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Recent performance of the Photon Factory grating/crystal monochromator station BL-1A in the soft X-ray region

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This paper describes the recent performance of the Photon Factory beamline 1A with InSb(111) crystals used as the diffracting elements of the grating/crystal monochromator for monochromatizing soft X-rays. Pt-coated collimating and focusing mirrors located upstream and downstream of the monochromator have recently been replaced with Ni-coated mirrors in order to remove absorption structures at the Pt *M*-edges from output spectra in the soft X-ray region. Output spectra without the absorption structures and with higher intensity in the range 2000–3400 eV were obtained by using the Ni-coated collimating and focusing mirrors.

Keywords: beamline; grating/crystal monochromator; mirror; soft X-rays.

1. Introduction

The UHV beamline 1A (BL-1A) at the Photon Factory was constructed for surface analysis of electronic materials (Kawamura *et al.*, 1989*a*,*b*). To analyse the chemical state of semiconductor surfaces by photoelectron spectroscopy (PS) and analyse the structure of the same surface by surface EXAFS (SEXAFS) at BL-1A, a grating/crystal monochromator (GCM) (Hunter *et al.*, 1982) was selected, as this provided the possibility of monochromatization in a wide energy range from VUV to soft X-rays by using both gratings and crystals as diffracting elements. After remodelling the exchange and adjusting mechanisms of the diffracting elements and developing the computer control system, the GCM installed at BL-1A provided monochromated VUV beams for PS and soft X-ray beams for SEXAFS and X-ray standing-wave experiments.

The optics of BL-1A consist of the GCM with collimating and focusing mirrors located upstream and downstream, as shown in Fig. 1. These are off-axis paraboloidal mirrors made from fused quartz and have focal lengths of 17 and 10 m. The grazing incident angle for these mirrors is 1°. Pt-coated collimating and focusing mirrors have been used since BL-1A was constructed, because the cut-off energy of Pt at a grazing incident angle of 1° is approximately 5 keV. However, output spectra in the soft X-ray region have absorption structures at the Pt *M*-edges as a result. To improve the performance of BL-1A in the soft X-ray region by eliminating the Pt *M*-edge absorption structures from the output spectra, we replaced the Pt coating of the collimating and focusing mirrors with Ni. We report here the output of BL-1A in the soft X-ray region before and after changing the coating of the mirrors.

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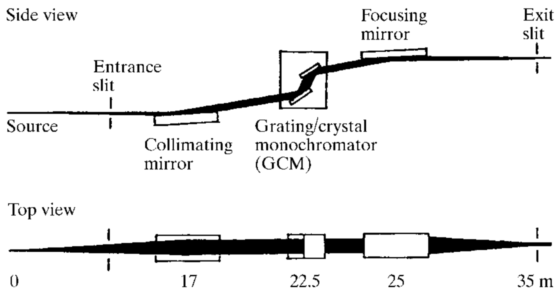

Figure 1
The optical layout of BL-1A at the Photon Factory.

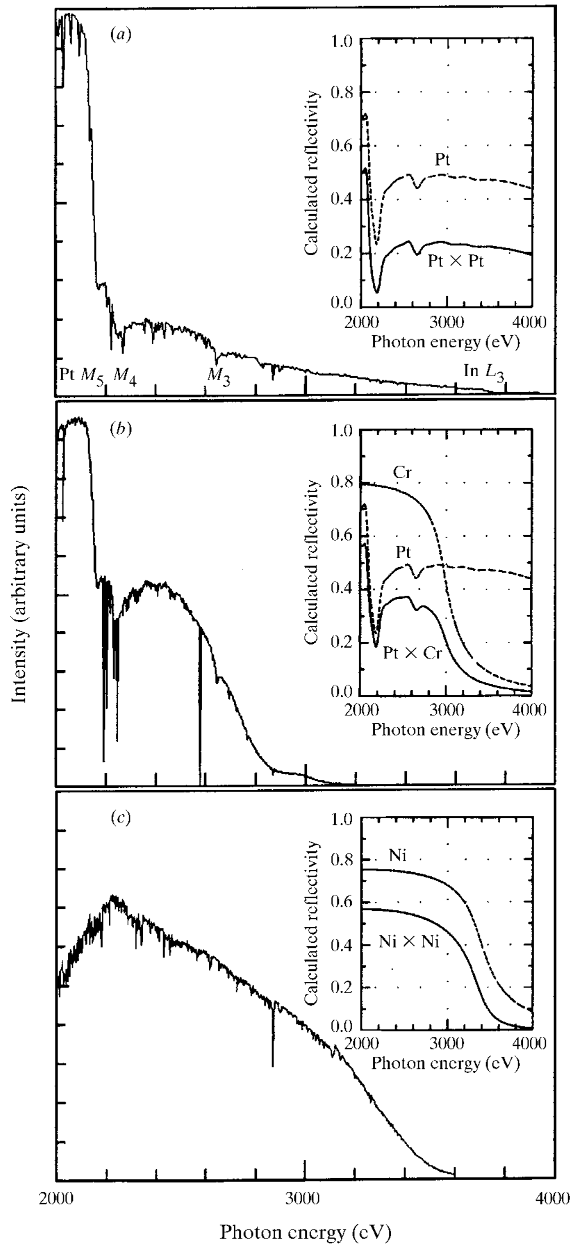

Figure 2
The output spectra of BL-1A for three combinations of collimating mirror (CM) and focusing mirror (FM): (*a*) Pt-coated CM and FM, (*b*) Pt-coated CM and Cr-coated FM, and (*c*) Ni-coated CM and FM. The insets show calculated reflectivities for Pt-coated, Cr-coated and Ni-coated mirrors, and combinations of these mirrors.

2. Experimental

To evaluate the output of BL-1A in the soft X-ray region, Ga $L\alpha$ and As $L\alpha$ fluorescence yields from a GaAs wafer were monitored as a function of the incident photon energy in the range 2000–4000 eV using an Si detector and the same experimental set-up before and after replacing the mirrors. A pair of InSb(111) crystals were used as the diffracting elements of the GCM for monochromatizing soft X-rays. The output spectra of BL-1A were obtained for three combinations of mirrors: the first was a Pt-coated collimating mirror (CM) and focusing mirror (FM), the second was a Pt-coated CM and a Cr-coated FM, and the third was an Ni-coated CM and FM. The first is the original mirror set-up and the third is the present mirror set-up after replacing the original mirrors. In the second, the Cr-coated FM was used for a preliminary test before replacing the Pt-coated CM and FM with the Ni-coated CM and FM. All the CMs and FMs were set to a grazing incident angle of 1°.

3. Results

Fig. 2 compares the output spectra measured by the fluorescence yield for the three combinations of the CM and FM: (*a*) the Pt-coated CM and FM, (*b*) the Pt-coated CM and Cr-coated FM, and (*c*) the Ni-coated CM and FM. Calculated reflectivities based on Henke's data (Henke *et al.*, 1993) for the three cases in addition to Pt, Cr and Ni-coated mirrors with grazing incident angles of 1° are also shown as insets in Fig. 2.

In the output spectrum obtained using the Pt-coated CM and FM, the intensity decreases rapidly because of absorption by the double Pt-coated mirrors at the Pt M_5-edge (2133 eV) and the low intensity is maintained up to the In L_3-edge (3730 eV). This output spectrum, in which absorption structures are observed at the Pt *M*-edges, is similar to that obtained for the soft X-ray double-crystal monochromator beamline at the Stanford Synchrotron Radiation Laboratory (SSRL) (Hussian *et al.*, 1982). In the output spectrum of BL-1A, however, the ratio of the intensity in the energy range above the Pt M_5-edge to the intensity at 2000 eV is lower than that for the beamline at SSRL, which has only a Pt-coated toroidal focusing mirror located upstream of the monochromator.

The output spectrum obtained using the Ni-coated CM and the Cr-coated FM shows that the absorption due to the Pt *M*-edges is reduced by replacing the original Pt-coated FM with a Cr-coated FM, which has higher reflectivity than the Pt-coated mirror in the energy range below 3000 eV. Thus, the intensity at 2400 eV increases approximately threefold compared to that for the double Pt-coated mirrors, while no intensity is observed at energies above 3200 eV because of the low cut-off energy of the Cr-coated mirror with a grazing incident angle of 1°.

The output spectrum obtained using the Ni-coated CM and FM demonstrates that there are no absorption structures resulting from the coating material of the mirror, since Ni as well as Cr has no absorption edge in this range. Furthermore, Ni has a higher cut-off energy than Cr, as shown by the calculated reflectivity, so the highest intensity in the range 2000–3400 eV was obtained using the double Ni-coated mirrors. It has been reported that the performance of the soft X-ray crystal monochromator station BL-11B at the Photon Factory has been improved by replacing the Pt-coated focusing SiC mirror without a cooling unit with a Ni-coated focusing silicon mirror with a water-cooled holder (Kitajima, 1996). At BL-11B, the grazing incident angle was also changed from 1 to 0.6° to maintain the same cut-off energy, and consequently all the downstream beam-pipes were rearranged. At BL-1A, only the coating materials of the CM and FM were changed and the optical layout was not modified. Nevertheless, the output of BL-1A in the energy range below 3000 eV has clearly been increased.

4. Conclusions

The performance of the grating/crystal monochromator station BL-1A in the soft X-ray region monochromated by InSb(111) crystals has been improved by replacing the Pt-coated collimating and focusing mirrors with Ni-coated mirrors. Mirror replacement is considered to be an effective method for improving the performance of old synchrotron-radiation beamlines.

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