Journal of Optoelectronics and Advanced Materials Vol. 6, No. 2, June 2004, p. 651 - 653

THE HALL EFFECT IN $Co_{72}Fe_2B_{17}Si_5Mn_4$ AMORPHOUS RIBBONS

M. Lozovan[a*], M. Neagu[a,b], C. Hison[a,c]

[a]National Institute of Research and Development for Technical Physics
47 Mangeron Blvd., 700050 Iasi 3, Romania
[b]"Al. I. Cuza" University, Faculty of Physics, 11 Carol Blvd., 700506, Iasi, Romania
[c]Istituto Nazionale per la Fisica della Materia,Universita "Federico II",Napoli, Italy

In this paper we have analyzed the crystallization effect on the galvanomagnetic properties of $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons prepared by rapid solidification from the melt. The samples were thermally treated at 600°C in argon atmosphere for 2.5 hours. Results concerning the Hall resistivity, the ordinary Hall coefficient R_0, the spontaneous Hall coefficient R_s, longitudinal and transversal magnetoresistance and ferromagnetic anisotropic resistivity (FAR) for as-cast and thermally treated samples are presented.

(Received April 26, 2004; accepted June 3, 2004)

Keywords: Amorphous ribbons, Hall Effect, Magnetoresistance, Ferromagnetic anisotropic resistivity

1. Introduction

Amorphous metallic alloys have been the subject of extensive investigations over the last two decades because of their interesting electronic transport and magnetic properties. The $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons are excellent soft magnetic materials having nearly zero magnetostriction and a very low magnetic anisotropy induced during the fabrication process. Structural changes are obtained in these materials by heat treatments and, as a consequence, the magnetic, magnetoelastic and electric properties of the material change [1, 2].

In this work we have studied the influence of the thermal treatments on the Hall Effect, magnetoresistance and ferromagnetic anisotropic resistivity (FAR) in $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons prepared by the melt spinning technique. Measurements of Hall Effect and magnetoresistance are important sources of information for ferromagnetic materials, such as structural characterization, electronic transport and magnetic properties. The amorphous ribbons were tested in the as-cast state and after thermal treatment.

2. Theory

The Hall resistivity, ρ_H, versus magnetizing field curve is fitted by the formula (in e.m.u. as generally used in literature):

$$\rho_H = E_y / j_x = hV_H / i_x = R_o B_z + R_s 4\pi M_z , \qquad (1)$$

where: j_x is the electric current density, E_y is the electric field, V_H is the Hall potential, h is the sample thickness, i_x is the current passing through the sample, B_z is the magnetic induction, M_z is the magnetization, R_0 is the ordinary Hall constant, R_s is the extraordinary (or spontaneous) Hall constant.

---

[*] Corresponding author: loz@phys-iasi.ro

From experimental point of view, the variation of ρ_H with the applied field, H_a, is more relevant than with B. In this case, Eq (1) can be rewritten as:

$$\rho_H = R_o\left[H_a + 4\pi M(1-N)\right] + R_s 4\pi M_z\,, \tag{2}$$

where N is the demagnetizing factor.

At saturation it follows that $H_a=4\pi M_s$ and the Hall coefficients R_0 and R_s are determined directly from ρ_H or V_H curve [3].

Usually, the magnetoresistance is characterized by relative change of resistivity $\Delta\rho/\rho = [\rho(H)-\rho(0)]/\rho(0)$ in magnetic field. It is possible to evaluate the ferromagnetic anisotropic resistivity from $\Delta\rho_{\|}/\rho$ and $\Delta\rho_{\perp}/\rho$. The curves $\Delta\rho_{\|}/\rho = [\rho_{\|}(H)-\rho(0)]/\rho(0)$ and $\Delta\rho_{\perp}/\rho = [\rho_{\perp}(H)-\rho(0)]/\rho(0)$ versus applied magnetic field are obtained experimentally by locating the ribbon sample with its longitudinal axis parallel and perpendicular to the magnetic field but with its plane parallel to the magnetic field. From these curves we calculated the ferromagnetic anisotropic resistivity defined as $(\rho_{\|}-\rho_{\perp})/\rho$, where $\rho_{\|}$ and $\rho_{\perp}$ are the resistivities of the sample obtained in a saturating magnetic field aligned parallel and perpendicular to the current direction, respectively, and ρ is the electrical resistivity measured in zero magnetic field [1,4].

3. Experimental

The nearly zero magnetostrictive amorphous ribbons prepared by the melt spinning technique with nominal composition $Co_{72}Fe_2B_{17}Si_5Mn_4$ were tested in the as-cast state and after thermal treatment at 600 ^{0}C for 2.5 hours in a furnace in argon atmosphere ensuring a uniform heating of the sample along its length.

The amorphous state of the samples and the evolution of the crystallization process after thermal treatment were examined by X-ray diffraction and differential thermal analysis (DTA).

The samples were typically $27\cdot10^{-6}$ x $3\cdot10^{-3}$ x $45\cdot10^{-3}$ m^3 in dimensions and the electrical contacts on the samples were made by using silver paint. The samples's support was obtained by masking and etching. The Hall voltage measurements were carried-out by the Van der Pauw method, at room temperature [2]. In our geometry $N \cong 1$ and then Eq. (2) becomes:

$$\rho_H = R_o H_a + R_s 4\pi M_z \tag{3}$$

The results are analyzed considering that, as indicated by Hurd, the slope of the curves below technical saturation is R_s and at high fields is R_0 [3].

The longitudinal and transversal magnetoresistance measurements on the applied magnetic field (H) up to about 28 kAm^{-1} were performed at room temperature. These measurements were realized by rotating the sample inside of the solenoid to locate the ribbon with its long axis parallel and perpendicular to the magnetic field but with its plane parallel to the magnetic field. The experimental results were obtained using a constant current power supply and a digital nanovoltmeter by means of a standard four-probe method in dc current.

4. Results and discussion

Fig. 1 presents the dependence of the Hall resistivity on the applied magnetic field for $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons tested in the as-cast and crystallized state. The value of the Hall resistivity for the melt-spun ribbons increases continuously with the applied magnetic field up to about 12 kA/m and then it approaches saturation.

The changes of the Hall resistivity in $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons after thermal treatment are due to the structural relaxation that affects the magnetic stability, important changes of the saturation magnetostriction being also observed.

The magnetic stability of an amorphous alloy is related not only to the variation of the induced magnetic anisotropy, but also to the value of the magnetostriction. In the as-cast state the saturation magnetostriction value is quite small (about 10^{-7}) and negative and its shifts to positive values after annealing [2].

The magnetoresistance dependence on the applied magnetic field for $Co_{72}Fe_2B_{17}Si_5Mn_4$ samples in the amorphous and crystallized state, respectively, is presented in Fig 2. After thermal treatment the asymmetry of the curves with respect to the field axis practically disappears because the induced magnetic anisotropy along the longitudinal axis of the ribbons is eliminated by thermal treatments and the crystallites are randomly oriented.

The value of FAR ($+4.74 \times 10^{-4}$) for crystallized samples is quite similar to that of the as-cast samples ($+4.35 \times 10^{-4}$). The values of the Hall coefficients R_0 and R_s of the studied samples are presented in Table 1.

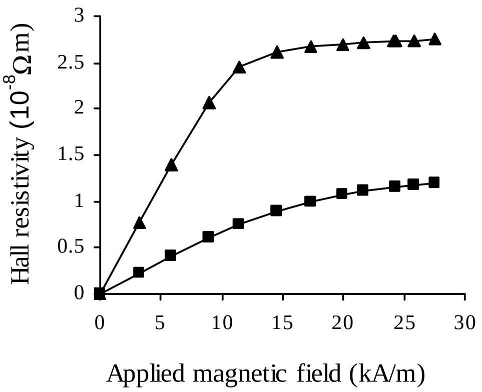

Fig. 1. The Hall resistivity dependence on the applied magnetic field for $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous ribbons (60 mA dc sample biasing current): ▲ in the as-cast state; ■ in the crystallized state.

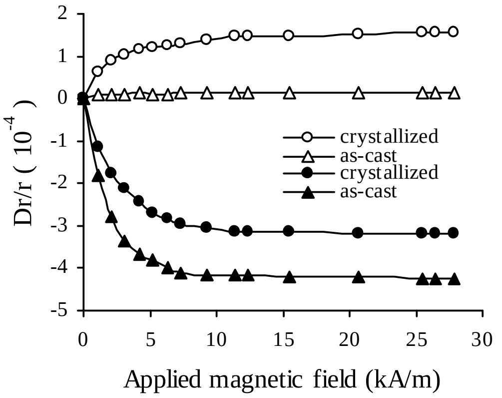

Fig. 2. The magnetoresistance dependence on the applied magnetic field for $Co_{72}Fe_2B_{17}Si_5Mn_4$ samples in the amorphous and crystallized state, respectively (o, Δ -.$\Delta\rho_{\parallel}/\rho$; •, ▲ - $\Delta\rho_{\perp}/\rho$).

Table 1. The Hall coefficients R_0 and R_s for $Co_{72}Fe_2B_{17}Si_5Mn_4$ samples in the amorphous and crystallized states.

Material	R_0 (10^{-9} m^3/As)		R_s (10^{-9} m^3/As)	
$Co_{72}Fe_2B_{17}Si_5Mn_4$	as-cast	crystallized	as-cast	crystallized
	1.72	0.84	26.35	7.24

5. Conclusions

The Hall resistivities, ρ_H, for $Co_{72}Fe_2B_{17}Si_5Mn_4$ amorphous and crystallized ribbons as a function of applied magnetic field are presented.

The value of the Hall resistivity of amorphous ribbons increases continuously with applied magnetic field to about 12 kA/m and then it approaches saturation. After thermal treatment at 600 °C for 2.5 hours, a remarkable change in the Hall resistivity is observed due to the thermally induced magnetic anisotropy.

The ferromagnetic anisotropic resistivity ($+4.74 \times 10^{-4}$) for crystallized samples is quite similar to that of the as-cast samples ($+4.35 \times 10^{-4}$).

References

[1] H. Chiriac, M. Lozovan, M. Neagu, Mater. Sci Eng. **A304-306,** 1023 (2001).
[2] H. Chiriac, M. Lozovan, M. Neagu, C. Hison, J. Magn. Magn. Mater. **215-216**, 378 (2000).
[3] C. M. Hurd, Hall Effect in Metals and Alloys, Plenum Press, New York, 1972.
[4] M. Neagu, H. Chiriac, M. Lozovan, Sensors Actuat. **A106**, 73, (2003).