Development of bulk-sensitive spin-resolved ultrahigh-resolution photoemission spectrometer

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Angle-resolved photoemission spectroscopy (ARPES) is known as a powerful technique to investigate the fine electronic structure relevant to the intriguing physical phenomena in solids such as superconductivity, heavy fermions, metal-insulator transition, and so on. This technique, yet, has suffered from two inherent problems originating in the principle of PES itself, namely, (1) the high surface sensitivity, and (2) the difficulty in resolving the spin polarization of electrons. To overcome those problems, we have constructed an ultrahigh resolution photoemission spectrometer equipped with a newly developed xenon-plasma discharge lamp and a mini-Mott detector.

Figure 1 shows the xenon plasma discharge lamp that provides several intense resonance lines from xenon plasma in the energy range of 8-11 eV, which is enough to achieve high bulk-sensitivity.[1] The energy width of radiation from the lamp is intrinsically very narrow owing to small Doppler broadening due to the high mass of the xenon atom, and low pressure operation of the discharging plasma reducing the self absorption effect. Combined with a large hemispherical energy analyzer and a spherical concaved grating, we achieved high energy resolution less than 1 meV as a total system in the spin-integrated mode. The photoelectron intensity excited by the xenon lamp is bigger than that of the ordinary helium lamps by 1-2 order of magnitude. This is quite useful to compensate the low efficiency in the case of spin-resolved photoemission.

We have developed a compact Mott spin detector operating at 25 kV and adapted it to the large hemispherical electron energy analyzer through an electron deflector lens. We have redesigned the analyzer and mounted the entrance of the deflector lens at a location close to the ϕ40mm microchannel plate (MCP). This enables the observation of electron energy and momentum by the MCP with comparable quality to modern electron analyzers, simultaneously to the electron spin measurement by the Mott detector.

Figure 2 shows spin-resolved ARPES spectra of the Shockley state of the Sb(111) surface, which is known as a typical case where the spin of the electron band is polarized along the plane due to the surface Rashba effect.[2] The spectra are recorded by four channeltrons in the Mott detector to measure the electron spin polarization of two orthogonal directions, that is, in-plane and out-of plane to the (111) surface. As clearly seen, a pronounced peak at 0.1 eV in the up-spin spectrum of the in-plane direction is considerably reduced in the down-spin spectrum, in sharp contrast to the perfect superimposing of the up- and down-spin spectra of the out-of-plane direction. This result is in good agreement with the surface Rashba effect and unambiguously shows the spin-resolving performance of the developed photoemission system.

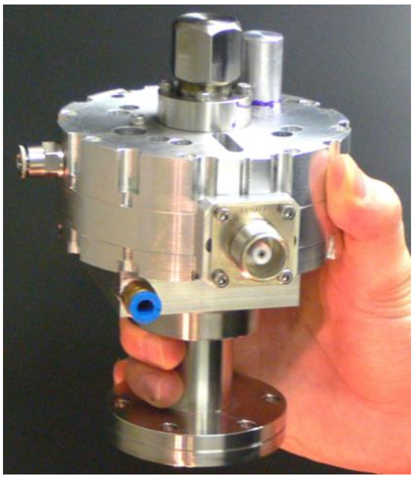

Fig. 1. Xenon-plasma discharge lamp

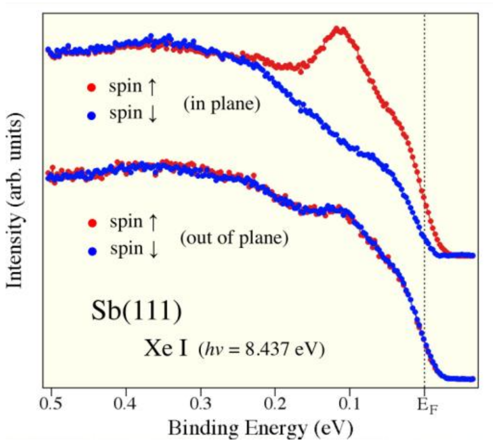

Fig. 2. Spin-resolved ARPES spectra of Sb(111)

[1] S. Souma *et al*., RSI, **78** (2007) 123104.
[2] K. Sugawara *et al*., PRL, **96** (2006) 046411.