Dirac point band gap opening in ferromagnetic Mn-doped topological insulators of the bismuth chalcogenides

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Topological insulators behave in bulk like ordinary insulators but exhibit a gapless Dirac like surface state that is topologically "protected" by time-reversal symmetry and immune to surface impurities [1]. A magnetic field perpendicular to the surface breaks the time reversal symmetry and opens a gap in the surface state. For 3D topological insulators, such as Bi_2Se_3 and Bi_2Te_3, a similar behavior is expected for ferromagnetic impurities like Mn [2] or Fe [3] and novel phenomena like topological magneto-electric effect, quantum anomalous Hall effect, half-integer charges at magnetic domain boundaries etc. are expected to occur [1].

Here, we present studies on Mn doped Bi_2Se_3 and Bi_2Te_3 combining a wide range of techniques to clarify the origin of the lifting of the degeneracy and gap opening induced by Mn incorporation. The samples were grown by molecular beam epitaxy and protected from oxidation by Se capping for subsequent synchrotron investigations. X-ray studies indicate a maximum solubility of Mn of about 8 % without strong structural degradation. As demonstrated by SQUID magnetometry and x-ray magnetic circular dichroism, $Bi_{2-2x}Mn_{2x}Se_3$ becomes ferromagnetic at low temperatures, with a Curie temperature of around 10 K for x_{Mn} = 8%.

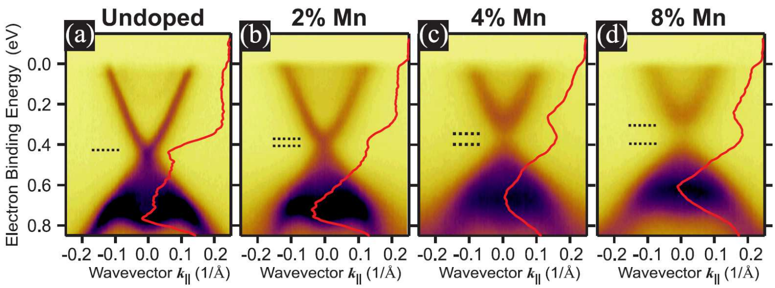

Figure 1: Mn-concentration dependent angle-resolved photoemission (ARPES) 2D maps of epitaxial $Bi_{2-2x}Mn_{2x}Se_3$ layers with increasing Mn content measured at 7 K. A clear Dirac cone is observed for x_{Mn} = 0% and a gap opening with increasing Mn content. The red lines represent the normal emission spectra.

Angular resolved photoemission maps are shown in Fig. 1, revealing n-type carriers of ~$10^{18}cm^{-3}$, i.e., Fermi level in the conduction band, which decreases with increasing Mn content. As indicated by the dotted lines, a gap is opened at the Dirac point which increases up to about 100 meV for x_{Mn} = 8%. However, temperature dependent measurements reveal that this band gap is independent of temperature and persists up to 300K. This unexpected behavior indicates that the breaking-up of the topological surface state is not caused by magnetism. Instead, we propose that this effect is caused by strong impurity scattering [4] that locally destroys the protection of the Dirac state.

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