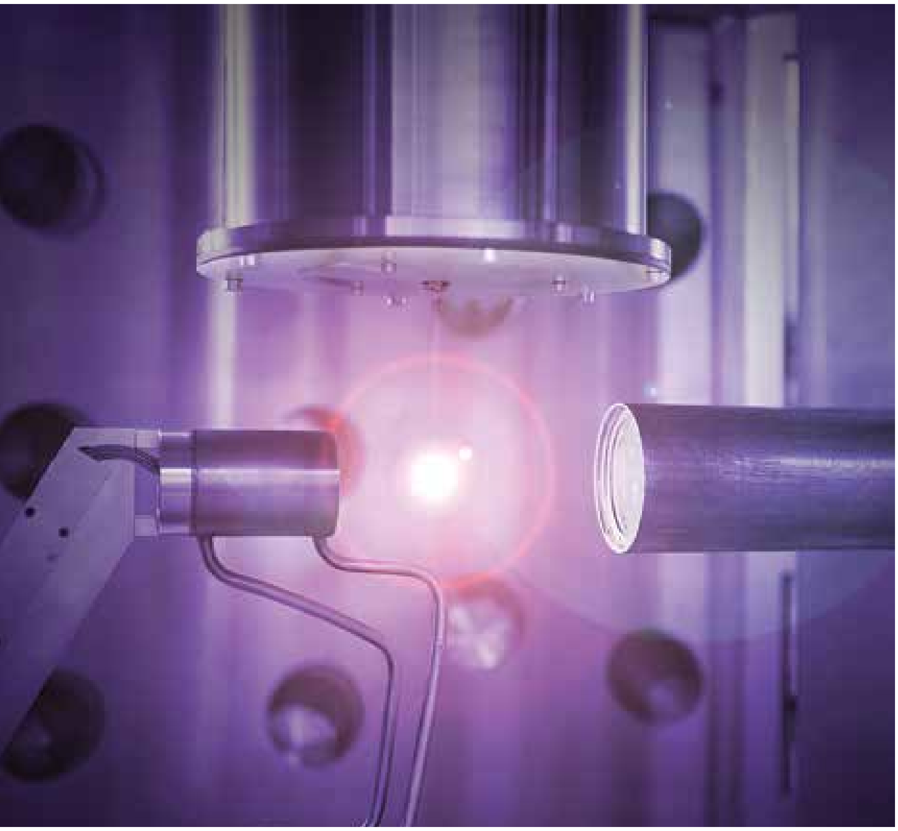
Machine aims to quiet EUV lithography critics

Is extreme ultraviolet (EUV) lithography almost ready to silence the skeptics who question whether the technology can meet required chip-production levels? Yes, reports a major supplier of semiconductor manufacturing equipment.



Prof. Reza Abhari, ETH-Zurich

The Swiss Federal Institute of Technology uses a laser firing 6,000 times per second to ignite droplets of liquid tin, creating a plasma that produces EUV light.

EUV lithography machines that can print finer features on chips than can current technology will be ready for "volume production" in chipmakers' plants sometime in 2016, said Ryan Young, a spokesman for ASML, the Veldhoven, Netherlands-based developer of photolithography equipment for the semiconductor industry.

One factor limiting the resolution of lithography machines is the wavelength of the light used to produce chip features. Shorter wavelengths translate into higher resolution and smaller features.

Currently, deep ultraviolet (DUV) lithography involves the use of wavelengths down to 193nm and can produce circuit features as small as 45nm. But this process has become costly and complex. Instead of etching an entire chip surface in a single exposure, chipmakers rely on double patterning, where two different masks are laid across the surface and two separate etching processes are performed. Even more masks could be added to the process, but doing so would further increase manufacturing time and costs.

Because of DUV lithography's drawbacks, the semiconductor industry has invested heavily in technology that incorporates EUV light with a wavelength of 13.5nm. With this much smaller feature-creating paintbrush, "you can expose the pattern in one pass, compared to the three or more passes that might be required by conventional equipment," noted Nigel Farrar, vice president of marketing for San Diego-based Cymer LLC, an ASML company that develops DUV and EUV light-source technology.

ASML reports that its EUV lithography equipment has produced 13nm, single-exposure lines and spaces, as well as 17nm contact holes. The technology also could provide chipmakers with a "credible path" toward a resolution of less than 10nm, according to the company.

That path does not exist yet because ASML and others continue to struggle with the technical challenges of bringing a production-ready EUV lithography system to market. Perhaps the main challenge is producing the EUV photons. ASML uses an approach called "laser-produced plasma," where a CO_2 laser is fired at a microscopic droplet of molten tin, heating it and turning it into a high-temperature plasma. It's this plasma that emits EUV light, which is then collected and focused into a beam.

One complication is that all matter absorbs EUV light, including the glass of a lens. Instead of lenses, ASML uses mirrors made with a coating consisting of hundreds of layers, some as thin as 3nm. Even with this coating, however, each mirror in the system

By William Leventon, Contributing Editor

still absorbs about 30 percent of the EUV light that strikes it. And because air also absorbs EUV light, the entire lithography process must take place in a vacuum chamber.

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Light source power depends on more than just the wattage of the CO_2 laser. Other key factors involved in getting enough EUV energy to the wafer include so-called conversion efficiency (converting the CO_2 laser power to EUV energy) and light-collection efficiency. ASML is trying to increase both.

Another productivity issue is the availability of the lithography machine, which depends in part on the availability of the collector, a large, expensive mirror. To reduce downtime for collector maintenance, “we’re working hard to minimize the amount of tin that’s deposited on the mirror, as well as methods of cleaning it in-situ,” Farrar said.

Production-ready EUV lithography equipment also depends on factors outside of ASML’s control. For example, the semiconductor industry needs inspection technology capable of finding small defects on EUV mask structures. One possibility is actinic mask inspection, which employs light with the same wavelength as that used by the lithography system to determine whether mask quality is good enough for printing thousands of wafers.

At the Swiss Federal Institute of Technology in Zurich (ETHZ) and a spinoff company called Adlyte Corp., researchers are working on light sources for actinic inspection of masks for EUV lithography. Where light is concerned, inspection requirements differ from those for the lithography machine, explained Reza Abhari, head of the ETHZ research team. "For a [lithography machine], you need a lot of power. For inspection, you need a very bright and stable light source."

Abhari and his colleagues use a laser to blast tiny droplets of tin 6,000 times per second. In addition to creating the

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An ASML NXE:3300 EUV scanner under assembly.

plasma that produces EUV light, this process generates high-energy tin particles. The researchers mapped where the tin debris landed and found zones around the plasma that were relatively safe from the particles and, therefore, good locations for the expensive optical components used in EUV systems.

The researchers also discovered that a significant amount of EUV emissions come from behind the droplet region struck by the laser. Previously, it was assumed that little EUV light radiated

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EUV source vessel in a Cymer cleanroom in San Diego.

from behind the droplet during laser bombardment. This discovery could lead equipment makers to relocate the mirrors around a droplet in order to maximize the EUV light collected.

So far, though, Abhari believes this discovery has had no impact on the development of current wafer-production systems. For instance, ASML's NXE:3300 model does not utilize the technology.

This unit is the company's most advanced commercial EUV lithography machine. To date, ASML has sold 11 of the machines, which are capable of producing 100 wafers per day for the development of chip-making processes. Larger numbers will be needed for production, but ASML is confident it can deliver them fairly soon. The company's EUV lithography machines will be capable of turning out 500 wafers per day by the end of this year and 1,500 wafers per day by 2016, according to ASML's Young.

There appears, however, to be some doubt about this forecast.

"At the moment," Abhari said, "nobody is making major investments in tools for inspection because there is so much uncertainty about EUV." µ

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