

# GUEST EDITORIAL

## MASK TECHNOLOGY FOR OPTICAL LITHOGRAPHY

Maskmaking is an essential element of any lithography system and is more critical today than at any time in recent memory. After the transition from 1X to 5X reticles in the 1980s, which started the sometimes called “maskmaker’s vacation,” reticles were viewed simply as a commodity product that contained magnified binary layouts of the wafer pattern. Then, as feature sizes continued to shrink, the relaxation in specifications gained by the switch to 5X magnification eroded away, and maskmaking again became a critical element in any lithography strategy.

Contemporary reticles can be very complex structures that control both the amplitude and phase of the transmitted light. Some features on these reticles are approaching the wavelength of the exposing light in size; and the reticle layouts can look more like diffractive optical elements rather than anything that would be found on a wafer. The technologies available for masks and reticles have expanded from simple binary chrome to a menagerie of mask species: attenuated phase masks, chromeless masks, paired masks for double exposure with various illumination conditions, and more. The customer and mask shop have never been so overwhelmed with choices.

Moore’s law drives the amount of information placed on a mask to grow exponentially, and the introduction of advanced resolution enhancement technologies, such as subresolution assist features, only amplifies the trend. An advanced reticle for the 65-nm node may contain as much as 100 Gbytes of polygon information and take more than a day to write.

A mask set fabricated using these advanced technologies is quickly approaching the psychologically important million dollar mark. These increasing mask costs are often blamed for the decline in application-specific integrated circuit design starts and have made the mask a target for reexamination. We hope that the community will also appreciate that although these mask sets have high cost they also deliver high value.

It is with this in mind that we have created this special section on mask technology for optical lithography. The pa-

pers presented here fall roughly into two distinct categories: those concerned with the technology of maskmaking, and those that show how the technology of maskmaking can improve the performance of lithography.

The first group of papers discusses mask processing and the issues in mask metrology that are vital in an era of ever more demanding specifications. There are also papers on the thermal response of the mask during exposure, and how the response with a hard pellicle is not as bad as expected.

The second group of papers concentrates on the impact that reticle technology choices have on the lithographic image formation. Some examine the consequences of mask properties such as reflectance, mask errors, and transmission as lithography is pushed to its limits. Others present novel mask tools, such as a focus monitor. There are also examples of new approaches to reticle design, such as phase-shifting vortex masks for the always difficult contact and via layers, and double exposure layout decompositions that form a single, well-managed image from two very different reticles.

Finally, we have, almost in a category all of its own, a return to 1X masks for use in imprint lithography. These are arguably the most advanced imprint masks being made today, and the incredible resolution these are capable of reproducing allows this technology to be considered for fabrication of the 32-nm node.

We hope you will enjoy reading this special section and find these articles a good representation of the high quality of work that is being done in optical mask technology today.

**Kevin D. Cummings,  
ASML**

**Frank M. Schellenberg,  
Mentor Graphics Corp.**

**Guest Editors**