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X-ray Optical Characteristics of Layered Synthetic Materials and their Applications

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The vacuum thin-film fabrication technology during the last decades has been advanced to such a degree that nanometer-scale thin-film structures are routinely produced in a controlled manner. The close proximity of different thin-film materials provides opportunity to study novel physical characteristics that are much different from their bulk properties. Multilayer thin-films have therefore been investigated in various scientific fields such as opto-magnetism, x-ray optics, and grand magnetoresistance. Their applications even only in the x-ray optics field are enormous: x-ray mirror, x-ray polarizer, x-ray waveplate, high-efficiency xuv grating, x-ray diffractometers and spectrometers.

Normal-incidence x-ray optics have already been utilized in various technological applications including x-ray projection lithography, x-ray microscopes, and x-ray laser cavities. A multilayer structure as a high-reflectivity mirror in the soft x-ray region should be composed of alternating layers of two elements whose indices of refraction are largely different at a wavelength in interest. Its performance is closely related to the micro-structural parameters of the multilayer structure such as the bi-layer thickness, the number of the bi-layers deposited, the ratio of the thickness of the high-Z element to the bi-layer thickness (multilayer period), the degree of the interface perfection, and the selection of materials. The combination of Mo and Si has been known to work well particularly for wavelengths longer than 12.4 nm and under many investigations.

In this paper, we present our study of multilayer structures as soft x-ray mirrors. The dependence of the normal incidence reflectivity on multilayer structural parameters, the fabrication of Mo-Si multilayer structures, their x-ray optical characterization are discussed. To understand and control the optical and/or physical properties of a multilayer structure and fabricate a better multilayer structure, one should be able to determine the structural parameters and correlate this structure with experimentally observed physical data. XRD is a promising technique for characterizing the structures. However, the interpretation of the XRD data and the extraction of reliable quantitative information on the structural parameters have been limited by the lack of a quantitative model which can incorporates the realistic interfaces into calculation. The effects of interface imperfections such as interdiffusion and roughness on the XRD data are described and these results are applied to characterize the structure of a Mo-Si multilayer soft x-ray mirror.