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Multiferroic Nanocomposite $0.5LaFeO_3$-$0.5PbZr_{0.58}Ti_{0.42}O_3$: Studies of Magnetoelectric Coupling and Dielectric Response

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Abstract. *We have investigated the magnetoelectric coupling and dielectric of* $LaFeO_3$-$PbZr_{0.58}Ti_{0.42}O_3$ *multiferroic nanocomposite, prepared by "pyrophoric reaction process" followed through solid state route. Structural characterization is carried out through X-ray diffraction technique, which shows coexistence of both the phases of the sample. The Magnetoelectric response is observed transverse and longitudinal direction at frequency of 73Hz. Magnetoelectric response has been detected in these multiferroic nanocomposite at room temperature attributing the presence of magnetostriction properties of piezomagnetic material. Furthermore, we have studies the dielectric properties of those nanocomposite at different dc magnetic fields, which reveals the Maxwell-Wagner interfacial polarization at low frequency.*

Introduction

Multiferroic materials that combine spontaneous magnetization (M_s) and ferroelectric polarization (P_s) have a continuous growing interest in technological and fundamental research field because of their wide applications in magnetoelectric devices, sensors and advanced logic devices etc. Magnetoelectric (ME) effect corresponds to the coupling between two or more multiferroic order parameters such as ferroelectricity, ferromagnetism or ferroeleasticity [1]. In multiferroic composite, ME effect is defined as dielectric polarization of a material in an applied magnetic field or induced magnetization in an electric field [2]. The dielectric polarization can induced electric field δE across the sample under application of dc magnetic field (H_{dc}) and an ac magnetic field δH. The ME voltage coefficient (MEVC) can be written as $\alpha_E = \delta E/(\delta H^*t)$, where, t is the thickness of the sample [3]. α_E is strongly depend upon H_{dc} and frequency (f) of the ac magnetic field.

In the present work, we have studied magnetoelectric coupling, dielectric properties of $0.5LaFeO_3$(LFO)-$0.5PbZr_{0.58}Ti_{0.42}O_3$(PZT) multiferroic nanocomposite. The dielectric studies of these nanocomposite at different magnetic fields and different temperatures.

Experimental Details

We have prepared LFO nanoparticle through low temperature chemical pyrophoric reaction process [4,5]. The PZT powder was purchased from APC international limited company, USA. Now LFO and PZT powder was taken into a mortar pestle and ground for 10 hours. Finally, we have made circular pellets from nanocomposite of 10 mm diameter and ~1 mm of thickness. Then these pellets have been used for magnetoelectric coupling and dielectric measurements.

The structural characterization has been done by X-ray diffraction technique (XRD) (Bruker D-8 Advance diffractometer) with a monochromatic CuKα radiation. The dielectric measurement has been carried out in the frequency range of range 50 Hz to5MHz through impedance analyzer (Keysight Technologies, Model-E4990A). For ME measurement, we have used ME measurement setup comprising of electromagnet (Polytronic laboratory electromagnet), electromagnet power supply, lock-in amplifier (SR830), Helmholtz coil, function generator and Keithely multimeter. Temperature dependent electrical measurement, we have used proportional–integral–derivative (PID) controlled portable furnace.

Results and Discussion

Structural Characterization

Structural characterization has been done by XRD technique at room temperature. Figure 1 shows the XRD pattern for 0.5LFO-0.5PZT nanocomposite. We have found coexistence of both LFO and PZT phases for the nanocomposites. The XRD peaks have been indexed using JCPDS software having PDF No. 74-2203 and 73-2022 for LFO and PZT nanocomposite, respectively. From XRD pattern, we have calculated the average crystallite size (Φ) for both LFO and PZT phases of the composite using Scherrer formula as $\Phi = k\lambda/\beta\cos\theta$ [6], where, Φ is the average diameter of the nanocrystals in Å, k is the shape factor, λ is the wavelength of 1.542Å, θ is the diffraction angle and β is full width half maxima of the XRD peak. The crystallite size is found to (Φ) ~ 52 nm for PZT phase and (Φ) ~ 36 nm for LFO phase.

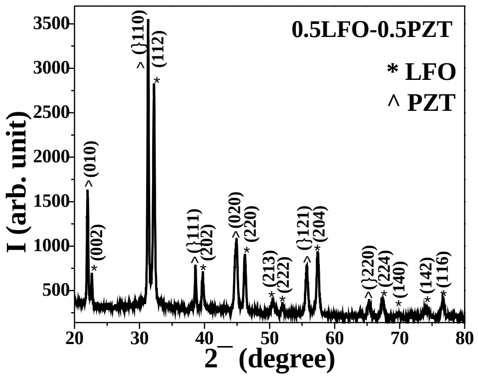

FIGURE 1. Shows the XRD pattern for 0.5LFO-0.5PZT nanocomposite

Magnetoelectric Coupling

We have measured the MEVC (α_E) for 0.5LFO-0.5PZT nanocomposite in both londitudinal and transverse direction to the applied H_{dc} at f of 73Hz as shown in Figure 2. The α_E is transverse and longitudinal direction is denoted as α_{E31} and α_{E33} respectively. α_{E31} and α_{E33} is found to decrease with increase in H_{dc}. The maximum value of α_{E31} is found to ~ 0.21 mV/cm-Oe at low H_{dc}. Similarly, maximum value of α_{E33} found to ~ 0.13 mV/cm-Oe. From our experimental observation α_E is found to be maximum in transverse direction. In longitudinal direction lower value of α_{E33} can be explained through demagnetizing effect in the sample. The observed α_E for all those nanocomposites is may be due to magnetostriction of the magnetostrictive and piezomagnetic coefficient of the materials [7,9].

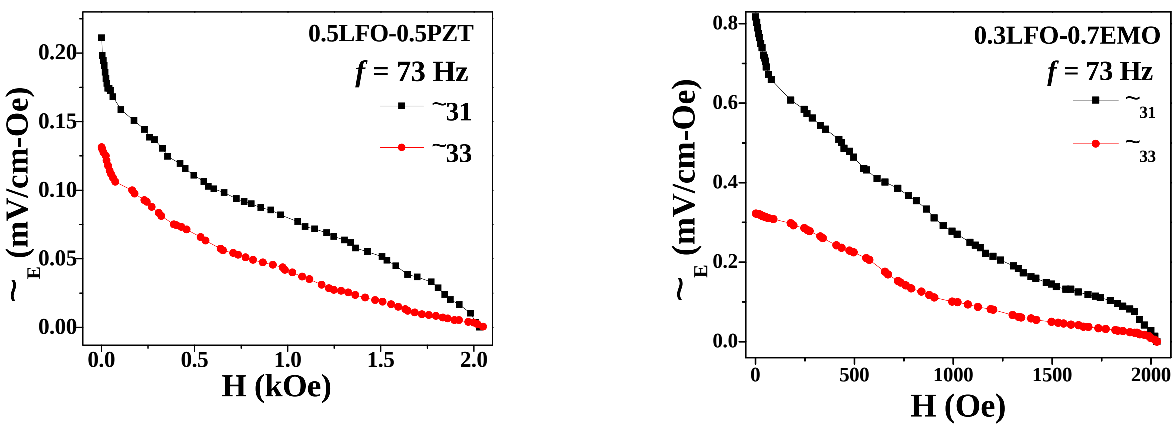

FIGURE 2. ME voltage coefficient (α_E) at transverse and longitudinal direction for 0.5LFO-0.5PZT nanocomposite

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Dielectric properties

The dielectric constant of a material provides a measure of its effect on a capacitor. The dielectric constant and loss coefficient with frequency at different magnetic fields and different temperatures are shown in Fig.3.

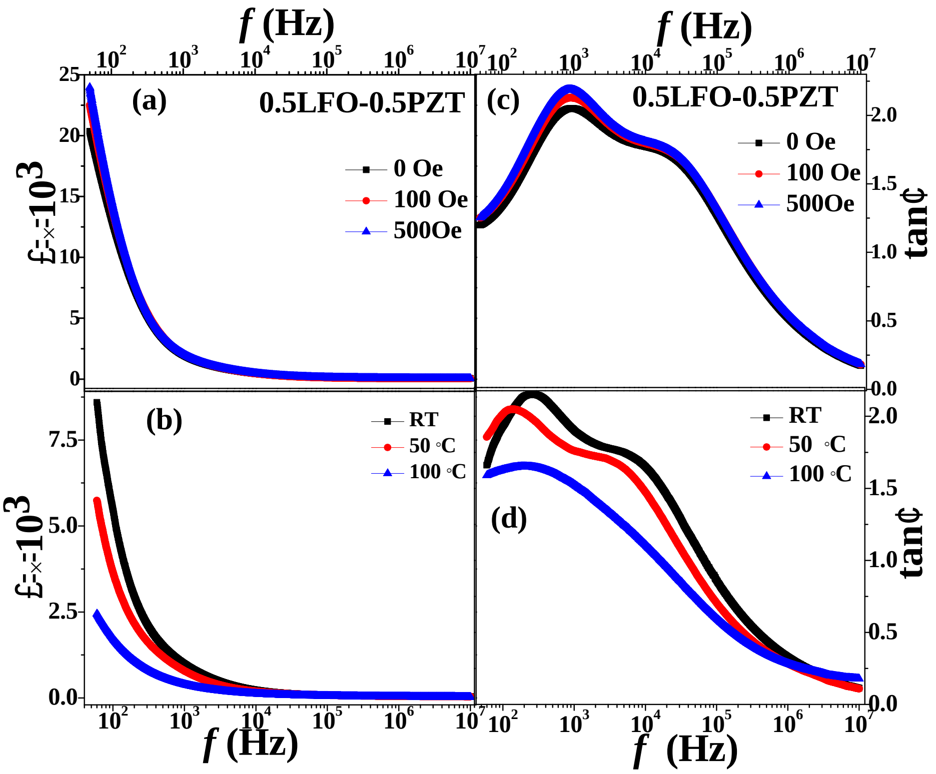

FIGURE 3. (a) ε as a function of *f* , and (c) tanδ vs. *f* at different magnetic fields, (b) ε vs.*f* , and (d) tanδ vs.*f* at different temperatures for 0.5LFO-0.5PZT nanocomposite

Dielectric constant is found to increase with increase in H_{dc} at low *f* region is governed by Maxwell – Wagner interfacial polarization of the sample [8,10] as shown in Fig. 3(a). The dielectric constant is decreased with increase in temperature at low *f* region attributing the enhancement of space charge polarization [8] and grain boundaries effect of the composite as shown in Fig. 3(b). Simultaneously, dielectric loss (tanδ) has been studied as a function of frequency as shown in Figs. 3(c) and 3(d), respectively. It is found that tanδ increases with increase in H_{dc} and decreases with increase in temperature

Conclusions

In conclusion, we have prepared 0.5LFO-0.5PZT multiferroic nanocomposite. Detailed analysis of XRD patterns shows the coexistence of both LFO and PZT phases in the sample. ME effect have been studied at room temperature of 0.5LFO-0.5PZT nanocomposite in both transverse and longitudinal direction. The maximum value of α_{E31} is found than α_{E33}.The observed α_E may be due to the presence of magnetostriction piezomagnetic material. Dielectric constant is found to increase with increase in H_{dc} and decrease with increase in temperature at low *f* region resulting interfacial polarization and space charge polarisation of the nanocomposite.

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