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CHAPTER -I

General Introduction

1.1 Introduction to Ferrite

The ferrite may be defined as magnetic materials composed of oxides containing iron ions as their main constituent and metal oxide [1]. The ferrite is often restricted to such materials having the cubic crystal structure of the mineral spinel, but it is also loosely applied to magnetic oxides in general, irrespective of their crystal structure. Ferrites are electrically non-conductive ferromagnetic ceramic materials dark gray or black in appearance and very hard hence brittle [2]. In saturated state they conduct a magnetic flux very well and have a high magnetic permeability, which allows them to store stronger magnetic fields than iron and are known as ceramic magnets.

Polycrystalline ferrites which have many applications in microwave frequencies are very good dielectric materials. The basic electrical and magnetic properties of ferrites depends upon several factors such as method of preparation, preparative parameters and preparative conditions, nature, type and amount of dopant [3, 4]. There are number of methods of preparation of ferrite which are divided in standard ceramic technique and wet chemical methods. Wet chemical methods include co-

precipitation [5] sol-gel [6], hydrothermal [7] etc. In the recent years, chemical synthesis of magnetic nano particles have drawn much attention due to the unique magnetic properties derived from small particle size and uniform distribution. The properties exhibited by nano size ferrite materials are altogether different material of their bulk counterpart.

Ferrites are generally classified into two groups, hard ferrites and soft ferrites. Ferrites for which coercive field is small are termed as soft ferrites. Soft ferrites are characterized by the chemical formula $MO-Fe_2O_3$ with M being a transition metal element e.g. iron, nickel, manganese, or zinc. Manganese Zinc ferrite, which are known under the commercial name Ferro-cube, can be used soft magnetic applications up to frequencies as high as 10 MHz.

Hard ferrites are permanent magnetic materials based on the crystallographic phases $BaFe_{12}O_{19}$, $PbFe_{12}O_{19}$. These can generally be written as $MO-6Fe_2O_3$ with M = Ba, Sr, Pb etc. Hard ferrites exhibits hexagonal crystal structure and a relatively high value of the anisotropy constant yielding the necessary ingredients for a permanent magnet materials.

Magnetically soft ferrites find wide applications in the television industry, deflection yoke, circulators, isolators, phase shifters, tuned

filters and switches etc. Hard ferrites find application in generators, computers, motors, memory devices and mechanical filters etc,

1.2 Chemical composition and crystal structure of ferrites.

Ferrites are nothing but mixed metal oxides with iron (Fe^{3+}) oxide as their main component and metal oxides. The crystallography of ferrite falls naturally into three types [8].

Type	Structure	General formula	Example
Spinel	Cubic	$\text{M}^{\text{II}} \text{Fe}_2\text{O}_4$	M^{II} (Cd, Co, Cu, Mn, Ni etc.)
Garnet	Cubic	$\text{Ln}_3^{\text{III}} \text{Fe}_5\text{O}_{12}$	Ln^{III} (Y, Eu, Gd, Tb, Ho, Er, Tm, Lu etc.)
Hexagonal	Hexagonal	$\text{Me}^{\text{II}} \text{Fe}_{12}\text{O}_{19}$	Me^{II} (Ba, Sr, Pb etc.)

1.3 Spinel Ferrite

The structure of spinel ferrite was first determined by Bragg [9] and Nishikawa [10]. The spinel ferrites are also called as ferro-spinels because they crystallize in the same crystal structure as the mineral

spinel [MgAl_2O_4] and they derive their general formula MFe_2O_4 in which M and Fe denote different metal cations but in few cases (e.g. magnetite $\text{Fe}^{\text{II}}\text{Fe}^{\text{III}}\text{O}_4$) only the valences differ. M is usually a divalent cation having radius between about 0.6 to 1.0Å such as manganese (Mn^{2+}), nickel (Ni^{2+}), cobalt (Co^{2+}), zinc (Zn^{2+}), copper (Cu^{2+}) or magnesium (Mg^{2+}) etc. and Fe is replaced by Fe^{3+} . All pure ferrites having the spinel structure are necessarily 2-3 spinels. The unit cell of spinel ferrite consists of 8 formula units of MFe_2O_4 . Hence, a unit cell of spinel contains 8M^{2+} ions, 16Fe_2^{3+} ions and 32O^{2-} ions. The close packed arrangement of 32 oxygen ions forms FCC lattice with M^{2+} and Fe_2^{3+} ions at two different crystallographic sites namely 64 tetrahedral site or A site in which a cation is surrounded by 4 oxygen ions and 32 octahedral site or B site in which a cation is surrounded by 6 oxygen ions respectively (Fig.1.1) out of these 96 interstitial sites, only 8-tetrahedral and 16-octahedral sites are filled.

The spinel ferrites are cubic in structure; with no preferred direction of magnetization, they are “soft” magnetically; i.e. it is relatively easy to change the direction of magnetization through the application of an external magnetic field. [11-13].

1.4 Spinel Unit Cell

The crystal structure of spinel ferrite is best described by subdividing the unit cell into eight octants with edge $\frac{1}{2}a$ ('a' is the edge of unit cell). Each octant in unit cell contains four oxygen ions on the body diagonal from alternate corners of the octant. The positions of metal ions are different in the two octants sharing a face. In one of the octants an occupied tetrahedral site is located at the centre and four more sites on the corners of the octant. In the adjacent octant the central site is not occupied but owing to translation symmetry, half of the corner sites are occupied. Each tetrahedral ion is surrounded by four other tetrahedral ions, which lie in the corners of a regular tetrahedron. There are twelve nearest neighbour octahedral ions for every tetrahedral ion. Each octant contains four octahedral metal ions and these are situated at sites analogous to those of the body diagonal from the other ends of the four body diagonals of the octant. Each octahedral ion is surrounded by six nearest neighbour tetrahedral ions. Each oxygen is surrounded by one tetrahedral ion (A ion) and three octahedral ions (B ion) as shown in Fig. 1.2. Each A ion belongs to four each units and each B ion to six. The direction of OA is that of the body diagonal of a cube and the directions OB are along the cube edges.

The interstices available in an ideal close packed structure of rigid oxygen anions would be able to incorporate in the tetrahedral sites only metal ions with a maximum radius $r_{\text{tet}} 0.30 \text{ \AA}$ and in octahedral sites only ions with a maximum radius $r_{\text{oct}} 0.55 \text{ \AA}$. In order to incorporate cations like Co, Cu, Mg, Ni, Mn and Zn lattice has to expand somewhat. The difference in the expansion of the tetrahedral and octahedral interstices is characterized by an oxygen parameter 'u' for an ideal spinel; tetrahedral and octahedral interstices are enlarged in the same ratio. The distance between the tetrahedral site (0, 0, 0) and the oxygen (3/8, 3/8, 3/8) is $u_{\text{ideal}}=3/8$. The incorporation of divalent metal ions in tetrahedral sites induces a larger expansion of the tetrahedral sites at the expense of the octahedral sites, leading to a large value for u from the ideal value.

The radii of ions in both the tetrahedral (A) and octahedral (B) sites are given by the expression;

$$r_A = (u-1/4) a \sqrt{3} - R_0 \quad \text{----- (1.1)}$$

$$r_B = (5/8 - u) a - R_0 \quad \text{----- (1.2)}$$

where

a – lattice Constant

R_0 - radius of oxygen ion (1.32Å)

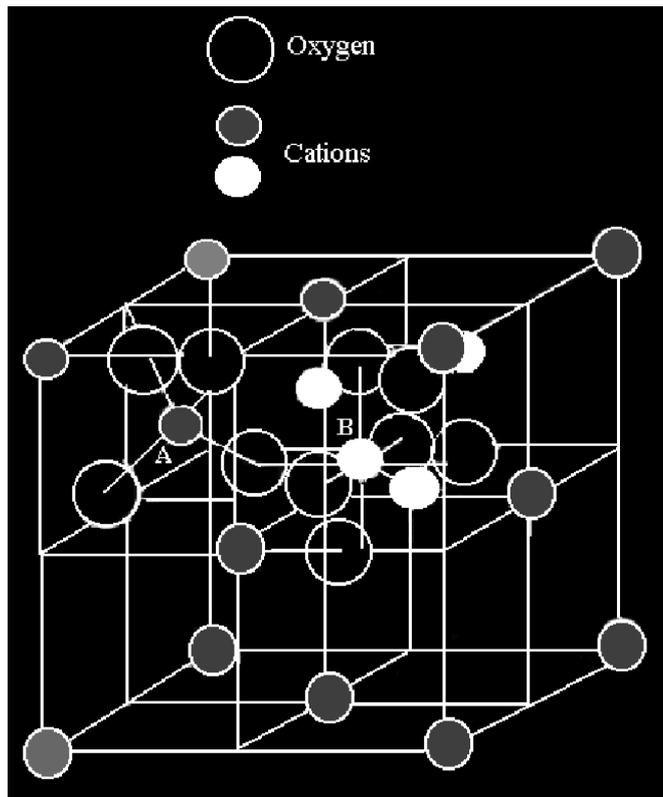


Fig 1.1 Crystal Structure of Spinel Ferrite

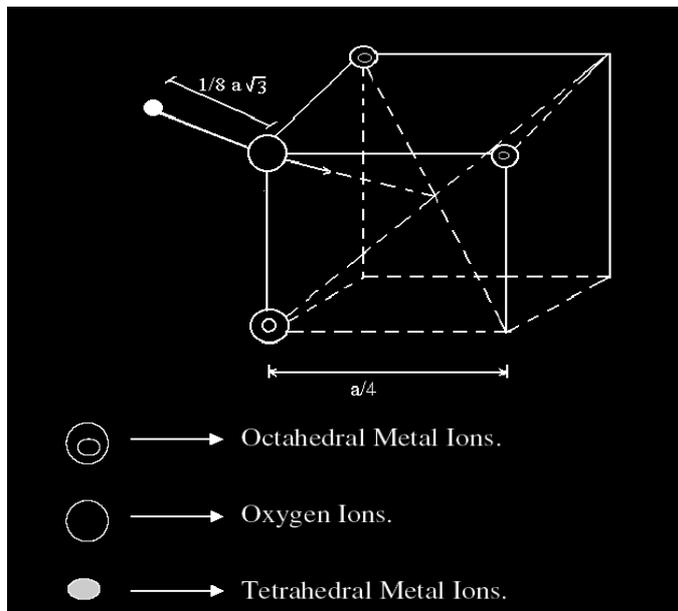


Fig 1.2 Position of A- site and B- site surrounding an oxygen ion

1.5 Types of spinel ferrites

The spinel lattice consist of two interstitial sites tetrahedral [A] and octahedral [B] sites in which cations of different valence and ionic radii can be incorporated. Depending upon the occupancy of cations at tetrahedral [A] and octahedral [B] sites, the spinel ferrite can be classified as Normal, Inverse and Random. The distribution of cations depends on method of preparation and prepared cations.

I) Normal Ferrite

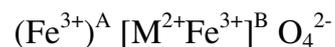
In normal ferrite all the divalent M ions are in the tetrahedral A sites and all the trivalent Fe^{3+} ions are in the octahedral B sites. This kind of distribution of cations can be represented as



Examples. ZnFe_2O_4 ; CdFe_2O_4 etc.

II) Inverse Ferrite

In Inverse ferrites, all the divalent M ions and half of the trivalent Fe^{3+} ions are in the octahedral [B] sites, while the remaining Fe^{3+} ions are in tetrahedral [A] sites. The distribution of cations in this type of spinel ferrite can be represented as



Examples. MnFe_2O_4 , CoFe_2O_4 and NiFe_2O_4

III) Random Ferrite

In random spinel ferrite, the divalent M and trivalent Fe ions are distributed randomly over the tetrahedral [A] and octahedral [B] sites. In random spinel ferrite the distribution is not uniform to both sites.

Generally, this type of distribution is shown as



Examples. $CuFe_2O_4$, $MgFe_2O_4$ etc [7, 8].

1.6 Garnets

The rare earth garnets have the general formula $M_3Fe_5O_{12}$ where M is rare earth metal ions or an yttrium ion (La, Gd, Nd, Sm, Ho etc.).

The metallic ions are all trivalent. An analogous mineral garnet is silicate.

In addition to tetrahedral sites and octahedral sites, such as those seen in spinel, garnets have dodecahedral (12-coordinated) sites. The net ferrimagnetism is thus a complex result of anti-parallel spin alignment.

Among the three types of ferrite garnets are magnetically hard.

1.7 Hexagonal ferrite

The general formula of hexagonal ferrite is $MeFe_{12}O_{19}$ where Me is a divalent ion of a large ionic radius, such as Ba^{2+} , Sr^{2+} or Pb^{2+} . Some compounds with trivalent Me (e.g. La, Al, Ga, Cr, Fe) are also known. In these, one iron ion per formula unit is present as Fe^{2+} to allow the charge compensation.

The unit cell is hexagonal and contains two molecules of $\text{MeFe}_{12}\text{O}_{19}$. The hexagonal ferrites have high magneto-crystalline anisotropy. They are thus ideally suited to be permanent magnetic material and having high coercivity. Their high anisotropy is attributed to the Fe^{3+} ions at the trigonal bipyramidal site.

1.8 Introduction to ferroelectric materials

Ferroelectrics are the polar materials, which can spontaneous, reversible electric polarization, which can be reversed by applying suitable electric field. Ferroelectric crystals have two or more orientation states, which are identical in structures and differ only in electric polarization vector at null electric field. The parameters affecting the reversibility of polarization are crystal perfection, electrical conductivity, temperature and pressure. The reversible non linear behavior of ferroelectric substances makes them useful in dielectric amplifiers, voltage regulators etc. These capable applications have attracted the attention of many research workers.

In the so-called dielectric material, depending on the crystal structure, the centers of the positive, negative charges may not coincide even without the application of an external electric field. Such crystal are said to possess a spontaneous polarization. When the spontaneous polarization, of the dielectric can be reversed by an electric field it is called ferroelectric. No every dielectric is ferroelectric [14]. Crystals are

classified into seven systems according to their geometry and based on their symmetry with respect to a given point the systems are further sub-divided into groups known as crystal classes.

Among the 32 crystallographic point groups describing all crystalline systems, ferroelectricity is allowed in a class of non-centrosymmetric and polar crystals that make ten out of these thirty-two crystal classes [15]. A ferroelectric material possesses a reversible spontaneous polarization in the absence of an external electric field and the direction of which may be altered by the application of an appropriate field. An important group of ferroelectric materials is the ferroelectric ceramics, of which BaTiO_3 is an example. These are polycrystalline ferroelectric materials with the perovskite crystal structure a tetragonal/ rhombohedral structure very close to cubic. They have general formula $\text{A}^{2+}\text{B}^{1+}\text{O}^{2-}_3$, in which A denotes a large divalent metal ion such as barium or lead, and B denotes a tetravalent metal ion such as titanium or zirconium. A material such as BaTiO_3 can be considered as a mass of minute crystallites.

Above temperature known as the Curie temperature, these crystallites exhibit simple cubic symmetry. The first observation of ferroelectricity was made in 1921 by Valasek [16]. He noted that Rochelle salt dielectric hysteresis in certain crystallographic directions. Valasek compared the phenomena with ferromagnetism, from which ferroelectricity gets its

name by analogy. Three things were noted, first the measured dielectric polarization depends upon their previously applied electric field is much the same way that the iron shows the hysteresis in a plot of induction versus field (B vs. H). Second, there is a transition temperature (T_c) above which there is no dielectric anomaly and there is large dielectric and piezoelectric response near and below (T_c). Above the transition temperature the ferroelectric material becomes paraelectric. Near the Curie temperature, ferroelectrics displays anomalous behaviour in their dielectric, elastic, optical and thermal properties. The exact nature of the anomalies depends on the order of the transformation. The crystal structure in the paraelectric phase is centro-symmetric. At the phase transition it changes to a more general structure, loses symmetry and becomes ferroelectric. The ferroelectric-paraelectric phase transformation of a material can be either first or second order or either of the displacive or order-disorder type. If the transformation is displacive, it referred to as a normal ferroelectric, of if order-disorder, as relaxor ferroelectric [17].

Depending on the dielectric, polarization and phase transition behaviour ferroelectric are classified into three categories

- 1) Normal ferroelectric
- 2) Ferroelectric with diffused phase transition and
- 3) Relaxor ferroelectric or relaxors [18].

Normal ferroelectric shows a normal anomaly in the dielectric permittivity at Curie temperature, T_c which point to a phase transition and hence vanishing of the spontaneous polarization upon heating. Ferroelectric with a diffused phase transition show broadening of the dielectric peak, which is caused by different kinds of cations being distributed over the 'B' sites of the perovskite structure. On the other hand relaxore exhibit a broad and frequency dependant dielectric permittivity peak. With an increasing frequency, the dielectric maxima (ϵ'_{max}) decreases and the temperature (T_{max}), at which maximum permittivity is observed, experiences an increase. The class of ferroelectric materials has a lot of properties high dielectric coefficients over a wide temperature and frequency range are used as dielectrics in integrated or in surface mounted device (SMD) capacitors. The large piezoelectric effect is applied in a variety of electromechanical sensors, actuators and transducers. Infrared sensors need a high pyroelectric coefficient which is available with this class of materials. Tunable thermistor properties in semi conducting ferroelectric are used in positive temperature coefficient of resistance (PTCR).

1.9 Chemical composition and crystal structure of ferroelectric

An important group of ferroelectric materials is the ferroelectric ceramics, of which $BaTiO_3$ or $KNbO_3$ is an example. These are polycrystalline

ferroelectric materials with perovskite crystal structure, tetragonal/rhombahedral structure very close to cubic. The schematic representation of the perovskite lattice structure as shown in Fig.1.3.

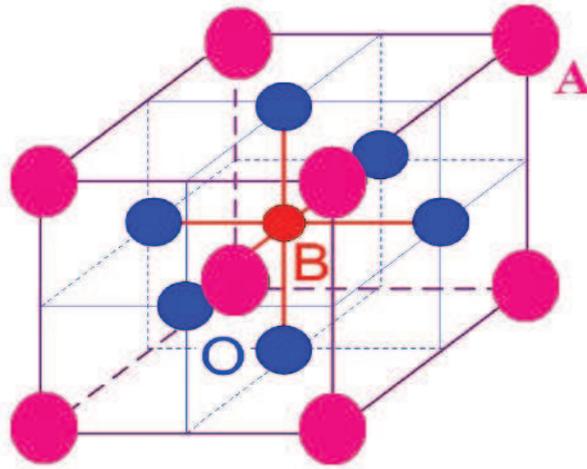


Fig 1.3 Schematic representation of the Perovskite lattice structure.

They have the general formula $A^{2+} B^{4+} O_3^{2-}$, in which A denotes a large divalent metal ion such as barium, potassium or lead, and B denotes a tetravalent metal ion such as titanium or niobium. Materials such as $BaTiO_3$ can be considered as mass of minute crystallites. Above a temperature known as the Curie temperature, these crystallites exhibit simple cubic symmetry, the elementary cell of which is shown in Fig. 1.4(a).

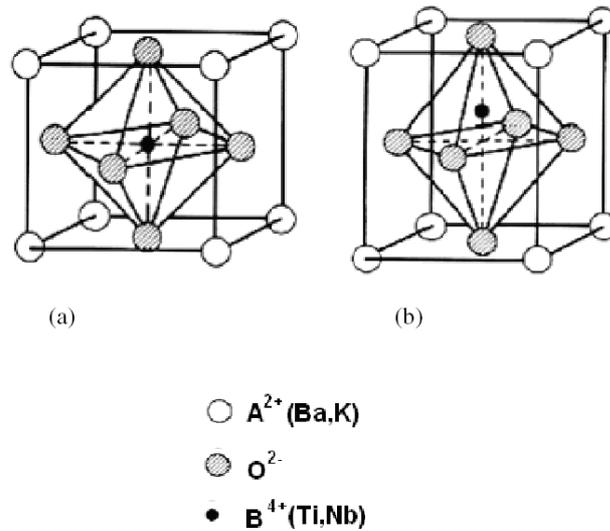
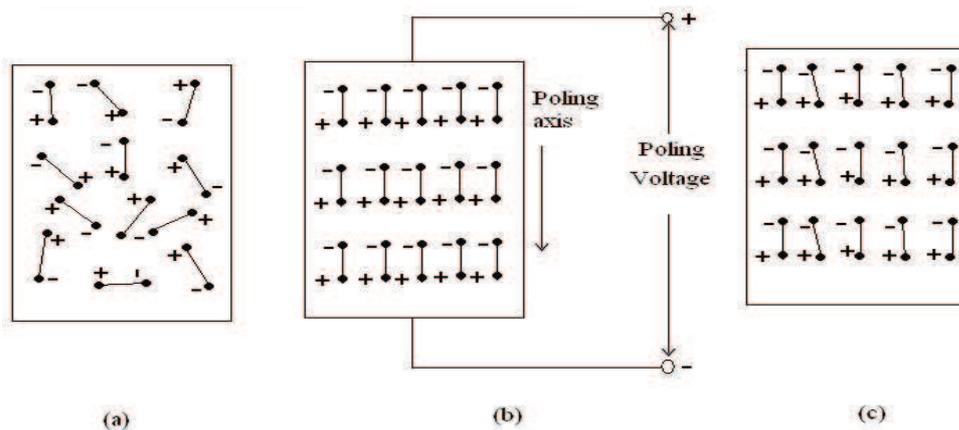


Fig 1.4 (a) Cubic lattice (above Curie temperature)

(b) Tetragonal lattice (below Curie temperature)

This structure is centro-symmetric with positive and negative charge sites coinciding, so there are no dipoles present in the material it means they exhibit paraelectric behaviour. Below the Curie point, however, the crystallites take on tetragonal symmetry in which the positive and negative charge sites no longer coincide as shown in Fig. 1.4(b). So each elementary cell that has a built in electric dipole which may be reversed and also switched to certain allowed direction is the application of an electric field. Such materials are termed as ferroelectric materials because this electric behaviour presents a physical analogy with magnetic behaviour of ferroelectric materials. They don't necessarily contain iron as an important constituent. The analogy can, in fact, be carried further,

since to some extent the polarization of ferroelectric materials exhibits hysteresis, and their dielectric constants are very high and temperature dependent same as that of permittivity in case of ferromagnetic materials. The dipoles are not randomly oriented throughout the material. Neighboring dipoles align with each other to form region of local alignment known as Weiss domains. Within a Weiss domain, therefore, all the dipoles are aligned giving a net dipole moment to the domain and hence a net polarization.



(a) Before polarization (b) During polarization (c) After Polarization

Fig 1.5 Electric dipole moments in Weiss domains.

The direction of polarization between neighboring Weiss domain within a crystallite can differ by 90° or 180° and owing to random distribution of Weiss domains throughout the materials as shown in Fig. 1.5(a), no overall polarization or piezoelectric effect is exhibited. The ceramic may be made piezoelectric in any chosen direction by a poling

treatment which involves exposing it to a strong electric field at a temperature slightly below the Curie point as shown in Fig. 1.5(b).

Under the action of this field, most of the domains nearly aligned with the field, will grow at the expense of other domains. The material will also lengthen in the direction of the field.

When the field is removed [Fig. 1.5(c)], the dipoles remain locked in approximate alignment, giving the ceramic material a remanent polarization and a permanent deformation.

1.10 Barium Titanate (BaTiO₃)

Barium Titanate is a ferroelectric material with a perovskite structure as shown in Fig (1.4). It is the first discovered piezoelectric ceramic. BaTiO₃ is cubic structure above Curie temperature, 120⁰C. Cubic barium titanate is non-ferroelectric because the centers of positive and negative charges overlap as the ions are symmetrically arranged in the unit cell. Below T_c, it has tetragonal structure, in which the O₂ ions in the BaTiO₃ crystal are shifted in negative c-direction, while the Ti⁴⁺ ions are shifted in the positive c-direction. It results an electric dipole along the c-axis. Therefore BaTiO₃ has ferroelectric structure. [19, 20].

1.11 Introduction to composite materials

The development of composite materials has been a subject of intensive interest in the last 45 years. In practical view, every material utilized

today is a composite, hence it is rare to find material used in its purest form. Many purest materials are converted into composite form for commercial reasons such as economy and ease of processing. It is also rare to find material without impurities, alloying element and unwanted second phase. Furthermore, if we consider them on the atomic or molecules. However, the composites as a special class of materials are required to meet the following criteria.

- The composite material must be a combination of at least two chemically distinct materials having a distinct interface separating the components.
- The separate materials forming the composite must be combined three dimensionally.
- The components of the composite must be present in repeating geometry, so that for large enough scale, the material could be considered homogeneous.
- The composite material should be created to obtain the properties, which would not be achieved by any of the component acting alone [21].

Based on these requirements composite materials can be defined as a physical mixture of two or more compatible micro or macro constituent particles which should differ in the physical form and chemical

composition, are essentially insoluble in each other and that can be best suited for a particular application, which would not be achieved by any of the component acting on its own.

So far most of the composite materials have been created to improve magnetic, electric and dielectric properties along with the mechanical properties. The numbers of industries materials and their uses continue to grow. The composite materials have the potential material of the future [22]. The use of composite material will continue to grow.

Composites are combinations of two materials in which one of the materials called the reinforcing phase, is in the form of fibers, sheets or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and matrix material can be metal, ceramic or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a tough material .If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in the single conventional material [23], accordingly composite materials are classified into three main types [24].

I) Dispersion strengthened composites:

These are characterized by micro-structure consisting of an elemental or alloy matrix within which fine particles of 0.01 to 0.1 micro meters in diameter are uniformly dispersed in a volume of 1 to 15%.

II) Particle Reinforced composites:

These are differing from the dispersion strengthened composites since the dispersion size exceeds 1mm and the dispersion concentration exceeds about 25%.

III) Fiber reinforced composites:

The reinforcing phase in fiber composite material spans the entire range of size from a fraction of micron to several mm in diameter and the entire range of volume concentration from a few percent to greater than 70%. Composites are able to meet diverse design requirements with significant weight savings as well as high strength-to-weight ratio as compared to conventional materials.

1.12 Composite materials and magnetoelectric effect

1.12.1 Magnetoelectric composites

As reported, every composite material is mixture of two or more phases. Consider a composite material having two different phases, phase-I and phase-II. The action of physical quantity 'X' of one phase resulting into a physical quantity 'Y' in the same phase can be considered as physical

property of that particular phase. This physical property may be defined as X-Y effect. Thus, the X-Y effect is property of phase-I and Y-Z effect is the property of phase-II and the resultant quantity of the phase-I is transferred to phase-II then the composite is said to exhibit an X-Z effect. This effect is defined as product property. The material exhibiting the ME effect can be classified into two types.

a) Single phase ME materials.

b) Composites ME materials.

a) Single Phase ME materials

Single phase materials exhibiting the ME effect have an ordered structure and require the presence of ferroelectric / ferroelectric / anti ferroelectric state. These materials show two transitions, one from ferroelectric to a paraelectric state and the other from a ferromagnetic / ferromagnetic / anti ferromagnetic to a paramagnetic state. The ME effect arises due to the local interaction between the ordered magnetic and ferroelectric sublattices.

The observed magnitude of the magnetoelectric output in the single phase material is not sufficient for practical applications. Another limitation on the uses of these materials is the working range of temperature. Most of the single phase materials can be used only at very low temperatures, involve expensive materials and processing techniques

and suffer from degradation under cyclic conditions. The solution to these was offered by composite ME materials [25].

b) Composites ME materials

Based on the concept of product property , Van Suchetelenc suggested that a suitable combination of two phases such as piezo magnetic (ferrite) phase and piezoelectric (ferroelectric) phase, known as ferrite-ferroelectric composite, may exhibits the ME effect. The composite prepared by combining these two phases in proper molar proportions has been observed to give higher ME output. The ME effect obtained in the composite is more than hundred times that of single phase ME materials.

The magnetoelectric effect is observed due to strain induced in ferrite phase being mechanically coupled to stress induced in a ferroelectric phase. Under the influence of an external applied magnetic field the magnetic phase deforms and if this phase mechanically coupled to a ferroelectric phase, which generates an electric voltage [26]. Thus the magnetoelectric effect is defined as in induced dielectric polarization of a material in an applied magnetic field and an induced magnetization in an external electrical field.

1.13 Literature Survey

The magneto electric effect has been first observed in Cr_2O_3 single phase material [27], these single phase materials show a weak ME effect that

they have not yet found any technological application. The ME effect in composite systems has been suggested by Suchetelene of the Philips Laboratory as a product property between a piezomagnetic and a piezoelectric materials. In the literature ME effect of various ferrite/ferroelectric composite has been reported [28].

In most of the studies BaTiO₃ was considered as ferroelectric material. B.K. Chougule and others have studied ME effect and other properties of CoFe₂O₄ + BaTiO₃ [29]. The conductivity, dielectric behavior and ME effect in CuFe₂O₄ + BaTiO₃ was reported by S. A. Patil [30]

Electrical behavior and ME effect in NiCoFe₂O₄ + BaPbTiO₃ was reported by S. L. Kadam and K. K. Patankar [31]. The ME effect in CoFe₂O₄ + BaTiO₃ was also reported by R. P. Mahajan [32]. The ME effect in NiCoMnFe₂O₄ + BaTiO₃ was also reported by R. S. Devan [33].

According to literature survey no reports has been seen on the ME effect and other properties on (1-x) Co_{1.2}Mn_{0.2}Fe_{1.6}O₄ + (x) BaTiO₃ composite materials. The ferroelectric material with perovskite structure ABO₃ are of great interest in modern technology they can be used for memory devices, light modulators for optical communication systems or piezoelectric detector of radiations amongst such perovskite oxides BaTiO₃ presents attractive properties for electro optical operations. BaTiO₃ with its Curie point of 120°C [34].

1.14 Aim of the present work

Ferroelectric materials have wide applications as nonvolatile memories, capacitors, transducers, actuators, etc. Magnetic materials are also used in data storage and variety of other applications. There is great technological promise and fundamental interest in the phenomenon if ferroelectricity and ferromagnetism co-exist at room temperature. The combination of both ferroelectric and ferromagnetic materials in single material is expected to produce new properties such as magneto-electric [35], magneto-optic [36] and other new properties, due to the occurrence of coupling effect between the magnetization and electric polarization. However, there are only a few naturally occurring materials that can exhibit both spontaneous magnetization and ferroelectric properties [37]. Recently the ferrite-ferroelectric composites obtained by standard ceramic technology have been attracted much attention, as they exhibit large ME effect. The studies of physical properties of these materials are interesting; they provide a basis for the technological and scientific application [38]. The selection of suitable combination of piezomagnetic and piezoelectric material to achieve better ME effect is however a challenging task.

In the present work Mn doped cobalt ferrite having high magnetostrictive coefficient was selected as piezomagnetic material

where as BaTiO₃ was chosen as a ferroelectric materials. We report the study of synthesis, characterization, electric, magnetic properties and ME coefficient of magneto electric composite having CoMnFe₂O₄ as a ferrite phase and BaTiO₃ as ferroelectric phase. The soft ferrite CoMnFe₂O₄ with low anisotropy and initial permeability is promising conditions [39]. Further a large net magnetic movement caused by the ion arrangement, which favors the ME effect can be obtained.

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