F-03

# COERCIVITY STUDY OF HYBRID MAGNET CONSISTING OF $Nd_2Fe_{14}B$ SINGLE PHASE AND NANOCOMPOSITE ALLOYS

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## Introduction

Exchange-coupled nanocomposite magnets consisting of a mixture of hard and soft magnetic phases are of great interest for permanent magnet developmentbecause of its enhanced remanence. This enhanced remanence leads to a higher energy product even in an isotropic magnet without magnetic alignment. More interestingly, it has been suggested that an anisotropic nanocomposite magnet, in which the hard magnetic phase has a texture, would exhibit a superior magnetic performance with energy product over 100 MGOe. Recent reports showed that an anisotropic nanocomposite R-Fe-B/Fe magnets (R = Pr) could be prepared by hot pressing and subsequent die-upsetting of the blend of $Nd_2Fe_{14}B$ single phase alloy nanocomposite alloy melt-spun ribbons [1]. It is believed that the nanocomposite alloy leads to a significant reduction of coercivity, and this, in turn, deteriorates the overall permanent magnetic performance. In the present study, the coercivity of hybrid anisotropic nanocomposite magnets prepared by hot pressing and subsequent die-upsetting blends of $Nd_2Fe_{14}B$ single phase and nanocomposite alloy melt-spun ribbons was investigated. The effects of the amount and composition of the added nanocomposite alloy on the coercivity of the hybrid magnets were examined. The effect of deformation during the die-upsetting on the coercivity was also investigated.

## Experimental work

In this study we have used $Nd_{13.5}Fe_{80}Ga_{0.5}B_6$ as the $Nd_2Fe_{14}B$ single phase alloy, and two types of $Nd_xFe_{93-x}Nb_1B_6$ (x = 6 and 9) as the nanocomposite alloy. The used alloys were prepared using pure elements by an arc-melting under argon gas. The prepared alloys were melt-spun into ribbon using a copper wheel with a speed of 30 m/s. The obtained ribbons were crushed into powders with particle size of 50 – 150 μm using a mortar and pestle, and the $Nd_2Fe_{14}B$ single phase alloy and nanocomposite alloy powders were mixed thoroughly with the desired ratio. The mixed powder was then compacted in vacuum at 750 °C with a pressure up to 410 MPa and subsequently die-upset at the same temperature with height reduction of 0 % - 80 %. Microstructure of the compacted and die-upset magnets was examined using a high resolution scanning electron microscope. Magnetic characterisation of the compacted and die-upset magnets was performed at 300 K. The cubic shape specimens were magnetized with dc field of 50 kOe in a SQUID and the room temperature demagnetization curves were measured using a combination of the SQUID and VSM. All measured demagnetization curves were corrected for the self-demagnetizing field using a demagnetizing factor of 0.33.

Results and discussion

Fig. 1 shows the coercivity variation of the compacted and die-upset hybrid magnets with varying wt% of the added nanocomposite alloy alloy. For both the compacted and die-upset magnets the coercivity decreases with increasing the added nanocomposite alloys, and with a more profound coercivity deterioration when the amount of nanocomposite alloy exceeded 20 wt%. Coercivity of the die-upset magnet was drastically deteriorated (< 5 kOe) when the amount of added nanocomposite alloy exceeded 20 wt%. The effect of chemical composition of the added nanocomposite alloy on the coercivity of the compacted and die-upset magnets can also be seen in Fig. 1. The coercivity of the compact and die-upset magnets with nanocomposite alloy containing 6 at% Nd shows consistently a higher value with respect to the magnets with the nanocomposite alloy containing 9 at% Nd. This result is somewhat unexpected, because the nanocomposite alloy with less Nd content (6 at%) may have a lower coercivity as compared to the nanocomposite alloy with more Nd (9 at%). It can also be found that the coercivity of the die-upset magnet is consistently and significantly lower than that of the compacted magnet. This reduced coercivity would be due to an excessive grain growth and/or texture development during the die-upsetting following the compaction. It was found that the coercivity reduction after die-upsetting is due mainly to the texture development in the $Nd_2Fe_{14}B$ single phase region rather than to an excessive grain growth.

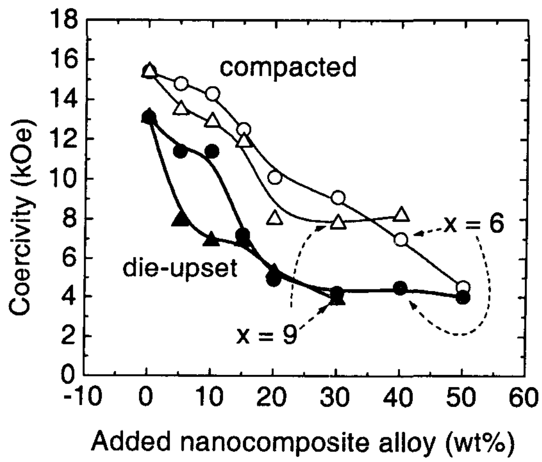


**Fig. 1** Coercivity variation of the compacted and die-upset magnets as a function of wt% of the added nanocomposite $Nd_xFe_{93-x}Nb_1B_6$ alloy.

Reference

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