Technolution

/customer interview

Optical lithography using electrons

A few years ago, the boundaries of optical lithography appeared to have been reached. Yet these days, the sky is the limit. Technically, much is possible, but costs are soaring. Which is precisely the area in which Mapper Lithography aims to compete.

Every year, the semiconductor industry develops chips with even smaller electronic switches. This is in keeping with Gordon Moore's Law, which states that technological progress will see the number of transistors on a computer chip doubling every 2 years. This requires production machines which can make ever smaller details. The core of the production machines is lithography: the transistors on the chip are created using optical techniques. Mapper Lithography is currently developing and building machines that write an image onto the silicon using not light but electrons, in much the same way that an electron beam scans the screen in an old-fashioned cathode ray tube. This technique was already experimentally used for lithography in the sixties. But the throughput time for electron lithography is low – very low. In the nineties, professor Pieter Kruit of TU Delft tried to ratchet up the speed by placing a large number of bundles in parallel. Two research students worked the idea out further. “That was Bert Jan Kampherbeek and myself,” explains technical director Marco Wieland. “We graduated in the subject at the end of 1999. We decided not to take it to PhD level but instead to set up a company to really develop the technology properly. So in 2000 we founded Mapper Lithography.”

Kruit's notion of using a large number of parallel bundles is still the heart of the current machine, as is his idea of switching the electron bundles on and off using light. The path of each electron bundle contains a switch that responds to light; so a light pulse switches the electron bundle on and off. Whereas optical lithography makes use of lenses, mirrors and prisms, the electron beams are steered using electron optics. “To make the optics, we use techniques from the IC industry”, explains Wieland. “It's such precise work; it has gone beyond what you can do with mills and lathes.”

Technical and economic limits

In the nineties, electron lithography was seen as the successor to optical lithography, which was running up against physical limits. However, those limits have been pushed back again and again with all kinds of tricks, but at the cost of making the machines ever more expensive. There is no longer a technical or fundamental limit to the development of optical lithography, but an economic one. And that is where the potential of Mapper's concept lies, believes Wieland. “Our machine costs five million and does ten wafers per hour. An EUV machine costs fifty million and does a hundred wafers per hour. In wafers per hour, that works out the same.”

Because electron optics are much smaller than EUV optics, the heart of the machine is small: a cube of slightly more than a cubic metre. There will be ten of those cubes side by side on the factory floor. Including all peripheral equipment, the setup is a little bigger than the current generation of wafer scanners, but significantly smaller than the future EUV wafer scanners. So it will save on expensive clean room space. Mapper is well placed to compete with optical lithography in economic and technical terms. “But our big advantage is that we work without masks,” emphasises Wieland. “In memory manufacturing, the issue is negligible; they make lots of the same memory chips with one set of masks. But in ‘random logic’ (everything except memory and standard PC processors), there are hundreds of millions to be saved using mask-free lithography. Ultimately, that kind of factory will be able to produce a lot cheaper using our machines.” Due to the high accuracy but low throughput time, the machine will initially perform only the most critical mask steps, which is where mask costs are highest. Manufacturers will combine electron lithography with optical lithography (mix & match).

Photo above:
Technical director
Marco Wieland

Illustration:

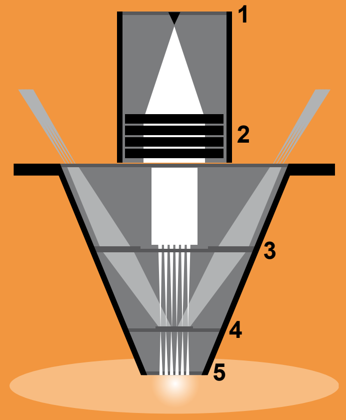
1 Electron source

2 Collimator lens

3 Arperture array
Condensor lens
array

4 Beam blanker array

5 Beam stop array
Beam deflector array
Projection lens array



Industrialisation first

In 2007, Mapper reached an important milestone: proof of lithography. “We demonstrated that we could perform lithography using this principle. We did so with an experimental machine that contains the core of the Mapper: 110 electron bundles that we switch using light, electron optics and data transport. We then decided to put pure technological progress on hold for a while in favour of first building an industry-ready system that meets the standards of the semiconductor industry. Only then can we ship machines to customers. There we can scale up experiments and make use of wafer pre-treatment and post-treatment plus analysis and inspection equipment. Only when the machine has proved itself in a proper wafer factory will people believe that it can work. That is important in marketing terms too: we want to prove that we are more than a bunch of people with a cool experimental solution. No, this is a real machine.”

13,000 bundles

“There are three important steps we need to take in order to get from the current test machine to the final version. Our current prototype can only light up separate small fields. By building in a metrology system, we can move the wafer under the bundles and knit the fields together. This so-called stitching will be ready early next year. We then increase the speed per bundle by a factor of fifty. That will make writing a whole wafer a realistic proposition (in approximately ten hours). And thirdly, we are going to increase the number of bundles to 13,000.”

Cooperation

Electron optics is Mapper’s core competency. For the other competencies, such as electronics and mechanics, the company works closely with partners. For example, Technolution supplies a significant share of the electronics. “The operation of the electronics (the data path) is closely linked to the machine. What we like about Technolution is that they are good at contributing ideas at the system level of the machine. That speeds things up significantly.” Early on, the data path was the big bottleneck. Every second, fifty terabits of data go to the electron bundles. That is the equivalent of the data on a thousand DVDs, every second! And the transfer has to proceed with extremely high reliability: not a single bit must be missing, because that could cause part of the circuit on the chip to fail. By cleverly placing sufficient channels in parallel, that bottleneck was resolved.

Confidence

Although it will still be a few years before the first complete machine rolls out of the factory, confidence in the product is high. Future customers are already generating income. “They want the product to become a reality and they are prepared to invest in our research”, explains Wieland. For the mass production of its machines, Mapper will seek collaboration with another machine manufacturer from the semiconductor industry. “It doesn’t necessarily have to be a litho manufacturer”, says Wieland. “We think the time will be right in 2010, once we have technically demonstrated the stitching and are able to achieve the required bundle flow and numbers of bundles in separate tests.”