



Effect of Mn doping on magnetodielectric properties of polycrystalline BiFeO₃ ceramics



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ARTICLE INFO

Article history:

Received 18 June 2020

Received in revised form

27 August 2020

Accepted 31 August 2020

Available online 18 September 2020

Keywords:

BiFeO₃

Rietveld refinement

Magnetization

Dielectric and magnetodielectric effect

ABSTRACT

This report reveals the room temperature magnetodielectric effect of polycrystalline BiFe_{0.8}Mn_{0.2}O₃ ceramics. Structural analysis shows that the additional phases of BiFe_{0.8}Mn_{0.2}O₃ are suppressed and compared with bare BiFeO₃. The difference in dissociation energies between Mn–O and Bi–O bonds traps the motion of oxygen ions and reduces the grain size of BiFe_{0.8}Mn_{0.2}O₃. Mn-doped BiFeO₃ samples exhibit a weak ferromagnetic response because of the effect of Mn in the Fe site which uncurls the spiral spin ordering by altering the canting angle. Additionally, Bi vacancies give rise to charge compensating oxidation of Mn³⁺/Mn⁴⁺ which causes the ferromagnetic weaker. BiFe_{0.8}Mn_{0.2}O₃ shows an improved dielectric permittivity compared to BiFe_{0.9}Mn_{0.1}O₃ and BiFeO₃ respectively. The magnetodielectric coupling coefficient of BiFe_{0.8}Mn_{0.2}O₃ ceramic at 6 kOe and 1 MHz is determined to be 4.64%.

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1. Introduction

Multiferroic materials fascinated the scientific community in the past recently for the synchronicity of multiple ferroic ordering in a single phase above room temperature [1]. During this context, materials possessing either magnetodielectric or magnetoelectric effects are divergent from one another because the former narrates the magnetic field triggering polarization and the latter narrates the magnetic field triggering dielectric permittivity (ϵ') [2]. It is worth to unveil that specific magnetic materials hold magnetodielectric behaviour without exhibiting spontaneous polarization (P_r) [3]. This magnetodielectric effect is extensively reviewed in more than a few materials are under low-temperature and in the high magnetic field [4–6]. Materials exhibiting magnetodielectric effect at ambient temperature are sparsely identified in the literature.

Bismuth ferrite is one of the exemplary type-I multiferroic material because of its infrequent appearance of multiferroic and linear magnetoelectric behaviours [7]. It behaves as antiferromagnetic beneath Neel temperature ($T_N \sim 370$ °C) and ferroelectric beneath Curie temperature ($T_c \sim 830$ °C) with a feeble

synchronization among them [8]. But the leakage behaviour resulting from the inhomogeneous spiral spin structure curbs the sensible applications of BiFeO₃ [9].

Likewise, BiMnO₃ belongs to the type-II multiferroic category (C2 space group) with improved ferromagnetic behaviour than BiFeO₃ [10]. But the mutual behaviours of magnetic ordering and ferroelectricity in BiMnO₃ are unable to show the magnetoelectric coupling at ambient temperature [11].

These outcomes create an opportunity for researchers to investigate Mn-doped BiFeO₃ (via Fe site) to show suitable rapid switching memory devices [12]. Sosnowska et al. [13] studied the neutron diffraction patterns of BiFe_{1-x}Mn_xO₃ ($x = 0, 0.1$ and 0.2) and observed that replacing Mn ions in Fe site widen the diffracted peaks and uncoils the helical spin structure of BiFeO₃. Chauhan et al. [14] investigated the Mn-doped BiFeO₃ nanoparticles (5%, 10% and 15% mole) and found that the system crystallizes from rhombohedral to orthorhombic phase with enhanced multiferroic and magnetocapacitance behaviours than pristine BiFeO₃. Chen et al. [15] studied the crystal structures of BiFe_{1-x}Mn_xO₃ ($0 \leq x \leq 0.3$) and identified that the system crystallized in the orthorhombic phase at $x = 0.3$ with enhanced remanent magnetization. Belik et al. [16] point out that the system crystallizes into the *Pnma* space when the substitutional percentage of Mn exceeds 20%. Dhanalakshmi et al.

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