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. A scientific aim of the beamline is to promote advanced spectroscopy for solid state and soft (including bio) materials. There are currently three regular endstations: time-resolved soft X-ray spectroscopy (TR-SX spectroscopy), 3D-scanning photoelectron microscope (3D nano-ESCA) and ultrahigh resolution soft X-ray emission spectroscopy (HORNET), along with a free port station for users who bring their own experimental apparatus.

The beamline BL07LSU is equipped with a segmented cross-type undulator. In 2016, polarization control of soft X-rays was performed by using phase shifter among the undulator segments. Circularly and linearly polarized soft X-rays at full energy range (250 – 2000 eV) have been available by tuning the permanent magnet type phase shifter. Moreover, fast circular polarization switching at a rate of 10 Hz and 13 Hz has been achieved around four incident photon energies, 440 eV, 573 eV, 639 eV and 709 eV.

At the beamline endstations, various scientific researches were carried out by both the laboratory staffs and general users (G-type application). Below are brief introduction of recent activities at each station.

(1) Time-Resolved soft X-ray spectroscopy station (TR-SX spectroscopy)

The station is to perform time-resolved photoemission spectroscopy experiments by synchronizing the high-brilliant soft x-ray and the ultra-short laser pulses. A new type of the electron spectrometer, the two-dimensional angle-resolved time-of-flight (ARTOF) analyzer, has been used for the efficient time-resolved measurements and a low temperature manipulator (15 K) is installed for extensive experiments for users. In 2016, high repetition rate (208 kHz) laser was installed and successfully synchronized with synchrotron soft X-rays. As a result, about 200 times higher detection efficiency of the time-resolved photoemission was realized compared with the previous experiments using 1 kHz repetition rate laser. The new system was provided for general user experiments from the 2016B cycle.

One of the most significant results in 2016 is the observation of change in the lifetime of photo carriers on the WSe_2 surface by electron or hole doping induced by an adsorbed atom or molecule. Carrier dynamics of high quality graphene was also studied for future applications as a material for terahertz laser devices operated at room

temperature.

Optical response of $SrTiO_3$ in $SrRuO_3/SrTiO_3$ hetero structure highly modulated by the thickness of the $SrRuO_3$ layer was reported. Time resolved photoemission results on a semiconductor surface at high temperature (880 ^oC) was realized by a technical development of the beamline.

(2) 3D-scanning photoelectron microscope (3D nano-ESCA)

An originally developed system "3D-nano-ESCA", which is a combination of soft X-ray scanning photoelectron emission microscopy (SPEM) and an angle-resolved electron analyzer, is installed in this station. Users can use 3D-nano-ESCA for sub-100 nm range microscopic 2D mapping and depth profile of the chemical structure of functional materials and devices.

In 2016, operando nano-spectroscopy was performed for GaN-HEMT devices as collaboration with Sumitomo Electric Industries, Ltd. and Tohoku University as part of the NEDO academic-industrial alliance project. Almost 10 V shift of the Ga 3d level observed by application of a voltage between the gate and the drain of the transistor was successfully explained by the presence of interface state with a doping level of 10^{13} cm^{-2} at the AlGaN/GaN interface, which was found to be the origin of the current collapse effects in GaN-HEMT. Moreover, reduction of the interface state was observed as a reduction of the Ga 3d peak shift by an epitaxial growth of a 3 nm SiN capping layer on the GaN surface. Another operando experiments were performed on a cathode material $LiNi_{0.5}Mn_{1.5}O_4$ of a Li-ion battery as collaboration with AIST. Changes in the local electronic structure of $LiNi_{1.5}Mn_{0.5}O_4$ after charging/discharging were analyzed to elucidate detailed charge redistribution upon Li-ion exertion/insertion.

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

The station is for soft X-ray emission (or resonant inelastic X-ray scattering: RIXS) spectroscopy measurements with ultra high-resolution ($E/\Delta E > 10^4$) and under various environmental conditions (gas, liquid and solid). In 2016, an original position-correction program was developed and successfully installed in the system to realize continuous horizontal rotation of the spectrometer for angle (momentum) resolved experiments without losing scattered soft X-rays. In order to satisfy the increasing needs for humidity controlled experiments new liquid flow-through cell system with precise control of humidity and temperature was also installed. The number of applications to the HORNET station is still increasing. In 2016, 14 user experiments were accepted and performed. 12 applications among them are evenly shared by strongly correlated

materials and catalytic materials. The other two are solution chemistry. Intriguing results were obtained for the analyses of water; one is encapsulated water in polyelectrolyte brushes, and the other is water at the interface of diblock copolymer. In both cases RIXS spectra revealed quite different hydrogen bond structure of water from the bulk, successfully explaining functions of those polymer interfaces such as antifouling property and biocompatibility. As the first application of an angle resolved experiment, the CDW diffraction peak in the elastic part and a dispersive charge excitation band in the inelastic part was observed at O K-edge XAS pre-edge resonant excitation of Bi2223.

(4) Free-port station

The station is equipped with a focusing mirror chamber, and users can connect their own experimental chambers. In 2016, the following experiments were performed: time resolved soft X-ray diffraction of $La_{0.33}Sr_{0.67}FeO_3$ thin film; time resolved XMCD of magnetic thin films such as FePt or CoPt; resonant magneto-optical Kerr effects using polarization switching of the undulator; ambient-pressure X-ray photoemission spectroscopy of an Pd alloy upon H_2 adsorption and humidity dependence of water structure around the surface of diblock copolymer; two-dimensional photoemission spectroscopy with a display-type ellipsoidal mesh analyzer (DELMA) to electronically distinguish two different iron sites in Fe_3O_4 and to observe strong anisotropy in O K-edge resonant photoemission of Bi2212 and to elucidate two boron sites in B-doped diamond.

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