It's EUV Source— again!

Vivek Bakshi, EUV Litho, Inc.
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Waikiki Beach, July 17, 2009

Arriving last Sunday at the Sheraton Waikiki for the 2009 International Workshop on EUV Lithography, I was welcomed by the stunningly beautiful Waikiki beach, with its clear turquoise water and magnificent surf. One of the best beaches in the world was crowded that day with an enthusiastic crowd watching a kayak race. It was an apt metaphor for the Workshop, where many participants learned of another race to make metrology tools for EUV mask inspection commercially available by the end of 2010. The requirements for this technology were debated at the workshop, and various technical solutions were presented.

Keynote talk

Intel Fellow and Director of Lithography Sam Sivakumar said that Intel plans to use ArF based immersion in 2011 for high-volume manufacturing (HVM) at the 22 nm node. However, for HVM in 2013, both ArF double patterning and EUVL are candidates. Sivakumar also identified a dearth of metrology tools to inspect mask defects as one of the leading gaps in the EUVL infrastructure.

Keynote speakers Seong-Sue Kim from Samsung focused on mask related issues and pointed out that defects must be reduced by 100X and defect inspection tools need to speed up 5X, while reiterating the lack of commercially available mask defect metrology tools.

EUV Metrology Tools

Enabling metrology tools to detect mask defects at the level and throughput required by chipmakers will require significant improvement in currently available EUV sources. However, these requirements are related to source brightness and not source power, as was previously the case for EUVL scanners. Since the numerical aperture (NA) of these metrology tools is very small, these tools are looking at a very small fraction of the source. This makes current candidates for high power sources too large and expensive for metrology tools. Given the need for a smaller source size, a LPP-based source appears better than a DPP source of similar power.

However, NanoUV proposed ways to make DPP sources brighter, while many tricks remain for making LPP sources smaller and brighter. Also, Prof. John Madey of the University of Hawaii at Manoa and Prof. Hironari Yamada of Ritsumeikan University in Kyoto proposed new EUV sources brighter than any currently in use, although their power is only in the mW range due to very small beam divergence and small source size. Only a few years ago, no one wanted to hear about theses exotic EUV source technologies, and it will be interesting if they become the saviors of mask metrology tools.

EUV Specs

The Workshop also provided lessons learned from the development of high-power EUV sources. A while back, the big scanner makers agreed to develop joint specifications for sources and put together a team consisting of Vadim Banine of ASML, Kazua Ota of Nikon and Yutaka Watanabe of Canon to work out the details. As the industry learned more about source technology, this team of source experts updated the specifications and provided guidance to source suppliers. Some of the source parameters, such as etendue, had a wider range due to difference in optics design of suppliers, but these specs still guided suppliers toward customer requirements.

What many did not realize was that these requirements reflected the expectations of chip makers to be able to print 100 wafers per hours at a given resolution. Responding to this demand, which was based on cost of ownership, one took into account resist performance and loss from optics, and came up with the required power for sources.

A similar exercise in joint spec development needs to occur for mask metrology tools. Although this has not happened yet, joint specs for sources for mask metrology tools were proposed at the Workshop. Of course, these specs are the first draft and will form the basis of discussion, hopefully resulting in specifications for source suppliers. (These specs, together with information on new and existing source technologies, will be available this month at no cost on the EUV Litho, Inc. website.)

As one supplier reminded me, I led a similar industry effort a few years ago to draft specs for collectors in high-power sources, and it took well over a year for all parties to agree to them. Since the industry is expecting to have tools available to support beta level scanners by end of 2010, all stakeholders will have to move more quickly this time.

No source supplier can be expected to start investing in development of sources for metrology tools unless there is a consensus on specs among tool makers. Of course, individual customers have their own specs, but these vary widely and suppliers cannot make different EUV sources for multiple customers.

Important to mention at this point is another program that contributed to the development of EUV sources, called Flying Circus. First proposed by ASML to independently assess the performance of EUV sources, this program took portable detectors from supplier to supplier, giving end-users information on source technology. As new technical solutions are proposed for high brightness EUV sources, suppliers need to be visited by a program like Flying Circus.

High Power Sources

Last week, Cymer announced the shipment of their Sn LPP source to support the ASML beta level scanner, which is excellent news for the industry. The shipped version of the source has estimated power in the 15-20 W range, and the shipment of a source that has been integrated with a collector (SoCoMo) is a significant milestone for both the industry and Sn LPP technology.

It took more than two years for Sn DPP sources to achieve 10 W of power after they were integrated in alpha scanners. Now the focus is on LPP sources, and although I do not anticipate 100 W integrated sources to be available this year, I do expect successful integration of sources in beta scanners that will be shipped late in 2010.

For Sn LPP, the main issue is tin debris mitigation. Many workshop papers addressed this topic, including an excellent presentation from the Tokyo Institute of Technology, which pointed out a new physics regime in LPP due to rapid heating and cooling of tin droplets. Other papers studied the characteristics of debris emitted by such plasmas, which hopefully will reveal new ways to control debris.

Prof. Kinoshita Recognized

In a sidelight, the Workshop took time to recognize Prof. Hiroo Kinoshita of the University of Hyogo with a lifetime achievement award. A pioneer of our technology, he published the first paper on EUVL and has guided the industry since early eighties. Prof. Kinoshita remains very active in EUVL, as evidenced by three Workshop papers from his group. He also received a cash award, raised from personal contributions of two dozen EUVL colleagues from around the world,.

Line Edge Roughness (LER)

As feature sizes get smaller, LER is a leading challenge to all optical lithography techniques. During the Workshop, Patrick Naulleau of Lawrence Berkeley National Laboratory (LBNL) presented his work showing the contribution of mask to LER, and proposed specs for mask roughness. These specs are not part of the ITRS guidelines that dictate how much LER is acceptable at a given nodes, and so I hope his recommendations will be accepted by the ITRS to provide more guidance to mask makers.

Amazingly, two EUV resist simulation papers recommended new processing steps to reduce LER to 1.2 nm! I believe ideas like these, combined with new resist chemistry (such as the molecular negative tone resist of Prof. Cliff Henderson of Georgia Tech) will allow the industry to produce resists that can support EUVL printing at 22 nm and beyond, and demonstrate why continued R&D is needed to address the remaining obstacles to bringing EUVL to HVM.

All in all, it appears that source has emerged again as the primary challenge to EUV, with a new twist – the need for higher brightness to enable next-generation metrology tools. The EUVL race continues, this time on a different track.