



Structural, dielectric and magnetic properties of Bi–Mn doped SmFeO_3

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ABSTRACT

We have studied the structural, magnetic, dielectric and impedance properties of the $\text{Sm}_{1-x}\text{Bi}_x\text{Fe}_{1-y}\text{Mn}_y\text{O}_3$ [SmFeO_3 (SFO), $\text{Sm}_{0.9}\text{Bi}_{0.1}\text{FeO}_3$ (SBFO), $\text{Sm}_{0.9}\text{Bi}_{0.1}\text{Fe}_{0.9}\text{Mn}_{0.1}\text{O}_3$ (SBFMO)] polycrystalline samples synthesized by solid-state reaction method. Rietveld refinement of room temperature (RT) powder x-ray diffraction pattern confirms the orthorhombic crystal structure with Pnma/Pbnm space group. The average particle size of Bi doped and co-doped (Bi–Mn) samples determined from SEM analysis are 5.6 μm and 5.2 μm , respectively. Room temperature field-dependent magnetization increases, suggesting the presence of magnetic contribution due to the Rare earth-Fe ion interaction which persists even at RT. However, with co-doping of Bi and Mn, a decrease in magnetization is observed, which corresponds to the dilution of Fe^{3+} - Fe^{3+} interactions due to the presence of Mn^{3+} ions. The observed values of magnetization at 90 kOe for Bi doped sample is (2.87 emu/g) approximately two times and for codoped (0.7 emu/g) sample is nearly half of that of pristine sample (1.51 emu/g). Dielectric measurements as a function of frequency/temperature and impedance analysis using equivalent circuit model reveal grain and grain boundary contributions of SBFO (at high temperature) and SBFMO (for all temperature) samples towards the electrical properties indicating the electrically heterogeneous nature of these samples. However, for SFO sample grain contribution is dominant. Observed value of dielectric constant varies from $\sim 10^3$ - 10^4 with Bi–Mn doping. The conduction mechanism of the studied samples has been explained by considering Jonscher power law. Arrhenius law fitting of AC conductivity data manifests two types of conduction mechanisms in these samples. The depressing nature of the semicircular arc observed in the Nyquist plot of all the samples indicates the presence of a non-Debye type of relaxation.

1. Introduction

Rare earth orthoferrites (RFeO_3) have received remarkable attention due to their interesting physical properties like multiferroicity, spin reorientation, magnetization reversal at very low temperature, canted antiferromagnetism, spin-phonon coupling, abnormal dielectric constant, etc [1–5]. Rare earth orthoferrites usually crystallize in a distorted orthorhombic structure with Pbnm/Pnma (#62) space group [3,4]. In this structure, octahedra corresponding to iron atoms (FeO_6) is unaffected by the ionic radii of rare-earth cations. However, for rare earth polyhedra, it is observed that the distortion increases with the decrease of the ionic radii of rare-earth cation [6]. These structural distortions due to change in the R–O bond lengths modify the physical

properties [7].

SmFeO_3 (SFO) is one of the special members of orthoferrite family due to its fascinating properties, i.e., magnetization reversal phenomenon at low temperature (~ 5 K), highest spin reorientation transition temperature (~ 470 K), particle size-dependent dielectric constant, low dielectric loss, ferroelectricity and considerable piezoelectricity at room temperature [3,5,8]. Three distinct magnetic interactions i.e., R^{3+} - R^{3+} (Rare earth–Rare earth) below 5 K, R^{3+} - Fe^{3+} (Rare earth–Iron) below 140 K and Fe^{3+} - Fe^{3+} interactions above 140 K [8,9] contribute to the magnetic behaviour of SmFeO_3 . Sm^{3+} - Sm^{3+} interactions (below 4 K) results in an interesting phenomenon called magnetization reversal, in which a change of sign in the total value of magnetization from positive to negative due to the competing interaction between Sm^{3+} and Fe^{3+}

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