【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : Electronic states of novel functional materials studied by ultrahigh-resolution three-dimensional spin- and angle-resolved photoemission spectroscopy

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Research Area : Mathematical and Physical Sciences
Keyword : spintronics, photoemission spectroscopy, topological insulator, surface

【Purpose and Background of the Research】

Recent discovery of novel functional materials such as topological insulators and GMR compounds has accelerated intensive researches on the basic sciences and device applications. While the complete understanding of the novel physical properties requires the experimental elucidation of the spin-dependent electronic states, there have been very few studies so far, mainly due to the difficulty in directly detecting the spin itself. In this project, we investigate the basic electronic states in the vicinity of the Fermi level for spintronics-related functional materials where the spin-dependent quantum transport plays an essential role in characterizing the physical properties.

【Research Methods】

To elucidate the fine electronic states of new functional materials, we develop an ultrahigh-resolution three-dimensional spin-resolved photoemission spectrometer which achieves the world best energy, momentum, and spin-resolutions. By utilizing the ultrahigh-resolution capability of the constructed spectrometer, we perform spin- and angle-resolved photoemission spectroscopy on topological insulators, Rashba metals, GMR compounds, and half-metals. We investigate the Fermi surface, energy band dispersion, spin polarization, spin vector, and quasiparticle dynamics by separately observing the electronic states from the bulk, surface, and interface.

【Expected Research Achievements and Scientific Significance】

(1) A systematic high-resolution ARPES study by changing the crystal structure, the composition, and the doping level on several candidate materials would reveal the essential key electronic structure for the topological insulator, leading to discovery/design of new non-trivial topological insulators.

(2) By spin-resolved ARPES, we map out the spin polarization and the spin vector in the whole momentum space. We investigate the relationship between the Fermi-surface warping and the out-of-plane spin component to reveal the key factor dominating the spin polarization vector.

(3) We examine the theoretical prediction for the topological phase in an ultrathin Bi film by comparing the experimental result with the theory. In addition, we prepare ultrathin films of heavy-elements such as Pb, Tl, and Au, and seek for new materials having a large Rashba splitting.

(4) We investigate the electronic structure of GMR materials and half-metals prepared by the PLD method. We also perform spin-resolved ARPES on hetero-structured oxide thin films and elucidate the origin for the anomalous magnetism and conductivity of the interface.

【Publications Relevant to the Project】

[1] T. Sato et al., Direct Evidence for the Dirac-cone Topological Surface States in the Ternary Chalcogenide $TlBiSe_2$, Phys. Rev. Lett. **105**, 136802-1-4 (2010).

[2] S. Souma et al., Direct Measurement of the Out-of-Plane Spin Texture in the Dirac Cone Surface State of a Topological Insulator、Phys. Rev. Lett. **106**, 021680-1-4 (2011).

[3] A. Takayama et al., Giant Out-of-Plane Spin Component and the Asymmetry of Spin-Polarization in Surface Rashba States of Bismuth Thin Film, Phys. Rev. Lett. **106**, 166401-1-4 (2011).

【Term of Project】 FY2011-2014

【Budget Allocation】 162,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://arpes.phys.tohoku.ac.jp