ABSTRACT

This thesis work explores the effect of magnetic and non-magnetic doping on structural, magnetic, and quantum-transport properties of Bi-based topological insulators (TIs). Initially, Bi_2Se_3 is taken as a host TI, and Mn (In) is chosen as the magnetic (non-magnetic) dopant. Starting from the good-quality bulk sample preparation by solid-state reaction technique, we have analyzed the characterized data in details, and found some interesting outcomes, such as, the preference of In-dopant for substitution of Bi in Bi_2Se_3 compared to Mn-dopant as evidenced from the XPS and XRD analysis; observation of defect induced paramagnetism (PM) for In-doped Bi_2Se_3, whereas the long-range RKKY-type ferromagnetism (FM) and Kondo effect for high Mn-doping. More importantly, there exists successive transformation of the weak anti-localization (WAL) feature of host towards the weak localization (WL), along with significant reduction in the host's phase coherence length (l_ϕ) for Mn-doping as compared to In-doping. Following this work, we have also performed a similar type of study on another Bi-based TI, selecting Bi_2Te_3 as the host and Fe as the magnetic dopant, keeping In constant as a non-magnetic dopant. The structural analysis manifests a similar type of data trend for the incorporation of Fe and In-dopants into Bi_2Te_3 crystal, as seen for Bi_2Se_3. However, the magnetism study reveals the formation of short-range anti-ferromagnetic (AFM) order of Fe-ions in paramagnetic background instead of long-range RKKY-type FM. The transport analysis also exhibits prominent anomaly in ρ_{xx} –T profiles for Fe-doping rather than Kondo type feature as noticed for Mn-doped Bi_2Se_3. Above all, similar type of results is visualized in our magneto-conductance study; signifies Fe-doping introduces a major deviation, while In-doping creates relatively minor deviation on the host's quantum WAL effect. From further literature survey we have realized that, the quantum-transport features are more clearly understood in nano-scale limit. For this reason, we have fabricated the un-doped as well as Mn and In-doped Bi_2X_3 (X= Se, Te) thin films on Si-substrate using an indigenously-developed electron beam evaporator through co-deposition technique. Along with the film growth, a detailed study of the structural, elemental, and morphological analysis has been presented through the GI-XRD, Raman spectroscopy, XPS, EDX, SEM, and AFM characterization. Finally, we have investigated the quantum-phenomena of our deposited films through low-temperature magneto-transport measurements. The results indicate an enhancement of the surface electronic contribution over bulk carriers, which was not possible in our micro-flake type samples. Interestingly, our Bi_2Se_3 film exhibits band-topology related physical phenomena through 2D WAL and Subnikov-de Hass (SdH) oscillation features. From which some novel physical entities are explored, such as: Berry's phase (β), phase coherence length (l_ϕ), Fermi velocity (v_F), Dingle temperature (T_D), quantum mobility (μ_q), and more importantly the cyclotron mass (m_c). The obtained m_c= 0.17m_e, which is very less compared to electron's effective mass (m_e), signifies that the mass-less Dirac fermions can be achieved in this kind of system. In case of Bi_2Te_3 film, we have found a quasi-2D transport with high magneto-resistance and l_ϕ. Upon magnetic Mn-doping, both of the Bi_2X_3 system reveals prominent semiconducting behavior, indicating the gap opening among topological surface states (TSS), which is also manifested through the WL and anomalous hall effect (AHE) type features. For non-magnetic In-doping into Bi_2Se_3, we have also found a crossover from WAL to WL, which is well supported by minor semiconducting and non-linear Hall responses. However, In-doped Bi_2Te_3 film does not exhibit any WAL-WL crossover or semiconducting response, instead it maintains the host's WAL as well as metallic features.

Keywords: Topological insulator, Quantum-transport, Spin-orbit coupling, Ferromagnetism, Pauli paramagnetism, Kondo effect, Weak anti-localization, Berry's phase, Subnikov-de Hass oscillation, Anomalous hall effect.