Magnetic Properties of Hddr-treated Nd-Fe-B-Type Materials

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1. Introduction

In spite of no straight forward theory for explaining the coercivity mechanism in the Nd-Fe-B-type magnet, it has been generally accepted that the microstructure consisting of ultrafine $Nd_2Fe_{14}B$ grains with a size close to a single domain grain size (~300 nm for $Nd_2Fe_{14}B$) is crucial for achieving high coercivity. The HDDR treatment can lead effectively to the ultrafine microstructure of the Nd-Fe-B-type alloy. It would be very promising if the HDDR powder can be consolidated into high density bulk magnet keeping the ultrafine microstructure in the HDDR powder state [1]. In the present study, an attempt was made to consolidate the HDDR powder by means of hot pressing technique. The desorption nature of residual hydrogen in the HDDR powder and its effect on the coercivity in the course of heating for consolidation were also investigated.

2. Experimentals

The starting material was $Nd_{12.5}Fe_{80.6}B_{6.4}Ga_{0.3}Nb_{0.2}$ HDDR powder with intrinsic coercivity of 13.5 kOe. Desorption behavior of the residual hydrogen in the HDDR powder was examined by vacuum gauge and TPA (thermopeizic analyser) with heating rate 7 °C/min. The powder was compacted by hot pressing in vacuum (3.2 x 10^{-5} mbar at RT) at a temperature ranges from 400 – 850 °C in a closed type die with induction heating at the rate of 200 °C /min. Magnetic characterization of the material was undertaken by means of vibrating sample magnetometer (VSM). Microstructure studies of the compacted material were performed using TEM, SEM and XRD.

3. Results and discussion

Fig. 1 shows the hydrogen desorption trace studied by TPA for the $Nd_{12.5}Fe_{80.6}B_{6.4}Ga_{0.3}Nb_{0.2}$ HDDR powder and HD materials. The desorption traces for alloy ingot and for the hydrogen decrepitated (HD) alloy were also carried out for comparison. The desorption behavior of HDDR powder was quite good agreement with HD alloy except that the amount of desorbed hydrogen was much smaller with respect to the HD material. These results indicated clearly that the HDDR powder contained significant amount of hydrogen. Hydrogen analysis performed by LECO Hydrogen Determinator revealed that hydrogen content in the starting HDDR powder was approximately 1520 ppm. The HDDR powder was hot pressed at different temperatures, and coercivity of the compact was shown in Fig. 2. Coercivity of the compact was lower than that of the initial HDDR powder, and it decreased with increasing the hot pressing temperature. It is worth noting that coercivity of the compact was radically reduced when the compaction was performed at the temperature above 650 °C. Microstructure observation of the hot pressed compact by SEM showed that no significant difference in the grain size was noti ced before and after the hot pressing at higher temperature. TEM observation showed, however, that in some local area, the α-Fe and Fe_2B phases were found in the compact hot pressed at higher temperature. It is believed that these α-Fe and Fe_2B phases may have been formed by the disproportionation of the $Nd_2Fe_{14}BH_x$. The presence of these soft magnetic phases, α-Fe and Fe_3B may be responsible for the radical coercivity reduction in the compact hot pressed above 650 °C. The magnetic soft phases facilitate the nucleation of reverse domain in a demagnetising field, hence reducing coercivity radically.

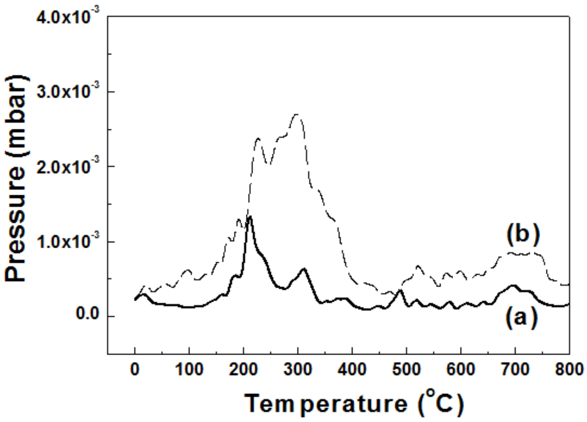

Fig. 1. Hydrogen desorption traces for (a) HDDR powder (b) fully hydrogenated of alloy ingot of $Nd_{12.5}$ $Fe_{80.6}$ $B_{6.4}$ $Ga_{0.3}$ $Nb_{0.2}$

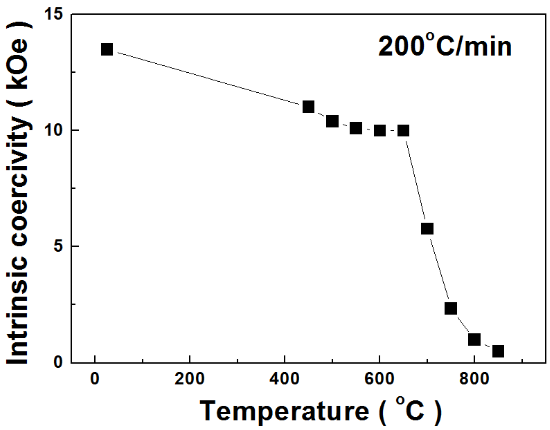

Fig. 2. Coercivity variation of hot pressed compact $Nd_{12.5}Fe_{80.6}$ $B_{6.4}Ga_{0.3}Nb_{0.2}$ HDDR powder as a function of hot pressing temperature.

Reference

[1] N. Nozawa , H.Sepehri-Amin , T.Ohkubo , K.Hono , T.Nishiuchi, .Hirosawa ,"Coercivity enhancement of HDDR-processed Nd–Fe–B permanent magnet with the rapid hot-press consolidation process" *J. Magn.Magn. Mater.*, **323**, pp. 115-121, (2011).