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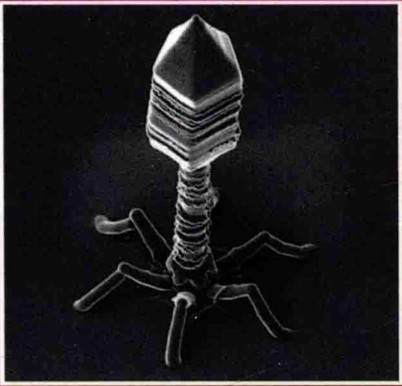

Nanolithography

The art of fabricating nanoelectronic and nanophotonic devices and systems

Edited by Martin Feldman

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Preface

No one ever thought that Moore's law would go on forever, that feature widths would continue to decrease by a factor of two every six years, or that the number of gates on a chip would double every six years or so. But these rates have never slowed down; if anything, they have become slightly faster. And now, with features *in production* just a few dozen atoms wide, the end is almost in sight. How will we deal with features ten atoms wide? What if they're not always ten, but sometimes nine and sometimes eleven? Will we call the two in the middle the thumbs, and the two at the edges the pinkies? Suppose gates shrink to just a few atoms. What will the wires connecting them look like?

The paths we have taken to get this far are fascinating, often using effects that everyone knew about, but were too constrained by long-standing inhibitions to consider practical. For example, immersion microscopy, in which a liquid between the objective and the work-piece is used to improve resolution, was probably older than anyone working in lithography. But for many years the worst crime a lab technician could commit was to allow anything to touch the surface of a resist-coated wafer. Yet now, exposing wafers under water is the mainstream method for fine line patterning.

As another example, contact printing was, and still is, a method for obtaining medium levels of resolution. Combined with the shorter wavelengths of X-rays, it promised resolutions below 100 nm. But the inhibition against touching mask to wafer in a production environment was so strong that even a 10 micron gap between the mask and wafer was considered dangerously small. This was one of the factors that ultimately led to the abandonment of X-ray lithography. Yet now, imprinting, in which the mask is literally pushed into the resist, is a major contender for the next generation of lithography.

As a final example, it has been long recognized that isolated features can be made narrower than densely packed ones. The trick is to control the developing, so as not to make the feature width zero, i.e., not to lose the feature completely. In addition, the use of double exposures with stencil masks was well known. But the tighter control and the longer exposure time did not seem suitable for a production environment. Nevertheless, the use of a first exposure for every other feature, and a second exposure for the remaining features, is also a major contender for the next generation of lithography.

This book is intended as a guide to the novice reading technical journals or facing the complexities of a conference dealing with lithography or nano-manufacturing. The novice may be a graduate student to whom everything is new, or he/she may be an experienced worker in a peripheral field. The authors, all experts in their fields, were instructed to give enough background information to enable novices to understand, and appreciate, new papers in those fields. My thanks to them for their patience in accepting this challenge.

The future belongs to the novice, armed with the knowledge of the past, but unhampered by its inhibitions. How will Moore's law end? I look forward to finding out.

M. Feldman
August, 2013

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