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Angle-resolved photoemission study of ultrathin Ag films on Si(111)

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Introduction

The *Rashba effect* has attracted great attention due to its potential application in the growing field of spintronics [1]. Due to the spin-orbit interaction and the loss of the inversion symmetry, the system possesses a spin-split band structure. By using such Rashba-split systems, it will be possible to manipulate the spin degree of freedom of nonmagnetic materials with an electric field. However, most of the studies have focused on surface states so far [2]. In ultrathin films, which are formed on a metal/semiconductor substrate, there are also quantum-well states that show up as a result of the confinement effect of the electrons inside the film. Because one side of the film is the vacuum and the opposite side is the substrate, they are also in a inversion-asymmetric environment and should show Rashba splitting. In the present work we have performed high-resolution angle-resolved photoemission study on ultrathin Ag films on a silicon (Si) substrate to see if such splitting behavior can be observed.

Experimental

The Si substrate was cut from a mirror polished *n*-type Si(111) wafer (1-10 Ωcm) followed by conventional cleaning procedures in ultrahigh vacuum (UHV) to prepare a clean Si(111)-7×7 surface. Deposition of Ag was done by resistive heating to tantalum filaments surrounding graphite tube cells. First, Ag was deposited onto the Si(111)-7x7 surface at ~100K. After the deposition, the films were annealed back to room temperature which resulted in a epitaxial Ag film showing a sharp 1x1 LEED pattern with strong spectral intensity. Photoemission measurements were performed at KEK-PF BL-18A. Angle-resolved photoemission measurements were performed at hυ=47 eV using a VG-Scienta SES-100 hemispherical analyzer at ~100K.

Results and discussions

Figure (a) shows the band dispersion image of an 8 ML ultrathin Ag film on Si(111). The surface state (SS) and the quantum-well state (QWS) closest to the Femi level can be apparently found, reproducing previous reports [3]. From the image, we cannot clearly distinguish if the band shows the spin-split behavior. Therefore we have performed further analysis and mapped the energy distribution curves (EDC, (b) and (c)) and angular distribution curves (ADC, (d)) to investigate the Rashba splitting of the QWS. However, we could not really find any features that may be a clue for the spin-split behavior, such as the appearance of two peaks or a broadening of the peakwidths. Therefore we conclude that the energy splitting is smaller than the energy resolution of the measurement which is ~20 meV. Recently, such small splitting of the QWSs have been found for lead (Pb) films on Si(111) [4] by means of spin- and angle-resolved photoemission spectroscopy.

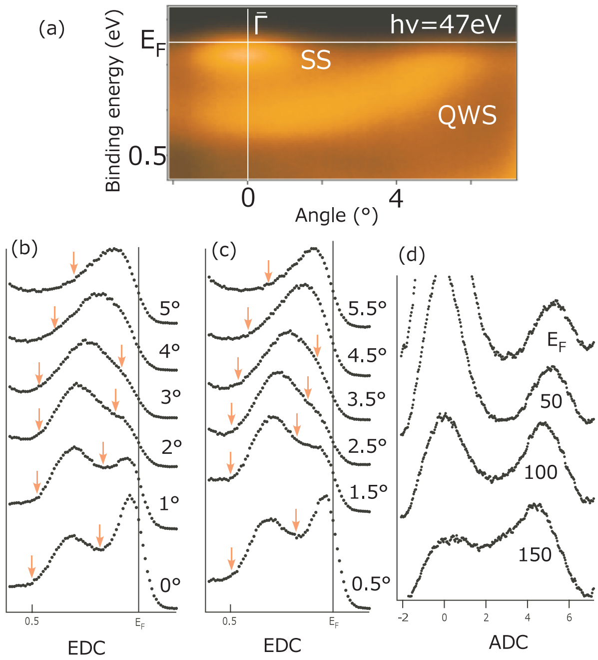

Figure: (a) Band dispersion image of an 8 ML Ag film on Si(111), showing the surface states (SS) and the quantum-well state (QWS) closest to the Fermi level. (b, c) Energy distribution curves (EDC) of the image shown in (a) for representative angles. (d) Angular distribution curves of the image shown in (a) for representative binding energies.

References

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