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Effect of chemical composition on the Curie temperature of FeCoB alloys

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Abstract

This paper presents the results of research on saturation magnetic polarisation, as a function of temperature, for a group of rapidly-cooled FeCoB alloys. The tested alloys have soft magnetic properties. Thermal stability, as determined by the Curie temperature, is one of the most important parameters for classifying the use of magnetic materials. In this work, the Curie temperature values for selected alloys were determined, using the critical factor of β = 0.36. The area under each saturation magnetic polarisation curve, and the shape of the curve itself, were also analysed. It was found that even small changes in the chemical composition of the alloy can lead to a shift in the temperature that marks the boundary between the ferromagnetic and paramagnetic states.

Introduction - essence

Curie temperature is one of the most important parameters describing ferromagnetic materials; it determines the stability of the ferromagnetic state, and more precisely the stability of the existence of magnetic domains. When the temperature is high enough for the domains in a ferromagnetic material to disappear, a second form of phase transition will begin and the material becomes paramagnetic. Currently, there is considerable interest in rapidly-cooled amorphous materials, as ferromagnetic alloys with unique magnetic properties [1-4]. […]

Experimental procedure - highligts

The samples for this research were prepared from high purity component elements: Fe - 99.99; Co - 99.99; Y - 99.95, B - 99.9. The ingots were melted, under an inert gas atmosphere, in electric arc furnace. Bonding of the alloying elements was carried out on a water-cooled copper plate by using a plasma arc with an operating current of 350 A. During each melting process, titanium was pre-melted to act as an absorbent for the remaining oxygen in the chamber. After the described homogenisation cycle, each alloy sample was subjected to both mechanical and ultrasonic cleaning. The ingots were then divided into smaller batch portions for production of amorphous samples of liquid alloy injected into a copper mould. A piece of each respective alloy was placed into a quartz capillary tube and melted using induction heating; the liquid alloy was then injected under argon pressure into a water-cooled copper mould. The rapidly-cooled samples were also produced under a protective gas shield inside the working chamber. The produced samples were in the form of plates with an area of 10 mm x 10 mm and a thickness of 0.5 mm. X-ray (XRD) examinations were performed on samples in the solidified state using a BRUKER D8 ADVANCE X-ray diffractometer, working in the Bragg-Brentano (CuKα) geometry. Measurements of magnetic polarisation, as a function of temperature, were obtained using a Faraday magnetic scale. The samples were heated at a rate of 10 K/min. Measurements were made, under a vacuum, for samples weighing 25 mg. The magnetic field intensity during the measurement was 0.7 T and the maximum measurement temperature, determining the stability of the measurement system, was 850K. Both measurements were made on low-energy powdered samples. The test samples were pulverised (under toluene) manually, using an agate mortar.

Results

Fig. 1. X-ray diffraction patterns for the rod-form samples of the investigated alloys: a) $Fe_{36}Co_{36}Y_8B_{20}$, b) $Fe_{39}Co_{43}Y_8B_{20}$, c) $Fe_{43}Co_{29}Y_8B_{20}$, d) $Fe_{48}Co_{24}Y_8B_{20}$

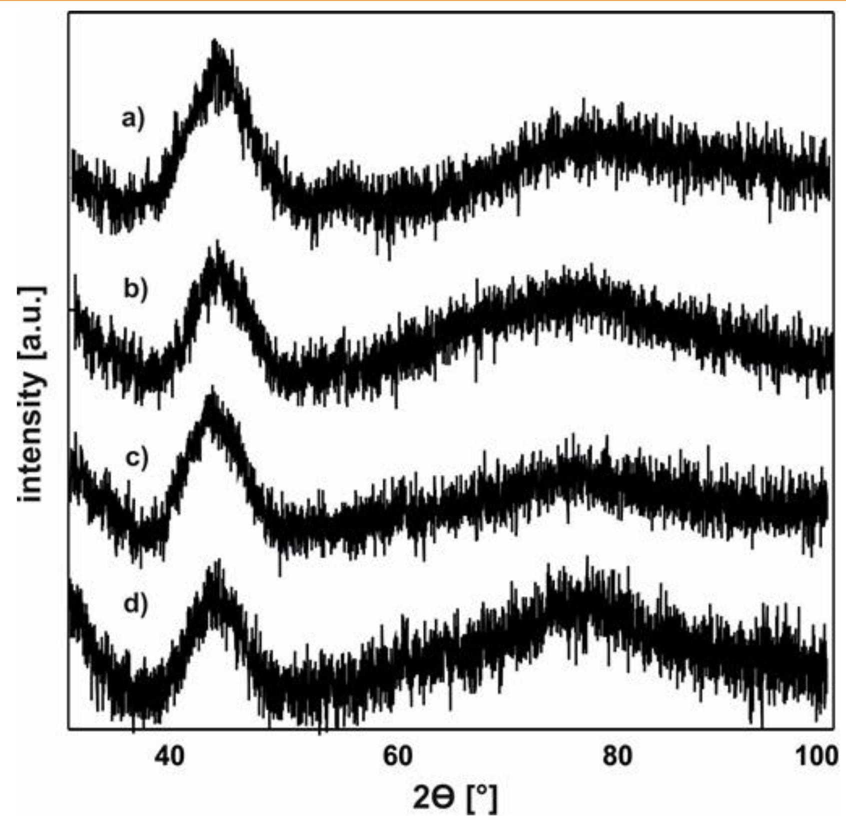

Fig. 2. Thermomagnetic curves obtained for the tested alloy samples. a) $Fe_{36}Co_{36}Y_8B_{20}$, b) $Fe_{39}Co_{43}Y_8B_{20}$, c) $Fe_{43}Co_{29}Y_8B_{20}$, d) $Fe_{48}Co_{24}Y_8B_{20}$ in the solid state.

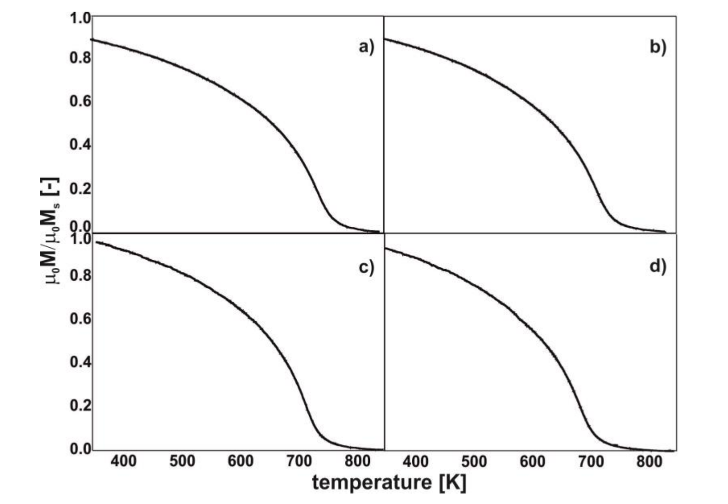

Fig. 3. Relationship of (μ0M)^1/B with temperature, T, for the tested alloys. a) $Fe_{36}Co_{36}Y_8B_{20}$, b) $Fe_{39}Co_{43}Y_8B_{20}$, c) $Fe_{43}Co_{29}Y_8B_{20}$, d) $Fe_{48}Co_{24}Y_8B_{20}$ in the state after solidification.

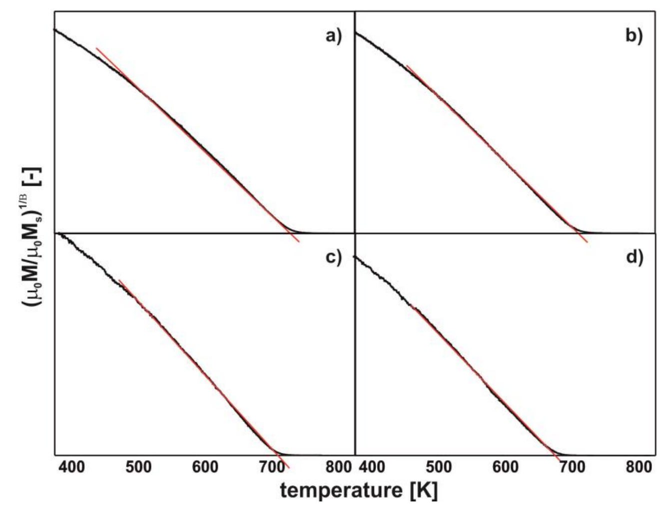

Table 1. Results of the research: maximum width of the amorphous halo, Curie temperature (T_C), area under the thermomagnetic curve (H_K):

	Maximum Width [°]	T_c [K]	H_K [-]
$Fe_{36}Co_{36}Y_8B_{20}$	11.8	741	357
$Fe_{39}Co_{43}Y_8B_{20}$	11.2	717	325
$Fe_{43}Co_{29}Y_8B_{20}$	11.1	700	301
$Fe_{48}Co_{24}Y_8B_{20}$	11.0	673	288

Conclusions

This paper presents the results of research carried out on rapidly-cooled solidified alloy samples, characterised by an amorphous structure. The tested alloys differed slightly in their chemical composition. Structural and thermomagnetic tests were performed and the obtained results are typical for amorphous alloys with good homogeneity. The performed changes in the chemical composition affect the width of the amorphous halo, the area under the thermomagnetic curve (H_K) and the Curie temperature (T_C). It should be noted that the Curie temperature in amorphous materials should be described as a very narrow temperature range rather than a discrete value. When designing amorphous alloys for use in electrical engineering, it is important not only that the Curie temperature itself is considered, but also that the shape of the saturation magnetic polarisation curve, as a function of temperature, should be carefully analysed. If this curve does not extend down to zero, it is most likely that there are crystallisation seeds in the amorphous matrix, which will affect directly the process of nanocrystallisation of the amorphous matrix.

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