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Development of Rare-Earth Doped Multifunctional Materials for Spintronic Devices Applications

Gadwala Naveena, D. Ravinder*
Department of Physics, Osmania University, Hyderabad, 500007, Telangana, India
**Corresponding author: D. Ravinder*

ABSTRACT
Bismuth doped neodymium nano crystalline ceramics having the chemical formula $Bi_{1-x}Nd_xFeO_3$ (Where **x = 0, 0.01,0.02,0.03,0.04,0.05)** were prepared by citrate gel auto combustion technique. Structural properties are carried out by using XRD and SEM.
Rhombohedrally distorted pervoskite crystal structure can be observed in all the samples that indicate the BFO phase formation. SEM images show the average grain size is in between 200nm-100nm and have spherical shape for BNFO all samples. Based on the research date the above rare earth doped neodymium ceramics for applications of spintronic devices.

Key words: Multifunctional Materials: Spintronic devices: Ceramics; Nano-Particles: Magnetic Materials : X-Ray Techniques: SEM

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I. INTRODUCTION

Multiferrioc, materials combine more than one form of primary ferroic order parameters simultaneously in a single phase. The primary ferroics are Ferro magnets, ferroelectrics and Ferro elastics. Magnetization in these materials gets affected on application of electric field and converse is also true. Magneto electric coupling between electric and Magnetic order parameters has an intense interest in its implementation for device applications such as increase storage density of memories, more efficient process of storing and sensor applications [1, 2].Among all the multiferroic materials bismuth ferrite is the only material at room temperature that exhibit strong ferro-electricity and G type anti-ferromagnetism (curie temperature T_c equal to 1103K and Neel temperature T_N equal to 643K) [3]. Ferro electricity in $BiFeO_3$ is due to the 6s lone pairs of Bismuth and magnetic behavior is due to partially filled d orbitals of iron [4]. Monodomain single crystal $BiFeO_3$ have rhombohedrally distorted pervoskite (ABO_3) structure with R3c space group with ions displaced along [111] direction [5-7]. By doping with rare earth at A-site of ABO_3 type or by replacing B-site ion with transition metal improves the magnetism and ferroelectricity properties in BFO [8-11].

II. EXPERIMENTAL DETAILS

The Bi–Nd nano ferrite powders were prepared with required amount of Bismuth nitrate, Iron nitrate and Neodymium nitrate were mixed in deionized water under continues stirring. Citric acid in molar ratio of 1:3 with reference to precursors was mixed to the solution as gelating agent and stirred for 2 hours to get homogeneous mixture of metal nitrates. Ammonia was added to the above solution so that it maintains pH value equal to 7. Continuous heating of resultant solution on a hot plate is done at a temperature of 100^0C till it dry by stirring continuously resulting in a viscous gel. Increase in temperature up to 200^0C leads to ignition of gel. Loose powder is formed by burning the dried gel in a self propagating combustion manner and finally the grinded powder was calcinated at a temperature of 500^0C for 5 hours.Structural Characterization of Nd doped BFO samples was done with the help of XRD by using PHILIPS XPERT-PRO with CuKα (λ=1.5406 Å) radiation operated at 45kV with 40mA in 2θ range between 20^0 to 80^0. The crystalline size of the Nd-BFO nanoparticles was calculated using the scherrer formula [12]

$$D = \frac{0.9\lambda}{\beta cos\theta}$$

The lattice parameters (a and c) based on hexagonal system calculated by using the equation

$$Sin^2\theta = \frac{\lambda^2}{4}\left[\frac{4}{3}\left(\frac{h^2+hk+l^2}{a2}\right)+\frac{l^2}{c^2}\right]$$

Where

θ = Bragg's angle, a & c = lattice parameters, hkl = miller indices given

λ = wavelength of the incident radiation.

Micro structure and surface morphology have been studied by SEM [Model: EVO Cari Zeiss, Germany) instrument was used.

III. RESULTS AND DISCUSSION

The refined patterns of XRD for $Bi_{1-x}Nd_xFeO_3$ compounds are given in **fig 1**.

XRD pattern of prepared BNFO nano particles with x=0, 0.01, 0.02, 0.03, 0.04, 0.05 sintered at 500^0C for 5 hours was observed. Rhombohedrally distorted pervoskite crystal structure can be observed in all the prepared samples that indicate BFO phase formation. Observations indicate a shift of main diffraction peaks towards angle of higher side with rise in neodymium concentration which may be because of substituting Nd^{3+} ions with smaller radius as compared to Bi^{3+} ions. The above pattern indicate two diffraction peaks at about $2\theta=32^0$ in the host BFO gradually merging into sharp single peak with increase in Nd concentration which confirms transformation of phase from rhombohedral structure to orthorhombic structure, which is almost equal to Nd^{3+} ions substitution in pervoskite structure that results in crystal lattice distortion [16]. The computed values of lattice parameter(a,c) and crystal size are given in Table.!. It can be seen from the table that the values of lattice parameters and crystal are decreases with the neodymium content. The small values of crystal size (12.81nm-14.98 nm) of neodymium doped bismuth multifunctional materials are useful for spintronic devices.

Fig 2(a-f) shows the images of SEM for Bi-Nd nano-ceramics with x=0.00, 0.01, 0.02, 0.03, 0.04 and 0.05 respectively. These images indicate that grains have morphology of spherical shape for all samples. The size of grain is 200nm on average for $BiFeO_3$ and neodymium introduction reduces the average grain size of $Bi_{1-x}Nd_xFeO_3$ to 200nm – 100nm. The effect on grain size is due to the concentration of Nd. Due to volatile nature of Bi more number of oxygen vacancies are present in pure $BiFeO_3$. By doping Nd^{3+} in Bi, oxygen vacancies are suppressed which lead to the decrease in oxygen ion migration between grains causing a decrease in grain size.

IV. CONCLUSIONS:

Homogeneous and reactive nanostructured $Bi_{1-x}Nd_xFeO_3$ multifunctional ferrites were prepared by citrate-gel auto combustion method. XRD pattern shows rhombohedrally distorted pervoskite crystal structure indicates BFO phase formation.

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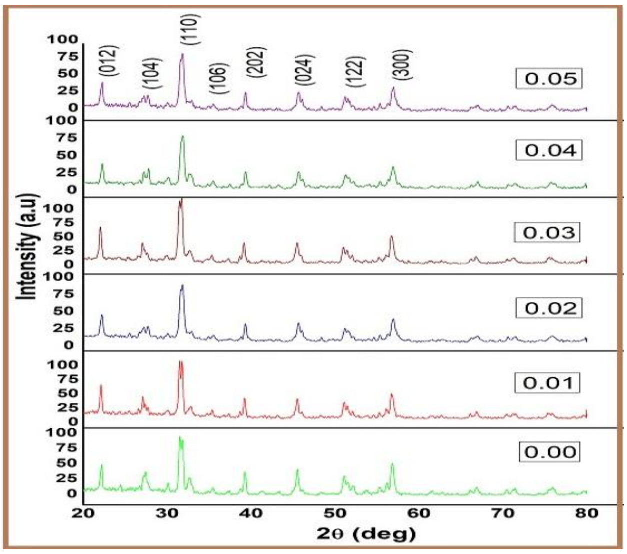
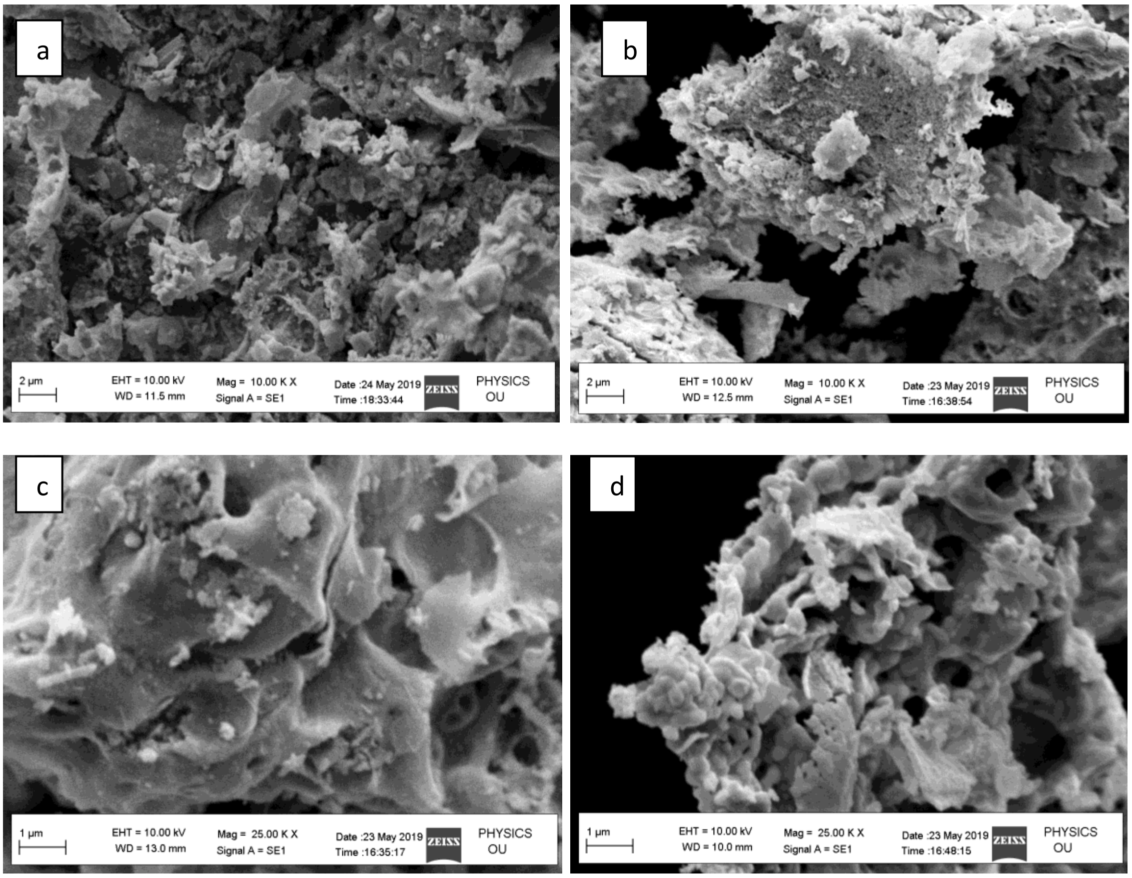


Fig 1 : XRD patterns for $Bi_{1-X}Nd_X FeO_3$ (x = 0, 0.01,0.02,0.03,0.04,0.05)

Composition (X value)	a(nm)	c(nm)	Crystalline size (nm)
0.00	0.565	1.385	14.98
0.01	0.564	1.384	14.84
0.02	0.563	1.379	13.77
0.03	0.561	1.361	13.56
0.04	0.560	1.378	13.08
0.05	0.559	1.380	12.81

Table 1 : Structural parameters for $Bi_{1-X}Nd_X FeO_3$ (x = 0, 0.01,0.02,0.03,0.04,0.05)



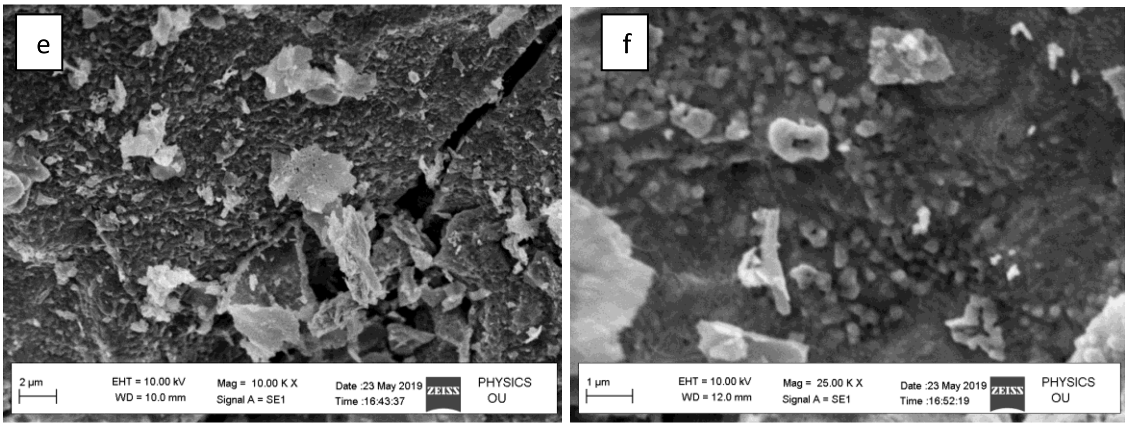


Fig 2 (a-f) :SEM images of $Bi_{1-x}Nd_xFeO_3$ (x=0.00, 0.01, 0.02, 0.03, 0.04, 0.05)

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