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REINFORCED MAGNETIC ANISOTROPY INDUCED BY STRESS-FIELD ANNEALING AND ITS DEPENDENCE ON PREANNEALING CONDITIONS IN CO-RICH METALLIC GLASSES

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Abstract. — New data concerning the reinforced anisotropy induced by stress-field annealing for Co-based amorphous alloys are reported and in particular the influence of preannealing on such anisotropy. It can be concluded that increasing the preannealing temperature and/or the preannealing time gives rise to stronger stress-field induced anisotropies.

Introduction

Ribbon-shaped metallic glasses are characterized by the lack of macroscopic magnetic anisotropy in its as-prepared state although local magnetoelastic anisotropies are induced by stresses when the samples are fabricated. Nevertheless, as shown in many publications, macroscopic anisotropies can be induced by convenient thermal treatments as field or stress annealings [1]. Moreover, as has been recently reported, thermal treatment under the presence of both field and stress applied during annealing can give rise to reinforced anisotropy whose uniaxial anisotropy constant can not be considered as the simple addition of the ones obtained by single field plus stress annealing [2-3]. This reinforced magnetic is strongly dependent on the alloys composition as was previously investigated for a series of Co and Fe-based amorphous alloys [3].

In the present work, we report new data concerning the magnetic anisotropy induced by stress-field annealing for two Co-based alloys which exhibit huge reinforced anisotropy as above explained. In particular, we have investigated the influence of the preannealing conditions on the magnetic anisotropy induced by stress-field treatments.

Experimental technique and results

Metallic glass ribbon were fabricated by means of the single-roller quenching technique and their nominal compositions are (Co1−xFex)75Si15B10 (x = 0.08 and 0.12). The cross sections of the ribbons were 0.50 mm × 20 μm and the length of the ribbons chosen for measurements was 70 mm. Preannealing and subsequent stress-field annealing of the ribbons were performed by the so called current annealing technique [4-6]. It is based on the heating of the samples when an electrical current flows along the ribbons.

The experimental system was built so as to allow the flowing of an electrical current through the samples and if necessary the simultaneous application of tensile stress and magnetic field transverse to the ribbon axis during the treatment. The temperature of the samples when annealing was evaluated by comparing the variation of the saturation magnetization with the intensity of the current annealing and the value of the saturation magnetization obtained in a furnace as a function of temperature. The transverse magnetic anisotropy induced by the stress-field annealing has been determined from the change of the magnetization work by applying tensile stress at room temperature when a magnetic field is applied along the axial direction of the ribbons. More detailed description of experimental technique can be found elsewhere [4, 7].

Preannealing treatments were performed by making an electrical current flow along the samples for a range of annealing time and intensity (annealing temperature). Annealing temperatures were mostly above the Curie point. After each preannealing treatment for a given time and temperature the ribbons were subsequently stress-field annealed at the presence of a transverse magnetic field \( H_t = 2.4 \times 10^8 \text{ Am}^{-1} \) and an applied tensile stress, \( \sigma_{an} = 600 \text{ MPa} \). For each annealing temperature and keeping \( H_t \) and \( \sigma_{an} \) constant for all annealings, the induced anisotropy measured at room temperature reaches a maximum after annealing during \( t_{an} \). The time \( t_{an} \) depends on the annealing temperature and decreases as \( T_{an} \) increases [3].

Experimental results for the (Co0.92Fe0.08)75Si15B10 alloy are plotted in figures 1 and 2. The figures, show the dependence of the maximum induced anisotropy, \( K_{ind} \), on the annealing temperature. In the case of figure 1 the parameter is the time of preannealing for a given temperature of preannealing while in figure 2 the preannealing time is fixed but the preannealing temperature is changed. Similar behavior is found for the (Co0.92Fe0.08)75Si15B10 alloy although the values for the induced anisotropy are slightly smaller.
Fig. 1. - Maximum stress-field induced anisotropy as a function of the annealing temperature when modifying the preannealing time for the \((\text{Co}_{0.92}\text{Fe}_{0.08})_{75}\text{Si}_{15}\text{B}_{10}\) amorphous alloys.

\[
\begin{align*}
K_{\text{ind}} (J/m^3) & \quad (\text{Co}_{0.92}\text{Fe}_{0.08})_{75}\text{Si}_{15}\text{B}_{10} \\
T_{\text{PA}} & = 400 \, ^\circ\text{C} \\
T_{\text{PA}} & = 1 \, \text{min.} \,
\end{align*}
\]

Analysis of the results and conclusions

From the results shown in the figures, it can be observed that the induced anisotropy reaches a maximum after stress-field annealing at \(T_{\text{an}} \sim 340 \, ^\circ\text{C}\). This maximum and the overall induced anisotropy increases for longer preannealing times as well as after preannealing at more elevated temperatures. Both types of results indicate that as structural relaxation proceeds (with preannealing) subsequent treatments biased by the action of stress plus magnetic field gives rise to enhanced effects. This would be in agreement with some previous results obtained when annealing under the only presence of applied stress [8].

It is worth to note that induced anisotropies at 340 \(^\circ\text{C}\) are rather strong and can be even increased with the preannealing parameters. As known from previous publications concerning field induced anisotropy and changes of the magnetostriction, annealing at such a temperature produce important microstructural transformations for Co-based alloys [9].

Finally, in comparing preannealing temperatures in both figures, no different behavior can be distinguished when preannealing above and just at the Curie point.