ELECTRONIC AND SPIN STRUCTURES OF SOLIDS BY MEANS OF SYNCHROTRON RADIATION PHOTOEMISSION

Masaki Taniguchi [1,2*]

[1] *Hiroshima Synchrotron Radiation Center, Hiroshima University, Kagamiyama 2–313, Higashi-Hiroshima 739–0046, Japan*

[2] *Graduate School of Science, Hiroshima University, Kagamiyama 1-3-1, Higashi-Hiroshima, 739–8526, Japan*

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* *e-mail*: taniguch@hiroshima-u.ac.jp

Synchrotron radiation photoemission is a powerful tool to directly clarify the electronic and spin structures of solids that are directly related to the physical properties. Angle-resolved photoemission spectroscopy (ARPES) with very high energy- and momentum-resolutions was successfully applied to investigations of many body interactions in single crystalline metals and unconventional superconductors. In addition, spin- and angle-resolved photoemission spectroscopy (SARPES), which can directly determine the spin-polarized band dispersions, was intensively employed for investigations on peculiar spin texture of surface states due to the spin-orbit interaction, such as surface Rashba spin splitting states or helical spin states of topological insulators.

In this talk, I will discuss electron-boson couplings in ruthenate superconductor Sr_2RuO_4 investigated by ARPES [1], and spin-polarized Dirac-cone like surface state with d character at W(110) by SARPES [2]. I also report high performance SARPES apparatus developed at Hiroshima Synchrotron Radiation Center [3].

The Sr_2RuO_4 has attracted considerable attentions for several reasons such as unconventional superconductivity, a structural similarity to the cuprates, and a two-dimensional Fermi liquid behavior in the normal states. Furthermore, the multiband electronic structure is essential feature of Sr_2RuO_4, which is contrast to the cuprates possessing a single band.

In order to resolve the complex electronic structure of Sr_2RuO_4, it is indispensable to utilize the linear polarization of the synchrotron radiation. By changing the polarization direction of the incident light, it is possible not only to identify the wave function parity of the initial states with respect to a mirror plane of single crystals [4] but also to select the observable electronic states. Namely, the even- (odd-) symmetry initial states are only observable with p- (s-) polarization because of the dipole selection rule.

We have observed the fine quasiparticle dispersions of Sr_2RuO_4 using the high-resolution ARPES with tunable polarization. We found strong hybridization between the in-plane and out-of-plane quasiparticles via the Coulomb and spin-orbit interactions [1]. This effect enhances the quasiparticle mass due to the inflow of out-of-plane quasiparticles into the two-dimensional Fermi surface sheet, where the quasiparticles are further subjected to the multiple electron-boson couplings. The result suggests that the spin-triplet p-wave superconductivity of Sr_2RuO_4 is phonon mediated.

Topological insulators and Rashba systems with spin-split surface states induced by strong spin-orbit interaction have attracted a great attention for the dissipationless spin current transport [5]. Such spin split surface states have been intensively studied by ARPES mainly for the surface of sp-electrons systems at heavy metals and topological insulators [6, 7].

A material with d-derived spin-splitting band remains yet to be explored. Possible strong correlation effects among d electrons in topological insulators and Rashba systems could be important scientific issue. We show the first experimental evidence of nearly massless and strongly spin-polarized surface states in a spin-orbit-induced symmetry gap of W(110) [2]. Our SARPES study reveals that the spin polarization is antisymmetric with respect to zone center. The constant-energy cuts of this Dirac-cone-like state are found to be strongly anisotropic, which paves the way to the study of peculiar d-electron based topological properties with anomalous spin textures.

Finally, I report our newly developed highly efficient SARPES apparatus developed at Hiroshima Synchrotron Radiation Center [3]. By utilizing high-efficient spin detector based on very low energy electron diffraction (VLEED) [8] by ferromagnetic target (Fe(001)p1x1-O) as the spin detector and combining it with high-resolution hemispherical analyzers (SCIENTA R4000), high-efficient and high-resolution SARPES experiment has been realized. Especially, the present machine was designed to improve the performance of the first prototype machine, and resolution of 7.5 meV in energy and $\pm 0.18^\circ$ in angle has been achieved with spin resolution [3]. One can observe both in-plane and out-of-plane spin components by a 90° electron deflector. In addition, the two-dimensional electron detector for conventional spin-integrated ARPES measurement can realize quick and precise observation of the electronic band structure and Fermi surfaces. Therefore, one can find the specific electronic structure where is interested in to observe the spin structure quite efficiently and measure the spin structure with high-resolution.

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