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CHEMICAL SHORT RANGE ORDER IN $\text{Fe}_{20}\text{Ni}_{60}\text{B}_{20}$ AMORPHOUS ALLOY¹

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Abstract. – We have seen, by Mössbauer spectroscopy, magnetization and resistivity, changes on the physical properties of the α - $\text{Fe}_{20}\text{Ni}_{60}\text{B}_{20}$ alloy induced by thermal relaxation, notably increases in T_c and resistivity. These changes can be explained by modifications of the chemical short range order around Fe favouring the formation of Fe-Ni pairs.

Introduction

Thermal relaxation of the free volume trapped in the process of rapid quenching needed to produce amorphous metals has been mainly studied through magnetic [1] and mechanical effects [2] at room temperature and above, heat conduction or calorimetry at low or high temperatures [3] and resistivity measurements in all ranges of temperature [4]. Metallic glasses relax structurally below the glass temperature T_g as a result of both chemical and topological short range order (CSRO and TSRO). In this work we have concentrated on the magnetic and resistive irreversible modifications produced on a $\text{Fe}_{20}\text{Ni}_{60}\text{B}_{20}$ amorphous alloy under thermal treatment by studying both the macroscopic and microscopic values for the magnetic parameters and their correlation.

Experimental

The ribbons, obtained by melt spinning, were tested for amorphicity through X-ray diffractometry, scanning electron microscopy and resistivity up to above crystallization ($T_x \cong 690$ K). After preparation the samples were kept in liquid nitrogen until used.

The “as-quenched” (AQ) samples were then measured by three different techniques: transmission Mössbauer spectroscopy, magnetization and resistivity. In all cases an *in situ* anneal was performed in order to assure internal consistency when comparing results before and after heat treatment.

For the Mössbauer effect experiment a full spectrum was obtained at room temperature, then the temperature was slowly raised (~ 1.2 K/min) while monitoring the total counting rate of the spectrometer to detect the critical temperature T_c . The temperature was stabilized at 473 K for 30 minutes, then cooled to 373 K where it stayed for 5 hours. After this the sample was brought back to room temperature while monitoring the counting rate. Full spectra for the relaxed samples

were obtained; first the ferromagnetic phase (at room temperature) then the paramagnetic phase at around 473 K. The magnetization experiment was performed in a similar way, with data obtained before, during and after the anneal. Resistivity measurements were made at a constant heating rate of 0.3 K/min up to the annealing temperature where, as was the case of the other experiments, the temperature was stabilized at 473 K until saturation was established. The system was then cooled at a constant cooling rate of 0.3 K/min while the resistance was recorded.

Results and discussion

From the results of the Mössbauer effect counting rate experiment a raise in T_c is observed upon annealing. The value found for $\Delta T_c = 9$ °C agrees within the precision of the thermocouples to that found for the bulk magnetization experiment (Fig. 1) where a change from $T_c \sim 420$ K to 429 K was verified.

The Mössbauer spectra can be fitted in the paramagnetic state by supposing a distribution of quadrupole splittings (QS) as well as a distribution of isomer shifts (IS). Using the parameters thus obtained, one may then determine a reliable fit to the ferromagnetic spec-

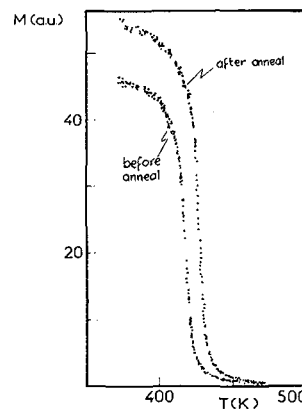


Fig. 1. – Magnetization in low field as a function of temperature.

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trum. To obtain this fit, one has to assume a distribution of hyperfine fields (HF); histograms of these distributions are presented in figure 2 for HF, for both AQ and relaxed (REL) states.

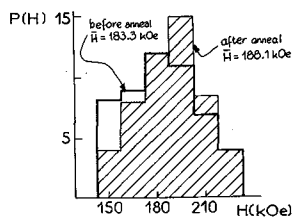


Fig. 2. - Histogram of the hyperfine field distribution.

The main changes observed are that the average field at the Fe site (\bar{H}) increases from ~ 183 kG to ~ 188 kG, and that the distribution is narrower around that average \bar{H} . According to the results obtained for crystalline FeNi alloys [5, 6], around the average composition which corresponds to Ni_3Fe , the rise seen in \bar{H} is equivalent to displacing towards lower Ni concentrations. This would mean that, transposing these results to a $-(\text{Fe} - \text{Ni}_3)_{20}\text{B}_{20}$, some of the Fe sites (at lower fields) have excess Ni around them before the anneal. Heat treatment would then reduce the number of Ni-Ni pairs at each site, favoring the Fe-Ni pairs. This corresponds to single atom displacements which is, in fact, a change in CSRO. We reach this conclusion by supposing that the metalloid in a $-(\text{FeNi}_3)_{20}\text{B}_{20}$ is present only as a glass former [7]. The saturation magnetization increases upon relaxation by $\sim 8\%$, which also fits nicely in the picture of a reduction of Ni-Ni pairs towards Fe-Ni pairs [8]. The resistance of the samples increases upon annealing by about $\Delta R/R \sim 0.5\%$ (Fig. 3). Only part of this increase can be associated

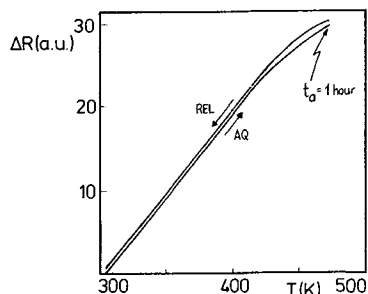


Fig. 3. - Resistance change as a function of temperature.

to densification upon relaxation [9]; at least two thirds of the observed change in resistance comes from an increase in resistivity (which is not expected for a simple Ziman formalism [9]). In order to understand the effect of CSRO on resistivity one has to assume this alloy to be a pseudo binary of the type $\text{T}_{80}\text{M}_{20}$ (T is a transition metal and M is a metalloid). Following Cote and Meisel [10], the resistivity can be described by the T structure factor only; since our T is in fact a binary, the expressions to be used should be those of a Faber-Ziman formalism [11] using partial structure factors. The partial structure factors (a_{ij}) for the hypothetical FeNi_3 amorphous alloy are not known but one can assume that the leading term in the expression for the resistivity comes from the "cross term" [11], that is, the term containing a_{FeNi} , thus explaining the increase in resistivity.

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