BL25SU
Soft X-ray Spectroscopy of Solid

1. Introduction

BL25SU is dedicated to soft X-ray spectroscopic studies on the electronic and magnetic states and the surface structures of solids. After a major upgrade in FY2014, the beamline now has two branch lines. The A-branch supports high-energy resolution measurements, while the B-branch is optimized for nano-focused beams with a small-angle divergence [1–3]. In FY2020, owing to a problem in the twin helical undulators, the circular polarization switching system was not available. To actualize X-ray magnetic circular dichroism (XMCD) experiments under this condition, we developed software to enable static circular polarization measurement for the XMCD apparatus.

In FY2020, (1) a spherical grid composed of numerous cylindrical microholes was developed in the A-branch second (retarding field analyzer: RFA) station to improve the energy resolution. (2) The focusing mirror with small-figure errors was installed in the A-branch third (microbeam angle-resolved photoemission spectroscopy: ARPES) station to improve the focusing beam profiles in the vertical direction. (3) A high-precision manipulator was installed in the B-branch second (electromagnet-type XMCD spectroscopy) station to highly reproduce the sample position. (4) Finally, a sample-heating system was developed in the B-branch third (nano-XMCD) station. The current status of each beamline station is described in detail in the next section.

2. Status of the experimental apparatuses

2-1. Two-dimensional photoelectron spectroscopy (A-branch first station)

The apparatus has an analyzer, which can measure the wide-angle distribution of photoelectrons. Using this apparatus, unique measurements such as surface-sensitive photoelectron holography, atomic orbital analysis by circularly polarized resonance photoelectron diffraction, and microscopic photoelectron diffraction have been developed. In FY 2021, the apparatus will be discontinued and its technologies and expertise will be transferred to the RFA (introduced next).

2-2. Retarding field analyzer (RFA) (A-branch second station)

Photoelectron diffraction (PED) or photoelectron holography allows nonperiodic local structures with multiple chemical states to be studied [4]. These methods require wide-range photoelectron angular distribution patterns measured with a sufficiently high energy resolution to resolve core level chemical shifts. For such measurements, a display-type RFA with a high resolving power ($E/\Delta E$) of 1100 was developed [5]. The retarding grid was a wire mesh, but simulations predicted that the energy resolution can be further improved by a retarding grid composed of cylindrical holes [5]. Therefore, in FY2020, we developed a spherical grid composed of numerous cylindrical microholes to be used for the retarding grid. The diameter and depth of each cylinder are 50 μm and 80 μm, respectively. We installed this spherical grid in the RFA and evaluated it using the synchrotron radiation. As a result, the energy resolution was experimentally estimated to be

$E/\Delta E$ = 2000 [6], which is almost two times higher than that of the previous RFA with a wire mesh retarder. The improved RFA will be used for public use from FY2021.

2-3. Microbeam angle-resolved photoemission spectroscopy (ARPES) (A-branch third station)

The ability of selecting flatly cleaved areas from poorly cleaved sample surfaces is valuable for ARPES [7]. To enhance this capability, a micro-ARPES end station equipped with a DA30 analyzer of Scienta Omicron and a microfocusing mirror were developed [8,9]. The typical focusing size is 0.4 μm (vertical) × 4 μm (horizontal). The beam spot size on the sample surface is 5 μm even at a glancing angle of 5 degrees. This end station has been opened for public use since FY2018.

When the focusing mirror was first installed in this end station in FY2018, the measured vertical beam profile at the focal point of the beam with a photon energy of 1000 eV showed small peak structures in the tail regions of the main peak [8]. This was caused by some figure errors of the mirror surface. In FY2020, we replaced the mirror with a new one with smaller figure errors. The measured vertical beam profile of the new focusing mirror showed no recognizable peak structures in the tail regions and was much improved compared with that of the previous focusing mirror. This focusing mirror has been opened for public use since FY2020.

2-4. Electromagnet-type XMCD spectroscopy (B-branch second station)

This apparatus can selectively use low-temperature, high-temperature, and voltage/current application measurements. Combining these methods with total electron yield (TEY), partial fluorescence yield (PFY), and transmission modes allows for diverse experimental environments. In FY2020, a high-precision manipulator with micrometer-order positional reproducibility was introduced to cope with the measurement of microscopically fabricated samples. The travel speed is the same as before, with a minimum translation distance of 0.2 μm for translational drive and a minimum angle of 0.001° for rotational drive.

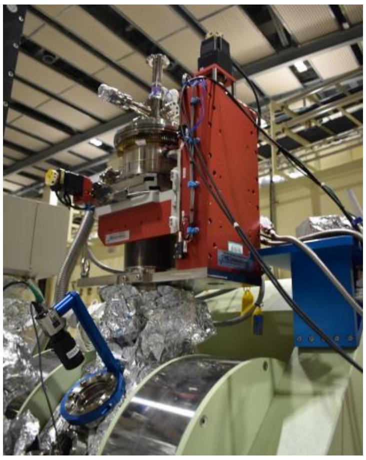

Fig. 1. Manipulator of the electromagnet-type XMCD apparatus at the B-branch of BL25SU.

2-5. Scanning soft X-ray microscope (nano-XMCD) (B-branch third station)

A scanning soft X-ray microscope was developed with the support of the Elements Strategy Initiative Center for Magnetic Materials (ESICMM) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan [10,11]. This unique apparatus features nanoscale XMCD imaging under high magnetic fields up to 8 T. In FY2020, we tested a sample-heating system (Fig. 2) and succeeded in the magnetic imaging of permanent magnets at a sample temperature of 200°C under high magnetic field.

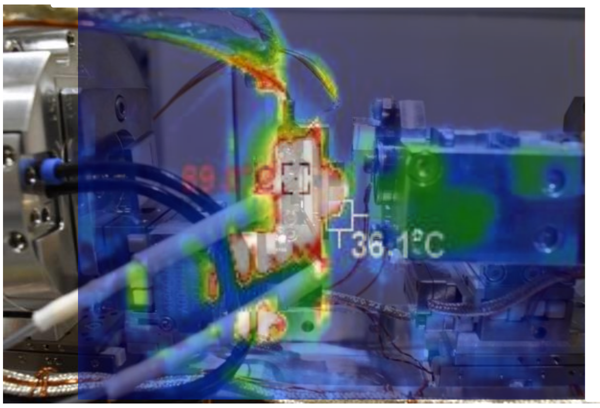

Fig. 2. High-temperature sample stage with overlaid thermal camera image for nano-XMCD at the B-branch of BL25SU.

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