Magnetic resonance in $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$ reentrant spin glasses

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A "narrow" resonance peak (of the ESR type), which has not been seen previously, has been observed in the amorphous frustrated alloy $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$ with $x = 0.08$. This alloy undergoes a reentrant paramagnet-ferromagnet-(spin glass) transition. The peak is seen below the Curie point but above the temperature of the transition to the reentrant-spin-glass phase. A broad magnetic-resonance line is also seen.

Several theoretical[1,2] and experimental[3] studies have shown that, as a frustrated ferromagnet is cooled, the formation of a reentrant-spin-glass phase is preceded by the appearance of a noncollinear magnetic (asperomagnetic) state, which is local in nature. Distortions of the collinear magnetic structure arise near "frustrated" sites,[1] which are occupied by atoms which are coupled with their neighbors by not only ferromagnetic but also antiferromagnetic exchange coupling. Significantly, the spins which are centered at these sites are in a molecular field far weaker than that at the spins of the surrounding ferromagnetic matrix.[1,2] One might therefore expect that under certain conditions a resonance of the ESR type involving these nearly free spins would arise. In the present letter we are reporting the detection of this effect, in the particular case of amorphous frustrated alloys $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$, which undergo reentrant temperature-induced paramagnet-ferromagnet-(spin glass) transitions.[4]

Magnetic-resonance studies were carried out at a frequency of 75 GHz in the temperature interval 0.3–200.0 K by the method of Ref. 5 in an orthogonal configuration of fields. A Buran rf-spectroscopic installation[6] was used.

Figure 1 illustrates the results with magnetic-resonance lines of the amorphous alloy $(Fe_{0.08}Ni_{0.92})_{77}B_{13}Si_{10}$ at various temperatures. At temperatures below the Curie point, $T_C = 32$ K,[4] the magnetic-resonance line broadens, and its center shifts to a weaker magnetic field. The resonance lines in the alloys $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$ with $x=0.09$ and 0.10 behave in a similar way. We can estimate the g-factors on the basis of the corresponding experimental data. For the alloys with $x=0.08$ and 0.10, for example, they turn out to be 1.860 and 1.827 near T_C. It can also be seen from Fig. 1 that at temperatures $T \approx T_f < T_C$, close to the temperature (T_f) at which the phase of a reentrant spin glass arises, the resonance line acquires an unusual Π shape. As the temperature is lowered, the half-width of this line increases dramatically (Fig. 2). This result agrees with the results of Ref. 7, when we allow for the fairly high frequencies used in the present experiments. However, we will not discuss these aspects of the magnetic-resonance line.

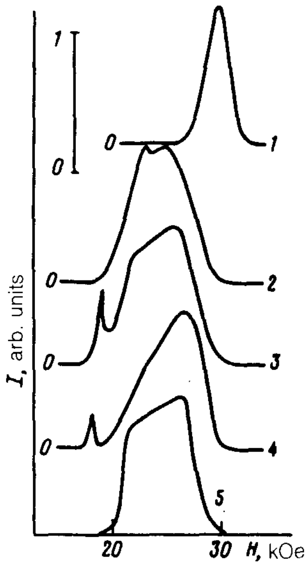

FIG. 1. Magnetic-resonance lines of the alloy $(Fe_{0.08}Ni_{0.92})_{77}B_{13}Si_{10}$ at several temperatures. *1*—27 K; *2*—21; *3*—18; *4*—16; *5*—11.5 K.

It follows from Fig. 1 that, in addition to the magnetic-resonance line discussed above, the alloy $(Fe_{0.08}Ni_{0.92})_{77}B_{13}Si_{10}$ exhibits another resonance peak, with a half-width $\Delta H_{1/2} \approx 200$ Oe. Within the experimental error, this width is independent of the temperature. For definiteness, we will refer to the latter resonance as the "narrow" one. To the best of our knowledge, this effect has not been seen previously in systems which exhibit reentrant paramagnet-ferromagnet-(spin glass) transitions. Study of this effect is accordingly of independent interest.

The reasons for the appearance of this narrow resonance can be understood by looking at the model of Refs. 1 and 2 for reentrant paramagnet-ferromagnet-(spin

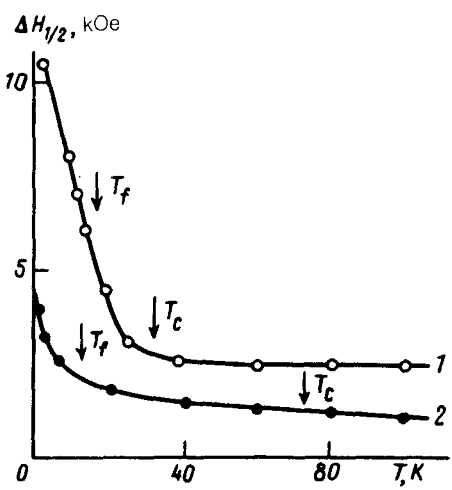

FIG. 2. Temperature dependence of the half-width of the resonance lines of the alloys $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$ with $x=0.08$ (1) and 0.09 (2). Here T_C is the Curie point, and T_f the temperature at the reentrant spin glass arises.

glass) transitions. According to that model, frustrated sites form at temperatures $T_f < T < T_C$ because of a competing exchange interaction in ferromagnetic alloys near the critical concentration for the onset of a long-range ferromagnetic order. The associated spins are in a molecular field far weaker than that of the spins of the ferromagnetic surroundings. If these nearly free spins furthermore interact with each other and with the surrounding ferromagnetic matrix only weakly, then they can apparently be regarded collectively as a nearly independent ESR system. Using the known expression for the spin-spin relaxation time T_2,

$$T_2 = h/\mu_B g \Delta H_{1/2},$$

along with the experimental value of $\Delta H_{1/2}$ of the resonance line, given above, and setting $g=2$, we easily find $T_2 = 2.8\times 10^{-10}$ s. This result is typical of the relaxation time of a nearly free (ESR) spin[8] 1/2.

Quite understandably, this resonance should disappear when the alloy undergoes a transition to a frozen state of a reentrant spin glass at a temperature[4] $T_f(H) < T_f(0) = 18$ K, where H is the external magnetic field. This is indeed what is actually seen (Fig. 1).

We wish to stress that this narrow resonance is not observed in the $(Fe_xNi_{1-x})_{77}B_{13}Si_{10}$ alloys with $x=0.09$ and 0.10. A possible reason is that on the magnetic phase diagram these alloys are farther from the critical concentration ($x_0 = 0.075$) for the onset of ferromagnetic order inside the ferromagnetic phase,[4] so that at temperatures $T_f < T < T_C$ there are far fewer frustrated sites in them than in the alloy $(Fe_{0.08}Ni_{0.92})_{77}B_{13}Si_{10}$. Furthermore, the smaller contribution of antiferromagnetic exchange to the overall exchange energy in this case should hinder the onset of the narrow resonance, by virtue of the increase in the molecular field at the frustrated sites.

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