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Rashba spin splitting of a metallic surface state band of Pb/Ge(111)-(√3×√3)R30°

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Introduction

Large Rashba spin splitting of a metallic surface state band on a semiconductor surface allows us to open a novel physics such as a spin transport/accumulation at surface. The Rashba spin-split bands on semiconductor surfaces have been identified on Si(111) and Ge(111) surfaces so far [1-3]. However, there are no metallic surface state bands for these surfaces and hence cannot contribute to the transport of spins. In the present study, we report an electronic states for a monolayer Pb-adsorbed Ge(111) surface measured by angle-resolved photoelectron spectroscopy.

Experiment

The angle-resolved photoelectron spectroscopy was performed at KEK-PF BL18A. The photon energy was set to 30 eV. A Ge(111) substrate was prepared by several cycles of 1.0 keV Ar^+ bombardment and subsequent annealing up to 870 K for a few seconds. Orderliness and cleanliness of the surface were checked by a sharp c(2×8) LEED pattern. Pb was deposited onto the surface at room temperature, which was then annealed at 570 K for five minutes to prepare a well-ordered wide terrace of Pb/Ge(111)-(√3×√3)*R*30°.

Results and discussion

Figure 1(a) displays the angle-resolved photoelectron spectra taken along the $M_1\Gamma_1M_1$ direction of (√3×√3)*R*30° surface Brillouin zone and a binding energy versus in-plane momentum (band dispersion) image is shown in Fig. 1(b). Three Pb-induced bands named S_1, S_2 and S_3 are observed. These bands are not observed on the clean Ge(111)-c(2×8) surface. The S_1 band is located in the projected bulk band gap and crosses the Fermi level. The S_2 and S_3 bands are surface resonance states because the states appear in the projection of bulk bands. The overall dispersion of S_1, S_2 and S_3 suggests that a *free-electron-like* parabolic band is hybridized with a nearly flat band at 0.9 eV (S_2), yielding upper (S_1) and lower (S_3) branches. Recently, we have characterized that the S_1 band splits into two due to the surface Rashba effect by means of spin-resolved photoelectron spectroscopy [4]. A first-principles calculation suggests that the S_1 and S_3 bands are predominantly of Pb $6p_{x,y}$ character. On the other hand, the S_2 band has a character of bonding orbital between Pb $6p_z$ and Ge $4p_z$ of the topmost Ge atoms.

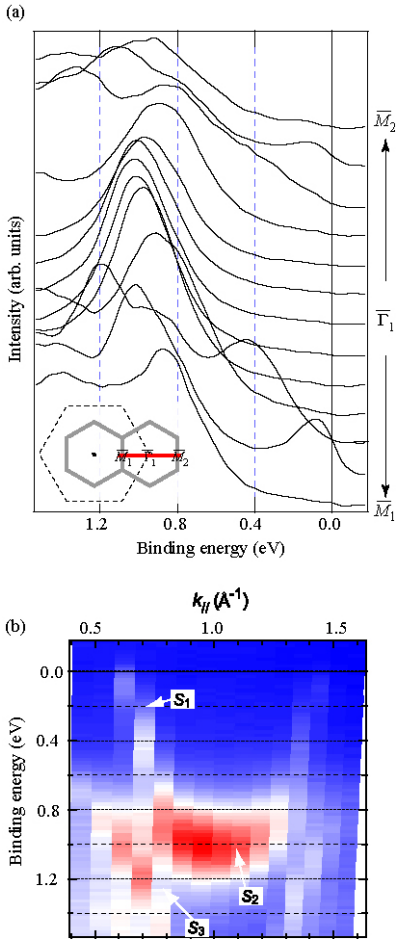

Fig. 1 (a) Angle-resolved photoelectron spectra taken along $M_1\Gamma_1M_2$ of the (√3×√3)*R*30° surface Brillouin zone as shown in the inset. (b) Energy band dispersion.

References

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