Reflection wave-front error compensation by surface milling at a layer prepared on top of an EUV multilayer mirror

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The imaging quality of normal incidence multilayer optics for extreme ultraviolet (EUV) light is governed by the quality of wave-front error correction. In the correction methods currently proposed, such as a substrate deformation as in adaptive optics and deposition figuring of a substrate, a refection surface is controlled physically in a sense by geometrical optics. Therefore, measurement and control of an extremely small amount below 1nm are needed for the correction.

In the transmission optics, however, the wave-front is governed physical-optically with multiplication of a refractive index difference (1-*n*). In the EUV region, the difference is of an order of 0.01, which should ease the control sensitivity required for the wave-front correction by a factor of several 10ths.

In an EUV multilayer mirror, reflection at each interface is very small and the large reflection is effected physical-optically by the total volume of the multilayer structure. This means that a phase correction layer prepared at the surface should work as that of a transmission type. The correction could be realized by deposition of an appropriate amount of material at appropriate position provided that the wave-front error has been measured at the EUV wavelength to be used. Although in practical sense, a layer thick enough to compensate the total phase error could be prepared in advance and appropriate milling can be applied. In this milling mode operation, the top surface, even though roughened, would give negligible effect on the transmission wave front since the refractive index difference with the vacuum is very small.

Material composing the phase correction layer should have a large difference (1-*n*) and a small extinction coefficient *k* for a larger amount of phase correction. Therefore, an optical selection criterion of material for an effective correction is described by a larger ratio of the refractive index difference and the extinction coefficient (1-*n*)/*k* of the material.

Taking a wavelength of 13nm as an example, a Mo layer (1-*n*=0.065, *k*=0.0065) can be used for this purpose. In this case, correction accuracy of reflection phase error of 0.1nm can be realized by milling accuracy of the layer of 1.5nm. Reflectance variation by this milling can be much smaller than 1% depending on the multilayer design. Examples of calculation predicting the milling effect will be given including an example showing a possibility of the phase correction by milling of the multilayer itself, which is especially interesting when a total amount of correction needed is relatively small.