GISAXS – a versatile inspection technique for multilayer interfaces

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The grazing-incidence small-angle X-ray scattering (GISAXS) proved to be a versatile technique for noninvasive characterization of multilayer interfaces [1, 2]. In contrary to traditional coplanar X-ray reciprocal space mapping the recording of GISAXS pattern in noncoplanar scattering geometry maps the lateral correlations of interfaces down to few nanometers. We demonstrated that table-top systems with collimated or focused microfocus X-ray sources are suitable for GISAXS inspection of multilayer mirrors in laboratory conditions.

In this contribution we review quality of interfaces of various multilayer mirror systems suitable for soft- and hard-X-ray region. The GISAXS pattern of typical multilayer mirror consists of series of Bragg sheets. The scattering from the vertically correlated multilayer interfaces adds up in phase and forms the Bragg sheets in reciprocal space (q_y, q_z). The GISAXS pattern shown in Fig. 1a shows the first Bragg sheet of W/B_4C multilayer mirror. The vertical q_z position of the Bragg sheets is given by the reciprocal value of the multilayer period. The lateral extension of the Bragg sheet along the q_y direction is given in the first approximation by the autocorrelation function of the interface roughness. A simulation of the intensity decay along the Bragg sheet yields the mean value of lateral correlation length and Hurst parameter. The width of the Bragg sheet along q_z at a given $q_y=2\pi f$ is inversely proportional to the number periods with correlated roughness frequency f. A modeling of the Bragg sheet width as a function of the lateral roughness frequencies provides an insight into the multilayer growth kinetics.

We show the effect of various deposition techniques on interface properties of Mo/Si mirrors. Short period mirrors suitable for the water window range such as Co/C or Cr/C can suffer from the cluster formation in absorber layers lowering their reflectivity performance. The appearance of a circular ring additional to typical Bragg sheets is a simple indication of the nanometer-sized clusters in the absorber layers. Assuming the Edwards-Wilkinson multilayer growth model and self-affine interfaces we were able to show that Hurst parameter is close to zero for short period W/B_4C multilayers. We also studied the effect of thermal annealing on lateral and vertical correlation lengths of W/B_4C, Co/C and La/B_4C multilayers. The Fig. 1b shows a GISAXS pattern of La/B_4C multilayer mirror suitable for soft X-ray free electron laser FLASH in Hamburg. The TEM cross section analysis revealed mounded interfaces with two prominent spatial frequencies. The GISAXS allows a straightforward determination of dominant frequencies for mounded interfaces and gives also insight into their vertical correlation along the multilayer stack.

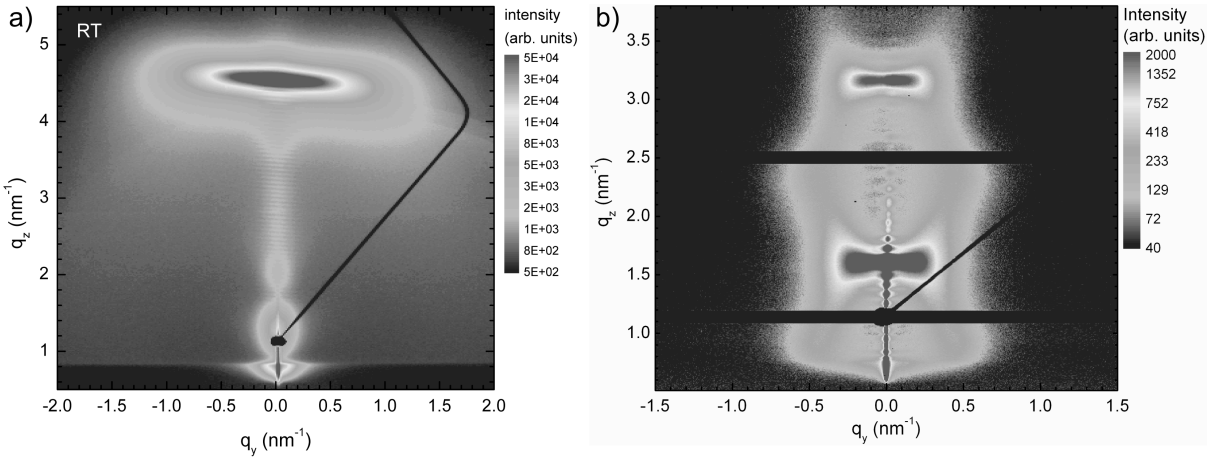

Fig. 1 – GISAXS patterns of (a) W/B_4C and (b) La/B_4C multilayer mirrors.

References

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