Phase change observation of EUV reflection multilayer by total electron yield X-ray standing wave method

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In extreme ultraviolet (EUV) wavelength region, normal incidence mirrors are made available with use of reflection multilayers. One of reflection multilayers at around 13nm wavelength is composed of a material pair, Mo and Si, and its reflectance is more than 60%. This reflectance is high enough; therefore many imaging optics using Mo/Si multilayers are planned including projection lithography in next generation. In reflection optics of high imaging quality like in lithography camera, figure errors should be 1/16 or less. To obtain such accurate optics, surface milling at the top of reflection multilayer was proposed as the figure-error-correction method [1, 2]. To correct the figure error, phase information of the optics should be known in advance of the correction.

Total electron yield (TEY) intensity is optically represented by three terms: absorption-, reflection-, and interference- terms [3]. TEY intensity of reflection multilayers is approximately represented by a simple phase term, which is included in the interference term. When the attenuation length L of emitted photoelectrons from the top layer is smaller enough than the thickness d of the top layer, the interference term of TEY intensity is represented by

$$2\,R\,\mathbf{cos}\,(\delta - 2\xi d - 2\xi L), \qquad (1)$$

where R is the real part of the complex reflectance of the top layer, δ is the phase at (m-1)-th layer (m-th layer is the top layer in the formula [3]), and ξ is the real part of the top-layer's propagation-vector represented by $\mathrm{Re}[(2\pi/\lambda)(\varepsilon - \varepsilon_v \sin^2\theta)^{1/2}]$ using angle of incidence θ and complex dielectric functions, ε and ε_v, of the top layer and the vacuum, respectively.

In this study, [Mo 2.6nm/Si 4.1nm]×20 multilayers with different thicknesses of top Mo layer were fabricated on a same Si substrate. Thicknesses of the top Mo layer were accurately controlled by the shutter that was placed in front of the sample, and were deposited from 0.4nm to 3.2nm at 0.4nm intervals. TEY spectra of these aperiodic multilayers were measured with reflection spectra. Obtained TEY spectra showed that peak-positions changed as the increase of the film thickness of the top Mo layer. These TEY spectral changes give the phase change on reflection according to the equation (1).

References

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