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Analysis of Side Band Structure in Spectral Reflectance of VUV Multilayers for Precise Determination of Period Thickness

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1 Introduction

Multilayers are useful elements to handle VUV lights in a normal incidence geometry, where the spectral property directly depends on the layer thicknesses. Small angle X-ray diffractometry, or X-ray reflectometry is usually used for the evaluation of the period thickness of multilayers, if the substrate surface is plane. In imaging optics, however, mirrors are curved and a grazing incidence geometry is difficult to apply to that. In this report, a new analysis method of the period thickness of a normal incidence VUV multilayer mirror is presented.

2 Theory

A periodic stack of bilayer, material 1 and material 2, is assumed as a multilayer structure. The complex refractive indices and layer thicknesses are (n_1, n_2) and (d_1, d_2), respectively. The period thickness and thickness ratio are defined as $D = d_1+d_2$ and $\gamma = d_2/D$, respectively. Then, the Bragg's condition can be written as

$$\frac{(1-\gamma)\mathrm{Re}(\sqrt{{n_1}^2-\sin^2\phi})+\gamma\mathrm{Re}(\sqrt{{n_2}^2-\sin^2\phi})}{\lambda}=\frac{m}{2D}, \qquad (1)$$

where λ and ϕ are the wavelength and the angle of incidence, respectively. The left-hand side represents the real part of the depth component of averaged wavenumber, $\mathrm{Re}(k_z)$. Since the refractive indices have a λ-dependence, the reflectances at higher orders are usually not so high, and $m = 1$ is the only diffraction order to be discussed as the main peak. When the period number is N, the existence of N–1 local minima between main peaks is known. The diffraction orders for local minima can be assigned as $m = 1\pm1/N, 1\pm2/N, 1\pm3/N, \ldots$. Relying on γ being not so much different from the designed value, $\mathrm{Re}(k_z)$ can be plotted against m. The goal is to determine D value which is given by the slop $1/2D$.

3 Experiments and Results

A Mo/Si multilayer of $N = 35$, $D \sim 7$ nm, $\gamma = 0.41$ was deposited on a concave substrate of a 300 mm radius of curvature. The spectral reflectance was measured at $\phi = 5°$ at BL-12A. The results are plotted in a logarithmic scale in Fig. 1. Each curve is shifted vertically by a factor of 4. Numbers in mm show the radial position of measurements. Figure 2 shows $\mathrm{Re}(k_z)$ at the local minima in Fig. 1 as a function of m. The period thickness determined from the slope is plotted in Fig. 3. The precision seems to be in a 0.1% order. The multilayer microscope of Tohoku University [1] was characterized by this method.

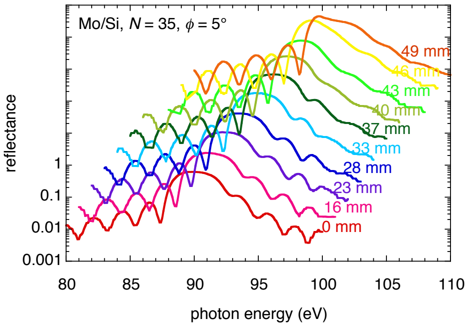

Fig. 1: Spectral reflectance of a Mo/Si multilayer.

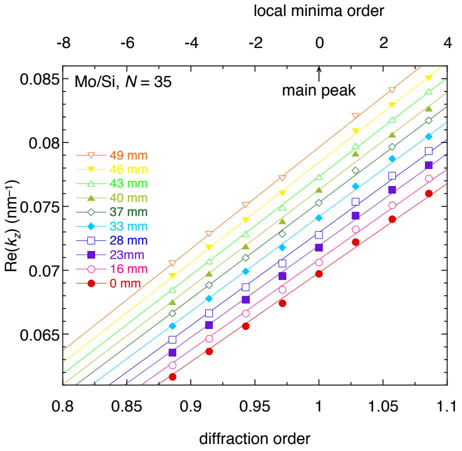

Fig. 2: Real part of the depth component of averaged wavenumber at local minima in spectral reflectance.

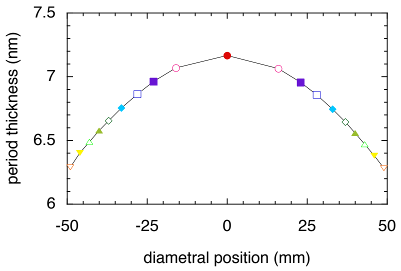

Fig. 3: Period thickness distribution of a Mo/Si multilayer deposited on a 300^r concave substrate.

Reference

[1] T. Hatano, T. Harada and M. Yamamoto, PF Act. Rep. 2007 A, **#25** (2009) 64.

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