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P-E STUDIES OF Nd MODIFIED $SrBi_4Ti_4O_{15}$ CERAMICS

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ABSTRACT
The $SrBi_4Ti_4O_{15}$ modified by the addition of rare-earth is prepared by traditional solid state reaction technique. X-Ray diffraction method is used to confirm single phase $Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$ formation. Scanning Electron Micrograph showed plate-like grains of different sizes. The Polarization .vs. Electric field loops showed the closed loops characteristic of ferroelectrics.
Keywords: X-ray diffraction, solid-state reaction method, Scanning Electron Micrograph, Polarization, ferroelectrics
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INTRODUCTION

The Bismuth Layer-Structured Ferroelectrics (BLSFs) have been studied by various researchers [1-3]. Because of their various applications, BLSFs are interesting materials. The uniqueness of BLSFs is high Curie temperatures, low dielectric constant and low aging rates. They are possible replacements to PZT which are widely used today.[4] The general formula of BLSFs is ($Bi_2O_2)^{2+}$ $(A_{m-1}B_mO_{3m+1})^{2-}$ [5], where A may be mono-, di-, or trivalent, B is transition element and m represents a number of octahedra in between Bismuth oxide layers. Usually, m is an integer and varies between 1 and 5.[6] The material $SrBi_4Ti_4O_{15}$ (SBT) exhibits excellent electrical properties[7]. Many researchers have studied SBT, a BLSF with m=4 [8-11]. In the present work, dielectric properties of Rare-Earth doped ceramics $Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$ (SN0.2BT) prepared via solid-state reaction method are reported.

EXPERIMENTAL

Polycrystalline ceramic $Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$ (SN0.2BT) is prepared using solid-state double sintering reaction method. The raw material is ground using an agate mortar and pestle, then calcined at 800°C for 2 hours. The powder is then mixed with 1% PVA, then pressed into 1 cm diameter and 0.1 cm thickness discs. These compact discs are finally sintered at 1130°C for 3 hours. Formation of a single phase is confirmed by XRD studies. SEM studies are performed. The pellets are electroded with conductive paint. Dielectric properties from room temperature to 600°C are done using an LCR meter.

RESULTS AND DISCUSSION

XRD Analysis

X-ray diffractogram of SNBT scanned in the range 2θ of 20-80 degrees (Fig.-1). The XRD confirms the single-phase orthorhombic structure. The maximum intensity peak (1 1 9), indicating four layered Aurivillius structure[12]. Archimedes method is used to calculate densities in liquid media of distilled water. Density is 96~98% of X-ray density.

Fractured surface of SNBT pellet is shown in Fig.-2. Plate-like grains with grain size up to 3μm is observed. Ferroelectrics have a characteristic feature: the P-E hysteresis loop. It describes the non-linear polarization switching behavior as a function of applied alternating electric field. The remnant polarization is the polarization remaining in the material even after applied field is zero. Remnant polarization ($2P_r$) is found from the P-E hysteresis loop. The coercive field ($2E_c$) is the field at which remnant polarization is zero. Unpoled discs of less than 1mm thickness and around 10 mm diameter are used for ferroelectric

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measurements. Local made (Marine India Pvt. Ltd) Polarization-Electric field loop tracer centered on sawyer-tower circuit is used for obtaining P_r and E_c at room temperature.
P Vs E Hysteresis loop shown in Fig.-3 is for pure SBT. With the increase of applied AC electric field, it is observed that the remnant polarization, as well as the coercive field, increased. The maximum field applied across the sample depends on the conductivity of the material. A maximum of 12 kV per mm is applied across the sample at a 50Hz frequency. SBT requires a very high field to saturate hence the loops observed are not fully saturated. This may be due to the limitations of the equipment available. The remnant polarization and coercive field for SBT are observed to be 8.55 and 40.95 respectively. Remnant polarization and coercive field for SN0.2BT are also shown in Fig.-3 and values are summarized in table 1. It is observed that addition of Nd, decreases the remnant polarization. The ionic radius of Nd is smaller than that of Bismuth. The substitution of smaller ionic radii elements in Bismuth site effects the polarization phenomena. A similar decrease in P_r is reported by Haixue. Yan et al. (2000)[13] when a smaller ion is substituted in A-site. This result is consistent with the results reported in previous papers.

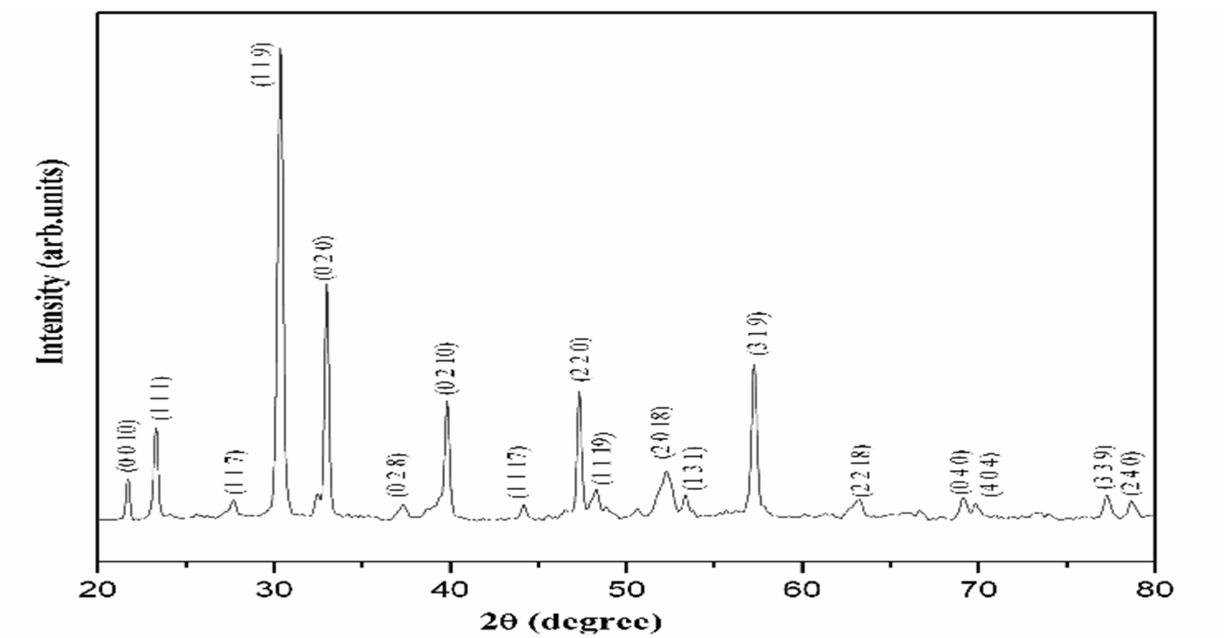

Fig.-1: XRD of SN0.2BT

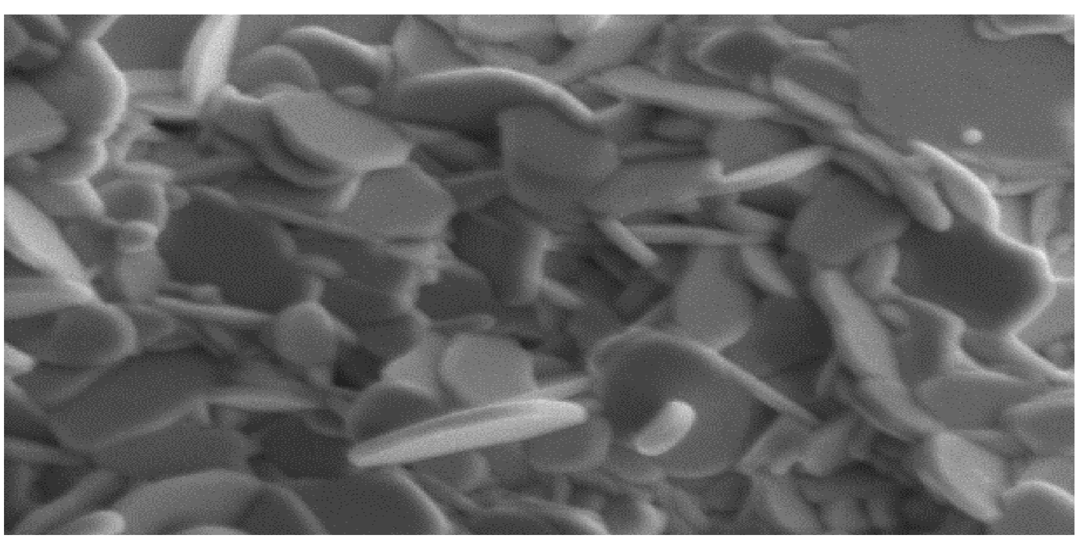

Fig.-2: SEM of SN0.2BT

Table-1: Remnant Polarization and Coercive field of SN0.2BT

Sample name	Remnant Polarization ($\mu C/cm^2$)	Coercive field (kV/cm)
$SrBi_4Ti_4O_{15}$	8.55	40.85
$Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$	3.046	14.050

In the family of BLSFs, the pseudo-pervoskite blocks [in the present study $(SrBi_2Ti_4O_{15})^{2-}$] contribution to P_r is dominant.[14] Oxygen and metal ion vacancies cause strong domain pinning which affects electrical properties specially ferroelectric properties.[15,16]

During sintering process at high temperatures, volatilization occurs and oxygen vacancies (V_o) are generated along with bismuth vacancies (V_{Bi}) due to Bi_2O_3 in the perovskite blocks. Due to the substitution of Nd in place of Bismuth, defects are created. The defects created due to substitution and the distributions of these defects in the lattice are critical for polarization mechanisms. Oxygen vacancies which are also created due to substitutions by themselves do not act as pinning sites effectively. V_{Bi}-V_o (Bi vacancies- O vacancies) complexes are responsible for domain pinning. This is due to the dipolar defects strong interaction with domain boundaries.[17] This pinning confines the macro-micro domain switching to a particular degree. This has an effect on the final polarization state of the material. An increase in domain pinning due to the substitution of Nd cations in pseudo perovskite layer must have occurred which causes a decrease in remnant polarization [P_r]. Similar effect of rare earth doping are discussed by researchers and the results in the present work are consistent with previous reports.[18-21] The decrease in the coercive field with the addition of Nd is observed and is attributed to the ionic radius of the substitute.

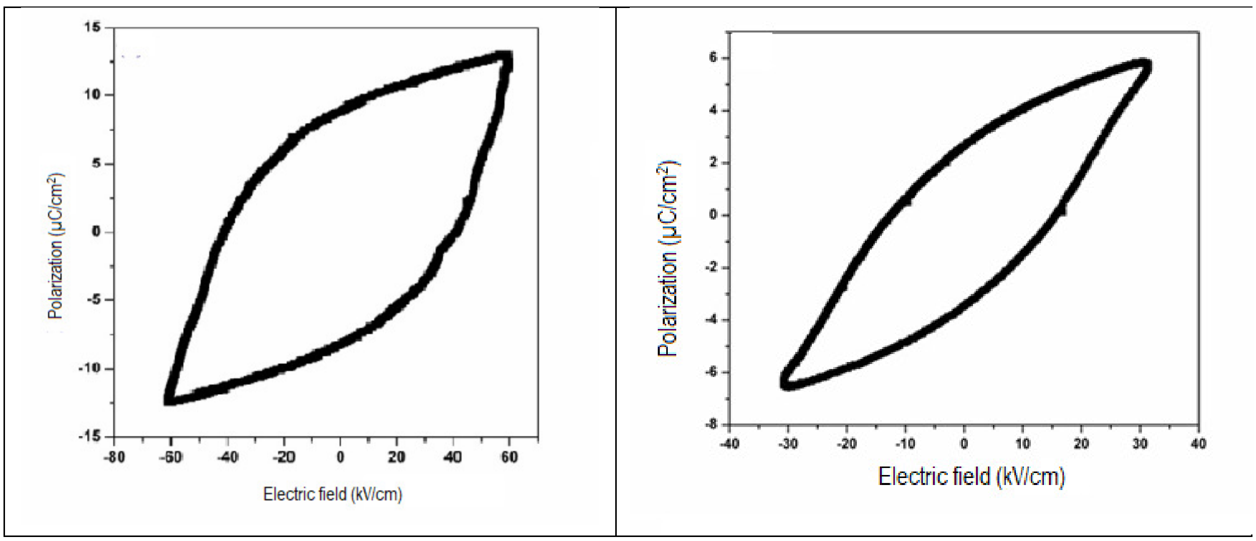

Fig.-3: P V/s E loop for $SrBi_4Ti_4O_{15}$ and $Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$

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CONCLUSION

$SrBi_4Ti_4O_{15}$and $Sr_{0.8}Nd_{0.2}Bi_4Ti_4O_{15}$ are prepared using solid-state sintering method. P-E loops observed showed closed loops that are characteristics of ferroelectric materials. A decrease in P_r and E_c values are observed in materials doped with Nd which is attributed to the ionic radius of a substitute.

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