1. Status of Beamline BL07LSU at SPring-8

The University-of-Tokyo high-brilliance synchrotron soft X-ray outstation beamline BL07LSU at SPring-8 has been maintained by the permanent staff members with adjuncts for user operations. The scientific aim of the beamline is to promote advanced spectroscopy for solid state and soft (including bio-) materials. There are three regular endstations for ambient pressure X-ray photoelectron spectroscopy, 3D-scanning photoelectron microscope (3D nano-ESCA) and high-resolution soft X-ray emission spectroscopy (HORNET) that are open for users. There is also a free port station for users who bring in their own experimental apparatus.

The beamline BL07LSU is equipped with a segmented cross-type undulator. Circularly and linearly polarized soft X-rays can be used in user experiments at full energy range (250 – 2000 eV). By using phase shifters between the neighboring undulator segments, polarization of the soft X-ray beam is regulated continuously and the switching frequency can be tuned up to 13 Hz. At the end-stations, various scientific experiments were carried out by both the laboratory staffs and users with applications of G-type (general), S-type (special), or P-type (priority). A user group of the S-type spends the long-term beamtime to pursue the challenging issues in synchrotron radiation research. A user team of the P-type proceeds an experiment mainly for developing technologies of beamline and end-station for the next generation light source.

It should be mentioned that the coronavirus (COVID-19) pandemic has continuously been a serious issue in 2021. Safety and health of users at the beamline have been taken care during their beamtime experiment at the end-station.

Status of the individual end-stations are briefly described below.

(1) Ambient-pressure X-ray photoelectron spectroscopy (AP-XPS)

AP-XPS station is aimed mainly for *operando* observations of catalytic reactions at the gas/solid interface. The AP-XPS system is equipped with a differentially pumped electron analyzer (SPECS, PHOIBOS 150 NAP) and an ambient pressure gas cell. XPS measurements can be performed both under ultrahigh vacuum and in near-ambient gas pressure up to 100 mbar. Reactant and product molecules of a catalytic reaction are monitored by mass spectrometer and, simultaneously, chemical states of the reaction intermediates at a surface can be examined by AP-XPS.

In 2021, a variety of research projects was conducted at the AP-XPS station, for example, *operando* observations of hydrogen permeations at metal alloys and of catalytic reactions at model surfaces.

(2) 3D-scanning photoelectron microscope (3D-nanoESCA)

3D-nanoESCA can be used for sub-100 nm range microscopic 2D mapping and depth profile of the chemical structure of functional materials and devices. In 2021, visible light responsive Al-doped $SrTiO_3$ photocatalytic particles and $BaTaO_2N$ photocatalytic particles, developed by Prof. Hisatomi group at Shinshu University, were measured to capture changes in band alignment by single-particle measurements. A core-level shift reflecting the Fermi energy shift caused by a change in catalytic efficiency was successfully monitored. As a demonstration study of the next-generation operando spectromicroscopy system with a piezoelectric four-tip unit, the potential distribution of single-layer CVD graphene on a p^+-Si/SiO_2 substrate was measured under an electric field applied to the probe, where the probe was fixed to a sample holder. As a result, a clear peak shift was detected only in the vicinity of the tip contact, suggesting a potential drop at the domain boundary.

(3) Ultra high-resolution soft X-ray emission spectroscopy (HORNET)

The station is dedicated for soft X-ray emission (or resonant inelastic X-ray scattering: RIXS) spectroscopy measurements with high-resolution ($E/\Delta E > 10{,}000$) and under various environmental conditions (gas, liquid, and solid).

In the beginning of this term, new soft X-ray CCD detector with ultra-high spatial resolution (< 5mm) for next-generation synchrotron radiation (NanoTerasu) was introduced. Although the total resolution was only slightly improved due to the limited beam size on the sample, it is expected that the resolution at NanoTerasu will be approximately three times higher than the current improvement.

HORNET station was used for studies on temperature-dependent water hydrogen-bond behavior in electrolyte membranes, spin polarization in half metals by RIXS-MCD, demonstration of soft x-ray inelastic diffraction, CO_2 sorption process in PDMS for silicon materials. Two abroad applications (RIXS-MCD of CrX_3 and dd excitation observation of Fe-Co spinel materials) were conducted remotely. As part of the New Academic Field Research, outstanding results were obtained in the study of a water molecule confined in C_{60}, and ionization of ultrafine water upon adsorption to hydrophilic and hydrophobic surfaces.

(4) Soft X-ray imaging (Free-port station)

This year, we developed a new soft X-ray ptychography system at the free-port station. The reflecting surface of the Wolter mirror, which was covered with Au, enables seamless

ptychographic measurements in a wide energy range of soft X-rays at BL07LSU.

A soft X-ray ptychographic system with a total-reflection Wolter mirror achieved a resolution of approximately 50 nm in a test chart evaluation. We have also shown that it is possible to visualize the microstructure of a mammalian cell over a wide photon energy range without chromatic aberration. Furthermore, taking advantage of the long working distance of the optical system, stereo imaging with a large rotation angle was also attempted to measure the cell sample. Ptychographic imaging with a pink beam from the undulator was also possible.

The soft X-ray ptychography system based on the Wolter mirror optics is expected to be highly effective for investigating thick samples with complex three-dimensional structures and chemical compositions.