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Nanocomposites of the Barium Ferrite/ δ -FeOOH System

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Abstract. Fine δ -FeOOH particles were introduced onto the surface of barium ferrite particles. The method was to coat the barium ferrite particles with Fe^{2+} solution first at certain concentrations, followed by addition of $\text{NaOH}_{(\text{aq})}$, and finally oxidized by 35 wt% $\text{H}_2\text{O}_{2(\text{aq})}$. The results showed that the coercivity of barium ferrite could be lowered greatly to 2290 Oe and its magnetization could be sustained at a level higher than 45 emu/g. It indicates that there exists an interaction between barium ferrite and δ -FeOOH fine particles, which leads to the decrease in coercivity, and this interaction is a matter of interface and may not bear dependency on whether chemical bonding is formed between them.

1. INTRODUCTION

In recent years there has been growing industrial and academic interest in the development of barium ferrite (BF) due to its potential application in high density magnetic recording. For this application, Ti, Co, Mn...etc. have been doped into BF to reduce its coercivity (H_c). However, in doing so, saturation magnetization was greatly lowered and thus deteriorated their performance. The surface modification of BF particles by the formation of a Fe_3O_4 epitaxial layer has been tried by Kiyama *et al.* and Sadamura *et al.*[1,2]. As reported for the modified BF particles, their coercivities decreased and magnetizations increased with the incorporation of Fe_3O_4 layers. In this work, we tried to introduce directly the fine δ -FeOOH particles, which exhibits a significant magnetization among ferric oxyhydroxides, onto the surface of the BF particles.

2. EXPERIMENTAL

Barium ferrite particles were firstly prepared by a salt-melt method according to our previous work.[3] They were typically hexagonal platelets with sizes 60-500 nm.

Fine δ -FeOOH particles were prepared in sequence by adding 1 M $\text{NaOH}_{(\text{aq})}$ into 2 M Fe^{2+} solution, dropping 35wt% $\text{H}_2\text{O}_{2(\text{aq})}$ into the resulting solution, filtering, washing with deionized water and drying at room temperature.

δ -FeOOH coated BF was prepared in sequence by adding BF powders into a Fe^{2+} solution with various concentrations, viz. 1 M, 2 M, 3 M, 4 M and 5 M, taking BF particles out of the solution by a magnet enclosed by a thin PVC film, placing the particles on a Teflon plate by taking the magnet away from the film, dropping 35wt% $\text{H}_2\text{O}_{2(\text{aq})}$ onto the particles until no reaction was observed, filtering, washing with deionized water and drying at room temperature.

The crystal structure was identified by X-ray diffractometry (XRD) using $\text{CuK}\alpha$ radiation. The particle morphology was examined by a transmission electron microscope (TEM). The magnetic properties were measured using a vibrating-sample magnetometer (VSM) with a maximum field of 2 T at room temperature.

3. RESULTS AND DISCUSSION

In Fig. 1, the diffraction patterns show that the pure barium ferrite and δ -FeOOH were obtained. Their magnetic properties are listed in Table 1. It is seen that the δ -FeOOH particles are superparamagnetic. When these δ -FeOOH fine particles move close to the surface of BF, they would be magnetized and attracted onto the BF surface under magnetic field of the BF

Fig. 1 XRD patterns of barium ferrite (a) and δ-FeOOH (b)

Fig. 2 The particle morphology of the surface coated BF

particles. Thus, if the surface of BF is coated with the Fe^{2+} solution first, after addition of $\text{NaOH}_{(\text{aq})}$ and $\text{H}_2\text{O}_{2(\text{aq})}$ in sequence, $\delta\text{-FeOOH}$ fine particles are then expected to form and adhere onto the surface of BF. With this approach, the BF surface coated with $\delta\text{-FeOOH}$ particles were fabricated and their magnetic properties are listed in Table 2. It is seen that the coercivity decreases with coating concentration of the Fe^{2+} solution while, however, the magnetization remains relatively high levels. It thus indicates that there exists an obvious interaction between the BF and $\delta\text{-FeOOH}$ particles thereon.

Table 1. Magnetic properties of barium ferrite and $\delta\text{-FeOOH}$

Materials	σ_s (emu/g)	σ_r (emu/g)	H_c (Oe)
Barium ferrite	70.3	35.3	3400
$\delta\text{-FeOOH}$	19.7	0	0

Table 2. Magnetic properties of surface coated barium ferrite

Sample	σ_s (emu/g)	σ_r (emu/g)	H_c (Oe)
$[\text{Fe}^{2+}]=1\text{ M}$	68.9	34.8	3340
$[\text{Fe}^{2+}]=3\text{ M}$	58.8	29.3	3220
$[\text{Fe}^{2+}]=5\text{ M}$	45.5	21.3	2290

The particle morphology of the surface coated BF with $\delta\text{-FeOOH}$ fine particles is shown in Fig. 2. It can be seen that there is a thin layer of $\delta\text{-FeOOH}$ covering the surface of BF.

For the surface coated BF, since there is seldom possibility that strong chemical bonding at the interface between the BF and $\delta\text{-FeOOH}$ can be formed by the room temperature process we adopted, the lowering of coercivity is a matter of interface interaction which leads to strong magnetic coupling. For comparison, the BF and $\delta\text{-FeOOH}$ particles with a weight ratio 2:1 were also wet-mixed directly. The resulting saturation magnetization and coercivity were measured to be 50.2 emu/g and 2670 Oe, respectively. No chemical reaction between the BF and $\delta\text{-FeOOH}$ particles is expected in this case. However, coercivity of BF can also be decreased by mixing with $\delta\text{-FeOOH}$. It is thus suggested that the decrease in coercivity caused by the magnetic coupling may not bear dependency on whether chemical bonding is formed.

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