PROCEEDINGS OF SPIE

Extreme Ultraviolet (EUV) Lithography V

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Editors

24–27 February 2014
San Jose, California, United States

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SPIE

Volume 9048

Proceedings of SPIE 0277-786X, V. 9048

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Extreme Ultraviolet (EUV) Lithography V, edited by Obert R. Wood II, Eric M. Panning, Proc. of SPIE Vol. 9048, 904801 · © 2014 SPIE · CCC code: 0277-786X/14/$18 · doi: 10.1117/12.2065428

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Please use the following format to cite material from this book:
Author(s), "Title of Paper," in *Extreme Ultraviolet (EUV) Lithography V*, edited by Obert R. Wood II, Eric M. Panning, Proceedings of SPIE Vol. 9048 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X
ISBN: 9780819499714

Published by
SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

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Introduction

The chairs of the Extreme Ultraviolet (EUV) Lithography V conference would like to thank the program committee, the session chairs, the presenters and the attendees for a successful 2014 meeting at SPIE Advanced Lithography in San Jose, California. Conference oral talks were up year over year with excellent worldwide representation. Peak session attendance at invited and joint sessions topped 600. Key topics included EUV scanner performance and EUV pellicle program progress, source scaling challenges including in-situ collector cleaning, mask metrology results from both the SHARP actinic microscope at LBNL and the Zeiss EUV AIMS™ tool, performance improvements in novel resist formulations, and improvement in on-product overlay, edge placement error (EPE) understanding, and EUV cost of ownership modeling.

The EUV conference received 135 abstract submissions in 2014, an increase of ~14% over the previous year. The receipt of a record number of abstract this year, 68 of which were accepted for oral presentation and 67 for presentation in the poster session, is evidence of the increasing interest in EUV lithography technology as it gets closer to HVM introduction. The 2014 SPIE Advanced Lithography Symposium preregistration totaled 2,360. This was up ~6% from 2013's count of 2230. The average attendance at the EUV conference was 332 per session and the peak attendance in the invited sessions was 629. Both stats were up from the 2013 numbers of 258 and 620 respectively.

Attendance by session is presented in Table 1.

Session	Count
Invited 1	629
Joint with PM (Resist)	614
Source	245
Mask 1	202
Mask 2	214
Integration	230
Mask Metrology	212
Metrology Sources	201
Outgassing	331
Resists	353
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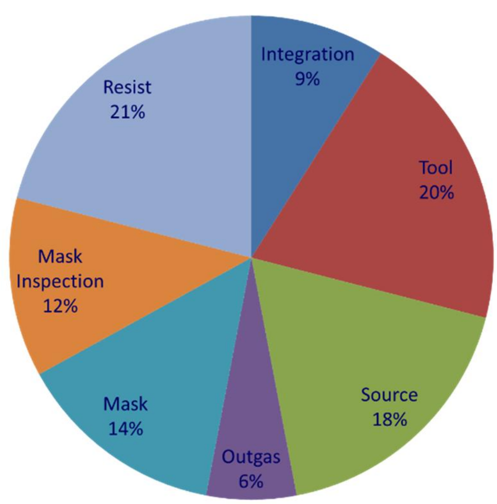
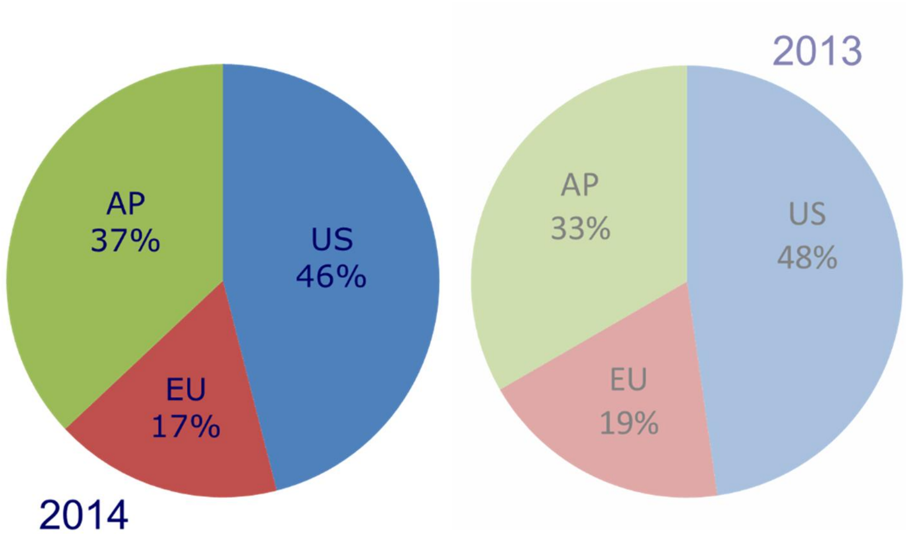


Submissions by region for 2014 and 2013 are shown in Figure 2.



2014 Conference Highlights

Scanners

ASML has delivered two NXE:3300B EUV scanners to customers, while installation has started on three additional systems. Six more NXE:3300Bs are currently in various stages of integration, and ASML has already begun work on its next generation EUV scanner, the NXE:3350[1]. The first projection optics (POB) for an NXE:3350 scanner has an rms wave front error (wfe) of ~0.2 nm—significantly lower than the wfe in a typical NXE:3300B POB. Some champion printing results obtained with a NXE:3300B scanner using 90°-dipole illumination are 16 nm lines and spaced at 10% exposure latitude (EL) and 100 nm depth of focus (DOF) and 24 nm regular 1:1 contact holes at 18% EL and >120 nm DOF and a full wafer CDU of 1.2 nm (3σ). The best full-wafer dedicated chuck overlay for an NXE:3300B scanner is ~1.4 nm (3σ).

In-use reticle defectivity continues to remain challenging. The fall-on particle rate (at 92 nm sensitivity) in a 20 hour test of 7 NXE platform systems varied from 0.00 to 0.04 particles per reticle pass—a number that will need to be improved by ~100X for high volume manufacturing (HVM). ASML presented excellent progress in their pellicle development program[2]. Photographs of two free-standing polysilicon membranes 106 mm × 139 mm in size were shown. One was 70 nm thick and had an EUV transmission of ~82%, and the other was 57 nm thick and had an estimated transmission of ~84%. The target for EUV pellicle transmission is <90% in a single pass and ~81% in a double pass.

Sources

ASML reported 30 W of EUV power from a production LPP source resulting in 100% die yield (percentage of simulated dies meeting the 0.5% dose repro spec).[1]

ASML/Cymer reported achieving 70 W of power at intermediate focus for six minutes in a low-rep-rate master-oscillator-power-amplifier (MOPA) LPP source at their factory in San Diego[3]. ASML's current productivity target is 70 wafers per hour (wph) in 2014 and 125 wph in 2015. TSMC reported that the no-master-oscillator (NOMO) LPP source in its NXE:3100 scanner typically provides ~ 10W at intermediate focus (IF) which would correspond to a scanner productivity of ~8 wph using ASML's ATP (acceptance test protocol)[4]. Researchers from the Univ. of Illinois at Urbana-Champaign described an in-situ hydrogen-based collector cleaning process with a Sn removal rate of 1.1 nm/minute at an RF power of 300 W and that no sputtering or other damage to the collector optic was observed[5].

Zeiss/Helmholtz Zentrum Berlin gave an interesting invited paper on accelerator-based EUV sources[6]. A design for a free-electron-laser (FEL) oscillator capable of > 1.0 kW of output power at 13.5 nm wavelength was described. The power level in an FEL oscillator will be limited by the maximum intracavity power that the cavity mirrors can handle. According to the presenter, the x-ray FEL source in Hamburg, Germany routinely operates with a reliability exceeding 90%. Even though the estimated cost of a FEL EUV source is expected to be >100M€, such a source should be able to supply power to more than one EUV scanner.

Metrology

Five years ago it was not possible to properly inspect EUV masks. Since then, SEMATECH's AIT tool and more recently SHARP actinic microscope have demonstrated excellent progress/results[7]. At this conference Zeiss reported that first light had been achieved in their EUV AIMS™ tool and showed some very high quality actinic images of 2D mask patterns[8]. This achievement appears to have removed the last remaining technical risk from Zeiss's EUV AIMS™ tool program and the first delivery of tools that can review the printability of 30-45 nm defects (7-11 nm at the wafer) is now expected to take place in 2015.

TSMC reported that defect-free masks can be fabricated using pattern shift defect mitigation given EUV mask blanks with < 20 defects at 25 nm SEVD size and accurate blank defect maps[4]. In other words, actinic pattern mask inspection tools may not be needed.

Materials

Continued progress on chemically amplified resist platforms was reported. JSR showed images of 16.7 nm lines and spaces printed at 46.5 mJ/cm^2 dose[9] and Fujifilm showed images of 14 nm hp features printed at 30.8 mJ/cm^2 dose[10]. Continued progress using novel organic/inorganic resist chemistries was reported as well. Inpria showed images of 22 nm lines and spaces with an LWR of only 2.0 nm (3σ) in a 20 nm thick film of their Generation 2 patternable hardmask material that can be developed with 2-heptanone[11]. A group at Cornell University showed images of ~20 nm lines and spaces[12] in ZrO_2 – based material with an LER of only 5-7 nm using an EUV dose of only 1.4 – 1.6 mJ/cm^2 and in HfO_2 –based material with an LER of only 3-5 nm using an EUV dose of only 2.5 mJ/cm^2.

Manufacturing

ASML reported that the current best NXE to NXT on-product overlay, using an optimized 18 parameter/field correction recipe, is 5.3 nm (3σ) in x and 5.4 nm (3σ) in y[13]. The on-product overlay target for the 7 nm technology node is ~ 3.0 nm (3σ).

Intel reported that as the basic CD and overlay performance of scanners have improved the relative magnitude of other contributions to the total edge placement error (EPE) have grown. The author presented a detailed model developed with Mike Hanna of ASML that identifies the root cause of machine to machine overlay errors and suggests ways to help minimize them[14].

IMEC presented cost of ownership estimates when using EUV litho at the 10 and 7 nm nodes. The author claimed that 193i side-wall-assisted-quadruple-patterning (SAQP) lithography will increase the cost of patterning back-end-of-line (BEOL) levels by ~16% when going from the 10 nm to the 7 nm technology node. And that the introduction of EUV lithography single exposure patterning will balance the cost of 193i SAQP when the EUV scanner throughput is above 55 wph[15].

2015 Conference Call For Papers

In 2014 the installation and ramp up of the first group of production EUVL scanners will be completed. In 2015 EUV lithography technology development will require higher power sources for full loop process development and optimization. Several critical technical challenges remain, i.e., fielding EUV sources with the power and reliability required for productive exposure tool throughput, mitigating all remaining printable mask blank defects, and developing manufacturing ready resists.Looking longer term, many important questions with respect to the extendibility of the technology to 7 nm and beyond remain unanswered. Chief among these are the roles of advanced resolution enhancement techniques, double-patterning EUVL, higher NA EUV imaging systems, new source technologies like FEL, and resist stochastic effects. Technical and scientific papers advancing the state of the art in EUV Lithography are solicited.

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