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Effect of $CoFe_2O_4$ weight fraction on multiferroic and magnetoelectric properties of $(1-x)Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3 - xCoFe_2O_4$ particulate composites

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Abstract

Different compositions of the composite lead-free multiferroic magnetoelectric systems are fabricated by employing piezoelectric $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BCZT) and magnetostrictive $CoFe_2O_4$ (CFO) by varying the CFO weight fraction. The magnetic, dielectric, ferroelectric and magnetoelectric (ME) properties of the system are analyzed and found to be varying with the ferrite concentration. Even though the composite systems exhibit high magnetocapacitance (MC) properties (~35%), the possible stray contributions from magnetoresistance and magnetostriction make it unreliable for the quantitative determination of ME coupling coefficient (MECC). Therefore, a dynamic method is chosen for the measurement of magnetoelectric coupling. All the compositions have shown fairly good ME coupling. It is found that the ME coupling increases with ferrite fraction and the highest ME coupling of 14.8 mV/(cm Oe) is observed for 0.6BCZT–0.4CFO composite. It is also observed that the ME voltage increases linearly with the ac modulating field with a voltage generation of 1.25 V/cm (for $x = 0.4$) for a small ac modulating field of 100 Oe. This high sensitivity and linear response of ME coupling to the ac magnetic fields offer the possibility of employing these particulate composites for a wide range of applications from magnetic field sensors to energy harvesters.

1 Introduction

Research on novel functional materials like magnetoelectric multiferroics attracts significant interest, due to its profound physics behind them as well as the large application potentials specifically in the field of energy harvesters [1–3], magnetoelectric sensors [4, 5] and storage devices [6, 7]. This special class of material exhibits both ferroelectric and magnetic properties in a single material or in an artificially engineered composite [8]. Beyond the concurrent existence of several order parameters in a single component, the switching of magnetic or electric polarization by the other's conjugate field can involve in the development of low-power consuming multifunctional memory devices, which can have the best properties of FeRAMs and MRAMs [9]. In single phase multiferroics, such as bismuth ferrite (BFO) [10, 11], the ME coupling is often due to the local interaction between the ordered ferroelectric and magnetic sublattices. They, however, exhibit weak coupling properties at room temperature [12], making them unusable for any practical applications. To obtain better ME coupling, an alternative strategy is to fabricate artificial heterostructures consisting of ferroelectric and magnetic phases [8, 13, 14]. In this kind of heterostructures, individual phases can be separately optimized for achieving high ME coupling at room temperature.

Magnetoelectric particulate composites belong to the class of engineered artificial systems, where the coupling is achieved via strain-mediated mechanical interaction at the piezoelectric/magnetostrictive interfaces. Since ME coupling is a product property, the piezoelectric constant and magnetostrictive properties of the individual ferroelectric and magnetic phases should be very high in order to obtain high coupling. Along with the high ferroic properties, the

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