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Synthesis of Zinc Ferrite Nanoparticles

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Abstract: Zinc ferrites have been prepared by conventional (Z1) method and mechanochemical processing (Z2) for comparing their structural properties. The X-ray diffraction (XRD) and transmission electron microscopy (TEM) is used to study on structural properties. The XRD pattern shows single phase of spinel ferrite structure. The average crystallite size estimated by using Scherrer's equation was 35 and 90 nm for Z2 and Z1 respectively. The XRD results shows lattice parameter of Z2 is larger than that of Z1, which has smaller particle size. It is attributed to the effect of the smaller particle size and interface structure with a larger volume fraction.

Key words:

INTRODUCTION

Zinc ferrite has long attracted researchers' interests because of its intriguing magnetic properties compared with other spinel ferrites. The traditional bulk $ZnFe_2O_4$ belongs to the normal spinel type with antiferromagnetic properties below the Néel temperature of about 10.5K and behaves paramagnetic at room temperature. All the Zn^{2+} ions reside in the tetrahedral sites (A sites) and the Fe^{3+} ions are totally in the octahedral sites (B sites). In 1961, Néel suggested that small antiferromagnetic particles can exhibit superparamagnetism and weak ferromagnetism due to uncompensated spins in the two sublattices [1]. In recent years, magnetic properties of many antiferromagnetic oxides, such as NiO [2, 3], MnO [4], CoO [5] and hematite [6,7], were experimentally studied. It was suggested that this might be resulted by the reduced coordination of the surface spins [2]. Recently, $ZnFe_2O_4$ nanoparticles prepared using various methods, such as traditional ceramic synthesis [11], aerogel procedure [9-13], low-temperature hydroxide coprecipitation and hydrothermal synthesis [13], have been studied and observed to be ferrimagnetic or superparamagnetic. The origin of the ferrimagnetic properties of $ZnFe_2O_4$ and other spinel ferrite nanoparticles was studied using low-temperature transmission Mossbauer spectrometer with applied magnetic field parallel to the direction of gamma rays [10, 11]. In this paper, $ZnFe_2O_4$ nanoparticles were synthesized by conventional method as well as ball milling are studied. Microstructures properties of the samples are studied using a X-ray diffraction, transmission electron microscopy (TEM).

Experimental Studies: In Conventional preparation *(Z1),* a dry mixture of ZnO and α-Fe_2O_3 is annealed at 1100°C; the progress of the formation of the ferrite is monitored by XRD analyses at different time intervals. The presence of octahedral zinc cation is observed along with the regular tetrahedral Zn in the sample that had undergone 30 minute heat treatment. After three hours of heating, pure normal zinc ferrite is formed. For ball milling preparation *(Z2),* commercial coarse-grained powder of $ZnFe_2O_4$ are milled in a high energy SPEX 8000D Mixer / Mill. In this method 5 g charges are sealed in a steel vial under an Ar atmosphere with two 11.5 mm diameter and four 6.2 mm steel balls, yielding a ball-to-power weight ratio of 3.5:1. X-ray diffraction (XRD) measurement was performed on a Philips X'Pert type diffractometer with Cu$K\alpha_1$ radiation to study the crystal structure and the phase composition. A JEOL 2000 FXII type transmission electron microscope (TEM) is used to observe the morphology and the size distribution of the nanoparticle samples.

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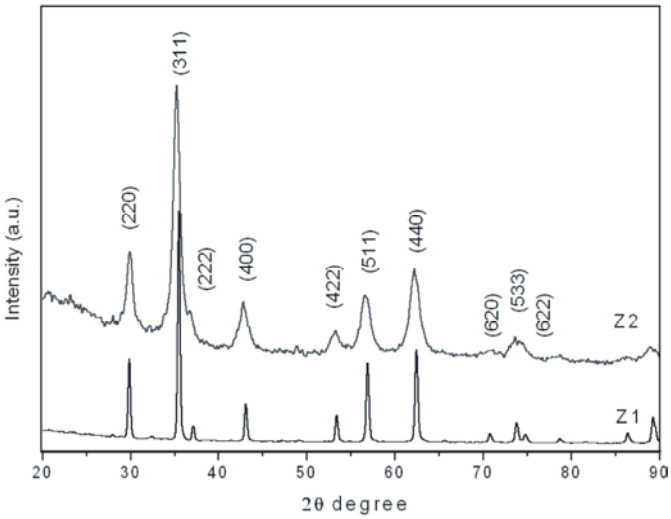

Fig. 1: XRD spectra of ZnFe2O4 nanoparticles produced under different processes.

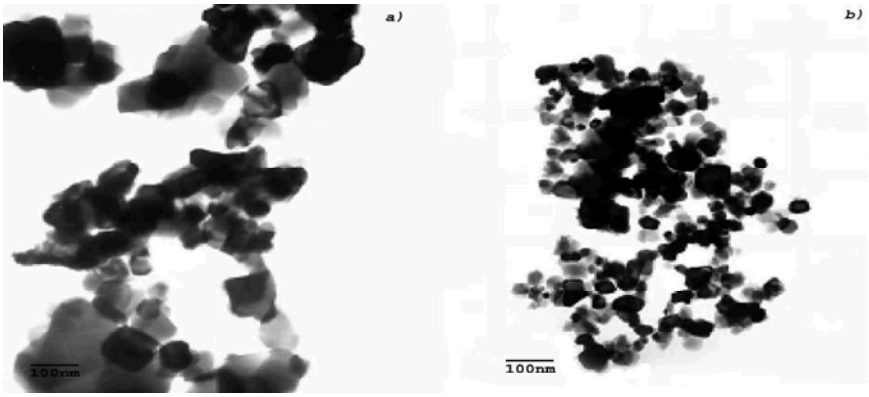

Fig. 2: TEM photographs of the samples a) Z1 and b) Z2.

RESULT AND DISCUSSION

The XRD spectra of the $ZnFe_2O_4$ nanoparticles prepared under different methods are shown in Fig. 1. All the main peaks fit well with those of the spinel structure for both of samples and there is no evidence of contamination from milling media for sample Z2. The average crystallite size of spinel phase has been estimated from the broadening of the XRD peaks using Scherrer's equation was 35 and 90 nm for Z2 and Z1 respectively. In Fig. 1 it may be noticed that X-ray line broadening of Z2 is more than Z1 which is due to size reduction effect of Z2. The lattice parameters obtained from the XRD results are attached in Table 1. The lattice parameter of Z2 is larger than that of Z1, which has smaller particle size. It may be caused by the smaller particle size and interface structure with a larger volume fraction.

Table 1: Lattice constant and average particle size of $ZnFe_2O_4$ nanoparticles prepared by different methods

	a(Å)	XRD (nm)	TEM (nm)
Z1	8.461	90	95
Z2	8.411	35	30

Fig. 2 shows the TEM photographs of the samples Z1 and Z2, with the average particle sizes of 90 and 35 nm, respectively, which are in agreement with the XRD results except for some agglomerated particles. These agglomerates can increase the magnetic interaction between particles and therefore may influence the magnetic properties of $ZnFe_2O_4$ nanoparticles.

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