Soft X-ray Cr/Sc Multilayer Mirrors: Effects of B_4C, O and N impurities

Naureen Ghafoor,[a] Fredrik Eriksson,[a] Eric Gullikson,[b] Lars Hultman [a], and Jens Birch[a]

[a] Department of Physics, Chemistry and Biology (IFM), Linköping University 581 83 Linköping, Sweden
[b] Lawrence Berkeley Lab, Bldg 2R0400, 1 Cyclotron Rd. Berkeley, CA 94720-8199, USA

The effects of different impurities correlated to structural morphology and normal incidence reflectivity of water window soft X-ray (2.3 nm < λ < 4.4 nm) Cr/Sc multilayers will be presented. In order to reach theoretical reflectance, these sub nm thin periodic structures must be fabricated with minimum interface mixing, interdiffusion and structural roughness. The role of impurities on layer densities, interfacial structure and resulting optical contrast between the layers, is however, widely unknown.

We find that the best performing mirrors are generally achieved with multilayers comprising amorphous metal layers, resulting in flat interfaces.[1,2] It is proposed that the formation of the amorphous phase may be promoted by the incorporation of impurities. The state-of-the-art Cr/Sc multilayer coatings were fabricated by incorporating B_4C layers as "diffusion barriers" on top of the Cr layers.[2] This indicates that to obtain interface abruptness is a main concern with these mirrors rather then interface flatness. In this study we have investigated the effect of co-deposition of B_4C with the multilayers in order to probe into the role of such an impurity.

All the multilayers used for impurity investigations were grown in a high vacuum chamber by dual cathode DC magnetron sputter deposition concurrent with modulated ion assistance.[1] To see the effects of above mentioned impurities on layer morphology several multilayers with the modulation periods in the range of 0.9- 4.5 nm and layer thickness ratios in the range of 0.17 – 0.83 were deposited. The magnetron current was controlled in order to vary the B_4C concentration in the multilayers.

Elastic recoil detection analysis was used to determine the impurity content in the multilayers while the structural investigations with varying impurity content in the multilayers were carried out by using hard and soft X-ray reflectivity and transmission electron microscopy.

In parallel to flat amorphous Cr/Sc multilayer structure a slightly rougher but highly textured crystalline layer structure was obtained by incorporating 30-40 at.% of N and 1-4 at.% of O. A controlled amount of air was introduced during multilayer depositions in order to control the N and O concentrations. As shown in Fig.1 twice as high absolute reflectivity was measured for the resulting CrN_x/ScN_y multilayers as compared to the pure Cr/Sc multilayers. The reduction in interface width in these structures is a consequence of reduced intermixing due to the formation of stable nitride layers.

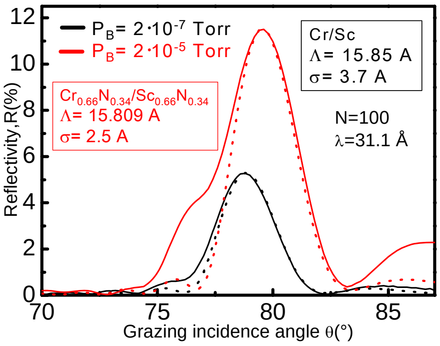

Fig.1: Soft X-ray reflectivity profiles for Cr/Sc multilayer deposited at two different background pressures (P_B).. Dotted lines are the simulated profiles.

1. N. Ghafoor, F. Eriksson, P.O.Å. Persson, L. Hultman and J. Birch, Thin Solid Films Available online 18 June 2007.
2. E. M. Gullikson, F. Salmassi, A. L. Aquila and F. Dollar, S8 04, PXRMS, Sapparo, Japan, 2006.

Email: naugh@ifm.liu.se