CHAPTER V

Magnetoelectric effect

Chapter V MAGNETOELECTRIC EFFECT

5.1 Introduction

Composite material is a combination of two or more dissimilar materials to form a new class of material, which shows new physical properties [1]. There are mainly two types of composites, bulk and layered. Bulk composites have the advantage of superior mechanical strength over layered samples. The ME property of piezoelectric and piezomagnetic composite is known as a product property of the composites, which is achieved from the interaction between different properties of the two phases in the composites. Though the component phases do not show this effect, when they are combined together, the composites show a remarkable ME effect [2]. Thus if the X-Y effect in sub material I and Y-Z effect in the sub material II are considered then by some mechanism the Y quantity is transferred from I to II. The two effects get coupled and the composite exhibits an X-Z effect, defined as product property. [3-7]. In magnetoelectric composites, the magnetic field induces a change in shape of the magnetostrictive phase in which an electric field is generated. The strength of ME interactions depends on the mechanical connectivity between the magnetic and piezoelectric phases [8].

Curie in 1894 stated that it would be possible for an asymmetric molecular body to polarize directionally under the influence of a magnetic field. Later Landau and Lifshitz showed from symmetry considerations that a linear ME can occur in magneto electrically ordered crystals [9]. The main requirement to obtain this effect is the coexistence of magnetic and electric dipoles.

In 1976, Boomgaard et. al. have given the relation for ME voltage coefficient as,

$$(dE/dH)_{composit} = (dX/dH)_{ferrite} \times (dE/dX)_{ferro} \dots (1)$$

where,

)

(dX/dH) is the change in dimension per unit magnetic field,

(dE/dX) is the change in dimension per unit electric field.

This is later modified by Zubkov as,

 $(dE/dH)_{\text{composites}} = m_v (dS/dH)_{\text{ferrite}} x (1-m_v) (dE/dS)_{\text{ferro}} \dots (2)$

where, S = strain

 $m_v =$ volume fraction of ferrite phase.

In the present work, static measurements have been carried out. The static ME voltage coefficient $(dE/dH)_{H}$ is measure of the change in ME output voltage as a function of dc magnetic field with respect to a constant flux of magnetic field [10, 11,12].

5.2 Experimental

For the measurement of ME voltage coefficient magnetic as well as electric poling of the composites is necessary and proper poling strategy should be adopted [13].

i] Electric poling

For electric poling the electric field of 2 kV/cm was applied to the sample at room temperature using the transistorized power supply. The experimental set up for electric poling is as shown in the Fig.5.1



Fig. 5.1 Block diagram for electric poling

ii) Magnetic poling

The electrically poled samples were poled magnetically by applying a dc magnetic about 5kOe at room temperature. For that the Laboratory made sample holder was fitted between the poles of a dc electromagnet.

Two silver electrodes were drawn from either side of the pellet. The stray charges developed during the poling were eliminated by grounding the plates holding the pellet. The experimental set up for the magnetic poling is as shown in Fig.5.2.



Fig. 5.2 Block diagram for magnetic poling and ME effect measurement

To measure the ME voltage coefficient the dc magnetic field was applied in the direction of applied electric field and perpendicular to the polished and flat faces of the samples. A Keithley electrometer (model 6514 /E) was used to measure the electric field generated across the sample as a result of applied magnetic field.

The static ME voltage coefficient i.e. dc (dE/dH) was calculated as a change in electric voltage with respect to dc magnetic field.

5.3 Results and discussion

Magnetoelectric effect in composite depends on its composition and resistivity which in turn depends upon the connectivity i.e. mechanical coupling between the phases and on microstructure [15, 16, 17].

Figs.5.3 and 5.4 show the variation of ME voltage coefficient with applied magnetic field at room temperature for (y) $Co_{0.9}Cd_{0.1}Fe_2O_4 + (1-y)$ PZT and (y) $Co_{0.7}Cd_{0.3}Fe_2O_4 + (1-y)$ PZT ME composites. From these plots it is clearly observed that initially the ME voltage coefficient increases linearly with the applied magnetic field, reaches a maximum and then decreases with increase in magnetic field. As the magnetic field is applied to the composite, the

magnetostrictive coefficient reaches saturation at a certain value of the magnetic field. Once the saturation is achieved, the magnetostriction and the strain thus produced produce a constant electric field in the piezoelectric phase forcing $(dE/dH)_{H}$ to decreases with increasing magnetic field [18].

In case of (y) $Co_{0.9}Cd_{0.1}Fe_2O_4 + (1-y)$ PZT ME composites the ME coefficient is maximum for the composite with y = 0.30 than that for the y = 0.15 and 0.45. This is mainly due to the fact that the resistivity of the composite with y = 0.30 is maximum as compared to that for the other two composites.





For the present ME composites the ME voltage coefficient decreases with ferrite content. The resistivity of the ferrite phase is less than that of the ferroelectric phase. So that during poling the leakage of charges may takes place. Therefore greater the ferrite content, greater is the leakage of charges and hence lower is the ME voltage coefficient. Similar reports have been reported by earlier workers [19, 20, 21].

In the present case the ME output for the composite with y = 0.15 is maximum than that for y = 0.30 and 0.45. This is attributed to its higher resistivity.

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