32 nm: Lithography at a crossroad

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Microlithography is used to define patterns on ICs. The workhorse for the lithography is optical projection lithography whereby a pattern on a mask is imaged on wafer with 4:1 reduction ratio.

Using water immersion objectives, a production-worthy lithography system using 193 nm wavelength and a numerical aperture *NA* = 1.2 has been shipped in early 2006. This system is capable of printing lines and spaces below 45 nm.

The next step will be a water-based system with an *NA* = 1.35, capable of printing lines and spaces below 40 nm.

Several options are pursued to extend the lithography roadmap down to 32 nm dense lines and spaces. Leading candidates are EUV, double patterning using water-based immersion and immersion using non-water based liquids.

EUV, having a wavelength of 13.5 nm, has the potential to be extended down to 22 nm and below. Significant progress has been made on this technology over last years: first full field tools became available early 2006. However additional progress will be needed on tools, resists and masks before this technology is suitable for mainstream production.

Double patterning, using water-based immersion, is the most straightforward extension but could almost double the cost of lithography and has a severe impact on tool requirements like overlay. Finally non-water based immersion liquids offer the prospect of increasing the *NA* beyond 1.5, but will require lens materials currently not available.

Since there is no clear winner and all options have their own technical and economical challenges, the industry could face a paradigm shift, by the end of this decade, at the 32 nm node.

An assessment of various leading alternatives will be given; an attempt will be made to rank the technical and economical challenges. Finally it will be speculated whether the 32 nm node offers an opportunity for technologies other than optical projection lithography (e.g. imprint, e-beam) to enter into mainstream IC fabrication.