Magnetic and spin waves studies in amorphous $Gd_{0.7}Y_{0.3}$

A. Kaal [(1)], K. Benbachir [(2)], S. Sayouri [(1)], and M. Tlemçani [(3)].
[(1)] *Laboratoire de Physique du Solide, Faculté des Sciences, B.P1796, Fès Atlas Marocco .*
[(2)] *Laboratoire de Magnétisme et de Physique des Hautes Energies, Faculté des Sciences, avenue Ibn Batouta,B. P. 1014, Rabat, Morocco .*
[(3)] *Laboratoire de Physique du Solide, E.N.S. Fès Bensouda , Marocco.*

In this paper, magnetic properties of amorphous $Gd_{0.7}Y_{0.3}$ alloys have been studied using a linear dependence on $H^{-1/2}$ of the saturation magnetization M(H); this dependence has been proved to be necessary for an adequate interpretation of magnetic behaviour of ferromagnetic amorphous compounds. Indeed, in a previous work, assuming a linear dependence on H^{-1} of M(H), magnetic parameters (magnetic moment, μ_{Gd}, of Gd, mean exchange integral (J)) relevant to $Gd_{0.7}Y_{0.3}$ have been undervalued. In the present work, these parameters, in addition to the stiffness constant, have been improved.

Keywords : amorphous ferromagnets- Gd-based alloys- Stiffness constant- Saturation - magnetization-Spin -wave- Exchange integral

I. INTRODUCTION

Because of their potential for technological applications [1,2], amorphous ferromagnets based on both rare earth (RE) and 3d transition metals (TM) have been extensively studied. Among these studies, a considerable part has been devoted to the amorphous Gd_xX_{1-x} (X = Cu, Al, Zr,…) alloys [3-15]. In particular, magnetic properties of these compounds have been investigated taking into account topological disorder and chemical short range order depending upon the electronegativity of the involved elements [3,16]. Moreover, magnetic behaviour seems to be very sensitive to the relative volume of ions of the alloys and to their valency [14], and different values of T_c have been reported depending on X species [17-20].

Krishnan et al. [20] have reported magnetic studies on amorphous Gd_xY_{1-x} (x = 0.17; 0.70).
In particular, they have evaluated the magnetic moment of Gd (x=0.7, $\mu_{Gd} = 6.2\ \mu_B$) using the following equation for the saturation magnetization :

$$M(T) = M(0)\,(1 - a / H) + \chi_{hf} H \qquad (1)$$

where H is the applied magnetic field and χ_{hf} the high field susceptibility. This value of μ_{Gd} for the sample $Gd_{0.7}Y_{0.3}$ is lower than that normally reported for both crystalline and amorphous Gd alloys [12, 14, 19]. To explain this lowering of μ_{Gd} the authors have discussed the possible effect of the nonmagnetic element Y and the existence of some amount of antiferromagnetic clusters even if, from other works, above x = 0.6 the alloy may order ferromagnetically [12].

In this paper we have used another modelisation of the behaviour of M(H) [21-24], which has been successfully applied to amorphous ferromagnets [25-28], to reinterpret the results concerning $Gd_{0.7}Y_{0.3}$ reported in Ref. [20].

II. RESULTS AND DISCUSSION

The variation of magnetization of amorphous $Gd_{0.7}Y_{0.3}$ alloy (which methods of preparation and chacterisation are given in Ref [16]), at 4.2 K and 40 K as function of the applied magnetic field ranging from 0 to 15 T is shown in Fig. 1. Magnetic saturation is not obtained down to 4.2 K even with an applied field of 15 T.

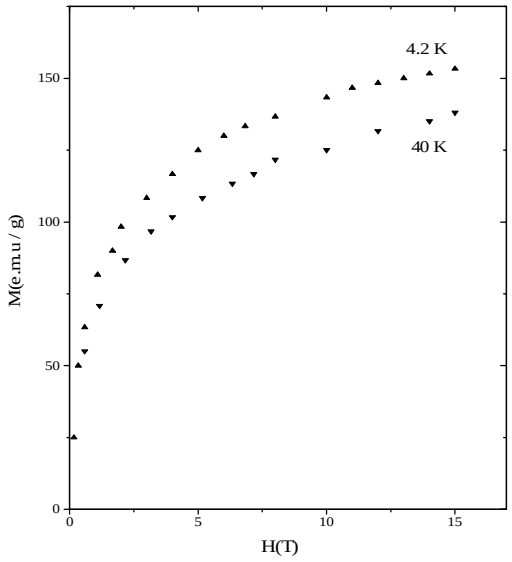

FIG. 1: Field dependence of the magnetization at 4.2 K and 40 K for the $Gd_{0.7}Y_{0.3}$ alloy.

The approach to saturation of the magnetic moment in random anisotropy magnets has been studied by Fähnle and Kronmüller [21]. They showed the presence of a $H^{-1/2}$ term in the saturation magnetization. Chudnovsky and Serota [22-24] have given a phenomenological model to interpret the approach to saturation. From this model, the magnetic moment is expected to show a linear dependence on $H^{-1/2}$.

The following equation describes this situation[22-24]:

$$M = M_0 (1 - b / H^{1/2}) \quad (2)$$

Plotting M as function of $H^{-1/2}$ one can deduce the magnetization extrapolated value to H_∞ (our concern is to calculate M_0, so we have adopted the eq.(2) for M (H)).

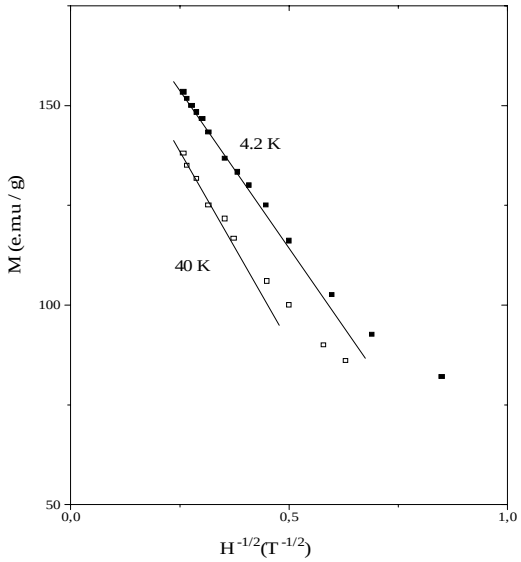

FIG. 2: $H^{-1/2}$ dependence of the magnetization Mat 4.2 K and 40K.

The alloy moment μ_{Gd} can be deduced from the relation

$$\mu_{Gd} = M_0 m / x N\mu_B \quad (3)$$

where N is Avogadro's constant, m the molecular weight of the alloys, x the proportion of Gd involved and μ_B the Bohr magneton. The values of M_0 and μ_{Gd} estimated for the composition x = 0.7 are reported in table 1.

Owing to the work done on amorphous Gd_xY_{1-x} alloys by Thoburn et al. [12], for x<0.6 the samples behave antiferromagnetically and when x exceeds 0.6 ferromagnetic order takes place. Thus, the value of $\mu_{Gd,}$ we have obtained, equal to 7.07 μ_B is more accurate in accordance with the fact that for x > 0.6 Gd-Y orders ferromagnetically. This result agrees with that deduced from the study of amorphous Gd-Zr alloys [14], those mentioned above [12,19], and improves that reported by Krishnan et al. [20], based on the assumption that the magnetic saturation shows a linear dependence on H^{-1}.

Fig.3 [20] shows the temperature dependence of M as function of $T^{3/2}$, which clearly follows Bloch's law, as for amorphous $Gd_{0.8}Au_{0.2}$ alloys [19] :

$$M (T) = M (0) (1 - B T^{3/2}) \quad (4)$$

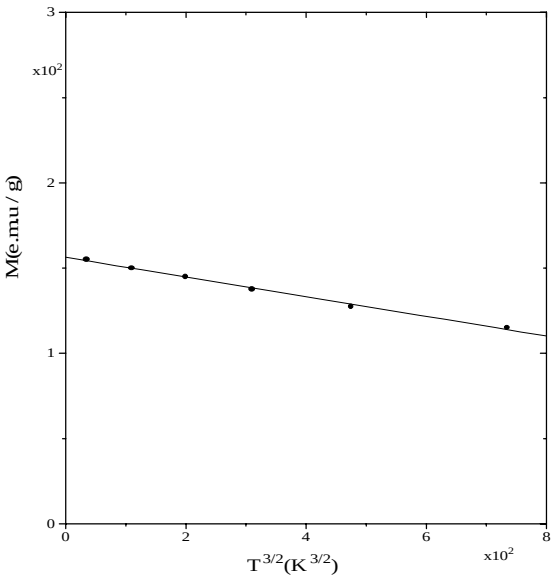

FIG. 3 : $T^{3/2}$ dependence of magnetization.

We have re-estimated the value of B using the value of M_0 (=M (0)) we have obtained B = 36.78 $K^{-3/2}$ which is more close to that obtained for $Gd_{0.8}Au_{0.2}$ [19] (Table 1). From the following relations given in Ref. [20]:

$$B = (0.0587 / QS) (k_B / 2J_{S.W}S)^{3/2} \quad (5)$$

$$k_B T_c / J_{T.C} = (5/96) (z-1) (11 S (S+1)-1) \quad (6)$$

where Q has been taken equal to 2 [20], S is the spin of Gd, J is the mean exchange integral (the labels S.W and T_C stand for spin wave and Curie temperature respectively), and z the number of nearest neighbours. We have obtained $J_{S.W}$ = 1.13 K and $J_{T.C}$ = 1.33 K which are close to each other. The parameters calculated together with those of Ref. [19] and [20] are represented in table 1. The value of $J_{S.W}$ is in good agreement with that obtained for $Gd_{0.8}Au_{0.2}$ [19].

III. CONCLUSION

We have reconsidered the magnetic and spin wave studies of amorphous Gd-Y alloys by using the more accurate magnetization law depending linearly on $H^{-1/2}$ instead of H^{-1}. The results given in Ref. [20] have been improved. The calculated magnetic moment values of Gd (μ_{cal} =6.93 μ_B; 7.07 μ_B) are more or less identical to that of the free ion as normally observed in such systems, contrary to that obtained (μ_{cal} =6.2 μ_B) in Ref [20]. This result is also supported by the calculations of the magnetic moment μ_{Co} of Co, carried out by Radwanski et al. [15], from magnetic studies in Gd_xCo_{80-x}, based on the assumption that μ_{Gd}=7.0 μ_B; the extrapolated value to x=0 of μ_{Co} fits reasonably well to with observed in $Co_{80}B_{20}$ [30]. Hassini

et al. [29], studying the influence of Gd on the magnetic properties of amorphous $(Fe_{1-x}Gd_x)_{80}B_{20}$ have obtained a value of μ_{Gd} equal to 7.0 μ_B. Besides, the obtained values of the mean exchange integral (J), using two different approaches (spin wave ($J_{S.W}$) and Curie temperature ($J_{T.C}$) studies) are close to each other; $J_{S.W}$ being in good agreement with that calculated for $Gd_{0.8}Au_{0.2}$[19].

Table. 1:

Some magnetic parameters relevant to $Gd_{0.7}Y_{0.3}$ compared to those of Refs [20] and [5].

	M_0 (emu/g)		μ_{Gd} (μ_B)	B($10^{-5}K^{-3/2}$)	$J_{S.W}$ (K)	$J_{T.C}$ (K)	Ref
$Gd_{0.7}Y_{0.3}$			6.2	42	0.8	0.9	[20]
$Gd_{0.7}Y_{0.3}$	4.2 K	201.4	7.07	36.78	1.13	1.33	This study
	40 K	197.2	6.93				
$Gd_{0.8}Y_{0.2}$			7.0	30	1.34	2.28	[5]

Bibliography:

[1] H .J. de Wit, C.H.M. Witmer, and F. W. A. Dirne, Adv. Mater. **3,** 356 (1991).
[2] H. J. de Wit, Rep. Prog. Phys. **55,** 113 (1992).
[3] K. H. J. Bushow, Solid StateCommun.**27,** 275 (1978).
[4] C. Jeandy, J. L. Oddou, B. Boucher, R. T. ourbot and G. Czizek, J. Magn .Magn. Mater. **89,** 330 (1990).
[5] S .J. Poon and J. Durand, Solid State Commun. **21,** 793 (1977).
[6] J. Mizogoshi and S. Kirkpatrick, Physica B.**86-88,** 783 (1977).
[7] J. Mizogoshi and S. Kirkpatrick, Phy. Rev. Lett. **38,** 89 (1977).
[8] P. Chieux, R de Konchovsky and B. Boucher, J. Phys. F**14,** 2239 (1984).
[9] S. W. Charles, J. Popplewell and P. A. Bates, J. Phys. F**3,** 664(1973).
[10] B. Barbara, A. P. Malozemoff and Y. Imry, Physica. B**108,** 1289(1981).
[11] C. Jeandey and J. L. Oddou, Solid State Commun. **50,**155(1984).
[12] W.C. Thoburn, S. Legvold and F. H. Spedding, Phys. Rev. **110,** 128(1958).
[13] Y. Mimura, N. Imamura, T. Kobayashi, Okadaand Y. Kushiro, J. Appl . Phys. **49**(3) 1208 (1978).
[14] O. Chen, K. Tourbot and B. Boucher, J. Magn. Magn. Mater. **110,** 9-146 (1992).
[15] R. J. Radwanski, J. .M. Franse,K. Krishnan and H. Lassri, J. Magn. Magn. Mater. **119,** 221-228 (1993).
[16] M. Laridjani, J. F. Sadoc, J. Physique **42,** 1293-1298 (1981).
[17] J. R. McGuire, T. Mizogoshi, R .J . Gambino and S. Kirkpatrick, J. Appl. Phys. **49,** 1689 (1978).
[18] N. Heiman and N. Kaazama, J. Appl.Phys**. 49,** 1686 (1978).
[19] S .J. Poon and J. Durand, Phys. Rev. B.**16** 316 (1977).
[20] R. Krishnan, M. Dancygin and M.. Laridjani, J. Magn. Magn. Matter. **98,** 78-82.m (1983).
[21] M. Fahnle and K. Kornmüller, J. Magn. Magn. Mater. **8** 149(1978).
[22] E. M. Chudnovsky, and R. A. Serota, J. Phys. C **16,** 4181(1983).
[23] E. M. Chudnovsky, J. Appl. Phys. **64,** 5770(1988).
[24] E. M .Chudnovsky, and R. A. Serota, J. Magn. Magn. Mater. **43,** 48(1984).
[25] H. Lassri, H. Arhchoui, S. Sayouri, M. Abid, and R. Krishnan, phys. stat. sol. (a) **158**, 553 (1996).
[26] H. Lassri, and R. Krishnan, J. Magn. Magn. Mater. **104,** 157 (1992).
[27] M. Slimani, M. Hamdoun, M. Tlemcani, H. Arhchoui, and S. Sayouri, Physica B **240,**) 372-377(1997.
[28] N. Hassanain, H. Lassri, R. Krishnan, and A. Berrada, J. Magn. Magn. Mater. **146,** 37-41 (1995).
[29] A. Hasssini, M. Slimani, M. Seqqat, H.. Oukriss, M. Hamedoun, A. Bouhdada and H. Lassri, phys.stat.solidi (a)**174**, 239(1999).
[30] P. Hansen, in : Handbook of Magnetic Materials, vol.**6**, ed. K.H.J. Buschow (North- Holland, Amsterdam, p.324(1991).