Research Activities

– Off-line Experiments –

Study of ARPES, Magnetic and Magneto-transport Properties of Dy-doped Bi_2Te_3 Topological Insulator

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Keywords: ARPES and Magneto-transport

Topological insulators are characterized by a gapped bulk state and gapless surface or edge states that is protected by time-reversal symmetry (TRS). TRS can be broken by magnetic impurities. To investigate the correlation between topological state and magnetism it is important to introduce magnetic elements into Topological insulators. In this study, we have synthesized the single crystals of $Bi_{2-x}Dy_xTe_3$ (x =0.06, 0.10, 0.16) and reported the effects of Dy-substitution on the topological properties in $Bi_{2-x}Dy_xTe_3$. XRD data indicate very good single crystallinity of $Bi_{2-x}Dy_xTe_3$ without any sign of secondary phase. We have measured the magnetization M(H) at different temperature and found that at low temperature it shows weak ferromagnetic ordering. From the ARPES and thermoelectric studies we found n-type nature of Dy-doped Bi_2Te_3. Figure shows the HR-ARPES spectra measured in *s*- and *p*-polarization geometry which revealed the existence of a Dirac-cone like surface states in Dy-doped Bi_2Te_3 samples.

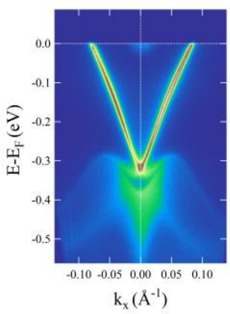

Fig.1 Bi_2Te_3:Dy5_**S-polarization**

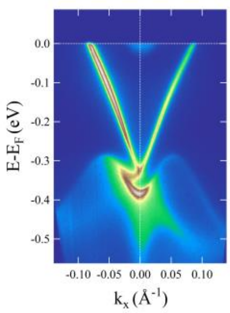

Fig.2 Bi_2Te_3:Dy5_**P-polarization**

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Nodal gap in electron-doped J=1/2 Mott insulators

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Keywords: Iridates, Mott insulators, Nodal gap

Many exotic states are induced by doping Mott insulators. In the cuprates high-temperature superconductors, many unconventional phenomena emerge when carriers are doped into the parent Mott state [1]. One of the most intriguing phenomena in hole-doped cuprates is the existence of an energy gap at the momentum location where the d-wave superconducting gap node is expected [2]. Continuous efforts have been made to understand its origin. Besides many interesting theoretical proposals, an intriguing question from experimental side is whether the observed nodal gap represents an intrinsic physics of doped Mott insulators.

Perovskite strontium iridates Sr_2IrO_4 is an effective spin-1/2 Mott insulator, in which pseudogap [3,4] and d-wave instability [5] have been observed, offering an unprecedented system to test the universality of the emergent phenomena in cuprates. To this end, we proposed the first systematic ARPES study on nodal gap in electron-doped Sr_2IrO_4.

ARPES measurements were carried out at HiSOR Laser-based μ-ARPES system on the La-doped Sr_2IrO_4 samples. However, we did not obtain clear band structure on our La-doped Sr_2IrO_4 samples, possibly due to the matrix element effects in ARPES (the photon energy may not be good for Sr_2IrO_4). But these initial tests provided us some very useful information for the follow-up beam time in other places.

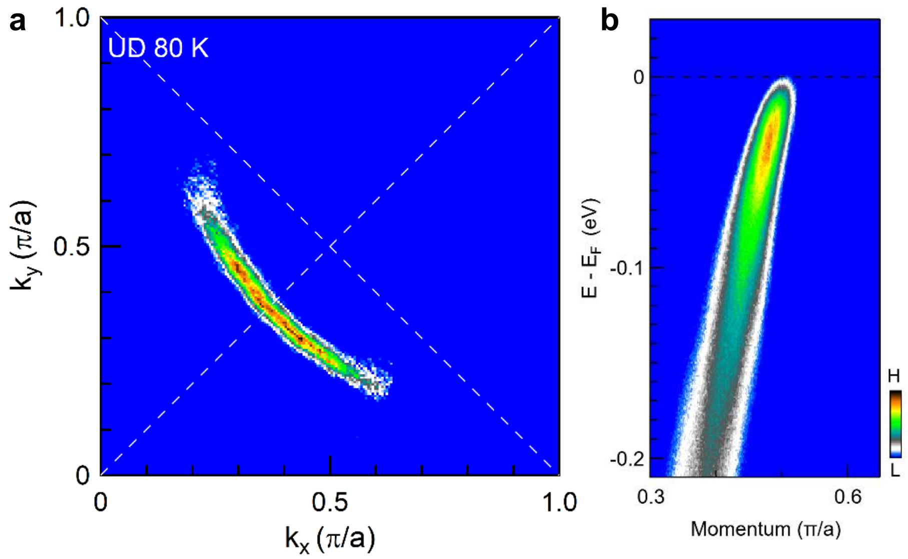

FIGURE 1. Fermi surface and band structure of an UD80 K Bi2212 sample. (a) Fermi surface of the UD80 K Bi2212 sample. (b) Band structure along the nodal direction [(0, 0) - (π, π)]. These data were obtained at 90 K by using μ-ARPES system.

For this beam time, we carried out the back-up plan and performed ARPES measurements on Bi2212 samples using the Laser-based μ-ARPES system. As shown in FIGURE 1, high quality data was obtained on an UD80 K Bi2212 sample. Detailed temperature dependent measurements were also performed on this sample (not shown here). Systematic data analysis is in process.

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ARPES Studies of Ultrathin Ferromagnetic Films on Topological Insulators for Spintronic Applications

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Keywords: Topological insulators, PbSnTe, $BiSbTeSe_2$, Dirac cone, ferromagnetic metal, interface.

Recently, expressed interest in the field of spintronics has been related to topological insulators, characterized by a unique electronic structure their surface states [1, 2]. Topological insulators are characterized as conventional insulators in the bulk and as objects with the Dirac cone of conducting spin-polarized states at their surface. The study of a ferromagnetic-topological insulator interface is of interest due to the effect of magnetic proximity acting as a factor which breaks the symmetry, with respect to the time inversion of topological surface states [3].

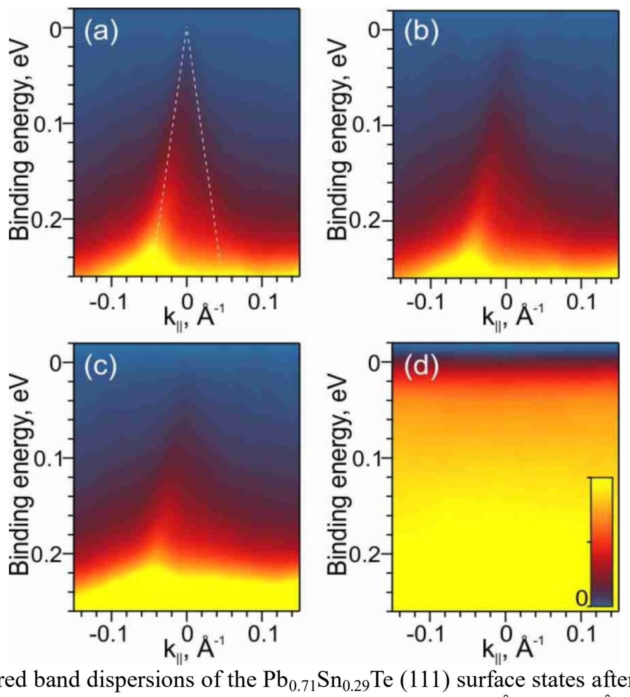

FIGURE 1. LARPES measured band dispersions of the $Pb_{0.71}Sn_{0.29}Te$ (111) surface states after the treatment in the HCl-iPA solution and annealing in vacuum at 300°C (a) and subsequent deposition of 0.3 Å (b), 1.1 Å and 3 Å of Co at 300 °C. Γ-M direction, hν = 6.3 eV, T = 20 K.

Mono-crystalline epitaxial films of ferromagnetic Co on the $Pb_{0.71}Sn_{0.29}Te$ topological insulator substrates were grown by the MBE method. The epitaxial relations for the film and the substrate were revealed using 3D reciprocal space mapping based on RHEED measurements. For the Co/ $Pb_{0.71}Sn_{0.29}Te$ system, a technology for cleaning the film surface by a thermal annealing in vacuum after a chemical treatment was developed. The successful cleaning is demonstrated by the presence of a clear topological state in the Laser ARPES measurement. One of the key results of this study is the observation of surface states with Dirac-like dispersion, occurring at the Γ position in the surface Brillouin zone. Fig. 1 (a) demonstrates the dispersion characteristic for the clean $Pb_{0.71}Sn_{0.29}Te$ (111) surface (see [4]) after a chemical treatment and a subsequent vacuum annealing. The valence band structure associated with the Γ - point position on the Fermi level was shown. The Co deposition leads to the noticeable upward band bending, with an electron doping induced shift of the electronic state of about 20 meV after deposition of ~1.1 Å of Co (Fig. 1 (b, c)). With thick Co coatings (~ 3 Å and more, Fig. 1 (d)), as expected, the metallic electronic states of Co start to dominate the dispersion. Thus, the stable topological state of PbSnTe was observed right up to no less than the monolayer thick Co coverage, including an upward band bending of around 20 meV.

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