CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Magnetic materials are playing a significant role in the advancement of science and technology. Magnetic nanoparticles have great demand in recent years due to their novel characteristics and extensive applications in various fields. Among these, spinel ferrite nanoparticles are attracting considerable attention due to their promising applications in several fields such as electronics, optics, ceramics, high-density magnetic storage devices, tumor-targeted drug delivery systems, contrast enhancers for magnetic resonance imaging, transformer cores, catalysis, biomedicine, etc. The discovery of novel materials, synthesis processes and the development of new theoretical and experimental techniques for research that provide opportunities for the development of innovative nanodevices and nanomaterials. In order to design nanomaterials and nanodevices for the next generation, it is requisite to understand their intrinsic features. Several researchers are working throughout the world towards the development of nanomaterials that are intended to perform more complex and efficient tasks. Thus, the development of completely new technologies and nanomaterials with desirable functional properties may lead to a generation of new products that will enhance the quality of the living environment in the near future.

Materials which are having the grain size smaller than 100nm are defined as nanomaterials. These materials possess the structural characteristics lies between those of bulk materials and atoms. The magnetic nanoparticles have been the focus of intense research recently because of their novel properties at the nanoscale. The characteristics of nanomaterials are drastically different from those of bulk materials and atoms. This is because of the tiny size of the particles which makes them:
Reduced imperfections
Quantum confinement
Large fraction of surface atoms

Because of their small dimensions, nanomaterials have a vast surface area to volume ratio (S/V), which causes the large fraction of atoms of the material be on the surface, resulting in more surface dependent material properties [1, 2]. The quantum confinement has profound effects on the properties of nanomaterials. The density of the charge carriers and energy band structure in the nanomaterials are quite different from their counterpart bulk materials and this, in turn, will alter the physical and chemical characteristics of the materials. Reduced imperfections are also a key factor which determines the properties of nanomaterials. Nanomaterials support a self-purification process in which the intrinsic material imperfections and impurities will reach up to the surface during the sintering process. This enhanced material perfection affects the intrinsic properties of nanomaterials [3].

In the case of bulk materials, their intrinsic magnetic properties like saturation magnetization ($M_S$), coercive force ($H_C$) and Curie temperature ($T_C$) depend on the chemical composition and crystallographic structure rather than their size and shape. Magnetic nanoparticles exhibit a great variety of unusual magnetic properties such as superparamagnetism, enhanced coercivity, magnetic quantum tunneling[4, 5], etc. These magnetic characteristics of the nanomaterials are significantly affected by the finite-size and surface effects[6]. Even though plenty of efforts continued in the last few decades, a clear understanding of the link between the physical characteristics and the atomic-scale structural parameters of the ferrite materials is essential in nano regime. The fabrication of spinel nano ferrite particles is of great importance for designing of particular electromagnetic characteristics. These unusual characteristics make nano ferrite particles to have multitudinous applications. Besides the magnetic properties, polycrystalline ferrites also exhibit dielectric behaviour which makes them suitable for high-frequency
applications (microwave and radio frequencies) [7-10]. So, it is important to analyze the
dielectric properties of nano ferrites at various frequencies. Detailed awareness regarding
the impact of dopant concentration on the dielectric behaviour of ferrites may be
beneficial for the fabrication of ferrites with tunable dielectric characteristics, which is
very helpful in practical applications.

1.2 HISTORICAL DEVELOPMENT OF FERRITES

Scientists believe that Greeks discover magnetism around 600BC in the mineral
lodestone (magnetite Fe$_3$O$_4$), the first ferrimagnetic material (ferrite). Much later in the
12$^{th}$ century, the magnetite was initially used by Chinese navigators in compasses. In the
16$^{th}$ century, English scientist William Gilbert published a book "De Magnete," in which
he described that the earth itself as a big magnet. Naturally occurring ferrite material is
magnetite, which has poor magnetic characteristic and not suggestible for the magnetic
applications. Kato and Takei and Snoek [11] have done research work (at Phillips
Research Laboratories) on the ferrites at the end of the first world war. Snock explained
the application of ferrites in science and technology. Kittel formulated a theory of domain
formation, domain wall dynamics and coercive force [12]. The work of Verwey and
Heilmann [13] on the metal cation distribution amidst the interstitial sites (i.e. tetrahedral
and octahedral sites) in the spinel lattice has contributed to progress in the chemistry and
physics of ferrites. Louis Neel formulated the theory of ferrimagnetism (uncompensated
anti-ferromagnetism) in 1948 [14]. This theory provides the basic information about spin-
spin interaction, taking place in the magnetic sublattice in ferrites. After the world war,
the development of ferrites proceeded quickly and by 1948 they were coming into
widespread use for radio and T.V purposes. In 1953 MIT built Whirlwind-I, the first
computer with ferrite core memory. During 1950’s Scientists from various countries
developed square-loop ferrite cores and ferrite devices for microwave applications. In
developments have been made on the magnetic properties of ferrites that have enhanced
the performances of microwave devices (high-frequency devices). At the end of the 20th century, Sugimoto[16] published a paper which surveys the past, present and future of the ferrite materials.

As ferrites are used commercially for large scale applications such as in T.V tube electron beam deflection yokes and voltage flyback transformers, so there is a huge demand for magnetic materials with low core losses in recent years. Extensive efforts have been carried out on ferrites to investigate their properties at the nanoscale and to extend ferrite materials suitable for various upcoming applications.

**1.3 FUNDAMENTALS OF MAGNETISM**

The magnetic moment of an atom originates from the movements of electrons. These magnetic moments are responsible for the magnetic characteristics of the materials. In general, the permanent magnetic moment of the atom originates from three sources:

1. **The orbital motion of electrons**: The atom of any material consists of a nucleus and the electrons. When the electron revolves around the nucleus in the specific orbits, an orbital magnetic moment arises.

2. **The electron spin**: Each electron is spinning about its axis and the spin motion of an electron also gives rise to a magnetic moment.

3. **The nuclear spin**: The nuclear spin also produces a magnetic moment in the atom. But the magnetic moment value of the nucleus is very small. Hence, the magnetic moment due to nuclear spin is neglected.

Therefore, the resultant magnetic moment of the atom is the sum of the orbital and spin magnetic moments of its constituent electrons. The major contribution to atomic magnetic moment comes from the spin of unpaired valence electrons, which produce
permanent magnetic moments. The number of such magnetic moments may align themselves in various directions to produce a net non-zero magnetic moments. Thus, the nature of induced magnetization depends on the total number of valence electrons present in the atoms and on the relative alignment of the neighboring magnetic moments.

1.4 CLASSIFICATION OF MAGNETIC MATERIALS

Based on the nature of interaction with the external applied magnetic field, magnetic materials have been classified into following five types[17, 18]

- Diamagnetic materials
- Paramagnetic materials
- Ferromagnetic materials
- Antiferromagnetic materials
- Ferrimagnetic materials

a) Diamagnetic materials

Diamagnetism is a weak magnetism and is the basic property of all matter[19]. It is mainly due to the non-cooperative response of the orbital electrons under the applied external magnetic field. When an external magnetic field is applied, material acquires weak magnetism in the direction opposite to the direction of applied field[20]. It is the result of changes in the orbital motion of electrons.

Examples: - bismuth, zinc, copper, gold, silver, lead, mercury, etc.

b) Paramagnetic materials

Paramagnetic materials have permanent magnetic moments, even in the absence of an applied field. It occurs due to the presence of one or more unpaired electrons in the
atomic orbital. In pure paramagnetic substance, the atomic magnetic moments are randomly aligned in the absence of an external field and do not interact among themselves, resulting in zero net magnetic moments. When the external magnetic field is applied, this magnetic field tries to turn the unfavorably oriented magnetic moments in the direction of the applied field. Paramagnetic materials do not retain any magnetization in the absence of an externally applied magnetic field [21].

Examples: - aluminium, copper chloride, platinum, manganese, etc.

c) **Ferromagnetic Materials**

If the interaction among the nearby magnetic moments is strong such that all the magnetic moments align in parallel, then the material is a ferromagnetic material. A ferromagnetic material possesses a net magnetic moment even in the absence of an external magnetic field [21].

Examples: - Iron, cobalt, nickel, etc.

d) **Antiferromagnetic Materials**

In certain materials when the separation between the atoms is small, the exchange coupling produce between neighboring magnetic moments causes the magnetic moments to orient in an anti-parallel direction. In these substances, the adjacent magnetic moments are equal and anti-parallel in orientation so the resultant magnetization vanishes [22]. The most characteristic feature of the anti-ferromagnetic substance is Neel temperature (T_N). The temperature above which an anti-ferromagnetic material becomes paramagnetic material is known as Neel temperature (T_N). In the periodic table chromium (Cr)[23] is the only one element exhibits anti ferromagnetic behaviour at room temperature.

Examples: - Cr, NiO, Fe₂O₃, etc.
e) **Ferrimagnetic Materials**

The term ferrimagnetism was first coined by Neel (1948) to explain the properties of those materials which below a certain temperature exhibit spontaneous magnetization originating from the anti-parallel alignment of atomic magnetic moments. In some materials, the magnetic moments are not equal and aligned anti-parallel to each other so that there is a net magnetic moment, and such materials are said to be ferrimagnetic [24]. Examples: - Ferrites

The arrangement of magnetic moments plays an important role in differentiating the different kinds of magnetism found in the materials (Fig. 1.1).

**Fig.1.1 Types of magnetism:** (A) Para (B) Ferro (C) Antiferro and (D) Ferrimagnetism
1.5 CLASSIFICATION OF FERRITES

1.5.1 TYPES OF FERRITES BASED ON CRYSTAL STRUCTURE

Ferrites are ferrimagnetic materials consisting of iron oxide as their main components. Based on the crystal structure ferrites are classified into four types [25], as described below:

- Spinel ferrites (or) cubic ferrites
- Garnets
- Magnetoplumbite (or) Hexagonal ferrites
- Orthoferrites

Table 1.1: Classification of Ferrites

<table>
<thead>
<tr>
<th>Ferrite Type</th>
<th>Structure</th>
<th>General formula</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinel</td>
<td>Cubic</td>
<td>MFe$_2$O$_4$</td>
<td>$M = Ni, Mn, Co, Cu, Mg, Zn$ e.g., CuFe$_2$O$_4$</td>
</tr>
<tr>
<td>Garnet</td>
<td>Cubic</td>
<td>3R$_2$O$_3$.5Fe$_2$O$_3$</td>
<td>$R = Dy, Gd, Ho, Pr, Yb, Y, Sm, Eu, Er, Lu$ e.g., 3Y$_2$O$_3$.5Fe$_2$O$_3$</td>
</tr>
<tr>
<td>Magnetoplumbite</td>
<td>Hexagonal</td>
<td>MFe$<em>{12}$O$</em>{19}$</td>
<td>$M = Ba, Sr, Pb, Ca$ e.g., BaO.6Fe$_2$O$_3$</td>
</tr>
<tr>
<td>Orthoferrites</td>
<td>Perovskite</td>
<td>RFeO$_3$</td>
<td>R is rare earth elements like Ho, Dy, Er, Y, Yb</td>
</tr>
</tbody>
</table>
1.5.1.1 Spinel Ferrites

Spinel ferrites are an important class of magnetic materials having the general chemical formula $\text{AB}_2\text{O}_4$, where A represents metal cation with +2 valence such as $\text{Mn}^{2+}$, $\text{Co}^{2+}$, $\text{Ni}^{2+}$, $\text{Cu}^{2+}$, $\text{Zn}^{2+}$, $\text{Mg}^{2+}$, etc. and B is the trivalent iron cation ($\text{Fe}^{3+}$). A can be replaced by divalent cations whereas $\text{Fe}^{3+}$ can be replaced by trivalent cations like $\text{Cr}^{3+}$, $\text{Al}^{3+}$, $\text{Ga}^{3+}$, etc. They have a crystal structure identical to naturally occurring mineral spinel ($\text{MgAl}_2\text{O}_4$). Therefore, as mentioned above the ferrites with $\text{AB}_2\text{O}_4$ structure are called as spinel ferrites or simply spinel.

Fig. 1.2 Crystal structure of spinel ferrite
Spinel ferrites crystallize in a cubic structure. Hence, these ferrites also called as cubic ferrites. The structure of spinel ferrites is shown in Fig.1.2. The spinel lattice is composed of a close-packed oxygen anions arrangement in which 32 $O^2-$ ions form the unit cell. These $O^2-$ anions are packed in the FCC arrangement leaving two types of interstitial gaps among oxygen anions. One is the tetrahedral (A) site surrounded by four nearest neighbouring oxygen anions while the other is the octahedral (B) site surrounded by six nearest oxygen anions. There are total 64 A-sites and 32 B-sites present in the unit cell, out of which only 8 A-sites and 16 B-sites are occupied by metal cations to maintain charge neutrality in the crystal. Therefore, the unit cell of spinel ferrite contains eight molecules (8 formula units $MFe_2O_4$).

8 $MFe_2O_4 = (8M + 16Fe)$ Metal cations + 32 Oxygen anions = 56 ions.

The cation distribution among octahedral (B) and tetrahedral (A) sites can influence by several factors such as the chemical composition, ionic radius, electronic configuration, electrostatic energy, method of preparation and preparation conditions [26-29].

Based on the cation distribution over two principle sites (i.e. A and B sites), spinel ferrites can be classified into three types.

- a) Normal spinel ferrites
- b) Inverse spinel ferrites
- c) Random spinel ferrites

**a) Normal spinel ferrites**

Spinels with only divalent metal cations in the tetrahedral sites (A sites) and the trivalent cations at octahedral sites (B sites) are called normal spinel ferrites.
Normal spinels have the general formula: \((M^{2+})_A[Me^{3+}]_B O_4\).

Where ‘M’ represents divalent cations and ‘Me’ for trivalent cations.

b) Inverse spinel ferrites

In the case of inverse spinel ferrites, the divalent metal cations \((M^{2+})\) and half of the trivalent cations \((Me^{3+})\) residing in the octahedral sites, whereas the other half of the Me\(^{3+}\) metal cations occupy the tetrahedral sites.

Inverse spinels have represented by the general formula: \((Me^{3+})_A[M^{2+}Me^{3+}]_B O_4\)

c) Random spinel ferrites

In some ferrites, the divalent and the trivalent metal ions randomly distributed over both the tetrahedral (A-site) and the octahedral (B-site) interstitial sites. These ferrites are called as random spinel ferrites. The random spinel ferrite composition represented by the general formula \((M^{2+}Me^{3+}_{1-\delta})_A[M^{2+}Me^{3+}_{1+\delta}]_B O_4\), where \(\delta\) is a degree of inversion. It also called as distribution parameter. It depends on the method of preparation and chemical composition of ferrites.

Depending upon the values of distribution parameter \(\delta\), the three different types of spinel ferrites are represented as,

\[\delta = 1 \quad \text{normal spinel ferrite,}\]
\[\delta = 0 \quad \text{inverse spinel ferrite,}\]
\[0 < \delta < 1 \quad \text{random spinel ferrite.}\]
Table 1.2: Classification of Spinel Ferrites

<table>
<thead>
<tr>
<th>Ferrite Type</th>
<th>General formula</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal spinel</td>
<td>$(M^{2+})<em>A [Me^{3+}]</em>{2B}O_4$</td>
<td>Zn Fe$_2$O$_4$, Cd Fe$_2$O$_4$</td>
</tr>
<tr>
<td>Inverse spinel</td>
<td>$(Me^{3+})<em>A [M^{2+}]</em>{2B}O_4$</td>
<td>Ni Fe$_2$O$_4$, CoFe$_2$O$_4$, Fe$_3$O$_4$</td>
</tr>
<tr>
<td>Random spinel</td>
<td>$(M^{2+}\delta Me^{3+}<em>{1-\delta})<em>A [M^{2+}]</em>{1-\delta} Me^{3+}</em>{1+\delta}B O_4$ $(0 &lt; \delta &lt; 1)$</td>
<td>MgFe$_2$O$_4$, MnFe$_2$O$_4$, CuFe$_2$O$_4$</td>
</tr>
</tbody>
</table>

1.5.1.2 Garnets

The rare earth garnets have the chemical formula $R_3Fe_5O_{12}$ or $3R_2O_{3.5}Fe_2O_3$ where, $R$ is the Yttrium (Y) or rare earth ions such as Dy, Ho, Gd, Pr, Yb, etc. The crystal structure of garnet is cubic. The rare earth garnets consist three interstitial sites namely dodecahedral (a), octahedral (c) and tetrahedral (d). Garnets have a complex crystal structure, and these are widely used in magneto-optical applications.

1.5.1.3 Hexagonal ferrites

The third group of ferrites is the Hexagonal ferrites having the general chemical formula $MFe_{12}O_{19}$ or $MeO. 6 Fe_2O_3$, where $M$ can be Pb, Sr or Ba. Hexagonal ferrites have three different interstitial sites i.e. tetrahedral, trigonal bipyramid and octahedral sites. The crystal structure of the hexagonal ferrites is highly complex. These are used as permanent magnets because of their intrinsic magnetic characteristics like high saturation magnetization ($M_S$) and coercivity ($H_C$). Barium ferrite ($BaFe_{12}O_{19}$) and Strontium ferrite ($SrFe_{12}O_{19}$) are the good examples of hexagonal ferrites, and these are widely used in microwave device applications.
1.5.1.4 Orthoferrites

Orthoferrites have the general chemical composition RFeO$_3$, where R represent various rare-earth elements like Ho, Dy, Er, Y, Yb, etc. Orthoferrites are transparent magnetic materials and can alter the polarization of a light beam under the control of a magnetic field. This property makes them potentially useful as sensors and actuators in optical communication techniques.

1.5.2 TYPES OF FERRITES BASED ON MAGNETIZATION

Based on the persistence of their magnetization, ferrites are classified into two types[30]:

a. Soft Ferrites.

b. Hard Ferrites.

1.5.2.1 Soft ferrites

Ferrites which are easily magnetized and demagnetized are known as soft ferrites. They have characterized by narrow hysteresis loop (Fig. 1.3).

Examples: - Iron-silicon alloy, Ni–Fe (permalloy), Mn–Zn ferrite, Ni–Zn ferrite, etc.

1.5.2.2 Hard Ferrites

The ferrites, which have a high resistance to magnetization and demagnetization called as hard ferrites. They have characterized by large hysteresis loop (Fig. 1.4).

Examples: - Strontium ferrite (SrFe$_{12}$O$_{19}$), Barium ferrite (Ba Fe$_{12}$O$_{19}$), Cobalt ferrite (CoFe$_2$O$_4$), etc.
Fig 1.3 Soft ferrites

Fig 1.4 Hard ferrites
**Table 1.3: Characteristics of Ferrites**

<table>
<thead>
<tr>
<th>Soft Ferrites</th>
<th>Hard Ferrites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hysteresis loop area is narrow</td>
<td>Hysteresis loop area is broad</td>
</tr>
<tr>
<td>Low hysteresis loss</td>
<td>More hysteresis loss</td>
</tr>
<tr>
<td>The retentivity and coercivity values are small</td>
<td>The retentivity and coercivity values are high</td>
</tr>
<tr>
<td>The permeability and susceptibility values are high</td>
<td>The permeability and susceptibility values are small</td>
</tr>
<tr>
<td>They are used to make electromagnets</td>
<td>They are used to make permanent magnets</td>
</tr>
<tr>
<td>Low magnetocrystalline anisotropy</td>
<td>High magnetocrystalline anisotropy</td>
</tr>
</tbody>
</table>

**Applications:**

**Soft Ferrites**
- In electromagnetic machines
- Recording heads
- O/P Transformers in T.V sets
- Transformer cores
- Inductors
- Microwave devices
- Switching devices
- Matrix storage of computers

**Hard Ferrites**
- In preparation of permanent magnets
- Voltage regulators
- Magnetic detectors
- Loud speakers
- Microphones
- Flux meters
- Damping devices
- Magnetic separators
1.6 APPLICATIONS OF FERRITES

Ferrites are the ceramic magnetic materials containing iron oxide as a main constituent. They have a wide variety of applications because of their combined twin characteristics of the electrical insulator and magnetic conductor. Ferrite exhibits high specific resistance, low dielectric and eddy current losses, high permeability, high saturation magnetization, Curie temperature, high chemical stability, etc. These are the properties which render that the ferrites are invaluable in radio communication and television application. They have found wide-spread use as cores for inductors and transformers. The properties which made ferrites so useful at radio and television frequencies also provide the key to their use at microwave frequencies. Microwave devices like switches, circulators, modulators, phase shifters, limiters, isolators which are composed of ferrite magnetic materials [31-38]. Recently, soft ferrites have become attractive for their applications in microwave devices, rod antennas, radio frequency circuits, transformer cores, high quality filters, inductors, noise filters, read/write head for high-speed digital tapes, memory cores, high-density data storage, gas sensors, magnetic sensors, chemical sensors, catalyst owing to their high resistivity, low magnetic, dielectric and eddy current losses, high Curie temperature, low coercivity, high physical and chemical stabilities, etc. [16, 39-48].

Substituted mixed ferrite materials with low coercivity, little eddy current losses and high resistivity values extensively used in radio, TV, radar, audio-video and digital recording, bubble devices and memory cores of computer [49-51]. The low loss polycrystalline ferrites should use in a high-frequency range for the good performance in the application. Another strong application for the ferrite material lies in the automotive industry and most recently in the hybrid cars[52, 53]. The ferrite materials are important in EMI applications as well. Spinel ferrites work very well as thin impedance matched absorber in the frequency range of MHz and widely used for TV ghost suppression and anechoic chambers [54, 55]. The use of small and compact power supplies for computers and microprocessors has also led to an increased demand for ferrites with high switching
frequencies and better material performance. Latest applications in the field of information technology and microwave engineering are rapidly growing. Research projects in these domains have created a huge demand for high-quality ferrites for transformer cores, power supplies, deflection yokes, data storage devices, recording, and interface suppression [48, 56].

Recently, there has been a renewed interest in the study of nanosized ferrites which have potential applications in modern science and technology. It has also been driven by the quest for new products with novel or enhanced features and fundamental understanding of properties of the material when the particle size approaches atomic scale. Magnetic nanoparticles (MNPs) have received special attention due to their several applications in biomedical field such as magnetic drug delivery[57], hyperthermia treatment for cancer [58, 59], contrast enhancers for magnetic resonance imaging (MRI contrast agent) [60-62], DNA hybridization [63] and cell separation [64]. Recent studies have demonstrated that mixed-ferrites (MFe₂O₄ where M= Co, Zn) are promising candidates for biomedical and biotechnology applications due to their biocompatibility, good physical and chemical stabilities, ease of synthesis and suitable magnetic characteristics [65-70]. Thus, a systematic study of nanosized ferrite materials has become a fascinating subject of recent interest.

1.7 OBJECTIVES OF PRESENT INVESTIGATIONS

The general objective of the present research work is to investigate the composition dependence of the structural, magnetic and dielectric properties of Cr-Zn and Cr-Co nano ferrites (CrₓZnFe₂₋ₓO₄ and CrₓCoFe₂₋ₓO₄, 0.0 ≤ x ≤ 0.5).

CoFe₂O₄ is a familiar hard magnetic material, which has been studied in detail due to its perfect chemical properties, thermal stability, high electrical resistivity, high coercivity and moderate saturation magnetization. ZnFe₂O₄ belongs to the category of
normal spinel ferrites. Among the spinel ferrites, Zn-ferrite has wide applications such as gas sensors, radar-absorbing materials, photo-catalyst, and electromagnetic wave-absorbing materials. Zn and Co-ferrites are of great research interest due to their scientific value and large number of applications in modern science and technology. Their usage is greatly influenced by their physical and chemical properties, which is in turn influenced by several parameters such as method and conditions of synthesis as well as the amount and type of additives. To our knowledge, very few reports are available in the literature on chromium substituted zinc and cobalt ferrite systems synthesized by sol-gel technique. The substitution of trivalent cations can lead to enhance the intrinsic properties. In view of this, the aim of the current work is to synthesize Cr-Zn and Cr-Co nano ferrites by sol-gel method and to investigate the structural, morphological, magnetic and dielectric properties thoroughly using standard experimental techniques. Further, it is also intended to investigate the impact of Cr$^{3+}$ substitution on the structural, magnetic and dielectric characteristics of the Zinc and Cobalt nano ferrite systems.

**The Specific Objectives of present work**

- To synthesize Cr$_x$ZnFe$_{2-x}$O$_4$ and Cr$_x$CoFe$_{2-x}$O$_4$ (with $x = 0.0$, $0.1$, $0.2$, $0.3$, $0.4$ and $0.5$) nano ferrites by using sol-gel method

- To characterize the synthesized materials for their various structural and microstructural properties using standard experimental techniques like X-ray diffraction (XRD), Fourier Transform Infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) with elemental analysis (Energy Dispersive X-ray Analysis - EDAX), etc.

- To study the magnetic characteristics of the synthesized materials using Vibrating Sample Magnetometer (VSM)
➢ To study the dielectric behaviour of the synthesized ferrites using LCR meter.

➢ Intention to improve the magnetic and dielectric characteristics such that the prepared samples meet the requirements for low-loss and high-performance ferrite based devices.