Interface properties of multilayer mirrors with sub-nanometer layer thicknesses

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The spectral range from 2.2 nm to 4.4 nm, also known as the “water window”, has a high relevance in the investigation of biological samples in a wet environment due to the low absorbance of these particular wavelengths in water. Highly reflective surfaces for EUV radiation in this range impinging near-normal incidence are a challenge in the optics fabrication process. Simple surfaces are replaced with multiple layers of alternating materials arranged as periodic multilayer structures to form an artificial one dimensional Bragg crystal. Multilayers composed out of Cr and Sc provide enough optical contrast, while maintaining low absorption, to reach theoretical reflectance values in the order of 40% at an angle of incidence of 1.5° from the surface normal. However, a respective choice of layer thicknesses down to the sub-nanometer regime directly related to the desired peak reflectivity at a certain wavelength and angle of incidence are required.

Disturbances of interfaces with respect to the ideal multilayer such as interdiffusion and roughness diminish the theoretically achievable maximum reflectivity. Experimental reflectivities show values below 20%, i.e. less than half of the theoretically achievable maximum. One possible reason is interface roughness causing diffuse scattering, which serves as a natural tool to analyze the morphology of buried interfaces enabling a distinction from interdiffusion related reflectivity loss. The amplitude and spacial frequency as well as correlation of roughness laterally and vertically give rise to characteristic resonant diffuse scattering (RDS) sheets. We analyze the RDS sheets in case of near-normal incidence diffuse EUV scattering from state-of-the-art multilayer mirrors. Multiple reflections of diffusely scattered light within the multilayer cause a strong resonant enhancement of the scattered intensity and require the application of a fully dynamic model in order to allow for the extraction of the power spectral density of roughness [1]. Strong interdiffusion combined with sub-nanometer layer thicknesses demands explicit modelling of the gradual interfaces.

References

[1] A. Haase et al. "Role of dynamic effects in the characterization of multilayers by means of power spectral density." *Applied optics* **53**. No. 14 (2014): 3019-3027.