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Time and Thermal Stability of Magnetic Properties in $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ Bulk Amorphous Alloys

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The paper presents studies of time and thermal stability of magnetic properties in $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ bulk amorphous alloys. The investigated sample was prepared by suction-casting method in the form of plate. The structure was studied using X-ray diffractometry. It was found that alloy was amorphous in the as-cast state. The magnetic properties were determined using completely automated set up for measurement of susceptibility and its disaccommodation. The disaccommodation curve was decomposed into three elementary processes, each of them was described by Gaussian distribution of relaxation times. From fit of theoretical curve the peak temperature, intensity at peak temperature, average activation energies, distribution parameter and pre-exponential factor of the Arrhenius law were determined. The obtained results indicate that the disaccommodation phenomenon in studied samples is related with directional ordering of atom pairs near the free volumes.

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1. Introduction

The bulk amorphous alloys have stimulated extensive research interest due to their good magnetic properties [1, 2]. Moreover, the lower quenching rate during the preparation of bulk amorphous materials, in comparison to classical amorphous alloys, leads to their good time and thermal stabilities of structure and magnetic properties, in the as-received state.

In magnetic materials the source of relaxation processes are reorientations of anisotropic structural defects. If an atomic defect interacts with the spontaneous magnetization, it comes to the magnetic after-effect phenomenon [3]. The initial magnetic susceptibility disaccommodation (MSD) is one of such a type of effects. This phenomenon is an important indicator of stability and ensures a favorable method to study the relaxation of the structure of bulk amorphous alloys. According to H. Kronmüller, the MSD phenomenon in amorphous alloys is connected with the reorientation of atom pair axes in the vicinity of free volumes [4].

The paper contains studies of time and thermal stabilities of magnetic properties within the framework of two-level model [4-5] in the as-quenched $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ alloy in the form of plates.

2. Experimental procedure

The amorphous plates of $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ alloys were obtained by the suction-casting method. The structure of the samples was studied by X-ray diffractometry. The low field magnetic susceptibility was measured in magnetizing field of the amplitude $H_m = 0.26$ A/m and frequency $f = 2$ kHz by means of a completely automated set-up. The magnetic after-effect was observed as a disaccommodation, i.e. a decrease over time of the initial magnetic susceptibility, after the demagnetization of the samples. The experimental results are presented as isochronal curves:

$$\Delta(1/\chi) = 1/\chi_{120} - 1/\chi_2 = f(T), \quad (1)$$

where: χ_2 and χ_{120} are the susceptibilities measured at 2 s and 120 s after demagnetization of the sample [6].

3. Results and discussion

The X-ray diffraction (XRD) shapes for the investigated alloys in the as-quenched state are demonstrated in Fig. 1; they display only one broad maximum, characteristic for amorphous materials.

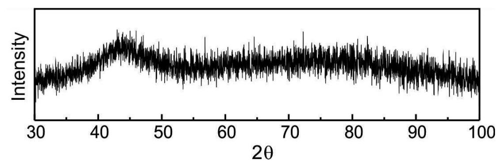

Fig. 1. X-ray diffraction patterns for powdered as-quenched $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ plates.

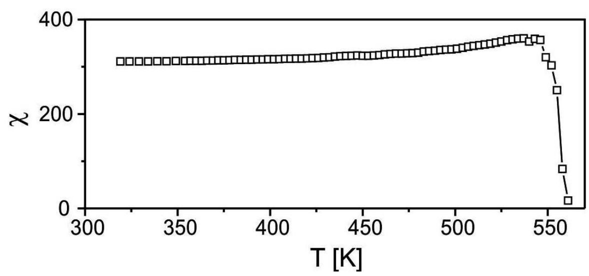

Fig. 2. Initial magnetic susceptibility versus temperature for as-quenched $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ plates.

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Figure 2 shows the initial magnetic susceptibility versus temperature for investigated alloy.

The initial magnetic susceptibility in the temperature range from 320 K to 525 K practically does not change. This means that the studied alloy exhibits good thermal stability of magnetic properties. Above the Curie temperature (~540 K) magnetic susceptibility decreases rapidly, which is associated with the transition from the ferromagnetic to the paramagnetic state.

The magnetic after-effect for the $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ plates was observed as a disaccommodation i.e. the time dependence of the initial susceptibility after the demagnetization at various temperatures. According to two-level model, the magnetic disaccommodation of initial susceptibility is usually attributed to reorientation of a mobile atom pair within a domain wall. The isochronal disaccommodation curves are decomposed, into three elementary processes each of them being delineated by the Gaussian distribution of relaxation times, by the method described elsewhere [7].

The theoretical isochronal disaccommodation curve, including experimental points obtained for the investigated alloy is presented in Fig. 3a. Additionaly, the distributions of deviations between the experimental points and the theoretical curve is shown (Fig. 3b). The presented isochronal after-effect curve (Fig. 3a) shows that a good fitting can be obtained after decomposition of the experimental curves into three elementary processes. The parameters obtained from the analysis of this curve is included in the Table.

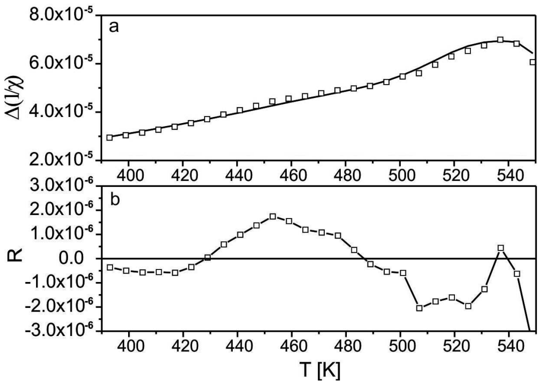

Fig. 3. (a) Theoretical isochronal after-effect curve and experimental points, obtained for the $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ plates and (b) distributions of deviations between experimental points and theoretical curve.

TABLE

The peak temperature (T_p), the intensity of the processes (I_p) at the temperature T_p, the average activation energy (Q) and pre-exponential factor in the Arrhenius law (τ).

Proces	T_p (K)	I_p	Q (eV)	τ 10^{-15} (s)
I	431	2.93×10^{-6}	1.36	3.41
II	480	6.97×10^{-6}	1.50	4.77
III	536	18.0×10^{-6}	1.65	8.19

The numerical analysis shows (Table) that the mean activation energies are comparable to those obtained for transition metals amorphous alloys. The listed pre-exponential factor values in the Arrhenius law are of the order of 10^{-15} s.

These results clearly suggest that the magnetic after-effect in the investigated plates is mainly caused by ordering of atom pairs near free volumes. The disaccommodation intensity is of order 10^{-6}, which means that the bulk $Fe_{61}Co_{10}Y_8Nb_1B_{20}$ alloy is characterized by higher time stability of magnetic properties than classical amorphous alloys (intensity in classical alloys is of order $\sim 10^{-5}$) [8].

4. Conclusions

The relatively low cooling rate during preparation of bulk amorphous alloys enables the structure relaxation which in turn involves higher atom packing density and their better time and thermal stability of magnetic structure than in the classical amorphous alloys.

The relaxation processes in investigated alloy are connected with reorientation of the mobile atom pairs in the vicinity of free volumes, according to the H. Kronmüller theory.

The investigated alloy is characterized by better time stability of magnetic properties. Intensity of disaccommodation of studied alloy is one order of magnitude lower than in classical amorphous alloys.

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