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Spin-resolved ARPES study on ultrathin Bi_2Se_3 films

Yusuke SAKAMOTO[1], Toru HIRAHARA[1*], Yasuo TAKEICHI[2], Akinori NISHIDE[1], Taichi OKUDA[3], Iwao MATSUDA[2], Akito KAKIZAKI[2] and Shuji HASEGAWA[1]
[1]Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan
[2]Synchrotron Radiation Lab, ISSP, Kashiwa, Chiba 277-8581, Japan
[3]Hiroshima Synchrotron Radiation Center, Higashi-Hiroshima, Hiroshima 739-0046, Japan

Introduction

Recently there has been growing interest in *topological insulators* or the *quantum spin Hall (QSH) phase*, which are insulating materials with bulk band gaps but have metallic edge states that are formed topologically and robust against any non-magnetic impurity [1]. In a three-dimensional material, the edge states become surface states and it was said that spin-split surface states of group V semimetals [2] are promising candidates for such edge states [1, 3]. However as the bulk electronic structure of these materials is not exactly an insulator, the surface-state band dispersion does not fulfill the criteria for the QSH phase edge states. There have been some theoretical proposals to open a bulk band gap for these semimetals and to realize a topological insulator [1]. One of them was to alloy antimony (Sb) into bismuth (Bi), which resulted in the first experimental observation of a topological insulator [4]. However, the band structure of BiSb is quite complicated with trivial as well as topological surface states. As the second generation topological insulators, materials such as Bi_2Se_3 or Bi_2Te_3 were found which had a much simpler band structure with only one band crossing the Fermi level [5]. They have the so-called helical Dirac Fermion surface states, although their spin structure is not fully unraveled. Therefore in the present study, we have performed spin- and angle-resolved photoemission spectroscopy to obtain a comprehensive understanding of the spin chirality of the Dirac surface states.

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 Bi and Se was done by resistive heating to tantalum filaments surrounding graphite tube cells. First Bi was deposited onto the Si(111)-7x7 surface at 520K and after the formation of the β√3x√3, Bi and Se were co-deposited at 400K [6]. The films showed a sharp 1x1 RHEED pattern with strong spectral intensity. Spin- and angle-resolved photoemission measurements were performed at KEK-PF BL-19A at hυ=21.2 eV using a SPECS PHOIBOS-150 hemispherical analyzer at ~100K [7]. The homogeneity of the films (absence of segregation of Se) and the ratio of Bi and Se were checked by measuring the Bi 5*d* and Se 3*d* core level spectra.

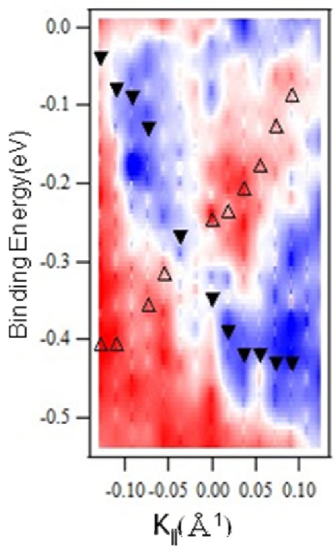

Figure: Spin polarization mapping and peak positions of the up(open triangles) and down(solid triangles) peaks.

Results and discussions

The Figure shows the results of the spin polarization mapping with the peak positions overlapped for the 80 Å Bi_2Se_3 ultrathin film along the Γ-M direction. As reported for the single crystal case, the band structure is linear with and has a helical spin structure; the negative wavenumber side has down spin and the positive side has up spin. We have therefore made clear the helical nature of the surface states using the newly developed spin-resolved ARPES machine.

References

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* hirahara@surface.phys.s.u-tokyo.ac.jp