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Diffraction order sorting of grating monochromator using a multilayer mirror

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1 Introduction

Soft X-rays monochromatized by a diffraction grating are series of diffraction orders being "polychromatic." Spectral impurity due to higher order diffraction is one of significant factors causing a measurement error in experiments at a grating monochromator beamline of synchrotron facilities. BL-11D of the Photon Factory is dedicated for characterization of soft X-ray elements [1], where the spectral purity is more important for quantitive measurements. To suppress the high harmonic energy impurities, varied-deviation-angle type was adopted in monochromator design [2]. Still remaining impurities have to be evaluated for data correction.

Suppose the monochromator is set at an energy E and its output is a series of harmonic energy E, $2E$, $3E$ and $4E$ whose power spectrum are I_1, I_2, I_3 and I_4, where "power" means the signal height of the detector given by the product of the source power, beamline throughput and detector sensitivity. Measured beam power is $I_1+I_2+I_3+I_4$. The goal of this work is to evaluate each impurity power I_n (n = 2, 3, 4) and to obtain I_1 as a deduction from the whole power. Since I_n (n = 2, 3, 4) is much smaller than I_1 in general, the purity factor $I_1/(I_1+I_2+I_3+I_4)$ will be relatively insensitive to error in evaluation of I_2, I_3 and I_4. A multilayer mirror set at an adequate angle of incidence is proposed as a tool for picking up one out of series of harmonic energies.

The monochromator at BL-11D covers 230–1200 eV and 60–290 eV with gratings G1 and G3, respectively [3]. The carbon window below C K-edge is one of useful energy regions for soft X-ray microscope and activities on characterization of carbon window multilayer mirrors are performed at this beamline [4, 5]. Since the carbon window lies between energy regions where G1 and G3 were optimized, spectral impurity problem might be serious in this region. Therefore the fundamental energy E = 282 eV were chosen in this work.

2 Principle

When the monochromator is set at an energy E, each high harmonic component is reflected by a multilayer with a periodic thickness D at an angle of incidence of approximately $\phi_n \sim \arccos(\lambda_n/2D)$ according to the Bragg condition with refraction neglected, where λ_n is the wavelength corresponding the photon energy nE.

In multilayer reflectance measurement at the angle ϕ_n around the fundamental energy E, the nominal value of the peak reflectance will be $R_nI_n/(I_1+I_2+I_3+I_4)$, where R_n is the intrinsic peak reflectance for energy nE and angle ϕ_n. If R_n is known, I_n can be obtained. Such procedure is similar to the higher order light analysis using an absorption edge measurement. In the present method, analysis on all n for a particular E is possible by changing the angle of incidence of the multilayer, and then the power series I_2, I_3, I_4 can be obtained.

3 Experiment

The multilayer for reflection measurement is a 300-period Cr/C deposited on a Si wafer by ion beam sputtering deposition. Sputtering targets were switched so that the thickness ratio should be $d_{Cr} : d_C = 3 : 7$. The peak energy in the spectral reflectance measured at a 5° angle of incidence was 282 eV, in advance, which determines the period thickness $d_{Cr}+d_C$ as 2.16 nm.

Grating G1 was used in R_2, R_3 and R_4 measurements above 500 eV. The spectral resolution estimated from the slit widths of the monochromator was 1000. Grating G3 was used in measurements around E = 282 eV with the spectral resolution of 2000. The converging angle onto the sample surface was 0.1°. The plane of incidence was vertical and the polarization state was s-polarized. The detector was AXUV100Ti2 photodiode (IRD Inc.).

4 Results

Reflectance peak angle at $2E$ = 564 eV was found at ϕ_2 = 59.4°. Measured spectral reflectance at ϕ_2 = 59.4° is shown by a blue line in Fig. 1. The energy scale is shown on the upper axis. The peak reflectance was R_2 = 2.49%. A small structure due to Cr $L_{2,3}$ absorption was observed around 590 eV. It is not a side band of multilayer reflection. At the same angle of incidence, spectral reflectance was measured around E = 282 eV. The result is shown by a red line in Fig. 1. The small peak pointed by arrows is a reflection signal of the energy $2E$ component, which gives $R_2I_2/(I_1+I_2+I_3+I_4)$ = 0.18%. Thus the second order impurity factor was obtained as $I_2/(I_1+I_2+I_3+I_4)$ = 0.072, which is an ordinary level.

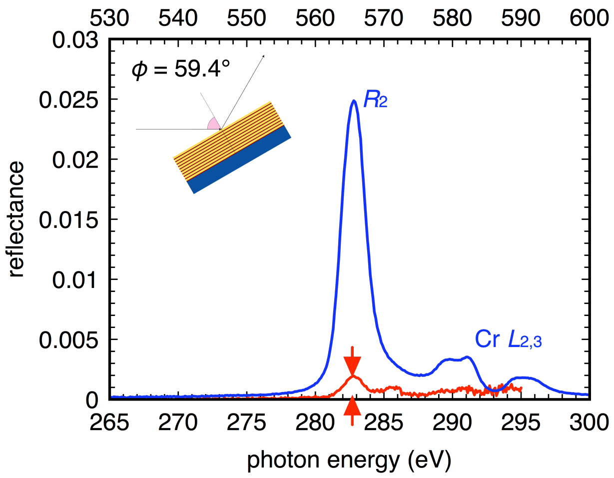

Fig. 1: Measured spectral reflectance of a Cr/C multilayer at angle of incidence of 59.4°.

Reflectance peak angle at $3E$ = 846 eV was found at ϕ_3 = 70.0°. Measured spectral reflectance at ϕ_3 = 70.0° is shown by a green line in Fig. 2. The energy scale is shown on the upper axis. The peak reflectance was R_3 = 3.92%. At the same angle of incidence, spectral reflectance was measured around E = 282 eV again. The result is shown by a red line in Fig. 2. The very small peak pointed by arrows is a reflection signal of the energy $3E$ component, which gives $R_3I_3/(I_1+I_2+I_3+I_4)$ = 0.05%. Thus the third order impurity factor was obtained as $I_3/(I_1+I_2+I_3+I_4)$ = 0.013.

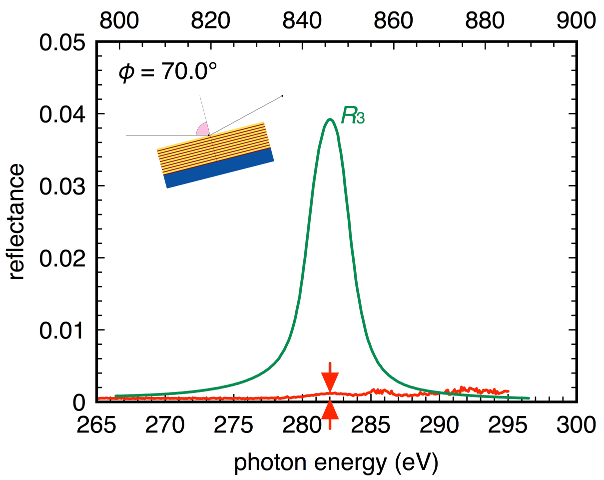

Fig. 2: Measured spectral reflectance of a Cr/C multilayer at angle of incidence of 70.0°.

Reflectance peak angle at $4E$ = 1128 eV was found at ϕ_4 = 75.3°. Measured spectral reflectance at ϕ_4 = 75.3° is shown by a purple line in Fig. 3. The energy scale is shown on the upper axis. The peak reflectance was R_4 = 6.71%. At the same angle of incidence, spectral reflectance was measured around E = 282 eV again. The result is shown by a red line in Fig. 3. The reflection signal of the energy $4E$ component could not be detected, which means I_4 should be negligible. Small peaks observed around 290 eV originates in C 1*s*-π* and C 1*s*-σ* transitions at a grazing incidence geometry.

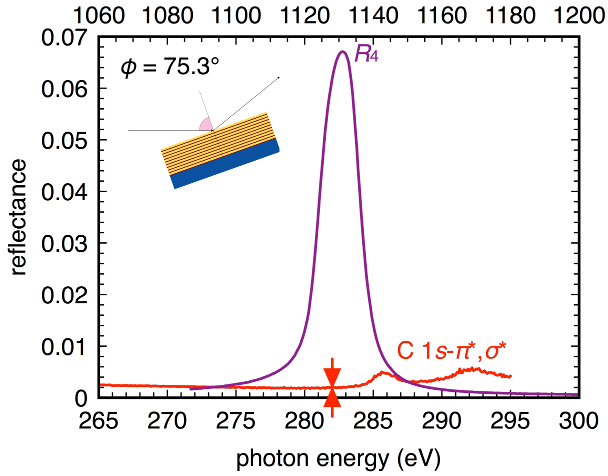

Fig. 3: Measured spectral reflectance of a Cr/C multilayer at angle of incidence of 75.3°.

Reflectance measurement at the same angle of incidence was also tried around $2E$ = 564 eV, but no reflection signal was detected. It means the monochromator is second-order-free when the fundamental energy is shifted to 564 eV. Therefore the value of R_2 measured above should be reliable.

As a result the second and third order impurity factors were determined to be 0.072 and 0.013, respectively, which give the purity factor $I_1/(I_1+I_2+I_3+I_4)$ = 0.915.

5 Conclusions

A simple method for quantitive analysis of the higher order impurities in a grating monochromator output was proposed. A multilayer is used as a bandpass filter for order sorting with the angle of incidence changed. We have characterized the BL-11D, PF at 282 eV using a 300 period Cr/C multilayer of a 2.16 nm period thickness. The power spectrum was determined to be $I_1 : I_2 : I_3 : I_4$ = 0.915 : 0.072 : 0.013 : 0.

References

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