19AG052, 19BG049, 20AG058, 20AU009 BL-1, BL-9B, BL-9A

ARPES study of antiferromagnetic $EuIn_2As_2$

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Soon after the discovery of topological insulators, antiferromagnetic topological insulators defined by Z_2 topological invariant were also theoretically proposed [1]. This new form of magnetically ordered topological insulators can be characterized by the symmetry operation $S = \Theta \cdot T_{1/2}$ obtained by multiplying time-reversal symmetry operation Θ and the 1/2 lattice translation symmetry operation $T_{1/2}$, and is expected to realize an "axion phase". The axion phase has attracted a great deal of attention as a platform for the new topological electromagnetic effect. Recently, a gapped topologically non-trivial surface state of the layered antiferromagnetic $MnBi_2Te_4$ has been predicted and realized [2]. However, the energy gap in $MnBi_2Te_4$ is located well below Fermi level (E_F), which becomes an obstacle for the realization of topologically interesting phenomena. Therefore, there is an strong need for more ideal antiferromagnetic topological systems.

In this study, we focus on the antiferromagnetic $EuIn_2As_2$. This is the heterostructure compound that undergoes a phase transition to layered antiferromagnetic order below $T_N = 16$ K [3]. It exhibits a large negative magnetoresistance near T_N, which is known to occur in Weyl semimetals. As another interesting aspect, this material is predicted to be a higher-order topological insulator candidate accompanying topological hinge and corner states in the antiferromagnetic phase [4]. Previous angle-resolved photoelectron spectroscopy (ARPES) studies on this compound provided controversial results on the electronic band structures crossing the E_F [5,6,7], which were interpreted to be either bulk or surface origin. To make a decisive determination of the band structures, orbital and spin resolutions for the ARPES measurement is highly desired. Motivated by this, we have performed the ARPES with linearly polarized light at HiSOR BL-1 and BL-9A and the spin-resolved ARPES (spin-ARPES) at BL-9B.

Figure 1 shows the observed band structures of $EuIn_2As_2$ along the $\bar{\Gamma} - \bar{K}$ line acquired with a photon energy ($h\nu$) of 25 eV at BL-1. Most importantly, linearly dispersive hole like bands that cross E_F is observed. In order to confirm if these linear bands stem from surface or not, we have tried to measure incident photon energy dependence and found no k_z dispersion. Figure 2(a) shows the ARPES energy dispersion acquired at $h\nu$ =28eV and Fig. 2(b) shows the y component of spin polarization (P_y) and spin-resolved energy distribution curves along the yellow cut line [see Fig.2(a)] of the linear band, exhibiting no spin polarization. We note here that no recognizable spin polarizations are found also for P_x and P_z componets.

Having considered the experimental results mentioned above, it can be safely concluded that the hole-like linear band stems from the bulk electronic states with high two-dimensionality.

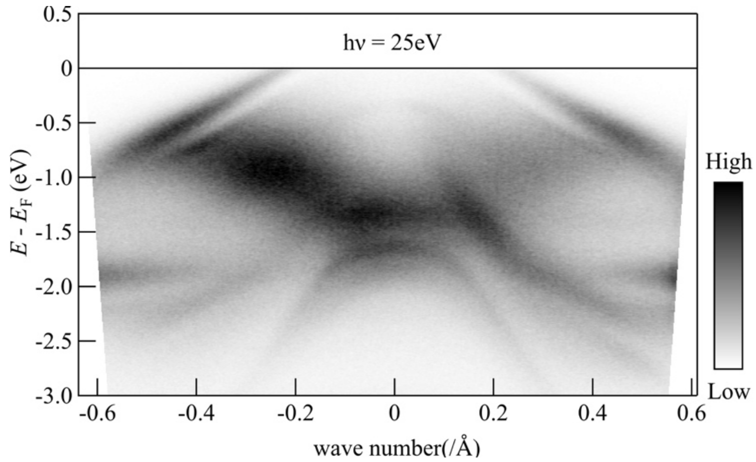

FIGURE 1. ARPES image of $EuIn_2As_2$ along $\bar{\Gamma}-\bar{K}$ line acquired at $h\nu$=25 eV.

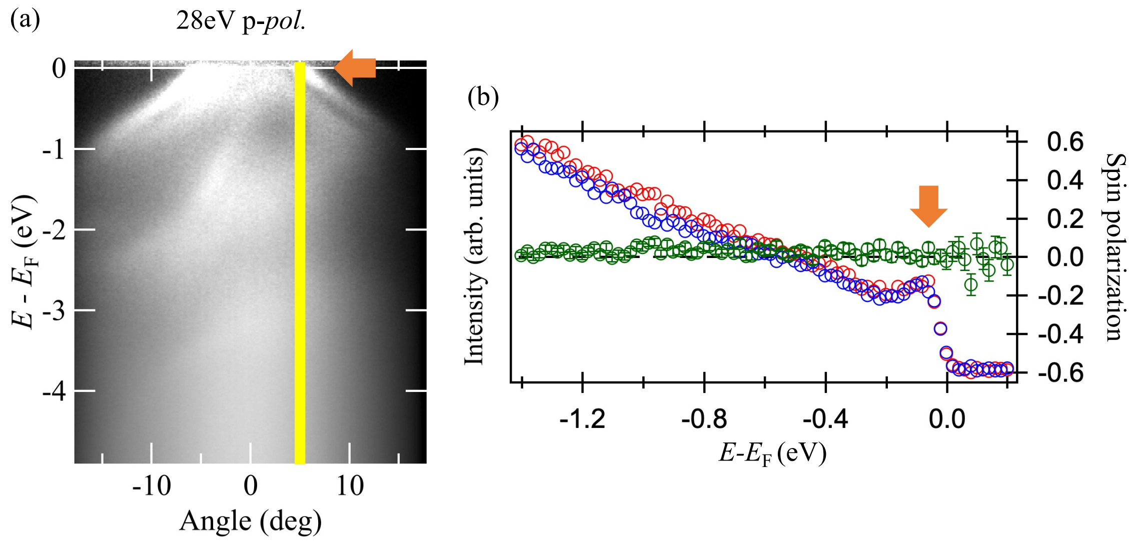

FIGURE 2. (a)ARPES image taken at $h\nu$=28 eV with *p*-polarization. (b)Spin-resolved energy distribution curve along the line at an emission angle of 5 deg. (see yellow cut line).

REFERENCES

[1] R. S. K. Mong *et.al.*, Phys. Rev. B **81**, 245209 (2010).
[2] M. M. Otrokov *et.al.*, Nature **576**, 416 (2019).
[3] A. M. Goforth *et.al.*, Inorg. Chem. **47**, 11048 (2008).
[4] Y. Xu *et.al.*, Phys. Rev. Lett. **122**, 256042 (2019).
[5] S. Regmi *et.al.*, arXiv:1911.03703 (2019).
[6] Y. Zhang *et.al.*, Phys. Rev. B **101**, 205126 (2020).
[7] T. Sato *et.al.*, Phys. Rev. Res. **2**, 033342 (2020).