Effect of Ba Stearate Addition on Magnetic Properties of Ba-system W-type Ferrite Magnets

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Abstract

An experiment was carried out to investigate the effect of Ba Stearate as a reducing agent on the magnetic and physical properties of anisotropic $BaFe_2$-W type ferrite magnets. It was found that the magnetic properties of $BaO \cdot 8.5Fe_2O_3$ were improved by adding 0.3 wt% of Ba Stearate, 0.5 wt% of SiO_2, and 0.5 wt% of CaO together. The optimum conditions for making magnets were as follows; semisintering condition: 1350 °C×4.0 h in nitrogen gas atmosphere, drying condition: 180 °C×2.0 h in air, sintering condition: 1160 °C×1.5 h in nitrogen gas atmosphere. Magnetic and physical properties of a typical sample were J_m = 0.46 T, J_r = 0.43 T, H_{cJ} = 182.3 kA/m, H_{cB} = 177.2 kA/m, $(BH)_{max}$ = 33.8 kJ/m^3, T_C = 495 °C and K_A = 2.65×10^5 J/m^3 and H_A = 1332 kA/m.

Keywords : $BaFe_2$-W type hexagonal ferrite magnets, Ba Stearate, reducing agent, SiO_2 and CaO additives, magnetic properties

1. Introduction

In 1980, Lotgering [1] reported that W-ferrite had a saturation magnetization of about 10 % higher than that of M-type ferrite, and an anisotropy field that was almost equal. Since then, W-type ferrite has gained great attention as an anisotropic permanent magnet material. As it is very complicated to prepare a W-type ferrite, it considered to be impractical for industrial application at present. Recently, it was reported that high-performance $SrFe_2$-W ferrite can be produced by using reducing agents [2-3] and controlling the drying temperature and the sintering temperature of green compacts. The present experiment was carried out to investigate the effect of Ba Stearate as a reducing agent, with SiO_2 and CaO additives, on the magnetic and physical properties of $BaFe_2$ W-type hexagonal ferrite.

2. Experimental and Results

The raw materials used in this experiment were $BaCO_3$, α-Fe_2O_3, SiO_2, $CaCO_3$, and Ba Stearate (Ba content: 19.5 wt%, bal.: stearic acid) powder. The basic composition of sample is $BaO \cdot nFe_2O_3$ (n = 7.5~9.0). Using these raw materials, the compound was prepared. Mixing of these powders was performed using a ball mill (wet method). After drying the mixed powder, the semisintering samples were molded into a cylindrical shape at a pressing pressure of 49 MPa. These samples were semisintered at between 1300 and 1375 °C for 4.0 h in nitrogen gas atmosphere. The semisintering samples were pulverized under 106 μm using an iron mortar, and then Ba Stearate, SiO_2, and CaO were added to these powders. The SiO_2 and CaO addition weight were determined by various experiments. Mixed samples were milled for 8.0 h using a stainless steel vibration mill (wet method). The pulverized, mixed, and semisintered powder in slurry form was pressed at 98 MPa into a cylindrical shape in 800 kA/m parallel magnetic field to pressing direction. These samples were dried between 160 and 200 °C, and drying time was 0 to 4.0 h in air. The samples were sintered from 1120 to 1200 °C for 1.5 h in nitrogen gas atmosphere. Magnetic properties of samples were measured using a high-sensitivity recording fluxmeter in the field up to 800 kA/m. Curie temperature (T_C) and temperature dependence of saturation magnetization (σ_s) and coercivity (H_{cJ}) were measured by a vibrating sample magnetometer (VSM). The microstructures of samples were examined by a scanning electron microscope (SEM). Crystal structures and phases present were examined by the powder X-ray diffraction method using Fe-Kα radiation. The torque curves were measured by a torque magnetometer.

From the phase analysis and the values of σ_s for semisintering temperature of $BaO \cdot 8.5Fe_2O_3$ sample, in samples obtained W-type single phase, the highest σ_s of these samples were about 97.3 ×10^{-6} Wb·m/kg. This value of σ_s was about 10 % higher than that of BaM type hexagonal ferrite.

The highest value of $(BH)_{max}$ was obtained for $BaO \cdot 8.5Fe_2O_3$ compound with the addition of 0.3 wt% Ba Stearate (Fig.1). It was found that a single phase of $BaFe_2$-W ferrite was obtained by the additional amount of 0.3 wt% Ba Stearate as a reducing agent.

From the microstructure observation, the grain size in this sample was found to be 1~2 μm. Curie temperature of this sample is 495 °C. This value is about 40 °C higher than that of the BaM-type ferrite[4].

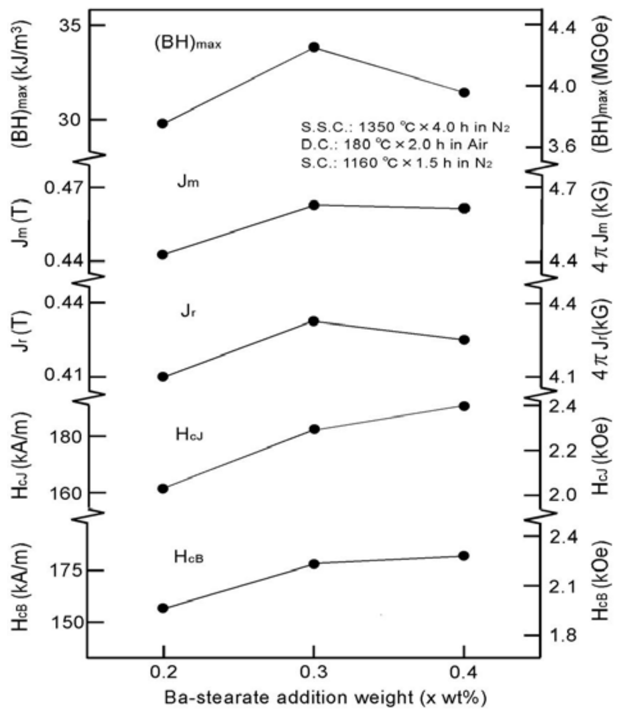

Fig. 1. Effect of Ba Stearate on magnetic properties of BaO·8.5Fe$_2$O$_3$ compounds added with 0.5wt% SiO$_2$ and 0.5 wt% CaO after semisintering treatment.

Fig. 2 shows the temperature dependences of σ_s and H_{cJ} in BaFe$_2$-W magnet with the best magnetic properties. The value of H_{cJ} increased with increasing temperature until about 210 °C, and it reaches the maximum value of 225.8 kA/m at about 210 °C, and then decreases with increasing temperature. These tendencies resemble those of the ordinary M-type ferrite. From this figure, the temperature coefficient of σ_s and H_{cJ} (from -30 to 120 °C) by a linear extrapolation were $\alpha(\sigma_s)$ = -0.12 %/°C, and α (H_{cJ}) = 0.24 %/°C, respectively.

On the surface perpendicular to the applied magnetic field direction (c axis) a maze pattern was observed. On the surface parallel to the applied magnetic field direction, 180° domain walls are observed in the demagnetic state.

The torque curves were measured by torque magnetometer. For the torque measurements, the fields were in the 1.27~1.75 MA/m. From the Fourier analysis of these torque curves, K_A was calculated. As the result, it was found that the value of K_A of the sample was 2.84 ×10^5 J/m^3, and H_A ($H_A = 2K_A/J_m$) was 1284 kA/m. These values were lower than these of BaM type hexagonal ferrite[4].

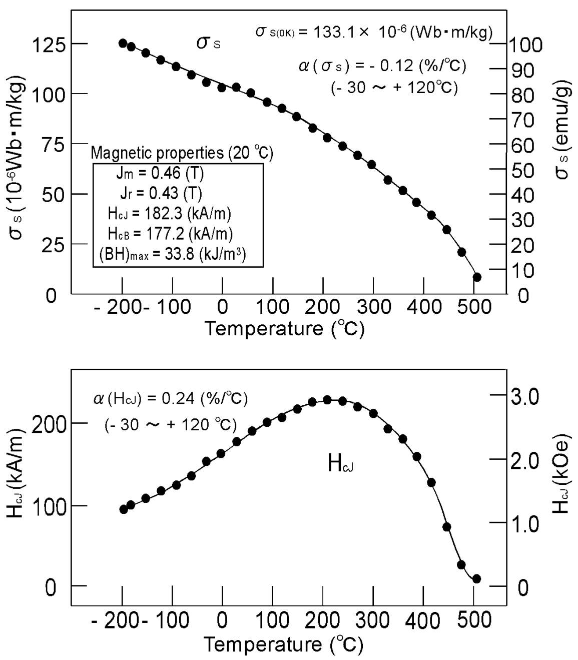

Fig. 2. Temperature dependences of σ_s and H_{cJ} in Ba Fe$_2$-W magnet with the best magnetic propert ies.

3. Summary

This paper describes the effect of Ba Stearate as a reducing agent, with SiO$_2$ and CaO additives, on the magnetic and physical properties of BaFe$_2$ W-type hexagonal ferrite. From this experiment, it was found that the magnetic properties of these compounds were significantly improved by adding Ba Stearate as a reducing agent, SiO$_2$ and CaO. Ba Stearate as a reducing agent was particularly effective for BaFe$_2$-W single phase formation. The value of $(BH)_{max}$ for BaFe$_2$-W magnet was 33.8 kJ/m^3. This indicates a potential industrial use of the W-type ferrite magnets.

4. References

1. F.K.Lotgering, P.H.G.M.Vromans and M.A.H.Huyberts, J.Appl.Phys.,Vol. 51,p. 5913(1980).
2. S. Toyota, J. Jpn. Soc. Powder Powder Metallurgy, V ol. 44, p 17(1997).
3. M. Ohmura and H. Yamamoto, IEEE Trans. Magn., Vol. 40, No3, p. 1695(2004).
4. K.J. Sixtus, K.J. Kronenberg, and R.K. Tenzer, J. Appl. Phys., Vol. 27, p. 1051(1956).