Available online at www.sciencedirect.com
ScienceDirect
Journal of Magnetism and Magnetic Materials 310 (2007) 2529–2531
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Magnetic properties of $BaFe_{12}O_{19}$ prepared by an ICR technique☆

J.M. Soares[a], F.L.A. Machado[b,*], J.H. de Araújo[c], F.A.O. Cabral[c], M.F. Ginani[d]

[a]Departamento de Física, Universidade do Estado do Rio Grande do Norte, 59633-010 Mossoró-RN, Brazil
[b]Departamento de Física, Universidade Federal de Pernambuco, 50670-901 Recife-PE, Brazil
[c]Departamento de Física Teórica e Experimental, Universidade Federal do Rio Grande do Norte, 59072-970 Natal-RN, Brazil
[d]Departamento de Química, Universidade Federal do Rio Grande do Norte, 59072-970 Natal-RN, Brazil

Available online 4 December 2006

Abstract

High purity $BaFe_{12}O_{19}$ samples were synthesized by an ionic-coordination-reaction (ICR) technique using chitosan as a complex agent. The mean size D_m of the particles and their magnetic properties were controlled by varying the concentration of chitosan in the starting solution. It was found that D_m, the coercive field H_C, and the Curie temperature T_C decrease when the concentration of chitosan is increased. In addition, the variation of H_C with D_m in these samples can be accounted for using the Stoner–Wolhfarth model. Finally, the magnetic field dependence of the transverse susceptibility were in good agreement with the theoretical predictions of Aharoni et al. [Bull. Res. Counc. Isr. A 6 (1957) 215. [1]].

PACS: 72.15.Gd; 75.50.Rr; 75.60.Jp

Keywords: Hexaferrites; Nanoparticles; Transverse susceptibility

1. Introduction

Interest in the structural and magnetic properties of barium hexaferrites has increased recently due to their potential in applications such as perpendicular magnetic recording [2]. Because of this, a large number of chemistry-based processing routes have been devised for obtaining fine particles of $BaFe_{12}O_{19}$. An important characteristic of these techniques is that the mixture of the materials occurs at an ionic level producing small particles at relatively low crystallization temperatures. In this work, we describe a new type of synthesis, based on the ionic-coordination-reaction (ICR) technique, that allows the production of ultra-fine single-domain particles of $BaFe_{12}O_{19}$ [3]. The structural and magnetic properties of the samples were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM) and magnetization measurements.

☆Supported by CNPq, FINEP, CAPES and FACEPE.
*Corresponding author. Tel.: +55 81 21268450; fax: +55 81 32710359.
E-mail address: flam@df.ufpe.br (F.L.A. Machado).

0304-8853/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2006.11.139

2. Experimental

A series of $BaFe_{12}O_{19}$ powders were prepared using the ICR technique [3]. Five grams of Ba nitrate, Fe nitrate and citric acid mixture ($Ba(NO_3)_2$:$Fe(NO_3)_3$:citric acid—2:23:50) was added to a volume V_{chit} of 2% chitosan biopolymer/5% acetic acid aqueous solution. The values of V_{chit} used were 0.05 L (sample A), 0.50 L (sample B) and 1.00 L (sample C). The resulting solution was burnt at ambient pressure for 4 h at 623 K to obtain the precursor powder. Then, the sample was calcinated at 1073 K for 1 h. The structural properties of the particles were characterized by XRD, using $Cu-K_\alpha$ radiation, and SEM. The magnetic properties of the samples were investigated using a vibrating sample magnetometer (VSM) and an AC-transverse susceptometer.

3. Results and discussion

XRD analysis showed that, within the limit of the technique, all the samples were single phase. The XRD pattern of sample A is shown in Fig. 1. For each sample the average crystallite size was obtained using the Rietveld X-ray refinement technique. The results are summarized in Table 1. It is observed that D_m decreases when the amount of chitosan is increased. This effect is related to the fact of that increasing V_{chit} also increases the amount of monomeric units capable of complexing metallic ions. A larger number of monomeric units allows the formation of more isolated clusters, impeding the nucleation of larger particles, in the burning process. The insets in Fig. 1 are SEM image and the corresponding number of particles as a function of D for sample A. The solid line corresponds to a lognormal function centered at 44 nm with a width of 0.144 and $D_m = 49$ nm. This value is close to the one obtained for the same sample using the X-ray refinement (51 nm). Moreover, the particles seen in the SEM are less than the single domain value of 900 nm. Thus, the results hold good irrespective of the particle size distribution.

From magnetic hysteresis measurements, it was found that the amount of chitosan affects not only the mean particle size but also the saturation magnetization M_S (= 57.8(A), 54.0(B) and 46.0(C) emu/g), the remanent magnetization M_R (= 32.2(A), 29.9(B) and 25.0 emu/g) and the coercivity H_C (see Table 1). The magnetic hysteresis loop for sample A is shown in the inset of Fig. 2. An additional parameter affected by V_{chit} is the Curie temperature T_C,

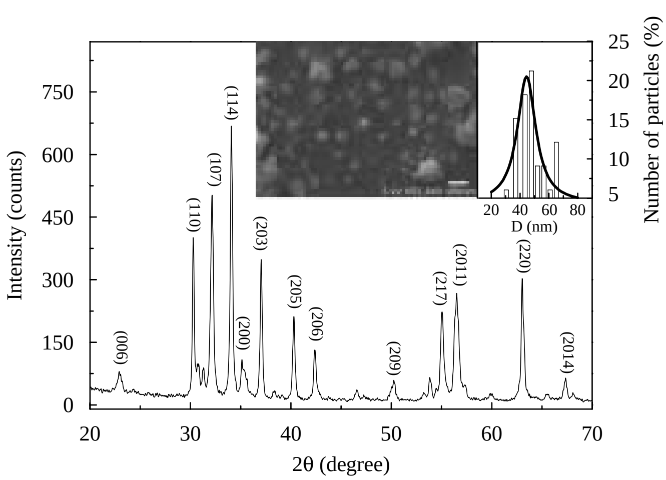

Fig. 1. X-ray pattern for sample A. The insets show the SEM image and the number of particles versus D obtained by direct counting from the SEM image (ignoring the agglomerated particles).

Table 1
Magnetic parameters for samples of $BaFe_{12}O_{19}$ prepared with different amounts of chitosan

V_{chit} (L)	D_m (nm)	H_C (kOe)	M_R/M_S	H_K (kOe)	T_C (K)
0.05(A)	51	5.02	0.55	11.7	718
0.50(B)	47	4.70	0.55	13.8	713
1.00(C)	36	4.54	0.54	13.2	705

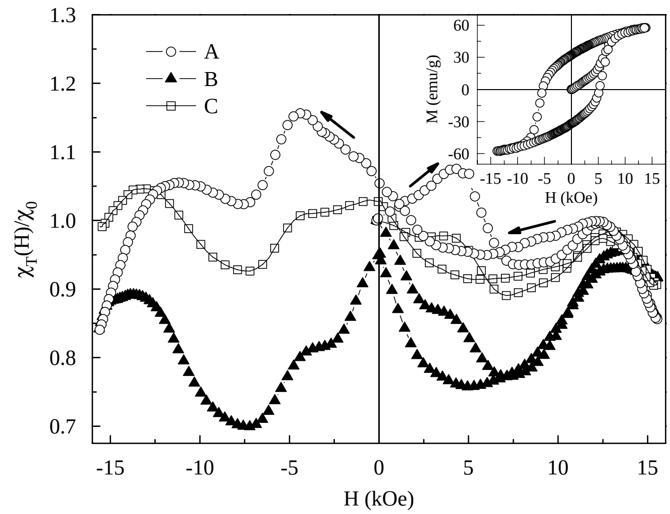

Fig. 2. Room temperature χ_T versus H data for the samples A, B, and C. The insets show the magnetic hysteresis loop for sample A.

obtained from the temperature dependence of the magnetic susceptibility, which decreases with increasing V_{chit} (see Table 1). The magnetic parameters are influenced by the size of the particles, which in turn are determined by the amount of chitosan. The observed variations in H_C, M_R/M_S, and T_C agree well with those expected for a system of randomly distributed single domain particles having positive uniaxial anisotropy [4].

Fig. 2 shows the transverse susceptibility χ_T versus H data for samples A, B, and C. The first part of the loop (H positive) shows two peaks for increasing values of H while for decreasing values of H a single peak is observed. However, for negative values of H two peaks are observed. The first peak should be located at H_C, and is in good agreement with the values H_C obtained using VSM. The maximum of the second peak is a measure of the anisotropy field H_K, and the results of these measurements are included in Table 1. The shape of the χ_T curves are in good agreement with the predictions of Aharoni et al. [1]. In their model, the χ_T versus H data for a system of randomly distributed single domain particles having positive uniaxial anisotropy show singularities located at the coercive and at the anisotropy fields. The shapes of the peaks differs from the singularities predicted by Aharoni et al. because they did not consider distribution of particle sizes.

4. Conclusions

The samples of $BaFe_{12}O_{19}$ prepared using the ICR technique showed a high degree of purity. It was observed that the magnetic parameters are influenced by the amount of chitosan present in starting solution. Moreover, the variation in the magnetic parameter with D_m agree well with those expected for a system of randomly distributed single-domain particles having positive uniaxial anisotropy, as proposed by current theoretical models.

References

[1] A. Aharoni, E.M. Frei, S. Shtrikman, D. Treves, Bull. Res. Counc. Isr. A 6 (1957) 215.
[2] T. Fujiwara, IEEE Trans. Magn. MAG-21 (1985) 1480.
[3] J.M. Soares, F.L.A. Machado, J.H. de Araújo, F.A.O. Cabral, H.A.B. Rodrigues, M.F. Ginani, Physica B 384 (2006) 85.
[4] E.C. Stoner, E.P. Wohlfarth, Philos. Trans. Soc. 240A (1948) 599.