INTRODUCTION
Chapter I

1.1 Introduction

The recent discovery of nanophase materials has opened up new vistas in the frontier area of material science and technology. Particles or layers possessing nanometric dimensions lying in the range of 10 – 50 nm are found to exhibit different (sometimes superior) physical properties with respect to their coarser sized counterparts. These materials will be the forerunners of many devices in the present century. The nanocrystalline materials exhibit an increased strength/hardness, enhanced diffusivity, improved ductility / toughness, reduced density, reduced elastic modulus, higher electrical resistivity, increased specific heat, higher thermal expansion coefficient, lower thermal conductivity, and superior soft magnetic properties in comparison with the conventional coarse-grained materials. However most of these novel properties are found to be very sensitive to the sample preparation procedures [C.Suryanarayana(1995), A.N.Goldstein (1997), K.Lu (1996)]. But on the other hand no ideal ferrite sample exists that meets the requirements of low eddy current loss and usefulness in the range of frequencies of the order of gigahertz. Each sample has got its own advantages and disadvantages. Scientists have not yet been able to formulate rigid set of conditions for ferrites with ideal property.

The spinel lattice is composed of close-packed oxygen arrangement in which 32 oxygen ions form a unit cell, which is the smallest repeating unit in the crystal network. Between the layers of oxygen ions are interstices that may accommodate the metal ions. Not all the interstices are similar. Tetrahedral (A) sites are surrounded by or coordinated with four nearest neighbouring oxygen ions, the lines connecting their centres form a tetrahedron. Octahedral (B) sites are coordinated by six nearest neighbouring oxygen ions whose centres where connected by lines describe an octahedron. There are 64 tetrahedral sites and 32 octahedral sites in the unit cell of 32 oxygen ions. If all these sites are filled with metal ions of either valence +2 or +3, the positive charge would be much
greater than the negative charge and so the structure would not be electrically neutral. It turns out that among the 64 tetrahedral sites, only 8 are occupied and of the octahedral sites, only 16 are occupied. The tetrahedral sites are occupied by divalent ions and the octahedral sites are occupied by the trivalent ions and the total positive charge will be $8 \times (+2) = +16$ plus the $16 \times (+3) = +48$, or a total of +64 which is needed to balance the $32 \times (-2) = -64$ for the oxygen ions. In a unit cell, there would be then eight formula units of MO-Fe$_2$O$_3$ or MFe$_2$O$_4$. A spinel unit cell contains two types of sub-cells. These sub-cells alternate in a three-dimensional array, so that each fully repeating unit cells requires eight sub-cell. The divalent ions are generally larger than the trivalent, because the larger charge produces greater electrostatic attraction and so pulls the outer orbits inward. The octahedral sites are larger than the tetrahedral sites (Fig. 1.1).

Ferrites are the mixed metal oxides as their main component. There are two important classes namely soft ferrites with spinel and garnet structure, and hard ferrites. The studies of ferromagnetic materials are not recent. From the survey of literature it is found that the properties of ferromagnetic materials mainly depend on the purity of the materials, grain size of the materials, the strength and applied frequency of the magnetic fields. In some cases the external size of the materials, their crystalline and nanosize materials and nanocomposite magnetic materials are potential candidates for a variety of new applications. They find their applications in the fields of image sensors, catalysis, biotechnology, drug delivery systems, medical diagnostics, magnetic refrigeration, magnetically assisted chemical separation of radioactive and hazardous wastes. Besides they are used to enhance the recording density in information storage and reduce core losses for high frequency and microwave applications. Significant improvement in properties is achieved by alloying, adding impurities, and changing the shape of the materials to suit the desired properties for different applications. The materials having both electrical and magnetic properties find potential application in batteries, non-linear optics,
electrochemical display devices, molecular electronic, electrical and magnetic
shields, and microwave absorbing materials [J.R. Ellis (1986), H.Yonoyama et
al. (1991), P. Shen et al. (1992), H. Kawaguchi et al. (2000), O. Kalinina et al.
(1999), G.R. Pedro (2001)].

Scientists still continue their efforts to achieve the optimum parameters of
ferrites, like high saturation magnetization, high permeability, high resistivity etc.
These optimum conditions depend upon the sintering conditions and method of
preparation. The processing of ferrites has been divided into two main groups.

- Conventional ceramic method also called as solid state reaction
  method.

- Non conventional method, also called as wet method. Among there
  processes are sol-gel synthesis, co-precipitation, organic precursor
  method, co spray roasting, freeze- drying, activated sintering, fused salt
  synthesis, etc.

The substitution of various magnetic and nonmagnetic ions at different
sublattices in ferrites materials has provided interesting magnetic structures and
electrical properties. The spinel ferrites are very attractive among them,
because it allows a variety of magnetic disorder, and frustration can be
introduced. This may be due to the fact that in spinel ferrite, the intrasublattice
interactions are weaker than the inter-sublattice interactions as a result of the
unsatisfied bonds in antiferromagnetic phase. The presence of unsatisfied
bonds results in increase in magnetic dilutions, which generate competition
between the various exchange interactions. These exchange interactions result
in a variety of magnetic structures.

A great progress has been made, through both theoretical and
experimental studies, in understanding the fundamental magnetic processes
taking place in these materials. This has been made possible by the
computational advances in theoretical physics and by the development of new
methods of material synthesis and characterization, which have been allowing a better control on the microstructure and on the desired properties to be realized. The basic idea of nanocrystalline materials is to generate disordered solids, which contain a high density of defect cores with 50% or more of the atoms (molecules) situated in the cores of these defects. Based on the type of defects (grain boundaries, inter phase boundaries, dislocations, etc.) nanocrystalline materials with different structures may be generated [R. Birringer et.al (1986)]. There are two types of atoms in the nanocrystalline structure; crystal atoms with neighbor configurations corresponding to the lattice and boundary atoms with a variety of inter-atomic spacings. As the nanocrystalline material contains a high density of interfaces, a substantial fraction of atoms lies in the interfaces.

In nanocrystalline materials with a large number of atoms (molecules) residing in the grain boundaries, the interface structures play a significant role in determining the properties of these materials. The structural characteristics which are controlled by the consolidation and processing, such as porosities, internal stress, etc. may play an important role in their properties. It is difficult to distinguish between the contributions to the enhancement of the properties from the grain size effect and from other effects such as pores or strain with the consolidated samples. Nanocrystalline materials crystallized from amorphous solids, however, can overcome this difficulty as there is no consolidation process involved in the sample preparation and the crystallized nanocrystalline samples are always porosity-free and of full density. Owing to these features, studies on properties have been carried out in a number of nanocrystalline materials crystallized from amorphous solids [Y. Yoshizawa et al. (1988)].

This provides an introduction to nanomaterials, describes the different techniques for the synthesis of nanocrystalline materials and discusses their structural and magnetic properties. Since the author is interested in the study of the magnetic properties of the nanocrystalline soft magnetic material, and the changes in the magnetic and electric and dielectric properties of nanocrystalline
spinel ferrites, a brief review of the literature on these materials and also the motivation for the present work are presented. Finally the applications of these materials are briefly discussed.

The crystallographic, electrical and magnetic properties depend upon the chemical composition as well as on various heat treatments during the course of preparation [Tahir Abbas et al. (1995)]. The lattice constant, X-ray density, bulk densities, porosity, resistivity, oxygen positional parameter, degree of inversion and saturation magnetization will change with heat treatment [L.G.Van uitert (1956), J.smit et al. (1959)]. The vacancy concentration of oxygen is another parameter, which changes during sintering process [M.M.Barakat et al. (1991)]. Verwey has made a general classification with the help of lattice constant. But the most exact information can be obtained from the values of the magnetic saturation at low temperatures.

1.2 Magnetic Property Of Ferrites

A ferrite may be defined as the one, which below a certain temperature bears a spontaneous magnetization that arises from non-parallel arrangement of the strongly coupled atomic dipoles. Ferrite is the substance consisting of two sublattices with magnetic moments of one sublattice tending to be antiparallel to those of the other. When the sublattice magnetizations are not equal, there will be a net magnetic moment. The term ferrimagnetism has been used in broad sense in order to include the materials with more than two sublattices and with other spin configurations, such as triangular or spiral configurations. It is usually assumed that a ferrimagnetic material has an appreciable net magnetization, although no precise definition of the term "appreciable" has been given. The two sublattices are denoted by A and B. If the magnetic moments of the ions at A and B sites are unequal, this inequality may be due to
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- Presence of elements in different ionic states. e.g. Fe$^{3+}$ and Fe$^{2+}$.
- Different elements in the same or different ionic states. e.g. Fe$^{3+}$ and Co$^{2+}$.
- Different crystalline field acting at two sites. The competition between the forces on the B spins may lead to the triangular configuration.

The high permeability material displays no net magnetization. Until a field is applied, these materials are termed magnetically "soft". "Hard" magnets require large fields for magnetization but remain magnetized unless large reversing fields are applied. This behavior is explained by the formation of domains, regions within a crystal in which all spins are aligned and the magnetization is thereby saturated.

Spinel ferrites and substituted nickel ferrites are found to be very attractive and versatile magnetic materials. The magnetic properties of materials are strongly affected when the particle size approaches a critical diameter, below which each particle is a single magnetic domain. As a result the influence of thermal energy over the magnetic moment ordering leads to super paramagnetic relaxation. Diamagnetic substitutions in super and mixed ferrites have received a great deal of attention over the past few years. The substitution of various magnetic and nonmagnetic ions at different sublattices in ferrite materials have provided interesting magnetic structures and electrical properties. The size of the magnetic domain is smaller than the size of the corresponding bulk materials. Novel magnetic behavior is observed for the nanosized magnetic particles when compared to that of the bulk.

Due to their small sizes, nanoparticles exhibit novel material properties that largely differ from the bulk solid state. Many reports on quantum size effects on semiconductor and the evolution of metallic particles depending on their size have been published in the last few years. Soft ferrites have been extensively used for many kinds of magnetic devices such as transformers,
inductors and magnetic heads for high frequency applications because their electrical resistivity is higher than those of soft magnetic alloys. During the last few years nanoscale spinel ferrites have drawn the attention of researchers because of their technological importance in magnetic recording devices and magnetic fluids.

The wide range in the saturation magnetization makes them useful from microwave to millimeter wave device applications. Ferrites have many applications in both low and high frequency devices and play a significant role in technological applications. Especially ferrites belonging to this class of materials are gaining prominence owing to their efficacious properties such as high thermodynamic stability and high corrosion resistance, making them suitable in metallurgical field and other high temperature areas.

1.3 Molecular Field Theory Of Ferrimagnetism

In ferrimagnetism spontaneous magnetization is due to cooperation of between the atomic dipoles within the single domain, i.e. there must be some kind of interaction between the atoms, which produces the tendency for parallel alignment of the atomic magnetic dipoles. In order to obtain a logical description of spontaneous magnetization, Weiss [Allan.H.Morrish (1965)] assumed that the molecular field $H_M$ acting on a dipole may be written as

$$H_M = H + \lambda M.$$  

Where $\lambda$ is the molecular field constant, it is clear that $\lambda M$ provide the cooperative effect. The molecular field theory of ferrimagnetism with two sublattices A and B was developed by L.Neel (1959).

The molecular field $H_{MM}$ acting on an atom at A site is

$$H_{mA} = -\lambda_{AA}M_A - \lambda_{AB}M_B.$$  

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The molecular field $H_{mb}$ acting on an atom at B site is

$$H_{mb} = - \lambda_{BA} M_A - \lambda_{BB} M_B$$

Here $\lambda_{AB} > 0$, since the interaction between the two sublattices is antiferromagnetic. The other molecular field constants $\lambda_{AA}$ and $\lambda_{BB}$ may in principle be positive or negative but apparently are positive for great majority of ferrimagnetic material. Usually $\lambda_{AA} < \lambda_{AB}$ and $\lambda_{BB} < \lambda_{AB}$. It is common to express $\lambda_{AA}$ and $\lambda_{BB}$ in terms of $\lambda_{AB}$

$$\lambda_{AA} = \alpha \lambda_{BB}$$
$$\lambda_{BB} = \beta \lambda_{BB}$$

The magnetization of the sublattices at thermal equilibrium is given by

$$M_A = \sum_i N_i g_i \mu_B S_i B_{si}(X_A)$$
$$M_B = \sum_i N_i g_i \mu_B S_i B_{si}(X_B)$$

Where as $X_A = (\mu_B S_i B_{si} / KT) H_A$

$$B_{si}(X_A) = 2S_i + 1/2S_i \coth 2S_i + 1/2S_i X_A -1/2S_i \coth xA/2S_i$$

Here $N_i$ is the number of atoms per unit volume with the spin quantum number $S_i$

1.4 Neel's Collinear Model

In Neel's theory the magnetic ions are assumed to be distributed among the tetrahedral A and B sites of the spinel structure. Negative exchange interactions exist between A&A, A&B and B&B

When A-B antiferromagnetic interaction is the dominant one, A and B lattices will be magnetized in opposite directions below a transition temperature, giving rise, when the magnetizations of the A and B sites differ in magnitude, to a special case of antiferromagnetism termed "ferrimagnetism" figure(1 2)
shows the model. When the A–A or B–B interaction is dominant, Neel finds that
the above transition will not take place and he concludes that the substance
remains paramagnetic down to the lowest interactions. Some kind of ordering
may be expected to occur at low temperature as claimed by [Y.Yafet et al.
(1952)].

1.5 Non-Collinear Model

The discrepancy in Neel’s theory was resolved by Yafet and Kittel
[Y.Yafet et al. (1952)], who formulated the non-collinear model of
ferrimagnetism as shown in fig (1.3). They concluded that the ground state at
0K might have one of the following configurations;

- Antiparallel arrangement of the spins on two sites.
- Triangular arrangement of the spins on the sublattices.
- Antiferromagnetism in each of the two sites separately.

1.6 MAGNETIC INTERACTION IN FERROMAGNETIC

Heitler and London (1927) [J.Crangle (1977)] presented the idea of
exchange coupling between the spins of two or more atoms. It is essentially an
electrostatic effect. The directions of the two interacting spins cannot be
changed due to quantum mechanical reasons without changing the spatial
distribution of charge. Consider the lobes of the charge density corresponding
to different electron states in a single free atom and what happens when such
atoms are near to each other. There is a possibility of overlap of charge density
contributed to both atoms, and the Pauli Exclusion Principle must be applied to
the region of overlap. No single electron state may be occupied twice. When
the orbital wave function is symmetrical the spin wave functions is symmetrical,
the spin wave function must be asymmetrical and vice versa. Changing the
spin symmetry by the reversal of one spin must change the orbital symmetry and this redistributes charge. This imposes a correlation between the electron spins of the two atoms, which is proportional to their product $S_1 S_2$, the exchange energy can be written as follows [J. Smit et al. (1959), M.A. Shamanov et al. (1975), Raul Venzula (1994)]

$$E_{ex} = 2JS_1 S_2$$

Where $E_{ex}$ is the contribution to the energy from exchange interaction $J$ represents an integral which involves the wave functions of the electrons and the potential. It is well known that the favoured situation is the one with the lowest energy and it turns out that because there are two ways in which the wave functions can combine. There are two possibilities for lowering the energy by $E_{ex}$.

- If $J$ is positive, the spins are parallel. This is the case leading to ferromagnetism because two neighbouring spins are held parallel even though it does not extend beyond nearest neighbours.

- If $J$ is negative, the spins are antiparallel. This situation leads to antiferromagnetism.

1.7 Theory Of Magnetic Domain

It was Weiss who first proposed that magnetic material consists of physically distinct regions called domains each of which is magnetically saturated in different directions. Fig(14) shows the random arrangement of the magnetic domains in unmagnetized material. Though each domain is fully magnetized, the material as a whole may have zero net magnetization.

The external applied field aligns the domains, so there is net magnetic moment. At low fields this alignment occurs through the growth of some domains at the cost of less favorably oriented ones and the intensity of the
magnetization increases rapidly. Growth of the domain stops as the saturation magnetization region is approached and rotation of unfavorably aligned domains occurs. Domain rotation requires more energy than domain growth, and hence, the slope of the M-H curve decrease at this point interprets the definition of initial magnetization curve but not the hysteresis. Hysteresis is caused due to the presence of imperfections, which act as obstacles to domain rotation and domain wall motion. When the field increases the obstacles are overcome by the energy supplied by the field. The field of the defects prevents the walls to return to their original positions. Thus, to return the domain structure to a random array, with zero net moment, it is necessary to supply more energy.

1.8 Origin Of Domains

Domain structure and dynamics determine the technologically important properties of permeability, coercive force, shape of the hysteresis loop and switching behavior. When a small magnetic field is applied to a specimen composed of relatively coarse grains, domain walls are perturbed from their equilibrium positions. If this field is removed, the wall returns to its original equilibrium positions. When a larger magnetic field is applied, domains that are favorably oriented to the applied field grow at the expense of unfavorably aligned domains.

A single crystal is single domain with large magnetic moment even in the absence of an applied field. There would be a large magnetostatic energy. Dividing the specimen into domains can reduce this magnetostatic energy. However, it costs energy to create boundaries between domains and there are a number of contributions to this energy. There is strain energy due to magnetostriction, which is roughly proportional to the volume of domains. Increasing the number of domains could decrease this. The contribution of anisotropy energy should also be minimized.
1.9 Magnetostriction

When the magnetic dipoles are rotated in the direction of the field, the fields of the dipoles influence the interatomic spacing. Therefore the shape and the volume of the ferromagnetic solid change as it is magnetized. The change is along the axis of the magnetization. This is called the magnetostriction. The magnetostriction coefficient \( \lambda \) is defined as the change in length when the magnetization changes from zero to saturation. The magnetostriction is partly anisotropic because the magnetization is also partly anisotropic.

1.10 Magnetic Anisotropy

The potential energy of a ferromagnet depends on the direction with respect to the crystal axes in which it is magnetized. This energy is lowered in easy direction, and higher field must be applied to magnetize the sample in harder direction.

The magnetocrystalline energy of uniaxial ferromagnetic crystal is written as follows

\[
E_M = K_1 \sin^2 \Theta + K_2 \sin^4 \Theta + \sum K_n \sin^{2n} \Theta
\]

Where \( K_1 \) and \( K_2 \) are the constants, which vary with temperature and are different for different materials. \( \Theta \) is the angle between the magnetization vector and the direction of crystallographic axis. In cubic crystals any of the three cube edge directions are the easy directions of magnetizations. The energy of the cubic crystal may be written as follows

\[
E_M = K_0 + K_1 (\alpha_1^2 \alpha_2^2 + \alpha_1^2 \alpha_3^2 + \alpha_2^2 \alpha_3^2) + K_2 (\alpha_1^2 \alpha_2^2 \alpha_3^2)
\]

Where \( \alpha_1, \alpha_2, \alpha_3 \) are the directions cosines of the magnetization direction with respect to the cubic axes of the crystal. The domain structure is severely
effected by the anisotropy energy because it imposes constraint on the direction of the magnetization when no external field is applied. Also it controls the thickness of the domain wall.

In transition elements the magnetic moments are due to spin moments, usually of 3d electrons, and these are not coupled directly with crystal lattice. The magnetic anisotropy energy comes from the indirect coupling of the spins with the lattice through spin orbit coupling and orbit lattice coupling.

1.11 Electrical Conductivity

Mixing of 4s and 3d orbitals in the transition metal atoms will result in electrical conductivity. Resistivites range from $10^{-5}$ – $10^{-6}$Ω cm that degrade the performance of magnetic metals used in audiotransformers and other devices. High conductivity reduces penetration of a alternating electromagnetic fields due to the eddy current losses that it produces.

1.12 Conduction Mechanism

Ferrites exhibit interesting properties that could be used in electronic devices. The increasing demand for low loss ferrites results in detailed investigations on conductivity and on the influence of various substitutions on the electrical conductivity. The conduction mechanism in ferrites is quite different from that in semiconductors. In semiconductors the band type conduction occurs, whereas in ferrites, the cations are surrounded by close packed oxygen anions and as a first approximation can be well be treated as isolated from each other. There will be a little direct overlap of the anion charge clouds or orbitals. In other words the electron associated with particular ion will largely remain isolated and hence a localized electron model is more appropriate than a collective electron (band) model. This accounts for the insulating nature of ferrites. These factors led to the hopping electron model
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[A A Samokhvalov (1964)] An appreciable conductivity in these ferrites is found to be due to the presence of iron with different valence states at crystallographically different equivalent lattice points [A J Bosmann et al (1966)] Conduction is due to exchange of 3d electron, localized at the metal ion ,from Fe$^{3+}$ to Fe$^{2+}$ [Ferrite Materials Science and Technology (1990)] Assuming that all the Fe$^{2+}$ ions in the B-sites participate in the hopping transport, the number of charge carriers (n) are worked out to be $\sim 10^{22}$/cm$^3$. Though n is large, the mobility is low, this is the reason for low conductivity.

Many models have been suggested to account for the electrical properties

1 Hopping Model of electrons
2 Small Polaron Model
3 Phonon Induced Tunneling

1.13 Hopping Model Of Electrons

G H Jonker [(1959)] suggested that in materials like ferrites there is a possibility of exchanging the valency of a considerable fraction of metal ions and especially that of iron ions. In the presence of lattice vibrations, however, the ions occasionally come close enough together for transfer to occur with a high degree of probability.

1.14 Small Polaron Model

A small polaron is a defect created when an electronic carriers become trapped at a given site in consequence of the displacement of adjacent atoms or ions. The entire defect then migrates by an activated hopping mechanism. The materials whose conduction electron belongs to incomplete overlap, tend to

1.15 Structural Studies

In Nickel ferrite eight units of NiFe$_2$O$_4$ are accommodated into a unit cell of the spinel structure. The ferric ions preferentially fill the tetrahedral sites, but there is room for only half of them (eight). The remaining eight go on to the octahedral sites, as do the eight Ni$^{2+}$ ions. The antiferromagnetic interaction orients these eight Fe$^{3+}$ moments and eight nickel moments antiparallel to the eight Fe$^{3+}$ moments on the tetrahedral sites. The Fe$^{3+}$ ion moments will just cancel, but the moments on the nickel ions give rise to an uncompensated moment or magnetization. This type of ferrite is called inverse ferrite. In the case of zinc ferrite, the tetrahedral sites are occupied by zinc ions, which, being diamagnetic, produce no antiferromagnetic orientation of the ions on the octahedral sites that are occupied by Fe ions. The Fe (B–B) interactions are very weak and can be neglected. Therefore, zinc ferrite is not ferromagnetic. This type of arrangement is called a normal spinel structure.

X-ray Powder Diffraction (XRD) is an efficient analytical technique used to identify and characterize unknown crystalline materials. Monochromatic x-rays are used to determine the interplanar spacings of the unknown materials. In 1914 Knipping and Von Laue made the first diffraction pattern of a crystal. Samples are analyzed as powders with grains in random orientations to insure that all crystallographic planes are "sampled" by the beam. In 1915 Bragg developed a theory to determine crystal structure from diffraction pattern. When the Bragg conditions for constructive interference are obtained, a reflection is produced, and the relative peak height is generally proportional to the number of grains in a preferred orientation. The x-ray diffraction generated by this technique, thus, provides a structural fingerprint of the unknown crystals.
Mixtures of crystalline materials can also be analyzed and relative peak heights of multiple materials may be used to obtain semi-quantitative estimates of abundances. A glancing x-ray beam may also be used to obtain structural information of thin films on surfaces. In addition, changes in peak position that represent either compositional variation, structure-state information are readily detectable. Data reduction routines rapidly determine peak position, relative intensities, and calculate intracrystalline d-spacings.

1.16 Irradiation Dependence Of Small Particle Magnetism

The crystallographic and magnetic changes in bulk samples induced by irradiation are known for various kinds of radiation such as fast neutron, low energy ions, high energy ions and for different kinds of ferrite structures such as spinels, garnets and hexa-ferrites [P Pascard and F Studer (1997)]. The observed effects depend on the mechanism of interaction of the irradiating particle with the ions of the material in the context of the structure. Ferrite in general is an ideal system as the effect of irradiation does not cause any destructive effect on the structure. In relevance to the above, the scenario on nanoparticle systems and the scope for such studies are discussed in small particle magnetism.

1.17 Small Particle Magnetism And Superparamagnetic State

Superparamagnetic (SP) state is usually observed in metal particles within a few nanometer size ranges [D L Leslie-pelecky and R D Rieke (1996)]. SP properties of materials are determined by magnetic anisotropy, which comes from electron spin-orbital angular momentum coupling at lattice site in the crystal structure. The major factors that control the strength of magnetic couplings are the magnitude of magnetic moment on each coupling component,
the distance between them, and the symmetry of the lattice site. These factors correspond to the crystal chemistry issues of chemical composition, lattice constant, and coordination environment at the lattice sites. In pure metal systems, these crystal chemistry issues are basically fixed. Apart from size, little variation can be chemically applied to change the crystal chemistry of pure metal nanoparticles to vary and control their SP properties. On the other hand, the crystal chemistry issues can be controlled in metal oxide such as spinel ferrite. At SP state, the collective behavior of the magnetic particles is the same as that of paramagnetic atom. Each particle behaves like a paramagnetic atom but with giant magnetic moment. There is a well-defined magnetic order within each nanoparticle. Spinel ferrite nanoparticles provide excellent experimental systems in which one can study the correlation between the crystal symmetry and SP properties on nanoparticles.

Aim and objective of the present research work

Challenges and probable solutions

The author is interested in the study of the magnetic properties of the nanocrystalline soft magnetic material, and the changes in the magnetic and electric and dielectric properties of nanocrystalline spinel ferrites, a brief review of the literature on these materials and also the motivation for the present work are presented. Finally the applications of these materials are briefly discussed.

The future challenges of nanoparticles and their applications are plenty only a few of them are mentioned below to get a glimpse of their importance.

The preparation of nanoparticles for a particular for application are neither ideal nor a standard one. Nanoparticles prepared by ballmilling which suffers the disadvantage of straining of the particles and distribution of particles.

Chemical routes generally involve the intermediate phases in addition to the required phase. The preparation of ferrite samples with low eddy current
losses and useful frequencies of the order of gigahertz is a challenging one. The property ferrite change from expected ones with a small change in sintering temperature, composition and grain size. Ferrites used for microwave application generally require low core loss impedance frequency response up to few gigahertz. Scientist are still improving the property of different preparation technique and also doping with impurities.

The magnetic nanoparticles are having technological applications such as magnetoresistive devices, magnetic sensors and magnetic recording devices. In the pursuit of high density recording the challenge is to have unidirectional permanent magnetism.

The magnetic relaxation which tends to destroy magnetization has to be successfully overcome by novel methods of preparation of samples.

The magnetic application can be classified into two groups

1. Magnetic flux multiplication which require soft magnetic materials with high magnetization, narrow hysteresis loop and low coercivity.

2. Magnetic storage of information (magnetic recording) which require hard magnetic materials with high magnetization and wide hysteresis loop. Therefore the study of materials prepared under different routes and also doping will guide us towards their possible applications.

The objective of the X-ray was for two specific purposes.

a) To determine the single phase or multiphase structures of the prepared samples as there were no additional peaks as compared to the pure samples the existence of the additional phases was ruled out.

b) To determine the size of the particles which were in the nanometer range as calculated from Debye formulae.
Figure (1.1) Spinel structure of ferrite

Figure (1.2)

Four spin configurations (a) Collinear state (b) A sublattice spins are parallel, B sublattice spins are canted, (c) A sublattice spins are canted, B sublattice spins are parallel, and (d) two independent antiferromagnetic sublattices.
Fig (1.3) The random arrangement of the domains in unmagnetized material

Fig (1.4) Magnetization along the easy axes