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Investigation of Amorphous $Fe_{80-x}Pr_xB_{20}$(2≤X≤8) Alloys

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Abstract: ***The investigation of amorphous $Fe_{80-x}Pr_xB_{20}$(2≤ X ≤ 8) alloyswas carried out by Mossbauer Spectroscopy. It was found that 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. Thus, a large number of highly disordered sites are created. In $Fe_{80-x}Pr_xB_{20}$the Pr atoms affect the structure only in their immediate environment. The hyperfine magnetic field, $H_{eff}(T)$ decreases with increase in temperature. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model.***

Keywords : Xray diffraction, alloysby Mossbauer spectroscopy,

INTRODUCTION

Ferromagnetic amorphous metals have received a great deal of attention both from a scientific as well as a technological point of view. Their physical properties depend on their composition. Among other spectroscopic methods, Mossbauer spectroscopy is a particularly suitable one for studying properties of amorphous metals since it probes the nature of intermediate surroundings of the resonating atoms. Due to a variety of environments which exist in amorphous alloys for each atomic species, , one finds, instead of unique properties, broad distributions in the spectral parameters such as hyperfine field, quadrupole splitting and isomer shift.Thus, it is possible to understand their influence on the thermal stability and the magnetic properties of the alloys. Considerable studies have been reported on binary alloys such as Fe-B [1]. Currently, there is interest in the study of ternary systems such as Fe-RE-B (RE = Rare- Earth) alloys [2]. Short- range order in 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 [3].

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. In iron based alloys, ^{57}Fe Mossbauer spectroscopy allows specific characterization atomic sites [4 - 8]. Thus, this paper presents the results of investigations performed on amorphous $\mathbf{Fe_{80-x}Pr_xB_{20}}$(2≤ X ≤ 8) alloysby Mossbauer spectroscopy. The variation of effective magnetic hyperfine field $H_{eff}(T)$ with temperature for different concentrations of Pr in $\mathbf{Fe_{80}B_{20}}$ is also discussed.

EXPERIMENTATION

Amorphous ribbons of $\mathbf{Fe_{80-x}Pr_xB_{20}}$(2≤ X ≤ 8), prepared by melt spinning under inert atmosphere were procured from our other researchers. These ribbons were about 1 mm wide and about 30 µm thick. The amorphous state of the alloys was checked by X – ray diffraction (XRD). Mossbauer measurements were performed using a conventional constant acceleration spectrometer in the temperature range 4.2 K-300 K.

RESULTS AND DISCUSSION

Figures 1 and 2 show Mossbauer Spectra of amorphous $\mathbf{Fe_{72}Pr_8B_{20}}$ and $\mathbf{Fe_{76}Pr_4B_{20}}$ alloys at different temperatures, respectively. In both the figures, the Six-line pattern, which is indicative of the ferromagnetic state of the samples are observed. Thus, large line widths in the Six- line Mossbauer Spectra of $Fe_{80-x}Pr_xB_{20}$ alloysare 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 in not same for all lines and that the line width increases from the central to the outermost lines of the spectrum. This shows that the major broadening is caused by the hyperfine magnetic field distribution. Furthermore, an asymmetry in line widths as well as someasymmetry in line intensities is also observed. From the two figures it is clear that the effective magnetic hyperfine field $H_{eff}(T)$ decreases with increase in temperature for all concentrations of Pr in $\mathbf{Fe_{80}B_{20}}$as shown in Fig. 3. The Curie temperature (T_c) of amorphous $\mathbf{Fe_{80-x}Pr_xB_{20}}$(2≤ X ≤ 8) alloy is determined by the extrapolation method as shown in Fig. 3 (TABLE 1) and the values are found to be less than the Curie temperature T_c of binary alloys such as $Fe_{80}B_{20}$ which is 685± 3K. [1]. From TABLE - 1, it is clear that theaddition of large size rare earth to iron- boron decreases Curie temperature. From the plot (Fig.3.), $H_{eff}(T)$ vs T, the values of $H_{eff}(0)$ for different amorphous $Fe_{80-x}Pr_xB_{20}$ (x=2, 4, 6, 8)alloys are also obtained (TABLE - 1). The decrease in T_c with increasing in concentration of Pr atoms in $Fe_{80}B_{20}$ is caused by two factors: 1. Thedecrease in the number of the transition metal atoms in the alloy and 2. The change in the exchange interactions.

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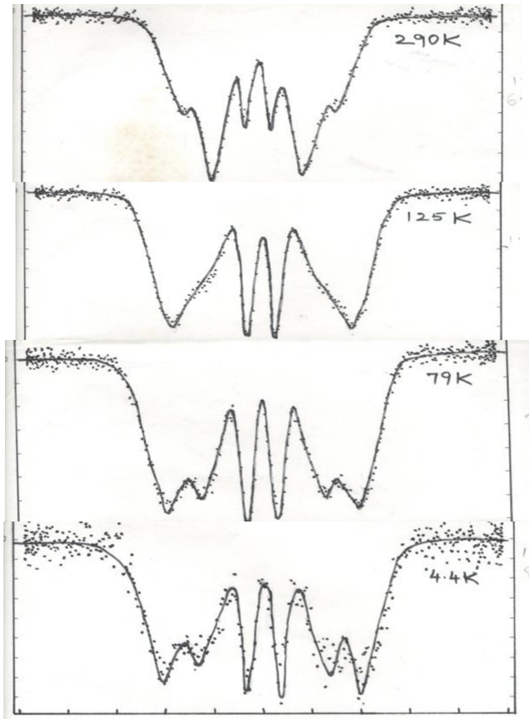

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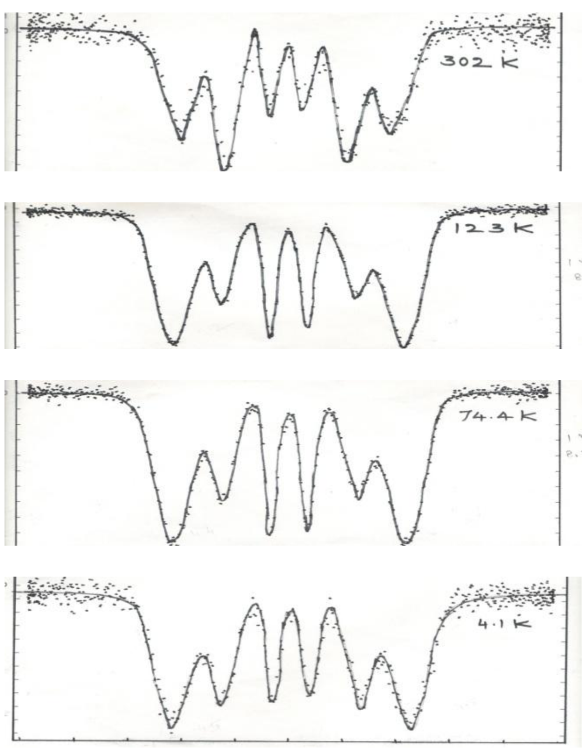
Velocity (mm/sec)

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



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Velocity (mm/sec)

Figure 2: Mossbauer Spectra of amorphous $Fe_{76}Pr_4B_{20}$ alloy at different temperatures.

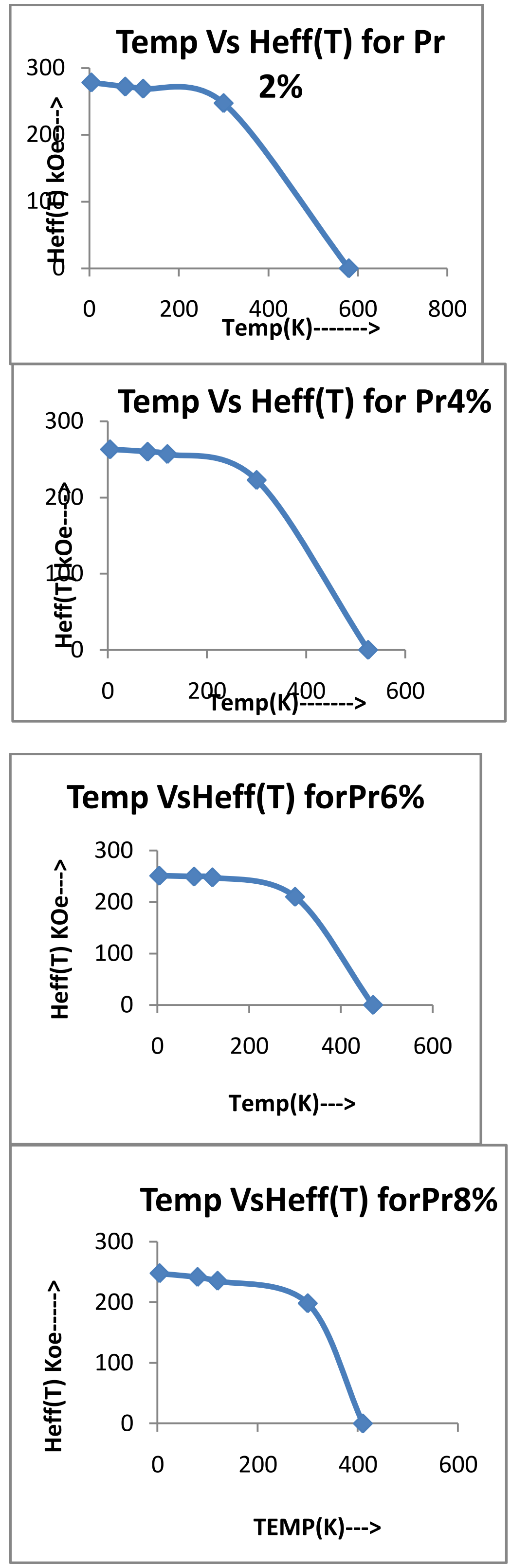

Figure 3: Temperature dependence of effective magnetic hyperfine field $H_{eff}(T)$ of amorphous $Fe_{80-x}Pr_xB_{20}$ (x=2,4,6,8) alloy

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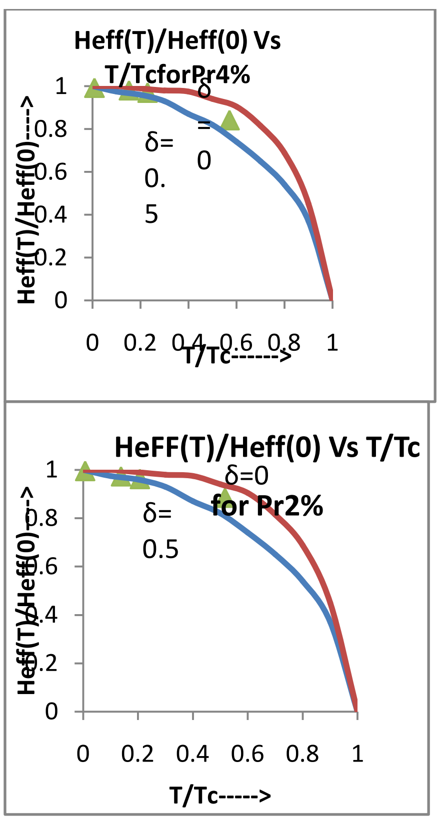
It was found that the hyperfine magnetic field, $H_{eff}(T)$ and the Curie temperature(T_c) decrease with the increase in Pr content for Low concentrations because Pr atoms in **$Fe_{80}B_{20}$** causes a large distortion of nearest neighbours. Because of the size differences between Pr and Fe ions, 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. In **$Fe_{80-x}Pr_xB_{20}$**the Pr atoms affect the structure only in their immediate environment, creating sites with very low symmetry. The hyperfine magnetic field, $H_{eff}(T)$ decreases with increase in temperature. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model.

Table 1

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



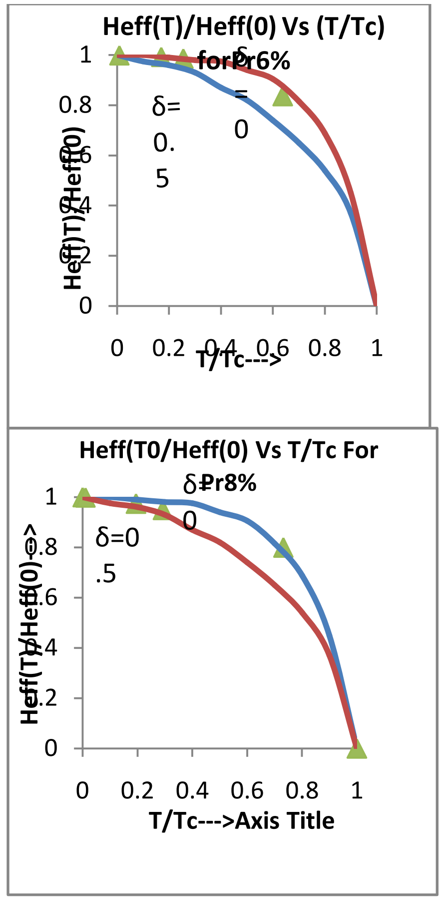


Figure 4: Reduced hyperfine magnetic field (RHMF) $H_{eff}(T)$ / $H_{eff}(0)$ vs. reduced temperature, (T/ T_c) of amorphous $Fe_{80-x}Pr_xB_{20}$ (x=2, 4, 6, 8) alloy with experimental points shown as Δ. The plots show theoretical curves of Handrich's model for δ = 0 and δ = 0.5.

Reduced magnetic hyperfine field (RMHF), $H_{eff}(T)$ / $H_{eff}(0)$ vs. reduced Rtemperature, (T/ T_c) of amorphous **$Fe_{80-x}Pr_xB_{20}$** (x=2, 4, 6, 8)alloy are plotted in Fig.4 **w**ith experimental points shown as Δ. Our observation is that the plots of$H_{eff}(T)$ / $H_{eff}(0)$ vs. T/T_c are not much different from those results of amorphous $Fe_{80}B_{20}$ reported by others [1].

Figure 4 also shows the plots of the Brillouin curves of Handrich's model for δ = 0 and δ = 0.5 for S = 1/2. Thus, in Fig. 4, the experimental data lie below the Brillouincurve as observed for other amorphous alloys[5]This observation is usually attributed to the distribution of exchange interactions in glassy ferromagnets arising from therandom environment around magnetic atoms. Handrich[4] obtained an analytical expression for the reduced magnetization of an amorphous ferromagnet given by

$m(T) = M(T)/M(0) = H_{eff}(T)/H_{eff}(0) = ½ B_s[(1+δ)x] + ½ B_s[(1-δ)x]$……………..(1)

whereB_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

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lies between 0 and 1. Equation (1) reduces, when □ = 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. 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 5 shows the concentration dependence of the effective magnetic field (H_{eff}) of amorphous $\mathbf{Fe_{80-x}Pr_xB_{20}}$($2 \leq X \leq 8$) alloy for x = 2 %, 4 %, 6 % and 8 %. In $\mathbf{Fe_{80-x}Pr_xB_{20}}$the Pr atoms distort the structure only in their immediate environment, creating sites with very low symmetry. Low concentrations of substitution of Pr atoms ln$\mathbf{Fe_{80}B_{20}}$causes a large distortion of nearest neighbours. Figure 6 shows that the effective magnetic hyperfine field (H_{eff})decreases with increase in the concentration of Pr in $Fe_{80}B_{20}$.

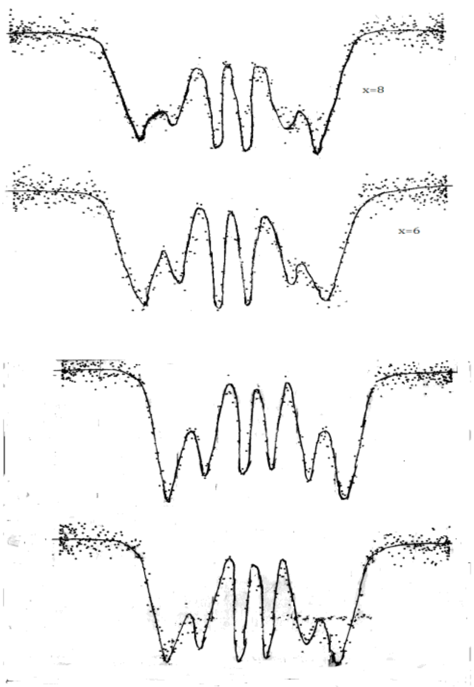
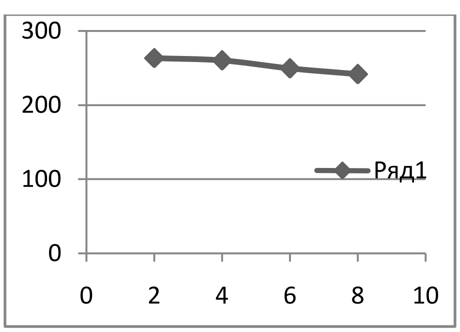


Figure 5 Mossbauer Spectra of Amorphous $Fe_{80-x}Pr_xB_{20}$ ($0 \leq X \leq 8$) alloysat 4.2 K for X = 2 %, 4 %, 6 % and 8 % (from bottom)



Concentration in %

Figure 6 Concentration dependence of the effective magnetic field (H_{eff}) of amorphous $Fe_{80-x}Pr_xB_{20}$ ($2 \leq X \leq 8$) alloy for X = 2 %, 4 %, 6 % & 8 %

Conclusions

In amorphous $\mathbf{Fe_{80-x}Pr_xB_{20}}$ **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 caused dramatic changes in the short-range order in the amorphous $\mathbf{Fe_{80}B_{20}}$structure. Low concentrations of Pr atoms in $\mathbf{Fe_{80}B_{20}}$ caused a large distortion of nearest neighbours. In amorphous $\mathbf{Fe_{80-x}Pr_xB_{20}}$($2 \leq X \leq 8$) alloy, the effective magnetic hyperfine field $H_{eff}(T)$ decreases with increase in temperature for all concentrations of Pr in the binary $\mathbf{Fe_{80}B_{20}}$. Similarly, the Curie temperature (T_c) of the sample decreases with increase in the concentration of Pr in the binary $\mathbf{Fe_{80}B_{20}}$. The reduced magnetic hyperfine field versus reduced temperature follows the Handrich's model. Low concentrations of Pr atoms in $Fe_{80}B_{20}$ caused a large distortion of nearest neighbours. The magnetic hyperfine field decreases with increase in the concentration of Pr in $Fe_{80}B_{20}$.

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