ORIGIN OF HIGH COERCIVITIES IN AS-CAST Dy-Fe-C MAGNETS
G. Hadjipanayis, N. Venkateswaran, J. Strzeszewski

To cite this version:

HAL Id: jpa-00228460
https://hal.archives-ouvertes.fr/jpa-00228460
Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
ORIGIN OF HIGH COERCIVITIES IN AS-CAST Dy-Fe-C MAGNETS

G. C. Hadjipanayis, N. Venkateswaran and J. Strzeszewski

Department of Physics, Carwell Hall, Kansas State University, Manhattan, KS 66506, U.S.A.

Abstract. As-cast Dy\textsubscript{15}Fe\textsubscript{77}Cs alloys develop high coercivities after a heat treatment at 900 °C. Magnetic and microstructure measurements show the presence of two phases: the anisotropic Dy\textsubscript{2}Fe\textsubscript{14}C phase and a DyFeC phase with $T_c$ around 40 K. The high coercivities are attributed to localized domain wall pinning at the boundaries between the Dy\textsubscript{2}Fe\textsubscript{14}C and DyFeC phases.

Introduction

The high coercivities observed in R-Fe-B alloys are only obtained in microcrystalline melt-spun samples [1, 2] and in permanent magnets made by sintering [3, 4] die-upsetting [5] and liquid dynamic compaction [6]. As-cast alloys do not have a high coercivity. On the contrary, as-cast R-Fe-C(B) alloys do show a high coercivity after a heat-treatment [7] at around 900 °C. The high coercivity has been attributed to a fine cellular microstructure which is produced with carbon substitution.

In the present study we have extended the magnetic measurements over a wider temperature range to search for any phases present in this system that can possibly help us understand better the origin of high coercivity.

Experimental

As-cast Dy\textsubscript{15}Fe\textsubscript{77}Cs alloys were prepared by arc-melting. Samples were heat-treated at 900 °C for 24 hours to produce the high coercivity. The magnetic properties were measured with a vibrating sample magnetometer and a SQUID magnetometer. The microstructure of the samples was determined with a JEOL 100C scanning transmission electron microscope.

Results and discussion

The as-cast samples are magnetically soft. A coercivity greater than 12 kOe is obtained in the heat-treated samples (Fig. 1). In the latter samples, the maximum magnetic field used (17 kOe) was not large enough to saturate the magnetization resulting in a minor loop. The steep increase of magnetization at low fields is similar to that observed in anisotropic sintered magnets [8] indicating the presence of rather large grains with a preferred orientation.

The field dependence of coercivity is shown in figure 2. The coercivity increases almost linearly with applied field and is not saturated even at fields of 55 kOe. This kind of behavior is characteristic of nucleation type or localized domain wall pinning magnets [8].

Thermomagnetic data $M_H(T)$ (Fig. 3) show that the majority phase in the as-cast samples is Dy\textsubscript{2}Fe\textsubscript{17}, consistent with the results of Liu et al. [7]. This phase has an easy plane resulting in low coercivity. Similar data on heat-treated samples show the presence of a phase with a Curie temperature around 300 °C. This phase is believed to be the tetragonal Dy\textsubscript{2}Fe\textsubscript{14}C with the c-axis as the easy axis of magnetization. The large decrease of magnetization and coercivity below room temperature observed in zero field-cooled (ZFC)
samples is related to hysteresis effects (Fig. 4). The anisotropy of the samples increases substantially below room temperature resulting in minor loops with a small coercivity. Field cooled (FC) (55 kOe) samples, on the other hand show giant coercivities and a smaller magnetization decrease at low temperatures as expected for strong anisotropic samples. The increase of magnetization observed at cryogenic temperatures is related to the magnetic ordering of another phase with a Curie temperature about 40 K. This phase is believed to be carbon rich, possibly the FeDyC phase suggested by Liu et al. [7].

Scanning electron microscope data (Fig. 5) show a microstructure consisting of a continuous matrix phase with two other phases randomly distributed in the matrix phase. The majority phase has an Fe/Dy ratio corresponding to Dy$_2$Fe$_{14}$C. The first minority phase is richer in Dy showing a ratio of Fe/Dy $\sim 1$. This is probably the phase with $T_c$ around 40 K. A similar B-rich phase has been reported [9] in R-Fe-B magnets but with different composition RFe$_4$B$_4$. The other phase which is sparsely found in the sample is believed to be Dy$_2$Fe$_{17}$. Transmission electron microscope studies verified the existence of the phases mentioned previously. Figure 6 shows the microstructure of the C-rich phase which is also heavily faulted like the B-rich phase [10]. The lattice parameters of the C-rich phase as found by electron diffraction are approximately $a = 8$ Å and $c = 24$ Å.

Fig. 4. – Magnetization and coercivity data below room-temperature.

Fig. 5. – Grain structure of heat-treated Dy-De-C samples, A $\equiv$ Dy$_2$Fe$_{14}$C, B $\equiv$ DyFeC.

Fig. 6. – (a) Microstructure.

This type of microstructure can explain the magnetic hysteresis behavior of the Dy-Fe-C magnets. The domain walls move easily inside the matrix phase resulting in the steep increase of magnetization at low fields. Localized domain wall pinning possibly takes place at the boundary region between the Dy$_2$Fe$_{14}$C and DyFeC phase resulting in the higher coercivities. Lorentz microscope studies are required to verify this hypothesis.

Acknowledgments

Work supported by both DOE-FG02-86ER45263 and the CEAM Program of the European Community.