Routine and expert analysis of multilayer mirrors

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The analysis of the internal structure of a multilayer mirror is of paramount interest for the understanding and optimization of the performance. In the ideal case we want to know the individual layer thickness, roughness, density and the extent of the mixed zones between the layers for each deposited multilayer mirror. The traditional technique for the reconstruction of a multilayer structure is grazing incidence hard X-ray reflectivity (GIXR) analysis. EUV reflectance spectra measured at more normal angles of incidence are usually measured for quality control of the multilayer stack. The GIXR is an in-house and a non-destructive technique, but the data analysis suffers from the cross correlation between structural parameters (layer densities, thickness ratio and interface thickness) and low sensitivity to atomic distributions. Data analysis starts to be even more difficult when the interface thickness is comparable to the layer thickness, as is for instance the case for La/B based mirrors with a period of 3.4 nm.

We are developing two separate approaches for multilayer characterization: a "routine" and an "expert" approach. The routine structure characterization is based on a combination of GIXR and EUV reflectivity analysis. The expert characterization involves Grazing Incidence Small angle X-ray scattering (GISAXS) and X-ray standing wave (XSW) techniques.

The simultaneous GIXR and EUV analysis combines the benefits of structural sensitivity when hard X-rays (0.154 nm wavelength) are used and the optical contrast sensitivity of soft X-rays or EUV radiation which is the working wavelength for the mirror. This analysis can produce an electron density profile that fits both wavelengths and will thereby increase the reliability of the results obtained.

Information about the interface structure like the roughness power spectral density function (PSD) and correlation length can be obtained from GISAXS measurements. The difficulty of GISAXS for periodic multilayer mirrors with a large number of interfaces (>100) is that rigorous calculation of the GISAXS pattern is very slow. The requirement of an individual model for every individual interface is virtually impossible. However it is still possible to characterize statistical average interface parameters like average an PSD and roughness correlation length. In this case each multilayer stack might require individual attention.

Examples of the analysis techniques will be given for La/B based multilayers with a period of 3.4 nm.