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# CHAPTER - I

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## CHAPTER – I

# AN INTRODUCTION TO COMPOSITE MATERIALS

### 1.1 NEED AND ADVANTAGES OF COMPOSITES

The word composite means, “consisting of two or more distinct parts”. Thus a material having two or more distinct materials or phases as constituent parts may be considered as a composite material, i.e. in other words a composite material can be yielded by combining two dissimilar materials into a new material that may be best suited for a particular application than the original materials [1]. A composite material is strictly defined [2] as a material composed of a physical mixture of two or more than two micro and macro constituents that differs in form and chemical composition and which are essentially insoluble in each other.

In the modern and constantly developing technological scenario the existing materials cannot meet the requirements even after treatments given to them for improvement of mechanical properties. A new group of materials called composites have been found to meet the requirements of strength, stiffness and toughness and are accepted as promising materials of the future, even in high-tech areas [3]. In composite materials the widely different mechanical properties of the two or more constituent materials are harnessed by using different geometrical shapes to give the desired mechanical properties. Besides the mechanical properties the other

technologically important properties like dielectric behaviour, magnetic and ferroelectric characteristics can also be manipulated using various shapes and composition in composite materials. Fabrication of composite materials for mechanical application involves embedding or dispersing the fibers or particles of a harder and stronger phase in the continuous phase or matrix of the other material [4] e. g. fiber reinforced plastic, reinforced concrete and ceramic metal (cermet) composite.

## **1.2 CLASSIFICATION OF COMPOSITE MATERIALS**

Composite materials can be classified based on the microstructure of the reinforcing component or in general of the composite, or the particle size (dimensions) of the reinforcing component. Mainly we get the following three groups, out of which we consider only the second group.

1. Dispersion strengthened composite materials.
2. Particle strengthened composite materials.
3. Fibre reinforced composite materials.

### **1.2.1 Particle Reinforced Composites**

The importance of the matrix phase in particulate reinforced composite materials is intermediate between dispersions strengthened and fibre reinforced composite materials. In dispersion strengthened composites the load is fully borne by the matrix whereas in fibre reinforced composites

the load is primarily borne by the fibres. In particle reinforced composites the load is borne by both. Structurally also this has an intermediate behaviour as the volume percentage of particles goes beyond 25% and the particle diameter and average free path in the matrix is more than 1  $\mu\text{m}$  [3].

In particle reinforced composites the particle dimensions are approximately same in all directions i.e. the dispersed phase for particle reinforced composites is equiaxed. The large particle composites and dispersion strengthened composites are two subtypes of particle reinforced composites. The distinction between them based upon reinforcement or strengthening mechanism.

#### **1.2.1.a Large particle Composites**

The term large is used to indicate that the particle matrix interaction can not be treated on atomic or molecular level and rather continuous mechanism is to be used. For most of these composites the particulate phase is harder and stiffer than the matrix. These reinforcing particles restrain movement of matrix phase in the vicinity of each particle. In essence the matrix transfers in some of the stress that the particle bears which is function of load. The degree of reinforcement in the mechanical behaviour depends on strong bonding at matrix interface. Some polymeric materials to which filler have been added are really large particle composites are using metals, polymers and ceramics. [5]

### 1.2.1.b Dispersion strengthened Composites

Metals and alloys may be strengthened and hardened by uniform dispersion of fine particles of very hard and inert material. The dispersed phase may be metallic or non-metallic. Oxide materials are often used. The strengthening mechanism involves interaction between the particles and dislocation within the matrix is the precipitation hardening. The dispersion strengthened effect is not for extended time periods because the dispersed particles chosen to be unreactive with matrix.

So far the composite materials prepared and studied are only related to mechanical properties and used in structural and high temperature applications. The physical properties can be modified by mixing two materials having different characteristics. The physical properties such as product and sum properties appear for the composites e.g. ME effect.

Recent study of composites by Van Suchetelene, shows that properties are entirely different than those of individual phases. For example ME effect was found in  $\text{NiFe}_2\text{O}_4$  – PBZT (Lead Barium Zirconate titanate). Nickel ferrite was found to be highly magnetostrictive ferrite. PBZT has superior dielectric and piezoelectric properties. Hence a combination of these two materials results in magnetoelectric effect due to the product of their intrinsic properties like piezomagnetism and piezoelectricity.

### 1.3 FERRITE FERROELECTRIC COMPOSITES (Two Phase Composite)

Composite materials of the type piezoelectric (ferroelectric) piezomagnetic (ferrite) are of interest in transducers, which transform changes in magnetic field into electric signals and vice-versa [6]. The phenomenon involving changes in magnetic field giving rise to electric signals is called as magnetoelectric effect (ME effect). ME effect observed in some insulating materials offers a challenge from both experimental and theoretical points of view, since the material showing the ME effect belongs to an entirely new class called as ferroelectromagnetics [7]. To realize magnetoelectric conversion in such composite materials, Van suchtelen suggested a suitable idea of the product of inherent properties of constituent phases in the composite [8]. The combinations of inherent properties in ferrite ferroelectric composites are : ferroelectricity-ferromagnetism, ferroelectricity ferrimagnetism, antiferroelectricity-antiferromagnetism. The amount of the output signal depends on the strength of interaction between the two subsystems. To realize higher output of ME conversion in composite materials the following guidelines are to be kept in mind [9].

- i) The two phases must be in equilibrium with each other.
- ii) Mechanical contact between grains must be intimate.
- iii) The value of magnetostriction coefficient of piezomagnetic phase must be high.

- iv) The value of piezoelectric coefficient of the piezoelectric phase must be high.
- v) The accumulated charges must not leak through the piezomagnetic phase. Hence this phase should have resistivity  $> 10^8$  ohm-cm.
- vi)  $T_c \gg R_t$  to facilitate poling and the relaxation time for charge compensation is to be longer.
- vii) Proper poling strategy is to be adopted for the materials to show higher ME conversion.

#### 1.4 Survey of the work done in Ferrite-Ferroelectric Composites

Boomgaard et. al. (1974) prepared composites of Ni(Co, Mn) Fe<sub>2</sub>O<sub>4</sub> and BaTiO<sub>3</sub>[10]. The observed high ME output of the order of 130 mv/cm/Oe in unidirectionally cooled composite for 60% Ni (Co, Mn) Fe<sub>2</sub>O<sub>4</sub> 40%. BaTiO<sub>3</sub> than in the same composite prepared by double sintering method [11]. V.M. Lalitin (1992) investigated Ni Fe<sub>2</sub>O<sub>4</sub> PBZT and CoFe<sub>2</sub>O<sub>4</sub> PBZT systems. He observed the value of  $dE/DH = 60$  mv/cm/Oe for nearly 50-50 mol percent of the constituent phases i.e. NiFe<sub>2</sub>O<sub>4</sub> and Fe<sub>2</sub>O<sub>4</sub> and BaTiO<sub>3</sub> and 12 mv/cm/Oe in CoFe<sub>2</sub>O<sub>4</sub> - BaTiO<sub>3</sub> composite with 30 percent CoFe<sub>2</sub>O<sub>4</sub>. [11,12] Sergey Lopatin (1994) investigated Ni<sub>0.9</sub>Co<sub>0.1</sub>, Fe<sub>2</sub>O<sub>4</sub>-PZT composites and obtained value of 110 V/cm/Oe, a very high value compared to others, for the range of composites with varying wt % of ferrites from 35 to

55 % [13]. A. E. Gelyasin observed maximum value of magnetoelectric output in 20%  $\text{NiFe}_2\text{O}_4$  composite with  $\text{BaTiO}_3$  [14]. S.V. Suryanaryana et. al. investigated  $\text{CoFe}_2\text{O}_4\text{-BaTiO}_3$ ;  $\text{LiFe}_5\text{O}_8\text{-BaTiO}_3$  prepared by solid state route and also  $\text{LiFe}_5\text{O}_8 - \text{BaTiO}_3$ ;  $\text{NiFe}_2\text{O}_4 - \text{BaTiO}_3$  prepared by Sol Gel method and obtained high value of  $dE/dH$  of the order of  $450 \mu\text{v/cm/Oe}$  in mole percent  $\text{NiFe}_2\text{O}_4 - 60$  mol percent  $\text{BaTiO}_3$  composite. Surprisingly no ME signal was obtained for  $\text{LiFe}_5\text{O}_8 - \text{BaTiO}_3$  composite though  $\text{LiFe}_5\text{O}_8$  is having high magnetostrictive coefficient [9]. T. G. Lupico et. al. (1992) observed  $56.5 \mu\text{V/A}$  ME output in  $\text{PZT} - \text{Ni}_{0.9}\text{Co}_{0.1}\text{Fe}_2\text{O}_4$  composites with 35-5- mass % of ferrite. Recently Patil et al [15] have observed the ME for  $\text{Cu-Cr Ferrite} - \text{BaTiO}_3$  and  $\text{CuFe}_2\text{O}_4 - \text{BaTiO}_3$ .

## 1.5 ORIENTATION OF THE PROBLEM

Properties of the composites are, often superior to those of the conventional materials. M. E. effect, a product property is absent in ferrite and ferroelectric but present in their composites. ME effect in composites has recently attracted much attention owing to the interest in using them for broad band magnetic field probes which exhibit large ME effect and exceptionally flat frequency response. In addition to this Wood and Astin (1974) indicated possible applications of magnetoelectric crystals as well as the characteristics of over 15 devices whose operation range varies from audio to optical frequency, including modulators, switches, phase inverters, rectifiers etc. Materials showing ME conversion can also be used as thin film wave guides in integral optics and fibre communication technology [16].



Taking into consideration the above possibilities of application the present work communicates the study of electrical properties in  $\text{MnFe}_{1.8}\text{Cr}_{0.2}\text{O}_4$  –  $\text{BaTiO}_3$  composites having higher content of  $\text{BaTiO}_3$  phases. Moreover the study of electrical properties in such composites has not been carried out hitherto and is not reported. The study of magnetoelectric output in these composites assumes importance in view of the requirements of the applications. [17] Therefore, we have chosen to study the M.E. effect in ferrite-ferroelectric composite with higher percent content of the ferroelectric, as it is expected to give longer M.E. effect. [16]

The choice of the ferrite fell on  $\text{MnFe}_{1.8}\text{Cr}_{0.2}\text{O}_4$  as a magnetostrictive phase, presuming Mn-Cr to be Jahn Teller ions [18] that induce mechanical distortion in ferrite lattice, and are supposed to be a pre-requisite for composites to yield high ME output. The following studies were undertaken during the course of this work.

- 1) Preparation
- 2) Characterization
- 3) Dielectric properties
- 4) AC and DC conductivity
- 5) Magentoelectric effect studies.

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