Journal of Magnetism and Magnetic Materials 215–216 (2000) 316–318
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Tensile stress dependence of the coercivity and magnetostriction of stress-annealed (by Joule heating) $Co_{66}Fe_4Mo_2Si_{16}B_{12}$ alloy

P. García-Tello[a], J. González[b,*], R. Valenzuela[c], J.M. Blanco[a]

[a]Dpto. Física Aplicada I, EUITI, San Sebastián, Spain
[b]Dpto. Física de Materiales, Facultad de CC Químicas UPV, IEHU, P°Manuel de Lardizabal 3, 20009, San Sebastián, Guipuzcoa, Spain
[c]Instituto de Investigaciones en Materiales, UNAM, D.F. Mexico

Abstract

The influence of applied tensile stresses (16–45 MPa) during Joule-heating thermal treatments on samples of nominal composition $Co_{66}Fe_4Mo_2Si_{16}B_{12}$ is reported. The influence of high axial stresses (0–1000 MPa, applied during measurements) on the coercive field was also investigated. The coercive field exhibited a maximum as a function of measuring stress. Very low values of the saturation magnetostriction constant have been obtained as a function of annealing stress.

Keywords: Alloys; Joule heating; Tensile stress

Structural relaxation mechanisms and the induced anisotropy that take place during Joule heating allow to change the magnetization process in Co-rich amorphous alloys [1,2]. These changes permit to obtain good candidates for technological applications such as high-power pulse transformers and tape-head recording applications, arising from the fact that large magnetic anisotropies may be induced by heat treatments at relatively low temperature. In this paper, the influence of Joule heating thermal treatments under longitudinal applied tensile stresses in samples of nominal composition $Co_{66}Fe_4Mo_2Si_{16}B_{12}$ is reported. The influence of high axial stresses (0–1000 MPa, applied during measurements) on the coercive field was also investigated.

Ribbon-shaped samples (10 cm long 1.5 mm wide and 20 μm thick) of nominal composition $Co_{66}Fe_4Mo_2Si_{16}B_{12}$, kindly supplied by Vacuumschmelze GmbH, Germany, were submitted to Joule-heating thermal treatments (1.55 A 5 min time and current density 0.1 A/mm^2) under applied tensile stresses in the range 16–45 MPa. After heat treatment X-ray diffraction and TEM studies were made showing that the microstructure of the samples was formed by nanocrystalline grains of Co (12 nm) embedded in an amorphous residual matrix. Magnetic measurements under applied tensile stresses in the range 0–1000 MPa were carried out with a conventional hysteresis loop tracer to study the variation of the coercive field, H_c, and saturation magnetostriction constant, λ_S, with the thermal treatment parameters. The saturation magnetostriction constant was obtained directly from the measurement of the anisotropy field of the hysteresis loops. Fig. 1 shows the behaviour of the coercive field as a function of tensile stress during the measurement for the studied samples. The tensile stress during the heat treatment appears as an additional parameter. Except for the sample submitted to the lowest stress during the Joule heating (16 MPa), the coercive field, H_c exhibits a maximum for all the other samples. As the annealing stress increases, the value of the maximum increases and the measuring stress at

* Corresponding author. Fax: + 34-43-21-2236.
E-mail address: wapgoesj@sq.ehu.es (J. González).

0304-8853/00/$ - see front matter
PII: S0304-8853(00)00144-X

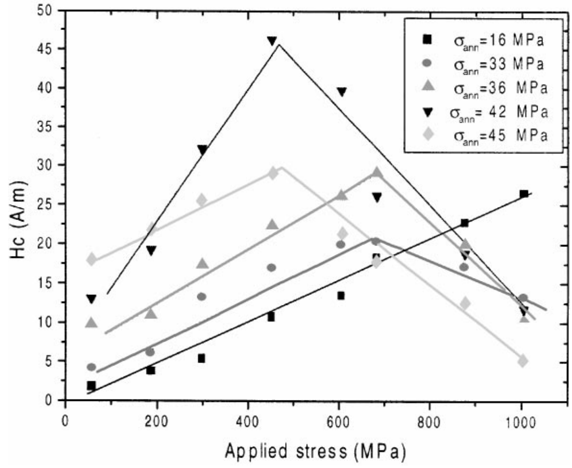

Fig. 1. Coercive field variation for the studied samples. The legend shows the annealing tensile stress for the samples.

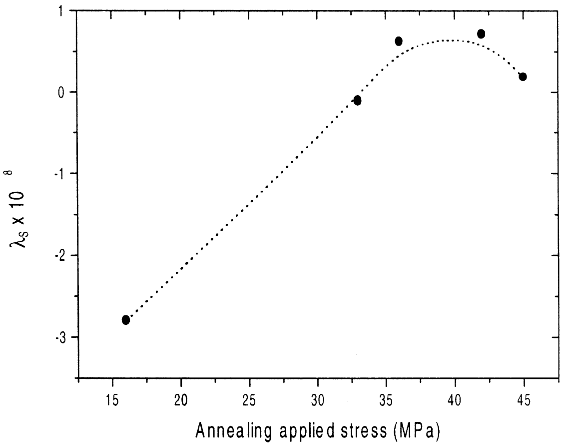

Fig. 3. Saturation magnetostriction behaviour for the annealing applied stress in the studied samples.

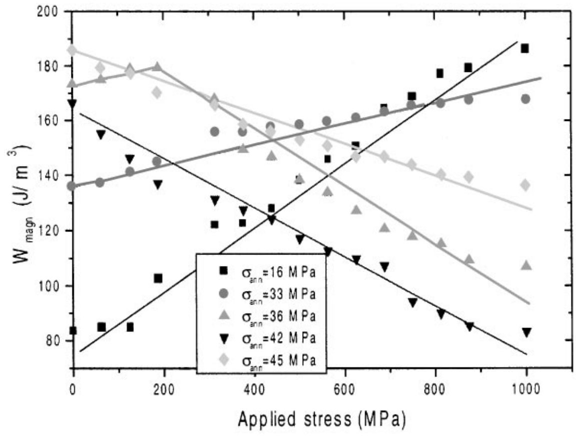

Fig. 2. Evolution of the anisotropy field for the studied samples. The legend shows the annealing tensile stress for the samples.

which the maximum appears decreases. The increasing behaviour of the coercive field for the low tensile stress section (before the maximum is reached) can be ascribed to the overcome of the internal stresses due to the annealing process by the applied stress during the measurement, as reported elsewhere [2]. In contrast, the decreasing behaviour as high tensile stresses are applied (to the right-hand side of the maxima), can be related to the polarization change of the residual amorphous matrix, which affects the magnetoelastic coupling with the crystallites [3]. The results of the anisotropy field with the applied stresses are shown in Fig. 2. It can be observed that this parameter shows a linear behaviour, and also a change of its slope for the sample treated at 1.55 A 5 min with an applied tensile stress of 36 MPa. In agreement with the coercive field results presented above, this change of the slope can be related with the polarization change of the residual amorphous matrix, leading to a change in the tensile back stresses exerted by the amorphous matrix over the nanocrystallites as it can be seen by comparing of the samples treated with applied stresses of 45 and 42 MPa as an example. In turn, these back stresses modify the magnetization process of the sample [3].

Fig. 3 shows the results concerning the behaviour of the saturation magnetostriction constant as a function of the applied stress during annealing. One can observe a change of sign of this parameter for the high-stress section. It is also observed that it is possible to obtain very low values of the saturation magnetostriction for this composition (-1.1×10^{-8} for the sample annealed under 33 MPa and 1.8×10^{-8} for the sample annealed at 45 MPa) by modifying the tensile stress applied during annealing. This technique can therefore lead to good candidates for technological applications where a very low magnetostriction constant (either positive or negative) is required.

Concluding results of the variation of the coercive field, anisotropy field and saturation magnetostriction constant of Joule heating, under applied tensile stresses, of samples (nominal composition $Co_{66}Fe_4Mo_2Si_{16}B_{12}$) have been reported. It has been shown that the coercive field goes through a maximum as applied stresses during measurement increase. Also, a change of the slope in the anisotropy field has been found. This behaviour could be associated to polarization change in the amorphous residual matrix which affects the magnetoelastic coupling of the nanocrystals in the sample. A change of sign in the saturation magnetostriction has been reported resulting in very low values of this parameter which permits to obtain good candidates for future technological applications where a low magnetostriction value is critical.

References

[1] J. Swierczek, S. Szymura, J. Zbroszcyk, A. Siemko, Physica B 161 (1989) 232.

[2] J. Zbroszcyk, W. Ciurcynska, B. Wyslocki, S. Szymura, J. Swierczek, Y. Yamashiro, K. Narita, J. Magn. Magn. Mater. 112 (1992) 341.

[3] G. Herzer, IEEE Trans. Magn. 33 (6) (1994) 4800.