Proceedings of the 15th Czech and Slovak Conference on Magnetism, Košice, Slovakia, June 17–21 2013

Magnetic Relaxations in Amorphous $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ Alloy

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Effects of annealing on the disaccommodation phenomenon in bulk metallic glasses (BMGs), obtained by injection-casting method have been studied. The amorphous structure has been confirmed using X-ray diffractometer. The annealing process has been performed at temperature below the crystallization temperature. For all investigated samples the disaccommodation curves have been determined. The susceptibility and its disaccommodation have been used in order to define thermal and time stability of magnetic properties. Obtained results have also been used to determine activation energies of elementary processes.

DOI: 10.12693/APhysPolA.126.106

PACS: 75.60.Lr, 75.50.-y, 75.50.Kj, 75.30.Cr

1. Introduction

The BMGs produced using injection-casting method are a group of very interesting materials from both scientific and technological points of view. Due to atoms arrangement in amorphous alloys which are distributed like in liquid, they display excellent magnetic properties [1-4]. BMGs are prepared at relatively low quenching rates, what results in occurrence of relaxation processes during the sample preparation. Therefore, the structure of the as-quenched BMGs seems to be at least partially relaxed and these materials should display good thermal and time stability of magnetic properties. Further relaxation of manufactured alloys can be achieved by annealing process [5, 6].

The magnetic susceptibility disaccommodation, is one of the magnetic after-effect phenomenon, very sensitive to presence of structural changes [5, 7-9]. The aim of this paper is to study the influence of annealing at 700 K for 1 h on the structural relaxations and stability of magnetic properties, determined from disaccommodation phenomenon studies for $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ amorphous alloy.

2. Experimental procedure

The amorphous $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ plates were prepared from ingots obtained by arc-melting in an argon atmosphere. Amorphous plates had 10 mm width and 0.5 mm thickness and were produced by injection-casting method.

The microstructure of the alloys in the as-cast state and after annealing was studied on powdered samples using X-ray diffractometer. Low field magnetic susceptibility and its disaccommodation were measured using a completely automated setup by the transformer method. All investigations were conducted for the samples in the as-quenched state and after annealing at 700 K for 1 h. The annealing process was performed at temperature below the crystallization temperature.

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3. Results and discussion

Figure 1 shows the X-ray diffraction patterns for powdered as-quenched and annealed $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ plates.

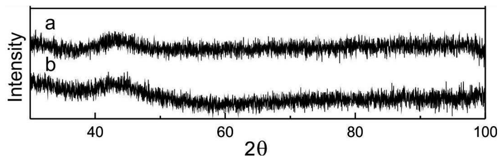

Fig. 1. X-ray diffraction patterns for powdered as-quenched (a) and annealed at 700 K/1 h (b) $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ plates.

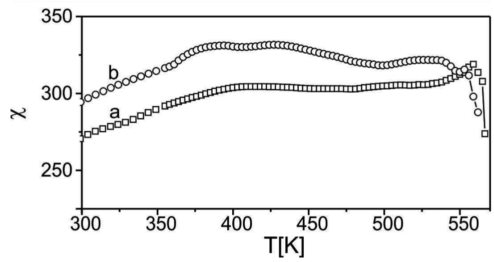

Fig. 2. Initial magnetic susceptibility as a function of temperature for the $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ alloy in the as-quenched state (a) and after annealing (b).

As can be clearly seen, in the charts there are no sharp peaks indicating the presence of crystalline structure. There is visible only broad halo which is typically found in amorphous alloys.

Figure 2 shows the initial magnetic susceptibility versus temperature for $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ alloy.

The values of the magnetic susceptibility at 300 K are equal to 270 and 295 for the alloys after solidification and after annealing, respectively. As can be seen from the Fig. 2, heat treatment at 700 K/1 h causes a distinct change in the shape of the $\chi(T)$ curve. Such characteristic of a curve can be elucidated taking into account two competitive processes: the decrease of the magnetic anisotropy and magnetization with temperature. Furthermore, after heat treatment a slight increase of the magnetic susceptibility (Fig. 2b) is observed, which can be explained by homogenization and a partial relaxation of the samples.

The typical isochronal disaccommodation curves (IDC) for $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ alloy are presented in Fig. 3.

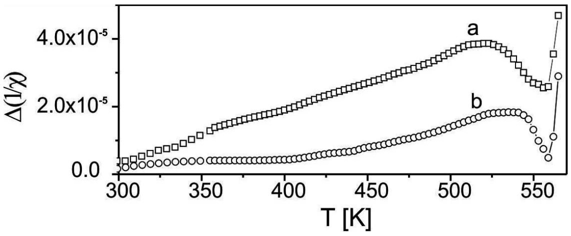

Fig. 3. The isochronal magnetic susceptibility disaccommodation curves $\Delta(1/\chi) = f(T)$ for $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ plates: (a) after solidification, (b) after annealing at 700 K/1 h.

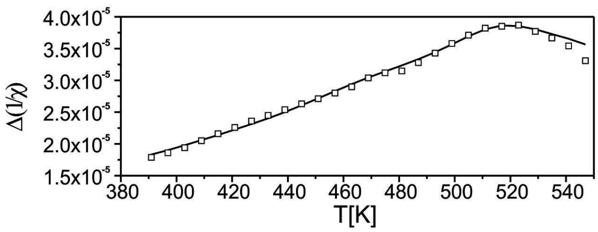

Fig. 4. Theoretical isochronal after-effect curve and experimental points obtained for the amorphous $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ plates.

The IDC for both studied samples i.e. amorphous plates after solidificaion and annealed at 700 K for 1 hour have similar shapes. On both figures broad maxima are present at about 525 K (Fig. 3a) and 540 K (Fig. 3b). The disaccommodation intensity for the as-cast sample is higher than for the annealed alloy. The increase in the disaccommodation intensity above 525 K is connected with deviations in magnetic ordering near the Curie temperature.

The isochronal disaccommodation curves are decomposed, into three elementary processes, each of them being delineated by the Gaussian distribution of relaxation times [5]. Finding the described processes, responsible for the total disaccomodation, is a result of the computer analysis (not of physical one). The experimental points and fitted theoretical disaccommodation curve for studied alloy in as-quenched state, as an example, are shown in Fig. 4.

The parameters of these processes, obtained for investigated samples are included in the Table, where: I_{pi} is the disaccommodation intensity at the peak temperature T_{pi}, Q_m – the average activation energies, and the preexponential factor (τ_0) in the Arrhenius law.

TABLE

Parameters obtained from fitting of isochronal disaccommodation curves, for the bulk amorphous $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ alloy in the as-quenched state.

Heat treatment	Process	T_p (K)	$I_p 10^{-6}$	Q_m (eV)	τ 10^{-15} (s)
as-quenched	I	430	3.10	1.33	6.31
	II	480	8.71	1.49	6.89
	III	524	9.88	1.63	5.32
annealed 700 K for 1 h	I	444	8.10	1.38	5.94
	II	481	2.63	1.50	6.18
	III	532	6.88	1.65	6.47

The activation energies of these processes are approximately 1.2 eV and the preexponential factor in the order of 10^{-15} s. This fact testifies that the disaccommodation effect in the investigated alloys is related with ordering of atom pairs in the vicinity of free volumes [10].

4. Conclusions

The isochronal disaccommodation curves of the $Fe_{61}Co_{10}Y_8Zr_1B_{20}$ alloy in the as-quenched state and after annealing can be described as superposition of three elementary processes. The relaxation processes in investigated samples are connected with reorientation of the mobile atom pairs in the vicinity of free volumes. After annealing at 700 K/1 h the initial susceptibility increases and the intensity of disaccommodation distinctly decreases. This is associated with the annealing out of some free volumes, which leads to stress relief of the samples and an increase in the packing density.

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