BL-11D/2017G638

Evaluation of second order light of BL-11D, the Photon Factory around a wavelength of 13.5 nm using La/C multilayer mirrors

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1 Introduction

In spectroscopic measurements using diffraction gratings, higher order lights deteriorate quantitative accuracy. Output of EUV and soft X-ray beamlines contains typically 10% second order light in flux. Even in spectrally purer experimental condition with higher order light absorbing filters, residual impurity has to be analyzed to discuss the accuracy of measured data. One of most frequently used spectral regions in optical element beamlines is 13.5 nm wavelength EUV. Reflectances of mirrors, transmittances of filters, sensitivities of detectors and photo-resist used in study for developing EUV lithography technologies are measured. Therefore high spectral purity is required especially around a wavelength of 13.5 nm.

BL-11D of the Photon Factory is dedicated to characterization of EUV and soft X-ray optical elements. The monochromator was designed with variable deviation angle type to suppress higher order lights. Higher order lights have been detected only in the carbon (C) *K*-absorption region where higher order lights are relatively not so low than other regions [1]. By multilayer reflectometry, it was found that 560 eV second order light and 840 eV third order light were contained by 7% and 1%, respectively, when the energy of first order light was set to 280 eV. Although higher order lights are expected to be low enough around 13.5 nm EUV region, high sensitivity detection of them are needed for confirmation of high spectral purity.

When reflectance of a multilayer reflecting 180 eV EUV is measured around 90 eV, a pseudo reflection peak due to the second order light will be observed, which will be an evidence of the existence of the second order light and will give a fraction of them by the ratio of the nominal reflectance at 90 eV to the intrinsic reflectance at 180 eV. The energy of evaluation is tunable by changing the angle of incidence.

2 Multilayer fabrication

Multilayers of which reflection peaks appear in 170 – 200 eV depending on the angle of incidence were designed. Material pair of Lanthanum (La) and C were used. Thickness ratio of La and C layers were 1:1. Figure 1 shows calculated spectral reflectance of a La/C multilayer with period number of N = 100, period thickness of D = 3.69 nm and angle of incidence of ϕ = 22°. Interface roughness was assumed to be σ = 1 nm *rms*. A sharp peak appears at 183.7 eV. A broad peak around 120 eV can be attributed to La $N_{4,5}$ absorption. When this reflectance is measured using a monochromatized light with second order impurity contained, a small but sharp peak will appear at 91.8 eV (13.5 nm). Two La/C multilayers with N = 100, D = 3.69 nm and N = 200, D = 3.37 nm were deposited on silicon wafers by ion beam sputtering.

3 Measuements

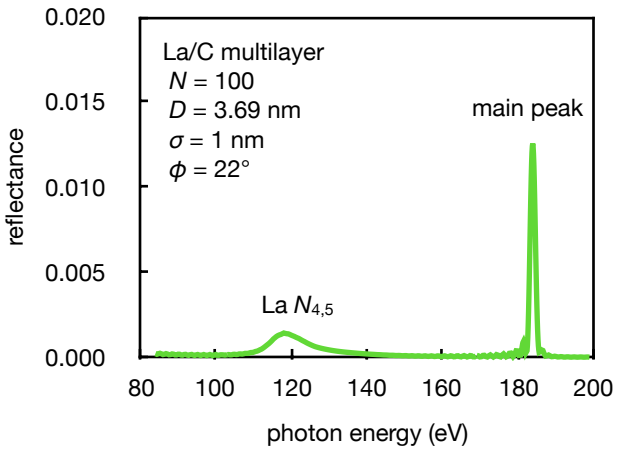

Fig. 1: Calculated spectral reflectance of a La/C multilayer.

Measurements were performed at BL-11D of the Photon Factory. Measured spectral reflectances around the peaks are shown in Fig. 2. The monochromator was moved to the half energy of the reflection peak and spectral reflectances were measured. Results are shown in Fig. 3. Simple oscillation was observed. The oscillation periods agreed with 1/N times of the peak energies for N = 100 and 200, which confirms that the oscillation is a well-known tail structure of multilayer reflection. Here, pseudo peaks that would appear if 1% second order light were contained in the incident light were plotted by dotted lines in Fig. 3. They are reduction of measured

reflectance curves plotted in Fig. 2 by 1/100 and 1/2 times, along ordinate and abscissa, respectively. The band width of pseudo peak are similar to the widths of a peak or a valley (half of the period) of tail oscillation because multilayer bandwidth approximately agree with 1/*N* times of the peak energy. From the experimental results that no pseudo peak were detected in spectral reflectances around 91.8 eV, it was found that the fraction of the second order light was no higher than 0.1% and a 0.1% accuracy of EUV element characterization at BL-11D of the Photon Factory was ensured.

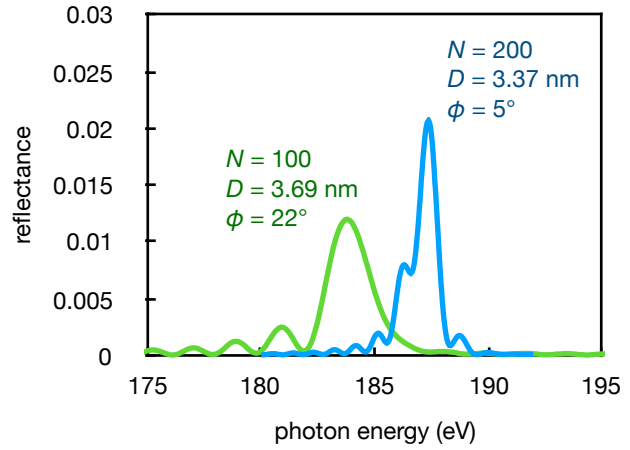

Fig. 2: Measured spectral reflectances of La/C multilayers around their peaks.

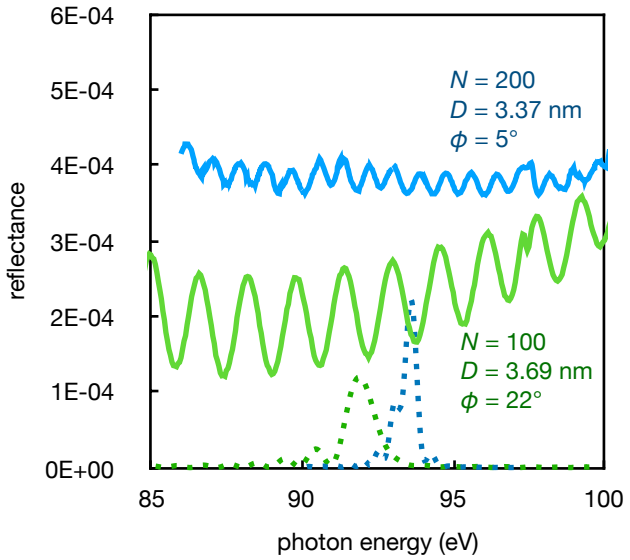

Fig. 3: Measured spectral reflectances of La/C multilayers in energy region of half of the peaks.

Acknowledgement

This work was partly supported by CAMS Project 2017, IMRAM, Tohoku University.

References

[1] T. Hatano and T. Harada, *J. Electron Spectrosc. Relat. Phenom.* **196**, 156 (2014).

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