Effect of Pre-sintering and Dipping Process on Microstructure and Magnetic Properties of Nd-Fe-B Sintered Magnet Dipped in DyH_x Suspension

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1. Introduction

Nd-Fe-B magnet has bloomed as an important component of modern automotive technology and attracted much attention in other fields as well. Despite of its outstanding magnetic properties at low temperature zone, lacking of some aspects such as thermal demagnetization at the operation temperature (>200^{0}C) of HVs and EVs has still been a great challenge to overcome [1]. The recent studies have been directed mostly on the performance enhancement to fulfill the current demand of its industrial applications for which higher coercivity is required to sustain demagnetization at high operating temperature [1-3]. The coercivity of Nd-Fe-B magnets can be enhanced by the partial substitution of a heavy rare-earth element such as Dy or Tb for Nd in $Nd_2Fe_{14}B$ main phase [4]. The coercivity enhances due to the increase of anisotropy field at possible nucleation sites, such as grain boundaries and interface between the Nd-rich grains and the $Nd_2Fe_{14}B$ phase [1, 5]. In this work, we studied the effect in magnetic properties of Dy diffused pre-sintered NdFeB magnet and tried to investigate the microstructural change due to pre-sintering process.

2. Experiment

Magnet with a nominal composition of $Nd_{27.7}Dy_{4.9}Fe_{64.0}B_{1.0}T_{2.4}$, (in wt. %, T= Cu, Al, Co and Nb) prepared by conventional powder metallurgy process was used in this study. After magnetic field alignment and pressing the green compacts were first pre-sintered at 600^{0}C and then dipped in DyH_x suspension in Ar environment. After sufficient drying, they were sintered and annealed in vacuum. A set of sample, which was pre-sintered before sintering without dipping, was also produced for comparison. The magnetic properties of Nd-Fe-B sintered magnets treated with DyHx and untreated samples were measured with Magnet Physik Permagraph C-300 BH loop tracer. Similarly, the chemical composition was analyzed using EPMA (SHIMADZU EPMA-1720) and fracture surface of the magnets were observed using JEOL JSM-6360 in BSE mode.

3. Result and Discussion

Dy atoms were sufficiently diffused into the interior of magnet from its coated surface during sintering and heat treatment process and reached more than 100 μm below the surface. The increase of Dy concentration is likely to enhance the anisotropic field which is believed to be an essential part of coercivity enhancement. The porous structure of the bulk of pre-sintered magnet allowed relatively large content of oxygen to enter into it, which was trapped inside the magnet during the sintering process. The diffused Dy atoms mainly segregated at the grain boundary and triple junction and reacted with oxygen thereafter led to the formation of RE oxide phases. Those non-magnetic RE-rich oxide phases prohibited coercivity enhancement of pre-sintered Nd-Fe-B magnets.

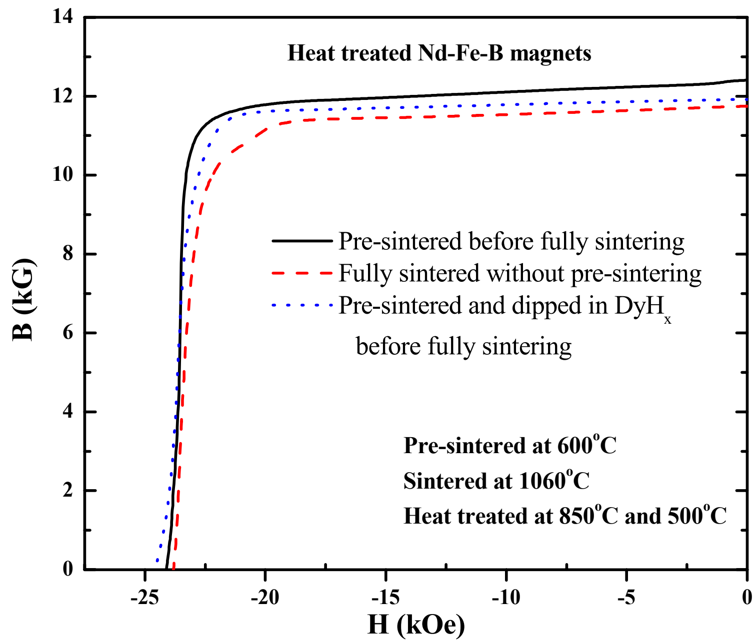

Fig. 1. Demagnetization curves of heat treated Nd-Fe-B sintered magnets.

4. Conclusion

Pre-sintering and dipping mechanism seemed to be effective to increase diffusivity of Dy atoms. However, our preliminary result showed that the pre-sintered magnets were more vulnerable to capture the oxygen so that non-magnetic RE oxide phases could developed.

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References

[1] W.F. Li, H. Sepehri-Amin, T. Ohkubo, H. N, K. Hono, Acta Materialia 59 (2011) 3061-3069.

[2] K. Hirota, H. Nakamura, T. Minowa, M. Honshima., IEEE TRANSACTIONS ON MAGNETICS 42 (2006) 2909-2911.

[3] N. Watanabe, M. Itakura, M. Nishida, Journal of Alloys and Compounds 557 (2013) 1-4.

[4] S.H. Masato Sagawa, Hitoshi Yamamoto, Setsuo Fujimura, Yutaka Matsuura, Jpn. J. Appl. Phys. 26 785-800.

[5] H. Sepehri-Amin, T. Ohkubo, K. Hono, Acta Materialia 61 (2013) 1982-1990.