Nanolithography: Can the Industry Afford to Extend Optical Microlithography or Do We Need a Paradigm Shift?

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Semiconductor industry has been on aggressive shrinkage over almost 40 years. The latest published version of the International Technology Roadmap for Semiconductors predicts this shrinkage will continue for the next decade leading to 18 nm gates by 2013.

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

Resolution is defined by:

$$R = k_1\lambda/NA$$

and can be improved by reducing the wavelength, increasing the numerical aperture *NA* or reducing the k_1 value. Currently, the wavelength transition from 248 nm to 193 nm is taking place in IC production, first full field 157 nm scanners are available for process development, 13 nm (EUV) lithography is in research/ advanced development phase. Lens *NA* of 0.85 will be used in production this year and *NA*'s > 0.9 are under development. *NA* could even be increased beyond 1.0 with immersion objectives. Also, in the low-k_1 area, significant improvements have been achieved over the last year using combinations of mask (e.g. chromeless phase shift masks), resist and illumination.

This presentation will discuss examples of state-of-art optical microlithography and the technology roadmap for next decade. Most critical technology challenges will be addressed. However, the biggest challenge will most likely not be technical but the economical viability of microlithography. High *NA* lenses, advanced masks and exposure tools have all increased in price, a trend which is only partly compensated by higher productivity of tools. It is an open question how long the industry can afford the aggressive shrinkage by extending optical lithography. Therefore many alternative solutions to optical projection lithography are proposed. These include use of charge particles, nanoimprint, maskless technology and self assembly. An overview of various alternatives will be given including some pro's and con's.