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Studies on the Enhancement of Magnetoelectric Properties of BFO Multiferroics

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Abstract: **Detailed investigations were made on the influence of doping on structural, electrical, ferroelectric and magnetic properties of the BFO. Magnetic hysteresis loops showed that retentivity (Mr), coercivity (Hc) and saturation magnetization (Ms) of the doped samples were improved. Furthermore, the doping enhances the dielectric properties as a result of the reduction in the Fe^{2+} ions and oxygen vacancies. The room temperature P-E loop study shows that ferroelectric properties are strongly depend on doping.**

Keywords: Multiferroic; Sol-gel; Structural; Magnetic; Dielectric; Ferroelectric

1. INTRODUCTION

Multiferroic materials, which exhibit the coexistence of ferromagnetism, ferroelectricity and/or ferroelasticity, have been studied intensively because they offer a wide range of potential applications in information storage process, spintronics, multi-state memories, as well as due to their interesting fundamental physics. Among the multiferroics, BFO is the leading candidate which gained the importance due to its stable ferroelectric and antiferromagnetic or ferromagnetic coupling at room temperature. It exhibits ferroelectric below ~ Tc = 1103 K and antiferromagnetism below ~ T_N = 643 K [1-6]. Due to the existence of Fe^{2+} and oxygen vacancies, BFO suffers from large leakage current, which limits the applications of BFO. The site-engineering concept has been widely explored in an effort to reduce the current leakage, improve the ferroelectric behaviour, and enhance the magnetoelectric coupling in BFO [7,8]. The Doped elements influence spatially modulation spiral spin structure of BFO and in this way small improvement in the magnetic properties can be achieved. There are many reports on the doping of transition metal ions
such as Co, Cr, Ti, Mn, Zn etc. at B-site (Fe-site) in BFO with the enhance magnetoelectric properties [9, 10]. In order to improve magnetic and electrical properties, partial substitution of rare-earth ions at A-site and transition metal ions at B-site has been reported. In this paper, the strategy of (Sm, Pr, Mn, Co, Cr) co-doping was adopted for the enhanced ferroelectric and magnetic properties in BFO. Sm/Pr and Mn ions were introduced in A-site and B-site of BFO, respectively and attempt to a systematic study on structural, dielectric, electric polarization and magnetic properties of doped bismuth ferrites.

2. EXPERIMETAL

In recent years, the sol-gel technique has emerged as a versatile method for synthesizing different inorganic materials. All samples were successfully synthesized by the sol-gel technique. The obtained powder samples were annealed at 650°C for 4h in order to obtain the pure phase. The well dense pallets of different samples were obtained by applying hydraulic pressure of 10 ton for the well grinded powder mixed with PVA solution and subsequently sintered at 650 ^{0}C for half four hours. Both sides of pallets were polished with silver paste for electric characterization. The initial investigation of structural and microstructure analysis was carried out by Philips X'Pert x-ray diffractometer using CuKα radiation with wavelength 1.54 Å. The room temperature magnetic measurements were performed with vibrating sample magnetometer (VSM). The ferroelectric were carried out using the Automatic P–E Loop Tracer.

3. RESULTS AND DISCUSSIONS

The XRD patterns for pure and Pr-doped BFO samples are shown in Figure 1. Pure sample show few impurity peaks (marked by * in Figure 1) of Bi_2FeO_9 (2θ = 27.6°) and $Bi_{36}Fe_2O_{57}$ (2θ = 32.8°), while no impurity peaks are observed for compositions of x = 0.1 and 0.2, which indicates that Pr doping in BFO at A-site is helpful in reducing the secondary phases.

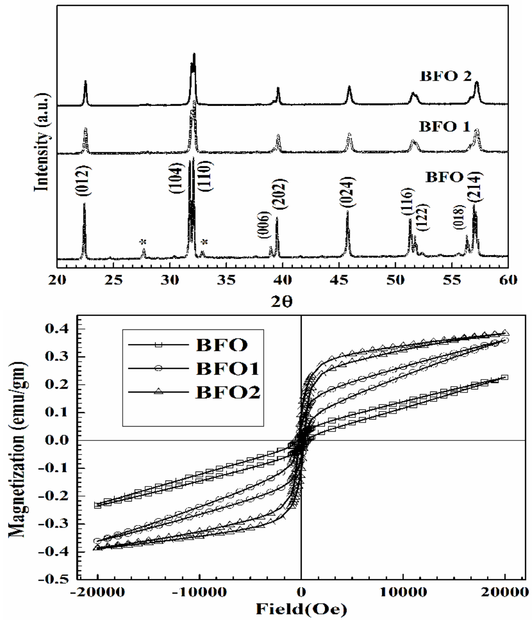

Figure 1. XRD pattern and M-H loops of pristine $BiFeO_3$ (BFO) and doped $Bi_{0.9}Pr_{0.1}FeO_3$ (BFO1), $Bi_{0.8}Pr_{0.2}FeO_3$ (BFO2) samples.

It is clear from Figure 1 that Pr doping plays the dominant role towards the increase in the magnetization of BFO samples.

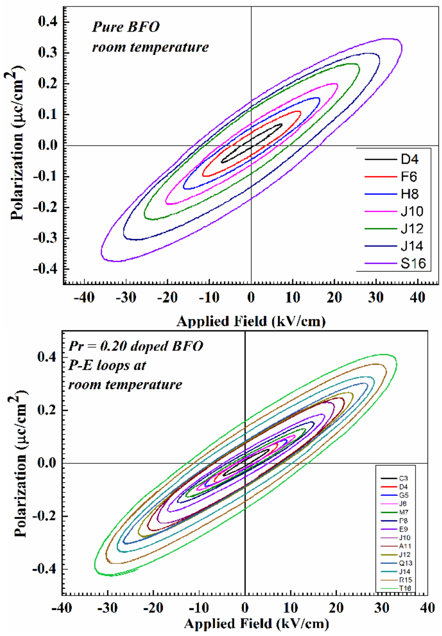

Figure 2. P-E loops for pristine $BiFeO_3$ (BFO) and Pr-doped $Bi_{0.8}Pr_{0.2}FeO_3$ (BFO2) samples at room temperature.

Figure 2 shows the ferroelectric hysteresis loop measured for pure and doped BFO at room temperature. All samples show a linear loosy and unsaturated loop. With Pr doping, there is an increase in observed saturation polarization (P_s), remnant polarization (P_r) and coercive field (E_c).

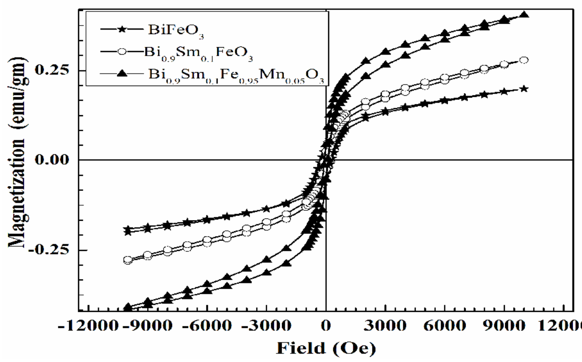

Figure 3. shows the hysteresis curve for pure $BiFeO_3$ and Sm and Mn doped ($Bi_{0.9}Sm_{0.1}FeO_3$ & $Bi_{0.9}Sm_{0.1}Fe_{0.95}Mn_{0.05}O_3$) bismuth ferrites at room temperature.

Figure 3 shows the hysteresis curve for pure and doped bismuth ferrites at room temperature. All the samples show magnetic hysteresis loops representing weak ferromagnetic (FM) behaviour. From the M-H loops, we obtained that remanant magnetization, Saturation magnetization and coercive field were inhanced due to doping.

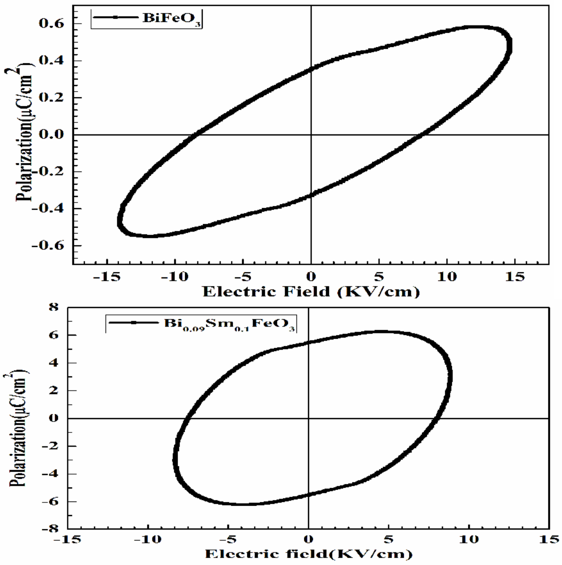

Figure 4. P-E loops for $BiFeO_3$ and $Bi_{0.9}Sm_{0.1}FeO_3$ samples

From the Figure 4 it is observed that With Sm and Mn doping, there is an increase in observed saturation polarization (P_s), remnant polarization (P_r) and coercive field (E_c). In case of undoped BFO, P_s reaches 0.584 $\mu C/cm^2$ in the presence of applied external electric field of 14 kV/cm with remnant poarization 0.349 $\mu C/cm^2$ and coercive field 8.4 kV/cm.

4. CONCLUSIONS

Pure and doped multiferroic samples of bismuth ferrites were susseccfully synthesized by the sol-gel technique. Due to volatility of Bi ions, the small amount of impurities was removed by Sm or Pr noticebly. Doped samples shows the higher saturation magnetization and retaintivity than the undoped sample. From the above studies it is concluded that Sm/Pr and Mn ions doping in A-site and B-site of BFO, respectively can improve the structural, electric polarization and magnetic properties of bismuth ferrites.

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