Abstract

Traditional electronic devices rely on the transport of electric charge carriers ‘electrons (e)’ in a Semiconductor devices such as silicon. Now, physicists are trying to take the advantage of the spin of the *e* to create remarkable new generations of "spintronics devices". They are smaller more versatile and stronger. The term “Spintronics” is a portmanteau of spin and electronics.

Spintronics is a developing field of electronics that incorporates the spin property of electrons with their charge property. This integration offers several benefits compared to traditional electronics, including faster processing speed, non-volatility, lower power consumption, and higher storage density. The spin degree of freedom is used in several spintronic devices such as spin diodes utilized in magnetic hard drives, read heads, magnetoresistive random access memory, spin transistors, tunnel diodes, and vortex oscillators. In order to create spintronic devices, it is necessary to use a certain sort of material that limits electrical conduction to just one type of spin carrier, either up or down. In half metals, spin-gapless semiconductors, and magnetic semiconductors, only one kind of spin participates in conduction. Therefore, they exhibited a significant level of spin polarization. The spintronic property is present in various types of materials, including magnetite Fe_3O_4, Double perovskites (La_2CoMnO_6, Pr_2CoMnO_6, Eu_2MnCoO_6, etc.). Heusler alloys have become well-known due to their unique characteristics such as high magnetic ordering temperatures, tunability, and structural stability. The alloys mentioned include $NiMnSb$, $PdMnSb$, $PtMnSb$, Co_2MnSi, Co_2MnGe, Mn_2CoAl, $CoFeMnSi$, $CoFeMnGe$, $CoFeCrGa$, and several Heusler alloys with non-stoichiometric compositions.

The modern hard drive and magnetic random access memory drive read head heads contain the spin valve (SV) structure. A spin valve is a microelectronic device in which high and low resistance states are realized by using the spin of carriers. SVs contain

two ferromagnetic electrodes whose relative magnetization orientations can be switched between parallel and antiparallel configurations yielding the desired giant or tunnelling magnetoresistance effect. In addition to this, the presence of high anomalous Hall conductivity makes the Heusler compounds more promising. Studying the anomalous Hall effect (AHE) with a focus on spin-orbit coupling provides deeper insights into the fundamental physics of condensed matter systems. It unravels the intricate interplay between the orbital motion of electrons and their intrinsic spins, enriching our understanding of quantum phenomena in materials. AHE is a manifestation of spin-orbit coupling and the coupling between electron spins and their motion. A high anomalous Hall conductivity suggests that the material has strong spin-dependent transport properties. This is of interest in the field of spintronics, where the manipulation of electron spins is utilized for information processing. The thesis is structured as follows:

Chapter 1 provides a comprehensive explanation of Heulser Compounds and their structure. The significance of these systems, such as their magnetic and transport properties, is thoroughly examined to understand their characteristics. The text discusses the process behind significant qualities associated with magnetic phenomena such as Spin-Glass (SG), spin frustration, and exchange bias (EB). The fundamentals of resistivity, magnetoresistance, and Hall effect are explored in the field of transport studies. This chapter also includes the objectives of the current thesis.

Chapter 2 focuses on the crucial importance of experimental procedures in interpreting the macroscopic behavior of Heusler compounds. This thesis aims to undertake thorough experimental studies to clarify specific systems' crystallographic, structural, electronic, magnetic, and transport features. The functional characteristics of these materials may be determined by the systematic substitution approach. In order to do this, sophisticated crystallographic, spectroscopic, and microscopic methods have been used, including X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), Raman spectroscopy, and X-ray photoelectron spectroscopy (XPS). The MPMS3 magnetometer is shown here, providing a comprehensive overview of its use in various magnetization measurements. The functioning principle of this instrument is also elucidated. The text discusses the use of cryogenic methods, namely the physical property measuring system, for transport measurement during transportation.

Chapter 3, shows the Co-based Heusler alloys which are the center of interest because of their properties such as high Curie temperature, spin polarization, and high value of exchange bias. Herein, we have used the macroscopic technique to probe the low-temperature exotic properties of $Mn_{1.5}Co_{0.5}FeAl$. First, we analyzed the dc magnetization data, and it unfolds the presence of a glassy phase at 33 K. The cluster spin glass phase is authenticated by measuring AC susceptibility. Furthermore, using empirical models like power law and Vogel-Fulcher fitting, the relaxation time for the spin is of the order of $\tau \sim 10^{-9}$s, confirming the presence of a cluster spin glass in $Mn_{1.5}Co_{0.5}FeAl$ below an irreversible temperature. The H-T phase space diagram ensures that it follows the Ising spin model. Furthermore, the glassy phase of the system is confirmed by magnetic relaxation, memory effect, and the presence of an exchange bias instead of a minor loop below spin-freezing temperature ($T_f \sim 33K$).

Chapter 4 discusses the semiconducting materials with a distinctive blend of high electrical and low thermal conductivity that are required for efficient thermoelectric devices. In this aspect, Heusler alloys are potential candidates for thermoelectric materials. It has been observed that Co doping in Mn_2FeAl enhances the electrical conductivity as well as reduces the thermal conductivity of the system leading to an improvement in figure of merit. The Seebeck coefficient suggested the p-type behavior over the whole temperature range, followed by a maximum at 150 K. Additionally, the electronic properties of the $Mn_{1.5}Co_{0.5}FeAl$, suggests that the observed Raman mode is due to the electronic excitations in the system. Interestingly, this system shows a decoupling between the

Seebeck coefficient and electrical conductivity, suggesting the promising potential of $Mn_{1.5}Co_{0.5}FeAl$ as a thermoelectric material and offering valuable insights into its electronic properties

Chapter 5 discusses the spin valve effect which is a phenomenon in condensed matter physics and materials science where the electrical resistance changes significantly in response to an applied magnetic field, playing a crucial role in magnetic sensing and storage technologies, particularly in the field of spintronics. Usually, Ni-based systems show the presence of asymmetric magnetoresistance, which is dedicated to the structural change under the application of an external magnetic field. Herein, we analysed the resistivity magnetization and structural property of the system to discuss the possible origin of the asymmetry in magnetoresistance. From the structural analysis, it was found that the system contains the antisite disorder as well as the magnetostructural change. To clarify this magneto structural change, the magnetization of the system is recorded. It shows that at T $\sim$ 260 K the system enters into the martensite state from a high temperature ordered austenite state. This finding is also confirmed by the resistivity data. The magnitude of resistance starts to decrease as the system is entered into the martensite state. Furthermore, an anomalous Hall is also observed in the system which also persists up to room temperature. After using the scaling relation, the dominating mechanism for the AHE is extrinsic skew scattering. This is confirmed by the temperature-dependent magnetic data where we observed a bifurcation showing the presence of a mixed state in the system and suggesting the presence of a glassy nature on the system. Therefore, the presence of mixed interaction, decrease in resistivity and change in magnetization of the system with temperature validate the presence of Spin valve in the present system.

Chapter 6 provides a comprehensive examination of the quaternary Heusler alloy *CoFeMnSn*, focusing particularly on the influence of atomic disorder on its magnetic and transport properties. The *CoFeMnSn* system adopts the cubic, standard $L2_1$ structure. The confirmation of antisite disorder is achieved through meticulous Rietveld refinement of the room temperature X-ray diffraction pattern. The Investigation of the impact of antisite disorder on the magnetic properties reveals an increase in the saturation magnetization, indicating a complete ferromagnetic nature sustained up to room temperature. The study extends to the realm of transport properties, where the presence of antisite disorder is found to amplify the magnitude of anomalous Hall conductivity. Further analysis identifies the intrinsic mechanism, specifically associated with the Berry curvature of the system, as the dominant factor contributing to the observed anomalous Hall effect. This detailed exploration sheds light on the intricate interplay between atomic disorder and the magnetic and transport characteristics of *CoFeMnSn*, contributing valuable insights to the broader understanding of quaternary Heusler alloys.

Finally, **Chapter 7**, contains the summary of the present thesis with a brief glimpse of future studies.