Chapter 5

Summary and Future Scopes

5.1 Summary

Transition Metal impurity (Fe) doped Germanium semiconductor was co doped with other sp group impurities, like Donors (As, Sb, Bi, S, Se, Te) Acceptor (In) and Neutral (Sn) atoms and were studied as a function of concentration variation. Investigations of local magnetic and non magnetic interactions were carried out using Fe^{57} Mossbauer spectroscopy, Resistivity, Magnetoresistance, Hall Coefficient and AC Susceptibility were also mesured. The results obtained from these measurements are summarised below.

Study of $Fe_{0.008}Ge_{0.992-x}$ system

- Fe^{57} doped in Ge has shown only one site A which is singlet with IS = 0.31 mm/sec and remains almost constant for iron concentration from 0.2 to 0.8%,this site was identified as due to stable phase $FeGe_2$ formation. It is our starting material where in the concentration of ^{57}Fe was fixed at 0.8% in the Ge host matrix.

Study of V Group Donors (As,Sb,Bi) in $Fe_{0.008}Ge_{0.992-x}M_x$ system

- With As 3% & 5 % only one quadrupole site B has observed and the quadrupole splitting is QS = 1.6mm/sec, it is identified as a stable compound phase of $FeAs_2$. The sample containing 1% As showed two distinct sites A and C. Site A is magnetic with HMF = 121 KOe and a Singlet site C with IS = 0.29 mm/s.

- Sb doped samples show three distinct sites A, B and C. with Sb 0.5 % a singlet site A, a Quadrupole site B and a magnetic site C having HMF = 115 KOe. Similar trend is observed with Sb at 1% and 3%, the Hyperfine Magnetic Field as well as the population of this site were found to be decreasing as a function of increasing Sb concentration. On the other hand, the charge carrier (electron) concentration was found to be increasing as a function of Sb concentration.
- In the case of Bi doped samples two distinct sites A and C are observed, where C is a singlet site and the A site is magnetic with HMF = 129 KOe. As a function of increase in Bi concentration the magnetic site population was increases.

Study of VI Group Donors(S,Se,Te) in $Fe_{0.008}Ge_{0.992-x}M_x$ system

- With S dopants in the system two distinct sites A and C were observed, site C is singlet and site A has HMF = 302 KOe, this field corresponds to FeS compound. Spectra are similar for all concentrations ranging from 0.5 to 5% .
- Se at low concentration of 1%, showed only one site C and at higher concentration of 3 % another site A was seen (along with the site C) with HMF = 133.31 KOe. However, the HMF observed for 5% Se is of stable phases of Fe_7Se_8 and the A site (133.31 KOe) observed in lower concentrations of Se was not observed at this concentrations.

- In the case of Te doped samples Three distinct sites A, B and C are present. Site C is singlet, site B is Quadrupole, and site A is Magnetic with HMF = 136 KOe. This field is constant over the concentration range studied.

Study of Acceptor (In) in $Fe_{0.008}Ge_{0.992-x}M_x$ system

- Acceptor (In)doped Ge sample showed a singlet up to 5 % Indium concentration, only site C is present.

Study of Neutral (Sn) in $Fe_{0.008}Ge_{0.992-x}$system

- Sn atom doped Ge sample showed a singlet site up to 5%. There is no change in the singlet except the line broadening.

XRD characterization of above samples reveals homogeneity with little change in lattice parameter and no additional peaks of other phases were seen. Hall effect and Resistivity measurement in the temperature range 4k to 300k confirms semiconductor behavior. At higher concentration of impurity doping, samples are showing transition from semiconductor to metallic nature. Magnetoresistance data shows positive response to the magnetic field with about a maximum up to 12% change in the resistivity at magnetic field of about 8 Tesla.

The Magnetic Hyperfine Interaction observed at Fe^{57}site in the above systems was found to be following a systematic trend. Introduction of donor impurities increases population of charge carrier (in this case electrons) densities and the magnetic interactions are observed in this case were found to be varying with change in the concentration. However in the case of neutral and acceptor impurity doped samples magnetic hyperfine field was absent. This shows there is a tendency to form donor-acceptor pairs (DAP) and possibly sp-d interaction between them is responsible for the moment formation with Fe as the acceptor in Ge. It also indicates that there is a long range interactions between Fe moments via charge carriers, it shows dependence on the population of charge carriers as well as nature of the charge carriers. However in all other donor doped samples the AC Susceptibility measurements gave a very weak signal (except in the case of the higher concentration of Bi doped samples). Hence it appears that it is possible to get reasonably good strength of the AC signal if the donor concentrations are higher (than studied presently) in the system, which can give better evidence for the carrier mediated magnetism.

5.2 Future Scope

Donor impurities doped $Fe_{0.008}Ge_{0.992-x}$ DMS system seems to be very important for the application in SPINTRONICS device fabrication as discussed in previous chapters . We have proposed magnetic moment formation through sp-d exchange interactions between electrostatically bound Acceptor (Fe) and Donor (sp metal) pairs, the stability and strength of the magnetic moment is observed to be dependent on charge carrier (electron) concentration. The work done on the Hyperfine Magnetic interaction at Fe^{57} through Mossbauer spectroscopy can be extended by replacing the other (TM) isotopes present in the system. For evaluating interaction strength between nearest neighbor and induced moment it is valuable to study the transferred hyperfine magnetic fields at the neighboring (to Fe) nuclei of impurity (Sb, Bi and Te) ions. The sensible way is to implant suitable radioactive ions at these sites and study the magnetic interactions at the nuclei of these ions through TDPAC or on line Mossbauer spectroscopy.

Surfaces and interfaces of solid materials have become a field of tremendously growing interest in many areas of physics, in particular in ultrathin metallic layer magnetism. The information on the variation of magnetic properties from atomic layer to atomic layer of ultra-thin multilayer systems is of fundamental interest. Therefore, local structural and electronic properties of surfaces and at interfaces measured on the atomic scale are in the centre of many investigations. For the future experiments, we have grown thin films of our system and have started characterizing it.

We would like to perform the in beam conversion electron Mossbauer spectroscopy by implanting ^{57}Mn into the Fe site of the sample.

In order to observe the transferred hyperfine magnetic field at the other participating atoms in the system, we intend to implant As, Sb, Se, Te as a probes.

7.1 hour ^{73}Se → ^{73}As, ^{116m}Sb → ^{116}Sn (5-, 370ns), 60.4m and 57 hour ^{77}Br → ^{77}Se shall be exploited for a TDPAC study. 38hour ^{119}Sb → ^{119}Sn can be used for online Mossbauer Spectroscopy.

The above isotopes with good yield has proven to be suitable for TDPAC studies. For such short lived isotopes the online radioactive ion beam is needed and is available at CERN, Geneva.

The experiment was proposed for doing at ISOLDE, CERN, Geneva and our proposal has been accepted. We are waiting for the beam time allotment for our experiment.