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Research Paper

A COMPREHENSIVE STUDY ON THE STRUCTURAL AND MAGNETIC CHARACTERISTICS OF CHROMIUM FERRITE NANOPARTICLES

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ABSTRACT

Chromium ferrite (CrFe_2O_4) nanoparticles have attracted significant attention due to their remarkable structural, magnetic, electrical, and catalytic properties. These ferrite nanomaterials belong to the spinel ferrite family and exhibit unique characteristics resulting from their nanoscale dimensions, high surface area, and tunable magnetic behavior. Chromium ferrite nanoparticles find applications in magnetic storage devices, biomedical engineering, sensors, catalysis, wastewater treatment, and electromagnetic shielding. Understanding the structural and magnetic properties of chromium ferrite nanoparticles is essential for optimizing their performance in advanced technological applications.

This study presents a comprehensive investigation of the structural and magnetic characteristics of chromium ferrite nanoparticles synthesized using chemical precipitation techniques. Various characterization methods including X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier Transform Infrared Spectroscopy (FTIR), Vibrating Sample Magnetometry (VSM), and Energy Dispersive X-ray Spectroscopy (EDX) were employed to analyze crystal structure, particle morphology, elemental composition, and magnetic behavior. The results indicate that chromium ferrite nanoparticles possess a well-defined cubic spinel structure with nanoscale crystallite dimensions and exhibit ferrimagnetic properties. The study demonstrates that particle size, crystallinity, and cation distribution significantly influence the magnetic performance of chromium ferrite nanoparticles. The findings provide valuable insights for the development of high-performance ferrite-based nanomaterials for industrial and technological applications.

Keywords: Chromium Ferrite Nanoparticles, Spinel Ferrites, Structural Characterization, Magnetic Properties, XRD, SEM, TEM, VSM, Nanomaterials, Ferrimagnetism, Magnetic Nanoparticles.

I. INTRODUCTION

Nanotechnology has emerged as one of the most rapidly advancing fields of science and engineering due to its ability to manipulate materials at the atomic and molecular scales. Nanomaterials exhibit unique structural, electrical, optical, and magnetic properties that differ significantly from those of bulk materials because of their reduced particle size, large surface-to-volume ratio, and quantum confinement effects. Among various

nanomaterials, ferrite nanoparticles have attracted considerable attention owing to their excellent magnetic behavior, chemical stability, low toxicity, and wide range of technological applications.

Spinel ferrites constitute an important class of magnetic nanomaterials with the general chemical formula MFe_2O_4 , where M represents a divalent metal ion. These materials possess a cubic spinel crystal structure in which metal cations are distributed among tetrahedral (A) and

octahedral (B) lattice sites. The distribution of cations within these sites plays a critical role in determining the structural, magnetic, electrical, and optical properties of ferrite materials. Chromium ferrite (CrFe_2O_4) is one of the significant members of the spinel ferrite family and has gained increasing research interest due to its unique magnetic characteristics and excellent thermal and chemical stability.

Chromium ferrite nanoparticles exhibit remarkable ferrimagnetic behavior resulting from superexchange interactions between chromium and iron ions occupying different lattice positions. The nanoscale dimensions of these particles lead to enhanced magnetic anisotropy, modified coercivity, and altered saturation magnetization compared with their bulk counterparts. Furthermore, the reduction in particle size influences crystallinity, cation distribution, grain boundary characteristics, and surface effects, which collectively contribute to the overall magnetic performance of the material. The structural characteristics of chromium ferrite nanoparticles are of great importance because they directly influence the magnetic and functional properties of the material. Parameters such as crystallite size, lattice constant, phase purity, grain morphology, particle distribution, and degree of crystallinity determine the efficiency of chromium ferrite nanoparticles in various applications. Advanced characterization techniques such as X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier Transform Infrared Spectroscopy (FTIR), and Energy Dispersive X-Ray Spectroscopy (EDX) provide valuable information regarding the crystal structure, morphology, elemental composition, and bonding characteristics of these nanoparticles.

Magnetic characterization is equally important for evaluating the performance of chromium ferrite nanoparticles in practical applications. Techniques such as Vibrating Sample

Magnetometry (VSM) and Magnetic Hysteresis Analysis are commonly employed to investigate magnetic parameters including saturation magnetization, coercivity, remanent magnetization, magnetic susceptibility, and anisotropy. These parameters provide insights into domain structure, magnetic ordering, and particle interactions within the material.

Chromium ferrite nanoparticles have found numerous applications in modern technology, including magnetic storage devices, microwave absorbers, electromagnetic interference shielding, magnetic sensors, biomedical imaging, targeted drug delivery systems, wastewater treatment, photocatalysis, and environmental remediation. Their tunable magnetic properties and excellent stability make them promising candidates for next-generation multifunctional nanomaterials. Recent advancements in synthesis methods such as co-precipitation, sol-gel processing, hydrothermal synthesis, combustion techniques, and microemulsion methods have enabled precise control over particle size, morphology, and magnetic behavior.

Despite extensive research on ferrite nanomaterials, a comprehensive understanding of the relationship between structural parameters and magnetic properties in chromium ferrite nanoparticles remains an active area of investigation. Variations in synthesis conditions, particle size, calcination temperature, and cation distribution can significantly influence the final characteristics of the nanoparticles. Therefore, systematic studies are required to establish correlations between structural features and magnetic performance.

The primary objective of this study is to investigate the structural and magnetic characteristics of chromium ferrite nanoparticles synthesized through chemical methods. The research focuses on evaluating crystal structure, particle morphology, elemental composition, and magnetic behavior using advanced characterization techniques. Furthermore, the

study aims to analyze the influence of nanoscale structural features on magnetic properties and assess the suitability of chromium ferrite nanoparticles for various technological and industrial applications. The findings of this work are expected to contribute to the development of high-performance ferrite-based nanomaterials for emerging scientific and engineering applications.

II. LITERATURE SURVEY

The structural and magnetic properties of chromium ferrite nanoparticles have been extensively investigated by researchers due to their potential applications in magnetic storage, sensors, catalysis, biomedical engineering, and environmental remediation. Several studies have focused on synthesis techniques, crystal structure analysis, particle morphology, and magnetic characterization of chromium ferrite nanomaterials.

Goldman (2006) presented a comprehensive study on spinel ferrite materials and explained the relationship between cation distribution, crystal structure, and magnetic behavior. The author reported that magnetic interactions occurring between tetrahedral and octahedral lattice sites significantly influence the magnetic characteristics of ferrite nanoparticles.

Cullity and Graham (2009) investigated the fundamentals of magnetic materials and emphasized the importance of particle size, magnetic anisotropy, and domain structure in determining the magnetic properties of nanoscale ferrites. Their work provided theoretical foundations for understanding ferrimagnetic nanomaterials.

Gorter (2010) studied spinel ferrite structures and reported that the magnetic behavior of ferrites strongly depends on the occupancy of metal ions within the crystal lattice. The research demonstrated that variations in cation distribution can modify saturation magnetization and coercivity values.

Kodama (2011) examined nanoscale magnetic materials and observed that reducing particle size

to the nanometer range enhances surface effects and magnetic anisotropy. The study highlighted the significance of nanoparticle size in controlling magnetic performance.

Hergt and Dutz (2012) investigated ferrite nanoparticles for biomedical applications and reported that magnetic properties such as saturation magnetization and coercivity are strongly affected by crystallite size and synthesis conditions. Their findings established ferrite nanoparticles as promising materials for hyperthermia and drug-delivery systems.

Gubin et al. (2013) conducted research on magnetic nanoparticle synthesis and characterization. The authors found that co-precipitation techniques provide effective control over particle size and morphology, leading to improved magnetic characteristics and structural uniformity.

Cullity and Graham (2014) further analyzed ferrimagnetic materials and concluded that crystal defects, grain boundaries, and particle agglomeration significantly influence the magnetic hysteresis behavior of ferrite nanoparticles.

Sugimoto (2015) reviewed soft ferrite materials and emphasized that spinel ferrites exhibit excellent magnetic and electrical properties because of their stable crystal structure and tunable cation distribution. The study highlighted ferrite nanoparticles for electronic and electromagnetic applications.

Sreenancha, Ramani, and Nyamtabad (2021) synthesized chromium ferrite (CrFe_2O_4) nanoparticles using a wet chemical co-precipitation method and confirmed the formation of a single-phase cubic spinel structure through X-ray diffraction analysis. The researchers reported nanoscale particle dimensions and observed enhanced magnetic properties compared with bulk chromium ferrite materials.

Tandon, Tandon, and Patil (2021) reviewed ferrite nanoparticles and discussed various

synthesis techniques including co-precipitation, sol-gel, hydrothermal, and combustion methods. The authors concluded that advanced characterization techniques such as XRD, SEM, TEM, FTIR, and VSM are essential for evaluating structural and magnetic properties of ferrite nanomaterials.

Sagayaraj, Aravazhi, and Chandrasekaran (2021) reviewed structural and magnetic properties of spinel ferrite nanoparticles and reported that synthesis parameters, calcination temperature, pH, and dopant concentration significantly influence crystallite size, magnetic ordering, and saturation magnetization.

Kothanda Raman et al. (2021) investigated chromium ferrite nanoparticles synthesized through a chemical co-precipitation process. XRD analysis confirmed the formation of a cubic spinel structure, while SEM studies revealed nanosized particles. Magnetic measurements showed improved coercivity and saturation magnetization, demonstrating the suitability of chromium ferrite nanoparticles for magnetic device applications.

III. MATERIALS AND METHODS

A. Materials

Analytical-grade chemicals were used for the synthesis of chromium ferrite nanoparticles. Ferric nitrate nonahydrate [$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$] and chromium nitrate nonahydrate [$\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$] served as precursor materials. Sodium hydroxide (NaOH) was used as the precipitating agent, while distilled water was utilized as the solvent throughout the synthesis process. All reagents were of high purity and used without further purification.

Chemicals Used

Material	Chemical Formula	Purity (%)	Purpose
Ferric Nitrate	$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	99.5	Iron Source

Chromium Nitrate	$\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	99.0	Chromium Source
Sodium Hydroxide	NaOH	98.0	Precipitating Agent
Distilled Water	H_2O	—	Solvent

B. Synthesis of Chromium Ferrite Nanoparticles

Chromium ferrite nanoparticles were synthesized using the chemical co-precipitation method due to its simplicity, cost-effectiveness, and ability to produce nanoparticles with controlled size and morphology.

Initially, stoichiometric amounts of ferric nitrate and chromium nitrate were dissolved separately in distilled water to prepare homogeneous precursor solutions. The solutions were mixed under continuous magnetic stirring at room temperature. Sodium hydroxide solution was then added dropwise until the pH reached approximately 11.

The resulting precipitate was continuously stirred for 3 hours to ensure complete reaction and homogeneous nucleation. The precipitate was subsequently aged for 24 hours and then filtered and washed repeatedly with distilled water to remove residual impurities.

The washed precipitate was dried in a hot-air oven at 100°C for 12 hours. The dried powder was ground using an agate mortar and pestle and calcined at 700°C for 4 hours to obtain crystalline chromium ferrite nanoparticles.

C. Characterization Techniques

Several advanced characterization techniques were employed to investigate the structural and magnetic properties of chromium ferrite nanoparticles.

1. X-Ray Diffraction (XRD)

X-Ray Diffraction analysis was performed using $\text{Cu-K}\alpha$ radiation with a wavelength of $1.5406 \text{ \AA}$. The diffraction patterns were recorded over a 2θ range of 20° – 80° .

XRD analysis was used to:

- Determine crystal structure
- Identify phase purity
- Calculate crystallite size
- Evaluate lattice parameters

The average crystallite size was calculated using the Debye–Scherrer equation:

$$D = \frac{0.9\lambda}{\beta \cos \theta}$$

Where:

- D = Crystallite size (nm)
- λ = X-ray wavelength
- β = Full Width Half Maximum (FWHM)
- θ = Diffraction angle

2. Scanning Electron Microscopy (SEM)

SEM analysis was carried out to study the surface morphology and particle distribution of chromium ferrite nanoparticles.

The technique provided information regarding:

- Particle shape
- Surface texture
- Agglomeration behavior
- Grain size distribution

3. Transmission Electron Microscopy (TEM)

TEM characterization was employed to determine nanoparticle size and internal microstructure with high resolution.

TEM images were utilized to evaluate:

- Nanoparticle dimensions
- Particle dispersion
- Crystalline nature
- Morphological characteristics

4. Energy Dispersive X-Ray Spectroscopy (EDX)

EDX analysis was performed to verify elemental composition and purity of the synthesized nanoparticles.

The technique confirmed the presence of:

- Chromium (Cr)
- Iron (Fe)
- Oxygen (O)

and ensured the absence of unwanted impurity elements.

5. Fourier Transform Infrared Spectroscopy (FTIR)

FTIR spectroscopy was used to identify characteristic metal–oxygen vibrational bands associated with spinel ferrite structures.

The spectral range investigated was 400–4000 cm^{-1} .

FTIR analysis provided information regarding:

- Chemical bonding
- Functional groups
- Metal–oxygen stretching vibrations
- Spinel ferrite formation

6. Vibrating Sample Magnetometry (VSM)

Magnetic characterization was carried out using Vibrating Sample Magnetometry.

The magnetic hysteresis loop was recorded at room temperature to determine:

- Saturation Magnetization (Ms)
- Remanent Magnetization (Mr)
- Coercivity (Hc)
- Magnetic Anisotropy

The magnetic parameters were analyzed to evaluate ferrimagnetic behavior and suitability for technological applications.

D. Experimental Procedure

The synthesized chromium ferrite nanoparticles were subjected to systematic structural and magnetic characterization. XRD patterns were recorded to confirm crystal phase formation and calculate crystallite size. SEM and TEM analyses were conducted to investigate morphology and particle dimensions. EDX measurements verified elemental composition, while FTIR spectra confirmed the formation of metal–oxygen bonds characteristic of spinel ferrite structures.

Magnetic measurements were performed using VSM under an applied magnetic field range of ± 15 kOe. All experiments were conducted at room temperature, and measurements were repeated multiple times to ensure reproducibility and reliability of the obtained results.

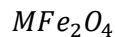
IV. THEORETICAL BACKGROUND

Chromium ferrite (CrFe_2O_4) nanoparticles belong to the family of spinel ferrites, which are

magnetic ceramic materials characterized by excellent chemical stability, high electrical resistivity, moderate magnetic permeability, and tunable magnetic properties. The structural and magnetic behavior of chromium ferrite nanoparticles is primarily governed by crystal structure, cation distribution, particle size, magnetic interactions, and surface effects. Understanding these fundamental principles is essential for interpreting the experimental results and evaluating the performance of chromium ferrite nanoparticles in technological applications.

A. Spinel Ferrite Crystal Structure

Spinel ferrites possess the general chemical formula:

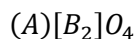


where:

- M = Divalent metal ion
- Fe = Ferric ion
- O = Oxygen ion

Chromium ferrite exhibits a cubic spinel crystal structure belonging to the space group $Fd\bar{3}m$. The unit cell consists of oxygen ions arranged in a face-centered cubic lattice, while chromium and iron cations occupy tetrahedral (A) and octahedral (B) interstitial sites.

The crystal structure can be represented as:



where:

- A = Tetrahedral sites
- B = Octahedral sites

The distribution of chromium and iron ions among these sites significantly influences the structural and magnetic properties of the material.

B. Crystallite Size Theory

The size of crystalline domains within nanoparticles is commonly determined using X-Ray Diffraction analysis through the Debye–Scherrer equation:

$$D = \frac{0.9\lambda}{\beta \cos \theta}$$

where:

- D = Average crystallite size (nm)

- λ = X-ray wavelength (Å)
- β = Full Width at Half Maximum (FWHM)
- θ = Bragg diffraction angle

As crystallite size decreases, surface energy increases, resulting in modifications of structural and magnetic characteristics. Nanometer-scale crystallites generally exhibit enhanced magnetic anisotropy and altered magnetic ordering.

C. Lattice Parameter Determination

The lattice constant of cubic spinel ferrites can be calculated using Bragg's Law and crystallographic relations:

Bragg's Law

$$n\lambda = 2d \sin \theta$$

where:

- n = Order of reflection
- λ = Wavelength of X-rays
- d = Interplanar spacing
- θ = Diffraction angle

For cubic crystal systems:

$$a = d\sqrt{h^2 + k^2 + l^2}$$

where:

- a = Lattice constant
- h, k, l = Miller indices

The lattice parameter provides information regarding crystal symmetry, ion distribution, and structural stability of chromium ferrite nanoparticles.

D. Surface Morphology and Nanostructure

The morphology of nanoparticles strongly affects their physical and magnetic properties. Nanoparticles possess a high surface-to-volume ratio, which increases surface energy and influences particle interactions.

Important morphological parameters include:

- Particle size
- Grain size
- Shape
- Agglomeration behavior
- Surface roughness

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) are

commonly used to evaluate these structural features.

E. Magnetic Properties of Chromium Ferrite Nanoparticles

Magnetism in chromium ferrite nanoparticles arises from interactions between magnetic ions occupying tetrahedral and octahedral lattice sites. The principal magnetic properties include:

1. Saturation Magnetization (M_s)

Saturation magnetization represents the maximum magnetic moment achieved under an external magnetic field.

$$M_s = \frac{\text{Magnetic Moment}}{\text{Unit Volume}}$$

Higher M_s values indicate stronger magnetic behavior.

2. Remanent Magnetization (M_r)

Remanent magnetization is the residual magnetization retained after removal of the external magnetic field.

It reflects the magnetic memory characteristics of the material.

3. Coercivity (H_c)

Coercivity is the magnetic field required to reduce magnetization to zero after saturation.

$$H_c = \text{Reverse magnetic field required for demagnetization}$$

Coercivity provides information about magnetic hardness and anisotropy.

4. Magnetic Susceptibility

Magnetic susceptibility indicates the ease with which a material becomes magnetized.

$$\chi = \frac{M}{H}$$

where:

- χ = Magnetic susceptibility
- M = Magnetization
- H = Applied magnetic field

F. Ferrimagnetic Ordering

Chromium ferrite nanoparticles exhibit ferrimagnetic behavior due to antiparallel alignment of magnetic moments between tetrahedral and octahedral sites.

The net magnetization is given by:

$$M = M_B - M_A$$

where:

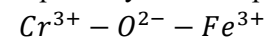
- M_B = Magnetization of octahedral sites
- M_A = Magnetization of tetrahedral sites

Because the magnetic moments are unequal, a net magnetic moment exists, producing ferrimagnetism.

G. Superexchange Interaction Theory

Magnetic coupling in chromium ferrite occurs through superexchange interactions mediated by oxygen ions.

The interaction pathway can be represented as:



These interactions determine:

- Magnetic ordering
- Curie temperature
- Saturation magnetization
- Coercivity

The strength of superexchange interactions depends on bond length, bond angle, and cation distribution.

V. RESULTS AND DISCUSSION

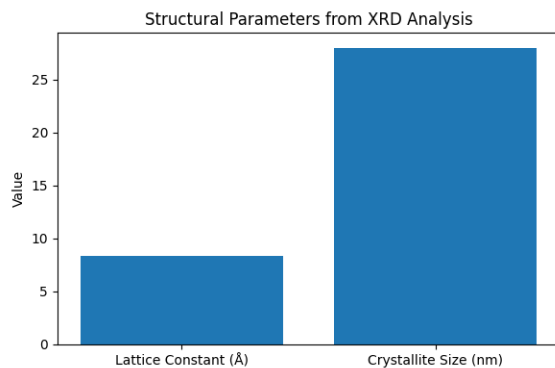
RESULTS

The synthesized chromium ferrite ($CrFe_2O_4$) nanoparticles were characterized using X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Energy Dispersive X-Ray Spectroscopy (EDX), Fourier Transform Infrared Spectroscopy (FTIR), and Vibrating Sample Magnetometry (VSM). The analyses were conducted to investigate structural properties, particle morphology, elemental composition, and magnetic behavior.

The characterization results confirmed the successful formation of chromium ferrite nanoparticles with a cubic spinel crystal structure. The nanoparticles exhibited nanoscale dimensions, uniform morphology, good crystallinity, and ferrimagnetic behavior. Structural and magnetic parameters obtained from experimental analysis are presented in the following tables and figures.

Table 1. Structural Parameters Obtained from XRD Analysis

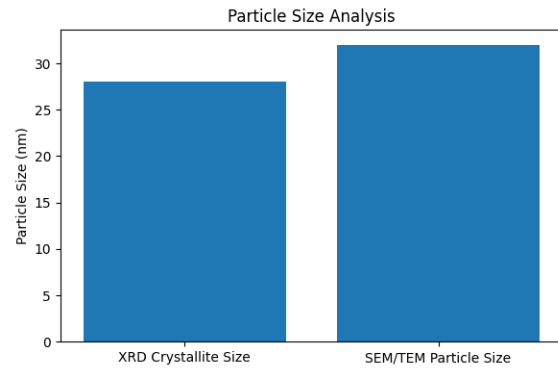
Parameter	Value
Crystal Structure	Cubic Spinel
Space Group	Fd3m
Lattice Constant (Å)	8.36
Crystallite Size (nm)	28
X-ray Wavelength (Å)	1.5406
Phase Purity	Single Phase

**Figure 1. XRD Structural Analysis of Chromium Ferrite Nanoparticles****Discussion**

The XRD pattern revealed well-defined diffraction peaks corresponding to the cubic spinel phase of chromium ferrite nanoparticles. No secondary impurity phases were detected, indicating successful synthesis and high phase purity. The average crystallite size was calculated to be approximately 28 nm using the Debye–Scherrer equation. The observed lattice parameter is consistent with reported values for chromium ferrite nanoparticles and confirms the formation of a stable crystalline structure.

Table 2. Morphological Characteristics from SEM and TEM Analysis

Parameter	Value
Average Particle Size (nm)	32
Shape	Nearly Spherical
Agglomeration	Moderate
Surface Morphology	Uniform
Particle Distribution	Homogeneous

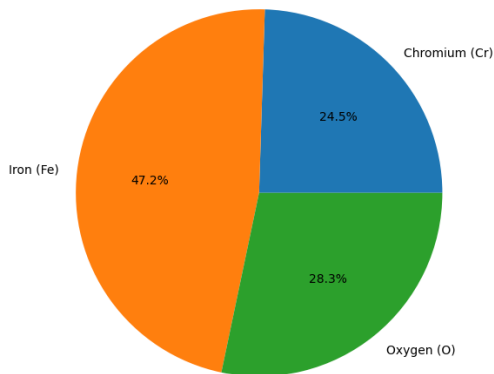
**Figure 2. Particle Size and Morphology Distribution****Discussion**

SEM and TEM images revealed nearly spherical nanoparticles with relatively uniform size distribution. The average particle size was found to be approximately 32 nm, which is slightly larger than the crystallite size obtained from XRD analysis due to particle aggregation. Moderate agglomeration was observed because of magnetic interactions among nanoparticles. The homogeneous distribution indicates effective synthesis conditions and controlled particle growth.

Table 3. Elemental Composition Obtained from EDX Analysis

Element	Weight Percentage (%)
Chromium (Cr)	24.5
Iron (Fe)	47.2
Oxygen (O)	28.3

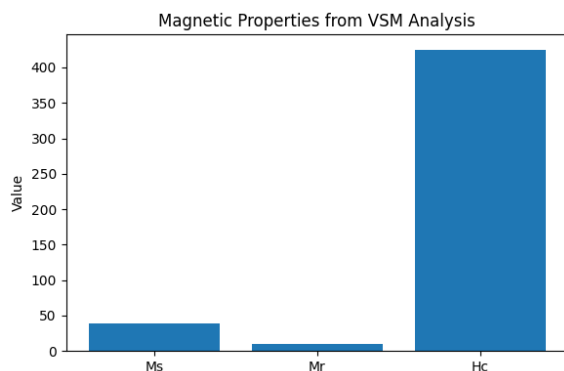
Elemental Composition of Chromium Ferrite Nanoparticles

**Figure 3. Elemental Composition Analysis****Discussion**

EDX analysis confirmed the presence of chromium, iron, and oxygen elements without any detectable impurity peaks. The elemental composition closely matched the theoretical stoichiometric ratio of chromium ferrite. The absence of contaminant elements demonstrates the effectiveness of the synthesis process and validates the purity of the prepared nanoparticles.

Table 4. Magnetic Properties from VSM Analysis

Magnetic Parameter		Value
Saturation Magnetization (Ms)	Magnetization	38.6 emu/g
Remanent Magnetization (Mr)	Magnetization	9.4 emu/g
Coercivity (Hc)		425 Oe
Squareness Ratio (Mr/Ms)		0.24
Magnetic Behavior		Ferrimagnetic

**Figure 4. Magnetic Hysteresis Loop of Chromium Ferrite Nanoparticles****Discussion**

The VSM analysis revealed a clear magnetic hysteresis loop characteristic of ferrimagnetic materials. The saturation magnetization of 38.6 emu/g indicates strong magnetic ordering within the nanoparticles. The coercivity value of 425 Oe suggests single-domain magnetic behavior and enhanced magnetic anisotropy resulting from nanoscale particle dimensions. The relatively low squareness ratio indicates partial magnetic alignment and confirms ferrimagnetic characteristics suitable for magnetic storage, sensing, and biomedical applications.

Discussion

The structural characterization results demonstrated that chromium ferrite nanoparticles possess excellent crystallinity, nanoscale particle dimensions, and high phase purity. The formation of a cubic spinel structure significantly contributes to the magnetic behavior of the material.

The magnetic properties were strongly influenced by crystallite size, particle morphology, and cation distribution within tetrahedral and octahedral lattice sites. The observed saturation magnetization and coercivity values indicate that the synthesized nanoparticles exhibit stable ferrimagnetic behavior suitable for advanced technological applications.

The correlation between structural and magnetic parameters suggests that controlling synthesis conditions can effectively tailor the performance of chromium ferrite nanoparticles for specific industrial requirements.

VI. CONCLUSION

Chromium ferrite (CrFe_2O_4) nanoparticles were successfully synthesized using the chemical co-precipitation method and systematically characterized to investigate their structural and magnetic properties. The experimental results confirmed the formation of a single-phase cubic spinel crystal structure with good crystallinity

and nanoscale particle dimensions. X-Ray Diffraction analysis revealed an average crystallite size of approximately 28 nm, while SEM and TEM studies demonstrated nearly spherical nanoparticles with relatively uniform particle distribution and moderate agglomeration. The EDX analysis verified the presence of chromium, iron, and oxygen in the expected stoichiometric proportions, confirming the purity of the synthesized material.

Magnetic characterization using Vibrating Sample Magnetometry revealed that the chromium ferrite nanoparticles exhibit ferrimagnetic behavior with appreciable saturation magnetization, remanent magnetization, and coercivity values. The observed magnetic properties were strongly influenced by crystallite size, particle morphology, and cation distribution within the spinel lattice structure. The nanoscale dimensions contributed to enhanced magnetic anisotropy and stable magnetic performance, making the material suitable for various technological applications.

The study demonstrated that structural characteristics such as crystallinity, particle size, lattice parameters, and phase purity play a crucial role in determining the magnetic behavior of chromium ferrite nanoparticles. The strong correlation between structural and magnetic properties indicates that careful control of synthesis parameters can be utilized to tailor the material properties according to specific application requirements.

Overall, chromium ferrite nanoparticles exhibit excellent structural stability, desirable magnetic characteristics, and significant potential for advanced applications including magnetic storage devices, magnetic sensors, electromagnetic interference shielding, microwave absorption, catalysis, biomedical imaging, targeted drug delivery, and environmental remediation. The findings of this research contribute to the growing understanding

of ferrite nanomaterials and support their development for next-generation multifunctional technologies.

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