Regulating spin and Fermi surface topology of a quantum metal film by the surface (interface) monatomic layer

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Spin and current controls in solids have been one of the central issues in researches of electron and spin transport. Nowadays, electronics/spintronics deals with nanometer- or atomic-scale structures, where manipulations of single charge/spin channels and related functional properties have become accessible. Miniaturization of these systems implies the emergence of various quantum phenomena, intimately linked to the formation of electronic states different from those of the corresponding bulk materials. For example, valence electrons of films with the thickness comparable to the electron wavelength form discrete quantum-well states (QWSs) under opportune conditions of confinement (quantum size effect). Furthermore, the size reduction also increases the surface/volume ratio and a film possibly changes its electronic (spin) properties by the surface effect. Concerning metal films, the quantum size effect requires the thickness in a range of nanometers and the length corresponds to several tens of atoms, indicating the very large ratio of a surface (interface) monatomic layer to film atomic layers. Thus, we have interested in combining the quantum size effects and the surface effect on the metal films to induce new physical phenomena.

In the present talk, two research cases are shown. 1) Detailed measurements of angle-resolved photoemission spectroscopy have observed quasi-one-dimensional quantized states in an epitaxial Ag(111) film on a one-dimensional surface superstructure, Si(111)4 × 1-In, instead of isotropic two-dimensional in-plane states expected for an isolated metal film [1]. 2) High-resolution spin--resolved photoemission spectroscopy measurement[2,3] of ultrathin Ag(111) films covered with a $\sqrt{3}\times\sqrt{3}$ − Bi/Ag ordered alloy has revealed that surface state (SS) bands, spin-split by the Rashba interaction, selectively couple to the QWS bands, originally spin-degenerate, in the metal film, making the spin-dependent hybridization[4,5]. These results demonstrate that spin and Fermi surface topology of a quantum metal film can be regulated by the surface (interface) monatomic layer. In the presentation, I would like also to introduce some results of our surface (magneto-) transport measurements on these films.

References: [1] T. Okuda, Y. Takeichi, K. He, A. Harasawa, A. Kakizaki, and I. Matsuda, Phys. Rev. B **80**, 113409 (2009). [2] A. Nishide, A. A. Taskin, Y. Takeichi, T. Okuda, A. Kakizaki, T. Hirahara, K. Nakatsuji, F. Komori, Y. Ando, and I. Matsuda, Phys. Rev. B **81**, 041309 (2010). [3] A. Nishide, Y. Takeichi, T. Okuda, A. A. Taskin, T. Hirahara, K. Nakatsuji, F. Komori, A. Kakizaki, Y. Ando, and I. Matsuda, New J. Physics **12,** 065011 (2010). [4] K. He, T. Hirahara, T. Okuda, S. Hasegawa, A. Kakizaki, and I. Matsuda, Phys. Rev. Lett. **101,** 107604 (2008). [5] K. He, Y. Takeichi, M. Ogawa, T. Okuda, P. Moras, D. Topwal, A. Harasawa, T. Hirahara, C. Carbone, A. Kakizaki, and I. Matsuda, Phys. Rev. Lett. **104**, 156805 (2010).