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Structural and Dielectric Characteristics of 0.20 $Ba(Fe_{0.5}Nb_{0.5})O_3$-0.80 $SrTiO_3$ nanomaterial

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ABSTRACT: *A complex Perovskite structure of barium iron niobate, Ba(Fe0.5Nb0.5)O3 (BFN) and strontium titanate SrTiO3 (ST) was fabricated by a ball milling induced solid-state reaction method. The phase formation of 0.20 Ba(Fe0.5Nb0.5)O3-0.80 SrTiO3 was checked using X-ray diffraction (XRD) technique. The X-ray structural analysis of BFN-ST80 nanomaterial, showed the formation of single-phase compound in the cubic system. Careful examination of microstructures of the individual compounds of the system was done by the Field emission scanning electron micrograph (FESEM), and confirms the polycrystalline nature of the systems. Detailed studies of dielectric properties of the systems in a wide range of frequency (100 Hz - 1MHz) and different temperatures (40°C -400°C) showed that electrical properties are strongly dependent on temperature and frequency.*

***Keywords*:** BFN-ST80 nanomaterial, Dielectric properties, FESEM, Polycrystalline, XRD

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I. INTRODUCTION

Complex perovskite materials with general formula A'A''B'B''O3 (A = mono-divalent, B = trid to hexavalent) are widely used for sensors, actuators, detectors, multi-layer ceramic capacitor (MLCC), , pyroelectric detectors, wireless communication systems, computer memories, microelectronics, global positioning systems and other electronic devices. Ferroelectric materials have been the subject of extensive studies due to their promising electrical characteristic which has a potential usefulness in fundamental research and technological applications. Investigation of the electrical properties of these materials is desirable to predict their suitability for electronic applications. Different relaxation processes seem to coexist in complex perovskite materials, which contain various energy barriers due to point defects appearing during their fabrication.

The dielectric constant of the material changes due to the change of time dependent polarization by an applied electric field. Due to resistivity to the motion of the atoms in the dielectric, there is always a delay between changes in the field and changes in the polarization, which results into dissipation factor tanδ and is proportional to the energy absorbed per cycle by the dielectric from the field [1].

Alternating current (AC) impedance spectroscopy is a very useful method to study (1) the characteristics of the intragranular and interfacial regions and their interrelations, (2) their temperature and frequency dependent dielectric properties[2-4]. AC impedance spectroscopy measurement of the capacitance (C) and tangent loss (tanδ) over a frequency range at various temperatures. Studies of electrical data in the different functions and forms allow different features of the materials to be recognized.

Recently, High dielectric permittivity has been reported for complex perovskite $BaFe_{0.5}Nb_{0.5}O_3$ (BFN) of certain compositions. Many researchers have studied BFN, including Saha and Sinha [5], Intatha *et al.* [6], Fang *et al.* [7], Raevski *et al.* [8] Nedelcu *et al.* [9], Tezuka *et al.* [10], Yokosuka *et al.* [11] and Rama *et al.* [12]. They have reported that the BFN-based perovskite materials exhibit a relaxor behavior by showing very attractive dielectric and electric properties over a wide range of temperatures. However, there still exist considerable debates concerning the physical mechanisms governing their electrical behavior [6]. Lead based perovskite materials are hazardous to environment. There are many popular synthesis methods have been used by researcher to get BFN based nanomaterials but we here present work on $0.20Ba(Fe_{0.5}Nb_{0.5})O_3$-$0.80SrTiO_3$ fabricated by a ball milling induced solid-state reaction method. The dielectric characteristics of this nanomaterial have evaluated in broad temperature and frequency ranges.

II. EXPERIMENTAL PROCEDURES

Complex perovskite material $(0.20)Ba(Fe_{0.5}Nb_{0.5})O_3$-$0.80SrTiO_3$ was prepared by a solid-state reaction technique. High -purity (≥99.9%) from M/s Merck specialities private limited ingredients: $BaCO_3$, $SrCO_3$, TiO_2, Nb_2O_5 and Fe_2O_3 were used for the preparation These chemicals were taken in stoichiometric ratio, and mixed in the presence of air for 2 h and in presence of acetone for 6 h. The finely mixed powder of were calcined at 1200°C for 8 h. The calcined powder of above mentioned ceramics were regrinded in Ratsche ball milling and used to make pellet of diameter ~10 mm and thickness 1 - 2 mm using polyvinyl alcohol as binder. The pellets were sintered at 1250°C for 5 h and then brought to room temperature under controlled cooling. The formation and quality of the com-pounds were checked with Ringaku miniflux 600 X-ray diffractometer . The frequency dependence of the capacitance and conductance is measured using an LCR meter in the temperature range from 40°C to 400°C and in the frequency range from 100 Hz to 1 MHz. The electrical property were obtained from the temperature dependence of the real (ε') and imaginary (ε'') components of the complex dielectric constant $\varepsilon^* = (\varepsilon'-j\varepsilon'')$. The X-ray powder diffraction pattern of the sam-ple is taken at room temperature using a X-ray powder diffractometer (Rigaku Miniflex, Japan) using Cukα ra-diation (λ = 1.5418 Å) in a wide range of Bragg angles 2θ (20° ≤ 2θ ≤ 80°) with scanning rate 2°/min. The mi-

III. RESULT AND DISCUSSION

The room temperature X-ray diffraction (XRD) patterns of BFN-ST80 nanomaterials is shown in **Figure 1**. The nature of XRD patterns appears to confirm the formation of single-phase with cubic crystal structure of the compounds. All the reflection peaks of the XRD pattern of the samples were fitted, and the lattice parameters were determined in the using a computer program "OriginLab".

The room temperature FESEM (Field Emission scanning electron microscope) micro-graphs of BFN-ST80 nanomaterial powder is shown in Figure 2. The nature of the microstructure exhibits the polycrystalline texture having highly distinctive and compact cubical/rectangular grain distributions. Careful examination (scanning) of the complete surface of the sample exhibits that the grains are homogeneously distributed through out the surface of the sample. The average crystallite size of the present sample has been found to be around 20 nm, which is well matched with the particle size calculated from Scherer's formula.

Figure 3 (a) and (b) shows variation of real part of dielectric constant and Figure 4 (a) and (b) shows variation of loss tangent as a function of the frequency at different measuring temperatures.

Increase in temperature results in to increase in dielectric constant and formation of plateau at high temperature. According to Chen et al. [13] and Huang et al. [14] it may be due to oxygen vacancies.

Loss in Dielectric constant with increase in frequency can be a result of the formation of barrier layers at the grain-grain boundary interfaces. Formation of Schottky barriers at the grain boundaries leads to formation of internal barrier layer capacitance causing a high dielectric constant inside the material [15]. As shown in Figure 5 and 6, loss tangent is low at room temperature but shows a plateau at low frequency and high temperature. Formation of layers at a near-electrode surface may be another cause of high values of dielectric constant in BFN-ST80 nanomaterial sample. [16]

In Table (2) representing maximum value of real part of dielectric constant at different frequency and various temperatures, we can observe that dielectric constant has maximum value 2868.8 at measuring temperature 350^{o}C at lower frequency nearer to 1 KHz and as frequency increases up to 1 MHz dielectric permittivity get vanishes. It may be due to with increase in frequency, net polarization of material decreases as each polarization mechanism ceases to contribute which leads to decrease the dielectric constant.

Figure 5(a)-(b) and 6 (a)-(b) shows the temperature dependence of the real part of dielectric constant ε', and loss tangent (tanδ) of BFN-ST80 nanomaterial sample at different frequencies respectively. At a given measuring frequency, Dielectric constant (ε') and Loss tangent (tanδ) shows high temperature relaxation. For all the frequency ranges the peak temperature for ε' and tanδ in High temperature relaxation region was almost same. Loss tangent (tanδ) supports this change in dielectric constant. A broad dielectric peak shifts towards higher temperature together with decrease in amplitude and increase in frequency.

High temperature relaxation in BFN-ST80 nanoceramics can be explained by Maxwell–Wagner (M–W) relaxation model. Figure 9.7 shows loss tangent slightly increases at room temperature with increase in frequencies. The High temperature relaxation is located at different frequencies for the same temperature. This indicates that the High temperature relaxation could be a result of intrinsic and extrinsic relaxation. As BFN-ST80 nanomaterial sample was annealed in air, it make an impact on High temperature dielectric peaks in it. So, relaxor like relaxation behavior could primarily be associated with oxygen vacancies [17,18].

IV. IFIGURES AND TABLES

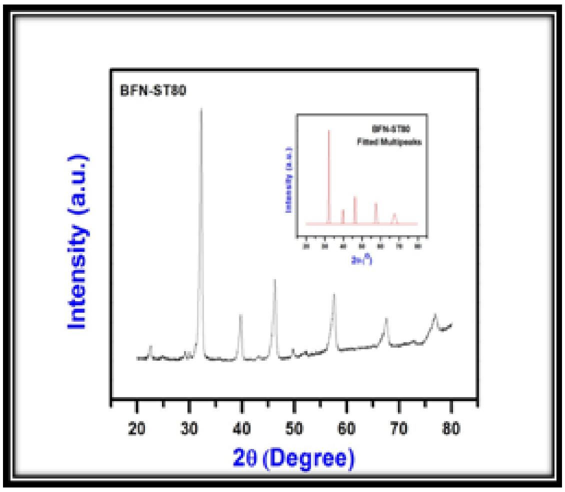

Figure 1. X-ray diffraction patterns of BFN-ST80 nanomaterials , at room temperature.

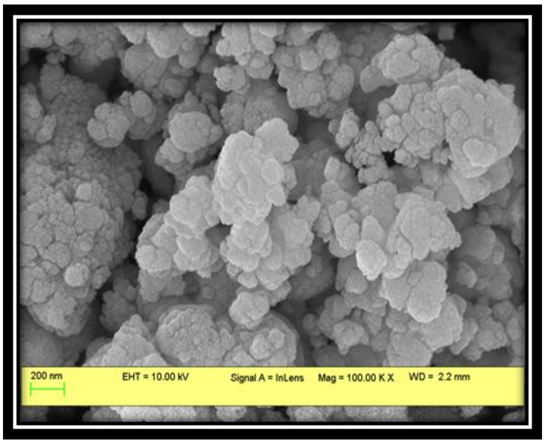

Figure 2. FESEM image of BFN-ST80 at magnification 100 KX

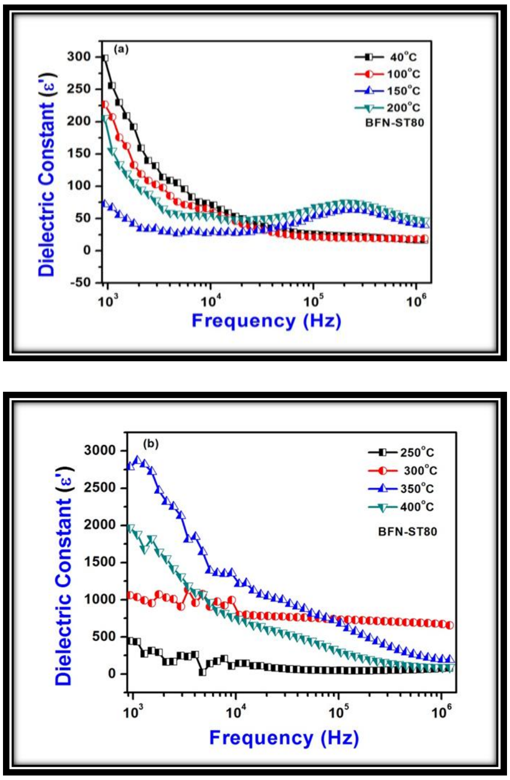

Figure 3 (a) and (b) shows Frequency dependence behavior of real part of Dielectric Constant at different temperatures.

Table 2. Maximum dielectric constant of BFN-ST80 nanoceramics at different temperatures.

Temper-ature (^oC)	**Freque-ncy (kHz)**	**Maximum value of** *ε')*
40	1	298.30
100	1	226.84
150	1	71.77
200	1	205.82
250	1	443.30
300	1	1059.86
350	1	2868.05
400	1	1968.41

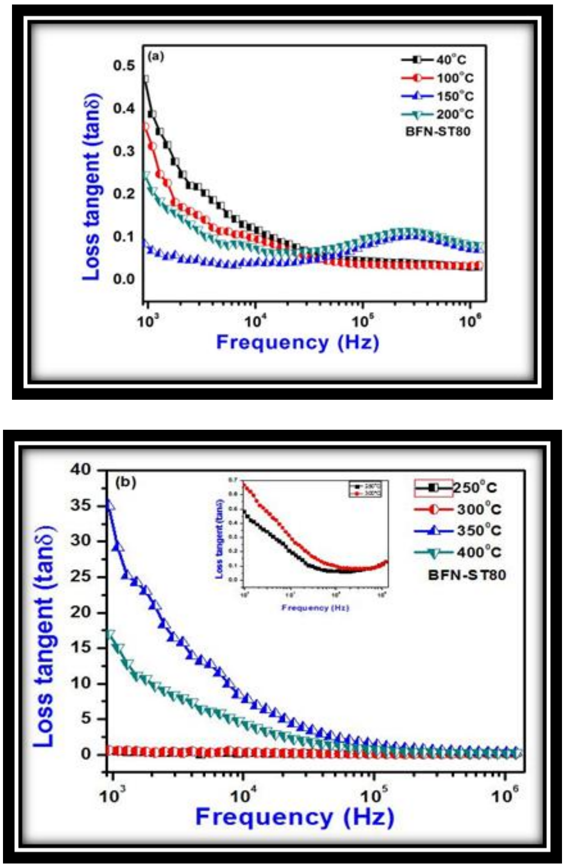

Figure 4 (a) and (b) shows Frequency dependent loss tangent at different temperatures.

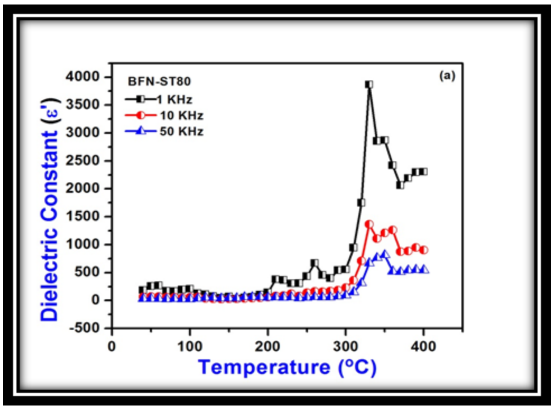

Table 3 .The peak values attained by temperature dependent Dielectric constant at different frequencies

Frequency (KHz)	Temperature (°C)	ε'(maximum) First peak value
1	330	3868.4
10	330	1366.4
50	350	814.6
100	400	366.2
500	400	135.6
1	400	113.3

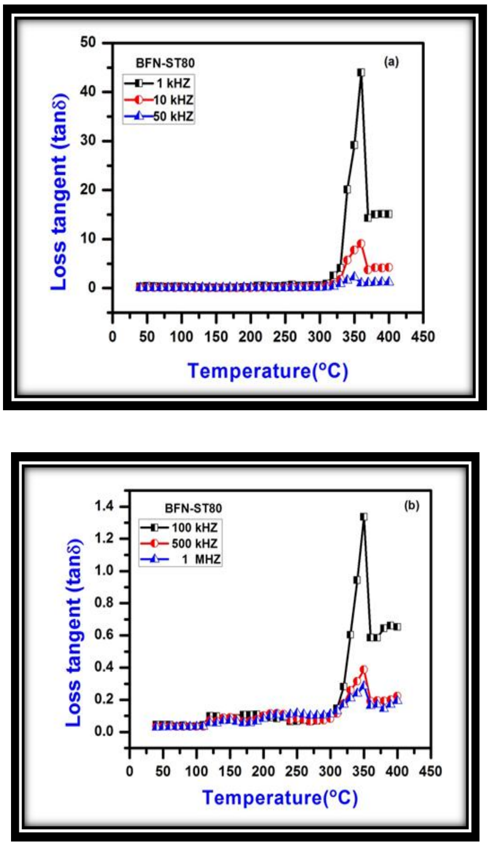

Figure 6(a)-(b) Shows variation of loss tangent with temperature in BFN-ST80 nanoceramic for different frequency ranges

V. CONCLUSION

In this work, we reported structural, dielectric and impedance properties of BFN-ST80 nanomaterials prepared by a high-temperature ball milling induced solid-state reaction method. Preliminary structural analysis suggests that formation of single-phase compound in the cubic system. Detailed studies of Dielectric properties exhibited a strong frequency dependent dielectric dispersion of the compound.It can be used as a potential environment friendly nanomaterial application in microelectronic devices.

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