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Construction of micro-ARPES end-station at BL28

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Currently, ARPES end-stations in synchrotron radiation facilities all over the world are actively promoting the reduction of the beam-spot size by using advanced focusing optics and low-emittance light sources. Such spectrometer system, so-called micro-ARPES or nano-ARPES, has attracted particular attention owing to a great deal of interest in elucidating the electronic structure of novel functional materials such as van-der Waals heterostructure (e.g. twisted graphene) [1] and helical/chiral edge modes of various topological materials [2]. Micro/nano-APRES also paves a pathway toward observing electronic band structure under applying voltage or current in micro-device structures [3].

To conduct the cutting-edge spectroscopy that enables the visualization of local electronic states, we have constructed micro-ARPES end-station at BL28. We first designed a K-B mirror system equipped in the UHV chamber and installed it in front of the main chamber. By adjusting the mirror position and by aligning the whole ARPES system, we have succeeded in focusing the VUV light into a micro spot of 12 μm (H) × 15 μm (V) at the sample. To accurately visualize the spatial distribution of the electronic states, we also developed high-precision and highly-reproducible 5-axis sample manipulator equipped with 1nm-resolution encoders. We found that amplitude of environment vibration is less than 50 nm, which is much smaller than the beam-spot size and does not deteriorate spatial resolution of the micro-ARPES system.

To verify the performance of the micro-ARPES system, we have carried out spatial mapping of ARPES intensity in a topological insulator Bi_2Se_3 by scanning sample positions with a micro-focused beam. Figure 1(a) shows the result of ARPES-intensity spatial mapping. The intensity was obtained by integrating the EDCs where the Dirac-cone surface state exists near the Fermi level [integration area is shown by a white rectangle in Fig. 1(c)]. By comparing with the microscope image in Fig. 1(b), one can recognize that the spatial mapping almost perfectly visualizes the shape of the sample. This confirms the fairly good focus of the beam spot as well as the high accuracy of scanning ARPES. Since the intensity mapping data was obtained by specifying certain momentum region in which the Dirac-cone state at the Γ point exists, the intensity pattern reflects to what extent the crystal is directed along the sample normal. At point B [dark region in Fig. 1(a)], a Dirac-cone state with strong intensity is observed not at the center but away from it [middle panel of Fig. 1(c)]. This strongly suggests that this dark area originates from the spatial area where the sample is bent by a few degrees after cleaving. Influence of such sample bent was found to be even stronger at point C as visible from the absence of the Dirac cone. These results demonstrate that the new micro-ARPES system is highly useful for visualizing the local band structure. Application of micro-ARPES to various functional materials and electronic devices is highly desired as a future study.

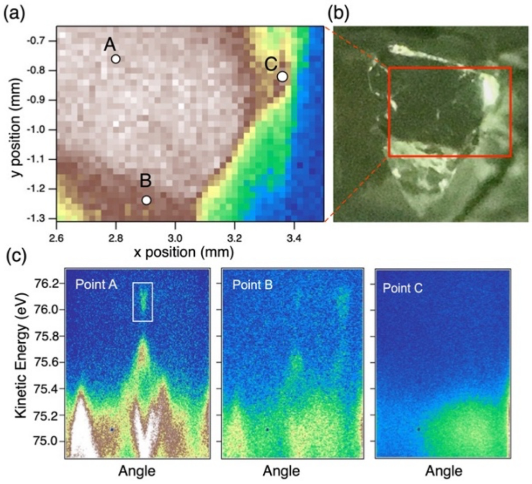

Fig. 1: (a) Spatial distribution of the ARPES intensity in Bi_2Se_3 obtained with a newly developed micro-ARPES system at BL28. Intensity was obtained in the area where the Dirac-cone surface state exists [white rectangle in (c)]. (b) Optical microscope image of the measured sample. (c) APRES intensity obtained at points A-C in (a).

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