BL17SU
RIKEN Coherent Soft X-ray Spectroscopy

1. Introduction

Over the past couple of years, efforts have been underway to restructure the soft X-ray (SX) spectroscopy beamline BL17SU into a SX spectromicroscopy beamline. BL17SU was originally constructed in 2004 to advance spectroscopic studies mainly for solid-state physics and materials science by means of conventional X-ray absorption, photoemission, and X-ray emission spectroscopies. In the early phase of BL17SU, the spectroscopic photoemission low-energy electron microscope (SPELEEM, ELMITEC GmbH) [1] was used not only by in-house staff but also by public users. Since then, BL17SU has provided opportunities to study both the local electronic and magnetic domain structure of advanced materials with a spatial resolution of about 22 nm.

2. Recent activities

To further extend the research opportunities of BL17SU to microspectroscopic studies on various kinds of materials, we installed a versatile photoemission electron microscope (PEEM, FOCUS GmbH) in the carry-in station of the BL17SU b-branch in FY2016. After commissioning, PEEM has been available for public use since FY2018. We also developed a time-resolved PEEM measurement system using the versatile PEEM combined with a femtosecond laser system and a SX chopper [2]. Advanced research using this system is underway to investigate the transient changes of electronic and magnetic structures.

Figure 1 highlights the versatile PEEM. Figures 1(a) and (b) show photographs of PEEM, while Fig. 1(c) shows experimental results obtained during the commissioning phase. Figures 1(d) and (e) are PEEM images of the patterned Au/Si structure together with their local X-ray absorption spectroscopy (XAS) spectra in Fig. 1(f). Figure 1(g) is a timing diagram of the pump-probe measurement scheme, and Fig. 1(h) presents the resultant time-resolved PEEM images.

We have also developed a scanning SX spectromicroscope with a modest spatial resolution (300–500 nm) [3]. It is designed to study local electronic structures on surfaces and interfaces of various advanced materials under conditions ranging from a low-vacuum to a helium atmosphere by taking advantage of the photon-in photon-out measurement scheme. Figure 2 shows a schematic illustration (a) and photographs of the apparatus (b–d) installed at the b-branch carry-in station; the end-station is shared with the versatile PEEM. Figures 2(e–h) show representative experimental results of the microspectroscopic data. In this carry-in station, the two instruments can be easily switched since they are built on slide rails. However, the scanning SX spectromicroscope will be moved to the a-branch of BL17SU in the near future.

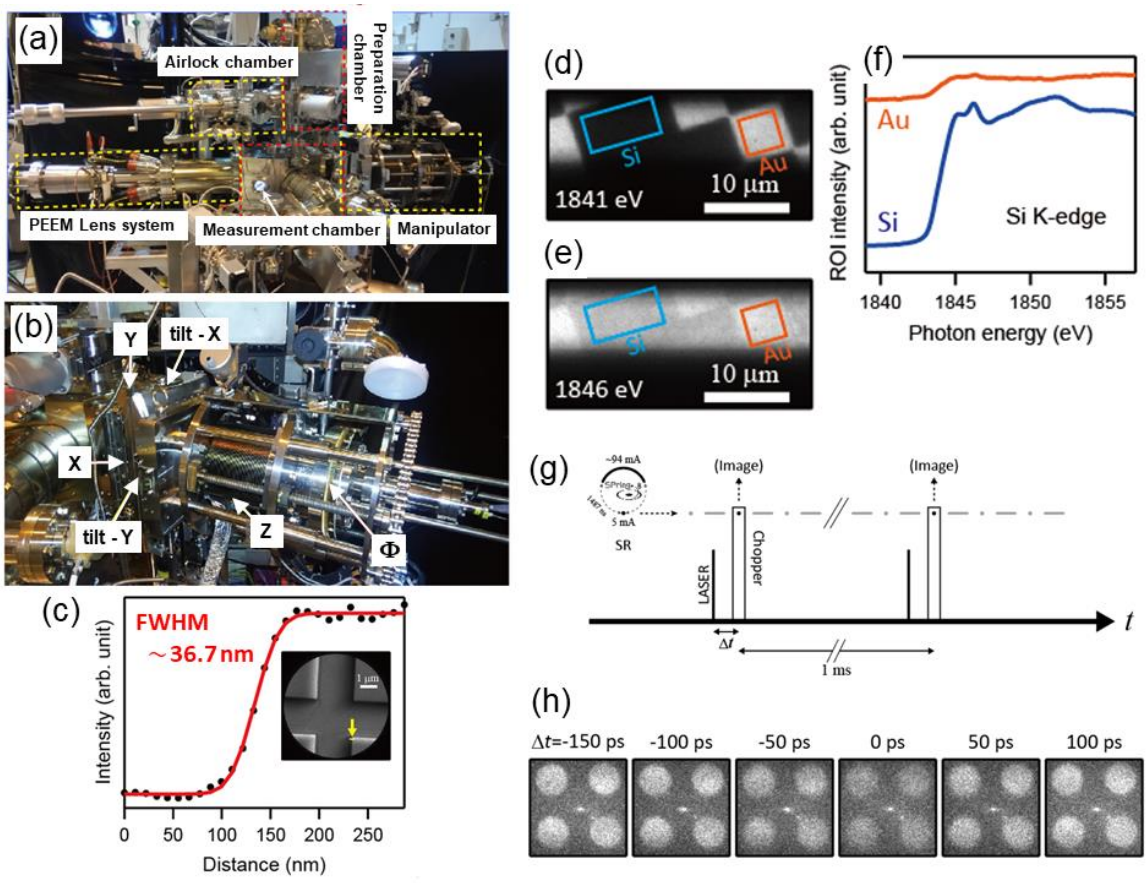

Fig. 1. (a) Photograph of the PEEM apparatus. (b) Photograph of specially made six-axis sample manipulator, which allows flexibility to adopt various kinds of experiments. (c) Line profile of the step edge of a silver film with lithographed pattern (black dots) and fitting result (red line). (Inset) Corresponding position is denoted with a yellow arrow. When a UV lamp is used (~100 nm when SR is used) achieves a spatial resolution of ~36.7 nm. (d), (e) PEEM images of Au patchwork pattern on a Si substrate recorded at (d) the Si K pre-edge and (e) Si K absorption peak energy. (f) Area-selected Si K-XAS spectra extracted from two regions of interest ("Si" and "Au") indicated in (d) and (e). (g) Timing diagram of pump-probe measurements using a laser pulse excitation. (h) Time-resolved PEEM images of $Ni_{81}Fe_{19}$ circular dots with a diameter of 5 μm obtained at the Fe L_3-edge.

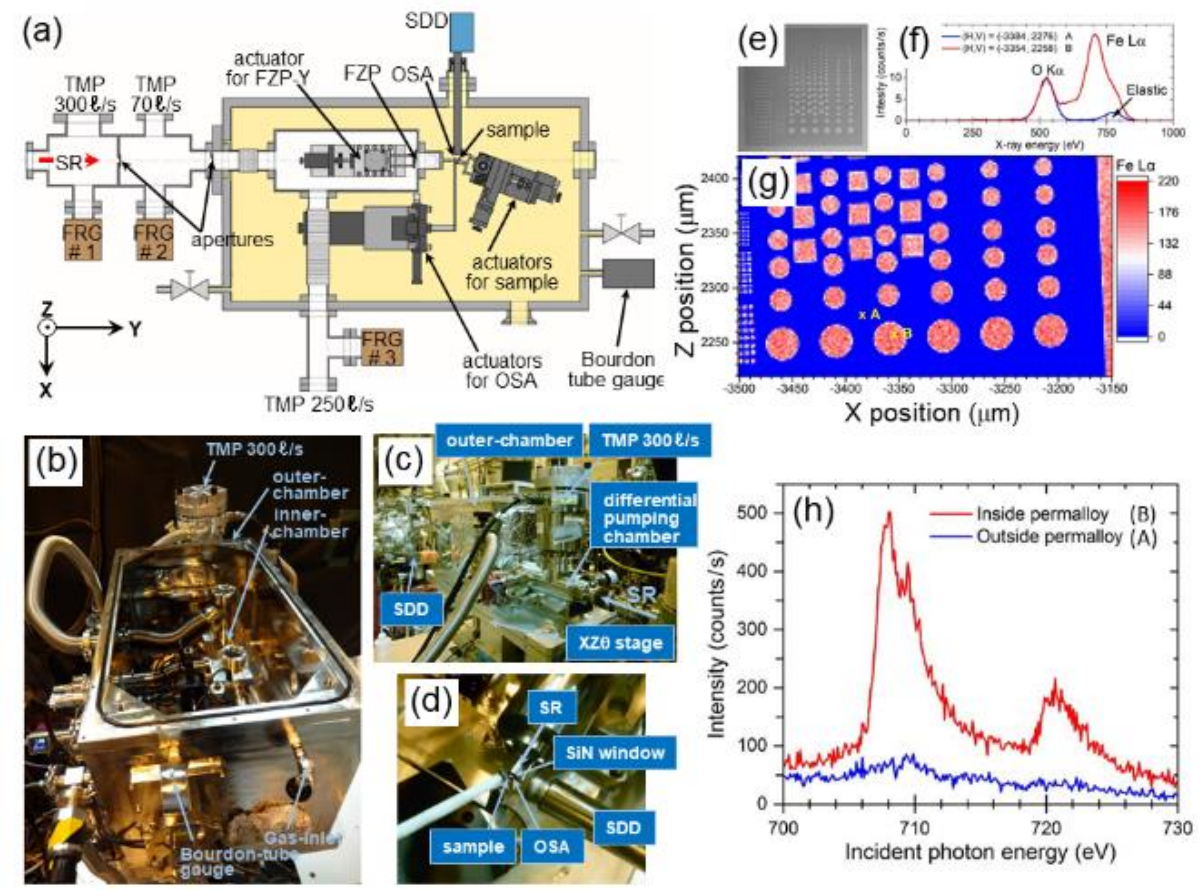

Fig. 2. (a) Schematic-drawing, top view, of the scanning SX spectromicroscope, where TMP is the turbo-molecular pump, FZP is the Fresnel zone plate, OSA is the order-sorting aperture, and SDD is the silicon drift detector. Photographs of the apparatus viewed (b) from downstream, (c) from upstream, and (d) around the sample. (e) Photograph of the permalloy micro-dot patterns fabricated on the Si substrate taken with a metallurgical microscope. (f) SX-induced fluorescence spectra recorded inside (red curve, point B) and outside the micro-dot (blue curve, point A). Points A and B are marked in (g). (g) Element-specific two-dimensional mapping of permalloy micro-dot measured by counting the number of Fe Lα X-rays. (h) Micro-XAFS recorded inside (red curve, point B) and outside the micro-dot (blue curve, point A) by sweeping the SX-beam energy across the Fe $L_{2,3}$-edges.

During the commissioning of the scanning SX spectromicroscope in FY2018, we simultaneously initiated microspectroscopic studies on various advanced materials. Since the end of FY2018, another scanning spectromicroscope with a spatial resolution less than 30 nm has been under development. Its commissioning will start in FY2020. Consequently, more than 50% of the total user time of BL17SU is now devoted to microspectroscopic studies.

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References:

[1] F.Z.Guo, T.Muro, T.Matsushita, T.Wakiya, H.Ohashi, Y.Senba, T.Kinoshita, K.Kobayashi, Y.Saitoh, T.Koshikawa, T.Yasue, M.Oura, T.Takeuchi, and S.Shin, Rev. Sci. Instrum. **78**, 066107 (2007).

[2] T.Ohkochi, H.Osawa, A.Yamaguchi, H.Fujiwara, and M.Oura, Jpn. J. Appl. Phys. **58**, 118001 (2019).

[3] M.Oura, T.Ishihara, H.Osawa, H.Yamane, T.Hatsui, and T.Ishikawa, J. Synchrotron Rad. **27**, 664-674 (2020).