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Studies on Structure and Dielectric Properties of ($Ba_xSr_{1-x}TiO_3$) (x=0.1, 0.3, 0.5, and 0.7)

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Abstract - Barium strontium titanate (BST) a sample with the molar formula BaxSr1-xTiO$_3$ in which x varies as 0.1, 0.3, 0.5, and 0.7 were prepared by standard double sintering ceramic method. From XRD, the tetragonal perovskite phase formation was confirmed. The lattice parameters a and c were calculated from the XRD data. As a function of frequency and temperature, the dielectric constant and Dielectric loss were studied in the frequency range 1 kHz to 1 MHz.

Index Terms— XRD data, dielectric constant, dielectric loss, lattice constant, unit cell volume, average particle size, structure,

1 Introduction

The most widely used ferroelectrics occur in the perovskite family, with possess the general formula ABO_3. Barium strontium titanate is also belongs to the perovskite family. In BST when strontium ions are introduced at A site of the perovskite matrix, they enter substitutionally on the Ba^{2+} site. A small decrease in the unit cell volume takes place as the Sr content increases. The behaviour of the material is changed from ferroelectric to paraelectric. The phase transition behaviour changes from sharp to diffuse [1]. The main purpose of addition of Sr^{2+} into BST is to shift the Curie temperature towards room temperature and make BST a paraelectric material at room temperature offering high dielectric constant, low leakage current and low dielectric loss against frequency [2].

2 Experiment

2.1 Preparation of samples

BST ($Ba_xSr_{1-x}TiO_3$, with x=0.1, 0.3, 0.5 and 0.7) was synthesized using a solid-state reaction method [3–6]. 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 1100 to 1300^{0}C 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 1200 to 1300^{0}C. To determine the dielectric 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 30^{0}C to 200^{0}C.

2.2 X-ray measurements

The powders were characterized by XRD diffract meter for crystal structure analysis. The XRD specturum of the BST semples were shown in Fig 1.

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2.3 Dielectric measurements

The AC parameters such as capacitance (c) and dielectric loss of the samples were measured in the frequency range 1K Hz to 1MHz using LCR meter (HIOKI 3532-50 LCR Hi Tester). The variation of dielectric constant and loss tangent 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:

$$\varepsilon_r = ct / (\varepsilon_o A)$$

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).

3 Dielectric Constant and Dielectric Loss

The variation of dielectric constant with temperature at 1 kHz 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.

It can be seen that like any normal ferroelectric the dielectric constant increases gradually with rise in temperature up to its maximum value at Curie temperature (T_c) and then it decreases, indicating the phase transition from ferroelectric state to paraelectric state at Curie temperature (T_c). 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 Ba^{2+} with Sr^{2+} and B - site occupied by Ti^{4+} with lattice vacancies, leading to a microscopic heterogeneity in the composition and thus results in the shift of Curie point [6]. 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 at Curie temperature. The dielectric constant increases with in-

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creasing Sr content and the Curie temperature decreases.

The variation of dielectric loss with temperature at 1kHz is shown in Fig. 3. At lower frequencies doelectric loss is large and it decreases with increasing frequency. At higher frequencies the losses are reduced and the dipoles contribute to the polarization [7].

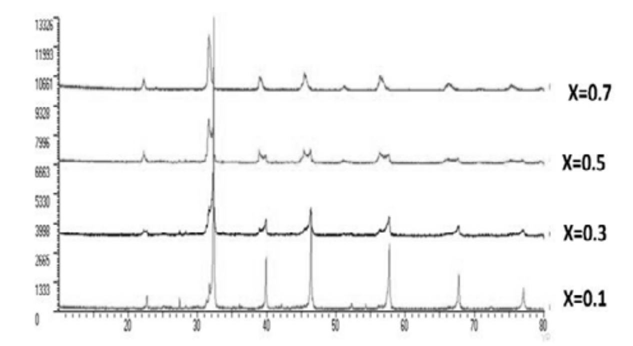

Fig. 1. XRD pattern of $Ba_xSr_{1-x}TiO_3$

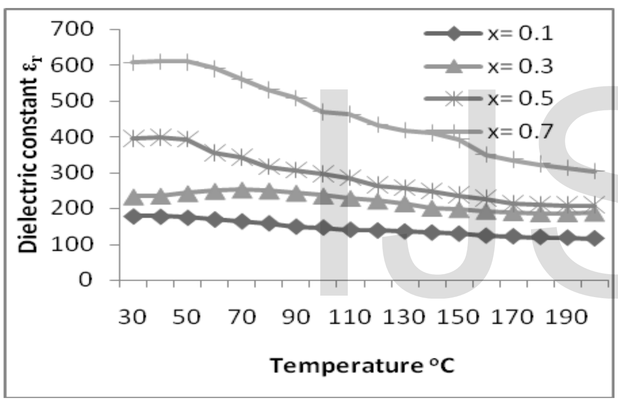

Fig 2. Dielectric constant Vs temperature plot of $Ba_xSr_{1-x}TiO_3$ at 1 KHz frequency

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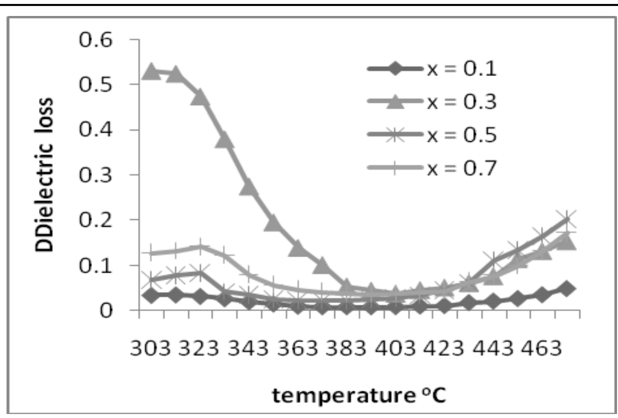

Fig 2. Dielectric loss Vs temperature plot of $Ba_xSr_{1-x}TiO_3$ at 1 KHz frequency

4 Conclusion

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 resistivity of the samples is also found to be increased with increase in Sr content. 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.

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