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MAGNETISM IN AMORPHOUS $Tm_xCo_{70-x}B_{30}$ ALLOYS[1]

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Amorphous $Tm_xCo_{70-x}B_{30}$, x=0, 2, 4, 6 and 8 alloys have been prepared by melt-spinning in argon atmosphere. Magnetic behaviour of the ribbons in temperature range 4.2-700 K is reported. Ordering temperatures of these alloys have been found to be in the range 200-500 K and well below crystallization temperatures. Thermal stability of as-quenched alloys was examined with a differential scanning calorimeter. As can be expected, for alloys with sperimagnetic ordering, a spin compensation effect has been observed in amorphous $Tm_8Co_{62}B_{30}$ at 9 K.

1. Introduction

The last few years have witnessed a come back of interest in rare earth (R)-transition metal-metalloid amorphous alloys where R ranges from several to a dozen or so per cent. Noncrystalline state of those materials offers wide possibilities to study non-collinear magnetic structures (e.g. [1],[2]). Many of those alloys are well known soft magnetic materials exhibiting high saturation magnetization. The rare earth with its local anisotropy causes high coercivity and magnetostriction. It is possible to weaken this apparent anisotropy in nanocrystaline materials by refining the grain size. An amorphous phase as a starting phase is used for obtaining nanostructured materials Fe-M-B, Fe-M-B-Cu, Fe-M-Cu-B-Si with different substitutions of M=Ti, Zr, Hf, Nb, Ta, Hf, U (e. g. [3]–[5]). Rare earth substitutions in such a kind of alloys lead to the enhancement of saturation magnetization in low temperatures [6]. Both amorphous and nanocrystalline alloys contain elements facilitating vitrification (e.g. B, Si, C). In this paper magnetism in amorphous Tm-Co-B alloys will be described.

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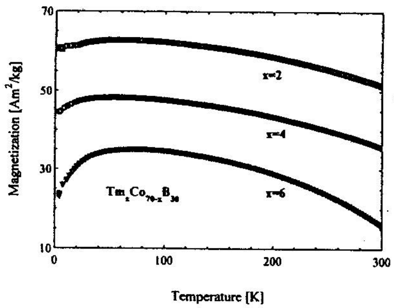

Fig. 1. Magnetization versus temperature of $Tm_xCo_{70-x}B_{30}$; x=2, 4 and 6 amorphous alloys in an external field of 2 T.

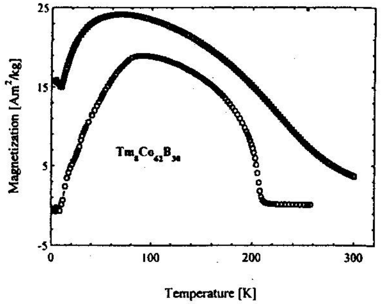

Fig. 2. Magnetization versus temperature of $Tm_8Co_{62}B_{30}$ amorphous alloys in an external field of 2 T (squares) and 2 mT (circles).

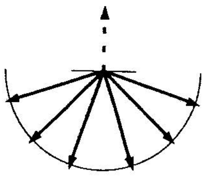

Fig. 3. The spatial distribution of the magnetic moment directions in amorphous sperimagnetic alloys with an asperomagnetic rare earth sublatice collinear transition metal sublatice (e.g. Tm-Co-B).

2. Experimental

Amorphous alloys of $Tm_xCo_{70-x}B_{30}$ were prepared over the range $0 \leq x \leq 8$ by single roller technique. High-purity elements (Tm 99.95, Fe 99.998, B 99.8 %) were used to make starting ingots. Each of them was flipped and remelted several times in a high-frequency induction furnace in a cold crucible to assure homogeneity. The most relevant technological parameters of the rapid quenched process and sizes of the ribbons are given in Table 1. The amorphous nature of the samples was established by x-ray diffraction using CoK radiation. Crystallization behaviour of as-quenched alloys was examined by differential scanning calorimeter (DSC 404, Netzsch). The magnetization behaviour was studied in temperatures ranging from 4.2 K to 300 K using a vibrating sample magnetometer and from room temperature to 700 K using Faraday balance and a mutual inductance bridge of Hartshorn type. The Curie temperature has been determined from the curves of squared magnetization versus temperature.

3. Results

Figures 1 and 2 show the experimental magnetization data as a function of temperature measured in an external field of 2 T and 2 mT, respectively. A spin compensation effect has been observed in amorphous $Tm_8Co_{62}B_{30}$ at 9 K. In the DSC traces with the heating rate of 10 K/min. one exothermic heat effect was observed. That effect is interpreted as the crystallization temperature. The results of those measurements are summarized in Table 2. Addition of Tm in amorphous $Tm_xCo_{70-x}B_{30}$ alloys causes increase in the crystallization temperature of about 26 K/at% Tm. Saturation magnetization and Curie temperatures are also specified in Table 2. Polycrystalline intermetallics $RCo_{12}B_6$ with all heavy rare earth are ferrimagnetic. Such a composition is close to the investigated amorphous alloy for x=6 (or more accurately $R_{5.2}Co_{63.2}B_{31.6}$). For R=Tm the compensation point, saturation magnetization and Curie temperature are 11.6 K, 13.37 Am²/kg and 143.9 K, respectively [7]. A comparison of properties of those two alloys clearly shows the influence of the amorphous state on the above mentioned parameters.

Chamber gas	Ar
Chamber pressure	~ 60 kPa
Wheel	Cu
Wheel diameter	39 cm
Wheel surface speed	40 m/s
Crucible type	quartz
Crucible gap width	0.3-0.4 mm
Ejection pressure	7-10 kPa
Ribbons thick	35-45 μm
Ribbons wide	1-1.5 mm

Table 1. Melt-spinning parameters and ribbons sizes.

x at.%	M_S [Am²/kg]	T_C [K]	T_x [K]
0	77.9	575	705
2	56.4	469	898
4	38.8	372	904
6	17.3	291	910
8	1.1	212	916

Table 2. Saturation magnetization et 4.2 K (M_S) extrapolated from the magnetizations curves, Curie (T_C) and crystallization (T_x) temperatures of $Tm_xCo_{70-x}B_{30}$ amorphous alloys.

4. Conclusion

Substituting cobalt atoms in amorphous $Co_{70}B_{30}$ alloys with Tm atoms linearly reduces the magnetization and Curie temperature and increases the crystallization temperature. Rare earth atoms, being much larger than Fe and B atoms, change the short-range order [8]. Those carrying the magnetic moments, can create alloys of two magnetic sublattices with a spatial distribution of magnetic moment directions (Fig. 3).

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