

## HOW MUCH LITHOGRAPHY CAN THE SEMICONDUCTOR INDUSTRY AFFORD?

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Growth is not sustainable, and the same holds for shrinkage. Miniaturization has been the major driving force for the semiconductor industry over several decades, and the end of this trend – or, more dramatically, the end of the roadmap – has been predicted many times. Typically, the conjecture has been – at any point in time – that the succession of new technology generations would continue for ten more years and then slow down or come to a complete stop, due to physical limitations. The emergence of new transistor and device concepts has postponed this moment. In fact, the projected ‘end of the roadmap’ follows a trend very similar to Moore’s Law itself.

The question on physical limits is more and more being replaced by the question on economical affordability of new technology generations. The ‘economics of scaling’ applies to both the maximum dimension on the wafer (the diameter) and the smallest feature (the transistor gate length). Both the wafer size and the density of integration are driving factors for manufacturing efficiency. This again, is substantially governed by the capability and cost of ownership of the lithographic infrastructure.

The recent history of the quest for a next generation lithography has made clear that – at least until now – efforts to introduce alternative lithography options (based either upon particle or photon optics) have been no match for the extension of conventional (*i.e.* optical) lithography. The case of immersion lithography, which can be considered as an extension of 193 nm lithography, may serve to illustrate this point. However, the price to be paid for this seemingly conservative approach is the necessity to image at ultra-low  $k_1$  or, which is equivalent, to perform lithography with an ever narrowing process latitude. This means that tolerances become more critical and, consequently, the costs of the imaging tool, optical materials, photoresists and other consumables and, in particular, masks are rising sharply. In addition, the need for more sophisticated metrology and inspection contributes substantially to an increasing cost of ownership for the lithography module.

The selection of a next generation lithography is no longer a question of technical capability exclusively. While Extreme UV lithography is slowly becoming technically mature, it could be losing ground from a cost of ownership perspective. The various maskless lithography approaches are still far from the resolution capabilities of EUV, but could be attractive nonetheless for certain production environments.

In the presentation, the merits and constraints of the various new lithography options will be discussed in terms of industrial requirements, both technically and economically. It may well be that in lithography, as elsewhere, one size does not fit all.