Status of spin- and angle-resolved photoelectron spectroscopy with laser light at Laser and Synchrotron Research Laboratory

Spin- and angle-resolved photoelectron spectroscopy (SARPES) is a powerful technique to investigate the spin-dependent electronic states in solids. For example, we will look at the exchange splitting of ferromagnetic materials. Also, recently, we have been intensively studied strongly spin-orbit coupled materials, such as Rashba spin-split systems and topological insulators. We developed a SARPES apparatus with a vacuum-ultraviolet laser at Laser and Synchrotron Research Laboratory in the Institute for Solid State Physics, named LOBSTER (Laser-Optics-Based Spin-vecTor Experimental Research) machine. The LOBSTER machine is utilized to obtain precise information on spin-dependent electronic structures near the Fermi level in solids. We started a project to construct the LOBSTER machine from FY 2014 and joint researches at this station have started from FY 2015.

Figure 1 represents an overview of the LOBSTER machine. The apparatus consists of an analysis chamber, a sample-bank chamber connected to a load-lock chamber, and a molecular beam epitaxy (MBE) chamber, which are kept in an ultra-high vacuum (UHV) environment and are connected with

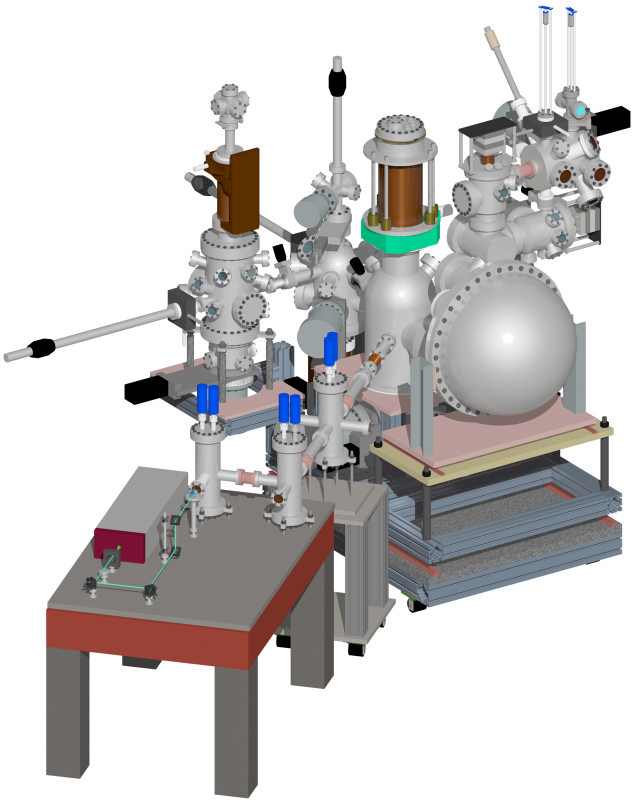

Fig. 1. Overview of the LOBSTER machine developed at the Laser and Synchrotron Research Laboratory at the Institute for Solid State Physics [1].

each other via UHV gate valves. The hemispherical electron analyzer is a custom-made ScientaOmicron DA30-L, modified to attach the very-low-energy-electron-diffraction type spin detectors. The electrons are excited by 6.994-eV photons, yielded by 6th harmonic of a Nd:YVO_4 quasi-continuous wave laser with repetition rate of 120 MHz. A helium discharge lamp (VG Scienta, VUV5000) is also available as a photon source. At the MBE chamber, samples can be heated by a direct current heating or electron bombardment. The surface evaluating and preparing instruments, such as evaporators, low energy electron diffraction, reflection high energy electron diffraction, sputter-gun and quartz microbalance, can be installed. At the carousel chamber, 16 samples can be stocked in the UHV environment.

Figure 2 shows Fermi edges taken from a gold (Au) thick film recorded with the ARPES and SARPES modes. The sample temperature was set to 9 K. The spectrum was taken with the analyzer pass energies of 1 and 2 eV for ARPES and SARPES modes, respectively. The sizes of an entrance slit and an exit aperture were set to 0.2 mm and 0.2 × 0.5 mm^2, respectively. The spectra were fitted with the Fermi distribution function. From the fitting, the energy resolutions were estimated to be 600 μeV for the ARPES mode and 1.7 meV for the SARPES mode. The new spectrometer can provide high-resolution spin-integrated and spin-resolved photoemission spectra in various types of solids, such as strongly correlated materials.

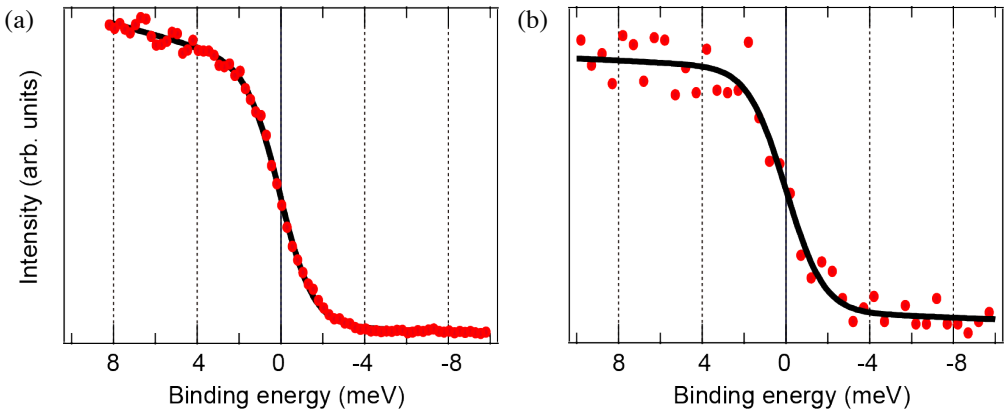

Fig. 2 The Fermi edges (circle plots) of a gold thick film recorded in (a) ARPES mode and (b) SARPES mode. Solid curves represent fitting results with the Fermi–Dirac distribution function and a polynomial background [1].

Reference

[1] K. Yaji, A. Harasawa, K. Kuroda, S. Toyohisa, M. Nakayama, Y. Ishida, A. Fukushima, S. Watanabe, C.-T. Chen, F. Komori and S. Shin, Rev. Sci. Instrum. **87**, 053111 (2016).