SYNTHESIS AND STUDY OF MAGNETIC AND MAGNETO-TRANSPORT PROPERTIES OF SOME TOPOLOGICAL INSULATORS

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By

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8.1 General Conclusion of the thesis work

With Cu doping in Bi_2Te_3 in Te site, electrical resistivity is increased as Fermi level is shifted into valence band with extra scattering centers. It is also observed that Cu doping tunes the carrier from from *n* to *p* type, which is attributed to the presence of Te_{Bi} and Bi_{Te} antisites. Carrier concentration increased due to the doping of Cu which is due to dominating effect of bulk over surface. Subnikov de Hass oscillation has been studied in the Cu doped samples. Moreover Cu doping induces room temperature ferromagnetism. By developing such type of magnetic TIs a new way may open to design and develop future spintronics and electronic devices where high carrier concentration and mobility, large magnetoresistance and room temperature ferromagnetism (RTFM) is required. Additionally, QAHE is observed even at room temperature in Cu doped Bi_2Te_3 sample which also supports the RTFM. The origin of MR was believed to be classical and the maximum value of MR was as high as 1000%.

MR value increases due to the presence of Zn in Bi_2Te_3. The MR behavior was consistent with the classical model proposed by Parish and Littlewood. Mobility initially decreases with Zn doping but with further doping, mobility is increased indicating increasing contribution of bulk in expense of surface state. The most important feature of the presence of Zn was simultaneous enhancement of electrical conductivity and thermopower leading to a significant enhancement of thermoelectric power factor. Moreover, very high power factor ($\sim$4.64 mW/K^2) value is observed in Zn doped sample.

SdH and dHvA oscillations simultaneously are observed in Cu doped Sb_2Te_3 material. We find the coexistence of both bulk and surface states from SdH oscillation. But from the dHvA oscillation we observed only the existence of bulk state. It is due to the fact that non magnetic Cu doping induces the magnetic ordering and induced magnetization is the bulk property. We have tried to distinguished the bulk effect from the surface state in the Cu doped Sb_2Te_3 from the simultaneous measurements of magneto-transport and magnetization at high field and low temperature.

Room temperature antiferromagnetic ordering is found in Co doped Sb_2Te_3 while the parent material Sb_2Te_3 is diamagnetic in nature. This is due to the exchange interaction between Co^{2+} and Co^{3+} ions, the presence of which has been confirmed by the XPS analysis. By developing such type of magnetic TIs, showing magnetic ordering at RT, may open a new way to design and develop future spintronics and electronic devices which may be important in quantum computing and multifunctional electromagnetic applications. Thickness of layer has been determined using AFM technique which is well matched with the theoretical value.

8.2 Future Perspectives

Since bulk is insulating and surface is conducting in TIs, therefore it is very challenging to separate out the bulk and insulating contribution. Angle resolved photo-emission spectroscopy (ARPES) is the strong technique by which we can characterize the surface of topological insulator. Using the momentum of ejected electron from the crystal surface; one can determine the bulk or surface electronic structure of the material. We can also distinguish the surface and bulk properties of the 3D topological insulator since there is no dispersion in the surface state along the perpendicular direction to the surface but the bulk state do. Moreover ARPES can be used in spin resolution mode also. Using this mode we can not only estimate the spin orientation on the Fermi surface but also get information about the Berry phase and spin momentum locking which is the peculiar property of the surface in TI.

Therefore, ARPES technique is required to provide the direct information about the position of Fermi level as well as the Dirac cone on the surface of TIs.

Moreover, measurement of magnetoresistance with applied magnetic field at different angle is also very sensitive technique to provide proof for the bulk and surface effect in TIs. As we change the angle of applied field, bulk and surface contribution in MR also changes. Therefore angle dependent MR is also required to differentiate the bulk and surface contribution.

Moreover, another important tool which is desired is density functional theory (DFT)) calculation, using which we can establish theoretically to the obtained experimental results. Using DFT we can also collect information about crystal structure, cell parameter, magnetic state, Fermi level position and Dirac cone on the surface of TIs.

X-ray magnetic circular dichroism (XMCD) is another technique for the investigation of magnetic origin. Since, the exact origin of room temperature ferromagnetism (RTFM) is still not cleared in Cu doped Bi_2Te_3 hence XMCD may helpful to investigate the spin state of the elements present in the materials.