EXPLORING THE STRUCTURAL AND MAGNETIC CHARACTERISTICS OF CHROMIUM FERRITE NANOPARTICLES: A COMPREHENSIVE ANALYSIS

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ABSTRACT
Pure chromium nanoparticles with the general formula CrFe2O4 have been produced using the conventional wet chemical co-precipitation process. For four hours, the prepared sample was annealed at 600 0C. The generated sample's room-temperature X-ray diffraction patterns were acquired to verify the creation of a single-phase cubic spinel structure. The surface morphology of the manufactured samples was examined using scanning electron microscopy. The results of the XRD and SEM examinations indicate that the particles' sizes are in the nanometer range. The specified range of the lattice constant was met. The magnetic characteristics were investigated by means of the pulse field hysteresis loop approach. It was discovered that the coercivity and saturation magnetization were greater than those in bulk.
Keywords: chemical co-precipitation, lattice constant, nanoparticles, and X-ray diffraction
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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 spinelferrite attracts several researchers because of their twin property ofmagnetic conductor and electric insulator. These materials are widely used in the electronic andelectrical industries for the fabrication of devices and components such as high-density magnetic coreofread/writeforthehigh-speedtapes etc.[2,3]

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

Among the several spinel ferrites Chromium ferrite is an interesting ferrite because it crystallizeseither in a tetragonal or cubic symmetry depending on the cation distribution among the interstitial siteof a spinel structure.[6,7]The other interesting feature of Chromium ferrite is that it contains Jahn Tellerion which is responsible for interesting electrical and magnetic properties. In bulk form, Chromium ferriteis a magnetic compound useful in many technological applications.[8] They can also be prepared bytechniques such as wet chemical co-precipitation,[9] sol-gel[10], hydrothermal synthesis[11] ormicrowave emulsion[12] at nanoscale, that can be employed in important applications such as ferro-fluidtechnology,[13]magneticallyguideddrugdelivery.[14] The magnetic properties of spinel ferriteoriginate from the antiferromagnetic coupling between the octahedral and tetrahedral sub lattices. Themagnetization results from the difference between the magnetization of tetrahedral(A) and octahedral [B] sites. The structural, electrical and magnetic properties of chromium substituted Chromium ferritepreparedinbulkformhavebeenreportedintheliterature.[15,16]However,thestructuraland magneticproperties of Chromium ferrite prepared by wet chemical co-precipitation method are not reported in theliterature.

In this study, we report our results on structural and magnetic properties of pure Chromium ferritenanoparticlesobtained bywetchemical 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 structuralcharacterization was made through X-ray diffraction technique in the 2⍰ range of 20^0 - 80^0. The XRDpatternwasrecordedatroom temperatureusingCr-Kαλ=1.521A^{0}radiation.Microstructuralstudies including evaluation of a particle size were conducted using a JEOL – JS scanning electronmicroscope. The magnetic measurements were carried out at room temperature using pulse field magnetic hysteresis loop tracer.

Resultsanddiscussion

StructuralAnalysis

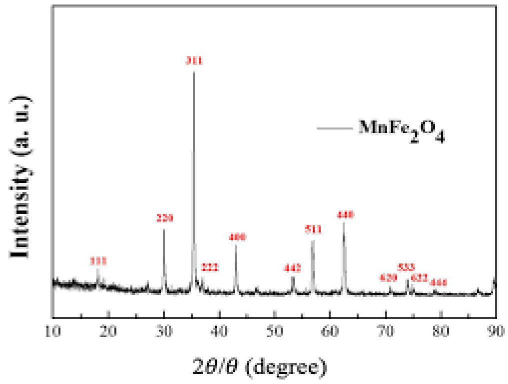

Fig.1: X-ray Fig.1 shows the X-ray diffraction (XRD) pattern of $CrFe_2O_4$ nanoparticles

All the Bragg reflections have been indexed, which confirms the formation of cubic spinelstructureinsinglephase.Bragg'sreflectionsarefoundtobesharpandintense.Thevaluesof latticeparameter calculated from interplanar spacing (d) values and Miller indices are given in table 1. The value of lattice parameter is found to be 9.214Å. The present value of lattice parameter of Chromium ferrite is in good agreement with the reported value.[18-21] Theaveragecrystallitesizewasdeterminedfrom themeasuredwidthofthediffractionusingSchererformula.[21] The particle size obtained from XRD data is found to be36 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

Scanningelectronmicrograph(SEM)oftheprepared sampleisshowninaboveFig.2. Itcanbeobservedthatthegrainsareinnano-meterrange.Themicrographrevealsdensemicrostructurewith developed grains along withfewpores.

MagneticProperties Study

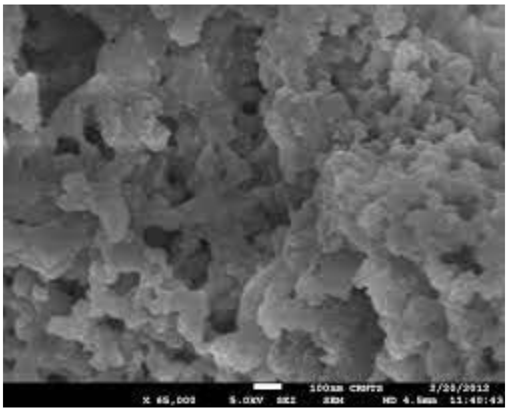

Fig.2 shows the magnetization versus field image plot of $CrFe_2O_4$ nanoparticles.

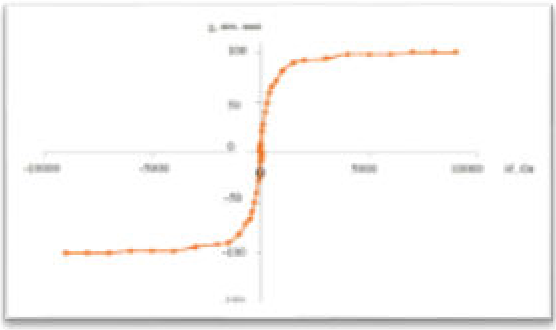

Fig.3:Hysteresis loop for $CrFe_2O_4$ nanoparticles

Theseplotsareusedtoevaluatesaturationmagnetization(Ms),remanencemagnetization(Mr)and coercivity (Hc). The values of these magnetic parameters are given in table 4. The saturationmagnetizationvalues(Ms)areusedtocalculatemagnetonnumbernBaregivenintable4.Theobservedvariation in magneton number was also studied by Neel's theory.[22-26]According to Neel's theory themagnetonnumberisthedifferenceofmagnetic moment ofBsublatticeand Asublatticerespectively, Thecalculated valueofmagnetonnumber isalsogiven intable 2. $n_B = M_B - M_A$

Table 2: Magnetic parameters of $CrFe_2O_4$

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

Chromium ferrite ($CrFe_2O_4$) nanoparticles were successfully made using the wet chemical co-precipitation method. The single-phase formation of the chromium spinel ferrite system was verified by X-ray diffraction. The lattice constant's stated range was satisfied. Elevated saturation, remanence magnetization, and coercivity values demonstrate the ferrimagnetic character of the material.

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