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INSIGHTS INTO THE STRUCTURAL AND MAGNETIC PROPERTIES OF CHROMIUM FERRITE NANOPARTICLES

[1]VELPULA VENKATESWARLU,[2]DHARMARAJULA NAGARANI,[3]K. VAMSHI

[12]Assistant Professor,[3]Student

Department of H&S Engineering

Abdul Kalam Institute of Technological Sciences,Kothagudem,Telangana

ABSTRACT

The traditional method of wet chemical co-precipitation has been used to produce pure chromium nanoparticles with the general formula CrFe2O4. The prepared sample was annealed at 600 0C for four hours. X-ray diffraction patterns at room temperature were obtained for the produced sample to confirm the formation of a single-phase cubic spinel structure. Scanning electron microscopy examinations were conducted on produced samples to investigate the surface morphology. The XRD and SEM measurements show that the particles are in the nanometer range in size. The lattice constant's stated range was satisfied. Utilising the pulse field hysteresis loop method, the magnetic properties were examined. The levels of saturation magnetization and coercivity were found to be higher than those in bulk.

Keywords: X-ray diffraction, nanoparticles, lattice constant, and chemical co-precipitation

1. Introduction

In the recent years ferrites having high electrical resistivity, low eddy current loss, structural stability, large permeability at high frequency, high coercivity, high cubic magneto crystalline anisotropy, good mechanical hardness, and chemical stability, nanosized spinel-type ferrites have emerged as an important class of nanomaterials.[1,2]As a result, research devoted to the development and characterization of such nanomaterials, the development of cost-effective, environmentally friendly synthesis processes, and the discovery of novel uses for existing materials has gained a great deal of interest. MFe2O4 type spinel ferrite attracts several researchers because of their twin property of magnetic conductor and electric insulator. These materials are widely used in the electronic and electrical industries for the fabrication of devices and components such as high-density magnetic core of read/ write for the high-speed tapes etc.[2,3]

In recent years there has been considerable interest in the study of the properties of nano-sized ferrite particles because of their importance in the fundamental understanding of the physical properties as well as to their proposed applications for many technological purposes.[4,5] The unique properties of nanoparticles are in general related to the adoption of materials, crystal structure to a small (nano size) and large surface to volume ratio.

Among the several spinel ferrites Chromium ferrite is an interesting ferrite because it crystallizes either in a tetragonal or cubic symmetry depending on the cation distribution among the interstitial site of a spinel structure.[6,7] The other interesting feature of Chromium ferrite is that it contains Jahn Teller ion which is responsible for interesting electrical and magnetic properties. In bulk form, Chromium ferrite is a magnetic compound useful in many technological applications.[8] They can also be prepared by techniques such as wet chemical co-precipitation,[9] sol-gel[10], hydrothermal synthesis[11] or microwave emulsion[12] at nanoscale, that can be employed in important applications such as ferro- fluid technology,[13] magnetically guided drug delivery.[14] The magnetic properties of spinel ferrite originate from the antiferromagnetic coupling between the octahedral and tetrahedral sub lattices. The magnetization results from the difference between the magnetization of tetrahedral (A) and octahedral [B] sites. The structural, electrical and magnetic properties of chromium substituted Chromium ferrite prepared in bulk form have been reported in the literature.[15,16] However, the structural and magnetic properties of Chromium ferrite prepared by wet chemical co-precipitation method are not reported in the literature.

In this study, we report our results on structural and magnetic properties of pure Chromium ferrite nanoparticles obtained by wet chemical co-precipitation method.

2. Experimental

The sample of $CrFe_2O_4$ spinel ferrite was prepared by wet chemical co-precipitation technique. The details of synthesis method have been discussed in our previous reports.[17] The structural characterization was made through X-ray diffraction technique in the 2□ range of 20^0 - 80^0. The XRD pattern was recorded at room temperature using Cr-Kα λ=1.521 A^0 radiation. Microstructural studies including evaluation of a particle size were conducted using a JEOL – JS scanning electron microscope. The magnetic measurements were carried out at room temperature using pulse field magnetic hysteresis loop tracer.

Results and discussion

Structural Analysis

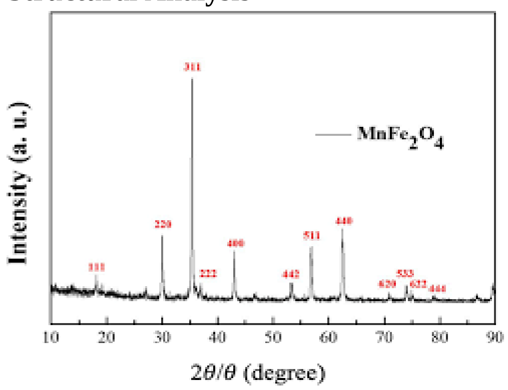

Fig.1: X-ray Fig.1 shows the X-ray diffraction (XRD) pattern of $CrFe_2O_4$ nanoparticles

All the Bragg reflections have been indexed, which confirms the formation of cubic spinel structure in single phase. Bragg's reflections are found to be sharp and intense. The values of lattice parameter calculated from interplanar spacing (d) values and Miller indices are given in table 1. The value of lattice parameter is found to be 9.214 Å. The present value of lattice parameter of Chromium ferrite is in good agreement with the reported value.[18-21] The average crystallite size was determined from the measured width of the diffraction using Scherrer formula.[21] The particle size obtained from XRD data is found to be 36 nm.

Table.1: Lattice constant, X-ray density and crystallite size from XRD data

Structural parameters	Values
Lattice constant (a)	9.214 AU
X-Ray density (? x)	5.241 g/cm^3
Crystallite Size (t)	36 nm

Scanning electron micrograph (SEM) of the prepared sample is shown in above Fig. 2. It can be observed that the grains are in nano-meter range. The micrograph reveals dense microstructure with developed grains along with few pores.

Magnetic Properties Study

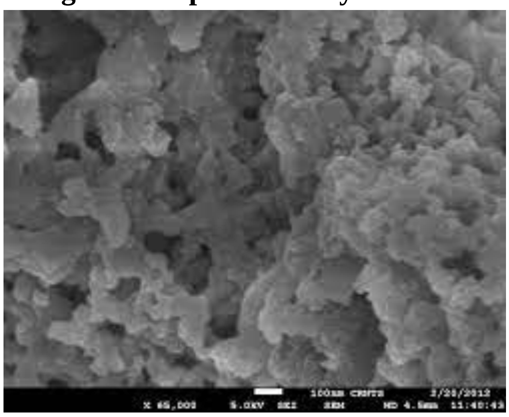

Fig. 2 shows the magnetization versus field image plot of $CrFe_2O_4$ nanoparticles.

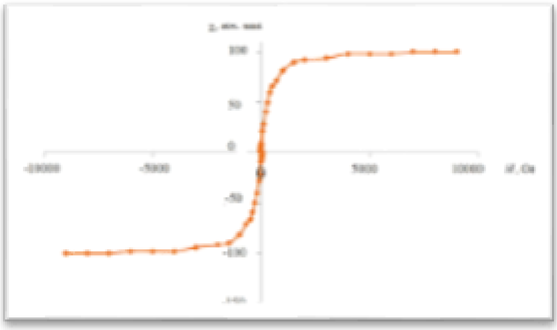

Fig. 3: Hysteresis loop for CrFe2O4 nanoparticles

These plots are used to evaluate saturation magnetization (Ms), remanence magnetization (Mr) and coercivity (Hc). The values of these magnetic parameters are given in table 4. The saturation magnetization values (Ms) are used to calculate magneton number nB are given in table 4. The observed variation in magneton number was also studied by Neel's theory.[22-26]According to Neel's theory the magneton number is the difference of magnetic moment of B sub lattice and A sub lattice respectively, The calculated value of magneton number is also given in table 2. nB = MB – MA

Table 2: Magnetic parameters of CrFe2O4

Magnetization parameters			Magneton number '? B'(? B)	
Mr (emu/gm)	Ms (emu/gm)	Hc (Oe)	Cal.	Obs.
20.14	45.21	221.35	1.2	0.98

Conclusions

The wet chemical co-precipitation process was effectively used to produce chromium ferrite (CrFe2O4) nanoparticles. X-ray diffraction was used to confirm that the chromium spinel ferrite system formed in a single phase. The range reported for the lattice constant was met. Saturation, remanence magnetization, and coercivity values are elevated and exhibit ferrimagnetic nature.

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