1. Status of Beamline BL07LSU at SPring-8

As described in the Preface, the University-of-Tokyo high-brilliance synchrotron soft X-ray outstation beamline BL07LSU at SPring-8 was maintained until the first half of 2022 by the permanent staff members with adjuncts for user operations for the purpose of promoting advanced spectroscopy of solid and soft (including bio-) materials, and various joint-research experiments were conducted by both staff and users in the G-type (general), S-type (special), and P-type (priority) applications. Here, the activities at the ambient pressure X-ray photoemission spectroscopy, soft X-ray spectroscopic imaging, 3D-scanning photoelectron microscope (3D nano-ESCA) and high-resolution soft X-ray emission spectroscopy (HORNET) stations until the first half of 2022, and development of soft X-ray spectroscopic imaging station through collaboration with RIKEN from the second half of 2022, are briefly described below.

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

AP-XPS station is aimed for *operando* chemical analysis during catalytic reactions at the gas/solid interface to unveil the reaction mechanism. 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 gas pressure up to 100 mbar. Reactant and product molecules of a catalytic reaction are monitored by mass spectroscopy and, simultaneously, chemical states of the reaction intermediates at a surface are directly examined by AP-XPS.

A variety of research projects has been conducted at the AP-XPS station. In 2022, issues at the atomic sheet were focused and the functionalities, such as sensing and reaction, were investigated.

(2) Soft X-ray imaging

We developed a new soft X-ray microscopy system named CARROT (Coherent Achromatic Rotational Reflective Optics for pTychography) in 2021. CARROT can realize high-resolution and high-sensitivity soft X-ray imaging by utilizing the coherent property of BL07LSU. The CARROT system with a total reflection Wolter mirror achieved a resolution of about 50 nm in a test chart evaluation. We have also shown that it is possible to visualize the magnetic domain structures of an ultrathin metal film using X-ray magnetic circular dichroism.

We also demonstrate the potential of applying CARROT to cell biology by measuring drug-treated mammalian cells. Various changes in the cell body were observed using soft X-ray imaging at 50 nm resolution.

(3) 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 2022, two significant experiments were performed. 2D electronic mappings of P-type and N-type alloyed thermoelectric materials (FAST) composed of safe, durable, and inexpensive Fe, Al, and Si elements developed by Dr. Takagiwa were obtained and compared and the p-type sample showed a peak shift to the lower binding energy for both Fe 2p, Al 2p, and Si 2p, and the shift of the chemical potential was quantitatively determined. The shape difference was also detected in the valence spectra, suggesting that the intra-gap position has an effect. Dr. Zhang obtained Ti 2p 2D photoelectron images of TiO_2 (anatase) particles with different facet surfaces, showing the existence of a space-charge layer of about 40 nm between the interfaces of the two facets. Photogenerated electrons and holes are expected to accumulate in the (101) and (001) facets, respectively, enhancing the photocatalytic activity.

(4) 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 2022, 11 studies were performed. Among them, the studies by Profs. Y. Higaki and S. Horiuchi, and Dr. Y. Hashikawa were performed under the Grant-in-Aid for Scientific Research New Science Project and targeted water at various interfaces; in concentrated polymer, within porous crystals, and encapsulated in fullerenes. Other works include secondary battery electrodes and catalysts for water electrolysis, aiming for the improved performance of them. Dr. Fujino et al. explored d/π-conjugated molecules in water and detected changes in the Ni 3d electronic states due to altered intermolecular interactions in film states upon heating. All these studies are quite advanced for operando RIXS measurements, and they will collectively advance our technique and suggest the possibility of practical applications in the future experiments at NanoTerasu.