Spin-split electronic structures of non-magnetic surfaces observed by high-efficiency spin- and angle-resolved photoelectron spectroscopy (SARPES)

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We have developed a high-efficiency electron-spin polarimeter based on Very-Low-Energy Electron Diffraction (VLEED) with the efficiency of 1.9×10^{-2}, which is approximately 100 times higher than a conventional Mott detector[1]. Combined with high-resolution hemispherical energy analyzer, we have observed SARPES spectra of so-called Rashba system and quantum spin-Hall system with high energy- and angular-resolution (ΔE～±50 meV and $\Delta\theta$ ～0.7°).

We have investigated the electronic structure of BiAg($\sqrt{3}\times\sqrt{3}$) grown on Ag(111) quantum well film. The surface states (SS) are spin-split by the Rashba effect and hybridized with quantum well states (QWS) in Ag film[2]. The energy dispersion of the spin-split SS are modified by the hybridization. In SARPES spectra, we have found that the interaction between QWS and SS are significantly spin-dependent; the QWS with spin anti-parallel to the SS show free electron like energy dispersion, while those parallel to the SS form gaps. The results are well described by the band hybridization model including spin-polarization of QWS.

We have also investigated spin-polarization of the surface electronic structures of $Bi_{1-x}Sb_x$(111), which is known to be a three-dimensional topological insulator, where the surface states, i.e. the edge states of three-dimensional materials are metallic and carrying spin current at the surface, while the bulk states are insulating. We observed that the five surface states crossing the Fermi level and determined the spin-polarizations of all these states. This result is the direct evidence for the quantum spin-Hall effect in this material and gives the answer for the contradiction between the theoretical predictions[3]

[1] T. Okuda et al., Rev Sci. Instrum. 79, 123117 (2008).
[2] K. He et al., Phys. Rev. Lett. 101, 107604 (2008).
[3] A. Nishide et al., Phys. Rev. Lett. submitted.