

# GUEST EDITORIAL

## LITHOGRAPHY FOR SUB-100-NM DEVICE FABRICATION

It is a great pleasure to introduce this special section of *JM<sup>3</sup>* devoted to papers on the subject of lithography for sub-100-nm device fabrication. For many years, lithographers have wished for a home, peer-reviewed journal in which they could report the latest developments in the field in an archival format. The *Journal of Microlithography, Microfabrication, and Microsystems* attempts to provide lithographers with such a dedicated forum. Most issues will also include papers from the microsystems and microfabrication fields, but periodically there will be special sections on dedicated topics in microlithography—this is the first in this series.

Advancements in optical lithography have paced progress in microelectronics for more than 30 years, allowing new technologies for computing, telecommunications, and entertainment to flourish. While progress has also been made in particle beam and hard x-ray lithography techniques, optical lithography, with wavelengths in the range of 436 to 157 nm, has remained the workhorse patterning technology for the industry. Optical lithography has been very successful because it has historically provided a complete system of solutions at a sufficiently low cost to enable profitable mass production of integrated circuits. This is largely the result of continuous and predictable improvements in resolution, pattern overlay, and production throughput. The stunning reduction in device minimum feature size, from around 5  $\mu\text{m}$  in 1980 to 90 nm in 2002, has been accomplished through the simultaneous reduction of wavelength, increase in lens numerical aperture, improvement of resolution enhancement techniques, development of high-contrast chemically-enhanced resist chemistries, and perfection of high-speed, fine precision tools such as steppers, scanners, and mask pattern generators.

There are 12 papers in this special section, most originally presented at SPIE's 2002 Microlithography Symposium. These papers were specially selected and reviewed by their peers. They cover various aspects of optical lithography, including scanner and lens technology at 193 and 157 nm, photoresist chemistry and processing, resolution enhancement techniques, and photomask technology.

Various imaging and processing issues related to the extremely high numerical apertures of modern scanner optics are explored in the paper of Brunner et al. Catadioptric optical designs for 157-nm projection lenses are presented in the paper of Webb et al. The paper by Suganaga et al. reports on the imaging performance of one such lens in a small-field 157-nm microstepper. The article of Burnett et al. reports

results of measurements of intrinsic birefringence in calcium fluoride crystals, and their consequences for 193- and 157-nm lens designs.

In an exciting development based on well-known ideas from the field of optical microscopy, Switkes and Rothschild present results for a feasibility study of liquid immersion lithography at 157 nm, which, if practical, could extend the usefulness of optical lithography to below 50 nm.

Photomask technology is the focus of much investigation because of its primary importance to both resolution limits and manufacturing economics. The paper by van den Broeke et al. explores a promising method of mixing phase shifting structures and chrome features on a single mask to enable resolution near theoretical limits for many types of device patterns. Tyrell et al. investigate the limits of the use of phase shifting mask technology as applied to dense pattern integrated circuits, such as memory structures. Light scattering from three-dimensional photomask structures is modeled by domain decomposition methods in the paper by Adam et al.

Advances in photoresist technology have been as exciting and important as the improvements in lithography optics and laser technology. A famous worker in the field, Ralph Dammel, outlines the development of high-contrast resist systems over the last 20 years and comments on the drivers for future improvements. Miyoshi et al. report results for pattern transfer processes for 157-nm lithography.

Resnick et al. report on templates for step-and-flash imprint technology, a new technique not yet used for device production that is capable of extremely fine resolution through optical methods.

Fundamental understanding of optical lithography has been facilitated by the development of sophisticated computer models. The paper by Singh and Garcia-Colevatti outlines the usefulness of lithography TCAD to enable "process-aware" integrated circuit design, leading to higher manufacturing yields.

My associate editors and I hope you enjoy this collection of articles. Since the journal is still very young, any suggestions for improvements or new topics are welcomed. We expect the next special section for microlithography will focus on challenges in mask technology.

**William H. Arnold**  
Senior Editor, Microlithography