MAGNETIC HYPERFINE INTERACTIONS IN AMORPHOUS $Fe_{72}Pr_8B_{20}$ ALLOY

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Abstract : Magnetic hyperfine interactions in amorphous $Fe_{72}Pr_8B_{20}$ alloy has been studied using Mossbauer Spectroscopy. In amorphous $Fe_{72}Pr_8B_{20}$ alloy, the effective magnetic hyperfine field $H_{eff}(T)$ decreases with increase in temperature. The Curie temperature(T_c) of this amorphous sample, $Fe_{72}Pr_8B_{20}$ is found to be 410 ± 10 K. The effective magnetic hyperfine field at 0 K, $H_{eff}(0)$ of this amorphous sample is found to be 248 kOe. It is observed that $H_{eff}(T) / H_{eff}(0)$ decrease much faster with increase in T/T_c. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model.

Keywords: **Magnetic hyperfine interactions, magnetic hyperfine field, effective magnetic hyperfine field, Mossbauer spectroscopy, reduced magnetic hyperfine field, reduced temperature.**

I. INTRODUCTION

Study of ternary systems such as Fe-RE-B (RE = Rare- Earth) alloys has become important to utilize them for various applications in the industries [1]. Short- range order in these amorphous alloys is a fascinating aspect for their applications. Much of the work carried out so far has been concentrated on NdFeB alloys, but PrFeB magnets have received much attention lately [2]. Rare earth atoms with orbital moment are known to give rise to large random magnetic anisotropy in amorphous alloys through spin-orbit coupling. As this interaction couples an atomic moment to its local environment, it is of great concern to investigate structural short-range order in such alloys to understand local properties of anisotropy. Thus, in this paper, magnetic hyperfine interactions in amorphous $Fe_{72}Pr_8B_{20}$ alloy is discussed using Mossbauer Spectroscopy.

II. EXPERIMENTAL

Amorphous ribbon of **$Fe_{72}Pr_8B_{20}$,** prepared by melt spinning under inert atmosphere was procured from our other researchers. This ribbon is about 1 mm wide and about 30 µm thick. The amorphous state of the as cast alloy was checked by X – ray diffraction. Mossbauer measurements were performed using a conventional constant acceleration spectrometer in the temperature range 4.2 K - 300 K in the standard transmission geometry.

III. RESULTS AND DISCUSSION

Figure 1 shows the Mossbauer Spectra of amorphous $Fe_{72}Pr_8B_{20}$ alloy at different temperatures. The Six-line pattern, which is indicative of the ferromagnetic state of the samples is observed in Fig.1. Large line widths in the Six- line Mossbauer Spectra of amorphous $Fe_{72}Pr_8B_{20}$ alloy is usually explained by involving the existence of a distribution of values of hyperfine magnetic fields which arise from the amorphous nature of solids. However, it is observed here that the broadening is not same for all lines and that the line width increases from the central to the outermost lines of the spectrum.i.e. $\Gamma_{1,6}>\Gamma_{2,5}>\Gamma_{3,4}$. This shows that the major broadening is caused by the hyperfine magnetic field distribution. Furthermore, an asymmetry in line widths as well as some asymmetry in line intensities is also observed. The Temperature dependence of hyperfine magnetic fields of amorphous $Fe_{72}Pr_8B_{20}$ alloy is shown in Fig.2. From the figure, it is clear that the effective magnetic hyperfine field, $H_{eff}(T)$ decreases with increase in temperature. The Curie temperature (T_c) of amorphous $Fe_{72}Pr_8B_{20}$ alloy is determined by extrapolation method as shown in Fig.2 and the value of T_c of amorphous $Fe_{72}Pr_8B_{20}$ alloy is found to be 410 ± 10 K which is less than the Curie temperature (T_c) of binary alloy such as $Fe_{80}B_{20}$ (T_c = 685 ± 3K) [3] as shown in Table 1. Similarly, the effective magnatic hyperfine field, $H_{eff}(0)$, at 0 K for amorphous $Fe_{72}Pr_8B_{20}$ alloy is found to be 248 kOe. From Table 1, it is clear that the addition of large sized rare earth to iron - boron decreases Curie temperature. For comparison sake the Curie Temperature,T_c and the effective magnetic hyperfine field, $H_{eff}(0)$ of our other samples is also reported.

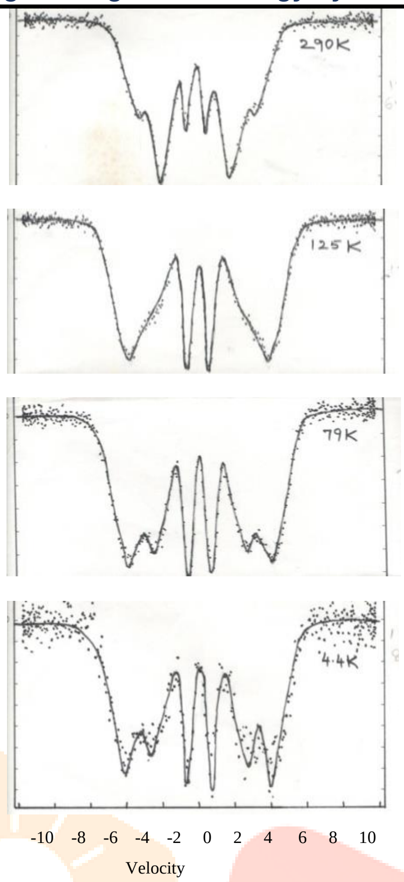

Figure 1 Mossbauer Spectra of amorphous $Fe_{72}Pr_8B_{20}$ alloy at different temperatures.

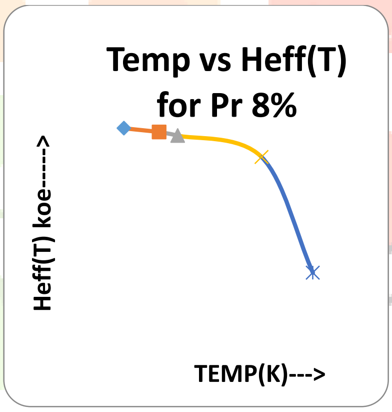

Figure 2 Temperature dependence of effective magnetic hyperfine field $H_{eff}(T)$ of amorphous $Fe_{72}Pr_8B_{20}$ alloy

TABLE – 1: The Curie Temperature (T_c) and $H_{eff}(0)$ of amorphous $Fe_{80-x}Pr_xB_{20}$ (x=2,4,6,8) alloys

Composition	Curie Temperature, T_c (K)	$H_{eff}(0)$ in kOe
$Fe_{74}Pr_2B_{20}$	580	280
$Fe_{74}Pr_4B_{20}$	525	265
$Fe_{74}Pr_6B_{20}$	470	251
$Fe_{74}Pr_8B_{20}$	410	248

Thus, the decrease in T_c with increase in the concentration of Pr atoms in $Fe_{80}B_{20}$ is caused by two factors: 1. The decrease in the number of the transition metal atoms in the alloy and 2. The change in the exchange interactions. Thus, the hyperfine magnetic field, $H_{eff}(T)$ and the Curie temperature(T_c) decrease with the increase in Pr content for Low concentrations because Pr atoms in $Fe_{80}B_{20}$ causes a large distortion of nearest neighbours. Because of the size differences between Pr and Fe ions, the local symmetry around Fe decreases markedly. This may be most probably due to the increase in the free volume in the structure. Praseodymium atoms are randomly distributed in the amorphous structure, but due to atomic size differences the new local structure is less symmetrical than $Fe_{80}B_{20}$. Thus, a large number of highly disordered sites are created. Hence, the hyperfine magnetic field, $H_{eff}(T)$ decreases with increase in temperature. The substitutions of Fe atoms by much larger Pr atoms caused dramatic changes in the short-range order in the amorphous $Fe_{80}B_{20}$ structure. Low concentrations of Pr atoms in $Fe_{80}B_{20}$ caused a large distortion of nearest neighbours. Thus, rare earth atoms with orbital moment are known to give rise to large random magnetic anisotropy in amorphous alloys through spin-orbit coupling. As this interaction couples an atomic moment to its local environment, it is of great concern to investigate structural short-range order in such alloys to understand local properties of anisotropy. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model [4].

According to average molecular - field model the Curie temperature

$$T_c = 2\langle Z\rangle J_{Fe\text{-}Fe} S_{Fe}(S_{Fe}+1)/3K_B \qquad (1)$$

where S_{Fe} is the spin of iron, $J_{Fe\text{-}Fe}$ is the exchange integral and $\langle Z\rangle$ is the average number of Fe nearest neighbors of Fe atoms. The Above relation indicates that T_c is directly proportional to $\langle Z\rangle$ and to $J_{Fe\text{-}Fe}$. [5]. Hence, the addition of large size rare earth to iron- boron decreases Curie temperature. Reduced magnetic hyperfine field (RMHF), $H_{eff}(T) / H_{eff}(0)$ vs. reduced temperature, (T/T_c) of amorphous $Fe_{72}Pr_8B_{20}$ alloy is plotted in Fig.3 with experimental points shown as Δ . Our observation is that the plot $H_{eff}(T) / H_{eff}(0)$ vs. T/T_c are not much different from those results of amorphous $Fe_{80}B_{20}$ reported by others [3]. The observed rapid decrease in reduced hyperfine field, $H_{eff}(T)$ is explained by Handrich's model for amorphous ferromagnets if one assumes a temperature dependent □, a measure of fluctuations in the exchange interactions in such solids. Figure 3 also shows the plots of the Brillouin curves of Handrich's model for $\delta = 0$ and $\delta = 0.5$ for $S = 1$. Thus, in Fig. 3, the experimental data lie below the Brillouin curve as observed for other amorphous alloys [3]. This observation is usually attributed to the distribution of exchange interactions in the amorphous ferromagnets arising from the random environment around magnetic atoms. Handrich[4] obtained an analytical expression for the reduced magnetization of an amorphous ferromagnet given by

$$m(T) = M(T)/M(0) = H_{eff}(T)/H_{eff}(0) = \tfrac{1}{2} B_s[(1+\delta)x] + \tfrac{1}{2} B_s[(1-\delta)x] \qquad \delta(2)$$

where B_s is the Brillouin function for spin S. $x = [3S/(S+1)](m/t)$, and $t = T/T_c$. The parameter 'δ' is a measure of random fluctuations in the exchange interaction and its value lies between 0 and 1. Equation (1) reduces, when $\delta = 0$, to the formula for the reduced magnetization applicable to crystalline ferromagnets. Thus, $H_{eff}(T)/H_{eff}(0)$ decreases much faster with increase in T/T_c. Hence, the observed rapid decrease in reduced hyperfine magnetic fields in this alloy is explained well by Handrich's model [4] used for amorphous ferromagnets.

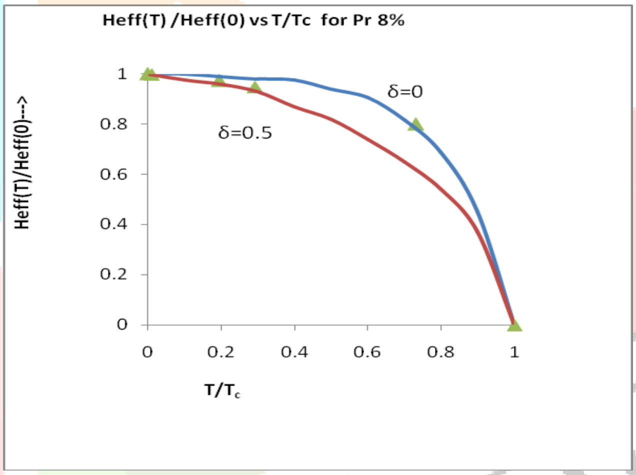

Figure 3 Reduced hyperfine magnetic field (RHMF) $H_{eff}(T) / H_{eff}(0)$ vs. reduced temperature, (T/T_c) of amorphous $Fe_{72}Pr_8B_{20}$ alloy with experimental points shown as Δ. The plots show theoretical curves of Handrich's model for □ = 0 and □ = 0.5

IV. CONCLUSIONS

In amorphous $Fe_{72}Pr_8B_{20}$ alloy the Pr atoms affect the structure only in their immediate environment, creating sites with very low symmetry. The substitutions of iron atoms by much larger Pr atoms cause dramatic changes in the short-range order in the amorphous $Fe_{80}B_{20}$ structure. In amorphous $Fe_{72}Pr_8B_{20}$ alloy, the effective magnetic hyperfine field $H_{eff}(T)$ decreases with increase in temperature. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model. It is observed that $H_{eff}(T) / H_{eff}(0)$ decrease much faster with increase in T/T_c.

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