Coercivity dependence on particle size in three $ThMn_{12}$-type magnetic materials

T. Kuno[1], K. Muramatsu[1], S. Suzuki[1], K. Urushibata[1], K. Kobayashi[1],
N. Sakuma[2,3], A. kinoshita[2,3], K. yokota[2,3], M. Yano[2,3], T. Shoji[2,3], A. Kato[2,3], A. Manabe[3]
[1]Shizuoka Institute of Science and Technology, Fukuroi, 437-8555, Japan
[2]Toyota Motor Corporation, Susono, 410-1193, Japan
[3]Technology Research Association of Magnetic Materials for High-efficiency Motors (Mag-HEM)
Higashifuji-Branch, Susono, 410-1193, Japan

Introduction

We found $RFe_{11-x}M_x$ (R=Nd,Sm) compounds having a $TnMn_{12}$ type structure as new magnet materials showing magnetic properties exceeding $Nd_2Fe_{14}B$ magnet at room temperature (RT). Typical examples of the compounds are $(Nd_{0.7}Zr_{0.3})(Fe_{0.75}Co_{0.25})_{11.5}Ti_{0.5}N_{1.3}$ [1) 2)] and sinterable $(Sm_{0.8}Zr_{0.2})(Fe_{0.75}Co_{0.25})_{11.5}Ti_{0.5}$ [3)]. Furthermore, it was revealed that the anisotropy magnetic field (H_a) of $Nd(Fe_{0.8}Co_{0.2})_{11}Mo$ nitrides in which the third component element is Mo has a high value of H_a=8.95 MA/m at RT. In this study, the improvement of coercivity (H_c) by decreasing particle size will be studied for the purpose of realizing the usable industrial magnets by the compounds.

Experimental method

We will report the results of Mo based compound in this manuscript. The $Nd(Fe_{0.8}Co_{0.2})_{11}Mo$ alloy prepared by the strip cast (SC) method was subjected to annealing at 1100°C/4 hours (h) and then pulverized and classified to prepare a powder sample having a particle size < 32 μm. The powder sample was nitrided in N_2 gas atmosphere at 600 °C/4 h, and the obtained $Nd(Fe_{0.8}Co_{0.2})_{11}MoN_{1.1}$ nitride was refined by ball mill grinding. Ball mill pulverization was carried out using stainless steel balls having a diameter of 3mmφ at a rotation speed of 180 to 300 rpm for 0 - 40 h in cyclohexane solvent.

The average particle diameter (D_{AVE}) of the powder sample was measured by scanning electron microscope (SEM) observation of the particle areas of about 100 particles and converted into particle diameters. The magnetic properties were measured using a 5T-VSM (manufactured by Toei Kogyo Co., Ltd.) and the oxygen content (wt.%) of the powder samples were measured by gas analysis (TC-436AR, manufactured by LECO Co., Ltd.) by inert gas melting method.

Experimental result

Figure 1 shows the SEM images of $Nd(Fe_{0.8}Co_{0.2})_{11}MoN_{1.1}$ nitride before and after ball mill grinding. By ball mill grinding 40 h, D_{AVE} of the same powder sample was refined from D_{AVE} =14.1 μm (0 h) to D_{AVE} =1.4 μm (40 h).

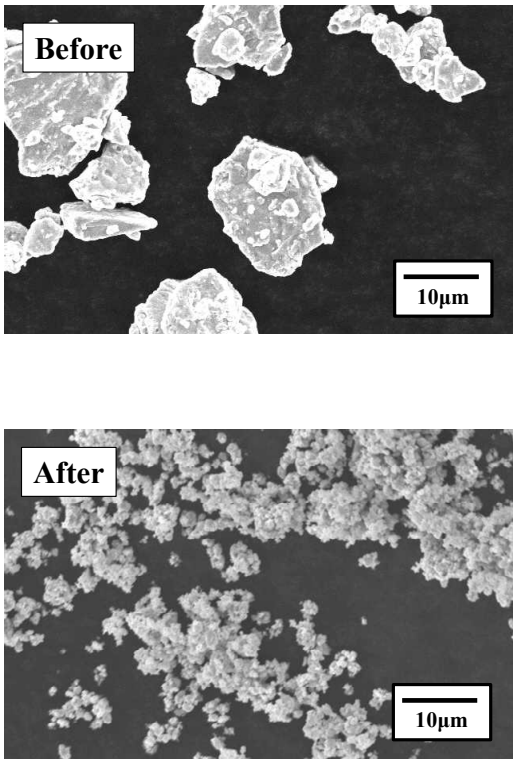

Fig. 1 $Nd(Fe_{0.8}Co_{0.2})_{11}MoN_{1.1}$ nitride before and after grinding (grinding time 40 h).

Fig. 2 shows the relationship between D_{AVE} and H_c, and oxygen contents (wt.%) of the same powder samples. H_c of the powder sample reached to the maximum value of H_c=2.4 kOe (D_{AVE} =1.7 μm) with milling for 16 h and decreased to H_c=2.1 kOe for 40 h. Since the oxygen contents (wt.%) by gas analysis of the powder samples were H_c=2.4 kOe (1.7 wt.%) and H_c=2.1 kOe (3.6 wt.%) respectively, the decrease in H_c in the latter powder should be due to oxidation.

In presentation, we will report similar H_c improvement by refining the sinterable R=Sm based compound and R=Nd based nitride.

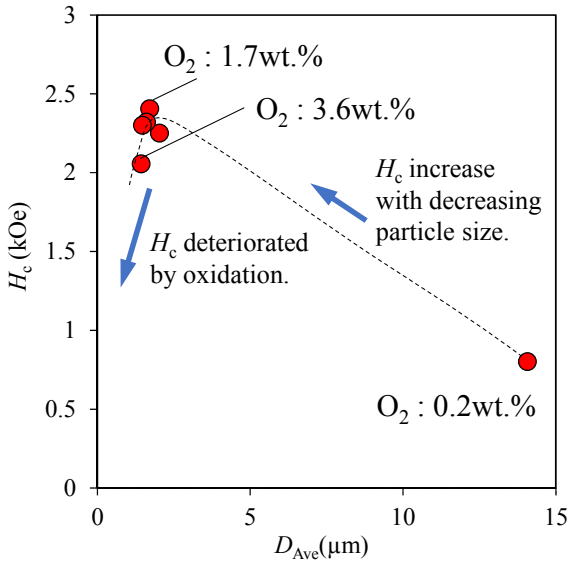

Fig. 2 H_c change with decreasing of D_{AVE}, and oxygen contents in $Nd(Fe_{0.8}Co_{0.2})_{11}MoN_{1.1}$ nitride.

Acknowledgment

This study is based on results obtained from the future pioneering program "Developments of magnetic materials technology for high efficiency motors" commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

Reference

1) S. Suzuki et al., AIP Advances, 4 (2014)
2) S. Suzuki et al., J. Magn. Magn. Mater., 401 (2016) 259-268.
3) T. Kuno, et al., AIP Advances, 6 (2016) 025221.