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Metallic surface state with upstanding spin on Tl/Si(111)

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Introduction

The so-called Bychkov-Rashba effect or simply Rashba effect [1] is a low-dimensional physical phenomenon that produces spin-polarized electron bands even for non-magnetic materials. The Rashba effect has not only a fundamental physical interest but also an interest in its application since this is the key concept for operating spintronic devices, devices in which the spin degree of freedom of an electron is used in addition to its charge degree of freedom. In our former study we have found that the spin-polarization vector of the Rashba spin, which was believed to be parallel to the surface and perpendicular to the wave vector, can rotate and point along the surface normal direction depending on the symmetry of the surface in a semiconducting system [2].

In this study, we have created a metallic surface with C_3 symmetry on a semiconductor substrate, and measured its spin-polarized electronic bands by using spin- and angle-resolved photoelectron spectroscopy (SARPES).

Experimental details

The SARPES measurements have been performed at beamline BL-19A at KEK-PF, a beam line equipped with a very-low-energy electron diffraction (VLEED) electron spin polarimeter [3], using a photon energy of 21.2 eV. The metallic surface on a semiconducting substrate was prepared in the following way. We first cleaned a Si(111) substrate by annealing at 1520K in ultra-high vacuum, and deposited 1.5 ML of Tl on top of it. After that we annealed the sample at around 500 K to make a Tl/Si(111)-(1 × 1) surface with a small amount of Tl overlayer. Figure 1 shows the LEED pattern and surface Brillouin zone (SBZ) of the obtained surface.

Results

The SARPES spectra measured around the K point are shown in Figure 2(a). The spectrum obtained at an emission angle (θ_e) of 31° roughly corresponds to the $\bar{K}$ point at the Fermi level. A metallic band, whose binding energy (E_B) is approximately 0.1 eV at the K point, is clearly seen in the spectra of down spin state, while no metallic state is observable in those of up spin state in Fig. 2(a). On the other hand, a metallic band is only observed in the spectra of up spin state in the SARPES spectra around the K' point (Fig. 2(b)). Together with these metallic bands, spin-polarized states that were reported to have spin-polarization vector perpendicular to the surface [2] are also observed at E_B~2.0 eV. Taking the spin-polarization vectors of these states and the geometry of the experimental setup, we conclude that the polarization vectors of the observed spin-polarized metallic bands are perpendicular to the surface.

References

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Figure 1: SBZ and LEED pattern of the measured sample.

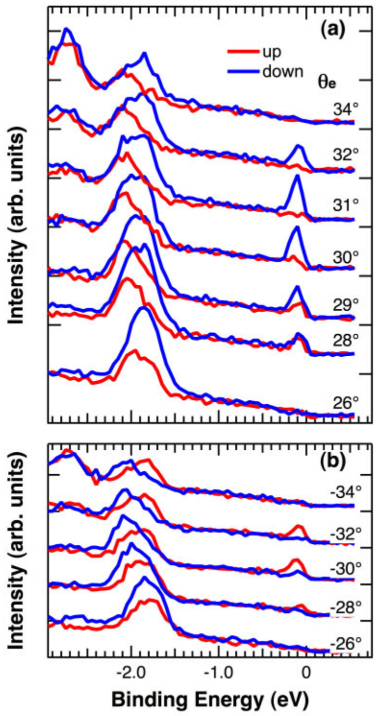

Figure 2: SARPES spectra measured using a photon energy of 21.2 eV around the (a) K and (b) K' points.

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