Magnetic study in amorphous $Gd_{0.7}Zr_{0.3}$ alloys

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We report here our magnetic study on amorphous $Gd_{0.7}Zr_{0.3}$ alloy. The magnetic saturation is difficult to obtain even for fields up to 50 kOe. This led us to the conclusion that ferromagnetic and antiferromagnetic clusters are present in this alloy. However, the presence of a well defined T_C indicate that the ferromagnetic clusters are dominant and he presence of the coherent anisotropy field can transform this type of magnetic ordering into a ferromagnetic domain structure. The thermomagnetization curve is found to obey the Bloch law, spin wave stiffness constant and the distance between nearest magnetic atoms were calculated from the experimental results.

I. INTRODUCTION

The magnetic properties of Gd based amorphous alloys have been interpreted [1-5] by considering the influence of the topological disorders and chemical short range order, depending upon the electronegativity of the involved element [6]. These effects strongly disturb the magnetic exchange and the exchange interactions are of RKKY (Ruderman-Kittel-Kasuya-yosida) type [7-9]. It was hence interesting to see the influence of amorphous structure on the magnetic properties of Gd-Zr alloys. The fact that Zr is nonmagnetic also helps to understand the results. In this work we describe the results of our studies in amorphous $Gd_{0.7}Zr_{0.3}$ alloy prepared by rf sputtering and discuss them in the context of conclusions published in the literature [1-5].

II. EXPERIMENTAL DETAILS

The amorphous $Gd_{0.7}Zr_{0.3}$ film was sputter deposited from a composite target using RF diode system. The starting vacuum was 10^{-7} Torr. The sputter gas was Argon of 5N purity. Water cooled glass substrates were used. The RF power was in the range 80-100 W and the Argon pressure was fixed at 6×10^{-3} Torr. Film thickness was held at about 3000Å. The magnetization up to 50 kOe was measured with a SQUID magnetometer and in the temperature range 4.2 to 120 K.

III. RESULTS AND DISCUSSION

The magnetic saturation is not obtained down to 4.2 K even with an applied field of 50 kOe, maximum available in our set up (figure 1). The saturation magnetization was determined by the expression

$$M(H,T) = M_S(T) \left(1 - a / (H+H_U)^{1/2} \right), \qquad (1)$$

where M_S is the saturation magnetization and a is a parameter depending on both exchange field and random anisotropy field. H_u is the uniform anisotropy field. From M_S we estimated the magnetic moment $\mu_{Gd} = 6.9\ \mu_B$ which is in agreement with the free ion value of 7 μ_B and those normally reported for both crystalline [10] and amorphous [11] Gd alloys.

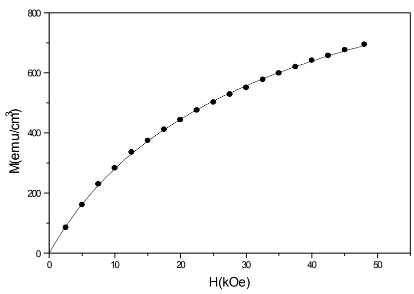

FIG. 1: The field dependence of the magnetization in $Gd_{0.7}Zr_{0.3}$ at 4.2 K

The difficulty to obtain magnetic saturation (figure 1) in our amorphous $Gd_{0.7}Zr_{0..3}$ alloy needs some further attention. This situation could be due to the existence of ferromagnetic and antiferromagnetic clusters. However, the presence of a well defined T_C indicate that the ferromagnetic clusters are dominant. From the M(H,T) = f(H,T) it was also possible to estimate the magnetic coherent anisotropy. The values for the uniaxial anisotrpy constants Ku were found to be positive (~10^7erg/cm^3). It is argued that this anisotropy originates from an anisotropic exchange interaction between the purely S-state spins, proceeding via the 5d electrons.
In such materials the mean field theories do not always explain local magnetic excitations. For an accurate description of the low temperature behaviour of magnetic properties the spin wave theory can be used.
The spin wave energy can be expressed by

$$h\omega(q) / 2\pi = E_0 + D\, q^2 + F\, q^4 + ..., \qquad (2)$$

where $E_0 << D\, q^2$ is the effective energy arising from dipole-dipole interactions, q is the wave vector of the

spin wave and D and F are spin wave stiffness constants. Thus, it would be of interest to examine the low temperature behaviour of systems with this type of magnetic ordering. The addition of Zr to Gd-based alloys change the ferromagnetic order and the effect of Zr seems to be specific.

According to the spin wave theory, the temperature dependence of the magnetization of ferromagnets is given by

$$[M_S(T) - M_S(0)] / M_S(0) = B\, T^{3/2}. \qquad (3)$$

Equation (3) is a good approximation of low temperature magnetization in both crystalline and amorphous ferromagnets [12, 13]. The parameter B introduced in equation (3) is related to the spin wave stiffness constant D by the following relation:

$$B = 2.612\, [\, g\mu_B / M_S(0)]\, [k_B / 4\pi D\,]^{3/2}, \qquad (4)$$

where g is the g-factor (g_{Gd}= 2), k_B Boltzmann's constant, μ_B is the Bohr magneton. The temperature dependence of M is shown in figure 2 where M(50kOe) is plotted againt $T^{3/2}$. It is seen that Bloch's law is verified in the range from 4.2K up to about $T_c/3$, a result similar to that reported for amorphous $Gd_{70}Y_{30}$ alloy[1].

We have adjusted experimental data by using equation (3) (figure 2) which allowed us to find B value of about $1.02\ 10^{-3}\ K^{-3/2}$.

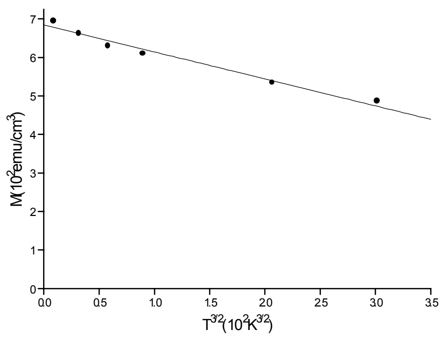

FIG. 2 : $T^{3/2}$ dependence of the magnetization for the $Gd_{0.7}Zr_{0.3}$ alloy.

The coefficient is used to calculate the exchange stiffness constant which is found to be equal to 11.7 meVÅ^2. According to the Heisenberg model, D and the Curie temperature (T_C = 100 K) fulfill the equation,

$$D = k_B\, r_{ij}^{\,2}\, T_C / 2(S_{Gd}+1), \qquad (5)$$

where r_{ij} is the distance between nearest magnetic atoms (Gd) and S_{Gd} is the spin moment of the Gd atom. Using equation (5) we found r_{ij} to be about 3.5 ± 0.1 Å which is in agreement with previous work [14].

IV. CONCLUSIONS

The magnetic saturation is difficult to obtain even for fields up to 50 kOe. This led us to the conclusion that ferromagnetic and antiferromagnetic clusters are present in this alloys. However, the presence of a well defined T_c and the coherent anisotropy field indicate that the ferromagnetic clusters are predominant.

We have studied the magnetization of amorphous $Gd_{0.7}Zr_{0.3}$ films in terms of the spin wave theory which allowed us to determine the Gd-Gd distance and the nature of the interactions in the magnetic sublattice.

[1] R. Krishnan, M. Dancygier and M. Laridjani, J. Magn. Magn. Mater. 38 (1983) 78.
[2] Q. Chen, R. Tourbot and B. Boucher, J. Magn. Magn. Mater. 110 (1992) 139.
[3] R.J. Begum, C.A. Cornelius, E.W. Lee and V. Samadian, J. Phys. F 14 (1984) 2739.
[4] C. Jeandey and J.L. Oddou, Solid state Commun. 50 (1984) 1555.
[5] T.R. McGuire, T. Mizoguchi, R.J. Gambino and S. Kirkpartrick, J. Appl. Phys. 49 (1978) 1689.
[6] K.H.J. Buschow. Solid State Commun. 27 (1978) 275.
[7] B. Boucher. Phys. Stat. Sol. (a) 40 (1977) 197.
[8] S.J. Poon and J. Durand. Solid State Commun. 21 (1977) 793.
[9] T. Mizoguchi and S. Kirkpatrick, Physica B 86-88 (1977) 783, Phys. Rev. Lett. 38 (1977) 89.
[10] W.C Thorburn, J. Legvold and F.M. Spedding, Phys. Rev. 110 (1958) 1298.
[11] S.J. Poon and J. Durand, Phys. Rev. B16 (1977) 316.
12] F. Keffer, Handbuch der Physik, vol. XVIII/2. Eds. F. Flügge, H. P. J. Wijin, Springer-Verlag, Berlin, 1966, p. 50.
[13] U. Krey, Z. Phys. B, 31. p. 247, 1978.
[14] V.G. Harris, K.D. Aylesworth, B.N. Das, W.T. Elam, N.C. Koon, Phys. Rev. Lett. 69 (1992) 1939