CHAPTER - V

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PRODUCT PROPERTY OF COMPOSITES

5.1 INTRODUCTION

A new class of physical properties of composite materials is that of "Product Properties" in which the phases or submaterials of the composite are selected in such a way that an effect in one of the phases or sub materials leads to a second effect in the other phase [1]. If the X-Y effect in sub-material I and Y-Z effect in sub-material II are considered, then by whatever 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" [2]. Mathematically this can be written as

$$(X/Y) * (Y/Z) \Rightarrow X/Z$$

A typical example is the magnetoelectric effect in a composite material having magnetostrictive and piezoelectric phases as constituent phases. A magnetic field induces a change in shape of the magnetostrictive phase, which in turn stresses the piezoelectric phase in which an electric field is generated. In this case the coupling is mechanical. The magnitude of Y parameter In material II in the composite is not necessarily the same as that in bulk material I. For example, distortion of piezoelectric phase due to magnetic field as a result of product property is smaller than that of magnetostrictive phase as it would be in the bulk magnetostrictive material.

5.2 MAGNETOELECTRIC EFFECT

In highly insulating composite material an application of magnetic field induces polarization and an electric field causes changes in magnetization. Such a phenomenon is called as magnetoelectric effect abbreviated as M. E. effect [3,4] following the product property introduced by Van-Suchetelen as suitable combination of a piezoelectric (ferroelectric) and piezomagnetic (ferrite), the composite also gives rise to a M.E. effect [1]. M.E. effect is due to the strain caused in the piezomagnetic phase, which is by mechanically coupled to a stress in piezoelectric phase, that generates an electric field (5).

Symbolically the M.E. effect can be described as

$$(dy/dx)*(dz/dy) = d(z)/dx.$$

Where X=> applied magnetic field

Y=> Strain induced due to magnetostriction

and Z=> Electric field generated due to piezoelectric effect.

5.2.1 MEASUREMENT OF DC $(ME)_H$B

In order to measure the magnetoelectric conversion factor; the composite has to be poled electrically and magnetically [2]. A suitable strategy of poling has to be employed for each material, judged on pragmatic considerations. The M. E. signal can be measured either in static field or in dynamic fields. Here we have made only static measurements.

Electric Poling

The sample was heated upto 150^0C, which is about 30^0 C above the ferroelectric curie temperature of the tetragonal phase of $BaTiO_3$. In an external field of about 2.5 kV/cm the composite samples were subsequently cooled fast to room temperature.

Magnetic Poling

The samples were poled magnetically by applying an external DC magnetic field of about 5K Oe at room temperature. The poling was carried out in the set up in which the DC $(ME)_H$ was measured using the DC magnetic bias field.[7]

5.3 EXPERIMENTAL

Experimental set up for measuring DC $(ME)_H$ signal is shown in Fig. 5.1 Two copper electrodes were brazed to the electrical leads and were kept on either side of the poled sample. The sample is kept between the two Perspex blocks. The whole sample holder assembly was kept between the pole pieces of DC electromagnet. All stray pick-ups have been avoided by proper grounding of the experimental setup. The two end leads from the sample were connected microvoltmeter through a shielded cable.

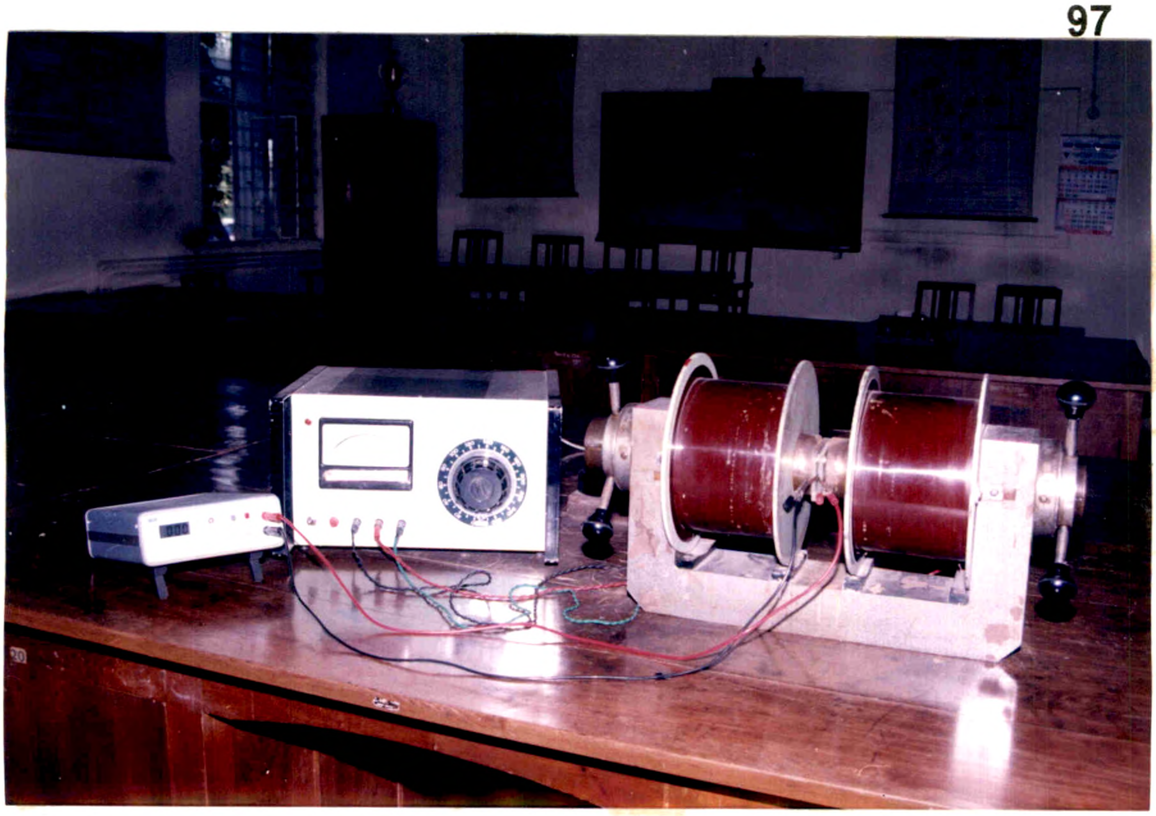
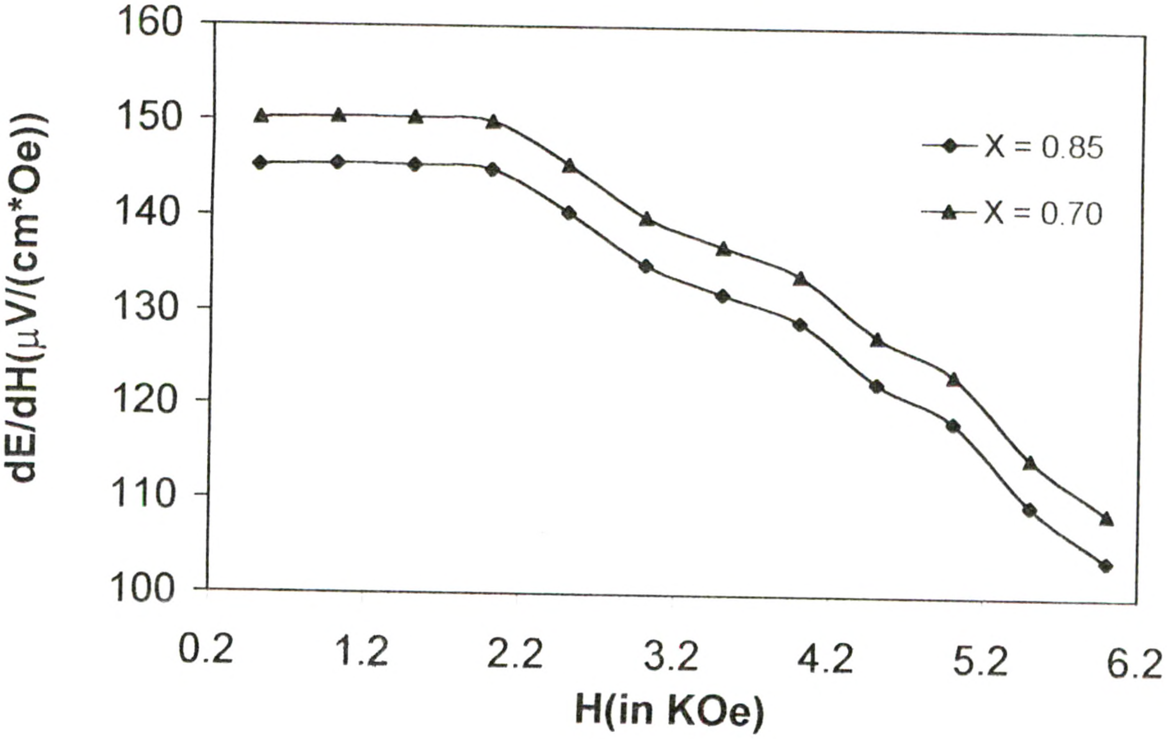


Fig 5.1 Magnetic poling and ME output

Fig.5.2



The measurement of output voltage is made after stabilization on the application of magnetic field. [2]

5.1.4 RESULTS AND DISCUSSION

It is well known that the magnetoelectric effect in a composite material is determined by the magnetostrictional deformation of one phase and the piezoelectric effect of the other phase and for this reason the magnitude of magnetoelectric sensitivity dE/dH should depend in a complicated way on the compositions of the composite material [8]. Fig.5.2 shows the variation of dE/dH with the magnetic field for x = 0.70 and x = 0.85 composite. The variation is similar to that obtained by the other workers [9,10]. Fig. 5.2 shows a decrease in dE/dH with increase in DC magnetic field beyond nearly 2K Oe. magnetic field for both the composites. As already mentioned, the magnetoelectric effect is a result of piezomagnetic strain in the spinel phase which creates piezoelectric charge in the ferroelectric phase and hence the later would depend upon the variation of piezomagnetic coefficient with the intensity of the magnetic field. In the spinels, the magnetostrictive coefficient reaches saturation concomitant with magnetization at a certain value of the magnetic field. Hence the strain produced in ferrite phase would produce a constant electric field in the piezoelectric phase, thereby decreasing dE/dH with increase in H [9]. No ME output was observed in x = 0.55 composite. This observation is akin to that obtained by other workers [8, 11, 12] in composites containing higher concentration of ferroelectric. Moreover resistivity is lower for x = 0.55 composite compared to those with to x = 0.70 and x = 0.85. This is also one of the reason for no ME output in x = 0.55 composite.

REFERENCES

1. J. Van. Suchtelen Philips Res. Repts. 27 (1972) 28-37.
2. S. V. Suryanarayana, Bull. Mater. Sci. 17(7) (1994) 1259-1270.
3. J. Van. Den. Boomgaard, A.M.J.G. Van. Run. and J. Van Suchtelen, Ferroelectrics, 10 (1976), 295-298.
4. Dzyaloshinskii I.E. J. Exp. Theor. Phys.(USSR) 37 (1959) 881.
5. CeWen Suchtelen Philips Res. Repts. 27 (1972) 28-37.
6. J. Van den Boomgaard, A.M.J.G., Van Run and J. Van Suchtelen, Ferroelectrics, 14 (1976) 727-728.
7. J. Van. Den Boomgaard, R.A.J. Born J. Mater. Sci. 13 (1978) 1538-1548.
8. IG Lupiko, I.B. Lopatina, I.V. Kozirev and L. A. Derbaremdiker.
9. A. Hanumaiah, T.Bhimasankaranm, S. V. Suryanarayana and G. S. Kumar, Bull.Mater. Scie. 17 (4) (1994) 405-411.
10. V. M. Laletin, Sov. Tech.Phy. Lett.18(8), (1992), 484-485.
11. A. E.Gelyasin, V.M. Lalitin and L. I. Trophimovich, Sov. Phy. Tech. Phy, 33 (11), (1988).
12. V. M. Laletin, Sov. Tech.Phy.Lett. 17(5), (1991), 342-343.