Paper

Investigation of the Influence of Raw Material Fe_2O_3 on the Magnetic Properties of Sr-ferrite Magnets

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ABSTRACT

The influence of specific surface area (SSA) of Fe_2O_3 was investigated while evaluating the raw material of Sr ferrite preparation. For hard ferrite magnet, SSA of Fe_2O_3 was found markedly affects the grain growth and the magnetic properties. Increasing of SSA of Fe_2O_3 resulted in the increase of remanence (B_R) and $(BH)_{\max}$, but also causes a decline in intrinsic coercive force (H_C). The SSA of Fe_2O_3 is most important factor in determining the reactivity of the ferrite specimens during calcinations and sintering processes. A larger SSA promotes reactivity, which results in larger grain size of either calcined or sintered powder, consequently larger B_R and smaller H_C were achieved, whereas, the opposite trend was observed for small SSA of Fe_2O_3 . Results are also confirmed that, when less impurity in Fe_2O_3 , the microstructure and magnetic properties of Sr-ferrite have smaller sensitivity to the SSA of Fe_2O_3 . As found in this study, well control of raw material Fe_2O_3 is shown to be very critical in tailoring suitable B_R and H_C for customized Sr-ferrite manufacturing process.

KEY WORDS

 Fe_2O_3 , SSA, Sr-ferrites, B_R , H_C , $(BH)_{\max}$

1 Introduction

The most important factors in the production of Sr-ferrite apart from the processing method are the cost and applicability of the raw materials¹⁾. The usual raw materials of Sr-ferrite are Fe_2O_3 and SrCO_3 ²⁾. In the manufacturing process of steel, a large number of byproduct Fe_2O_3 could be recovered and derived from the Ruthner process³⁾. Although the magnetic properties of Sr-ferrite are lower than that of rare-earth magnet, e.g. NdFeB magnet, the Fe_2O_3 accounts for up to 90 wt% of Sr-ferrite. Sr-ferrite has the advantages of low cost raw material, so far is still the largest usage amount of permanent product⁴⁻⁶⁾. The improvement of Sr-ferrite materials with respect to specific material properties or application fields is still a vital field of research. The development of Sr-ferrite is also of great importance for steel industry. In this work we have used Fe_2O_3 byproduct of China Steel Corporation in Taiwan to prepare the sintered Sr-ferrite samples.

Sr-ferrite magnet is widely used as the rotor of brushless direct current motor due to its low cost advantage, the power consumption of motor could be effectively reduced. In this respect, one crucial issue is the development of large remanence (B_R) and the maximum energy product ($(BH)_{\max}$). The main magnetic properties of Sr-ferrites depend on the powder characteristics after molding. Remanence B_R can be described as:

$$B_R = 4\pi M_s \cdot \alpha \cdot \rho \quad (1)$$

A large saturation magnetization $4\pi M_s$, the same with intrinsic coercive force (H_C), is essential to precisely tailor the applicable raw material Fe_2O_3 (i.e. SSA), suitable additives, calcined condition and sintered condition which in turn controls the complex interplay between microstructure and grain growth. Besides, a large remanence B_R also requires a high density and anisotropy factor of sintered structure which both are affected by the morphology, uniformity and distribution of ferrite powder. Magnetic ferrite powder should have dimension below the critical size for single domain particles of about $1 \mu\text{m}$ ⁷⁾ to allow some unavoidable grain growth during sintering and to limit grain size in the sintered magnets to a few microns. The formation of the desired ferrite powder could be controlled by the selection of raw material. The SSA of Fe_2O_3 play crucial roles in determine their effectiveness for microstructure control. Too large or too small SSA of Fe_2O_3 raw materials are both detrimental with respect to magnetic properties because the particle size match with SrCO_3 should be considered. Particle size of raw material mismatched will cause the slurry dispersed unevenly in the mixing process or incompletely reaction in the calcinations process, which results in poor magnetic properties.

In previous reports, the mechanism of the action of additives in ferrites, calcinations and sintered behaviors of Sr-ferrite have been widely studied. Nevertheless, the relation between microstructure,

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magnetic properties of Sr-ferrites and raw material Fe₂O₃ are still less discussed. In this work, we report on microstructure control of the magnetic properties by using different purity grades Fe₂O₃ produced by China Steel Corporation (CSC) Ruthner process in a SSA range from 3.0–4.0 m²/g. Based on a stoichiometric ferrite SrO·5.8Fe₂O₃, systematically change purity and SSA of Fe₂O₃ raw materials to investigate its effect on the ferrite microstructure and magnetic properties. We address the following issues: (i) Investigation of the interrelationship between impurities concentration and SSA and (ii) role of Fe₂O₃ particle size matching in microstructure formation. Positive effects of high purity and applicable SSA Fe₂O₃ were demonstrated with a remanence $B_R = 4270$ G, a intrinsic coercive force $iH_C = 3515$ Oe and a maximum energy product $(BH)_{\max} = 4.405$ MGOe.

2 Experiment Procedures

2.1 Sample preparation

All ferrite samples in this work are prepared using standard ceramic process. Different grades raw materials Fe₂O₃ (Acid recycle Ruthner process, China Steel Corporation (CSC), Taiwan, Taiwan) and SrCO₃ (Solvay Barium Strontium B Grade, Germany) are mixed in a molar ratio SrO:Fe₂O₃ = 1:5.8. The additives SiO₂ and H₃BO₃ are added simultaneously into the slurry and then granulated. The granules (3–10 mm diameter) were calcined at 1290 °C for 1 hr. The calcined granules were coarse milled in a rotary vibration mill to ~2 µm. The other additives SiO₂, CaCO₃, Al₂O₃, Co₃O₄ and SrCO₃ were added in various concentrations and then the ferrite powders were fine milled in an attrition mill for 12 hr (batch size: 0.6 kg ferrite powder). This procedure gives a powder with a mean particle size of about 0.7 µm. The ferrite slurry was pressed in a magnetic field of 1.5 Telsa (field parallel to the direction of pressure) into discs of Φ26.5 mm in diameter and 13 mm in height

(based on Japanese Industrial Standard, JIS C2501). The samples were sintered at a peak temperature of 1235 °C for 1 hr. To study the effect of SSA of raw material Fe₂O₃, Samples A–Sample D were prepared using China Steel Corporation DC Grade Fe₂O₃ in a SSA range from 3.0 m²/g~3.6 m²/g. Sample E was also prepared using China Steel Corporation SB Grade Fe₂O₃ (high purity) in a SSA = 3.0 m²/g to investigated the influence of impurity in Fe₂O₃ under the same SSA. Further, to explore the detriment of excessive SSA of Fe₂O₃, CSC SA4 Grade Fe₂O₃ (high purity) in a SSA = 4.0 m²/g was selected for raw material of Sample F. In all samples, the SSA and impurity composition are compared in Table 1.

2.2 Measurements

The specific surface area (SSA) of raw materials Fe₂O₃ was all determined by adsorption of nitrogen in a BET apparatus (Micromeritics). Vibrating sample magnetometry (VSM, MicroSense EZ7-380V) was used to characterize the magnetic properties of the calcined magnetic powders, in an applied field of 18 kOe, such as coercivity and saturation magnetization at room temperature. X-ray diffraction (XRD, Cu-Kα radiation) was used for phase identification of the calcined magnetic powder. The particle size of the calcined magnetic powders after coarse milling and fine milling were both measured with a Sympatec laser scattering system (system Rodos), respectively. The magnetic properties of the sintered magnets were measured at room temperature with a NIM-2000HF Hysteresis graph meter on polished discs. The ceramic microstructures were analyzed on polished and thermally etched faces of the magnets (perpendicular to the applied pressure and field) by SEM (Zeiss).

3 Results and Discussion

3.1 Influence of selection of Fe₂O₃ to calcined magnetic powders

The microstructure of Sample A–Sample F using different SSA

Table 1 Different SSA and impurity concentration Fe₂O₃ manufactured by Acid recycle Ruthner process, China Steel Corporation (CSC).

Fe ₂ O ₃ element [wt.%]	CSC DC Grade Fe ₂ O ₃				CSC SB Grade Fe ₂ O ₃	CSC SA4 Grade Fe ₂ O ₃
SSA	3.0 [m ² /g]	3.2 [m ² /g]	3.4 [m ² /g]	3.6 [m ² /g]	3.0 [m ² /g]	4.0 [m ² /g]
Fe ₂ O ₃	99.30	99.30	99.30	99.30	99.30	99.30
Al ₂ O ₃	0.132	0.135	0.1372	0.131	0.0017	0.0018
Cr ₂ O ₃	0.0464	0.0456	0.0455	0.0487	0.0001	0.0001
SiO ₂	0.0077	0.0074	0.0072	0.0077	0.0059	0.0058
CaO	0.08954	0.008726	0.008755	0.008954	0.005736	0.005812
MnO	0.297	0.297	0.308	0.297	0.2840	0.297
MgO	0.0017	0.0015	0.0018	0.0015	0.0008	0.0009
ZnO	0.00037	0.00037	0.00037	0.00037	0.000125	0.000125
Na ₂ O	0.00624	0.00578	0.00578	0.00578	0.0031	0.00274
Cl	0.06	0.07	0.08	0.07	0.06	0.07
Ni	0.0077	0.0080	0.0087	0.0079	0.0072	0.0072
Cu	0.0060	0.0054	0.0063	0.0055	0.0009	0.0009
P	0.0081	0.0068	0.0068	0.0060	0.0018	0.0014
V	0.0026	0.0022	0.0023	0.0020	0.0005	0.0002
Mo	0.0042	0.0038	0.0043	0.0039	0.0001	0
Other impurity	0.0837	0.0849	0.0852	0.0843	0.0242	0.0241

Fig. 1 SEM micrographs of magnets Sample A–Sample F calcined at 1290 °C for 1 hr.

and impurity concentration raw material Fe_2O_3 calcined at 1290 °C for 1 hr is shown in Fig. 1. The SEM micrographs were taken at random with 5000X magnification. The microstructures of Sample A–Sample D using CSC DC grade Fe_2O_3 as raw material were shown in Fig. 1 (a)–(d). The particle size of the calcined magnetic powder is about 1–3 μm giving uneven grain size and the grains tend to be irregular and angular in shape. For sample E using CSC SB grade Fe_2O_3 (low impurity concentration grade) as raw material, Fig. 1 (e) shows the morphology of calcined magnetic powder with a larger particle size of 2–3 μm tend to be regular and rounded in shape. Compared with Samples A–Sample D, Sample E had a large, uniform particle size. It shall be noted that the morphology of Sample E is preferable to magnetic properties reflected in Fig. 6. Furthermore, the comparison can be done with CSC SA4 grade Fe_2O_3 which having the same impurity concentration but larger SSA than CSC SB grade. The microstructure of Samples F, i.e. with SA4 grade Fe_2O_3 , shows smooth and regular in shape. Whereas in samples with large SSA Fe_2O_3 raw material, small grains down to only 1–2 μm are observed. In general, using larger SSA of Fe_2O_3 as raw material tends to grow to larger grain size due to larger reaction area with SrCO_3 during calcinations process would lead to larger grain growth; however, insignificant difference in grain size was observed for Sample A–Sample D. Regarding the manufacturing of Fe_2O_3 in acid recycle Ruthner process, the iron oxide usually contains some amount of the impurities coming from waste hydrochloric acid generated from the pickling of steel sheet. It could be suspected due to that a larger content of Al_2O_3 and Cr_2O_3 in CSC DC grade Fe_2O_3 were effective for the suppression of grain growth⁸⁾. So that, we could assert that the impact of SSA of Fe_2O_3 to the morphology of calcined magnetic powder decreased while higher quintiles of impurities contained. Whereas in comparison between the SEM micrograph of Sample A and Sample E calcined at 1290 °C, a significant difference in microstructure was observed.

In agreement with above explanation, this is a result of the larger content of impurities, such as Al_2O_3 , Cr_2O_3 and even SiO_2 , may cause significant difference in microstructure where for the same SSA of Fe_2O_3 . This is also reflected in the magnetic properties of VSM (Fig. 6). Besides, inspection of the microstructures of calcined magnetic powder of Sample E and Sample F, i.e. Fig. 1 (e) and Fig. 1 (f), show that if the SSA of raw material Fe_2O_3 becomes excessive large (i.e. SA4 grade Fe_2O_3), the calcined grains progressively tend to be relatively smaller while contained smaller amount of impurities than those of DC grade Fe_2O_3 . In the use of SA4 grade Fe_2O_3 and Solvay B grade SrCO_3 as raw material where is speculated that the relative large SrCO_3 particle size could not match with Fe_2O_3 (i.e. $\text{SSA} = 4.0 \text{ m}^2/\text{g}$) during mixing. The morphology of the Solvay B grade SrCO_3 powder with particle size range from 2–5 μm is shown in Fig. 2.

Compared with SB and SA4, SA4 contains finer particles. The SEM images in Fig. 3 also reveal the micrographs of those two

Fig. 2 SEM micrographs with 8000X magnification of Solvay B grade SrCO_3 powder using in this work.

Fig. 3 SEM photographs of (a) SA4 grade and (b) SB grade Fe_2O_3 manufacturing by CSC.

Fig. 4 XRD patterns of the calcined magnetic powders of Sample A–Sample F.

kinds of Fe_2O_3 . The mismatch of particle size between SA4 grade Fe_2O_3 and SrCO_3 explains why the high activity of large SSA Fe_2O_3 raw material instead did not cause a large grain growth, which also reflected the degradation of magnetic properties of sintered magnet.

Fig. 4 presents the X-ray diffractograms for calcined specimens of Sr-ferrites with Sample A–Sample F, respectively. The standard patterns for calcined hexagonal Sr-ferrite are also given in Fig. 4 based on the JCPDS card 84-1531 clearly revealing that hexaferrite phase is formed after calcining at 1290°C . It is also seen that at 1290°C , only the Sr-ferrite phase could be detected. From Fig. 4, all the peaks can be indexed as M-type hexagonal structure (i.e. $\text{SrO} \cdot 5.8\text{Fe}_2\text{O}_3$) with the following miller indices: (006), (110), (008), (107), (114), (200), (108), (203), (204), (205), (206), (209), (300), (303), (2011), (218), (219), (220), and (2014). Fig. 5 shows the plots of the saturation magnetization (M_s) as a function of the applied field (H_c) in the field range of $\pm 18\text{ kOe}$ for all samples at room temperature using a vibrating sample magnetometer (VSM). The samples calcined at 1290°C shows smooth hysteresis loop, which confirms the formation of pure Sr-hexaferrite^{9,10}. All samples do not show the saturated magnetization despite high magnetic field. The saturation magnetization values are estimated from the extrapolating of M versus $1/H$ curves when $1/H$ goes to zero. The obtained results are all compared in Table 2. The reduction in M_s and increasing in H_c of calcined magnetic powder could be attributed to the decrease in the size of the calcined particles. It is to be noted that the observed value of H_c , M_r and M_s for Sample F are not regular with SSA, which may be due to the excessive SSA of Fe_2O_3 .

Fig. 5 M - H hysteresis curve of the calcined magnetic powders of Sample A–Sample F measured by VSM at room temperature.

Table 2 VSM results of the calcined magnetic powders of Sample A–Sample F.

Samples	VSM Measurement Results		
	H_c [Oe]	M_r [emu/g]	M_s [emu/g]
Sample A	3444.843	34.262	63.391
Sample B	3609.568	33.004	63.175
Sample C	3686.548	34.118	62.574
Sample D	3898.644	33.571	61.254
Sample E	3312.458	33.202	63.786
Sample F	3507.287	33.640	61.030

3.2 Influence of selection of Fe_2O_3 to sintered magnetic powders

The calcined granules of Sample A–Sample F were coarse milled in a rotary vibration mill to $\sim 2\text{ }\mu\text{m}$, respectively. Additives SiO_2 , CaCO_3 , Al_2O_3 , Co_3O_4 and SrCO_3 were added in various concentrations to coarse milled ferrite powders and then simultaneously milled in an attrition mill for 12 hr to a mean particle size of about $0.7\text{ }\mu\text{m}$. After fine milled, the ferrite slurry was wet molded in a magnetic field of 1.5Telsa and subsequently sintered at a peak temperature of 1235°C for 1 hr. To check impact of SSA of raw material Fe_2O_3 to the particle characteristics of calcined magnetic powder, the particle size distribution of Sample A–Sample D after coarse milling and fine milling are analyzed in Fig. 6. Although insignificant difference was observed in Fig. 1 (a)–Fig. 1 (d), the particle size and its distribution of calcined powder after coarse and fine milling were found to still dependent on the SSA of iron oxide powder as the main raw material. The D_{10} , D_{50} and D_{90} of the calcined powder after coarse and fine milling are listed in the inset tables in Fig. 6 (a) and Fig. 6 (b), respectively. In fact, larger calcined powder can be obtained by using larger SSA of fine iron oxide powder as the starting raw material. This means that the larger SSA of Fe_2O_3 raw material used is effective for increasing the reactivity during calcinations.

The microstructure of Sample A–Sample E sintered at 1235°C for 1hr is shown in Fig. 7. The SEM micrographs were also taken at random with 5000X magnification. The SEM micrographs

Fig. 6 Particle size distribution of the calcined magnetic powders of Sample A–Sample F after (a) coarse milling and (b) fine milling.

Fig. 7 SEM micrographs of magnets Sample A–Sample E sintered at 1235 °C for 1 hr.

were taken parallel to the direction of pressure and magnetic field during wet molding; the view is along the basal planes of the platelet shaped ferrite particles. If we take into account the size of the fine-milled after sintering of about 1 μm , it was obvious that grain growth predominately occurs perpendicular to the hexagonal C -axis. From Fig. 7 (a)–Fig. 7 (d), with SSA of DC grade Fe_2O_3 ranging 3.0 m^2/g to 3.6 m^2/g , insignificant difference in sintered

Table 3 Magnetic properties and density of Sample A–Sample F sintered at 1235 °C.

Samples	Density [g/cm^3]	B_R [G]	iH_C [Oe]	$(BH)_{\max}$ [MGOe]
Sample A	4.94	4197	3710	4.240
Sample B	4.97	4222	3636	4.260
Sample C	5.00	4259	3537	4.310
Sample D	5.01	4267	3489	4.340
Sample E	5.03	4270	3515	4.405
Sample F	4.79	3877	4123	3.632

grain size was observed and grain tend to be poor in uniformity and distribution. This result was also reflected in the aforementioned discussions of calcined magnetic powders. That is, the impact of SSA of Fe_2O_3 to the morphology of sintered magnetic powder also decreased while higher quintiles of impurities contained. Moreover, by using high purity of SB grade Fe_2O_3 as the starting raw material, more uniform, regular and rounded sintered grain can be obtained. Compared with Fig. 7 (e) and Fig. 7 (a), the particle shape and its distribution of sintered grain were found to strongly dependent on the impurity concentration of iron oxide powder as the main raw material, which then results in the significant difference of magnetic properties.

3.3 Influence of selection of Fe_2O_3 to sintered magnet

A series of magnets (Sample A–Sample F) with the same processed condition and different raw material iron oxide was prepared. The magnetic parameters of sintered magnet are extracted from demagnetization curves. The variation of B_R , iH_C and $(BH)_{\max}$ correlated with the raw material Fe_2O_3 used in this work are shown in Fig. 8. The relation of Sample F compared with others are inserted in the inset figures. The magnetic parameters are collected in Table 3. Consequently, gradual increase in density with increasing B_R was observed. The raising of SSA of Fe_2O_3 seems very effective for promotion of B_R and $(BH)_{\max}$ but sufficient to substantial grain growth and the subsequent decrease of coercivity. Differed from Sample A, Sample E using high impurity iron oxide powder as the raw material for ferrite nevertheless appears a dissimilar result. The higher density of magnet Sample E is transformed into high remanence, but due to the relatively large platelet-shaped grains the coercivity is low. For magnet Sample E the B_R is increased to almost 4270 G, but iH_C is reduced. On the other hand, if Sr-ferrite prepared by excessive SSA of Fe_2O_3 , the reaction area to react with SrCO_3 is expected to increase. However, the results of Sample F are not in agreement with those of Sample A–Sample D, contrary B_R and $(BH)_{\max}$ decline and iH_C increases due to the mismatch of particle size between SA4 grade Fe_2O_3 and Solvay B grade SrCO_3 , which are also indicated in Fig. 1 (f).

Interpreted the above results, the magnetic properties of a hexaferrite are strongly determined by microstructure and its raw materials. To obtain high B_R , a dense microstructure with well aligned particles and possibly little non-magnetic secondary phase

Fig. 8 The variation of B_R , iH_c and $(BH)_{max}$ correlated with the raw material Fe₂O₃ used in this work.

is necessary. On the other hand, if a large iH_c would be desired the particle size of sintered magnet should be in the order of critical diameter d_c for single domain behavior given by⁽¹¹⁾:

$$d_c = \frac{18\sqrt{AK_1}}{\mu_0 M_s^2} \quad (2)$$

where A is the exchange energy constant, K_1 is the magnetocrystalline anisotropy constant and M_s is saturation magnetization. The grain size of sintered magnet in our work had also achieve the requirement of $d_c \approx 1 \mu\text{m}$ for Sr-ferrite⁽⁷⁾. The intrinsic coercivity according to the Stoner–Wohlfahrt situation of noninteracting single-domain particle with the anisotropy provided by magneto-crystalline anisotropy is:

$$iH_c = \alpha H_a - N(B_R + 4\pi M_s) / \mu_0 \quad (3)$$

where N is the demagnetizing factor, α is the microstructure constant which is inversely proportional to sintered grain size, H_a is anisotropy field, N is demagnetization factor and μ_0 is vacuum permeability. From equation (3), to obtain a high coercivity the material should possess a large anisotropy field (H_a) and small demagnetization factor (N)⁽¹²⁾. It is well known that the intrinsic coercivity will reduce when the sintered grain grow into platelet-shaped with large aspect ratio. In addition to the grain size, this makes the grain shape another critical factor affecting the coercivity. Besides, larger sintered grain size leading to small microstructure constant (α) and also promote densification, which results in increased B_R and decreased iH_c .

The different microstructures of Sample A–Sample D (Fig. 7) confirm that larger SSA of Fe₂O₃ is effective for the enhancement of B_R and $(BH)_{max}$ and the suppression of iH_c . This is presumably due to the phenomenon whereby the larger sintered grain size of Sample D; however which could not be reflected in the SEM results. Traced back to Fig. 6, larger D_{10} , D_{50} , and D_{90} of calcined powder can be attained by using larger SSA of fine iron oxide powder as the starting raw material, which could be ascribed to its better reactivity. This phenomenon instead leads to attenuated reactivity, which then results in smaller grain size during sintering. Nevertheless, inspection of results of Fig. 7 and Fig. 8 don't show the tendency to form larger sintered grain using larger SSA of Fe₂O₃ and further go towards increased B_R , $(BH)_{max}$ and decreased iH_c . These irregular phenomenons were presumably caused by the impurity contained in the main raw material Fe₂O₃. Thus, some indications could be seen that the impact of impurity concentration on magnetic properties is larger than that of SSA of main raw material Fe₂O₃. The impurities coming from the starting raw materials, such as Al₂O₃ and Cr₂O₃ play a crucial role in determining their effective for iron exchange and are also introduced as grain growth inhibitor in hexaferrites.

Further analysis of the magnetic properties results of Sample A and Sample E, declining in B_R and $(BH)_{max}$ with increasing Al³⁺ and Cr³⁺ concentration in raw material Fe₂O₃ are observed. Besides, as the increasing of Al³⁺ and Cr³⁺ concentration, iH_c raises due to enlargement in critical size of single domain (R_c) and anisotropy field (H_A), which in turn facilitate the grain growth inhibition^(13,14). As summarized above discussion and the explanation of equation (3), the difference also could be inspected from the comparison

microstructure of sintered magnets of Sample A and Sample E that when the same SSA of Fe_2O_3 are used as raw material. Samples E used CSC grade SB Fe_2O_3 shows higher B_R and $(BH)_{\max}$ due to its higher purity raw material Fe_2O_3 leading to more uniform and large grain size as well as better particle orientation, which is in conformity with the SEM images shown in Fig. 7.

4 Conclusion

Strontium hexaferrite have been prepared using different purity grades Fe_2O_3 in a SSA range from $3.0 \text{ m}^2/\text{g}$ – $4.0 \text{ m}^2/\text{g}$ and the influence of impurity concentration and SSA of starting raw material on their morphological and magnetic properties have been studied. The magnetic properties of a hexaferrite are determined by its chemistry and microstructure. The impurity and SSA of Fe_2O_3 both play crucial roles in determine their effectiveness for microstructure control. To obtain high performance magnets, the SSA of Fe_2O_3 should be selected appropriately to meet the particle size matching with another starting raw material SrCO_3 . Regarding the impurity, some results in our work also reveal the impact of impurity concentration on magnetic properties is larger than that of SSA of main raw material Fe_2O_3 . The higher purity of Fe_2O_3 , the better magnetic properties was achieved. Such behavior may be explained according to the influence of Al_2O_3 and Cr_2O_3 . The best magnetic results with $B_R = 4270 \text{ G}$, $iH_C = 3515 \text{ Oe}$ and $(BH)_{\max} = 4.405 \text{ MGOe}$ were close to the most widely used commercial product FB6N (without Lanthanum addition)¹⁵⁾, which also provided a reference guide for the selection of Fe_2O_3 as the raw material for strontium ferrite, especially for Brushless DC electric motor applications.

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