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MAGNETIC PROPERTIES OF AMORPHOUS Dy_xFe_{1-x} THIN FILMS

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Abstract. Magnetic properties of amorphous Dy_xFe_{1-x} (x = 0.15, 0.21, 0.25) with the random anisotropy and exchange were investigated by the measurements of magnetization and Hall effect vs. temperature and external field H. Speromagnetic behavior was shown in all samples measured for H = 1 kOe. A reentrant phenomenon from ferrimagnetic to speromagnetic behavior was observed for x = 0.25 with coherent perpendicular anisotropy. At H = 12 kOe, all samples show ferrimagnetic behavior.

In the last decade, the experimental [1] and theoretical studies [2, 3] for the effects of random anisotropy on the ferromagnetism have been extensively developed. Rare-earth rich amorphous alloys such as DyCu [4], Dy_{x}Gd_{1-x}Ni [5], Gd_{65-x}Tb_{x}Co_{35} [6], Dy_{60}Fe_{30}B [7], show a transition to a speromagnetic [1] (spin-glass-like) state. Recent neutron [1], susceptibility [6], magnetization measurements [8] suggests that the system cross over to the asperomagnetic (or ferromagnetic) state in a large external field H.

The spin system such as heavy-rare-earth-iron amorphous alloy has two subnetworks coupled antiferromagnetically, though individually coupled ferromagnetically. The random anisotropy give a similar effect on such ferrimagnetic systems, however it has not sufficiently clarified for the iron rich or moderately rare-earth containing compositions.

In this paper, we investigated the magnetic properties of amorphous Dy_{x}Fe_{1-x} (x = 0.15, 0.21, 0.25) by the measurements of magnetization and Hall effect against temperature and external field H. The Hall effect is very sensitive methods to study the critical behavior both for spin-glass such as AuFe [9] and for rare-earth-transition-metal ferrimagnet [10]; the Hall resistivity ρ_H in the amorphous rare-earth-transition alloy exhibits the fairly large anomalous Hall component reflecting the magnetization of the subnetwork(s), then ρ_H changes the sign at the compensation temperature T_{comp}.

The amorphous Dy_{x}Fe_{1-x} films were prepared by r.f. sputtering technique from a composite target onto glass substrates under the Ar pressure of 5 ~ 20 × 10^{-3} Torr. The film composition was determined by ICPS technique, and the film thickness by a stylus step method, which are of the order of 1.3 μm ~ 1.7 μm. The amorphous character was checked by X-ray scattering. Temperature dependence of magnetization was measured by a vibrating-sample magnetometer. Hall resistivity was measured at current I = 1 mA.

For magnetization measurements, H was applied in the easy axis direction of DyFe films; normal to the film plane for samples with the coherent perpendicular anisotropy (x = 0.21, 0.25), parallel to the plane for x = 0.15. Hall effect measurements were performed by applied H normal to the films.

Figure 1a shows magnetization of amorphous Dy_xFe_{1-x} for x = 0.15 and 0.25 at H = 1 kOe as a function of temperature. ρ_H corresponding to the two samples in figure 1a are shown in figure 2a. For x = 0.21, only ρ_H is plotted in figure 2b. The temperature dependence of magnetization resembles to that of ρ_H, though -ρ_H (x = 0.25) > ρ_H (x = 0.15). The field-cooled (FC) and zero-field-cooled (ZFC) magnetization or ρ_H becomes to behave differently at low temperature indicating that all samples measured exhibit the spero or spin-glass like behavior at 1 kOe. Figure 2a shows that the sign of ρ_H (x = 0.25) and ρ_H (x = 0.15) are different. This is because that for x = 0.25 sample there is T_{comp} at about 327 K as indicated by an arrow in figure 2a. The Dy_{0.25}Fe_{0.75}, therefore, exhibits a reentrant behavior from paramagnetic to ferrimagnetic (or sperimagnetic) to speromagnetic phase with decreasing temperature.

Fig. 1. - Magnetization of amorphous Dy_xFe_{1-x} films for (a) x = 0.15, 0.25 at external field H = 1 kOe, (b) x = 0.25 at H = 12 kOe as a function of temperature.

[Note: The figure 1 and 2 are not shown in this text.]

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Fig. 2. - Hall resistivity $\rho_H$ of amorphous $\text{Dy}_x\text{Fe}_{1-x}$ for (a) $x = 0.15, 0.25$ at $H = 1$ kOe, (b) $x = 0.21$ at $H = 1$ kOe as a function of temperature.

In figure 2b, $\rho_H$ at $H = 13$ kOe is shown. The speromagnetic behavior of $\rho_H$ at $H = 1$ kOe converts drastically into ferrimagnetic state with $T_{\text{comp}} \approx 250$ K. Figure 1b also exhibits the change to the ferrimagnetic state for $x = 0.25$ sample at $H = 12$ kOe; there is almost no difference between FC and ZFC, also for $x = 0.15$, though not shown in the figure.

The external field ($H = 12$ kOe) sensitively converts the speromagnetic state at 1 kOe into ferrimagnetic state for all samples measured, and the one ($x = 0.25$) with the perpendicular anisotropy exhibits a reentrant behavior at 1 kOe. For $x = 0.21$, with also perpen-
dicular anisotropy, the magnetic state above the speromagnetic freezing temperature $T_f \approx 280$ K may be ferrimagnetic state, though the compensation point is not seen because $T_{\text{comp}}$ lies below $T_f$. The reentrant phenomenon was also reported in GdErCo system [11]. From above results, the coherent uniaxial anisotropy and the large uniform external field seem to stabilize the ferrimagnetic state.

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