



## **Researchers at 2011 EUVL Workshop offer ways to further improve EUV Sources at 13.5 nm and extend EUVL to 6.x nm**

The 2011 International Workshop on EUVL was held from June 13-17, 2011 in Maui, HI. Participants representing universities, national labs, tool suppliers and chip manufacturers discussed ways to address current technical challenges for inserting EUVL into high-volume manufacturing (HVM). Discussions focused on making EUV sources more efficient, R&D needed to insert EUVL in HVM, and extending EUVL from the current 13.5 nm wavelength to 6.x nm for patterning at future nodes.

### **Keynote talks**

In the opening keynote talk, Vadim Banine of ASML reviewed the development of source technologies since 1985 and explained what worked, what didn't, and why. It was noted that current sources at 10 W need to improve by 10x, but engineering development is expected to achieve this goal. The second keynote was given by Gerry O'Sullivan of University College Dublin, who has studied laser produced plasma (LPP) in the EUV region, the current EUV sources of choice for more than 30 years. O'Sullivan reviewed the physics of LPP-based sources for EUV and mentioned the need for optimum pulse length (~ 40 ns) for driver lasers to achieve the maximum possible conversion efficiency (CE) of 6% from current CO<sub>2</sub>-based LPP sources. Sources in commercial tools today have about one-third of this efficiency.

Other presenters in the workshop discussed ways to improve the efficiency of CO<sub>2</sub> laser-based LPP sources by tailoring droplets, pre-pulses and main laser pulses. Mark Tillack of UCSD mentioned that the optimum laser excitation wavelength for LPP plasmas may be between 1 and 10  $\mu\text{m}$ , which means other types of lasers may need to be explored. Hakaru Mizoguchi of Gigaphoton presented results for his 20 W average power commercial source, and 3.3% CE results with 20  $\mu\text{m}$  droplets from his R&D lab. For mask metrology sources, several solutions to limit debris and decrease plasma size were presented by Energetiq, NanoUV and NewLambda Technologies.

### **Mask and Resist**

Asahi Glass presented progress on mask blank defect reduction. The new champion defect density is 0.20 defects per cm<sup>2</sup>, or 34 defects per plate at 50 nm SiO<sub>2</sub>. UIUC and XEI Inc. presented solutions for optics and mask cleaning to reduce mask defects generated during wafer processing. CXRO presented their next-generation actinic mask defect inspection tool, and researchers from Hyogo University described the performance of their EUV and coherent scattering microscopes for inspecting EUV masks.

In other presentations, Osaka University described the fundamentals of EUV resist development; EUV Technologies showcased their tool for resist outgassing measurements; and the University at Albany-SUNY offered studies of resist outgassing measurements.



## **EUV Optics**

Optics sessions provided an overview of state-of-the-art EUV optics. Yuriy Platonov of RIT gave an excellent summary of the EUV optics field, noting that although EUV optics is ready for pre-HVM, many questions remain on HVM-level EUV optics and the development of 6.x nm optics. Discussions identified a need for aperiodic multilayer (ML) for better bandwidth at 13.5 and 6.x nm, in order to improve throughput. Regina Soufli of LLNL presented an overview of advanced substrate polishing, saying that advanced polishing techniques developed for synchrotrons and FEL also can be used for EUVL collector optics. Eric Louis from FOM presented peak reflectivity of 70.3 % at 13.5 nm for their ML with a compounded interlayer system, and discussed high-temperature ML development. Talks in the EUV optics session were considered by many to be the most informative.

## **Poster Session**

The 2011 EUVL Workshop concluded with the poster session. The first place award was given to Thomas Cummins of UCD for his poster, "Laser Plasma Pumping by Variable-length CO<sub>2</sub> Laser Pulses." Second place went to Inhwan Lee of Hanyang University for his "Thin Half-tone Phase Shift Mask Stack for Extreme Ultraviolet Lithography."

## **Beyond EUV (BEUV)**

Wavelengths of 6.x nm for continued extension of EUVL or the beyond EUV (BEUV) region were covered in many talks, including the second keynote's description of optimum conditions for plasmas to generate EUV at these wavelengths. Takeshi Higashiguchi of Utsunomiya reported CE of 1.8% for an unoptimized Gd source. Many papers focused on fundamentals of EUV generation in LPP at 6.x nm and indicated that this information, added to experience with 13.5 nm plasma, will lead to efficient generation of EUV at 6.x nm. Akira Sasaki of JAEA discussed the potential of other elements such as Kr to generate 6.x photons, and the need to further explore this option.

Workshop participants agreed that since the bandwidth (BW) for 6.x nm mirrors is narrower than that of 13.5 nm, we need to set BW percentage standards for power measurements at this wavelength. Resists for 6.x nm need to be developed, and source developers and optics manufacturers must work together to define the precise wavelength to ensure maximum throughput for the system. This is due to a mismatch between peak source emission and peak transmission for ML for this wavelength region.

In other presentations:

- Regina Soufli and others from LLNL noted that recently determined experimental values for the optical constants of B<sub>4</sub>C and boron enable accurate modeling of B<sub>4</sub>C and B-based multilayers in the 6.x nm region. These measurements will lead to better modeling for ML at beyond-EUV (BEUV) wavelengths.



- Ken Goldberg of CXRO presented a design for inspection tools that can detect mask defects at the BEUV wavelength of 6.x nm
- Seiichi Tagawa of Osaka University discussed fundamental considerations in designing resists for 6.x nm.

## Summary

Workshop highlights included:

- Presentations on ways to increase CE of current CO<sub>2</sub>-based LPP sources at 13.5 nm
- Papers on continued progress in mask defect reduction
- Technology overview papers in source and optics
- Talks on EUVL development at BEUV wavelengths

The next EUVL Workshop is scheduled for the week of June 4<sup>th</sup>, 2012 in Maui. For more information about this workshop and to download presentations provided at no cost to the EUVL community, please visit [www.euvlitho.com](http://www.euvlitho.com). Questions about the 2012 EUVL Workshop may be sent to [info@euvlitho.com](mailto:info@euvlitho.com).