Studies on Structural, Electrical and Dielectric Properties of Barium Strontium Titanate ($Ba_xSr_{1-x}TiO_3$ with x=0.5) Ceramics

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Abstract **- Barium strontium titanate sample with the molar formula Ba_xSr_{1-x} TiO_3 in which x=0.5 (BST50) were prepared by standard double sintering ceramic method. The structure of BST50 was studied by XRD. The lattice parameter a, particle sizes and unit cell volume were calculated from the XRD data. As a function of frequency and temperature, dielectric constant dielectric losses were studied in the frequency range 1 kHz to 1 MHz.**

1. INTRODUCTION

The most widely used ferroelectrics occur in the perovskite family, with possess the general formula ABO_3; the oxidation states of A, B and O are 2+, 4+ and 2- respectively. Barium strontium titanate is also belongs to the perovskite family [1, 2]. Barium strontium titanate (BST) based ceramics are chosen because of its several industrial applications, including dynamic random access memory (DRAM) capacitor [3, 4], microwave filters, infrared detectors, and dielectric phase shifters [5-7], due to their excellent ferroelectric, dielectric , piezoelectric and pyroelectric properties

2. PREPARATION OF SAMPLES

BST50 was synthesized using a solid-state reaction method [8–11]. Reagent grade, $BaCO_3$, $SrCO_3$ and TiO_2 powders were used as starting materials. The powders were mixed by ball milling for 10h for uniform mixing. The mixed powders were calcined at 1200^0C for 24h. After calcining the samples are ballmillied for 20h. Fine calcined powders were pressed into disc-shaped pellets at an isostatic pressure of 10 tons. No binder was used. The pellets are sintered at 1250^0C. To determine the properties, silver paste applied on both surfaces the sintered samples. The dielectric properties were measured using HOCI LCR HITESTER-3532-50 meter at 1 kHz– 1 MHz from room temperature to 300^0C.

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2.1 X-ray measurements

For crystal structure analysis, the powders were characterized by XRD diffract meter

2.2. Dielectric measurements

The AC parameters such as capacitance (*c*) and dielectric loss (tan δ) of the samples were measured in the frequency range 1 kHz to 1MHz using LCR meter (HIOKI 3532-50 LCR Hi Tester). The variation of dielectric, dielectric loss and ac conductivity with temperature were studied by recording these parameters at different frequencies (viz. 1 kHz, 10 kHz, and 100 kHz and 1 MHz). The dielectric constant (ε_r) was calculated using the relation:

$$\varepsilon_r = \frac{ct}{\varepsilon_0 A}$$

Where *c* is the capacitance of the pellet, *t* the thickness of the pellet, *A* the area of cross section of the pellet and ε_o is the permittivity of free space (8.854×10−12 F/m).

2.4. AC conductivity

The AC conductivity of the samples was estimated from the dielectric parameters. The AC conductivity (σ_{AC}) was calculated using the relation

$$\sigma_{AC} = \omega' \varepsilon \varepsilon_0 \tan\delta$$

where ε_o is the permittivity of the free space, ω the angular frequency and tan δ is the loss tangent.

3. RESULTS AND DISCUSSION

3.1. Crystal structure

Fig. 1 shows the *x*-ray diffraction patterns of BST50 ceramics. There is no impurity peaks observed in the XRD patterns. From XRD pattern we conformed that the structure of the BST is cubic structure. The lattice parameter of BST 50 is $3.9539A^0$. The volume of unit cell and average particle sizes of BST 50are are 61.8126 cm^3 and 12.57nm respectively. The peak sharpness and intensity indicate that

BST is fully crystalline. It is observed that the BST50 crystal structure is cubic.

3.2. Dielectric constant and dielectric loss

The variation of dielectric constant of BST50 with temperature at 1 kHz to 1MHz frequency is shown in Fig. 2. From the plot it is clear that the dielectric constant decreases rapidly with increase in frequency in the lower frequency region and attains a saturation limit at higher frequencies. The pattern at lower frequencies may be attributed to different types of polarization (electronic, atomic, interfacial and ionic, etc.). At higher frequencies it arises due to the contribution from electronic polarization.

The broadened peaks indicate that the transition in all the cases is diffused type, and important characteristic of a disordered perovskite. The broadening is attributed to the disorder in the arrangement of cations at A-site which is occupied by Ba2+ with Sr2+ and B-site occupied by Ti4+ with lattice vacancies. Also the broad peaks observed in dielectric constant versus temperature may be due to poor densification/microstructure in the samples. The maximum dielectric constant was observed at 1 kHz frequency.

The variation of dielectric loss of BST50 with temperature at 1 kHz to 1MHz frequency is shown in Fig. 3. At lower frequencies tan δ is large and it decreases with increasing frequency. The tan δ is the energy dissipation in the dielectric system, which is proportional to the imaginary part of dielectric constant ε. At higher frequencies the losses are reduced and the dipoles contribute to the polarization [5]. The variation of ac conductivity of BST50 with temperature at 1 kHz is frequency is shown in Fig. 4.

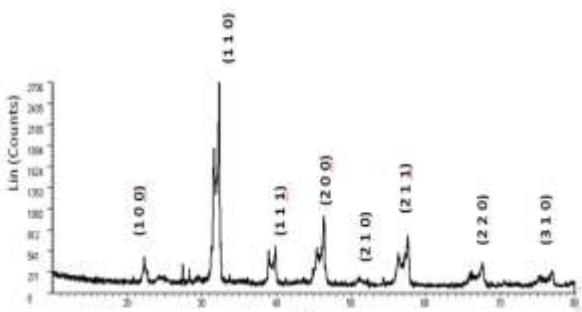

Fig. 1 XRD patterns of BST50

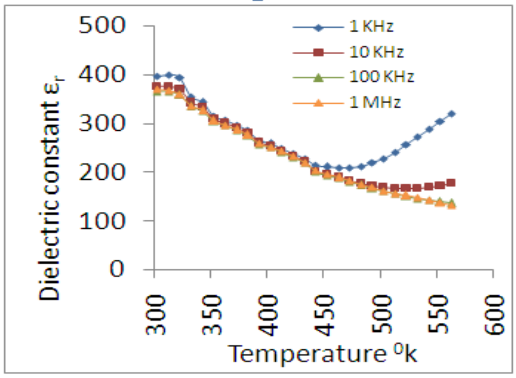

Fig 2. Dielectric constant Vs temperature plot of BST50

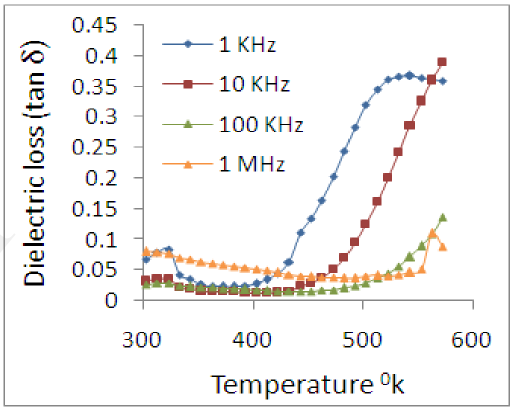

Fig 3. Dielectric loss Vs temperature plot of BST50

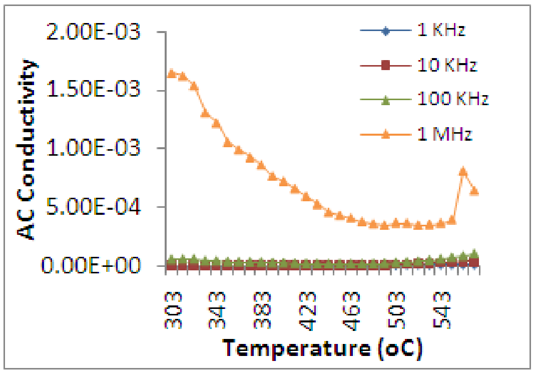

Fig 4. AC conductivity Vs temperature plot of BST50

4. CONCLUSIONS

BST ceramics prepared by high temperature solid reaction technique exhibit good homogeneity, small particle size and formation of single phase compounds with tetragonal structure. The compound also have negative temperature coefficient of resistivity (NTCR), which is most desirable for developing highly sensitive thermal detectors, sensors, etc. Sr doping in $BaTiO_3$ provides many interesting features such as shift in transition temperature, diffuse phase transition and increase in dielectric constant. The AC conductivity increases with decrease in the frequency, which may be due to the strong hopping mechanism of ions.

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