A year ago we introduced you to the concept of immersion lithography—filling the air gap between the wafer and the lens with a higher-refractive-index fluid such as water. In that time, this innovative technology has come a long way. Firmly embedded on most semiconductor manufacturers’ roadmaps, 193-nm immersion lithography is now also the focus of an IMEC International Affiliation Program (IIAP) to ease and speed up immersion process integration.

ASML is at the forefront of advances to enable industrial immersion lithography processes. Providing a leap forward in both tool and process development, the TWINSCAN AT:1150i took us from theory to proof of concept. This prototype tool has already cycled more than 10,000 wafers, with the immersion performance benefits confirmed by 16 leading-edge IC manufacturers. The new XT:1250i system delivers the next significant step—pre-production. With the shipment of the first XT:1250i tools and recent advances in photoresist technology, commercial immersion lithography is poised to take fabrication to the edge of extreme ultraviolet (EUV).

**The TWINSCAN XT:1250i**

Designed to let customers test and qualify immersion processes, the TWINSCAN XT:1250i is a 193-nm pre-production lithography scanner with an NA of 0.85. It combines the improved Depth Of Focus (DOF) of immersion lithography with the precision of “dry” systems. Using water as the immersion fluid, it operates at 70-nm half pitch with a $k_1$ of 0.31.

As with all our TWINSCAN products, the XT:1250i is a dual-stage system allowing one wafer to be exposed while the next is being measured, thereby maximizing throughput. And because the use of the immersion fluid is confined to the exposure area, all measurements can be carried out under dry conditions for maximum precision. Figure 1 shows that the XT:1250i improves the DOF by a factor of 1.7 over our standard XT:1250D system—at full step and scan speed. This allows it to deliver a throughput of 85 300-mm wafers per hour.
Figure 1
70-nm dense line imaging showing the 1.7 times DOF improvement from dry to wet imaging on the XT:1250i at full scan speed (500 mm/s).
The XT:1250i employs Zeiss’ Starlith 1250i lens, which is based on the same lens design as the Starlith 1250 lenses used in dry systems, significantly shortening the development cycle. In addition, this simplifies high-volume production and ensures the same high quality for immersion lens as for dry lenses—clearly highlighted by the measured aberration levels in the first manufactured Starlith 1250i lenses (Figure 2). What’s more, as this approach can be extended to higher-NA lens such as the 0.93 NA Starlith 1400, lens quality is maintained in future immersion systems. The fact that our dry and immersion 0.85 NA and 0.93 NA solutions use the same lens design also allows a simple conversion from a dry tool to an immersion tool.

In the course of 2005, we will be releasing the next of our immersion lithography solutions. With 0.93 NA, the TWINSCAN XT:1400i continues the family trend by offering a DOF twice as large as a comparable dry scanner (shown in Figure 3). It is expected to be the first immersion tool for high-volume production at the 65-nm node. The simulations shown in Figure 4 indicate the potential yield improvements the XT:1400i will offer thanks to its enhanced focus budget.

Photoresist Developments

Of course, the scanner is only one element in turning immersion lithography into a commercial process technology. That’s why we work closely with leading photoresist suppliers to develop new resist solutions that are optimized for immersion techniques. By hosting researchers from all the leading names, we are helping speed the arrival of these new solutions. As shown in Figure 5, this cooperation has had impressive results over the last six months, with significant improvements in image quality. Furthermore, new resists that do not require protective topcoats are now delivering precision levels comparable to dry lithography, reducing costs and increasing throughput.
Pathway to the Future

With the advent of 65-nm feature sizes, dry 193-nm (ArF) lithography is reaching its limits. Immersion lithography offers a way to extend the range of 193-nm processes, and in the last twelve months has supplanted 157 nm as the way forward. Water-based immersion systems will take us down to 45-nm manufacturing processes, and investigations are already under way to find a suitable fluid with an even higher refractive index that could extend 193-nm immersion lithography to the boundaries of EUV techniques.

The XT:1250i and XT:1400i are the first steps on our complete roadmap of immersion lithography solutions, which extends to NA > 1 systems. This roadmap provides you with an easy migration to future technology nodes that will only be realizable using immersion techniques. With the XT:1250i you can start building your immersion lithography expertise and qualifying immersion processes now—rather than in the time-critical technology development phase—giving you a real head start over your competitors.