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Low Field Magnetic Properties of FeCo-Based Alloys

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Low field magnetic properties of amorphous $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ alloys ($x = 3$, 6 and 9) were characterized by magnetic after-effect and initial magnetic susceptibility. Activation energies and pre-exponential factors of the Arrhenius law that were derived from the disaccommodation curves are of about 1.188 eV and 10^{-15} s, respectively. Local magnetic arrangement was investigated by ^{57}Fe Mössbauer spectrometry. The average hyperfine magnetic field decreases with increasing Fe/Co ratio due to smaller relative contribution of cobalt. The overall magnetic parameters of the alloy prove its good soft magnetic properties with an application potential.

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1. Introduction

Excellent soft magnetic properties of metallic glasses that could provide nanocrystalline alloys are frequently investigated. Along with classical compositions [1], novel structures containing Mo [2], Co [3], or more recently also combination of these two [4], are of close interest. Partial replacement of Fe atoms by Co in such alloys leads to both, changes in the structure, and to the increase of magnetic inductions at elevated temperatures. Employing Mössbauer spectrometry, behaviour of metallic glasses can be studied also at elevated temperatures [5]. The aim of this paper is to study low field magnetic properties of amorphous FeCo-based alloys containing Mo with varying Fe/Co ratio.

2. Experimental details

$(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ ($x = 3$, 6, 9) metallic glasses were prepared by rapid quenching. The amorphicity of the alloys was checked at room temperature by X-ray diffractometry and ^{57}Fe Mössbauer spectroscopy in transmission geometry. The initial magnetic susceptibility was measured for toroidal samples in AC magnetizing field with frequency of 2 kHz by means of a completely automated set-up.

3. Results and discussion

Magnetic characterization was done by investigating the initial magnetic susceptibility (χ_2) and the magnetic after-effect ($\Delta(1/\chi)$). The highest value of the initial magnetic susceptibility at room temperature is found for $x = 9$ (Fig. 1). With decreasing x, an increase in transformation temperature from ferro- to paramagnetic state (the Curie temperature of the amorphous matrix, T_C) was observed. Moreover, χ_2 values for the $x = 3$ sample are not constant below T_C like for the other two compositions.

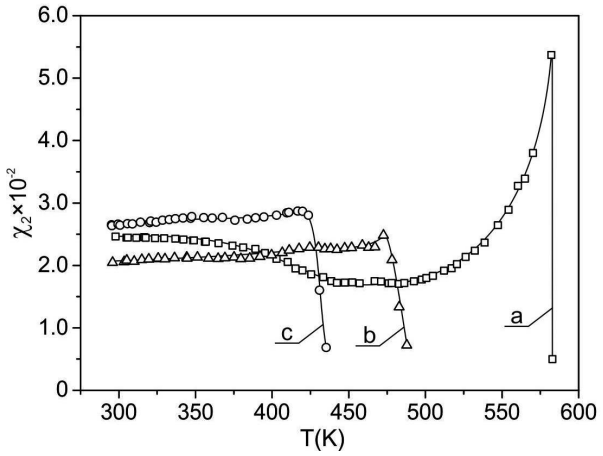

Fig. 1. The initial magnetic susceptibility χ_2 plotted against temperature T for the as-quenched $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ for $x = 3$ (a), $x = 6$ (b) and $x = 9$ (c).

The magnetic after-effect was derived from decomposition of isochronal disaccommodation curves that were obtained as follows: $\Delta(1/\chi) = 1/\chi_2 - 1/\chi_1$. Here χ_1 and χ_2 are initial susceptibilities measured at the times $t_1 = 2$ s and $t_2 = 120$ s after demagnetization. Temperature dependence of isochronal disaccommodation, which

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is presented in Fig. 2, was analyzed in the temperature range (300–500 K).

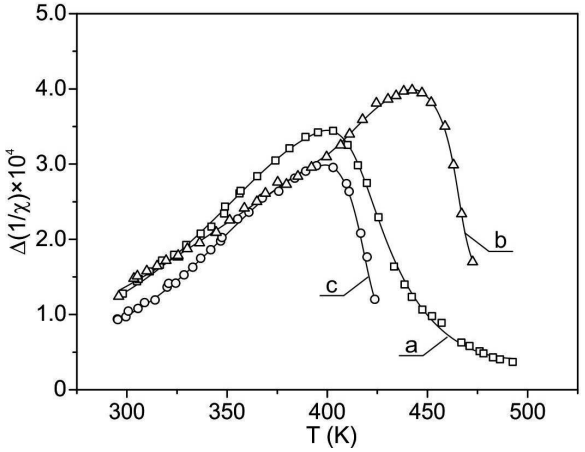

Fig. 2. The isochronal disaccommodation $\Delta(1/\chi)$ plotted against temperature T for amorphous $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ for $x = 3$ (a), $x = 6$ (b), and $x = 9$ (c).

Using gaussian distributions of $\ln\tau$ (τ – relaxation times), the values of activation energies and pre-exponential factors of the Arrhenius law were calculated. The isochronal disaccomodation curves were deconvoluted into three elementary processes and the resulting parameters are listed in Table I.

TABLE I

The activation energy (E) and pre-exponential factor of the Arrhenius law (τ) obtained for $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ ($x = 3$, 6, 9) alloy.

sample	process	E (eV)	τ (s) $\times10^{15}$
$(Fe_3Co_1)_{76}Mo_8Cu_1B_{15}$	I	1.151	1.23
	II	1.213	2.96
	III	1.288	2.45
$(Fe_6Co_1)_{76}Mo_8Cu_1B_{15}$	I	1.115	4.85
	II	1.272	3.34
	III	1.390	5.50
$(Fe_9Co_1)_{76}Mo_8Cu_1B_{15}$	I	0.973	3.18
	II	1.086	2.51
	III	1.203	5.05

Room temperature Mössbauer spectra in Fig. 3 exhibit broad sextuplet-like absorption lines which are characteristic for amorphous structural arrangement. The associated distributions of hyperfine magnetic fields $P(B)$ demonstrate structural differences among the investigated samples, that stem from different Fe/Co ratio. Subsequent deviations in chemical and/or topological short-range order of the resonant ^{57}Fe nuclei resulted in the average hyperfine magnetic fields of 19.00, 16.25, and 14.80 T for $x = 3$, 6, and 9, correspondingly. They were derived from the $P(B)$ distributions with the accuracy of ±0.06 T.

It is noteworthy that the average hyperfine magnetic field decreases with x, i.e. with decreasing relative contribution of Co, which has a higher magnetic moment than Fe.

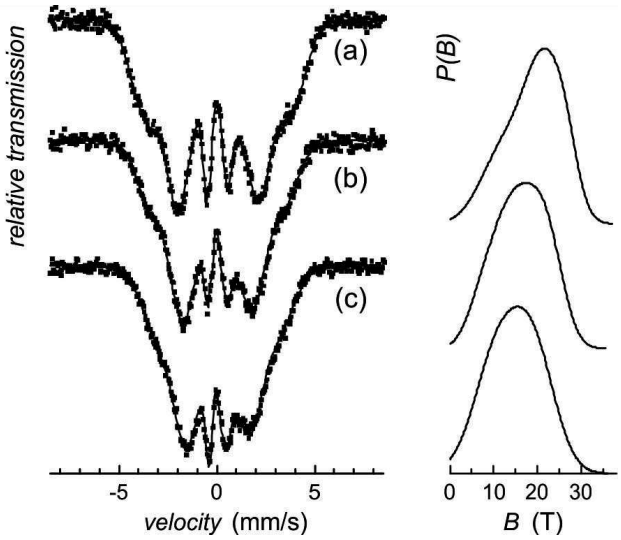

Fig. 3. Mössbauer spectra (left) and corresponding $P(B)$ distributions (right) of the $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ alloy for $x = 3$ (a), $x = 6$ (b), and $x = 9$ (c).

4. Conclusions

We have investigated magnetic properties of $(Fe_xCo_1)_{76}Mo_8Cu_1B_{15}$ ($x = 3$, 6, 9) metallic glasses. Activation energies and pre-exponential factors of the Arrhenius law that were derived from the disaccommodation curves are of about 1.188 eV and 10^{-15} s, respectively. The overall magnetic parameters of the alloy prove its good soft magnetic properties with a potential for applications.

Acknowledgments

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