Chapter 6

Conclusions and Future Plan

6.1: CONCLUSION

To conclude the thesis work, we have successfully synthesized Bi_2Se_3 topological insulators doped with different materials such as, Co, S and Fe and studied different physical properties such as, thermoelectric, magnetic, magneto-transport and electrical properties etc. In different chapters we have discussed the studies mentioned above and conclude that doping enhanced the properties of Bi_2Se_3 topological insulator. The results are summarized below.

When Co is doped at Bi site of Bi_2Se_3 topological insulator, it has been observed that high doping and high magnetic field raise the Dirac cone above Fermi level and leaves a gap from the valence band. The undoped sample shows the maximum MR as the destructive interference in doped samples due to a π-Berry phase leads to a decrease of MR which is the key feature of topological surface states. In topological surface states Dirac fermions travel around a self intersecting path or loop due to the spins rotating in opposite ways for the different path directions and a π-Berry phase is accumulated. Magnetization behavior indicates the establishment of ferromagnetic ordering with Co doping. Furthermore, Hall effect data also supports the ferromagnetic behavior of Co-doped Bi_2Se_3 samples with the appearance of non-linearity. In case of $Bi_2Se_{3-y}S_y$ (where y= 0, 0.06, 0.15, 0.21, 0.30) topological insulators, we have investigated the magneto-transport properties of pure and doped samples. All the samples show the metallic behavior throughout the whole range of temperature measurement. The MR also decreases with increase of S content and finally for y=0.21 sample, it becomes negative. The Negative magneto-resistance of y=0.21 sample has been explained as the dominance of the bulk conduction over surface conduction. Furthermore, with further increase of S content (y=0.30) the non-trivial bulk state is destroyed.

The interesting observation of S doped Bi_2Se_3 was appearance of negative magnetoresistance which is generally observed in case of ferromagnetic material due to suppression of spin-disorderness with magnetic field. In this context, we have co-doped Fe as well as S in Bi_2Se_3 at Bi site and Se site respectively. With the increase of doping concentration in $Bi_{2-x}Fe_xSe_{3-x}S_x$ (where x=0, 0.06, 0.09 and 0.12), MR gradually decreases and for x=0.09 it shows giant negative MR even at room temperature. The negative MR is observed when the system is in the FM state. The origin of FM ordering is attributed to the RKKY interaction. At large doping (> 9%) the non-trivial surface state is completely destroyed which in effect destroys the spin-orbit coupling. As a matter fact, the conduction band cannot hybridize with the Fe 3*d* orbitals as the conduction band is no more inverted and the Fe 3*d* orbitals will not have any particular orientation. This is the reason of the reappearance of positive MR with larger doping concentration. The ARPES data indicates that above a critical doping concentration (x>0.09), the non-trivial bulk state is completely destroyed.

Future plans;

- We have planned to enhance magneto-resistive properties of topological insulator at room temperature by doping different magnetic elements.
- The thermoelectric property of topological insulators is very significant property to be studied. We have planned to enhance it upon doping of transition metal and rare earth elements.
- We have also planned to introduce superconducting property in 3D topological Insulator as well as magnetic ordering which could be a prominent way to get the Majorana fermions.