Construction of a High-Resolution Beamline BL-5 for Soft X-Ray Spectroscopic Analysis on Industrial Materials

The X-ray absorption fine structure (XAFS) technique in the soft X-ray region has attracted much attention from the industrial world as a powerful tool for investigating the electronic and geometric structures of industrial materials. In addition, photoemission spectroscopy (PES) technique is also an effective means for researching the electronic structure of material surfaces in the soft X-ray region. Thus, there is a need for the analysis ability in the soft X-ray region to increase with the development of nanotechnology in the industrial yields. A new beamline was constructed in response to such a demand in the industrial world (Fig. 1). The decision on the optical design and specifications of end stations was made in cooperation with the University of Hyogo and industrial companies joining Synchrotron Analysis LLC, as described below. This beamline is anticipated to prosper the co-research with University of Hyogo and industrial companies, and expected to advance the analysis abilities of industrial companies.

A high-resolution beamline was constructed at BL-5 of NewSUBARU, where a 30-m-long beamline can be built. The light source of BL-5 is the bending magnet, which can provide photons in the region of up to 4000 eV. BL-5 consists of two branch lines for use in the wide range from 50 eV to 4000 eV. BL-5A, which is mounted with a double-crystal monochromator, can be used in the energy range of 1300-4000 eV. On the other hand, BL-5B is mounted with a valid-line-spacing grating monochromator, which is designed to cover the energy range of 50-1300 eV using three kinds of grating. The incident beam from the bending magnet is provided for two branch lines through different windows of a mask. Therefore, these two branch lines can be employed simultaneously.

A layout of the BL-5A is shown in Fig. 2. InSb crystals and Si crystals are prepared for a double-crystal monochromator. Toroidal mirrors are used as a pre-mirror and a focusing mirror of BL-5A. XAFS measurement in the total electron yield mode and fluorescence XAFS measurement using SSD (SII Vortex) can be performed. The fluorescence XAFS spectra can be measured for samples at the end station filled with He gas.

A layout of BL-5B is shown in Fig. 3. The constant-deviation monochromator consisting of a demagnifying spherical mirror and a varied-line-spacing plane grating (VLSPG), which can provide high resolution, simple wavelength scanning with fixed slits, was mounted on BL-5B. The optical system consists of a first mirror (M0), a second mirror (M1), an entrance slit (S1), a pre-mirror (M2), and three kinds of plane grating (G), an exit slit (S2) and a focusing mirror (M3). The deviation angle of the monochromator is 175°. The VLSPG achieves high resolution in the extreme ultraviolet region by diminishing various kinds of aberration. In the case of the VLSPG, the groove parameters can be expressed in the following form by expanding the groove density N with coefficients a_i:

$$N(w)=N_0\,(1+a_1 w+a_2 w^2+a_3 w^3+\cdots)\,,$$

where N_0 is the groove density at the center of the grating and w is the distance from the center of the grating along the direction of light traveling. Aberrations, such as defocus, coma, and spherical aberration, were computed with the present geometrical and ruling parameters. For BL-5B, we use three kinds of grating with groove densities of 100, 300 and 800 grooves/mm at the center of the grating, N_0 and the space variation parameters a_1, a_2

Fig. 1. Constructed high-resolution beamline BL-5 for soft X-ray spectroscopy analysis of Industrial Materials.

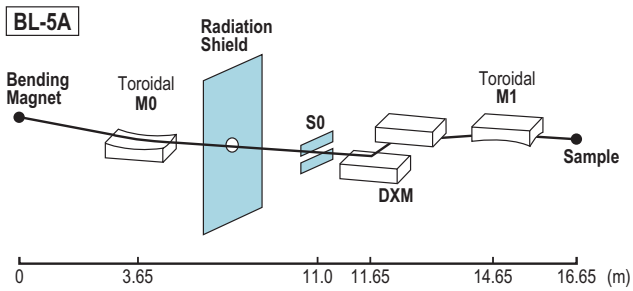

Fig. 2. Layout of BL-5A.

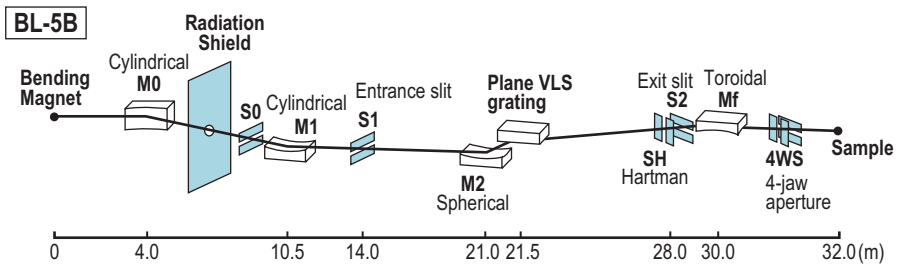

Fig. 3. Layout of BL-5B.

and a_3 are determined to minimize the aberration in the specified photon wavelength region to -3.0727×10^{-4}, 7.1×10^{-8} and -1.7×10^{-11}, respectively. Figure 4 shows the calculated resolving powers at entrance and exit slit widths of 50 and 100 μm with the slope error limit. A total resolving power of about 3000 can be realized in the entire energy region. Two measurement chambers are prepared at the end station of BL-5B. The XAFS spectra in the total electron yield mode and fluorescence XAFS spectra using SDD (EDAX) can be measured in a high vacuum chamber. In addition, the photoelectron spectrum can be measured using spherical electron analyzer (VG Sienta, R3000) in an ultra high-vacuum chamber. The chambers can be replaced by each other within 1 hour.

The B *K*-edge and N *K*-edge NEXAFS spectra of hexagonal-boron nitride (h-BN) measured at BL-5B are shown in Fig. 5 and Fig. 6, respectively. The B *K*-edge NEXAFS spectrum was measured using G1 with 100 grooves/mm. On the other hand, the N *K*-edge NEXAFS spectrum was measured using G2 with 300 grooves/mm. The entrance and exit slit widths were 100 μm. NEXAFS measurement was performed in the total electron yield (TEY) mode.

The maintenance and management of BL-5 are performed by Synchrotron Analysis LLC, which is a consortium of user companies, under the supervision of the LASTI staff. The companies that wish to use BL-5 have to join Synchrotron Analysis LLC, with the payment of a membership fee. If users want help with measurements at BL-5, operators of Synchrotron Analysis LLC can assist them.

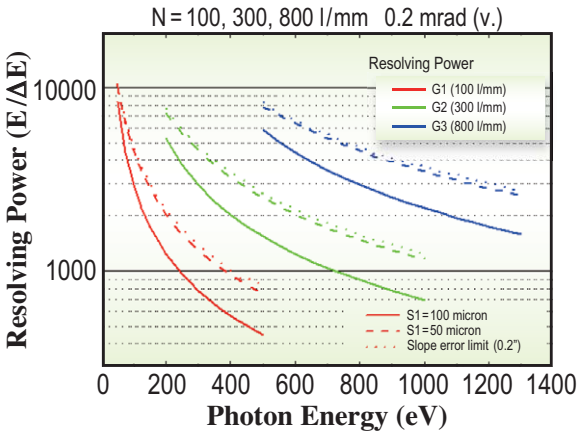

Fig. 4. Calculated resolving power of BL-5B.

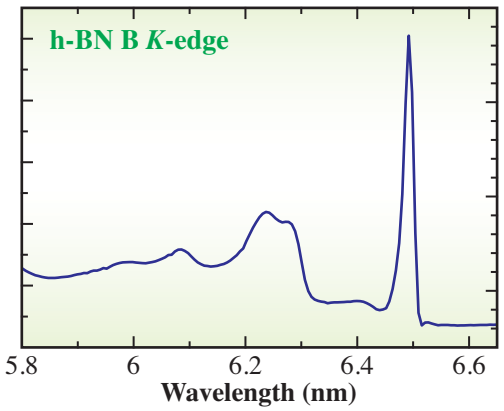

Fig. 5. B *K*-edge NEXAFS spectrum of h-BN.

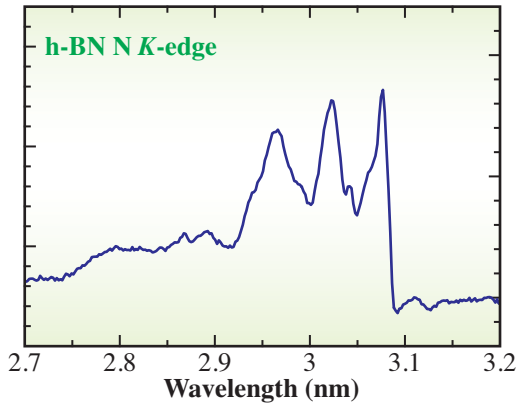

Fig. 6. N *K*-edge NEXAFS spectrum of h-BN.

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