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MAGNETIC ALIGNMENT STUDY OF HYBRID MAGNET CONSISTING OF R-RICH AND R-LEAN Nd-Fe-B ALLOYS

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1. Introduction

Nanocomposite permanent magnetic materials consisting of $Nd_2Fe_{14}B$ and α-Fe phases are of great interest due to their highly enhanced remanence [1,2]. Most of the nanocomposite materials are, however, virtually isotropic, in which the magnetically hard $Nd_2Fe_{14}B$ grains are oriented randomly. In addition to the isotropic nature, a lower coercivity due to an averaging effect of the magnetocrystalline anisotropy of the hard and soft phases in the nanocomposite is also a drawback of the nanocomposite. The present authors extended their idea to a hybridization between the nanocomposite and $Nd_2Fe_{14}B$ single phase materials [3,4]. For the preparation of hybrid magnet over- and under- $Nd_2Fe_{14}B$ stoichiometric alloys are used. The over-stoichiometric alloy contains single magnetic phase of $Nd_2Fe_{14}B$ (called R-rich alloy, hereafter), and the under-stoichiometric alloy is a typical nanocomposite material containing hard $Nd_2Fe_{14}B$ and soft Fe phases (called R-lean alloy, hereafter). The hybrid magnet, therefore, can exploit the merits of the single phase alloy and the nanocomposite alloy: The $Nd_2Fe_{14}B$ single phase alloy guarantees high coercivity and the nanocomposite alloy provides high magnetization. In the present study the microstructure and magnetic properties of the hybrid magnet were investigated, and a special interest was focused on the magnetic alignment of the die-upset hybrid magnet.

2. Experimentals

The R-rich and R-lean alloys used in the present study have compositions of $Nd_xFe_{93.5-x}Ga_{0.5}B_6$ (x = 13.5 and 11.8) and $Nd_xFe_{93-x}Nb_1B_6$ (x = 6, 9), respectively. The R-rich alloys contain a single hard magnetic phase of $Nd_2Fe_{14}B$, and is used as a host alloy for the hybridization. The R-lean alloy contains composite magnetic phases of $Nd_2Fe_{14}B$ /Fe, and is used as an added alloy for the hybridization. The alloys were melt-spun using Cu wheel with 30 m/sec speed. The crushed melt-spun alloy ribbons were mixed thoroughly with the desired ratio. The mixed powder was then compacted in vacuum at 750 ℃ with a pressure up to 410 MPa and subsequently die-upset with height reduction up to 80 %. For a magnetic characterization of the compacted and die-upset magnets, cubic shape specimens (1 × 1 × 1 mm^3) were pre-magnetized with dc field of 50 kOe in a SQUID and the room temperature demagnetization curve was measured along the direction parallel or perpendicular to the pressing direction using a combination of the SQUID and VSM at room temperature. Magnetic alignment in the compacted and die-upset magnets was evaluated by comparing the remanence values along the parallel and perpendicular directions. Microstructure of the hot-pressed and die-upset magnet was examined using SEM and TEM.

3. Results and discussion

In the hot-pressed or die-upset hybrid magnet the R-rich and R-lean alloy regions existed independently without alloying between them. The two alloy regions in the die-upset hybrid magnet were coupled effectively via a magnetostatic interaction. A texture was developed only in the R-rich $Nd_2Fe_{14}B$ single phase alloy region in the die-upset hybrid magnet, and this led to a magnetic alignment in die-upset hybrid magnet. The effects of deformation rate and host alloy composition on the magnetic alignment in the die-upset hybrid magnet were evaluated using the ratio of Mr(//)/Mr(⊥), and the results are shown in Fig. 1. The magnetic alignment indicated by the Mr(//)/Mr(⊥) ratio appears to increase with increasing the deformation rate (height reduction). There also appears that the die-upset hybrid magnets containing higher Nd-content (13.5 at%) host alloy shows consistently a better magnetic alignment with respect to the magnets with lower Nd-content (11.8 at%) host alloy. The poorer magnetic alignment in the die-upset hybrid magnet containing a lower Nd content (11.8 at%) was clarified by a microstructural observation. The grains in the R-rich alloy region of the die-upset hybrid magnet containing a lower Nd content (11.8 at%) were less deformed and had poorer texture compared to the die-upset hybrid magnet containing a higher Nd content (13.5 at%).

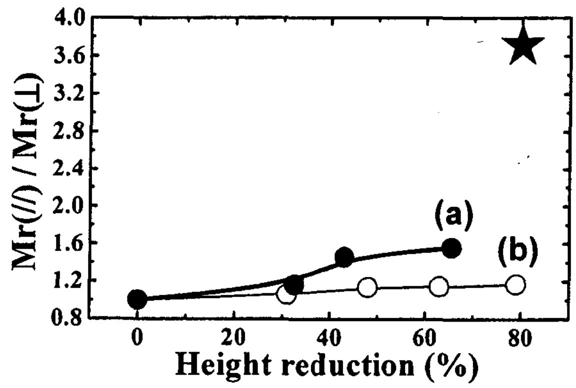

Fig. 1. Variations of the magnetic alignment for the die-upset hybrid magnets containing 85 wt% $Nd_xFe_{93.5-x}Ga_{0.5}B_6$ (x = (a) 13.5 and (b) 11.8) and 15 wt% $Nd_9Fe_{84}Nb_1B_6$ alloy.

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4. References

[1] R. Coehoorn, D. B. de Mooij, J. P. W. B. Duchateau, and K. H. J. Buschow, J. de Phys Colloque C8, 49 (1988), p. 669.

[2] E. F. Kneller, R. Hawig, IEEE Trans. Mag. 27 (1991), p. 3588.

[3] A. M. Gabay, Y. Zhang, and G. C. Hadjipanayis, Appl. Phys. Lett. 85 (2004), p. 446.

[4] H. W. Kwon and G. C. Hadjipanayis, IEEE Trans. Mag. 41(10) (2005), p. 3856.