sup>1</sup>, Felix Staub<sup>1</sup>, Yasin Ekinici<sup>2</sup>, Vivek Bakshi<sup>3</sup>, and Juerg Balmer<sup>1</sup>

<sup>1</sup>*Institute for Applied Physics, University of Berne, Berne, Switzerland*

<sup>2</sup>*Paul Scherrer Institute, Laboratory for Micro & Nanotechnology, Villigen PSI, Switzerland*

<sup>3</sup>*EUV Litho, Inc., Austin TX, USA*

#### **An Investigation of Flare Value at Pattern Edge Region in EUVL** (Resist -5)

Kangyoo Song, Junhwan Lee, Changreol Kim<sup>1</sup>, Yongdae Kim<sup>1</sup>, Ohyun Kim

*Pohang University of Science and Technology, Pohang, Republic of Korea*

<sup>1</sup>*Hynix Semiconductor Inc, Republic of Korea*

#### **Counting outgassing molecules** (Contamination-5)

Chih-H. Shao, Chih-B. Kao, Yu-L. Chou, Wei-L. Hung and Grace H. Ho\*

*Department of Applied Chemistry, National University of Kaohsiung, Nanzih, Kaohsiung 811, Taiwan*

#### **Contamination Removal using the Evactron® De-Contaminator**

(Contamination-6)

Christopher G. Morgan, Ronald Vane, Senajith B. Rekawa<sup>1</sup>, Paul E. Denham<sup>1</sup>, Brian H. Hoef<sup>1</sup>, Michael S. Jones<sup>1</sup>, and Patrick P. Naulleau<sup>1</sup>

*XEI Scientific, Inc.*

*1755 E. Bayshore Blvd., Redwood City, CA 94063*

<sup>1</sup>*Center for X-Ray Optics (CXRO), Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, CA 94720*



**A New Resist Evaluation System developed at NewSUBARU** (Resist-7)

Hiroo Kinoshita and Takeo Watanabe

*Laboratory of Advanced Science and Technology for Industry*

*University of Hyogo, 1-1-2 Kouto kamigoro Ako-gun Hyogo Pref., Japan 678-1205*

**7:00 PM**

***Dinner (Pacific Lawn)***



**Thursday, June 24, 2010**

**8:00 AM [Welcome and Announcements](#)**

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

**8:10 AM Session 8: Keynote – 2**

**[EUVL Development in Japan](#) (Keynote-3)**

Iwao Nishiyama  
*SELETE, Japan*

**8:45 AM Session 9: EUVL R&D Status**

***Session Chairs: Hiroo Kinoshita (Hyogo University) and David Attwood (University of California at Berkeley)***

**Panelists:**

[EUVL R&D –USA](#) (R&D-1)  
Greg Denbeaux – USA (University of Albany)

[EUVL R&D –Japan](#) (R&D-2)  
Hiroo Kinoshita –Japan (Hyogo University)

[EUVL R&D –Europe](#) (R&D-3)  
Padraig Dunne – Europe (University College, Dublin)

[EUVL R&D –Taiwan](#) (R&D-4)  
Chun-Hung Lin – Taiwan (National Cheng Kung University)

[EUVL R&D –Korea](#) (R&D-5)  
Jinho Ahn – Korea (Hanyang University)

**10:00 AM Break (15 Minutes)**

**10:15 AM**

**Session 10: EUVL Mask**

**Session Chair: Jinho Ahn (Hanyang University)**

**Development Status of EUVL Blank and Substrate** (Mask-6, Invited)

Yoshiaki Ikuta and Toshiyuki Uno

*Central Research Center, Asahi Glass Co. Ltd., JAPAN*

**Defect Detection and Inspection Unmasked: The current state of EUV mask defects** (Mask-2, Invited)

Kenneth A. Goldberg, Iacopo Mochi, Sungmin Huh<sup>1</sup>, David Chan<sup>1</sup>

*Lawrence Berkeley National Laboratory, Berkeley, CA, USA*

<sup>1</sup>*SEMATECH, Albany, NY, USA*

**Study of the Minimum Phase Defect Affecting the Exposure Result** (Mask-5, Invited)

Hiroo Kinoshita,<sup>1, 3</sup> Kei Takase<sup>1, 3</sup>, Toshiyuki Uno<sup>2</sup>, Takeo Watanabe<sup>1, 3</sup>, and Tetuo Harada<sup>1, 3</sup>

<sup>1</sup>*Laboratory of Advanced Science and Technology for Industry, University of Hyogo  
1-1-2 Kouto Kamigori, Ako-gun, Hyogo 678-1205, Japan*

<sup>2</sup>*Asahi Glass Co., Ltd., R&D Center, Yokohama 221-8755, Japan*

<sup>3</sup>*JST, CREST, Yonban, Chiyoda, Tokyo 102-0081, Japan*

**11:15 AM**

**Session 11: LER**

**Session Chair: Patrick Naulleau (LBNL)**

**Mask Metrology and Pattern Profile Analysis Using the AIT: Down to 64 nm** (Mask-4)

Iacopo Mochi, Kenneth A. Goldberg, Tom Wallow<sup>1</sup>

*Lawrence Berkeley National Laboratory, Berkeley, CA, USA*

<sup>1</sup>*Global Foundries, Albany, NY, USA*

**Stochastic Resist Simulation at EUV** (LER-2, Invited)

John J. Biafore, Mark D. Smith

*KLA-Tencor, Austin, TX, USA*



**The Influence of Photoresist Development on Line Edge Roughness** (LER-1, Invited)

Chris Mack

*Lithoguru.com, Austin, TX, USA*

**12:10 PM – 1:10 PM Lunch (Holokai Pavilion)**

**1:10 PM Session 12: EUV Resist**

**Session Chairs: Chris Mack (Lithoguru.com) and Takahiro Kozawa (Osaka University)**

**Contact Size Variations: Dissecting the Sources** (Resist-8, Invited)

Patrick Naulleau

*Center for X-ray Optics, Lawrence Berkeley National Laboratory*

*MS 2-4001 Cyclotron Rd, Berkeley, CA 94720*

**Flare Mapping and Correction results for EUV Alpha Demo Tool** (Resist -4, Invited)

James Moon, Cheol-Kyun Kim, Byoung-Sub Nam, Chang-Moon Lim, Donggyu Yim, and Sung-Ki Park

*Hynix Semiconductor Inc., Kyungki-do, Korea*

**Nanoscale Chemical Reaction Induced in Chemically Amplified Resists upon Exposure to Extreme Ultraviolet Radiation** (Resist-1, Invited)

Takahiro Kozawa

*Osaka University, Osaka, Japan*

**Novel molecular Materials based on Noria and Double Calixarene for EB and EUV Resist Systems** (Resist -2, Invited)

Tadatomi Nishikubo and Hiroto Kudo

*Kanagawa University, Japan*

**Effects of Acid Amplifiers and Polymer Bound Photoacid Generators on EUV Resist Performance: Fundamental Studies and Lithographic Results** (Resist-3, Invited)

Gregory M Wallraff, Phillip J. Brock, Young-Hye Na, Mark Sherwood, Hoa D. Truong, William S. A. Swanson, H. C. Kim, W.D. Hinsberg, Masaki Fujiwara\* and Kazuhiko Maeda\*, Ramakrishnan Ayothi #, Yoshi Hishiro#

*IBM Almaden Research Center, San Jose, CA, USA,*

*\* Central Glass Corporation, Ltd., Tokyo, Japan*

*# JSR Micro, Sunnyvale, CA USA*



**Radiation Chemistry of EUV and EB Resists** (Resist-6)

Seiichi Tagawa<sup>1,2</sup>

<sup>1</sup> *The Institute of Scientific and Industrial Research, Osaka University,*

<sup>2</sup> *Japan Science and Technology Agency, CREST, c/o Osaka University, Japan*

**2:45 PM**

**WORKSHOP SUMMARY**

**EUVL Workshop Summary and Announcements**

Vivek Bakshi

*EUV Litho Inc, Austin, TX, USA*

**3:00 PM**

***Adjourn***



**Friday, June 25, 2010**

**EUVL Workshop Steering Committee Meeting**

**8:30 AM**

**Breakfast**

**9:00 -10: 00 AM**

**EUVL Workshop Steering Committee Meeting**

