Preface

In 1879, Edwin H. Hall discovered the Hall effect while measuring the transverse resistivity (resistivity corresponding to the voltage orthogonal to the applied current) in a current-carrying conductor under a perpendicular magnetic field. After two years, the same scientist discovered an anomalous contribution to the Hall effect in ferromagnetic conductors, known as the anomalous Hall effect (AHE). In recent years, the connection of Berry curvature physics with the quantum phenomena has reignited the field of AHE, driven by the Berry curvature. Over the last decades, magnetic systems with non-coplanar spin textures with non-zero spin chirality have demonstrated an extra contribution to the Hall effect along with the ordinary Hall and AHE. This additional contribution arises from the real space Berry curvature associated with the non-coplanar spin textures and is known as the topological Hall effect (THE). The THE is a widely used indirect tool to detect the microscopic non-coplanar magnetic texture/mesoscopic skyrmion-like topologically stable non-coplanar spin texture, which have promising applications as memory and logic elements of energy-efficient and stable spintronic-based devices. Not only the transverse resistivity can show fascinating properties of a material, but the longitudinal resistivity can also exhibit exotic electrical transport properties such as the Kondo effect, which results in a low-temperature logarithmic upturn in resistivity when the localized magnetic impurity is screened by the non-localized conduction electrons. The Kondo effect has been a time-honored problem in the area of strongly correlated electron systems. Detailed investigation of electrical transport properties, particularly in intermetallic compounds, has attained vast interest in current years due to its role in understanding of the Berry curvature physics and potential for applications in spintronic-based data storage devices and Hall sensors.

Intermetallic compounds are a class of metal alloys that form ordered solid compounds involving two or more metallic elements and optionally one or more non-metallic elements. These compounds

have attracted immense attention due to their multifunctional properties, including magnetism, superconductivity, high melting point, low chemical reactivity, unique mechanical and electrical properties. These properties hold tremendous potential in technological applications across aerospace, high-temperature materials, magnetic materials, hydrogen storage, thermoelectric materials, coatings, dental amalgams, and superconductors. Particularly, Mn-based intermetallic compounds, primarily composed of Mn along with other elements, are of significant interest in terms of both fundamental physics and technological applications. Their remarkable properties, such as spin gapless semiconducting and half-metallic feature, shape memory effect, AHE, and THE, qualify them as promising candidates for future spintronic-based devices and magnetic sensors.

Mn-rich Heusler compounds, which belong to a particular class of Mn-based intermetallics, have recently gained enormous attention in the field of high-temperature spintronic devices due to their high Curie temperature, spin gapless semiconducting, and half metallic characteristics, shape memory effect, and peculiar electronic band structure resulting from the interplay between spin-orbit coupling (SOC) and crystal structure. The spin gapless semiconducting Mn_2CoAl compound has been observed with a larger experimental value of AHE than the theoretically predicted value and literature also suggests the presence of atomic disorder in the Mn_2CoAl. Such defect/disorder may affect the electronic band structure and therefore AHE. This observation motivated us for a detailed investigation of structural and magneto-transport properties of the Mn_2CoAl compound through experimental as well as theoretical approaches. Notably, the Mn-rich Heusler compounds exhibit low saturation magnetization, low damping constant, and the coexistence of ferro- and antiferromagnetic exchange interaction that make them potential candidate to search for THE associated with the non-coplanar magnetic texture. Therefore, we have further analyzed the magneto-transport data of the Mn_2CoAl compound to search for the THE. Besides the Mn_2CoAl compound, the Mn_2NiGa compound, which is well known for its shape memory effect, exhibits thermally activated structural phase transition from high-temperature austenite (cubic) to low-temperature martensite (tetragonal) phase, provides a fruitful platform for investigating whether there is any straightforward correlation between the crystal symmetry and Berry curvature induced AHE associated with electronic band structure.

Another important class of Mn-based intermetallics is binary Mn-pnictides, which exhibit high

Curie temperature, large uniaxial magnetocrystalline anisotropy (MCA), spin reorientation transition (SRT), and unique electronic band structure. These materials have recently attracted immense interest for a detailed investigation of magneto-transport properties, including AHE and THE. The non-trivial features in electronic band structure on considering SOC such as linear band dispersion, gapped nodal line, and band splitting, may give rise to a large Berry curvature and AHE. In a recent study on Mn-pnictide, MnAs, the SOC-induced band splitting and enhanced intrinsic anomalous Hall conductivity (AHC) depending on the magnetization orientation have been observed. In addition, the large uniaxial MCA plays an crucial role in the formation of non-coplanar magnetic texture or skyrmion, contributing to the THE. A Mn-pnictide, MnSb, in which literature suggest the presence of SRT, large uniaxial MCA, and AHE, provides a useful platform to explore the effect of SRT on the AHE, and to search for the non-coplanar magnetic texture induced THE due to its large uniaxial MCA.

In addition to the Mn-rich Heusler compounds and Mn-pnictides, the Mn-based antiperovskites with formula Mn_3BA, where B can be Ni, Ga, Sn, Cu, etc. while A can be C, N, B, offer enormous flexibility in accommodating various chemical substitutions/atomic displacement at their three atomic sites and, thereby, the scope for improving the functional properties of these materials. Particularly, the antiperovskite Mn-nitrides have gained a lot of interest due to their geometrically frustrated magnetic texture, giant barocaloric and baromagnetic effect, large AHE and anomalous Nernst effect, etc. The Kondo effect is another interesting phenomenon that is possible in these compounds due to the magnetic impurities resulting from the chemical disorder. Most recently, the AHE has been observed because of the atomic displacement induced spin canting from non-collinear antiferromagnetic spin ordering in the Mn_3SnN compound. Similar atomic displacement and disorder has been anticipated in the Mn_3GaN compound without changing its crystal structure. Therefore, we acquired the temperature-dependent resistivity and magneto-transport data in order to investigate the Kondo effect and AHE in the Mn_3GaN compound.

This thesis is divided into VIII chapters-

Chapter I gives an introduction to several basic concepts related to the AHE, THE, and Kondo effect, followed by a brief review on some Mn-based intermetallic compounds such as Mn-rich

Heusler compounds, Mn-based binary pnictides, and Mn-based antiperovskites, which are being investigated in this thesis.

Chapter II describes the details of the sample preparation methods, and different characterization techniques used to investigate the properties of prepared samples.

Chapter III presents a combined experimental and theoretical investigation of synchrotron x-ray powder diffraction and magneto-transport data in the Mn_2CoAl compound, which reflects that the antisite disorder modifies the momentum space Berry curvature associated with the electronic band structure and enhances the AHE.

Chapter IV presents a giant THE over a wide temperature range (2-300 K) in the Mn_2CoAl compound, which may arise due to the microscopic non-coplanar magnetic structure resulting from the interplay between the cubic MCA, the ferro- and antiferromagnetic exchange interactions.

Chapter V involves a combined experimental and theoretical study of anomalous Hall data in the Mn_2NiGa compound, which concludes that the AHE due to the intrinsic Berry curvature is being suppressed as we move from the less symmetric tetragonal phase to the highly symmetric cubic phase, and suggests that there is no straightforward rule to connect the Berry curvature to the mirror symmetry; rather, it depends on the symmetry-induced change in the electronic band structure. Additionally, we found that the large temperature dependence of AHE in the austenite cubic phase can be explained in terms of side jump mechanism.

Chapter VI provides evidence of changes in the sign and magnitude of intrinsic anomalous Hall conductivity in the MnSb compound, which may arise due to the anisotropic electronic band structure around the SRT. In addition, we observed the THE due to the emergence of skyrmionic bubbles below the SRT, whereas above the SRT, a large value of THE might be attributed to the microscopic non-coplanar magnetic texture.

Chapter VII demonstrates the first signature of a single impurity Kondo effect and a series of magnetic transitions in the temperature-dependent resistivity data of the Mn_3GaN compound. Furthermore, the Hall data reveals the presence of AHE, which is possibly attributed to spin canting from the Γ^{5g} non-collinear antiferromagnetic ordering due to the coexisting phase of the ferrimagnetic

ordering.

Chapter VIII summarizes the key findings of the present thesis and proposes a few suggestions for future work in the field related to this study.