L.11: Magnetically driven ferroelectric output voltage in $La_{0.7}Ba_{0.3}MnO_3$/P (VDF-TrFE) particulate nanocomposite

A strain mediated magnetoelectric (ME) nanocomposite (NC) consists of at least two phases i. e., piezoelectric and piezomagnetic, which is useful in device applications like sensors, energy harvesters, actuators, etc. The measurable quantity for ME coupling effect is ME coupling coefficient and direct ME coupling coefficient (α_{ij}) is expressed as, $(\alpha_{ij}) = \frac{\partial P_i}{\partial H_j}$ where, α_{ij} is a second rank tensor, i is the direction of ferroelectric polarization (P) and j is the direction of applied magnetic field H or Magnetization (M). Out of the two techniques used for measurement of α_{ij} i. e., strain gauge technique and Lock-in technique, Lock-in technique was adopted for measurement of α_{ij}. In Lock-in technique, α_{ij} is expressed as, $\alpha_{ij} = \alpha^V \varepsilon_0 \varepsilon_r$; $\alpha^V = \frac{V_{out}}{t \times h_{ac}}$; where α^V is the ME voltage coefficient, V_{out} is the ME output voltage, t is the sample thickness, h_{ac} is the amplitude of AC part of total applied magnetic field $H = H_{dc} + h_{ac} \sin\omega t$ and ε_r is the dielectric constant of the piezoelectric phase of the ME composite.

A ME coupling coefficient measurement set up was assembled at RRCAT and Figure L.11.1 shows the schematic of the instrument. An ac magnetic field ($h_{ac} \cos\omega t$), produced by Helmholtz coils is superimposed on dc bias magnetic field (H_{dc}) produced by electromagnet. A current is induced in Helmholtz coil by the function generator, where $\omega = 2\pi \times 10$ kHz is used to produce ac magnetic field of 25 Oe. The ($H_{dc} + h_{ac} \cos\omega t$) field is applied on nano-composite films placed between Helmholtz coils. The voltage generated in these films is measured using lock-in amplifier (model SR830, Standford Research System). A computer is used for data collection and further tasks.

Among various ME coupled composite materials, the polymer composites are preferred compared to ceramic composites due to flexibility, non-hydroscopic, low dielectric losses ($<10^{-2}$), high electrical resistance and easy fabrication method. Poly (vinylidenefluoride-co-trifluoroethylene) [P(VDF-TrFE)] copolymer in its β-phase possess highest piezoelectric and ferroelectric properties at room temperature. The $La_{0.7}Ba_{0.3}MnO_3$ (LBMO) is one of the colossal magneto resistance (CMR) materials, which has ferromagnetic-paramagnetic Curie temperature at 343 K and also shows high volume magnetostriction at 300 K (nearly -2.54×10^{-4} for single crystal at 8.2 kOe). The LBMO/P (VDF-TrFE) NC films for the LBMO volume fractions 0.5%, 1%, 1.5% and 2% were prepared by solution casting method. Fig. L.11.2 shows the as prepared NC film in laboratory. ME voltage of these NC films was measured at 10 kHz with (25 Oe) AC magnetic field using ME coupling measurement set up. The variation of ME voltage coefficient (α^V) with H_{dc} in 31 (P, $V \perp M$) mode is shown in Figure L.11.3. The α^V decreases with the increase of LBMO volume fraction, which attributes to increase in conductivity of NC films. A maximum (α^V) in 31 mode $\alpha_{31}^V = 121.44 \frac{mV}{Oe.cm}$ is observed for 0.5% LBMO in P(VDF-TrFE) matrix, which confirms that these NC composite films can be used in ME devices.

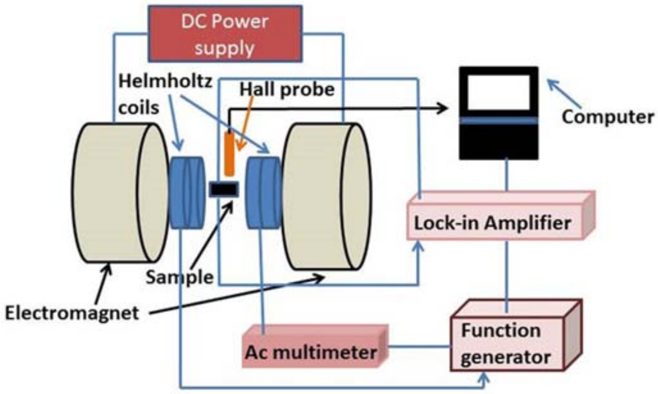

Fig. L.11.1: ME voltage measurement experimental set up (Lock-in technique).

Fig. L.11.2: Photograph of LBMO/P (VDF-TrFE) nanocomposite film.

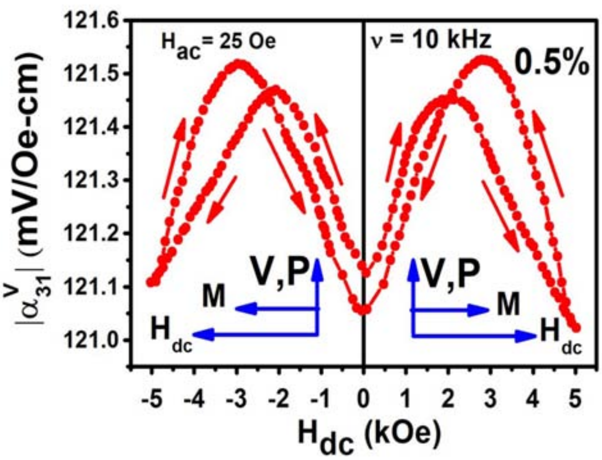

Fig. L.11.3: The variation of ME coupling coefficient α_{31}^V with respect to applied H_{dc}.

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