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MAGNETIC RELAXATION SPECTRA OF AMORPHOUS FeCrB ALLOY[1]

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We have investigated temperature and long-time dependences of reluctivity ($r=1/\chi$) of amorphous $Fe_{80}Cr_3B_{17}$ alloy. The long-time measurements were performed for different temperatures. The spectra of activation energies were evaluated from these measurements. The Wolfe method was used for the determination of the spectra of activation energies.

1. Introduction

It is well-known that many magnetic properties of the Fe-B alloy vary by substitution of iron by the transition metal [1].

The Magnetic After-Effect (MAE) phenomenon is a very useful tool to study of reversibile or irreversibile relaxation in those alloys. Previously, MAE analysis has been used on FeCrB alloy [2] but there have been no analysis of influence of Cr on spectra of activation energies.

In the present work we have analyzed the time and temperature dependencies of the relative change of reluctivity of an amorphous FeCrB alloy assuming two-level system [3, 4].

2. Experimental

2.1 Sample preparation and measuring technique

MAE has been studied in amorphous $Fe_{80}Cr_3B_{17}$ ribbons obtained by the melt-spinning method. The ribbons were approximately 30 μm thick, 1 mm wide and 30 mm long. The measurements were performed fusing a resonance LC circuit [5] with a magnetic field H=0.25 A/m. Isothermal curves were obtained for different temperatures (T=323, 373, 423 and 463 K) in the time interval $1 \div 10^4$ s after demagnetization. Isochronal

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curves were measured for different times (t=10,30,60 and 120 s) with t_1=1 s in the temperature interval 173÷473 K.

Magnetic relaxation is reprezented by the relative change of reluctivity according to the following relationship :

$$\frac{\Delta r}{r} = \frac{r(t) - r(t_1)}{r(t_1)} \tag{1}$$

2.2. Method of estimation of activation parameters

The time dependence of the reluctivity r can be described as follows [3]:

$$r(t) = r(0) + (r(\infty) - r(0)).(1 - e^{-t/\tau}) \tag{2}$$

where relaxation time:

$$\tau = \tau_0.e^{Q/kT} \tag{3}$$

and τ_0 is a pre-exponential factor, Q - activation energy, k - Boltzman constant and T - temperature.

In analyzing MAE spectra we assume instead one discrete relaxation time, a continuous distribution of relaxations times,p(τ), which is normalized:

$$\int_{\tau_1 \to 0}^{\tau_2 \to \infty} p(\tau) d ln\tau = 1 \tag{4}$$

We can substitute the distribution functions p(τ) by a series box-type distribution functions of Q, where p(τ) = const. between lower activation energy Q_i and upper activation energy Q_{i+1}. The reluctivity then can be described:

$$r(t) = r(\infty) + \sum_{i=1}^{n} \Delta r_i . \frac{Ei(-t/\tau_{i,2}) - Ei(-t/\tau_{i,1})}{ln(\tau_{i,2}/\tau_{i,1})} \tag{5}$$

where Ei(x) is so-called exponential integral :

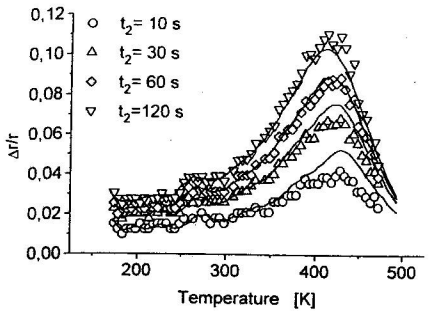
$$Ei(-t/\tau) = -\int_{t/\tau}^{\infty} \frac{e^{-x}}{x} dx \tag{6}$$

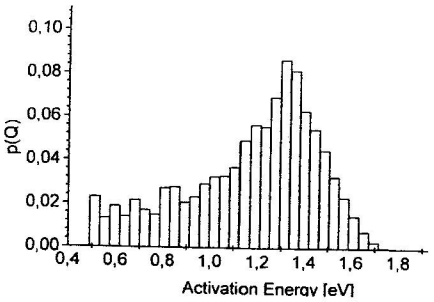
and Δ r_i corresponds to relaxation amplitude of i-th box with activation energy Q_i and the width Q_{i+1}-Q_i and τ_0 is taken to be a constant for all boxes.

$p(Q)$ spectra were obtained by Wolfe method [6].

3. Results and Discussion

Fig.1 shows the isochronal curves of MAE. Alloy $Fe_{80}Cr_3B_{17}$ has the maximum value in the relaxation spectrum at the temperature 423 K. Fig. 2 shows the spectrum of activation energies accompanied with isochronal curves of MAE with τ_0=10^{-15} s. The spectrum starts from the value of ≈ 0.5 eV and ending at ≈ 1.75 eV. The maximum value in the spectrum of activation energies is about 1.3 eV. Assuming two-level system





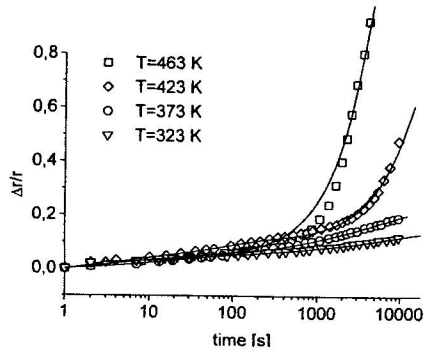


Fig.1.: Isochronal curves of Δ r/r for different times after demagnetization.
Fig.2.: Spectra of activation energies for isochronal curves of Δ r/r.
Fig.3.: Isothermal curves of Δ r/r for different temperatures.

[3, 4] we can suppose that the relaxation processes are caused by rearangements of atom pairs within domain walls.

By measuring isotherms of MAE we have studied these relaxation processes that correspond to the temperature and to the time of measurement. Fig.3 shows the long-time isotherms of Δ r/r. Spectra of activation energies for these isotherms are in the fig.4. The solid lines in fig.1 and 3 correspond to the fit (5) for the pre-exponential factor $\tau_o \approx 10^{-15}$ s.

It can be seen that at temperature T=323 K the value of Δ r/r is relatively small (≈ 10 %) . From the spectra we can assume that the processes of reorientation of atoms pairs with activation energy 1.2 ÷ 1.7 eV cause this relaxation process. The most probable process is that with Q ≈ 1.5 eV.

Increasing temperature to 373 K results in a slight increase of Δ r/r (≈ 17 %) and this is accompanied with translation of spectra of activation energies ≈ 1.4 ÷ 1.82 eV with main peak of about 1.7 eV.

The measurement at the temperature 423 K is connected with spectra in fig.4c that shows translation of main process to the range 1.85 ÷ 2.2 eV.The most probable process is that with Q=2 eV. These processes cause the relative change of reluctivity to become higher (≈ 47 %).

Finally, from fig.3 we can observe that temperature 463 K initiates a relaxation of

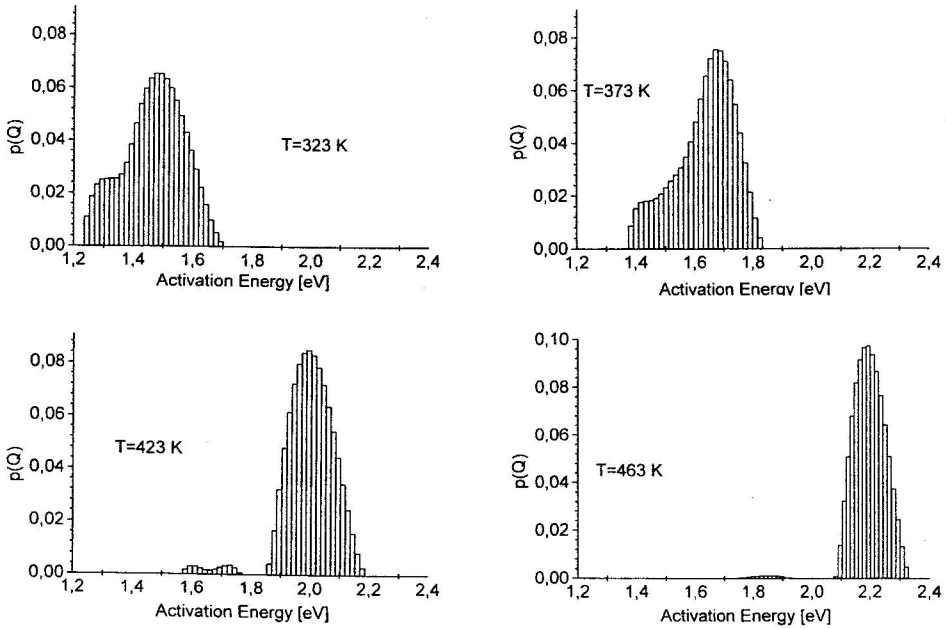


Fig.4.: Spectra of activation energies for isothermal curves of $\Delta r/r$: a) T=323 K; b) T=373 K; c) T=423 K; d) T=463 K;

atom pairs with activation energies again higher than in previous level $2.05 \div 2.35$ and with main peak at Q=2.2 eV that causes a relative change of reluctivity of about 160%.

We have found that magnetic relaxation in amorphous three-component alloy $Fe_{80}Cr_3B_{17}$, for temperature interval $173 \div 473$ K and time of measurement $1 \div 120$ s, is characterized by activation energies within range $0.5 \div 1.8$ eV with most probable value at 1.3 eV for pre-exponential factor $\tau_o \approx 10^{-15}$ s. By measuring in the time interval $1 \div 10^4$ s can be the magnetic relaxation characterized by interval of activation energies with most probable value of 1.5 eV at 323 K, 1.7 eV at 373 K, 2 eV at 423 K and 2.2 eV at 463 K.

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