THE STUDY OF COEXISTENCE OF SUPERCONDUCTIVITY AND SPIN GLASS IN IRON PNICTIDE($Fe_{1+Y}Se_XTe_{1-X}$)

By

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Abstract

Superconductivity and magnetism were previously thought as incompatible until the discovery of some rare earth ternary compounds that shows the coexistence of superconductivity and magnetism. In some of the recently discovered iron-based layere. Superconductivity and magnetic order system are coexist, that occur in only 11 and 122 family. The present work we examine the possibility of coexistence of superconductivity and disorder of magnetic spin is called spin glass, when freeze the system that can show the superconductivity and spin glass coexist. In this present work we can examine the possibility of coexistence of superconductivity and spin glass in detailed 11 family of $Fe_{1+Y}Se_XTe_{1-X}$ compound. We show that spin glass like behavior is present in FST for b/n X=0.1 and X= 0.15. We present evidence form magnetization measurement and characterized the short-range order with neutron scattering. One of our main results in the short-range order depend on structural as well as magnetic order. The factor of magnetic order exchange in long range depend on temperature, pressure, number of doping and other external factor discussed it. We found mathematical expression for superconductor transition T_C, spin glass temperature T_g, Susceptibility X(q) and retardation time τ using for born approximation and digamma function depend on wave vector(q) and cut off frequency(ω) in the region coexistence of superconductivity and spin glass in $Fe_{1+Y}Se_XTe_{1-X}$ compound.

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ANTENEH YESIGAT

Introduction

Superconductivity is a phenomena occurring in a certain materials at extremely low temperature, characterized by exactly zero electrical resistance as wall as there is no magnetic field. It was discovered in 1911 by Heike kamerlingh Onnes, who was studying the resistance of solid mercury at extremely low temperatures using the recently discovered liquid helium as a refrigerant. He found that DC resistivity of suddenly drops to zero below 4.2 k and [1] observed that the resistance appropriately disappeared[2]. Superconductivity has been found early in various elements such as mercury, lead and aluminum. Most early superconductors are superconducting at extremely low transition temperature and low magnetic field.

Until 1986 was record the highest critical temperature was 23 K for Nb_3Ge. In this time a new La-Ba-based copper-oxide superconductor $(La, Ba)_2CuO_4$, with critical temperature of 35 K was discovered by Alex Muller and Georg Bednorz[1]. During the past decades, it was subsequently established that superconductivity in all of these high temperature superconductors (HTS)containing Y, Bi, Tl and Hg instead of La can be maintained up to much higher magnetic field and temperature. Moreover, materials of this class of oxides have been discovered with transition temperature well above 100 K in 2001. The discovery of non-oxide based superconductor in MgB_2 by Nagamatsu and Akimitsu [3] has restored the huge interest in the field of superconductivity. The remarkable discovery renewed interest in the superconductivity related material, which is to known as cuprtes were discovered until highest value of critical T_c=134 k was achieved in 1993.

In recently February 2008, Hideo Hoson(from the Tokyo Institute of Technology in Japan) has discovered an iron-based superconducting material in LaOFFeAs (1111) family. The critical temperature for this iron-arsenide compound with lanthanum, oxygen and fluorine is 26 k. The general formula (1111) family RFeAsO, where R-replaced by (R= La,Ca,Sm,Pr,Nd) and other rear earth elements. The corresponding elements increase the transition critical temperature markedly: 41 K for Ce, 52 K for Pr, 52 K for Nd and 55 K for Sm. The Superconductivity has been also discovered in fluorine-free systems, including $RFeAsO_{1-X}$ (R=La, Ce, Pr, Nd, Sm, Gd and T_C value b/n = 31K - 55 K), it was surprising that there could be another material other than the cuprate which could become superconducting an elevated temperatures. The recent discovery of non-oxide superconductors in MgB_2 and iron-based compound RFeAsOF would also assist theoretical physicists to be closer to a fundamental understanding in the basic mechanism behind high temperature of superconductivity. In general, the iron pnictide superconductor family has been quickly expanded to six different structures and the superconducting transition temperature has been rapidly raised to approximately 57 k.

Most physical properties of superconductors vary from material to material, such as heat capacity, critical temperature, critical current density and critical field at which superconductivity is will differ. However, there is a class of properties that are not dependent of the mentioned material. For instance, all superconductors have exactly zero resistance and there is no internal magnetic field[4].

Inter play between superconductivity and magnetism interesting topic in condensed matter physics. The magnetic system exhibit different types of order depending on temperature(T), spin alignment based on external magnetic field(H) etc. In experimentally a magnetic material frustration in the spin of interaction that is called spin glass(S.G). Some property of spin glass as following can be show that (i) low field low frequency a.c susceptibility $X_{a.c}$ (T) exhibiting a cusp of at temperature T_g, the cusp can get flatted at temperature cold for small magnetic field(H) as 50 Gauss. (ii) no sharp anomaly appears in the specific heat. (iii) AC susceptibility begins to deviate from the curie low at temperature $T >> T_g$ and soon. Superconductivity and ferro-magnetism are often thought to be incompatible, according to BCS theory[5], a superconductor explain in a magnetic field, which in turn destroys superconductivity. However, both superconductivity and magnetic order has been seen in harmony(coexists) in some of rare earth compound. The coexistence of superconductivity and ferro-magnetism is quite peaceful and very weakly influences each other. Mostly the superconductivity coexist with spin glass occur in (11) and (122) family, because they have vary at low critical temperature $Fe_{1+Y}Se_XTe_{1-X}$ and $Ba(Fe_{1-Y}Co_X)_2As_2$ there is evidence for coexistence of Spin glass and superconductivity. In generally believed that magnetism play fundamental role in superconducting mechanism like other family, because superconductivity occurs when mobile electrons or holes are doped into anti-ferromagnetic elements like Te or Se parent compound. Experimentally has been revealed that superconductivity and spin glass coexist in Selenium (Se) and Tellurium (Te) iron pnictide compound of $(Fe_{1+Y}Se_XTe_{1-X})$ with occur in the short range in the region of $(0.1 \leq X \leq 0.5)$.

In this paper we studied theoretical coexistence of superconductivity and spin glass(SG) in $Fe_{1+Y}Se_XTe_{1-X}$. For this reason we include literature review on magnetism and superconductivity in iron based in the first chapter, mathematical method of formulation in the second chapter, and theoretical formulation the in third chapter and finally summery in fourth chapter.

Chapter 1

Review of Literature

1.1 Over View of Ferro pnictides

A discovery of high temperature superconductivity in cuprate superconductors appears in twenty years ago. In the recent time the high temperature of superconductor unexpected discovered based on Fe-Pnictides approximately six different structure of the FeAs layer families have been found. They are 11, 111, 122, 1111, 32522 and 21311(or 42622) families. Let see different families of Fe-pnictides.[1,2]

1) 1111 family[1]

The first discovery of high-T_C superconductivity in $RFeAsO_{1-X}F_X$ for (R= La, Sm, Ce, Nd, Pr). The critical temperature (T_C) rapidly increased by exchanging lanthanum with rare earth ions of smaller atomic radii in LaFeAsO and appropriate carrier doping or creating oxygen deficiency, it reached a maximum value of ∼56 K until in $Gd_{1-X}Th_X$ FeAsO. This family LaFeAsO came to be known as 1111 family. Note that LaFePO also discovered by Kamiara et al in 2006 was the first 1111 compound to show superconductivity but with very low (T_C ∼5 - 7K). In addition to $LaFeAsO_{1-X}F_X$, the most remarkable 1111 compounds that show high-T_C superconductivity discovered until now are:

(i)SmFeAs$O_{1-X}F_X$(T_C ≈43 K)

(ii)CeFeAs$O_{1-X}F_X$(T_C ≈41 K)

(iii)NdFeAs$O_{1-X}F_X$(T_C ≈ 51 K)

(iv)PrFeAs$O_{1-X}F_X(T_C \approx 52$ K)

2)122 family.

RFe_2As_2 for (R= Ba, Ca, Sc) $BaFe_2As_2$ as a potential new parent compound based on the similarities between $BaFe_2As_2$ and LaFeAsO. In fact, both compounds contain identical(FeAs)layers, and have the same charge accordance as follows: $Ba^{2+}[(FeAs)]$ vs $(LaO)^+(FeAs)$. Partial replacement of Barium with Potassium (hole doping) induced superconductivity at 38 K in $Ba_{0.6}K_{0.4}Fe_2As_2$ the first member of a new family of superconducting iron arsenide known as the 122 family. This discovery was followed by reports of similar compounds with:

(i)Strontium ($T_C \approx 37K$)

(ii)Calcium ($T_C \approx 20K$)

(iii)Europium ($T_C \approx 32K$). Later electron doping in $BaFe_2As_2$ by the partial replacement of Fe with Co with $T_C \approx 22K$ was reported by Se fat.

3) 111 family.

The discovery of another new superconducting iron arsenide system AEFeAs (AE= alkaline metal) Superconductivity with T_C up to 18 K in these compounds.

4)11 family

The observation of superconductivity with zero resistance transition temperature at 8 K in the PbO-type α-FeSe compound known as 11 family. Although FeSe has been studied quite extensively, a key observation is that the clean superconducting phase exists only in those sample prepared with intentional Se deficiency.

- The crystal structures of the four families of iron pnictide are discussed briefly below.

1.2 Crystal Structure of Fe pnictide

1)1111 family[1]

LaFeAsO (1111) family of iron pnictide crystallizes in the ZrCuSiAs type structure, (space group P4/nmm). In this structure, two-dimensional layers of edge-sharing $FeAs_{4/4}$ tetrahedral alternate with sheets of edge sharing $OLa_{4/4}$ tetrahedral as shown below fig 1(a). Because of the differences between the ionic nature of the La-O(Lanthanum oxide) bonds and the more covalent Fe-As (iron arsenide) bonds, a distinctive two-dimensional structure forms, where ionic layers of lanthanum oxide $(LaO)^+$ alternate with metallic layers of iron arsenide $(FeAs)$.

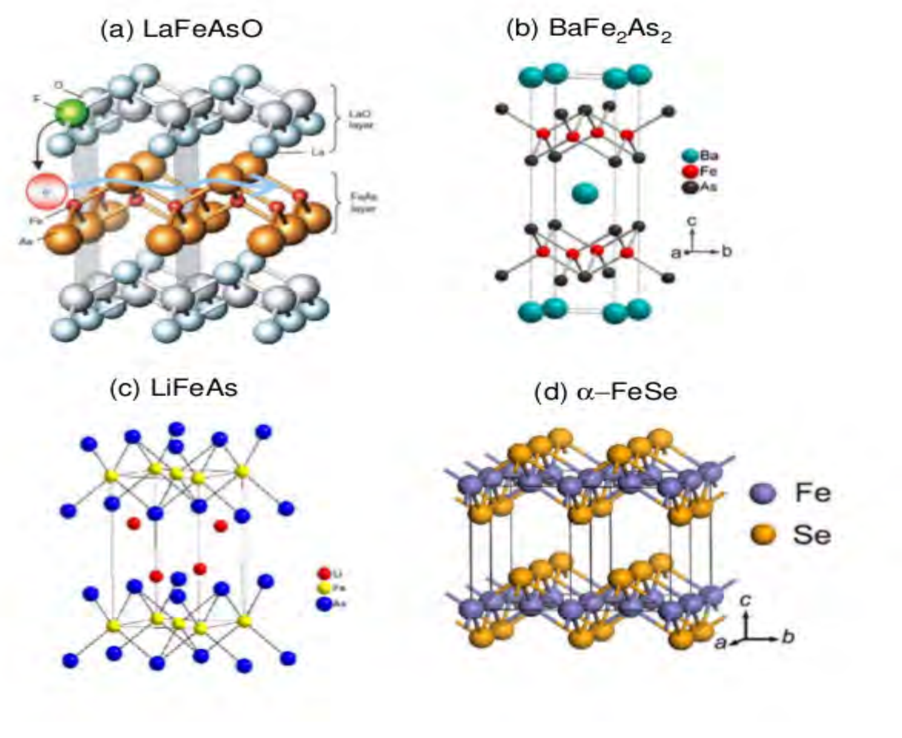

Figure 1.1: Schematic crystal structure of:(a) LaFeAsO, (b)$BaFe_2As_2$ (c) LiFeAs (d) $\alpha FeSe$Ref.[1]

2)122 family

The ternary iron arsenide $BaFe_2As_2$ with the tetragonal $ThCr_2Si_2$-type structure (space group $I_{4/nmm}$) contains practically identical layers of edge-sharing $FeAs_{4/4}$ tetrahedral but they are separated by barium atoms instead of LaO sheets. This structure is shown in Fig 1.1(b).

3)111 family

LiFeAs crystallizes into a Cu_2Sb-type tetragonal structure containing[FeAs] layer with an average iron valence Fe^{2+} like those for 1111 or 122 parent compounds. This structure is shown in Fig 1.1(c).

4)11 family

The PbO-type $\alpha FeSe$ crystal structure is shown in Fig 1.1(d). They have been particular interest the activity brining between the magnetic spin fluctuation and superconductivity. When the anti-ferromagnetic (AFM) order associated with the Fe-X(X = As/Te) layers is weakened by doping electrons or holes. Mostly occur in (1111)and (122)families, such as $SmFeAsO_{1-X}F_X$ and $Ba(Fe_{1-X}Co_X)_2As_2$ there is evidence for coexisting anti-ferromagnetic order and superconductivity. The other situation different in the chalcogenide system in 11 family of $Fe_{1+Y}Se_XTe_{1-X}$ compounds.

Here detail in sensitive to the Fe as well as Se concentration and we will focus on the situation for decrease excess Fe ($i.e, Y \approx 0$). The Neel temperature drops rapidly for $X \lesssim 0.1$ but our measurements indicate that bulk superconductivity only appears for $X \gtrsim 0.4$.

We will present the $Fe_{1+Y}Se_XTe_{1-X}$(FST) compound in magnetic and superconducting property as well as the coexistence of spin glass with superconductivity behavior in the short regime.

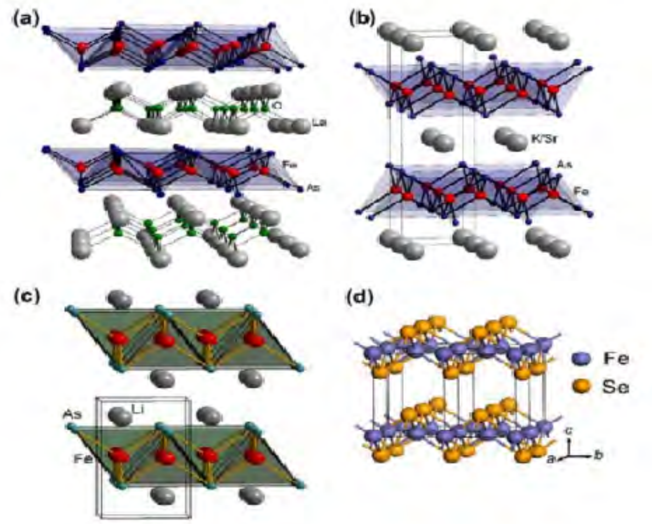

Figure 1.2: The four pnictide families currently known the superconductor occur the Fig(a,b,c) three metallic layer is FeAs but Fig(d) metallic layer in FeSe Ref[6]

1.3 High-Tc Superconductivity in Iron pnictide

High-Tc superconductivity at 26 K was reported by Kamihara et al. He was seen LeFeAsO (1111) family for doping of fluorine element to form $LeFeAsO_{1-X}F_X$ compound was formed. The high T_C superconductor is completely a new class in nitrogen family for Fe based compound is called iron pnictide. This was the discovery as generated a great interest of material sciences community opening a new route for the high T_C in the Fe-pnictide class. However, this has also brought new challenges on both experimental and theoretical side view. A new problem for material scientists in the cuprate and ferro-pnictde. Let see LaFeAsO 1111 family compound dope electron transfer from oxygen to fluorine atom that compound change to $LaFeAsO_{1-X}F_X$ form. This is completely new class increasing T_C value, so this iron based compound is called iron pnictide. I will discus low T_C in 11 iron family[1].

From the above figure see for the previous year conventional superconductor occur in heavy element like(Hg, Pb,..) in the half century the compound form superconductor

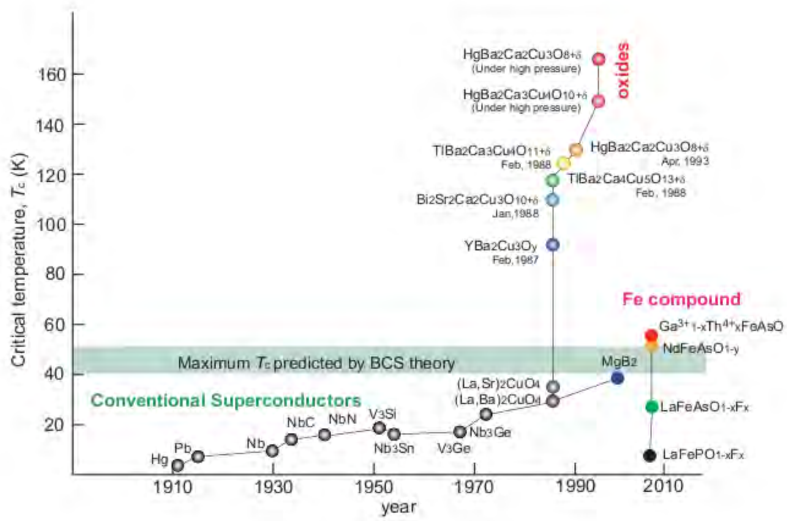

Figure 1.3: The time evolution of the superconducting critical temperature.Ref.[1]

exist very low critical temperature. The compound that have CO_2 layer is called cuprate, recently interesting study of superconductivity coexist with magnetism by exchange magnetic interaction and electron interaction study by BCS theory, the corresponding CO_2 layer change to FeAs layer.

- For the different family of Fe-pnictide have different T_C value.

Families	Formula	T_C Value
11	$Fe_{1+y}Se$, $FeTe_{1-X}Se_X$	8 k
111	LiFeAs, NaFeAs	18 k
1111, oxygen based	electron doping $ReFeAsO_{1-X}F_X$ hole doping $RE_{1-X}AE_XFeASO$	55 - 56 K,25 K
1111, Florine based	$AE_{1-X}RE_XFeAsF(AE = Ba, Sr, Ca)$	56 - 57 k
122	$AE_{1-X}AL_XFe_2As_2AE(Fe_{1-X}TM_X)_2AEFe_2AS_{2-X}P_X$	38 K, 20 - 28 K, 30 K
32522	$Sr_3Sc_2O_5Fe_2As_2$	0 k

Table 1.1: For Six different structures and typical superconductors in the FeAs-based system. Abbreviations: RE, rare earth; AE, alkaline earth; TM,(3d5d) transition metals; HP, high pressure[2]

1.4 Inter relationship existence of Fe-pnictide with cuprate

The electrons in Fe-pnictide are strongly correlated as cuprate, which surely in their parent and lightly hole doped state evidently behave Mott-insulator.

•Important similarity between Fe pnictide and cuprates.

1)Both are layer system.

2)Both have d-electron playing a crucial role.

3)Both feature close proximity of AFM order and SC in respective phase diagram.

•But there are critical difference as wall as.

1)The d-electron count in Fe use six (even) but Cu use nine(odd).

2)The parent state of a CuO_2 layer can be modeled by a single (hole) half-filled band and discovered band-structure theory, should be good metal.

3)Cuprate are any thing but as their parent state is turned into Mott-insulter and Neel AFM by strong short-range coulomb repulsion U. Penalizes putting two electrons or holes in this case on the same site making it impossible to move the charge around in a(half-filled band) in the context having six d-electrons or four d-holes in a filled d-shell Fe-pnictide demand a multi-band description from the start.

4)Fe pnictide layer demand a multi-band description. It parent is semi-metal for several electron and hole pocket on Fermi surface defined as boundary b/n occupied state function of momentum.

	CuO_2 Systems	$FeAs$ Systems
Mother Compound	AFM order $T_N \sim 500$K	Structure phase change $T_S \sim 150$ AFM order $T_N \sim 135$K
Phase diagram	Carrier doping	Chemical Substitution pressure
Electronic state	Single band	Multi band
SC order parameter	d-wave $T_C = 135K$	Extend $S_{\pm} - wave$ T_C= 57 K
pairing Glue	AFM interaction	Under debate??

Table 1.2: Summary of cuprate and Fe pnictide

•The Fe-pnictides also different with chalcoginides concerns the nature of AFM order.

1.5 Superconductivity in Meissner Effect

The Meissner effect was discovered in 1933 by Water Meissner and Robert Ochsnfield[9]. It is one of the properties of superconducting materials. When a superconductor below critical temperature (T_c) is placed under a weak external magnetic field B, it repels the magnetic flux (field) B completely from its interior. It does setting up electric currents near to surface. The magnetic field of these surface currents that cancels out the applied magnetic field with bulk of superconductor. However, near to the surface distance called the London penetration depth. The magnetic field is not completely canceled, this region also contains the electric currents, whose field cancels the applied magnetic field with in the bulk superconductivity. This exclusion of magnetic flux from superconductor(B = 0) is known as Meissner effect[7].

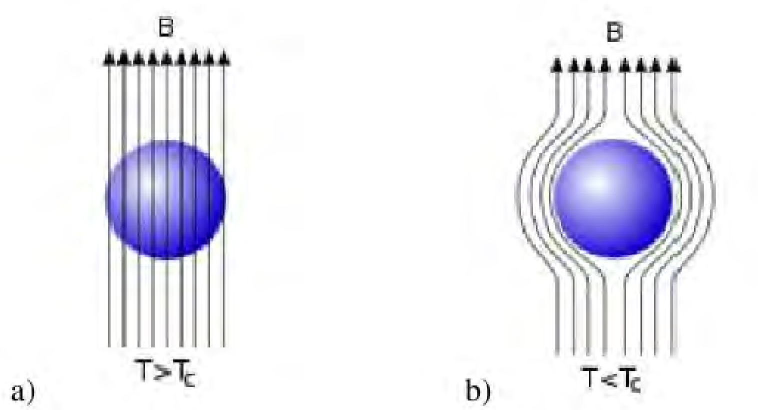

Figure 1.4: The Meissner effect.Ref.[8]

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a) Magnetic field penetration above the critical temperature.
b) Magnetic field explained from it below critical field.

$$(CGS)B = B_a + 4\Pi M = 0$$

$$\frac{M}{B_a} = \frac{-1}{4\pi} \tag{1.5.1}$$

$$B = B_a + \mu_o M = 0$$
$$(SI)\frac{M}{B_a} = \frac{-1}{\mu_o} = -\epsilon_o c^2 \tag{1.5.2}$$

The result B= 0 can not be derived from the characterize of superconductor as medium of zero resistivity. From Ohm's law $E = \rho_j$. We see that if the resistivity ρ goes to zero while current density(J) is held finite, E must be zero. By the Maxwell equation relation $\frac{dB}{dt} = \nabla X E = 0$, so that zero resistivity implies $\frac{dB}{dt}$= 0. This argument is not entirely transparent. But the result predicts that the flux through the metal can not change on cooling through the transition. The Meissner effect suggests that perfect diamagnetic is an essential property of the superconducting state.[9]

1.6 General Overview of Superconductivity in Fe pnictide

Cuprate can be understood with in the strong electron correlation picture with the valance electron of pnictide show more itinerant and good bond-structure. The anti-ferromagnetic and superconductor in the pnictide need to be considered including the three-dimensional electronic structure which is not the case of cuprate. Moreover, the Fermi surfaces of Fe pnictide in contrast with a single Fermi surface in cuprate and an unusual chemical potential shift in cuprate whose origin may be the strong electron correlation as compared with a simple rigid band-model shift in case of pnictide. The superconducting occur in the Fe-pnictide for differently physical and chemical property this pepper detailed in 11 compound family[1].

1.7 Superconductivity of $FeSe_{1-X}Te_X$ compound

The family of Fe-based superconductor on FeSe has attracted extensive attention for similar to those FeAs layer mentioned above crystal structure in fig (1.d) The FeSe superconducting transition temperature of Tc ($\sim 8K$) exhibits a compositional dependence, decreasing for both under doped and over doped material[54] as observed in the cuprate. When see Crystal structure does not have a separating layer in ferromagnetic. For (11) type pnictide the T_C value around 8 K. Superconductivity show only, when prepared with deficiency of selenium (Se) and substituting doping of electron from Tellurium (Te) element.

The PbO-type compound $FeSe_{1-X}Te_X$ in the region b/n X= 0 and X=1, the Te doping concentration has an effect on superconductivity.[10-12] It was found that superconducting transition temperature increases with Te doping maximum electron that reaching a maximum $T_c \sim 15K$ at about $50 - 70\%$ substitution, and then decreases with more Te doping. For polycrystalline of FeSe and $FeSe_{1-X}Te_X$ sample compound can be also increase T_C value with applying pressure. Superconducting phase transition has been found as high $27K$ at $1.5GPa$, when we see in FeSe or $FeTe_{1-X}Se_X$ compound the transition temperature was improved to approximately 37 K. The structural distortion change the lattice parameters with out breaking magnetic symmetry was reported and believed to have a strong correlation with the occurrence of superconductivity. This suggests that a detailed investigation of the magnetic and electronic behavior of these material that interplay with structural change.[13]

$FeSe_{1-X}Te_X$ crystal with Te doping ($X \geq 0.5$), although resistivity measurement show superconductivity with on set transition temperatures around 14 K for b/n X = 0.5 and X= 0.7 the resistance did not zero down in crystals of X = (0.9, 0.75, 0.67, 1.0). Note that in polycrystalline sample with X= 0.9 there is also a non zero residual resistance. The fact that the resistance does not completely reach zero indicate a nonuniform distribution of Se and Te consequently a low concentration of superconducting component in as grown crystal. The FeSe is also much easier to synthesize, since it $doesn't$ include toxic arsenic.[10,11,14]

- For T_C values varies it depending on doping elements $FeSe_{1-X}Te_X$.

starting composition	Crystal composition	T_C, on set	$\Delta T_C, (K)$
$FeSe_{0.7}Te_{0.3}$	$FeSe_{0.56}Te_{0.41}$	8.9	3.8
$FeSe_{0.5}Te_{0.5}$	$FeSe_{0.39}Te_{0.57}$	13.1	2.2
$FeSe_{0.4}Te_{0.6}$	$FeSe_{0.3}Te_{0.66}$	13.1	2.8
$FeSe_{0.3}Te_{0.7}$	$FeSe_{0.25}Te_{0.72}$	13.6	1.5
$FeSe_{0.1}Te_{0.9}$	$FeSe_{0.09}Te_{0.86}$	11.5	2.3

Table 1.3: Chemical Compositions, Superconducting Properties and Structural Characteristics for $FeSe_{1-X}Te_X$ Single Crystals[15]

1.8 Magnetic correlation with superconductor in $FeSe_XTe_{1-X}$ Compound

We discuss the phase diagram of this compound $FeSe_XTe_{1-X}$ in 11 iron family. These compound form with the largest amount of extra Fe observed near the Te rich side of the phase diagram. Initial measurement of the $Fe_{1+Y}Te_{1-X}Se_X$[16] compound show superconductor with critical temperature at 15 K for $X \sim 0.5$, there exist for all value less than 0.5 but when the value of X near to Zero the superconductivity will be destroyed. Under this condition different phase diagram of superconductivity can be occur. However, specific heat measurement in the single crystal that indicate bulk superconductivity for only concentration near to X = 0.5. From this circumstances, the phase diagram was investigated and indicated magnetic order for small value of X, which coexist with superconductivity over a range of concentrations in a manner very similar to the doped (122) and (1111) materials e.g $SmFeAsO_{1-X}F_X$. As mentioned previously, materials with low Se concentrations have a tendency to form with excess Fe to measured the phase diagram with sample intentionally grown with $Fe_{1.03}$ at $Y \approx 0.03$. It show an additional spin glass phase which coexist with superconductivity over much of measured concentration range. This show the sensitivity of these material to stoichiometry and particular amount of excess Fe present.[17]

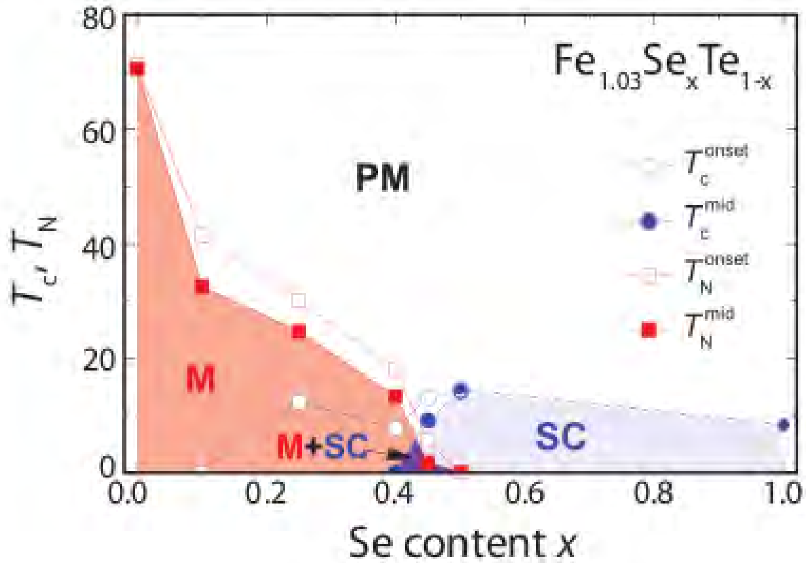

Figure 1.5: Experimentally determined phase diagram for $Fe_{1.03}Te_{1-X}Se_X$(Reprinted with permission from copyright 2009 the American Physical Society)Ref[18].

Although, discussed above there are some differences in the concentration dependent phase diagram of various Fe-based superconductor shows that there are some common features. All materials exhibit a SDW state at low concentrations and this state suppressed with doping allowing for the emergence of superconductivity.This show strong similarity with cuprate phase diagram[18]

The paramagnetic impurity theory of superconductivity is show the superconducting transition temperature was supposed by magnetic impurities. At some critical impurity concentration the transition temperature down to zero. which gives an example of a quantum critical point. The critical concentration can be determined by this condition: $\tau_s T_{CO} = \frac{2\gamma}{\Pi}$, where T_{CO} is the superconducting transition temperature with out impurity and τ_s the inverse proportion $(\tau \sim \frac{1}{n_s})$ $(n_s \sim \frac{1}{\tau_S})$ It is the inverse life time the spin-flip process for conduction electron. Note that The effect of magnetic impurity on S.C is many aspects, similar to the one of the external magnetic field.

★ Theoretically we can distinguish two region.[19]

1)The first region above the concentration dependent magnetic critical temperature T_M, it mens the transition of temperature from magnetic order change to disordered state. For above ($T > T_M$), it valid to assume that the magnetic impurity are non-interacting. Abrikosov and Gorkov (AG) have shown that the superconducting transitions temperature T_C decreases linearly as a function of the concentration(X) at small concentration of magnetic impurities and vanishes at a critical impurities concentration X_{AG}. However, near the magnetic transition the assumption of non interacting magnetic impurities break down.[20]

2)The second region of interest in $T < T_M$, where the interaction between magnetic impurities are strong and spontaneous magnetic ordering set in. There exists an additional exchange field acting on the conduction-electron spin and conduction-electron scattered by excitation of spin system. Additional mechanism lead to pair breaking in the superconducting state, for ferromagnetic ordering it is difficult to modify AG theory in this region to account for the magnetic interaction because of these additional mechanism.[21]

1.9 Spin Glass Magnetic Ordering

According to Edwards-Andersen model said that atoms are located on lattice point at regular intervals in a crystal. This is not the case in glass, where the positions of atoms random in space. An important point is that in glasses the apparently random locations of atom do not change in a day or two in to another set of random locations. A state with the spatial randomness apparently does not change with time. The term spin glass implies that the spin orientation has been similarity to this type of location of atom in glasses: spin are randomly freezing in glass is called spin glass. Spin glasses are disordered or random solid state magnetic system in nonmagnetic host characterized by a random freezing of spin at rather well defined temperature T_g. It is the transition temperature exchange of impurity particle. However, it is very difficult to investigate the effect of single magnetic impurities experimentally based on measurement of sensitivity.In spin glasses the concentrations of the magnetic ion has to be small so the magnetic impurities substitute non-magnetic element at random position is known as QUENCHED[22], the other hand the crystallographic disordering an inter metallic compound. This characteristics of spin glass system namely FRUSTRATION. That able to detect the effects that need one needs a sufficient number of these impurities. It is also important to exists long-range interaction the magnetic spin is far apart between the (localized) impurities via the conduction of electrons.

The very important property of spin glass is their *unique nature* is the oscillating character of the exchange interaction. Because the randomly located spin that have interactions of essentially random sign,so that spin glass is the peculiar (Douala) characteristics. The effective coupling between the magnetic moments can be either ferromagnetic or anti-ferromagnetic in short-range ordered is particularly favored energetic, it depend on the separation distance between two impurities. For example consider the square lattice, here (+) corresponds to $J > 0$ (ferro) and (−) to $J < 0$ (anti-ferro). Where J exchange interaction strength. The individual band energies are minimized if the two spins connected by any arbitrary bond $\langle ij \rangle$ are *parallel* to each other for $j > 0$ and anti parallel for $J < 0$. Now, since the impurities are randomly located with in the crystal. The magnetic interactions are also randomly distributed. Thus the term spin glass is used in analogy with a real glass or an amorphous solid where the atoms are randomly distributed without any order or regular structure.[22]

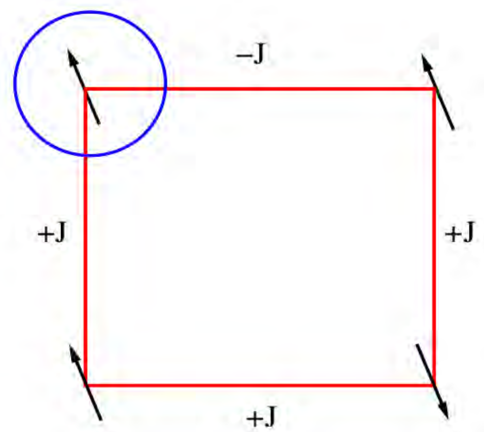

Figure 1.6: Illustration of Frustration: The circled spin receives conflicting information from its neighbors and can point either up or down with the same energy. There is no way of minimizing its energy.Ref[23]

The electrical resistivity, as well as the specific heat has been measured in the spin glass systems. From this measurement it has been found that a great deal of short- range magnetic clustering is already present at $T < T_g$. Such measurements establish beyond doubt that a majority of the spin participate in a local type of correlation. As temperature is lowered many of the randomly located, freely rotating spins come together by means of the correlation into clusters that can then rotate as a whole. The remaining isolated spins are uncorrelated but serve to transmit interactions between the clusters. At $T = T_g$ these independent isolated spins freeze out in random directions.[24,25]

Spin glass is rapidly developing aspect of solid which limit the usage of metallic alloys where long-range magnetic interactions are present. It is this long-range interaction (short-range interaction may also be present through to a much smaller extent) that produces the random freezing of the spin moments a rather well defined temperature T_g Short range and long range it depend on J_{ij} factor by $r_i - r_j$ distance b/n neighbor spin. $|J_{ij}| \to \infty$ for long range and $|J_{ij}| \to 0$ Short range. We have also examined a variety of recent experiments performed on spin glass alloys with respect to three ranges of temperature $T > T_g$, $T = T_g$ and $T < T_g$. When $T > T_g$ the system usually occur in paramagnetic $T < T_g$ is the magnetic susceptibility to be constant in the agreement in the experimental result and $T = T_g$ is not reel but on artifact the temperature depends on Q [26]. In the interpretation of the experimental behavior a phenomenological model depending on the dynamically growing. It has been observed even at $T = T_g$ that some local correlations among the randomly separated spins also exist. The growth of magnetic clusters continues until $T \simeq T_g$, when a few of the largest clusters freeze out in random orientations. The spin glass behavior may be theoretically described by the method of critical phenomenon by Edward and Anderson. Apart from small ferromagnetic clusters above T_g clusters with more or less random spin directions are indicated by specific heat measurements, to fluctuate rapidly with time but instead are locked into random orientation. The random spin freezing mathematically.

$$\langle S_i \rangle_{\tau_0} = \tau_0^{-1} \int_0^{\tau_0} S_i(t)dt \tag{1.9.1}$$

are non for some range of τ_0. Their mean square.

$$q(\tau_0) = N^{-N^{-1} \sum_i \langle S_i \rangle_{\tau_0}^2} \tag{1.9.2}$$

is this nonzero for some τ_0 . The absence of *long-range* order and the for a fixed impurity configuration we have, for $T > T_g$

$$\sum_i g_i \langle S_i \rangle_{\tau_0} = 0 \tag{1.9.3}$$

Since the internal energy felt by a spin averages to zero if the (thermal) average is taken over a sufficiently long time, where as for $T < T_g$ we have for spin glasses.

$$g_{ij} \langle S_i S_j \rangle = 0 \tag{1.9.4}$$

Hence the spin glass order parameter is related to the above equation will give to Zero result.

$$|i - j| \to \infty \tag{1.9.5}$$

1.10 Ginzburg-Landau theory of fluctuation

Generalized Ginzburg-Landau theory for a spin glass and superconductor that based on a free energy functional depending on superconducting and spin glass order parameters is presented. It is found that the coupling between the superconducting and spin glass order assists in freezing of spins by enhancing the spin glass order parameter but acts as pair breaking effect for superconducting order by decreasing the superconducting order parameter, while the BCS is a weak-coupling microscopic model theory. Which is very powerful and provide at least a quantitatively correct description of most aspects of classic superconductor and spin glass, whose the energy gap is constant in space. There is a complimentary theory which is simpler and more physically transparent. Although valid only near transition and provide exact result under certain circumstances such as existence of spatial homogeneity. This is the macroscopic Ginzburg-Landau theory.[7,27,53]

1.11 The BCS theory

The BCS theory was developed by Bardeen, Cooper and Schrieffer in 1957 to quantum-mechanically treat superconductivity. All properties of superconductors attractive effective $e$lectron-electron interaction to form Cooper pairs, when see the ferromagnetic can cooled temperature the sign and direction of magnetic field applies an opposing field and large enough to polarize them in the opposite direction. So that magnetism and superconductivity might coexist. In some dilute solutions of magnetic ions in superconductors the presence of the vague susceptibility peaks and permanences characteristic of spin glasses.

BCS theory of superconductivity with a very wide range type (I) and type (II) metallic superconductors and to high-temperature superconductors based on planes of Fe pnictide layer. Further, there is a "BCS wave function" composed of particle pair $K\uparrow$ and $k\downarrow$. The familiar electronic superconductivity observed in metals and exhibits the energy gaps. This pairing is known as s-wave pairing.

- The BCS theory with wave theory with a BCS wave function, which include:

1) An attractive interaction between electrons can lead to a ground state separated from excited states by an energy gap (Δ).(The critical field, the thermal properties, and most of the electromagnetic properties are consequences of the energy gap).

2)The electron-lattice-electron interaction leads to an energy gap of the observed magnitude. The indirect interaction proceeds, when one electron interacts with the lattice and deforms it, a second electron sees the deformed lattice and adjusts itself to take advantage of the deformation to lower its energy. Thus the second electron interacts with the first electron via the lattice deformation.

3)The penetration depth and the coherence length emerge as natural consequences of the BCS theory. The London equation is obtained for magnetic fields that vary slowly in space. Thus the central phenomenon in superconductivity.

4)The criterion for the transition temperature of an element or alloy involves the electron density of orbitals $D(\epsilon_F)$of one spin at the Fermi level and the electron-lattice interaction U, estimated from the electrical resistivity it measure of the electron-phonon interaction in room temperature. For $UD(\epsilon_F) \ll 1$ BCS theory predicts:

$$T_c = 1.14\Theta \exp\left(-\frac{1}{UD(E_F)}\right) \tag{1.11.1}$$

$$\Theta = \frac{\hbar\omega}{K_\beta}$$

Where Θ is the Debby temperature and U is an attractive interaction. The result for T is satisfied at least qualitatively by the experimental data. and thus the more likely it is that the metal will be a superconductor when cooled.

5)Magnetic flux through a superconducting ring is quantized and the effective unit of charge is 2 e rather than e. The BCS ground state involves pairs of electrons; thus flux quantization in terms of the pair charge 2 e is a consequence of the theory.[7]

In superconducting state, a finite fraction of the total number of electrons in the system have condensed into a superfluity static. The pairing instability of the Fermi see ground state occurs for an arbitrarily week interaction.[28,29]

Zero Temperature

∗The reduced BCS-Hamiltonian[29]

$$\hat{H} = \sum_{k,\sigma} \xi_k \psi^+_{k\sigma} \psi_{k\sigma} + \sum_{k,k'} V_{k,k'} \psi^+_{k\uparrow} \psi^+_{-k\downarrow} \psi_{-k'\downarrow} \psi_{k'\uparrow} \tag{1.11.2}$$

Where all irrelevant and marginal interaction have been neglected and Kinetic energy with respect Fermi-energy .

$$\xi_k = \frac{\hbar^2 K^2}{2m} - \varepsilon_F \tag{1.11.3}$$

$\psi_{k\sigma}$ creates an electron with momentum k and *spin* σ the existence of the cooper instability.

The expectation value of the Hamiltonian can be[30,31]

$$\langle \psi_{BCS} | H | \psi_{BCS} \rangle = 2 \sum_k u_k^2 \xi_k - \sum_{k,k'} V_{KK'} U_K U_{K'} V_{K'} \tag{1.11.4}$$

and upon varying with respect to V_k at the variational mine condition.

$$2\xi_k u_k v_k = \sum_{k,k\prime} V_{KK'} (U_K^2 - V_K^2) U_{K'} V_{K'} \tag{1.11.5}$$

We now make a charge of variable from (U_K, V_K) to (E_k, Δ_k) .

$$U_K = \frac{1}{\sqrt{2}} \sqrt{1 + \frac{\xi_k}{E_k}} \tag{1.11.6}$$

$$V_k = \frac{1}{\sqrt{2}} \sqrt{1 - \frac{\xi_k}{E_k}} \tag{1.11.7}$$

where

$$E_K = \sqrt{\xi_k^2 + \Delta_K^2} \tag{1.11.8}$$

substituting the above three equation can get.

$$\Delta_k = -\frac{1}{2}\sum_{k'} \frac{V_{KK'}\Delta_{K'}}{\sqrt{\xi_{k'} + \Delta^2_{k'}}} \tag{1.11.9}$$

$$\Delta^2_k = E^2_k - \xi^2_k \tag{1.11.10}$$

so we can take the simple possible form for the puring interaction

$$V_{kk'} = \Bigg\{ - V; |\xi_K|, |\xi_{K'}| \leq \hbar w_D \Bigg\} \tag{1.11.11}$$

$$V_{kk'} = \{0; otherwise\} \tag{1.11.12}$$

Where $V > 0$, immediately leading to

$$\Delta_k = \{0, |\xi_k| > \hbar w_D\} \tag{1.11.13}$$

$$\Delta, |\xi_k| < \hbar w_D. \tag{1.11.14}$$

with w_D the phonon Debby frequency and Δ a constant. This form loads to a much simplified gap equation, is given.

$$1 = \frac{V}{2}\sum_k \frac{1}{\sqrt{\xi^2_k + \Delta^2}} \tag{1.11.15}$$

converting the sum over K in to an integral over energy using the normal density of state $N(\xi)$ we can find.

$$= \sinh^{-1}(\frac{\hbar w_D}{\Delta}) \tag{1.11.16}$$

Where $N(\xi) \approx N(O)$,

The density of sate at the Fermi-energy. interested in a small interval of width $\hbar w_D \ll \varepsilon_F$ the solution only if $V > 0$ and week coupling require were $N(0)V << 1$

$$\Delta \simeq 2\hbar w_D \exp^{-\frac{1}{N(0)V}} \tag{1.11.17}$$

•At Finite temperature.[32]

For the derivation of the gap equation can be straight forwardly generalized to $T > 0$ quasi-particle above the superconducting ground state will be thermally excited. So non-interacting particle and the only modification will be that gap Δ acquires a temperature dependence.

$$\frac{1}{N(0)V} = \int_0^{\hbar w_D} \frac{d\xi}{\sqrt{\xi^2 + \Delta^2}} \tag{1.11.18}$$

Where f(x) is the Fermi function.

$$f(x) = \frac{1}{\exp^{\frac{X}{K_\beta T}} + 1} \tag{1.11.19}$$

It is easy to see that in the $\lim T \to 0$ this reduces to our previous result. The transition temp T_C is defined

$$1 = N(0)V \int_0^{\hbar w_D} \frac{d\xi}{\xi} \tanh \frac{\xi}{2K_\beta T_C} \tag{1.11.20}$$

$$\frac{1}{N(0)V} = \int_0^{\hbar w_D} \frac{d\xi}{\xi} \tanh \frac{\xi}{2K_\beta T_C} \tag{1.11.21}$$

For $K_\beta T_C \ll \hbar w_D$

$$\frac{1}{N(0)V} = \ln \frac{1.14\hbar w_D}{K_{\beta T_C}} \tag{1.11.22}$$

OR

$$K_\beta T_C = 1.14\hbar w_D \exp^{\frac{-1}{N(0)V}} \tag{1.11.23}$$

$$T_C = 1.14\frac{\hbar w_D}{K_\beta} \exp^{\frac{-1}{N(0)V}} \tag{1.11.24}$$

$$\Longrightarrow T_c = 1.14\Theta \exp\left(-\frac{1}{UD(E_F)}\right) \tag{1.11.25}$$

1.12 Methodology and Experimental Views

Single crystals of $Fe_{1+Y}Se_XTe_{1-X}$ were grown by a modified Bridgman method as reported by neutron scattering. The neutron scattering measurements were carried out on triple-axis spectrometer TASP at the spin Q installation source Paul Scherrer Institute in Switzerland. Bragg reflections from Pyrolytic Graphite PG(002) monochromatic and analyzer were used at a fixed final wave vector of $2.66\AA$. A Pyrolytic Graphite filter was placed after the sample to reduce contamination from higher order harmonics in the beam and the instrument set up in the open collimation with the analyzer focusing in the horizontal plane. The crystals were single rods with masses of approximately 4 g. Magnetic excitations of $Fe_{1+Y}Se_XTe_{1-X}$ in magnetic and superconductivity in three phase. The $Fe_{1.10}Se_{0.25}Te_{0.75}$ sample was orientated in two settings to give access to (h,0,l) and (h,k,0) planes in reciprocal space. Measurements of $Fe_{1.01}Se_{0.50}Te_{0.50}$ were made in the (h,k,0) plane only. In this report we index the reciprocal lattice with respect to the primitive tetragonal unit cell described by the P 4/n mm space group with unit cell parameters $a \sim 3.8\AA$ and $C \sim 6.1\AA$ along lines joining the nearest neighbor Fe atom.[33]

Zero-field-cooled magnetization measurements were performed on a quantum design in MPMS magneto meter with a measuring field $H = 0.3mT$ using the direct current method. That reduce to the effects of demagnetization, thin plate-like pieces of $Fe_{1+Y}Se_XTe_{1-X}$ cleaved from the main single crystals. Zero-Field (ZF), Transverse Field (TF), muon-spin rotation (μSR) experiments were perform on the three beam line. Transverse Field experiments a magnetic field of 11.8 m T was applied parallel to the crystallographic the crystal and and perpendicular to the muon-spin polarization.

1.13 The Neutron Scattering Experiments

This scattering intensity shown the large range of magnetic order at the same time the behavior of neutron scattering intensity was very similar to spin-glass historically the first observation of the coexist with superconductor.[34]

The spin glass perform at cold-neutron triple-axis spectrometer SPINS. Most of the experiments on the X= 0.15 and 0.3 single crystal were done with the instrument configuration of guide-open-80 open and energy of the scattered neutrons fixed to $E_f = 5$ me V. One Be filter cooled by liquid nitrogen was placed after the sample for the elastic measurements. The X= 0.15 single crystal was aligned in the (h,k,0) and the (h,0,l) plane. High Q-resolution elastic measurement on the X=0.1 and X=0.15 single crystal ware performed using a back scattering geometry with energy $E_i = 10meV$. The neutron scattering experiment were determined the elemental concentration of electron in the crystal.

1.14 Mean-Field Theory of Spin Glass

If the interaction between spins are not uniform in space. When the interactions are ferromagnetic for some bonds and anti-ferromagnetic for other than the spin orientation can not be uniform in space, unlike the ferromagnetic system even at low temperatures.Under this circumstance it sometime happens that spins become randomly frozen-random in space but freeze in certain time. This is the intuit picture of spin glass phase. It is applicable to the problem of disordered systems with random interaction[35]. In particular we elucidate the properties so called replica symmetric solution.

1.15 Experimental properties of Spin-Glasses

Spin-glass behavior is usually characterized by AC susceptibility. The magnetic spins experience random interactions with other magnetic spins, resulting in a state that is highly irreversible and metastable with realized below the freezing temperature (T_f) and the system is paramagnetic above this temperature.[17]

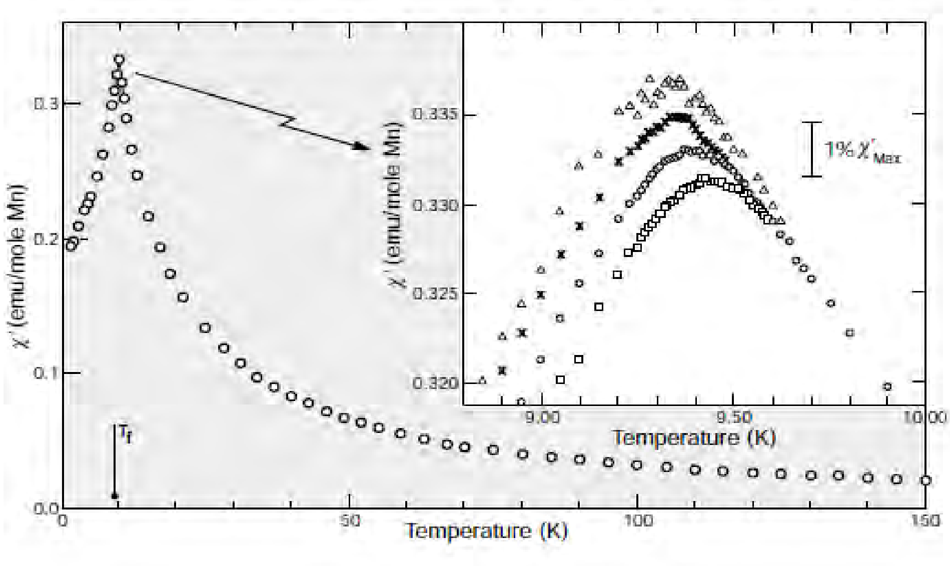

Figure 1.7: AC susceptibility of CuMn (1 at % Mn) showing the cusp at the freezing temperature. The in set shows the frequency dependence of the cusp from 2.6 Hz (triangles) to 1.33 kHz (squares). Figure reprinted with permission.Ref[36]

The pressure(P) depending of a.c susceptibility and electrical resistivity of $FeSe_{0.88}$ and $FeSe_{0.5}Te_{0.5}$ has been studied. The superconducting transition temperature (T_C) of $FeSe_{0.5}Te_{0.5}$ is found to be more sensitive to pressure than it is in $FeSe_{0.88}$, which is believed to arise from the strongly distorted structure. The enhancement of (T_C) by(P) is mainly attributed to an increase of density of states, which implies that the superconductivity in $FeSe_{1-X}Te_X$ favors pairing mechanism in the context of strong-coupling in BCS theory.[37] From the above figure has shown two characteristics of spin-glass. When the line sharp cusp at a temperature T_f this cusp indicate the a.c susceptibility is found to be an increasing function of concentration of the magnetic constituent in the alloy, it should be noted that for spin-glasses. In another said the line cusp flatted a temperature that means extremely depending on magnetic field. *At very low magnetic fields the corresponding to d.c magnetization depend on relaxation time τ.* This magnetic field cooled to the fill down up to zero cooled state. The a.c susceptibility measurement is the frequency dependence of T_f. It is found that T_f increases with ω(frequency). The the presence of large relaxation time of these samples was one of the first indicators that for these materials the coarse-phase space coordinates exhibits many valleys.[37] Assume free energy of valley is as shown (Mean field theories also predict this but in this case in thermodynamics limit the height of the valley diverges. But for real systems it is finite) even though the presence of the sharp cusp in the a.c susceptibility.

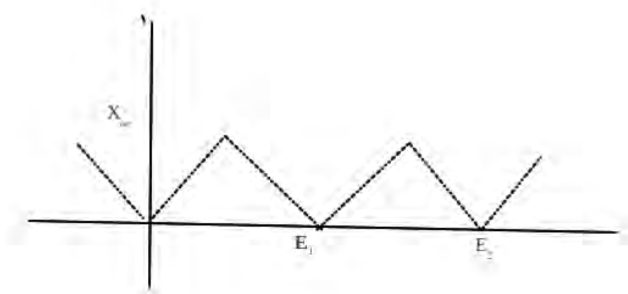

Figure 1.8: For free energy valley sharp cusp in the a.c susceptibilityX_{ac}.Ref[17]

Prompted the experimental lists to propose the existence of a phase the transition at T_f the specific heat measurement put some doubts in to the existence of the phase transition.

1.16 Coexistence of Magnetism, Spin Glass with Superconductivity

The Fe-pnictides or Chalcogenides is gradual emergence of the superconductivity when the anti-ferromagnetic (AFM) order associated with the Fe-X(X=Te/As) layers is weakened by doping. $Fe_{1+Y}Te$ [38,39] has a tetragonal α-Pbo-type structure and forms only in the non stoichiometric form (Y in the range between 0.05 to 0.22) with excess iron atoms Fe(2), occupying the octahedral positions in randomly. The Fe(2) directly couples to the four nearest neighbor but Fe(1) atoms in the Fe planes and could effectively introduce frustration in the underlying anti-ferromagnetic state. While $Fe_{1+Y}As$ orders AFM, FeSe could be prepared in the stoichiometric form and is superconducting below 8 k. Density functional theory suggests that FeSe could be an anti-ferromagnetic the bored line b/n *itinerant* and *localized* behavior and in plane Fe-Fe exchange coupling depend on Fe-Se distance. Mossbeur Spectroscopic and bulk magnetic studies of Fe excess compounds $Fe_{1.1}Te_{1-X}Se_X$ and stoichiometric with $FeTe_{1-X}Se_X$. When we see $Fe_{1.1}Te_{1-X}Se_X$ in this region $(0.1 \leq (X) \leq 0.55)$ the system is magnetic state developed in local moment, but at the same region $FeTe_{1-X}Se_X$ display bulk superconductivity with no magnetic order.[5,9] The doping concentration of electron $Fe_{1.1}Te_{1-X}Se_X$ X=(0, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.55 and 1) and $FeTe_{1-X}Se_X$ (X= 0.1, 0.3, 0.4, 0.5) are prepare mixing stoichiometric quantities of constitute element. Further increase of $Se(X > 0.1)$ in both $Fe_{1.1}Te_{1-X}Se_X$ and $FeTe_{1-X}Se_X$ series in superconductivity in temperature range 12 k and 15 k respectively. Because The superconducting transitions observed from the the electrical resistivity and magnetic susceptibility in the $Fe_{1.1}Te_{1-X}Se_X$ so (T_C) value well be less than $FeTe_{1-X}Se_X$.

DC magnetization measurements in applied field of 0.5 T investigation bulk magnetic order in these system, for the $Fe_{1.0}$ series, the Dc-magnetization is nearly constant above T_C this implying that Fe is either no-magnetic or weakly magnetic property occur. This magnetization for the $Fe_{1.1}$ series combine with Te to form $Fe_{1.1}Te$ compound sharply drop in below 65 K. When the temperature freeze the magnetic order form in AFM exist the transition temperature of (T_{SDW}) 49 k with doping X= 0 and 0.05 composition of electron.[39] For X= 0.1,the Dc magnetization displays a clear cusp at 36 k with further substitution of Se. The magnetization shows broad maximum that progressively shifts to lower temperatures. This type of magnetization behavior is typical of spin-glass(SG) system. This Spin glass nature is confirmed from sharp cusp in the X_{ac} data, identified as the spin-glass temperature,T_g. The X_{ac} peak for X= 0.55 shifts to higher temperature at higher frequencies proving the Spin glass nature beyond doubt. Magnetic field cooling effects are also observed below the spin glass transition temperature T_g.

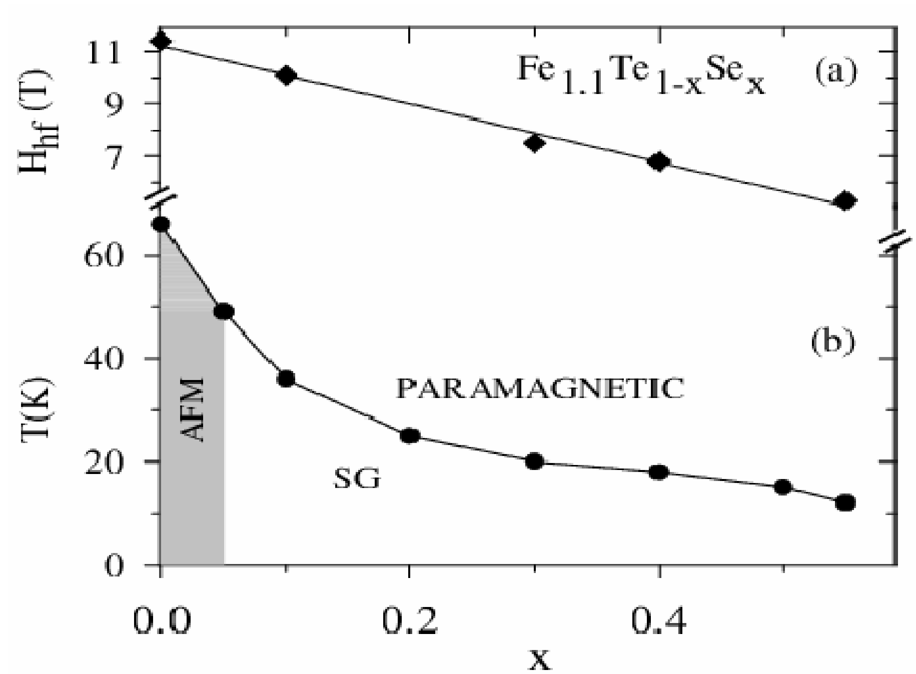

Figure 1.9: (a) Variation of average hyperfine field with Se concentration (b) Magnetic phase diagram Ref[40]

This phase diagram can assume that a model, where Fe(1) planes are made weakly magnetic as result of Se substitution, while Fe(2) displays local magnetism and interacts with Fe(1), there by strongly influence the superconductivity caused by the Fe(1) layer. Therefore Fe(2) interact magnetically and Fe(1) superconductivity in the $Fe_{1.1}Te_{1-X}Se_X$ series with $X \geq 0.1$. The stoichiometric series in bulk superconductivity for X = (0.3, 0.4 and 0.5). The Fe Mossbauer live indicates no magnetic features down to 4.2 K. The material depending on ac susceptibility, when $Fe_{1.1}Te_{1-X}Se_X$ series with $X \geq 0.1$, This show magnetic and superconducting state. In this case X =(0.3, 0.4 and 0.5) superconducting state. The diamagnetic screen corresponding to full X the heat capacity measurements do not show near T_C, where as the curve showed stoichiometric series. When X= (0.3, 0.4 and 0.5) the magnetic field of 14 k, at this time the exponential drop indicating a Semiconductor energy gap is form superconducting state sample.

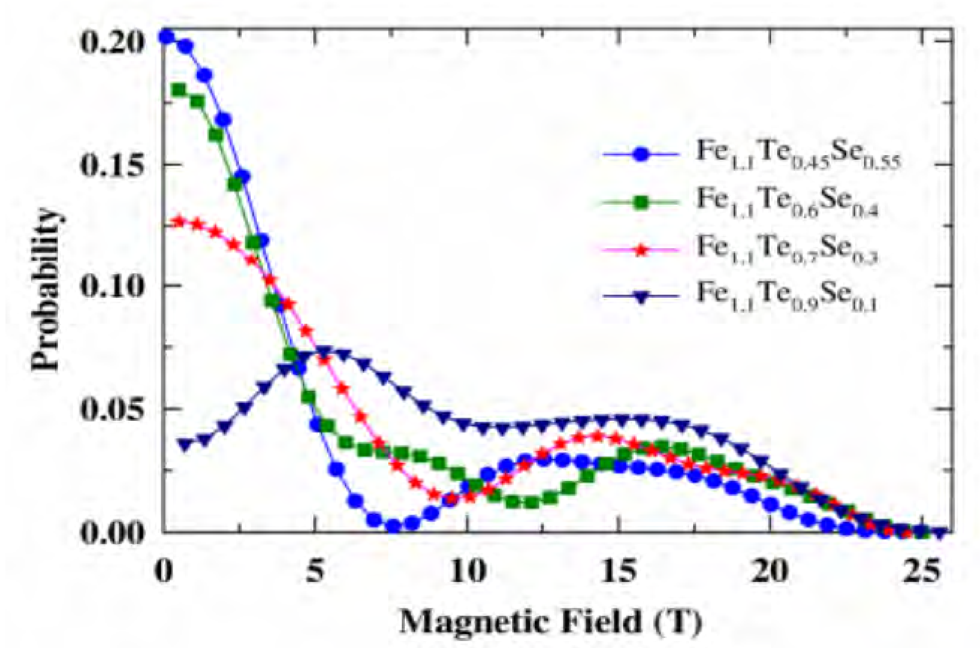

Figure 1.10: (color on line).Hyperfine field distribution from the Mssbauer spectra $Fe_{1.1}Te_{1-X}Se_X$ (X = 0.1, 0.3, 0.4,0.55). Ref[40]

The probability distribution of hyperfine field obtained the distribution is very broad. The Hyperfine Mssbauer field sensitive nature of the Fe its local environment in this system. The distribution is nearly bimodal with a high field component centered around 15 T possibly representing Se deficient neighborhood. The low field component is strongly enhanced by the Se substitution and this contribute factor emergence of competing magnetic interactions leading to the spin-glass state. The average hyperfine field (H_{av}) is found to drop linearly with the Se substitution (Fig.10) indicating that Se substitution gradually decreases the Fe moment, agreement with the bulk magnetization data. Non-magnetic iron as if it were a magnetic hyperfine pattern with $H_{av} < 4$ Tesla. The magnetic fraction of Fe atoms are estimated from the hyperfine distribution excluding the region up to 4 Tesla.

The fractional values obtained are (0.75, 0.5, 0.43 and 0.32) corresponding to each other X = (0.1, 0.3, 0.4 and 0.55). It clearly exceeds iron in Fe(2) fraction, which is only 10%. This indicates that Fe(2) in the octahedral site has strong direct magnetic coupling with the Fe(1) in the planes.

The progressive reduction in the magnetic fraction of the Fe atoms can be linked to the reduction of μ_{eff} with the substitution of Selenium (Se) from Tellurium (Te).

1.17 Coexistence anti-ferromagnetic, spin glass and superconducting in phase diagram

For there is evidence for coexisting anti-ferromagnetic order and superconductor[41,42] in chalcogenides system the compound ($Fe_{1+Y}Se_XTe_{1-X}$). Focusing the structure to minimize for Fe ($Y \approx 0$). The Neel temperature drops rapidly for $X \lesssim 0.1$ but our system indicate that bulk superconductivity only appears for X$\gtrsim$ 0.4. In the α Pbo structure of ($Fe_{1+Y}Se_XTe_{1-X}$) (FST), the Fe layers have a square lattice structure. However, the position of the translational symmetry. Thus, it is crystallographic appropriate to choose a unit cell with tow Fe atoms per layer, such that lattice parameter is a≈ 3.8Å. We will specify reciprocal lattice vector, Q = (h, k, l) the reciprocal lattice units (rlu) of $(2\pi/a, 2\pi/b, 2\pi/c).In$(Fe$_{1+Y}Te$) the long-range SDW state is accompanied by a tetragonal to monoclinic. The spin arrangement is ferro magnetic along the b direction and alternates in a ++ – fashion along the a-direction, leading to a characteristic reciprocal wave vector (0.5,0,0.5). For larger Y value the in-plane component of the magnetic wave vector becomes slightly incommensurate.[43]

In $Fe_{1+Y}Se_XTe_{1X}$ with 0.25≤ X≤ 0.33 static but short-range incommensurate magnetic order with $Q_m = (0.5 \pm \delta^{'}, 0.5 \mp \delta^{'}, l)$ is observed.[38,44,45] At higher Se concentration X$\gtrsim$ 0.4 bulk superconductivity is achieved. The spin resonance energy at $\hbar\omega \simeq 6.5$ meV appears at incommensurate Q_C=(0.5 $\pm\delta^{'}$, 0.5$\mp\delta^{'}$,l).[46,47] The reduction in crystallographic symmetry important for magnetic ordering in $Fe_{1+Y}Te$. The monoclinic (or orthorhombic) structure provides the magnetic ordering wave vector with a unique orientation with in the Fe planes. In the short-range magnetic order observed at $X \sim 0.3$ occurs in a tetragonal phase. It has two degenerate orientation for Q_m. This suggests that computation among degenerate domains may lead to frustration and keep the ordering SR. The exchange interaction J_{ij} on the H=$\sum J_{ij}\ \overrightarrow{S_i}.\overrightarrow{S_j}$ is called SR and LR it depending on strength of exchange interaction in the separation distance between the spins.[22] A recent study has shown that the cross over to the tetragonal phase occurs between X= 0.075 and X= 0.1 with long Range the magnetic order only for X$\lesssim$0.075, thus might expect transition to short range SDW order for $X \gtrsim 0.1$ and the exchange interaction J_{ij} on this compound $Fe_{1+Y}Se_XTe_{1-X}$(FST) for X = 0.1 and 0.15 present the spin glass can be shown.[48]

Compounds	X doping value	Description
$Fe_{1+Y}Se_{0.75}Te_{0.25}$	$X = 0.75$ and	it show among degenerate domains may be lead to frustration.
$Fe_{1+Y}Se_{0.10}Te_{0.9}$	$X = 0.1$	it keep to ordering short range.
$Fe_{1+Y}Se_{\leq 0.075}Te_{\geq 0.025}$	$X \leq 0.075$	with Long-Range magnetic-order.
$Fe_{1+Y}Se_{\geq 0.1}Te_{\leq 0.9}$	$X \geq 0.1$	a transition to Short-Range SDW-order,
$Fe_{1+Y}Se_{\leq 0.075}Te_{\geq 0.025}$	at $X = 0.1$ and $X = 0.15$	we show that spin-glass like behavior is present FST.

Table 1.4: The magnetic order dependence on No of doping (hole or electron)

$Fe_{1+Y}Se_XTe_{1-X}$(FST) and nature of magnetic correlations in three Non-superconducting samples of ($Fe_{1.01}Se_{0.1}Te_{0.9}$,$Fe_{1.01}Se_{0.15}Te_{0.85}$ and $Fe_{1.01}Se_{0.3}Te_{0.7}$).We present evidence from magnetization measurement and characterize the SHORT-RANGE order with neutron-scattering one of the main result in short range order is structural as will as magnetic, consistent with present that orbital order. It is important part of the magnetically ordered state.

At low energy spin fluctuation for X= 0.15 and X = 0.3 with inelastic neutron-scattering. While there is some weak critical scattering that extends out to Q_C near the on set of elastic magnetic scattering that disappears at low temperature, as spin fluctuation are dominantly associated with Q_m. Thus, these appear to be a broad spin glass (SG) regime in (FST). associated with a type of geometrical frustration. The eventual onset of superconductivity appears to be associated with an evolution of the characteristic wave vector associated with the spin fluctuation.

For bulk magnetization measurements $\sim 0.01g$ single crystal with various Se concentration from X = 0 up to X = 0.7, were used Superconducting quantum interface device (SQUID)[49]magnetometer, while for neutron measurement, 0.39 g single crystal of $Fe_{1.01}Se_{0.3}Te_{0.7}$ were used. The bulk magnetic [16] susceptibility data obtained from single crystal of FST. with four different Se-concentration X=(0.04,0.15,0.3 and 0.5).

Compound	No of X-doping value	Bulk Magnetization.
$Fe_{1.01}Se_{0.1}Te_{0.9}$	X= 0.1	0.39 g
$FeSe_{0.15}Te_{0.85}$	X = 0.15	10.1 g
$Fe_{1.01}Se_{0.3}Te_{0.7}$	X = 0.3	5.3 g

Table 1.5: Bulk magnetization is dependence on No of doping(hole or electron).

No of X-doping value	The transition temperature	Indicating and Description.
$X = 0.04$	At $T_{SDW} = 49K$ (sharply decrease)	A long-range magnetic order.
$X = 0.15$ and 0.3	$T_{SG} \sim 23K$ (by $FC - ZFC$ below hysteresis)	A short-range magnetic order.
$X = 0.5$	$T_C = 14.5K$	The superconducting phase transition.

Table 1.6: The freezing process $Fe_{1+Y}Se_XTe_{1-X}$ [55,56] from high T_C.

The X -T phase diagram for (FST) based only the bulk susceptibility obtained from the single crystal sample. Even though the values of X and Y are normal values or may not be exactly correct. The phase diagram clearly shows the trends and the existence of three distinct phase. When the $X \lesssim 0.1$ the anti-ferromagnetic phase, $X \gtrsim 0.4$ the bulk Superconducting phase occur and between the ($0.1 \gtrsim X \gtrsim 0.4$) this Regine the spin glass can be exist. In the spin glass compounds the transition is second order with

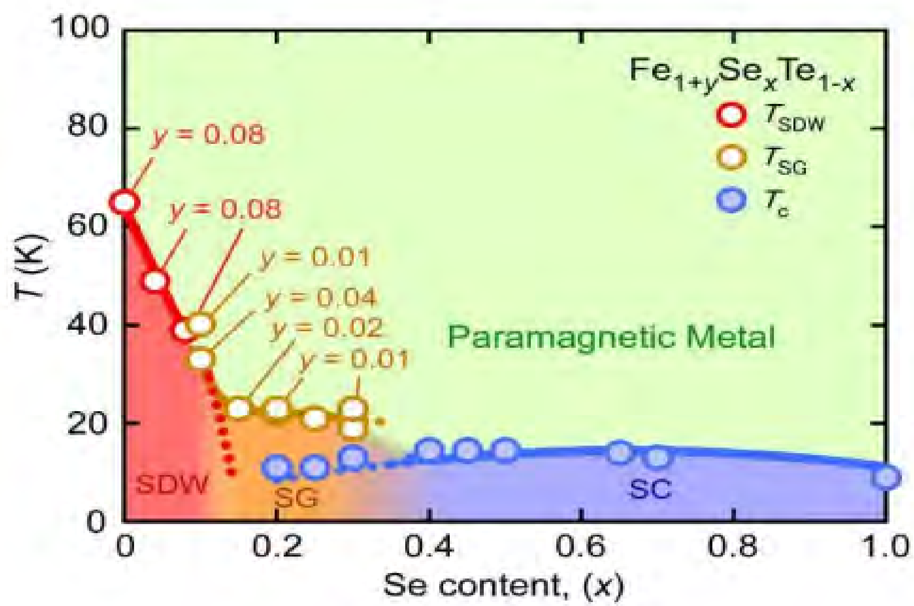

Figure 1.11: Phase diagram of $Fe_{1+Y}Se_XTe_{1-X}$ with $Y \sim 0$ as a function of X and T constructed from single crystal bulk susceptibility data some of which are shown in except for X = 1 which is taken from. The nominal Fe content Y = 0 unless it is specified. T_C (blue circles) represents the superconducting onset temperature.Refs.[16,49]

neither observable long-range structural phase transition nor superconducting transition upon doping Se become superconducting. The $X-T$ Phase diagram for FST based only on the bulk superconductivity data obtained from the single crystal samples X and Y are normal integral value may not exactly correct see the above table. The phase diagram can be experienced the long-range in SDW is non-superconductor and the intermediate phase, some sample should partially superconductor below $T_C \sim 11$ K, while other were non-superconducting down to 1.4 k. Some process to seen the spin glass form and coexist with superconductor.

Firstly in order to investigate, what happen the crystal structure at low temperatures in the Spin-glass phase. We take performed high Q-resolution elastic measurement on the X= 0.1 and X= 0.15 in single crystals. The low temperature boarding the structural tendency to wards at lower symmetry. The same scans were done at several different temperatures the data fit to a single Gaussian. The structural modification develops below 40 k and weakness with increasing Se concentration.

Secondly the static spin correlation in the spin glass phase were investigated using elastic Neutron scattering. The scans on X = 0.15 at 1.5 k reveal prominent static magnetic peaks at incommensurate wave vectors Q = (0.46,0,l + 0.5) for integer of l. On cooling from higher temperatures the static spin correlations gradually freeze below T_f = 40 k.The increase of spin correlations coincides with the reduction in the intensity of the low energy excitation. The T_f measured by elastic neutron scattering with an energy resolution of $\Delta E \sim 0.3meV$ is higher than the T_{SG} measured by static bulk susceptibility, which is common in system involving spin freezing.[16,41]

Chapter 2

Mathematical Formulation Of the Problem.

To study the coexistence of superconductivity and spin-glass (SG) in $Fe_{1+Y}Se_XTe_{1-X}$ calculate of the time dynamics into the spin-flip scattering time τ. This give an approximation introducing the effect of dynamics on the pair breaking. While realize that it is only an approximation, it should be consider to complete solve the the problem. Born approximation use in the spin-boson model in the Ohmic regime. We observe non-Markovian effects at zero temperature that scale with the system-bath coupling strength and cause qualitative changes in the evolution of coherence at intermediate times of order of the oscillation period. The expression for $\frac{1}{\tau_S}$ in first Born approximation contains the spin-spin correlation function, near T_C the dominant contribution comes from long-range fluctuation. Using Born approximation is $\psi_k(r) \approx \phi_k(r)$.[50]

2.1 First Born Approximation

$$\psi_k(r) \approx \quad \phi_k(r) + \frac{2m}{\hbar^2}\int d^3r^{'} G_K^{\dagger}(r,r^{'})V(r^{'})\phi_k(r^{'})$$

A way to motivated this to note that if we substitute the(exact) integral equation in to it self.

$$\begin{aligned}\psi_k(r) \approx \quad & \phi_k(r) + \frac{2m}{\hbar^2}\int d^3r^{'} G_K^{\dagger}(r,r^{'})V(r^{'})\phi_k(r^{'}) \\ & +(\frac{2m}{\hbar^2})^2 \int\int d^3r^{'3}r^{'3} G_K^{\dagger}(r,r^{'})V(r^{'})G_K^{\dagger}(r,r^{''})V(r^{''})\psi_k(r^{'3})\end{aligned} \quad (2.1.1)$$

We see that approximation, introduce error order V^2 this term is likely to be sub-dominate, we can write.

$$\psi_k(r) \approx \frac{1}{(2\Pi)^{3/2}}e^{ik.r} - \frac{2m}{\hbar^2}\frac{1}{4\Pi}\frac{e^{ik.r}}{r}\int \frac{d^3r^{'}}{(2\Pi)^{3/2}}e^{i(k-k_{out}).r^{'}}V(r^{'}) \quad (2.1.2)$$

so that

$$f(k,k_{(out)}) = \frac{-m}{(2\Pi)\hbar^2}\int d^3r^{'}.e^{i(k-k_{out}).r^{'}}V(r^{'}) \quad (2.1.3)$$

Which we recognize as being $q = k - k_{out}$, where q is wave vector.

$$q^2 = k^2 + k_{Out}^2 cos\Theta^{\cdot} = 2k^2(1-cos\Theta) = 4k^2 sin^2(\frac{\Theta}{2}) \quad (2.1.4)$$

2.2 Second Born Approximation

The once more them the first $\psi_k(r) \approx \phi_k(r)$ only at the second step.

$$\psi_k(r) \approx \phi_k(r) + \frac{2m}{\hbar^2}\int d^3r^{'} G_K^{\dagger}(r,r^{'})V(r^{'})\phi_k(r^{'}) + (\frac{2m}{\hbar})^2 \int\int d^3r^{'3}G_k(r,r^{,}V(r^{,})G_k^{\dagger}V(r^{''}\phi_k(r^{''})) \quad (2.2.1)$$

2.3 The Digamma Function

The define of D.F is the logarithmic derivative of the Gamma function.[51]

$$\psi(z) = \frac{d}{dz}\ln\Gamma(x) = \frac{\Gamma(x)}{\Gamma(x)} \tag{2.3.1}$$

This is continuous except for the poles at zero and the negative integers, we can use the expression of the digamma function.

$$\Gamma(z) = e^{-\gamma z}\frac{1}{z}\prod_{k=1}^{\infty}\frac{e^{z/k}}{1+\frac{z}{k}} \tag{2.3.2}$$

Where γ is the Eular-Mascheron const, and thus

$$\begin{aligned} \ln\Gamma(z) = \quad & \ln[e^{-\gamma z}\frac{1}{z}\prod_{k=1}^{\infty}\frac{e^{z/k}}{1+\frac{z}{k}}] \\ & = -\gamma z - \ln z + \sum_{k=1}^{\infty}\ln[\frac{e^{z/k}}{1+\frac{z}{k}}] \\ & = -\gamma z - \ln z + \sum_{k=1}^{\infty}[\frac{z}{k} - \ln(1+\frac{z}{k}] \end{aligned} \tag{2.3.3}$$

Taking the derivative with respect to z, we get

$$\begin{aligned} \psi(z) = \quad & -\gamma - \frac{1}{z} + \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k}] \\ & = -\gamma + \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k-1}] \end{aligned} \tag{2.3.4}$$

Now, immediately what happens if Z is a positive integer n: the terms

$$\frac{1}{n+k-1}$$

K = 1,2,3,4...... canceled by the terms $\frac{1}{k}$ for k=n,n+1,n+2,........ thus

$$\sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k-1}] \tag{2.3.5}$$

and

$$\psi_0(n) = -\gamma + \sum_{k=1}^{n-1}\frac{1}{k} = -\gamma + H_{n-1} \tag{2.3.6}$$

and so we see immediately that $\psi_0(1) =$ - y and $\psi_0(2) =$ 1- y (and thus only positive Zero of ψ_0 use b/n these two.) Using the series form.

$$\psi(z) = -\gamma + \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k-1}] \tag{2.3.7}$$

we use

$$\psi(z+1) = -\gamma + \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k}] \tag{2.3.8}$$

and

$$\begin{aligned} \psi(z+1) - \psi_0(z) = \quad & \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k}] - \sum_{k=1}^{\infty}[\frac{1}{k} - \frac{1}{z+k-1}] \\ &= \sum_{k=1}^{\infty}[\frac{1}{z+k-1} - \frac{1}{z+k}] \\ &= \frac{1}{z} \end{aligned} \tag{2.3.9}$$

$$\psi_0(z+1) = \psi_0(z) + \frac{1}{z} \tag{2.3.10}$$

As recurrence relation for ψ_0, now recall the Euler-reflection formula we derived previously.

$$\Gamma(x)\Gamma(1-x) = \frac{\pi}{\sin \pi x}$$

Taking the logarithm of Both said, and differently.

$$\ln(\Gamma(x)\Gamma(1-x)) = \ln(\frac{\pi}{\sin \pi x})$$

$$\ln\Gamma(x) + \ln\Gamma(1-x) = \ln\pi - \ln\sin(\pi x)$$

$$\psi_0 - \psi_0(1-x) = -\pi\cot(\pi x)$$

$$\psi_0(1-x) = \psi_0(x) + \pi\cot(\pi x)$$

Applying a similarly Legendre duplication form.[52]

$$\Gamma(2z) = \frac{2^{2z-1}}{\sqrt{\pi}}\Gamma(z+\frac{1}{2})\Gamma(z)$$

$$\ln\Gamma(2z) = (2z-1)\ln 2 - \frac{1}{2}\ln\pi + \ln\pi(z) + \Gamma(z+\frac{1}{2})$$

$$2\psi_0(2z) = 2\ln 2 + \psi_0(z) + \psi_0(z) + \psi_0(z + \frac{1}{2})$$

$$\psi_0(2z) = \frac{1}{2}\psi_0(z) + \frac{1}{2}\psi_0(z + \frac{1}{2}) + \ln 2 \qquad (2.3.11)$$

put in $z = \frac{1}{2}$, in to eqn(2.0.16) we can get

$$\psi_0(1) = \frac{1}{2}\psi_0(\frac{1}{2}) + \frac{1}{2}\psi_0(1) + \ln 2$$

$$\frac{1}{2}\psi_0(1) = \frac{1}{2}\psi_0(\frac{1}{2}) + \ln 2$$

$$\psi_0(1) = \psi_0(\frac{1}{2}) + 2\ln 2$$

$$\psi_0(\frac{1}{2}) = \psi_0(1) - 2\ln 2$$

$$\psi_0(\frac{1}{2}) = -\gamma - 2\ln 2 \qquad (2.3.12)$$

Chapter 3

Theoretical formulation

3.1 Introduction

The model Hamiltonian for coexistence Spin glass Superconducting in the compound of $(Fe_{1+Y}Se_XTe_{1-X})$ and $(R(Fe_{1-X}Co_X)_2As_2)$ our system can be described as:[26]

$$H = H_{intra} + H_{inter} \tag{3.1.1}$$

$$H_{intra} = H_{BCS} = \sum_{p\sigma} \epsilon_p \hat{c}^{\dagger}_{p\sigma}\hat{c}_{p\sigma} - V \sum_{kk^{,}} \hat{c}^{\dagger}_{p\uparrow}\hat{c}^{\dagger}_{-p\downarrow}\hat{c}_{-p\downarrow}\hat{c}_{p\uparrow}$$

$$H_{inter} = -\frac{I}{2} \sum_{i,j,\sigma,\sigma'} e^{i(k-k').R_j}[\overrightarrow{S_i}(C^{\dagger}_{K\sigma}\sigma_{\sigma\sigma'}C_{k^{,}\sigma'})] - \frac{1}{2}\sum_{ij} J_{ij}\overrightarrow{S_i}\overrightarrow{S_j},$$

Where H_{BCS} is the BCS Hamiltonian for the system with out magnetic impurities $(\sigma^x, \sigma^y, \sigma^z)$ are the three Pauli matrices and S_i magnetic spin located at R_i. I is the s-f block exchange term and J_{ij} is the exchange interaction. The second term describes the interactions between the electrons and the localized spins of rare-earth (R) or transition metal ion while the third term describes the interactions b/n localized spins. The coupling lead to magnetic ordering at temperature T_M the concentration of magnetic impurities X.

3.2 Theoretical formulation based on Born approximation

Abrikosov and Gorkovisos first show that is the Born approximation, T_C is given by.[26]

$$\ln \frac{T_C}{T_{CO}} = \psi_0(1/2) - \psi_0\left[\frac{1}{2} + \frac{1}{2\Pi T_C \tau}\right] \tag{3.2.1}$$

Applying the above expression for the diagram for using $\psi(z)$ is digamma function, for z=1/2, than recall the digamma function.

$$\psi_0(1/2) = -\gamma - 2\ln 2 \tag{3.2.2}$$

and

$$\psi_0\left[\frac{1}{2} + \frac{1}{2\Pi T_C \tau}\right] = \psi(z + \frac{z}{\Pi T_C \gamma}) \tag{3.2.3}$$

FOR $z = 1/2$ and that $m = \frac{1}{\Pi T_C \gamma}$

$$\begin{aligned} \psi(z+zm) = \quad & -\gamma + \sum_{k=1}^{\infty}\left[\frac{1}{k} - \frac{1}{Z+Zm+K-1}\right] \\ & = \psi(z) + \sum_{k=0}^{\infty}\left[\frac{1}{k} - \frac{1}{Z+Zm+K-1}\right] - \left[\frac{1}{k} - \frac{1}{Z+Zm+K-2}\right] \end{aligned} \tag{3.2.4}$$

$$\begin{aligned} \psi(z+zm) - \psi(z) = \quad & \sum_{k=1}^{\infty}\left[\frac{1}{k} - \frac{1}{Z+Zm+K-1}\right] - \left[\frac{1}{k} - \frac{1}{Z+Zm+K-2}\right] \\ & = \sum_{k=1}^{\infty}\left[\frac{-1}{Z+Zm+K-1} + \frac{1}{Z+Zm+K-2}\right] \end{aligned} \tag{3.2.5}$$

$$\begin{aligned} & = \sum_{k=1}^{\infty}\left[\frac{-1}{Z(m+1)+K-1} + \frac{1}{Z(1+m)+K-2}\right] \\ & = [\frac{-1}{zM} + \frac{1}{ZM-1} - \frac{1}{ZM+1} + \frac{1}{ZM} - \frac{1}{ZM+2} + \frac{1}{ZM+3} \\ & = -\frac{1}{ZM+3} + \frac{1}{ZM+2}...] \end{aligned} \tag{3.2.6}$$

$$\psi(z+zm) - \psi(z) = \frac{1}{ZM-1} - \frac{1}{ZM+1} \tag{3.2.7}$$

combining the tow equation, we can get

$$\psi(z+zM) = \psi(z) + \frac{1}{ZM-1} - \frac{1}{ZM+1}$$

Than substitute the value of $z = 1/2$,and $M = m + 1$, $m = \frac{1}{\pi T_C \tau}$

$$\psi\left[\frac{1}{2} + \frac{1}{2\pi T_C \tau}\right] = \psi(\frac{1}{2}) + \frac{2}{(ZM)^2 - 1} \tag{3.2.8}$$

Recall from eqn(3.2.1)

$$\begin{aligned} \ln \frac{T_C}{T_{CO}} &= \psi(\frac{1}{2}) - \psi\left[\frac{1}{2} + \frac{1}{2\pi T_C \tau}\right] \\ &= \psi(\frac{1}{2}) - \psi(\frac{1}{2}) + \frac{8}{(M)^2 - 4} = \frac{8}{(\frac{1}{\pi T_C \tau} + 1)^2 - 4} \end{aligned}$$

$$(\frac{1}{\pi T_C \tau} + 1)^2 - 4 = \frac{8}{\ln(\frac{T_C}{T_{CO}})}$$

Rearranging the above equation is gives

$$\tau = \frac{1}{\pi T_C}\left[\left(\frac{8}{\ln(\frac{T_C}{T_{CO}})} + 4\right)^{1/2} - 1\right]^{-1} \tag{3.2.9}$$

Take the the value of T_{C0}= 8 k, AND $T_C = 14.5$ k value of this compound $Fe_{1.1}Se_XTe_{1-X}$ for, we can get

$$\tau = \frac{1}{3.14 * 14.5}\left[\left(\frac{8}{\ln(\frac{14.5}{8})} + 4\right)^{1/2} - 1\right]^{-1} \tag{3.2.10}$$

Than $\tau = 0.006912$, the spin flip scattering time

When the spatial and time correlation are take the result for τ can be generalized with in Born approximation.

$$\frac{1}{\tau} = \frac{1}{\tau_{AG}} \frac{1}{2K_F^2 S(S+1)} \int^{2K_F} q dq \int_{-\infty}^{\infty} d\omega g(q,\omega) \frac{\beta\omega}{e^{\beta\omega} - 1} \tag{3.2.11}$$

Where

$$g(q,\omega) = S(q,\omega) - S_{Bragg}(q,\omega) \tag{3.2.12}$$

and

$$S(q,\omega) = \frac{1}{2\pi N} \int_{-\infty}^{+\infty} dt \sum_{ij} \langle S_i(t) S_J(O) e^{iq.R_{ij}} \rangle$$

$$S_{Bregg}(q,\omega) = \frac{1}{2\pi N} \int_{-\infty}^{+\infty} dt \sum_{ij} \langle S_i(t) \rangle \langle S_J(O) e^{iq.R_{ij}} \rangle$$

This result for $1/\tau = 1/\tau_{AG}$ in the limit $S(q,\omega) \sim \delta(\omega)\delta(q)$,

$$g(q,\omega) = \frac{K_\beta T}{q^2\mu^2}(X(q))(\frac{\beta\omega}{e^{\beta\omega}-1})F(q,\omega) \tag{3.2.13}$$

Insert eqn(3.2.13) in to eqn(3.2.11), we can get

$$\frac{1}{\tau} = \frac{1}{\tau_{AG}}\frac{1}{2K_F^2 S(S+1)}\int^{2K_F} qdq \int_{-\infty}^{\infty} d\omega \frac{K_\beta T}{q^2\mu^2}(X(q))(\frac{\beta\omega}{e^{\beta\omega}-1})\frac{Dq^2}{\Pi(Dq^2)+\omega^2} \tag{3.2.14}$$

$$\frac{\tau_{AG}}{\tau} = \frac{1}{2K_F^2 S(S+1)}\int^{2K_F} qdq \int_{-\infty}^{\infty} d\omega \frac{K_\beta T}{q^2\mu^2}[\frac{S(S+1)}{T-T_M+a^2q^2}]\frac{\beta\omega}{e^{\beta\omega}-1}\frac{Dq^2}{\Pi(Dq^2)^2)+\omega^2}$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T}{2K_F^2\mu^2}\int^{2K_F}\frac{q*D}{T-T_M+a^2q^2}dq\int_{-\infty}^{\infty} d\omega\frac{\beta\omega}{e^{\beta\omega}-1}\frac{1}{\Pi(Dq^2)^2)+\omega^2}$$

For the power series expansion.

$$e^{\beta\omega}-1 = 1+\beta\omega+(\beta\omega)^2+(\beta\omega)^3.......-1 = \beta\omega \tag{3.2.15}$$

so that $\frac{\beta\omega}{e^{\beta\omega}-1} = 1$

$$\frac{\tau_{AG}}{\tau} = \frac{1}{2K_F^2}\int^{2K_F} qdq\int_{-\infty}^{\infty} d\omega\frac{K_\beta T}{q^2\mu^2}\left[\frac{1}{T-T_M+a^2q^2}\right]\frac{Dq^2}{\Pi(Dq^2)^2)+\omega^2}$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T}{2K_F^2\mu^2}\int^{2K_F}\frac{q*D}{T-T_M+a^2q^2}dq\int_{-\infty}^{\infty} d\omega\frac{1}{\Pi(Dq^2)^2)+\omega^2}$$

We assume that the spin-diffusion constant D

$$D = D_0(T/T_M - 1 + a^2q^2)^{1/4} \tag{3.2.16}$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T}{2K_F^2\mu^2}\int^{2K_F}\frac{q*D}{T-T_M+a^2q^2}dq[\frac{1}{\pi}*\pi]$$

integrate above equation we obtain

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T}{2K_F^2\mu^2}\int^{2k_F}\frac{q*D}{a^2(\frac{T-T_M}{a^2}+q^2)}dq \tag{3.2.17}$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T}{2K_F^2\mu^2}\int^{2k_F}\frac{q*D_0(T/T_g-1+a^2q^2)^{1/4}}{a^2(\frac{T-T_M}{a^2}+q^2)}dq \tag{3.2.18}$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T D_0}{2K_F^2\mu^2 T_M}\int^{2k_F}\frac{q(T/T_M-1+a^2q^2)^{1/4}}{(T/T_M-1+\frac{q^2a^2}{T_M})}dq \tag{3.2.19}$$

For approximation the two term so that

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T D_0}{2K_F^2\mu^2 T_g}\int^{2k_F}\frac{q}{(T/T_M-1+q^2a^2)^{3/4}}dq$$

$$\frac{\tau_{AG}}{\tau} = \frac{K_\beta T/T_g D_0}{K_F^2\mu^2}[\frac{1}{a^2}(T/T_M-1+(2K_F)^2a^2)^{1/4}] \tag{3.2.20}$$

we take the Brillouin zone wave vector $q_{BZ} = 2K_F$, we can simplify to gat and Where the constant value take

$$C = \frac{K_\beta D_0}{K_F^2 \mu^2 a^2} \qquad E = \frac{q^2 a^2}{T_{CO}} = \frac{(2K_F a)^2}{T_{CO}}$$

$$\frac{\tau_{AG}}{\tau} = C[(T/T_M - 1 + ET_{CO})^{1/4}] \tag{3.2.21}$$

If the ω dependence of $g(q,\omega)$ is purely elastic, we obtain the expected behavior of $1/\tau$ expressing more in this equation,

$$g(q,\omega) = \frac{K_\beta T}{q^2 \mu^2} X(q) \frac{\beta\omega}{e^{\beta\omega} - 1} F(q,\omega) \tag{3.2.22}$$

Where X(q) is the q-dependent susceptibility and $F(q,\omega)$ is the spectral weight function, since

$$F(q,\omega) = \frac{1}{\Pi} \frac{Dq^2}{(Dq^2)^2 + \omega^2} \tag{3.2.23}$$

Where D is the spin-diffusion constant.

$$\begin{aligned} X(q) &= \frac{q^2\mu^2}{K_\beta T} \frac{e^{\beta\omega} - 1}{\beta\omega} \frac{g(q,\omega)}{F(q,\omega)} \\ &= \frac{q^2\mu^2}{K_\beta T} \frac{e^{\beta\omega} - 1}{\beta\omega} \frac{\frac{1}{2\Pi N}\left[\int_{-\infty}^{+\infty} dt e^{-i\omega t} \sum_{ij}[\langle S_i(t) S_j(0)\rangle e^{ir.R_{ij}} - \langle S_i\rangle\langle S_j\rangle e^{ir.R_{ij}}]\right]}{[\frac{1}{\Pi}\frac{Dq^2}{(Dq^2)^2+\omega^2}]} \end{aligned}$$

Rearrange the above equation using power series for ferromagnetic case eqn(3.2.15) assume orstein-Zernike form can we get

$$X(q) = \frac{S(S+1)}{T - T_g + a^2 q^2} \tag{3.2.24}$$

and we also assume that the spin-diffusion constant D takes its form

$$D = D_0(T/T_g - 1 + (aq)^2)^{1/4} \tag{3.2.25}$$

We tried different form for D, including D constant and find that the results for $1/\tau$ and the phase diagrams are essentially insensitive to the T and q dependence of D.

When the spin-flip scattering rate form

$$\tau_0\tau_s n_s = \frac{1}{4\Pi^2 s(s+1)} \tag{3.2.26}$$

When the spin of magnetic impurity $\tau_s \sim \tau_{AG}$ insert eqn(3.2.26) into eqn(3.2.24) we can get

$$X(q) = \frac{1}{T - T_g + a^2q^2} * \frac{1}{4\Pi^2\tau_0\tau_s n_s} \tag{3.2.27}$$

From RKKY interaction radiation system theory the spin glass transition $T_g \sim \tau_0 n_s$

$$\begin{aligned} X(q) &= \frac{1}{4\Pi^2 T_g\tau_s(T - T_g + a^2q^2)} \\ &= \frac{1}{4\Pi^2 T_g\tau_s(T - T_g + ET_{CO})} \\ &= \frac{1}{4\Pi^2 T_g T_{CO}\tau_s(\frac{T}{T_{C0}} - \frac{T_g}{T_{CO}} + E)} \end{aligned} \tag{3.2.28}$$

$$X_s(q) = \frac{1}{4\Pi^2 T_g T_{CO}\tau_{AG}(\frac{T}{T_{C0}} - \frac{T_g}{T_{CO}} + E)} \tag{3.2.29}$$

Where $X_s(q)$= $X_{AG}(q)$ $E = \frac{a^2q^2}{T_{CO}}$ certain constant value

For the spin glass condition

$$g^{SG}(q,\omega) = \frac{1}{2\pi N}\int_{-\infty}^{+\infty} dte^{-i\omega t}\sum_{ij} e^{-iq.R_{ij}}\Big[\langle S_i(t)S_j(0)\rangle e^{ir.R_{ij}} - [\langle S_i\rangle][\langle S_j\rangle]\Big]_c \tag{3.2.30}$$

Where $[3.2.30]_c$ is the configuration average

Insert eqn (3.2.30) in to eqn(3.2.11), we can get.

$$\begin{aligned} \frac{\tau_{AG}}{\tau} &= \frac{1}{2K_F^2 S(S+1)}\frac{1}{2\pi N}\int^{2K_F} qdq\int_{-\infty}^{\infty}\frac{\beta\omega}{e^{\beta\omega}-1}d\omega\int_{-\infty}^{+\infty} dte^{-i\omega t} * \\ &\sum_{ij} e^{-iq.R_{ij}}[\langle S_i(t)S_j(0)\rangle e^{ir.R_{ij}} - [\langle S_i\rangle][\langle S_j\rangle]_c \end{aligned} \tag{3.2.31}$$

$[S_i(\infty)S_j(0)] = Q_{ij}$ and $[\langle S_j\rangle]$=0 in time independent. so that

$$\frac{\tau_{AG}}{\tau} = \frac{Q}{S(S+1)} + \frac{1}{2K_F^2 S(S+1)}\int_{-\infty}^{+\infty} qdq\int_{-\infty}^{+\infty} d\omega\frac{\beta^2\omega^2}{(e^{-\beta\omega}-1)^2}K_\beta T X(q)F(q,\omega) \tag{3.2.32}$$

From eqn (3.0.33) $\frac{\beta^2\omega^2}{(e^{-\beta\omega}-1)^2} = 1$ than

$$\frac{\tau_{AG}}{\tau} = \frac{Q}{S(S+1)} + \frac{K_\beta T}{2K_F^2 S(S+1)} \int_{-\infty}^{+\infty} qdq \int_{-\infty}^{+\infty} d\omega K_\beta T X(q) F(q,\omega) \qquad (3.2.33)$$

and substitute $F(q,\omega)$ from eqn(3.2.23) in to eqn(3.2.25)

$$\begin{aligned} \frac{\tau_{AG}}{\tau} &= \frac{Q}{S(S+1)} + \frac{1}{2K_F^2 S(S+1)} \int_{-\infty}^{+\infty} qdq \int_{-\infty}^{+\infty} d\omega K_\beta T X(q) \frac{1}{\Pi} \frac{Dq^2}{(Dq^2)^2+\omega^2} \\ &= \frac{Q}{S(S+1)} + \frac{1}{S(S+1)} \frac{1}{2\pi K_F^2} \int_{-\infty}^{+\infty} X(q) qDdq \int_{-\infty}^{+\infty} \frac{1}{(Dq^2)^2+\omega^2} d\omega \end{aligned} \qquad (3.2.34)$$

When the spin glass case take D_0 = D a constant. However, the result are not dependent for $F(q,\omega)$ both above and below the transition T_g from equation, and use the above expression.

$$\begin{aligned} \frac{\tau_{AG}}{\tau} &= \frac{Q}{S(S+1)} + \frac{1}{S(S+1)} \frac{1}{2\pi K_F^2} \int_{-\infty}^{+\infty} X(q) qDdq \int_{-\infty}^{+\infty} \frac{1}{(Dq^2)^2+\omega^2} d\omega \\ &= \frac{Q}{S(S+1)} + \frac{K_\beta T}{S(S+1)} \frac{D_0}{2\pi K_F^2} \int^{2K_F} X(q) qdq \int_{-\infty}^{+\infty} \frac{1}{(D_0 q^2)^2+\omega^2} d\omega \\ &= \frac{Q}{S(S+1)} + \frac{K_\beta T}{S(S+1)} \frac{D_0}{2K_F^2} \int^{2K_F} X(q) qdq [\frac{1}{\pi} * \pi] \\ &= \frac{Q}{S(S+1)} + \frac{D_0 K_\beta T}{2K_F^2} \int^{2K_F} q \frac{(X(q)}{(T-T_g+a^2q^2)} dq \end{aligned} \qquad (3.2.35)$$

when use this form for $F(q,\omega)$ both above and below transition temperature $T_g$at low temperatures, we do not have well define like diffusive type. eqn(3.2.22) and eqn(3.2.30) combine together For X(q), we neglects the dependence and can get

$$X(q) = \begin{cases} \frac{S(S+1)}{K_F T} & T \geq T_g \\ \frac{S(S+1)}{K_\beta T_g} & T \leq T_g \end{cases} \qquad (3.2.36)$$

For above T_g we use the usual paramagnetic result, but below T_g, we take x to be constant in experimental result. The quality Q is like an order parameter

For spin glass.

$$Q = (S^2(1 - T/T_g) \qquad (3.2.37)$$

Substitute eqn(3.2.37) in to eqn(3.2.35) we can get

$$\begin{aligned}
\frac{\tau_{AG}}{\tau} &= \frac{S^2(1-T/T_g)}{S(S+1)} + \frac{D_0 K_\beta T}{2K_F^2}\int^{2K_F} q\frac{X(q)}{(T-T_g+a^2q^2)}dq \\
&= \frac{S^2(1-T/T_g)}{S(S+1)} + \frac{D_0 K_\beta T}{2K_F^2}\int^{2K_F} q\frac{\frac{S(S+1)}{K_\beta T_g}}{(T-T_g+a^2q^2)}dq \\
&= \frac{S^2(1-T/T_g)}{S(S+1)} + \frac{D_0 T/T_g}{2K_F^2}\frac{1}{2a}\ln(T-T_g+(2K_Fa)^2) \\
&= \frac{S^2(1-T/T_g)}{S(S+1)} + \frac{D_0 T/T_g}{2K_F^2}\frac{1}{2a}\ln(T-T_g+ET_{CO}) \\
&= \frac{S^2(1-T/T_g)}{S(S+1)} + B(\frac{T}{T_g})\ln(T_{CO}(\frac{T}{T_{CO}}-\frac{T_g}{T_{CO}}+E)) \qquad (3.2.38)
\end{aligned}$$

Where B= $\frac{D_0}{4(aK_F)^2}$ and E= $(2K_Fa)^2T_{CO}$ For $\frac{X_{AG}}{X}$ can get from eqn(3.2.29) and eqn(3.2.36)

$$\frac{X_{AG}}{X} = \frac{K_\beta}{4\Pi^2 T_{CO}(S(S+1))\tau_{AG}(\frac{T}{T_{C0}}-\frac{T_g}{T_{CO}}+E)} \qquad (3.2.39)$$

$$\frac{X_{AG}}{X} = \frac{A}{(\frac{T}{T_{C0}}-\frac{T_g}{T_{CO}}+E)} \qquad (3.2.40)$$

Where $A = \frac{K_\beta}{4\Pi^2 T_{CO}(S(S+1))\tau_{AG}}$.

Chapter 4

Summary

Superconductivity and magnetism were previously thought as incompatible in BCS theory the superconductor explain in magnetic filed, which is turn destroy superconductivity. The discovery of some rare earth ternary compounds that shows the superconductivity and magnetic order in system are coexist.The random of magnetic mostly the superconductivity coexist with spin glass occur in (122) and (11) family, because they have vary at low critical temperature and mobile electrons or holes are doped into anti-ferromagnetic elements like Te or Se parent compound from $Fe_{1+Y}Se_XTe_{1-X}$.

- The observation of superconductivity with zero resistance critical transition temperature at 8 K in the PbO type $FeSe$ compound known as 11 family. The crystal structure based on $FeAs$ layer of tetragonal form.

- Anti-ferromagnetic change to paramagnetic Neel temperature drops rapidly increase for $X \lesssim 0.1$,but our measurements indicate that bulk superconductivity only appears for $X \gtrsim 0.4$..

- The$FeSe$ superconductor transition temperature T_c $(zero \sim 8k)$ exhibits a compositional dependence,decreasing for both under doped and over doped materials, the doping concentration of $FeSe_XTe_{(1-X)}$ has effect of superconductivity in the region Of $X = (0 - 1)$ at reach the maximum depend material $T_C \sim 15k$.

- When ($T > T_M$) the magnetic impurity are non interacting.When ($T < T_M$) the interaction between magnetic impurity are strong and spontaneous magnetic ordering set in.

- Spin glasses are disordered or random solid state magnetic systems in nonmagnetic host characterized by a random freezing of spin well defined temperature T_g.

- Important property of spin glass their *unique nature* is the oscillating character of the exchange interaction. Because the randomly located spin that have interactions of essentially random sign, so that spin glass is the peculiar (Douala) characteristics coupling between the magnetic moments can be either ferromagnetic or anti-ferromagnetic in short-range ordered.

- Short range and long range depend on exchange interaction J_{ij} with the separation $|r_i - r_j|$ distance between the two impurities.$|J_{ij}| \to \infty$ for long range and $|J_{ij}| \to 0$ Short range.

- For $T > T_g$ paramagnetic occur, For $T < T_g$ the paramagnetic susceptibility to be constant and For $T = T_g$ is not reel but on artifact the temperature depends on Q. that some local correlations among the randomly separated spins also exist.

- Genzebrg Landon theory for the spin glass based on free energy and order parameter. For BCS the electron superconductivity observed in metal and exhibits the energy gap (Δ).

- The neutron scattering were determined the experimental concentration of electron in the crystal.

- $FeSe_XTe_{1-X}$ was found that superconductor transition temperature with Te doping maximum electron reach $T_c \sim 15k$ and also change applying external pressure at $1.5GPa$,the superconducting $T_c \sim 27k$. as well as $FeSe_XTe_{1-X}$ in FeSe layer the the transition temperature under pressure approximately 37 k.

- $FeSe_{1-X}Te_X$ crystal is Te doping ($X \geq 0.5$) the resisting measurements showed superconducting with $T_c \sim 14k$for $x = 0.5 - 0.7$,$Fe_{1+Y}Te_{1-X}Se_X$ forming a compounds initially show its superconducting with T_c at high as 15 k for $x \sim 0.5$. But X value near to zero, superconducting will be destroyed.

- The phase diagram was increasing and indicated magnetic order for small value of X,which coexist with superconducting over small range of concentration in the layer of Fe-x ($X = Te/As$)layers is weekly drop.

- FeSe could be an anti-ferromagnetic bound line between interact and localized behavior and in plane Fe-Fe exchange coupling doped on Fe-Se distance.

- The doping concentration of electron $Fe_{1.1}Te_{1-X}Se_X$ (X= 0, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.55 and 1) and $FeTe_{1-X}Se_X$ (X=0.1, 0.3, 0.4, 0.5)

- Increase of $Se(X > 0.1)$ in both $Fe_{1.1}Te_{1-X}Se_X$ and $FeTe_{1-X}$ series in superconductivity in temperature range 12 k and 15 k respectively.

- The phase diagram clearly shows the trends and the existence of three distinct phase.When the $x \lesssim 0.1$ the anti-ferromagnetic phase, $x \gtrsim 0.4$ the bulk Superconducting phase occurs and intermediate between the two Regine the SG phase can be occur.

- $Fe_{1.1}Te_{1-X}Se_X(0.1 \leq X \leq 0.55)$ system is magnetic developed in local moment, but $FeTe_{1-X}Se_X$ display bulk superconducting with no magnetic order.

- The ferromagnetic system even at low temperatures the spins become randomly frozen in random space, it is applicable to the problem of disordered systems with random interaction solved by Mean-Field theory.

- The model Hamiltonian for coexistence Spin glass Superconducting in the compound of $(Fe_{1+Y}Se_XTe_{1-X})$ the BCS Hamiltonian for the system with out magnetic impurities using by first low of Born approximation.

$$\tau = \frac{1}{\pi T_C}\left[\left(\frac{8}{\ln(\frac{T_C}{T_{CO}})}+4\right)^{1/2}-1\right]^{-1} \tag{4.0.1}$$

so τ = 0.006912, the spin flip scattering time .initial T_{CO}=8 K ,and T_C= 14.5 K

- we take the Brillouin zone wave vector $q_{BZ} = 2K_F$, the ratio of $\frac{\tau_{AG}}{\tau}$.

$$\frac{\tau_{AG}}{\tau} = C[(T/T_M - 1 + ET_{CO})^{1/4}] \tag{4.0.2}$$

Where,

$$C = \frac{K_\beta D_0}{K_F^2\mu^2a^2}E = \frac{q^2a^2}{T_{CO}} = \frac{(2K_Fa)^2}{T_{CO}}$$

- The ac.susceptibility depending on temperature and spin diffusion constant.

$$X(q) = \frac{S(S+1)}{T - T_g + a^2q^2} \tag{4.0.3}$$

and

$$D = D_0(T/T_g - 1 + (aq)^2)^{1/4} \tag{4.0.4}$$

From RKKY interaction radiation system theory the spin glass transition $T_g \sim \tau_0 n_s$ and the ac.susceptibility with in spin flip scattering form.

$$X(q) = \frac{1}{T - T_g + a^2q^2} * \frac{1}{4\Pi^2\tau_0\tau_s n_s} \tag{4.0.5}$$

- when the spin glass condition both above and below transition temperature $T_g$at low temperatures For X(q) we get.

$$X(q) = \begin{cases} \frac{S(S+1)}{K_FT}T \geq T_g \\ \frac{S(S+1)}{K_\beta T_g}T \leq T_g \end{cases} \tag{4.0.6}$$

- The quality Q is like an order parameter for spin glass.

$$Q = (S^2(1 - T/T_g) \tag{4.0.7}$$

- For spin glass the ratio of retardation time and ac susceptibility in AG and simple dependent of q and ω is:

$$\frac{\tau_{AG}}{\tau} = \frac{S^2(1 - T/T_g)}{S(S+1)} + B(\frac{T}{T_g})\ln(T_{CO}(\frac{T}{T_{CO}} - \frac{T_g}{T_{CO}} + E)) \tag{4.0.8}$$

$$\frac{X_{AG}}{X} = \frac{A}{(\frac{T}{T_{C0}} - \frac{T_g}{T_{CO}} + E)} \tag{4.0.9}$$

Where $A = \frac{K_\beta}{4\Pi^2 T_{CO}(S(S+1))\tau_{AG}}$.

- Take for $Fe_{1+Y}Se_XTe_{1-X}$ compound T_{C0}= 8 K and τ_{AG}=τ_S = 0.006912 sec show the graph description.

4.1 Graphical description

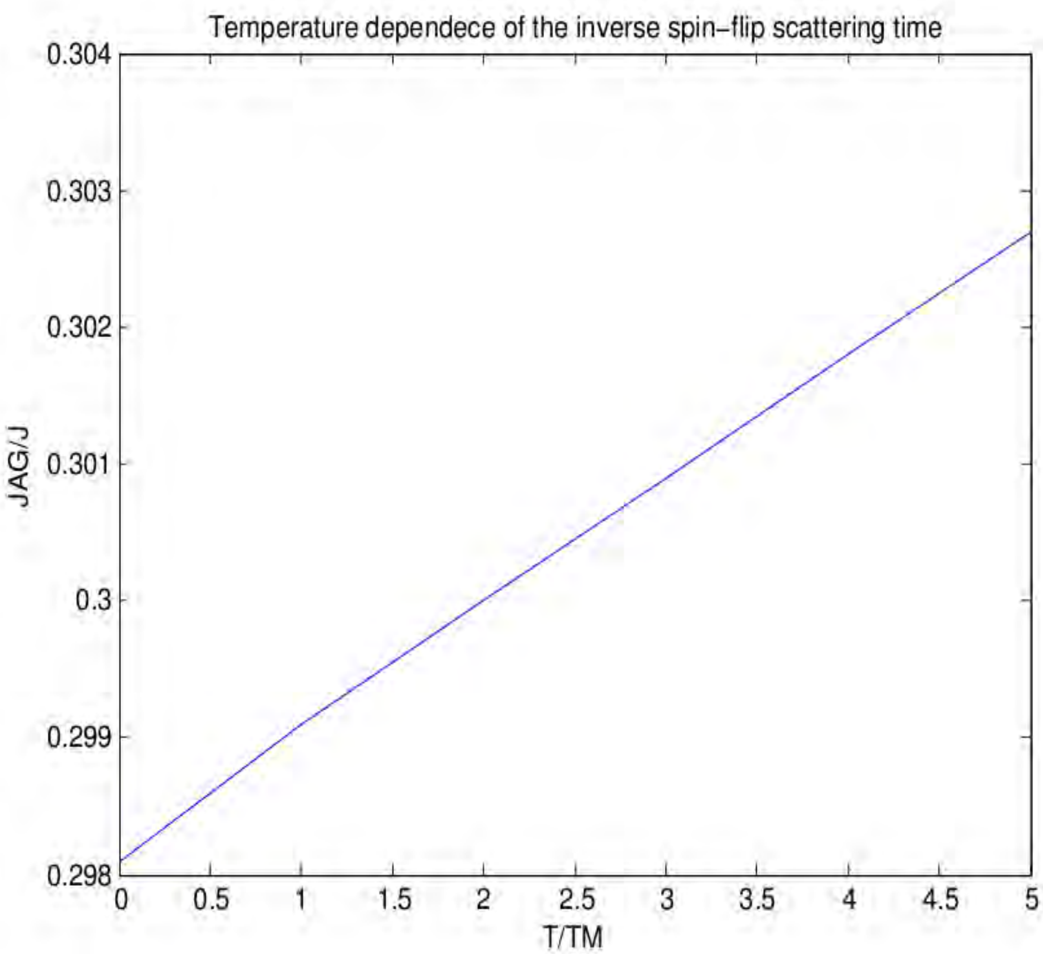

Figure 4.1: Temperature dependence of the inverse spin-flip scattering time $\frac{1}{\tau}$ normalized with $\frac{1}{\tau_{AG}}$ where C=0.1, and E=10 for large T the AG result in$Fe_{1+Y}Se_XTe_{1-X}$. compound.

This figure shows that the ratio of temperature with magnetic impurity transition temperature $\frac{T}{T_M}$ increases the ratio of AG retardation time $\frac{\tau_{AG}}{\tau}$.

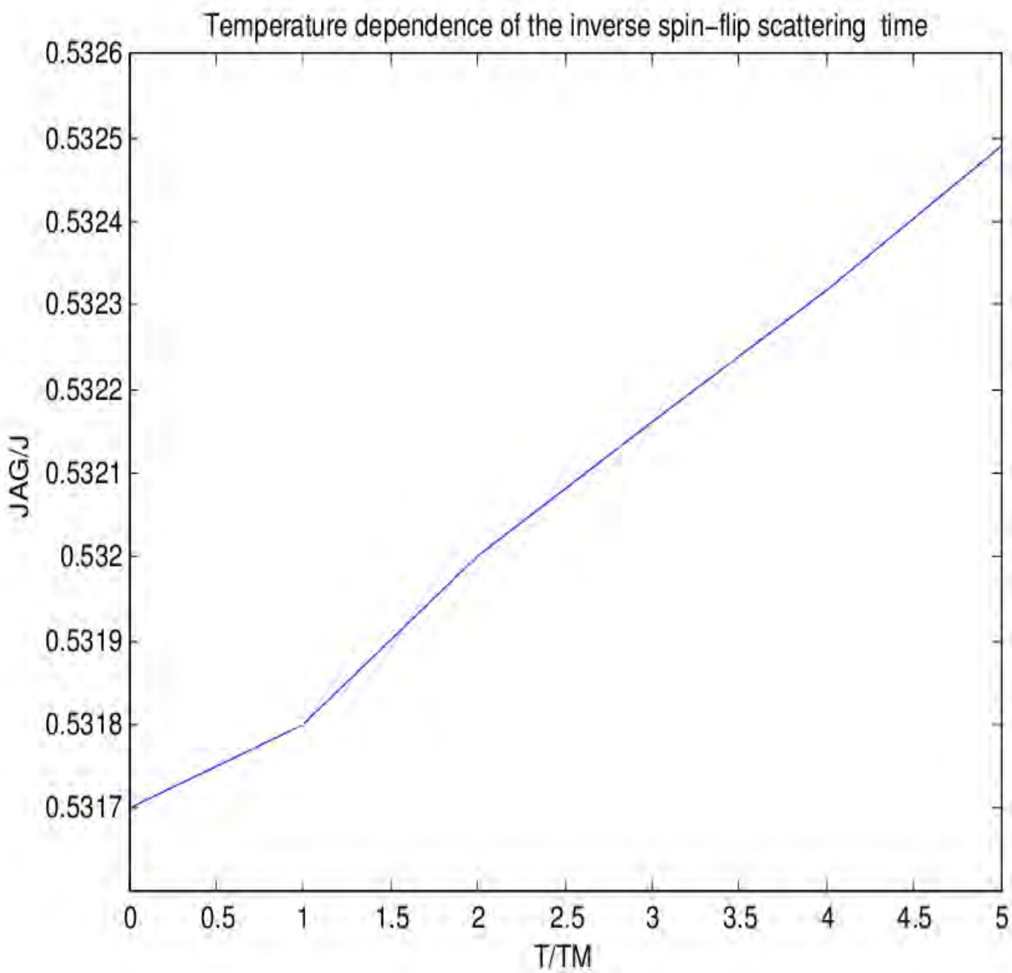

Figure 4.2: Temperature dependence of the inverse spin-flip scattering time $\frac{1}{\tau}$ normalized with $\frac{1}{\tau_{AG}}$ where c=0.1, and E=100 for large T the AG result in $Fe_{1+Y}Se_XTe_{1-X}$

This figure shows that the ratio of temperature with magnetic impurity transition temperature $\frac{T}{T_M}$ increases the ratio of AG retardation time $\frac{\tau_{AG}}{\tau}$also increases. also increases.

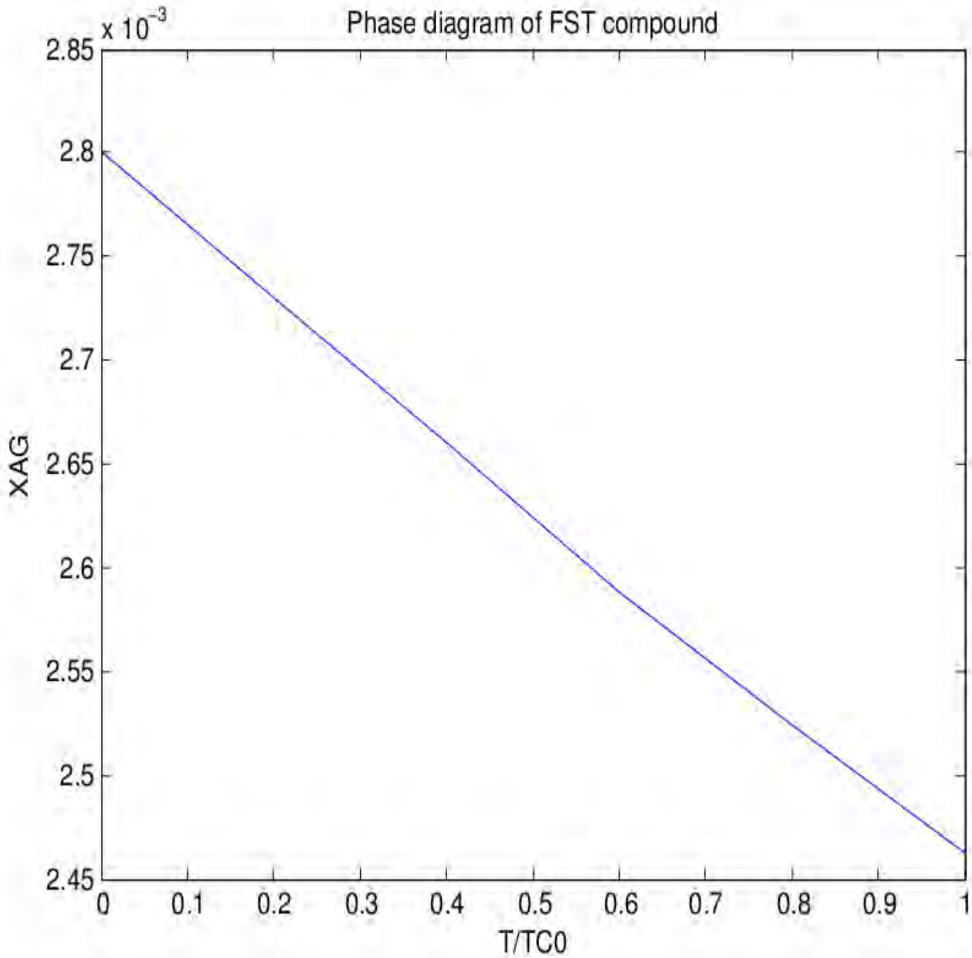

Figure 4.3: Phase diagram for $Fe_{1+Y}Se_XTe_{1-X}$ it show the superconducting transition temperature for E=10 take $T_c = 8k$ and $\tau_S = 0.00169$

This figure shows that the ratio of temperature with magnetic impurity transition temperature $\frac{T}{T_{CO}}$ increases but ac susceptibility depending on q $X(q)$ decreases.

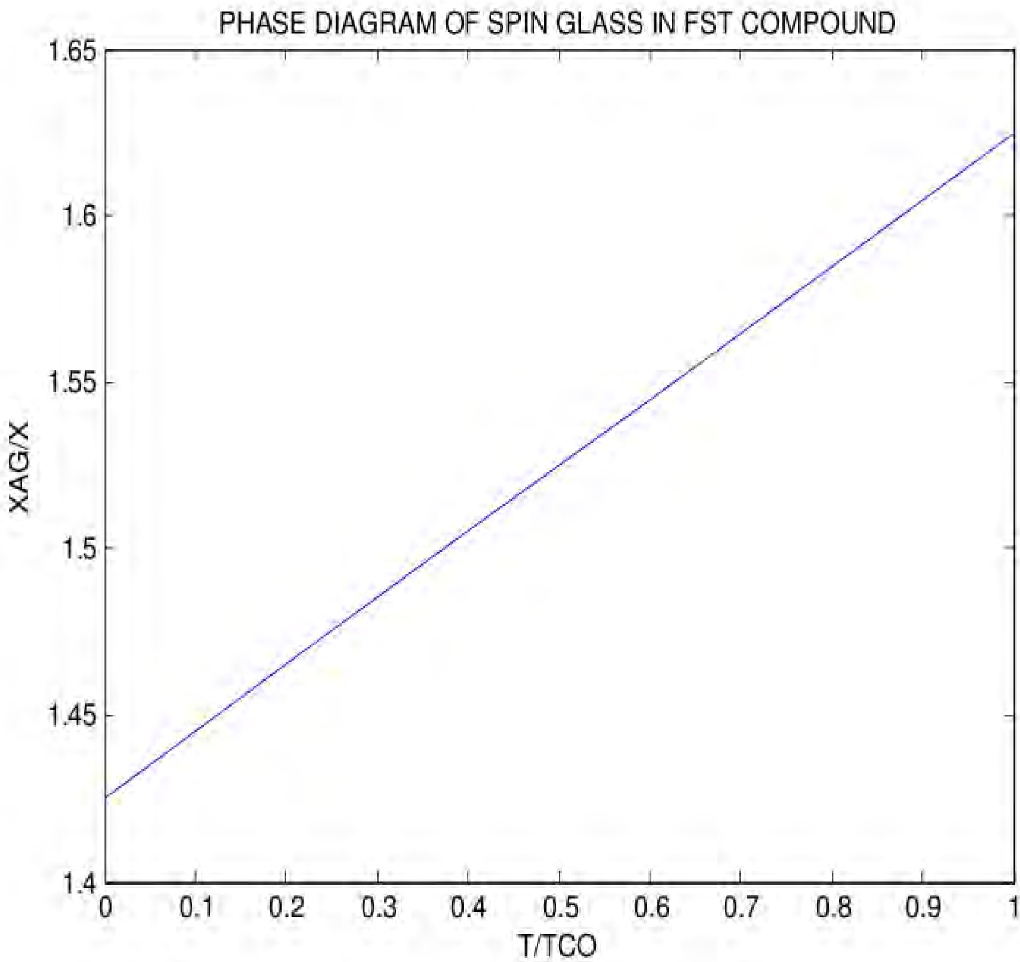

Figure 4.4: Phase diagram for $Fe_{1+Y}Se_XTe_{1-X}$ it show the superconducting transition temperature for A=5 and E=10 take $T_c = 8k$ and $\tau_S = 0.00169$

This figure shows that the ratio of temperature with magnetic impurity transition temperature $\frac{T}{T_{CO}}$ increases but ac susceptibility ac susceptibility depending on q $X(q)$ increases.

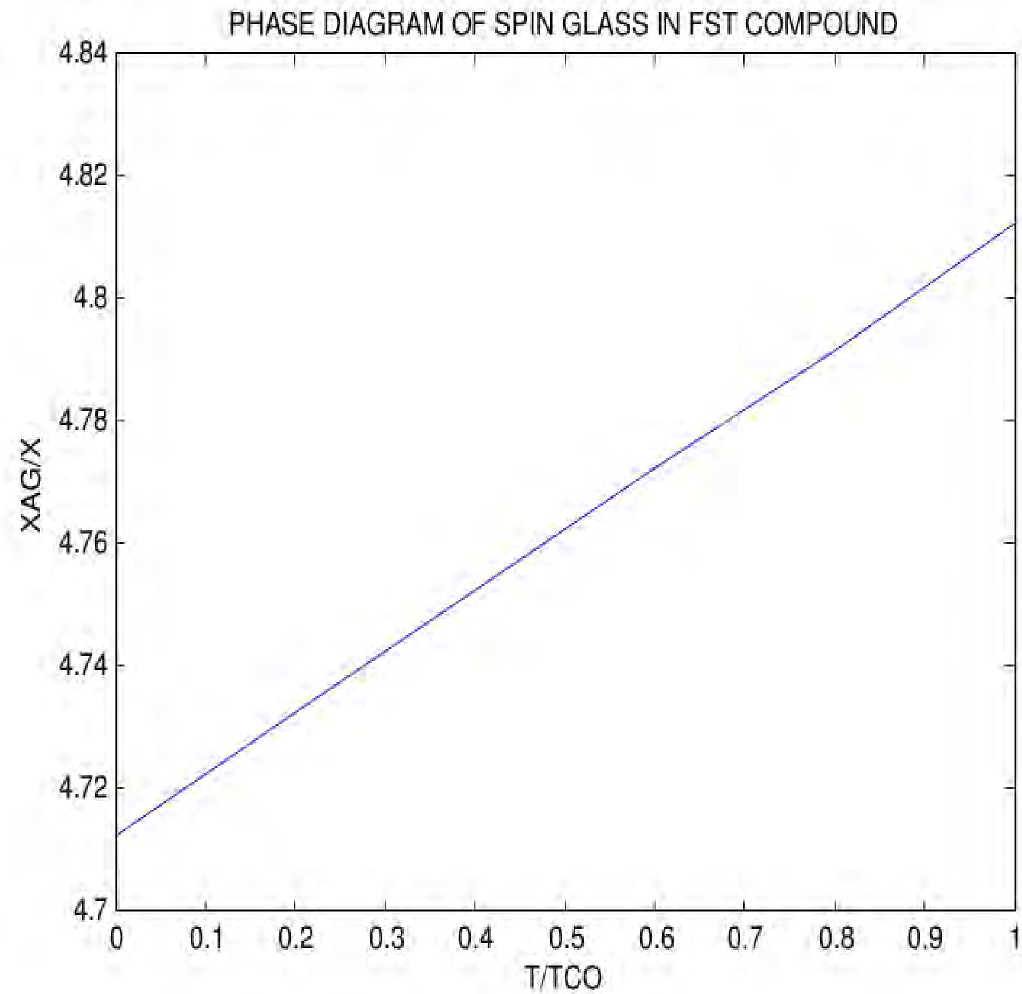

Figure 4.5: Phase diagram for spin-glass with spin $s = \frac{5}{2}$ $Fe_{1+Y}Se_XTe_{1-X}$ for A=10 and E=50 take $T_c = 8k$ and $\tau_S = 0.00169$

This figure shows that the ratio of temperature with magnetic impurity transition temperature $\frac{T}{T_{CO}}$ increases but ac susceptibility depending on q $X(q)$ increases.

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Declaration

This project is my original work, has not been presented for a degree in any other University and that all the sources of material used for the project have been dully acknowledged.

Name: ANTENEH YESIGAT

Signature:– – – – – – – – – – – – –

Place and time of submission: Addis Ababa University, June 2011

This project has been submitted for examination with my approval as University advisor.

Name: Prof.SINGH

Signature:– – – – – – – – – – – –