

Current Activities of Research and Education on BL-5 (FY2023)

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We present an overview of our recent research and educational activities on beamline 5 (BL5) in the fiscal year 2023. Our beamline has two experimental stations in a tandem way. The first station is equipped with an angle-resolved photoemission spectrometer (ARPES), a low energy electron diffraction (LEED) apparatus and an X-ray source. The hemispherical analyzer of ARPES spectrometer (HA54, VSW) has a mean radius of 50 mm and is mounted on a twin axis goniometer in ultra-high vacuum chamber. Using this goniometer, one can perform ARPES and photoelectron diffraction (PED) measurements. It is also possible to perform resonant photoemission spectroscopy (RPES) measurements by using photon energy tunability of synchrotron radiation with X-ray absorption spectroscopy (XAS) measurement. With the X-ray source (XR2E2, FISOONS), we can perform an X-ray photoelectron spectroscopy (XPS) measurement for the chemical state analysis and the PED. At the second station, we have installed a photoelectron emission microscope (PEEM, 'PEEM III', Elmitec). PEEM provides a magnified image of lateral intensity distribution of photo-emitted electrons from a sample surface. The spatial resolutions are several ten nanometers with Hg lamp and a few micrometers with synchrotron radiation. The sample is transferred between the ARPES and the PEEM chamber in-situ, and one can perform measurements at both stations for the same sample.

In the recent researches on BL-5, we have studied the electronic structure of potassium doped aromatic molecule (K_x picene) [1], iron-based superconductor ($FeSe_xTe_{1-x}$) [2], transition metal di-oxide films such as VO_2 thin films which exhibits a first-order metal-to-insulator transition at 340 K [3], CrO_2 thin films which are known as a half-metallic material [4], TaO_2 film which is stabilized with a new technique developed in our group [5], and phase-separated TiO_2 - VO_2 films on mica substrates. We have also studied the electronic structures of a high-quality boron-doped diamond film which shows a signature of the highest superconducting transition temperature of 25 K [6] and a high quality single crystal of $YbFe_2O_4$ which is one of multiferroic materials [7], by utilizing RPES at B K - and Fe $M_{2,3}$ - edges, respectively. In addition, we have studied the sp^3 content in diamond-like carbon films by using photoemission spectroscopy in order to optimize the conditions to produce Q-carbon (quenched carbon) which is a newly discovered amorphous phase of carbon with several exotic properties [8]. In the last few years, we have performed PEEM and TEY measurements at BL5 in HiSOR for (1) a B-doped carbon nano wall film on a Si substrate, (2) a micro-droplet of solidified L-boronophenylalanine (L-BPA) on a Si substrate and (3) cancer cells dosed with L-BPA in order to investigate microscopic chemical states of trace B atoms in them from fine structures in local- and wide-area-XAS spectra near B K -edge and to visualize B distributions on their surfaces. For this kind of measurements with PEEM, we have developed a new auto-measurement system where we can obtain a serial PEEM images with excitation x-ray energies for a certain energy range with a fixed energy step.

Recently, we have prepared an auto-measurement system and an X-ray focusing capillary lens for photoemission holography (PEH) measurements. PEH is a method that has been greatly developed in Japan in recent years as a measurement method for elucidating the local structure of materials with an atomic resolution [9]. In particular, various results have been reported in the study of the three-dimensional atomic configurational structure around the dopants in crystals [10]. However, the opportunity to use state-of-the-art apparatuses (for example, DA30 analyzer and RFA of BL25SU at SPring-8) are limited. Although our photoelectron energy analyzer is an old model and it is difficult to separate and observe small shifts in core levels because of the energy resolution of 1-2 eV of the system, we expect that our apparatus will be used for preliminary experiments on undoped materials prior to experiments for doped samples using state-of-

the-art systems. It can also be used for educational purposes such as experiencing photoelectron holography experiments and learning the analysis methods.

We have used the BL-5 for education activity as well, for example, practical education for undergraduate students of Okayama University. The students have an opportunity to study the synchrotron radiation mechanism and to experience XPS measurement which is very useful for the surface science research. We accepted more than 100 students from 2006 to 2012. From 2014, we have started to join the practical lecture for experiments using the beamline end stations in HiSOR for both graduate school students of Hiroshima and Okayama Universities. In 2018, we have had a new project for education under a Japan-Asia youth exchange program in science supported by Japan Science and Technology Agency (JST), “Sakura Exchange Program in Science”. We have accepted six students from Changchun University of Science and Technology in China.

REFERENCES

1. H. Okazaki *et al.*, *Phys. Rev* **82**, pp. 195114 (5 pages) (2010).
2. Y. Yoshida *et al.*, *J. Phys. Soc. Jpn* **78**, pp. 034708 (4 pages) (2009).
3. K. Saeki *et al.*, *Phys. Rev* **80**, pp. 125406 (5 pages) (2009).
4. Y. Muraoka *et al.*, *MRS Proceedings* **1406** (2012).
5. Y. Muraoka *et al.*, *Thin Solid Films* **599**, pp. 125-132 (2016).
6. H. Okazaki *et al.*, *Appl. Phys. Lett* **106**, pp. 052601 (5 pages) (2015).
7. K. Fujiwara *et al.*, *Trans. Mater. Res. Soc. Jpn.* **41**, pp. 139-142 (2016).
8. H. Yoshinaka *et al.*, *Carbon*.**167**, pp. 504-511 (2020).
9. T. Matsushita *et al.* *Europhys. Lett.* **71**, 597 (2005). *Phys. Status Solidi B* **255**, 1800091 (6 pages) (2018).
10. K. Hayashi, T. Matsushita, *SPring-8 Research Frontiers* **2020**, pp. 12 -15 (2021).