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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 . Sperrimagnetic 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], $Dy_xGd_{1-x}Ni$ [5], $Gd_{65-x}Tb_xCo_{35}$ [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 system 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_xFe_{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_xFe_{1-x} films were prepared by r.f. sputtering technique from a composite target onto glass substrates under the Ar pressure of $5 \sim 20 \times 10^{-3}$ Torr. The film composition was determined by ICPS technique, and the film thickness by a stylus step method, which are of the order of $1.3 \mu m \sim 1.7 \mu m$. 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

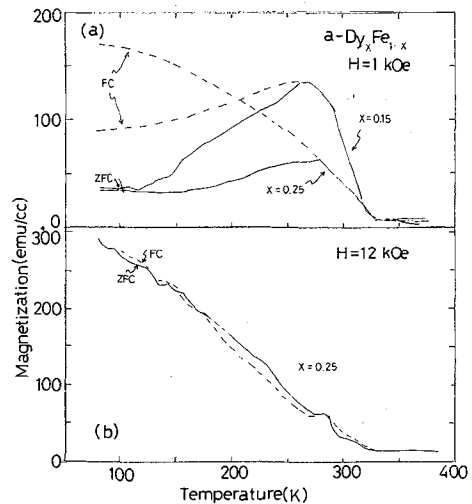


Fig. 1. - Magnetization of amorphous Dy_xFe_{1-x} films for (a) $x = 0.15, 0.25$ at external field $H = 1$ kOe, (b) $x = 0.25$ at $H = 12$ kOe as a function of temperature.

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 $-\rho_H$ ($x = 0.25$) $>$ 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.

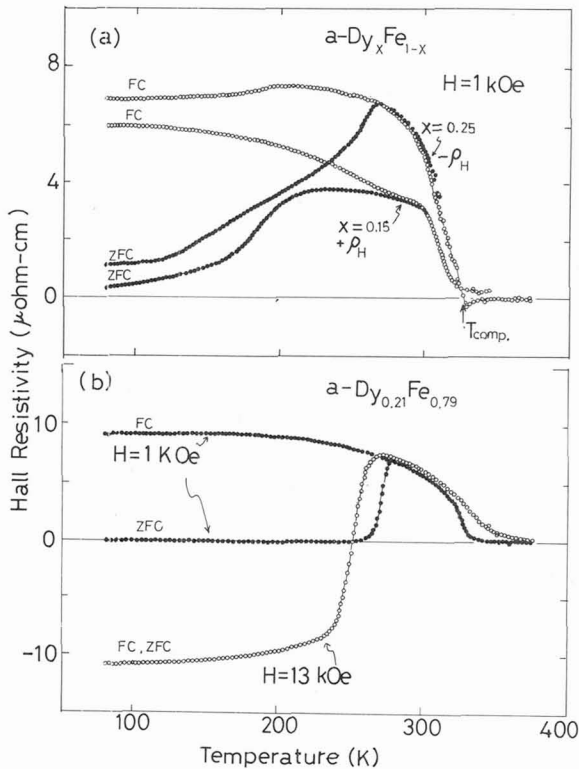


Fig. 2. - Hall resistivity ρ_H of amorphous $\text{Dy}_x\text{Fe}_{1-x}$ for (a) $x = 0.15, 0.25$ at $H = 1 \text{ kOe}$, (b) $x = 0.21$ at $H = 1 \text{ kOe}$ as a function of temperature.

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

The external field ($H = 12 \text{ kOe}$) 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 $T_f \simeq 280 \text{ K}$ may be ferrimagnetic state, though the compensation point is not seen because T_{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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