Title: Standing-wave-grazing-incidence x-ray diffraction from polycrystalline multilayers

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Abstract:

In this dissertation we present a new method, which uses the concept of x-ray standing wave in the grazing-incidence geometry, in which both the incidence and exit angles $\alpha_{i,f}$ are close to the critical angle $\alpha_c$ of total external reflection. If the angle of incidence $\alpha_i$ of the primary x-ray wave onto a periodic multilayer is close to $\alpha_c$ or to a "Bragg-like" maximum on the reflectivity curve, the interference of the transmitted and reflected waves creates a standing wave pattern in the multilayer volume, the period of which equals the multilayer period. If the multilayer contains crystalline grains (crystallites), the intensity of diffraction from these crystallites depends on the mutual position of the crystallites and the antinodes of the standing wave. Similarly, the wave diffracted by the crystallites is reflected from the multilayer interfaces, which results in a standing wave pattern as well. The standing wave pattern is shifted by changing $\alpha_i$ or $\alpha_f$ so that from the measured dependence of the diffracted intensity on $\alpha_{i,f}$ it is possible to determine the position of the diffracting crystallites. Moreover, measuring the dependences of the diffracted intensity on the in-plane scattering angle $2\theta$ at various $\alpha_i$ it is possible to determine the lateral sizes of the crystallites in different depths in the multilayer. The theoretical description of the scattering process is based on the Distorted-Wave Born approximation.

I this work we prove the feasibility of this concept by measuring the standing-wave effects in $C/Ni_3N$ multilayers using synchrotron radiation, and we were able to determine the sizes of the crystallites in different depths in the multilayer and the thicknesses of amorphous $Ni_3N$ transition layers at the $C/Ni_3N$ interfaces.

We demonstrate that this method can be carried out also at a modified x-ray diffractometer, and it is capable of studying the structure of crystalline layers in a periodic multilayer at a laboratory. We have used this method for the investigation of the structure of Nb/Si multilayers, and we obtained the thicknesses of amorphous and crystalline parts of the Nb layers. These thicknesses agree very well with the transmission electron microscopy observations.

Presented method is very suitable for a detailed study of sizes and positions of crystallites in periodic multilayers, as well as for the determination of the depth profile of the crystallite size.

Keywords: grazing-incidence x-ray diffraction, standing wave, polycrystalline multilayers