Predicting the lifetime of extreme ultraviolet optics

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Extreme ultraviolet lithography (EUVL) may be the next-generation patterning technique used to produce smaller and faster microchips with feature sizes of 32 nanometers and below. However, durable projection optics must be developed before this laboratory technique can become commercially viable. As part of its long-standing effort to develop EUVL metrology and calibration services (summarized in a recent paper*), the National Institute of Standards and Technology (NIST) is creating a measurement system for accelerated lifetime testing of the mirrors used in EUVL.

The light to be used in EUVL has a wavelength of only 13 nm. It can only be efficiently reflected with mirrors consisting of 50 alternating bi-layers of molybdenum and silicon, each only 7 nm thick and deposited with near-atomic-scale precision. So although the EUVL mirrors will be very large, up to 35 centimeter (cm) in diameter, they are actually incredibly precise nanostructured devices. A single commercial lithography instrument may require six of these mirrors at a cost of more than $1 million each.

The mirrors are delicate, but the EUV radiation they must reflect is intense and damaging. The combination of this harsh radiation with the trace levels of water vapor and hydrocarbons typically found in the vacuum environment of EUV first-generation exposure tools can lead to rapid corruption of the EUVL mirror surfaces. And a loss of just 1 percent to 2 percent of a mirror's reflectivity renders the optical system useless for efficient production of nanometer-resolution circuit features.

To help the semiconductor industry meet its goal of EUVL production by 2010, NIST has established a dedicated beamline at its Synchrotron Ultraviolet Radiation Facility for durability testing of multilayer mirrors. Initial tests established that standard mirrors topped with silicon would have lifetimes of just minutes to hours, while ruthenium-capped mirrors had lifetimes of a few tens of hours, still a thousand times less than industry's requirement.

To determine how damage scales with various parameters, NIST researchers recently exposed EUVL mirrors (provided by SEMATECH from work it co-funded) to varying levels of light intensity, water and hydrocarbon concentrations.

Contrary to expectations, they found that increasing amounts of water vapor caused less mirror damage, which may be due to a simultaneous increase in the ambient hydrocarbon levels. Subsequent experiments have shown that deliberately introducing trace amounts of a simple hydrocarbon like methanol can mitigate significantly the water-induced damage. NIST scientists are commissioning a new beamline devoted to accelerated testing and will add a second branch to the existing beamline that will provide broadband illumination (wavelengths of approximately 11 nm to 50 nm) into a single spot at approximately 100 times the intensity of the current system.

*S. Grantham, S.B. Hill, C. Tarrio, R.E. Vest and T.B. Lucatorto.2005. EUV component and system characterization at NIST for the support of extreme-ultraviolet lithography. Proceedings of SPIE 5751, 1185-91.

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