Characterization of EUV multilayer masks using X-ray reflectivity and Auger electron spectroscopy

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The fabrication of masks for EUVL requires that a blanket multilayer mirror be processed to form a patterned mirror. The reflective regions must have the same excellent reflective properties as the original multilayer coating. A quick and sensitive metrology routine is required to evaluate such patterning processes during their development and to use for statistical process control (SPC) in multilayer mask production. We have evaluated a combination approach of x-ray reflectivity (XRR) and Auger electron spectroscopy (AES) for metrology while successfully developing a patterning process that does no significant damage to the multilayer coating.

The XRR measurements were made at small detector angles, $2\theta=0\text{–}15°$, with a Philips X'Pert diffractometer configured to have an effectively narrow, and low-divergence beam with Cu K-alpha ($\lambda=1.542$ Å) radiation. the data can be fit with an optical model that uses the scattering factors of the materials, their densities, the thickness of each layer, and the roughness of each interface. For periodic multilayer stacks used in EUVL optics, the period of the multilayer (i.e. the thickness of a Mo/Si or Mo/Be bilayer) can be measured with high absolute accuracy (better than 1%) by fitting the positions of the large Bragg peaks. By fitting the peak intensities, one determines interface roughness parameters. Although this is a composite roughness parameter that incorporates multiple types of interface imperfections, it is very useful for sample-to-sample comparisons. In some cases the ratio of the layer thicknesses also can be measured. The Philips GIXA software was used for the XRR simulations

We performed a series of experiments to characterize multilayers of Mo/Si, Mo/Be and MoRu/Be. XRR spectra and complementary AES sputter depth profiles were obtained for multilayers before and after various process steps. At-wavelength characterization was also performed. The AES data compliment the XRR spectra since certain kinds of surface contamination and damage are more apparent with this technique than with XRR. The total number of bi-layers can be counted from peaks in the AES profile to be sure that no layers were lost at the top surface due to mask fabrication.

Results show that a correlation can be established between the non-synchrotron based (XRR and AES) and synchrotron based at-wavelength (EUV) film characterization for multilayer integrity. Films which were confirmed damaged due to process steps using at-wavelength characterization, showed a different XRR spectra and auger response in comparison to undamaged multilayer films. This approach allows us to establish statistical process controls for processing multilayers, comprising substrates such as EUV mirrors and masks, without using the synchrotron for characterization once the SPC standards are established.

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