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Multiferroism in rare earth metals-doped $BiFeO_3$ nanowires

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ABSTRACT

Nanowires are the key multifunctional materials for the development towards device miniaturization and high-density data storage systems for future nanoelectronics. In the present report, multifunctional undoped and rare earth metals ions (Gd^{3+}, Tb^{3+}, Dy^{3+})-doped $BiFeO_3$ nanowires with 20 nm diameter, have been synthesized by template-assisted colloidal dispersion technique. The effect of the size of synthesized nanowires, as well as, the doping of rare earth ions on the structural, magnetic, dielectric and magnetodielectric properties have been studied. The doping of rare earth metals ions leads to structural transition from rhombohedral to orthorhombic $BiFeO_3$ nanowires. The synthesized nanowires exhibit ferromagnetic nature with high value of saturation magnetization, dielectric constant and magnetodielectric coefficient.

1. Introduction

$BiFeO_3$ is one of the scarcest multiferroic exhibits spontaneous polarization and antiferromagnetism ordering with high Curie ($T_C \sim 830$ °C) and Nèel ($T_N \sim 370$ °C) temperatures [1–12]. The practical applications of bulk $BiFeO_3$ have been mired by its weak ferromagnetic character (antiferromagnetism) and low magnetoelectric coupling resulting due to its spiral modulated spin structure (SMSS) with incommensurate spiral period of ~62 nm. The SMSS can be broken and high magnetoelectric coupling may be achieved if the size of the $BiFeO_3$ should be less than its SMSS spiral period, i.e., 62 nm [1–6,9]. The partial substitution of Bi^{3+} ions by rare earth ions resulting in improved multiferroic properties of $BiFeO_3$ [4–8,10–16]. This has been the motivation for the present study. A few

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reports are available on the synthesis and characterization of $BiFeO_3$ nanowires, nanotubes and nanofibers [17–23].

This communication reports synthesis of rare earth metal doped-$BiFeO_3$ nanowires by template assisted colloidal dispersion technique, as well as their structural, magnetic, dielectric and magneto-dielectric properties.

2. Experimental

This communication aimed to study phase-dependent multiferroic properties of undoped and rare earth metals ions viz., Gd^{3+}, Tb^{3+}, Dy^{3+} (RE)-doped $BiFeO_3$ nanowires. Therefore, undoped and 15% RE-doped $BiFeO_3$ nanowires having rhombohedral and orthorhombic phases respectively, have been synthesized by template-assisted colloidal dispersion technique using commercially available anodic alumina template of average pore diameter, 20 nm [5,6].

The morphological study is carried out by scanning electron microscope (SEM) of JEOL (JSM-6510LV). The structural analysis of synthesized nanowires has been examined by X-ray diffractometer (PANalyticalX'PertPRO MRD with Cu Kα (λ = 1.54060 Å). The magnetization hysteresis (M-H) loops study has been done using SQUID (Quantum Design). Dielectric measurements have been performed using impedance analyzer (Agilent HP 4294A). The dielectric and magnetodielectric measurements have been done using the experimental set-up as reported in our earlier publications [5,6]. To demonstrate the magnetoelectric coupling effect in the synthesized nanowires magnetic field-induced changes in the relative dielectric constant have been measured at room temperature (10 kHz).

3. Results and discussions

Fig. 1 shows XRD patterns of the synthesized nanowires. XRD reflection peaks of undoped $BiFeO_3$ are indexed and well matched with polycrystalline rhombohedral distorted perovskite (R3c) possessing hexagonal phase (JCPDS file no. 86-1518) [3–9]. The peak marked by "#" attributed to secondary impurity – $Bi_2Fe_4O_9$ and it is non-ferromagnetic (JCPDS file no. 20-0836) [9]. XRD patterns of RE-doped $BiFfeO_3$ nanowires divulge that the splitting of reflection peaks (marked by "*") in undoped $BiFeO_3$

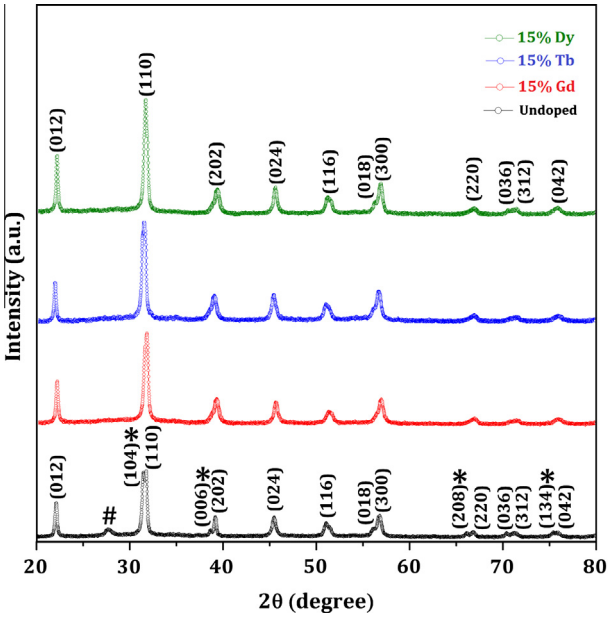

Fig. 1. XRD patterns of undoped and RE-doped $BiFeO_3$ nanowires.