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Fab Future

The "Litho Guru" takes a dim view of lithography remaining a top dog in semiconductor manufacturing and in fueling Moore's Law. Growth and fun are slowing.

By Chris A. Mack

It's been nearly 50 years since the invention of the planar transistor kicked off the integrated circuit industry and its siren call, Moore's Law. In that time frame, semiconductor chips have gone from a handful of integrated components with minimum dimensions of about 25 µm to billions of transistors with minimum dimensions nearing 25 nm.

What is most remarkable about this 50-year journey is that the cost of making one of these integrated circuits has stayed about the same even as the capabilities of the chips have grown by many, many orders of magnitude. The consequences are familiar, though still profound: the ubiquity of sophisticated electronic devices and the easy availability and use of the information that they allow.

Many factors have enabled Moore's Law to continue and electronics to thrive. A major factor (possibly the most significant factor) has been the improvement in lithography for semiconductor manufacturing. From contact printing in the 1960s to 1X scanning projection printing in the 1970s to reduction step-and-repeat cameras in the 1980s to deep-UV step-and-scan tools in the 1990s, regular increases in numerical aperture, decreases in wavelength, improvements in photoresists, and many other techniques have enabled dramatic improvements in resolution.

Costs Constant

All the while, the cost of printing a square centimeter of silicon has remained about constant. Today, the state-of-the-art lithography tools use a wavelength of 193 nm (from an ArF excimer laser) and a water immersion lens with a numerical aperture of 1.35 to print lines and spaces of less than 45 nm in width.

While past developments have been nothing less than phenomenal, the future of semiconductor lithography is less certain than it has ever been. Raising the numerical aperture beyond 1.35 will require high-refractive-index immersion fluids and lens materials, both of which face daunting material development tasks.

Lowering the wavelength to 157 nm has been deemed not worth the effort, and so the development of extreme ultraviolet (EUV) technology, at a wavelength of 13.5 nm, is the only lower-wavelength option under consideration. But this radically new technology is rife with difficulties, most notably the availability of a high-power light source and defect-free masks.

Technology Development

In the near term, lithography will move forward using basically the same imaging tools as today, but with a new process technology called double patterning. By interdigitating two separately printed and etched patterns, the classical resolution limit can be broken, but at the expense of about 2X the cost, plus very stringent requirements for pattern placement accuracy (overlay).

Double patterning has received significant attention lately, and it seems clear that this approach will allow 193-nm-wavelength water immersion lithography to push on for at least another technology generation, and possibly two.

The challenges facing lithography technology development are severe.

Fun Factor

In general, one would think then that lithography would be a great field to work in. After all, what could be better than a technical challenge in a field where a solution will make a difference (and make money)?

Lithography has been a great place to be for the last 25 years (the time that I have been working in the field). But other factors are conspiring to make some of the challenges we face less than fun.

Growth in the semiconductor industry has dramatically slowed in the last eight years. As the industry matures, consolidation has led to fewer and fewer companies willing to invest in new technology development. There are probably only five semiconductor companies with both the desire and the financial wherewithal to build the next generation manufacturing fab. And with this maturity also comes increased focus on cost reduction rather than performance improvement - usually not the most fun environment for the majority of engineers.

Moore's Law

But the biggest fun-dampening factor of all, in my opinion, will be the changing role of lithography in pushing Moore's Law forward. To put it bluntly, lithography has been top technological dog for the past 25 years, but that is unlikely to continue for more than the next five years. Other developments in semiconductor device structure and design are already playing a bigger role and may soon eclipse lithography as the future driver of density and performance improvements.

Lithography will still be important; it just won't be the one thing everyone is counting on, and investing in, to make things work.

The job environment surrounding semiconductor lithography has been exceptionally fun, at least for me. The future will also be exciting. But the maturation and consolidation of the semiconductor business will mean that lithography's heyday will soon be over.

Moore's Law will march on, at least for another eight to 10 years, but in a different form and in a different way. Innovations are sure to come, but they are less sure to come from lithographers.

Is lithography's star dimming? I suppose that it is.

- *For another view of the future of lithography, see "Fab Expectations."*
- *Check out the upcoming SPIE Lithography Asia-Taiwan symposium in Taipei.*

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