Looking for Lake Tahoe:
A Metaphor for EUVL Development

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Arriving in Lake Tahoe Sunday afternoon for this week's International Symposium on Extreme Ultraviolet Lithography, one of the first things I did was to walk around looking for the lake. But all I could find was the hotel swimming pool. For a worrisome moment, I thought that I'd ended up in the wrong place, even though I distinctly remembered flying into the Reno/Tahoe International Airport and seeing familiar faces from other lithography conferences. The staff at the Resort at Squaw Creek in Olympic Valley, Calif., told me later that the lake itself was about nine miles away — which turned out to be a fitting metaphor for a technology that is almost within sight.

The EUVL Symposium opened to the good news of achieving 50 W of power from EUV sources based on laser-produced plasma (LPP) and discharge-produced plasma (DPP), with 100 W sources on the horizon. As the conference progressed, many continuous improvements were reported in other technical areas, including mask and resist maturity, defect reduction, and patterning capabilities.

Masks, resists not limiting factors

It appears that mask and resist development will not be getting in the way of using EUVL for high-volume manufacturing. Intel reported a capability to make EUVL masks with 60 nm features, which correspond to 15 nm printed features on the wafer. AMD — in the first demonstration of a functional SRAM device with critical-layer patterning — showed that only 3% of mask defects end up being printed. This takes the pressure off our having to reach near-zero mask defects for production, and a good thing, too: Current mask defects are at 0.3/cm2 at the 60 nm technology generation, compared with a goal of 0.003 defects/cm2 at 25 nm. So, many of the mask defects we're worried about may not be printable after all.

The main issue in dealing with mask defects seems to be inspection capability (if you can't see them, you can't fix them). EUV metrology needs the ability to inspect defects below 25 nm, but currently can only provide reliable inspection at 60 nm. There's some hope that future-generation non-actinic inspection tools will be able to do the job, but several papers offered actinic inspection as the most probable route. That's a lucky thing, given the amount of work that's been done already on actinic inspection of mask defects.

In the patterning arena, presenters from the University of California, Berkeley, showed 26 and 22 nm patterning capabilities from their micro-exposure tool (MET). A paper from the Paul Sherrer Institute in Switzerland demonstrated 11 nm features printed via EUV photons (using grating-based optics), reinforcing the point that EUV resist will not be a limiting factor in EUVL resolution capability.

Source progress

Chipmakers are very serious about getting EUVL ready as soon as possible for high-volume manufacturing. In a keynote presentation, Samsung's Woosung Han pointed out the cost advantage of EUVL over double patterning, and advantages in throughput and overlay defects compared with nanoimprint lithography. "EUVL shows superior patterning performance as compared to immersion ArF-based lithography," Han summarized. Samsung expects to start EUVL pilot lines by 2010 (with NA>0.25 tools), and begin using EUVL in production lines by 2012 (NA>0.32). Samsung believes 193 nm immersion-based double patterning will be needed to bridge the gap between 193 nm immersion and EUVL, but stressed that 100 W source power is needed soon for EUVL to stay on its current roadmap.

Source suppliers described prototypes that can deliver ~50 W to support beta-level scanners, with plans to reach 100 W by 2009. Cymer presented a 45 W LPP source and Gigaphoton unveiled a 50 W LPP source, both with a duty cycle of ~10%. The best LPP news was that the pulsed CO2 lasers that power these sources now have operating times measured in hours. This is a big deal, and shows very serious commitment and investment by source suppliers. Not long ago, I was skeptical of these high-power lasers ever working, but now I see light at the end of the tunnel.

LP Photonics showed an interesting approach for an LPP source with multiplexing, using commercial YAG lasers and reaching 20 W of power. The YAG approach has positives and negatives (like every other method), so we'll see how it progresses. Philips Xtreme's tin DPP source currently has 5 W of power with 100% duty cycle, and supports ASML's alpha-level scanners (which are now qualified and up and running). The source developer presented its 50 W prototype, which achieves power scaling with higher-frequency operation.

Given what I saw in the supplier presentations, I can predict with confidence the source technology's future in the 30-50 W range, and believe that both DPP and LPP sources can meet the goal of 50 W for beta-level scanners. In this context, I find Nikon's EUVL scanner roadmap, which has both DPP and LPP sources, to be less risky than ASML's roadmap, which depends on LPP only. Timely availability of a beta-level scanner is critical to mitigate further delays for EUVL. Much is already known about DPP sources, so I think the industry needs to keep the DPP source option open for now. To get a reliable 50 W source, debris mitigation will be the main challenge for LPP sources, and thermal mitigation will be the main hurdle for DPP sources. Although none of these challenges are showstoppers and will be addressed, I don't think we can say yet which will be overcome more quickly.

Scanner throughput advances

Most encouraging to me on the first day of the symposium was that both ASML and Nikon presented scanner design plans with improved optical throughput. Up to now, the source suppliers have had the biggest burden for EUVL scanner throughput, but now scanner manufacturers are looking at designs with higher optical efficiency. Since an EUVL scanner loses most of its photons before they get to the wafer, any improvement in throughput is very welcome. Scanner designs that can reduce EUV photon loss by 2-3× — combined with a 50 W source — can translate into a 50+ wph throughput. With this throughput and superior EUVL imaging performance (both of which I believe are attainable by 2010), the line of customers for EUVL scanners should grow even longer. Lake Tahoe seems to be getting closer every day.