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LETTER TO THE EDITOR

The effect of annealing on the magnetostriction of the $Co_{70}Mn_{10}B_{20}$ amorphous alloy

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Abstract. The thermal variation, from 0 K up to the Curie Temperature (T_C), of the magnetostriction λ_s of $Co_{70}Mn_{10}B_{20}$ amorphous alloy after annealing at 580 K for 1 h has been studied. The results obtained for λ_s for this sample differ from the ones previously observed for the same 'as-quenched' sample. The study of the variation of $\lambda_s/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$ versus $m^2/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$, where m is the reduced magnetisation, enables us to speculate about the origin of λ_s in metallic glass ribbons.

The magnetostriction λ_s in Co-rich metallic glasses exhibits an anomalous thermal variation in nearly zero-λ_s alloys, where bumps and changes of sign are observed. To explain this effect, a competition between a single-ion contribution, λ_1 and a two-ion contribution, λ_2, of opposite sign has been suggested (Barandiarán *et al* 1987, O'Handley and Sullivan 1981).

Letting m be the reduced magnetisation, the magnetostriction λ_s can be written as

$$\lambda_s(T) = \lambda_1 \hat{I}_{5/2}(\mathcal{L}^{-1}(m)) + \lambda_2 m^2 \tag{1}$$

where $\hat{I}_{5/2}$ is a modified hyperbolic Bessel function of the inverse Langevin function ($\mathcal{L}$) (Callen and Callen 1965), which varies as m^3 at low temperatures ($m \geqslant 0.9$), and as $\frac{3}{5}m^2$ near T_C. The validity of equation (1) can be checked by plotting $y = \lambda_s/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$ versus $t = m^2/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$, which gives a linear dependence of $y(t)$, with t ranging from unity at $T = 0$ K down to $\frac{5}{3}$ at $T = T_c$.

In this work, we have investigated the validity of equation (1) for a $Co_{70}Mn_{10}B_{20}$ amorphous alloy, after annealing it at 580 K for 1 h. In previous work (du Tremolet de Lacheisserie and Yavari 1988), a linear dependence of $y(t)$ in 'as-quenched' $Co_{80-x}Mn_xB_{20}$ amorphous alloys was established. But for $x = 10$, the curve $y(t)$ showed no clear linear dependence. So, we have relaxed this sample by annealing and have then checked equation (1) again.

The sample that we studied was a ribbon with nominal composition $Co_{70}Mn_{10}B_{20}$ (10.24 mm width, ≃35 μm thickness) obtained by the single-roller technique. Both surfaces were checked to be amorphous and DSC data showed a crystallisation at 775 K.

The magnetostriction constant has been measured directly below room temperature by a capacitance method using a ribbon rolled onto itself in order to give a cylindrical sample, and slipped into a copper ring (du Tremolet de Lacheisserie and Krishnan 1984).

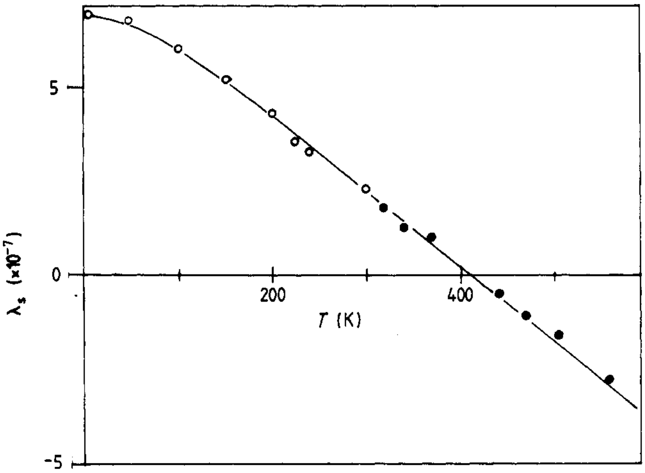

Figure 1. Thermal dependence of the magnetostriction λ_s of $Co_{70}Mn_{10}B_{20}$ amorphous alloy, after annealing at 580 K for 1 h: (○) values obtained by direct measurement (dilatometer); and (●) values obtained from indirect measurement (strain dependence of the magnetisation work, after [6]).

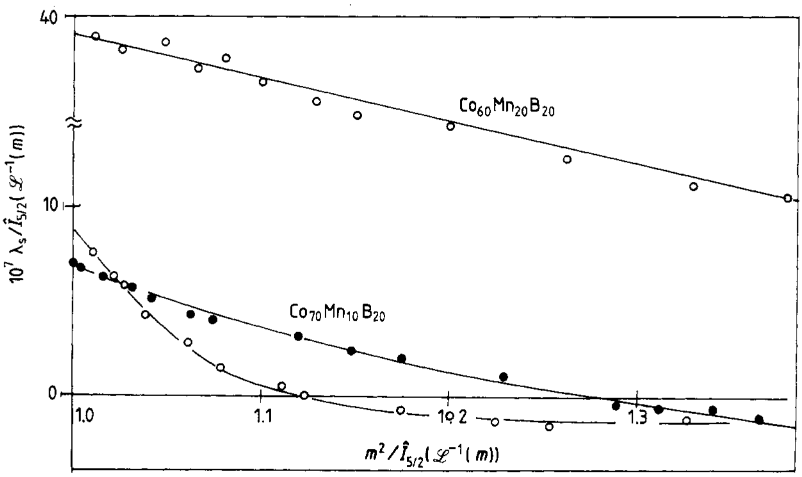

Figure 2. Plot of $\lambda_s/I_{5/2}(\mathcal{L}^{-1}(m))$ versus $m^2/I_{5/2}(\mathcal{L}^{-1}(m))$ (see text). Open circles: data taken from [4] for 'as-quenched' $Co_{60}Mn_{20}B_{20}$ and $Co_{70}Mn_{10}B_{20}$ amorphous alloys. Full circles: annealed samples of $Co_{70}Mn_{10}B_{20}$ (this work).

At higher temperatures, the magnetostriction has been evaluated from the variation of the magnetisation work as a function of applied tensile stress (González *et al* 1986).

The thermal variation of the magnetostriction λ_s of the annealed sample is shown in figure 1. In order to analyse the microscopic origin of the magnetostriction, we have plotted, in figure 2, $y = \lambda_s/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$ versus $t = m^2/\hat{I}_{5/2}(\mathcal{L}^{-1}(m))$. Also shown are the values obtained for an 'as-quenched" (AQ) sample (du Tremolet de Lacheisserie and Yavari (1988)). The non-linearity observed with the AQ sample shows that the thermal variation of the single-ion and two-ion correlation functions does not account for the observed temperature dependence: a slight temperature-induced structural change can result in a strong relative change of λ_s, near the zero-λ_s composition where a compensation between the negative (Co) and positive (Mn) contributions is observed. After annealing, the straight line $y(t)$ indicates that there are no longer structural changes when the sample is heated up to T_C: the relaxed state is more stable than the AQ one, and the thermal dependence of λ_s is then well accounted for by the competition between a positive one-ion contribution $\lambda_1 = +19 \times 10^{-7}$ and a negative two-ion contribution $\lambda_2 = -12 \times 10^{-7}$, similar to the one observed in the $Co_{60}Mn_{20}B_{20}$ amorphous alloy (the two straight lines are parallel).

In conclusion, the thermal variation of the magnetostriction appears to be a sensitive probe for detecting small variations of the local order in metallic glasses; the two-ion contribution to λ_s is negative and relatively small in this series ($\lambda_2 \simeq -1 \times 10^{-6}$), but plays an important role when the one-ion contribution cancels it out near the $\lambda_s \simeq 0$ composition.

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