Yoneda effect in planar x-ray waveguide

J.-M. André[1], P. Jonnard[1], K. Le Guen[1], M.-Y. Wu[1], R. Dhawan[2], A. Singh[2], M. H. Modi[2], M.-C. Lépy[3], Y. Ménesguen[3], A. Novikova[3], W. Pessoa[4]

[1]*Sorbonne Universités, UPMC Univ Paris 06, CNRS UMR 7614, Laboratoire de Chimie Physique - Matière et Rayonnement, 11 rue Pierre et Marie Curie, F-75231 Paris cedex 05, France*

jean-michel.andre1@upmc.fr

[2]*Indus Synchrotrons Utilization Division Raja Ramanna Centre for Advanced Technology, Indore 452013, India*

[3]*CEA, LIST, Laboratoire National Henri Becquerel, F-91191 Gif-sur-Yvette Cedex, France*

[4]*CEA, LETI, MINATEC Campus, 17 rue des Martyrs, F-38054 Grenoble Cedex 9, France*

Summary

A stack of nanolayers forming a planar x-ray waveguide with a ZrC/Al core was fabricated by sputtering deposition. Using the CASTOR instrument of LNHB at the Metrology beamline of the SOLEIL synchrotron facility, ω-scans (or rocking scans) were recorded at an incident photon energy of 10.25 keV. They reveal asymmetric Yoneda wings arising from diffuse radiation scattered by the interfacial roughness of the waveguide stack. We have found that the small-angle Yoneda peak presents some structures consisting in intensity dips. Although it seems that these structures are the signature of the guided mode within the waveguide, they are not reproduced by well-established theory of diffuse scattering in multilayer system.

Experiments and results

A four-layered stack, Al[7nm] / ZrC[5nm] / Al[15nm] / W[50nm] / Si[substrate] was fabricated by sputtering deposition. This multilayer structure forms an x-ray waveguide with the pair of Al[7nm] and W[50nm] cladding layers sandwiching a ZrC/Al bilayer core. The specular and off-specular scattering of this device was measured at 10.25 keV in the *p*-polarization configuration by means of the CASTOR instrument, equipped with a goniometer working under vacuum. It allows performing x-ray reflectivity and fluorescence measurements under grazing incidence of the incident beam.

The specular reflectivity curve (Fig. 1) shows that this structure exhibits a guided mode for a grazing angle α equal to 0.23°. Here, the angles are considered between the surface of the waveguide and the direction of the incident beam. For the off-specular measurements, some ω-scans (detector fixed, sample rotating) were recorded revealing asymmetric Yoneda wings noted Y1 and Y2 in Fig. 2. For the detector fixed at an angle θ_d equal to 2° with respect to the direction of the incident beam, the structures Y1 and Y2 are located at the angles close to the critical angle $\alpha_c \approx 0.3°$ and to the angle $\theta_d - \alpha_c \approx 1.7°$ respectively, in agreement with the theory of the Yoneda effect [1,2]. This kind of structures comes from the diffuse radiation scattered by the interfacial roughness of the stack and are well documented both for simple mirrors [1] or interferential mirrors (periodic multilayers) [2] but not for waveguide systems.

From our measurements, it appears that the small-angle Yoneda peak Y1 presents some particular features: two dips noted D1 and D2 as shown in Fig. 3. Although these two structures seem to be intuitively associated with the guided mode, calculations [3] based on a well-established theory of diffuse scattering by multilayer system [2] do not reproduce the experimental results (see Fig. 4). The resolution of this problem is in progress.

Acknowledgments

We acknowledge SOLEIL for provision of synchrotron radiation facilities and we would like to thank Pascal Mercere and Paulo da Silva for assistance in using beamline METROLOGY.

Reference

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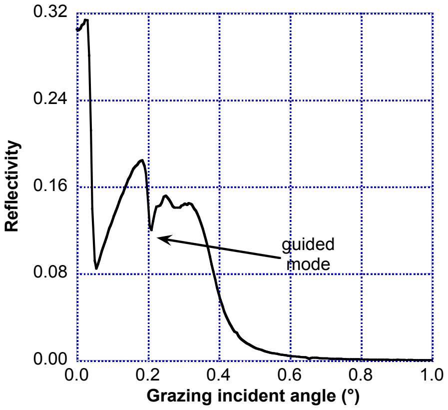
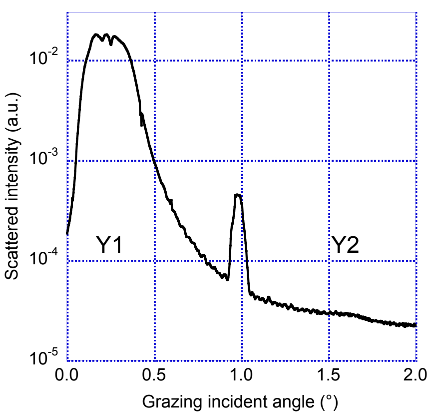


Figure 1: Reflectivity at 10.25 keV of the Al/ZrC/Al/W stack.



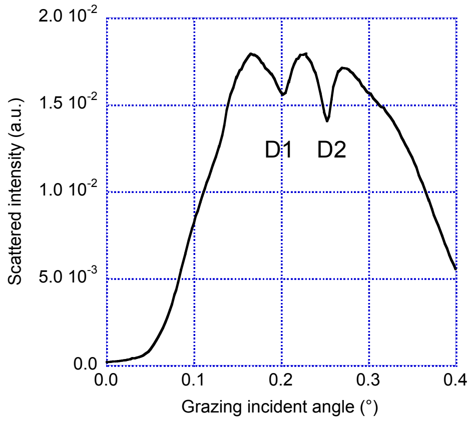


Figure 2 (left): ω-scan on a log scale at 10.25 keV of the Al/ZrC/Al/W stack with the detector fixed at 2°.

Figure 3 (right): ω-scan on a linear scale at 10.25 keV of the Al/ZrC/Al/W stack with the detector fixed at 2° in the region of the Y1 Yoneda feature.

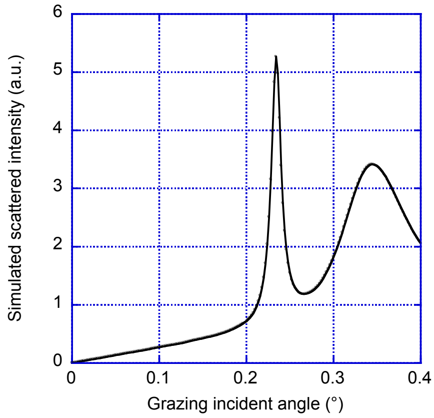


Figure 4: simulation of the ω-scan scale at 10.25 keV of the Al/ZrC/Al/W stack with the detector fixed at 2°.