HIGH FIELD MAGNETIZATION AND ^{57}Fe HYPERFINE FIELD IN AMORPHOUS $Ru_xFe_{80-x}B_{20}$ ALLOYS

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Magnetism in amorphous alloys of $Ru_xFe_{80-x}B_{20}$, $0 \leq x \leq 22$ has been investigated using high field magnetization and Mössbauer spectroscopy. The average Fe hyperfine field in $Ru_{18}Fe_{62}B_{20}$ shows an anomalous rise at low temperatures. In Ru rich alloys a low field component appears in the hyperfine field distribution and the alloys do not saturate magnetically in 80 kG fields. It is inferred that their magnetic structure is non collinear and that antiferromagnetic exchange in the system increases with Ru concentration.

1. INTRODUCTION

Amorphous alloys of $Ru_xFe_{80-x}B_{20}$, $0 \leq x \leq 22$ show interesting changes in magnetic behaviour with Ru concentration and temperature. As a function of these, distinct regimes occur in these alloys which exhibit ferromagnetic, double transition and spin glass like behaviour at low temperatures respectively /1/. Ferromagnetism in this system disappears at a critical iron concentration far from that suggested by percolation theory. To improve our understanding of the magnetism of these alloys we have carried out high field magnetization measurements at 4.2K and ^{57}Fe Mössbauer studies as a function of Ru concentration and temperature. We report here the results of our investigations. The alloys used in the present study are of nominal composition based on weights before casting and are same on which ac susceptibility and dc magnetization measurements in very low fields were made earlier /1/.

2. HIGH FIELD MAGNETIZATION

DC magnetization was measured at 4.2K with a Faraday balance in the field provided by a superconducting magnet. The magnetic moment per Fe atom shown in Fig. 1 for different alloys was derived from the magnetization as a function

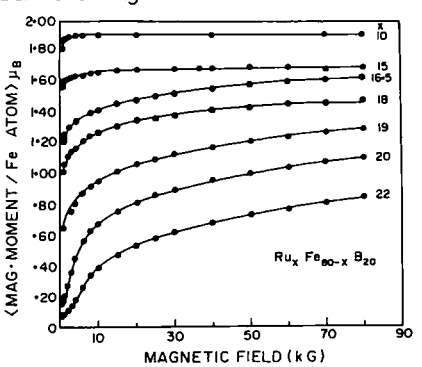

Fig.1. Magnetization in moment per Fe atom at 4.2K as a function of applied field. The numbers shown against different curves represent x, the Ru concentration in the alloy.

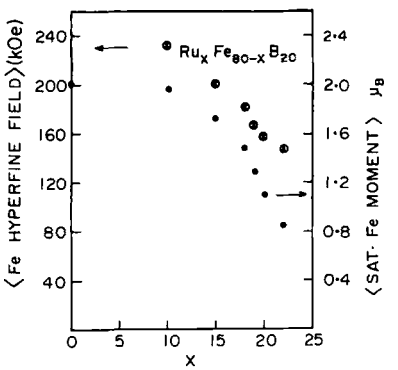

Fig.2. Average Fe hyperfine field and average saturation Fe moment at 4.2K as a function of Ru concentration.

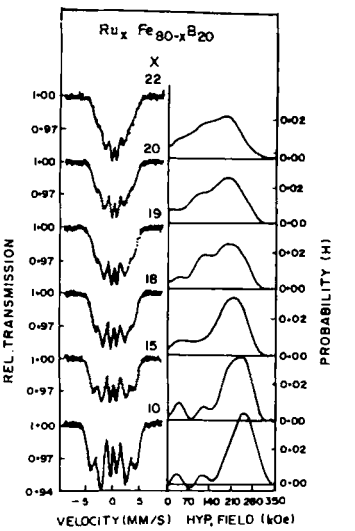

Fig.3. ^{57}Fe Mössbauer spectra and hyperfine field distribution at 4.2K in $Ru_xFe_{80-x}B_{20}$ alloys.

of applied field assuming a zero moment on Ru. Extrapolating against 1/H the value of the saturation magnetization was obtained.$\langle \mu_s \rangle$, the average saturation moment per Fe atom shown in Fig.2 decreases with increasing Ru content. While the alloys with Ru concentration X of 10 and 15 atomic % magnetically saturate in fields of 20 and 30 kG respectively the Ru rich alloys do not saturate even at 80 kG, the maximum applied field in our experiments. The values of $\langle \mu_s \rangle$ are 5,11,15 and 25% larger than the values measured in the field of 80 kG for alloys with x = 18,19,20 and 22 respectively.

3. ^{57}Fe MÖSSBAUER SPECTRA

In the paramagnetic state the spectra in all the alloys consisted of an asymmetric quadrupole doublet with little temperature variation. The quadrupole splitting is typically 0.43 mm/sec for x = 20 alloy. Fig. 3 shows the spectra at 4.2K for six of the alloys. The hyperfine field distribution p(H) was obtained using the Fourier series method of Window/2/The average Fe hyperfine field deduced from p(H) decreases with increasing Ru concentration while the width of p(H) incrases. In Ru rich alloys a low field component develops in hyperfine field distribution and becomes prominent with increase in Ru concentration. For $Ru_{18}Fe_{62}B_{20}$, $Ru_{19}Fe_{61}B_{20}$ and for $Ru_{20}Fe_{60}B_{20}$ which undergoes a transition from paramagnetic to a spin glass like phase /1/ at low temperatures the average Fe hyperfine field was evaluated as a function of temperature . The hyperfine splitting in these alloys appears progressively on cooling below the ordering temperature as illustrated in Fig. 4 for $Ru_{20}Fe_{60}B_{20}$. Fig.5 shows the average Fe hyperfine field as a function of temperature in the above alloys. The average Fe hyperfine field rises anomalously below 70K in $Ru_{18}Fe_{62}B_{20}$.

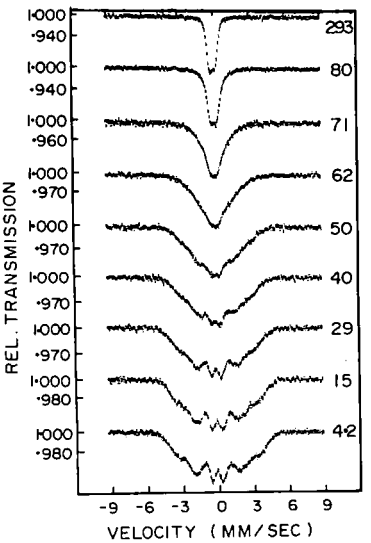

Fig.4. ^{57}Fe Mössbauer spectra in $Ru_{20}Fe_{60}B_{20}$. The numbers shown against different spectra are temperatures in K.

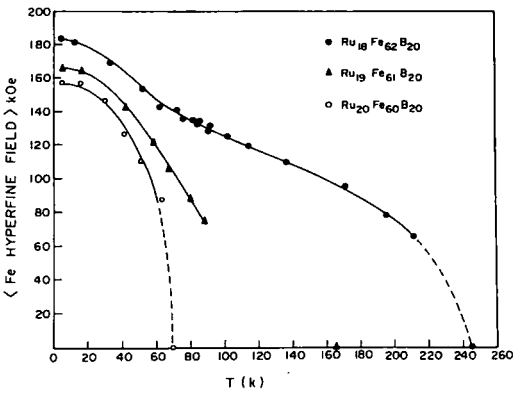

Fig.5. Average Fe hyperfine field in $Ru_{18}Fe_{62}B_{20}$, $Ru_{19}Fe_{61}B_{20}$ and $Ru_{20}Fe_{60}B_{20}$ alloys as a function of temperature.

We have shown earlier that spin glass like behaviour appears in this alloy below 65K /1/. Anomalous increase in average Fe hyperfine field at a temperature below the Curie temperature T_C has recently been observed in some glassy alloys /3,4/. The observed increase in average hyperfine field in these cases has been interpreted in terms of the Gabay-Toulouse theory /5/. The data presented in Fig.5 indicates that a change in slope in the hyperfine field vs temperature curve is likely in $Ru_{19}Fe_{61}B_{20}$ at a temperature above 80K. Although spectra could be observed in different alloys at higher temperatures than those shown in the above figure, the average hyperfine field could not be evaluated accurately at temperatures close to T_C due to the magnetic and quadrupole interactions becoming comparable and due to lack of structure in the spectra.

4. DISCUSSION

The appearance of a magnetic moment on an iron atom in an amorphous alloy is known to be related to its number of iron nearest neighbours /6/. The moment appears inhomogeneously near a critical iron concentration in the alloy. For all concentrations investigated during the present study the average Fe hyperfine field at 4.2K shown in Fig.2 is sizeable. In Ru rich alloys a plot of magnetization M vs H at 4.2K in the form M^2 vs HM^{-1} and its extrapolation to zero applied field indicates that there is an average spontaneous moment in the system. It is clear that even in the alloy with highest Ru concentration of 22 atomic percent we have not reached the critical concentration for the disappearance of the average iron moment. However, in these alloys magnetic and nonmagnetic iron atoms with differences in short range order can coexist. The low field component seen in hyperfine field distribution in Ru rich alloys at fields of less than 100 kOe may arise due to such effects.

The Curie temperature drops rapidly as Ru replaces Fe, particularly below x=18. If Ru acts as a simple dilutant one would expect the behaviour of the system as describable by that of percolation. However, the critical concentration for the disappearance of ferromagnetism in this alloy lies between 60 and 61 atomic percent of iron (Ru concentration between 19 and 20 atomic percent) at a value far from that suggested by percolation theory. For alloys with x = 10,15 which magnetically saturate, the spontaneous iron moment deduced from the magnetization data describes well the hyperfine field distribution with 120 kOe/ μ_B. For the Ru rich alloys the difference between the average saturation moment and the average iron moment obtained from the magnetization in the field of 80 kG progressively increases with Ru concentration. We attribute this to a noncollinear magnetic structure in these alloys and to rise in antiferromagnetic exchange. The observation of a magnetic phase diagram /1/ reveals the presence of competing exchange interactions in the system.

5. CONCLUSIONS

In summary substitution of Ru for Fe in $Ru_xFe_{80-x}B_{20}$ alters the exchange distribution greatly. Competing interactions exist in the system which are on the average positive but decrease in proportion to Ru concentration.

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