EUV Sources Come Back as Top EUV Lithography Concern

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Although extreme ultraviolet (EUV) lithography is widely regarded as the leading candidate for post-optical lithography, there is considerable concern about the availability of metrology tools for EUV mask inspection. The dearth of mask inspection tools has been pointed to repeatedly as one of the leading gaps in the EUV lithography infrastructure.

Sam Sivakumar, Intel Fellow and director of lithography at the leading chipmaker reiterated that point in his keynote talk at last week's International Workshop on EUV Lithography in Waikiki, Hawaii. Intel plans to use 193 nm (ArF) immersion lithography 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.

Keynote speaker Seong-Sue Kim of Samsung also noted the lack of commercially available mask defect metrology tools. He pointed out that defects must be reduced by 100× and defect inspection tools need to speed up 5×.

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 metrology requirements are related to source brightness rather than source power, which is the case for EUVL scanners. Because their numerical aperture (NA) is very small, the metrology tools are looking at a very small fraction of the source, making high-power sources too large and expensive for metrology tools.

Given the need for a smaller source size, laser-produced plasma (LPP) sources appear to be better candidates that dischargeproduced plasma (DPP) sources of similar power. Many tricks remain for making LPP sources smaller and brighter. However, Nano-UV (Courtaboeuf, France) also proposed ways to make DPP sources brighter.

John Madey of the University of Hawaii at Manoa and Hironari Yamada of Ritsumeikan University (Kyoto, Japan) proposed new EUV sources that are brighter than any currently in use, although their power is only in the milliwatt range because of very small beam divergence and small source size. Just a few years ago, there was little interest shown in such exotic EUV source technologies, but they have the potential to become the saviors of mask metrology tools.

Specifications in the making

The workshop also provided lessons learned from the development of high-power EUV sources, which had as its basis specifications developed jointly by the big three scanner suppliers. Vadim Banine of ASML, Kazua Ota of Nikon and Yutaka Watanabe of Canon worked out the spec details, and as the industry learned more about source technology, the team of source experts updated the specifications and provided guidance to source suppliers. Although some source parameters, such as etendue, had wider ranges because of differences in optics designs, the specs still guided suppliers toward customer requirements.

The high-power source requirements reflected cost-of-ownership (CoO) expectations from chipmakers, which called for throughputs of at least 100 wph. The required power source also accounted for resist performance and optical losses.

A similar exercise in joint spec development needs to occur for mask metrology tools, and specifications were proposed at the workshop. These make up only the first draft of specifications that will form the basis of further discussion, hopefully resulting in specifications for source suppliers. (These specs, together with information on new and existing source technologies, will be available for free later this month on the EUV Litho 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 supplier can be expected to invest in source development for metrology tools unless there is a consensus on specs among toolmakers. Individual customers have their own specs, but these vary widely and suppliers cannot be expected to customize each EUV source.

Another program, called Flying Circus, contributed to the development of EUV sources by independently assessing source performance. First proposed by ASML, the program took portable detectors from supplier to supplier, giving end users information on source technology. Such a program would also benefit metrology sources, with suppliers being visited as new technical solutions are proposed for high-brightness EUV sources.

High-power source ships

Last week, Cymer announced the shipment of its tin LPP source to support ASML's beta-level EUV 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 tin LPP technology.

It took more than two years for tin 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 tin 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 because of the 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.

Line-edge roughness

As feature sizes get smaller, line-edge roughness (LER) is a leading challenge to all optical lithography techniques as well as EUV. Patrick Naulleau of Lawrence Berkeley National Laboratory (LBNL, Berkeley, Calif.) presented his work last week showing the contribution of the mask to LER, and proposed specs for mask roughness. These specs are not part of the International Technology Roadmap for Semiconductors (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 maskmakers.

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 Georgia Tech's Cliff Henderson), 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 higherbrightness sources to enable next-generation metrology tools.