BL16XU
SUNBEAM ID

1. Introduction

BL16XU, which is referred to as SUNBEAM ID, together with its sister beamline BL16B2, was built to develop various industrial materials by utilizing the high-brightness beam at the large-scale synchrotron radiation facility in SPring-8. It is operated by the SUNBEAM Consortium, which is a private organization comprising 13 companies[*] (12 firms and one electric power group). BL16XU and BL16B2 began operations in September 1999, and the beamline use contract was renewed in April 2018. In August 2020, we received an interim evaluation and obtained a "continuation" evaluation result.

X-rays emitted from an undulator are monochromatized, shaped, and converged in an optics hutch. The experimental hutch contains four experimental devices. Figure 1 and Table 1 schematically depict and outline the characteristics of BL16XU, respectively.

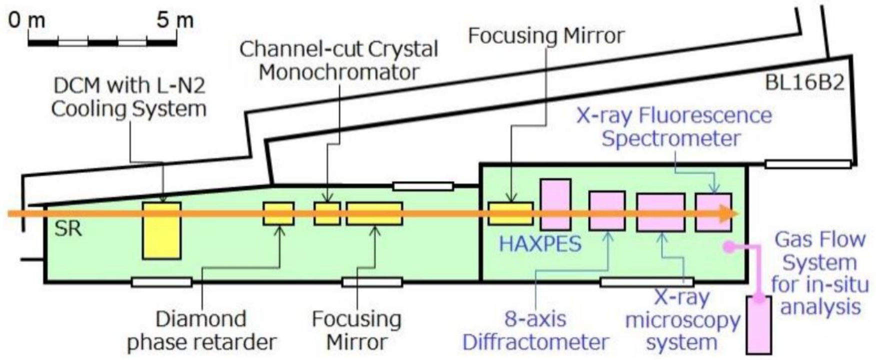

Fig. 1. Outline of BL16XU.

Table 1. Characteristics of BL16XU.

Light source	in-vacuo X-ray undulator $\lambda = 40$ mm, $N = 112$
Energy range	4.5–40 keV
Energy resolution ($\Delta E/E$)	$\sim 10^{-4}$
Photon intensity, beam size	$\sim 10^{12}$ photons/s, < 1 mm × 1 mm $\sim 10^{10}$ photons/s, < 500 nm × 500 nm
Beam position stability	±0.1 mm horizontal ±0.8 mm vertical (5.0–30 keV)
Experimental facilities	HAXPES, XRD, XRF, Microbeam (Microscopy), Gas flow system (corrosive or toxic gas is possible)

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[*] Kawasaki Heavy Industry, Ltd., Kobe Steel, Ltd., Sumitomo Electric Industries, Ltd., Sony Group Corp., Electric power group (Kansai Electric Power Co., Inc., Central Research Institute of Electric Power Industry), Toshiba Corp., Toyota Central R&D Labs., Inc., Nichia Corp., Nissan Motor Co., Ltd., Panasonic Holdings Corp., Hitachi, Ltd., Fujitsu Ltd., Mitsubishi Electric Corp.

2. Utilization

Figure 2 shows the utilization of BL16XU in the past decade. The vertical axis shows the proportions of users, excluding the tuning and studying of the beamline itself. The upper graph depicts the utilization by field. The application fields are mainly semiconductors, batteries, and materials. In recent years, research related to green innovations, such as lithium-ion batteries, fuel cells, SiC, and GaN, has been progressing.

The lower graph shows the utilization of equipment (technology). The utilization of hard X-ray photoelectron spectroscopy (HAXPES) equipment, which was installed in 2014, is increasing. HAXPES is mainly used for semiconductors and battery materials.

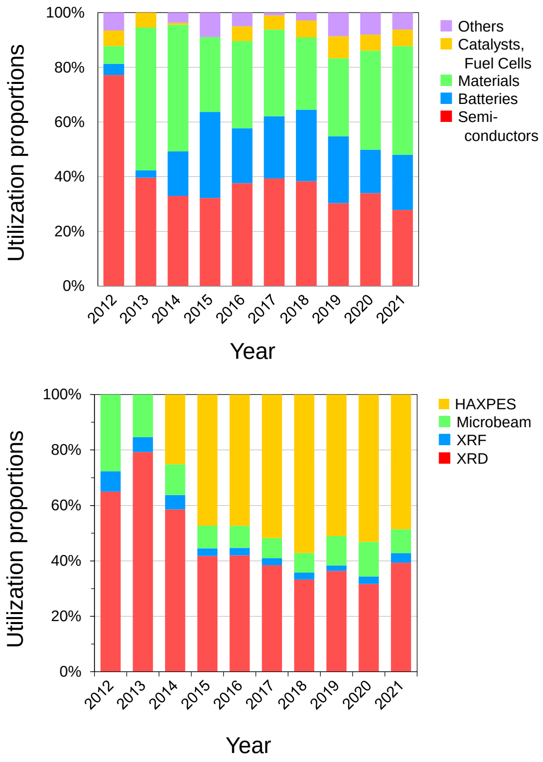

Fig. 2. Relative utilization times of BL16XU in the past decade.

3. Topics in FY2021

Below, the research and upgrades conducted in FY2021 are described.

3-1. Suppression of charging effects by X-ray shutter in HAXPES

As described above, in BL16XU, HAXPES is widely used for various materials such as semiconductor and battery-related materials. One of the issues in HAXPES measurements is charging effects, which result in peak shift and/or broadening. The effects prevent accurate measurements, especially for insulator samples. To suppress the charging effects and maintain accurate measurements, we introduced an X-ray shutter system to our HAXPES in BL16XU [1].

Figure 3 shows schematic diagram of the system. An X-ray shutter (Uniblitz XRS6, Vincent Associates) was placed just upstream of an attenuator. The duty ratio was fixed at 50%, whereas the maximum speed of the shutter was ten cycles per second. Opreraition of the shutter reduces the total radiation dosage, but still intense enough for accurate measurements, owing to the high intensity of the SR X-rays. Samples such as Au thin films, thermally oxidized SiO_2 with a thickness of 30 nm on non-doped Si substrates, and SnO_2 powder were prepared. For comparison, measurements with the Al attenuator were also performed.

Figure 4(a) shows the Au 4f spectra obtained from the Au thin film. The normalized spectra for Au $4f_{7/2}$ are also shown in Fig. 4(b). The spectra are identical regardless of the duration of the X-ray shutter, confirming that the attached shutter does not affect the HAXPES measurements. Figure 5 shows the Si 1s spectra obtained from SiO_2/Si samples. The peaks at 1839 eV originate from Si, and those

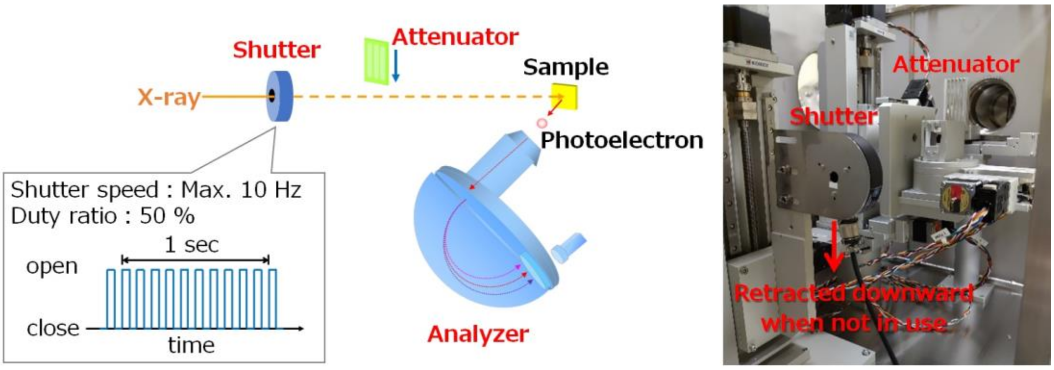

Fig. 3. Schematic diagram of HAXPES system.

around 1844–1845 eV from SiO_2. With the use of the shutter, both peaks shifted toward lower binding energies. The maximum peak shift was determined to be 0.3 eV for Si and 0.4 eV for SiO_2. This proves the suppression of the charging effects by introducing the shutter system. Figure 6 shows the peak position of Sn $2p_{3/2}$ on SnO_2 powder as a function of relative X-ray intensity. The peak shifted by 2.8 eV as the incident X-ray intensity increased with the charging effect. It was found that the peak shift of Sn $2p_{3/2}$ with the shutter was 0.4 eV lower than that without the shutter at a maximum. Thus, the effectiveness of the present system in terms of the suppression of the charging effects is confirmed. It is concluded that the X-ray shutter system is applicable to various industrial materials.

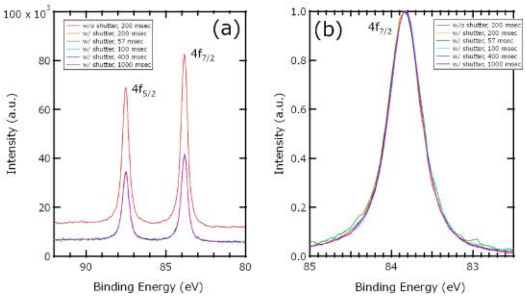

Fig. 4. (a) Au 4f spectra obtained from Au thin film. (b) Normalized spectra for Au $4f_{7/2}$.

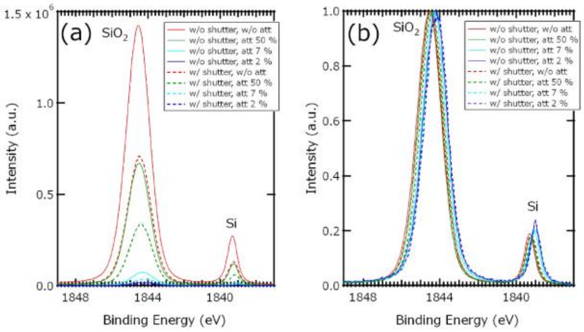

Fig. 5. Si 1s spectra from SiO_2/Si samples.

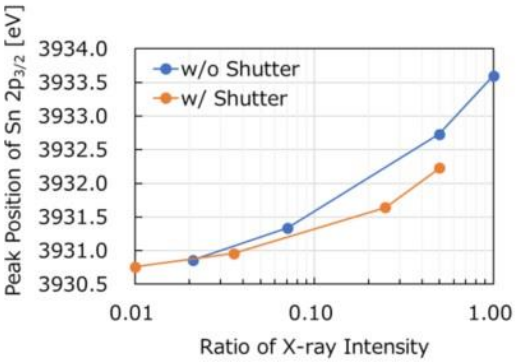

Fig. 6. Peak position of Sn $2p_{3/2}$ as a function of relative X-ray intensity.

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Reference:

[1] Arai, R. (2022). *SPring-8/SACLA Research Report* **10**, 324.