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Short Communication

Thin Film Production and Characterization $Ba_{1-x}Sr_xTiO_3$ (x = 0.9) for Capacitor Applications

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Abstract

The thin films of Barium Strontium Titanate (BST) material of $Ba_{0.1}Sr_{0.9}TiO_3$ were fabricated using sol-gel method and annealed at temperature 600 °C, 650 °C and 700 °C in order to obtain its crystalline structure. The thin films of BST were characterized using FESEM, XRD and Impedanceof Spectroscopy. The results of characterization use FESEM at temperature of 600 °C, 650 °C and 700 °C to obtainin thickness such as 51,36nm; 53,59nm and 87,09nm. The results of characterization use XRD with the temperature annealing. its angle 10,26° at temperature 600 °C, 650 °C and 700 °C to obtain the intensity 244, 280 and 300. The characterization uses Spectroscopy Impedance to obtain the values complex capacitance and dielectric constant are inversely proportional to the frequency and while the loss of dielectric values areproportional to the frequency. At frequency 100Hz with of the temperature 600 °C, 650 °C and 700 °C obtaining the complex capacitance of values which are 5.59481×10^{-11}F; 7.73048×10^{-11}F and 9.38054×10^{-11}F. The dielectric constant values are 6.3215; 8.7350 and 10.5994. The loss of dielectric values is 0.0234; 0.0069 and 0.0066. The increasing temperature annealing the thickness value, the complex capacitance, the constant of dielectrics and the losses of dielectrics are increasing.

Keywords: Barium strontium titanite; Sol-gel method; XRD; FESEM; Impedance spectroscopy

Introduction

The development of the era of many changes that occurs in materials is often studied by scientists of science. Ferroelectric is one of the unique materials to be studied and researched. Commonly used ferroelectric thin film materials include Barium Strontium Titanate (BST), Barium Titanate ($BaTiO_3$) and Strontium Titanate ($SrTiO_3$). The $BaSrTiO_3$ material in the last year is highly reviewed and developed, from the above-mentioned ferroelectric thin films $Ba_{0.8}Sr_{0.2}TiO_3$ which acts as a dielectric to increase the capacitance value of the capacitor [1]. This study is a study for the manufacture of BST thin film from a mixture of Barium Carbonate, Strontium Carbonate and Titanium Isopropoxide with a composition ratio of Ba and Sr 0.1: 0.9 or can be written $Ba_{0,1}Sr_{0,9}TiO_3$. The treatment is made by sol gel method or with CSD model, then continuous spin coating and annealing process at temperature 600 °C, 650 °C and 700 °C. Light sensor made of thin film material $Ba_{0,5}Sr_{0,5}TiO_3$ above Si substrate (100) p-type by means of chemical-assisted chemical solution deposition (CSD) method [2].The capacitor is one of the electronic devices that play an important role in the electronics circuit. The value of the capacitor depends on how much charge can be stored. This dependence leads to a capacity already limited to the capacitor. The capacitance of a capacitor can be increased by a dielectric material in the capacitor [3]. BST is a perovskite material based on Barium Titanate ($BaTiO_3$) [4]. Figure 1 shows the perovskite crystal structure of the BST ferroelectric material [5].

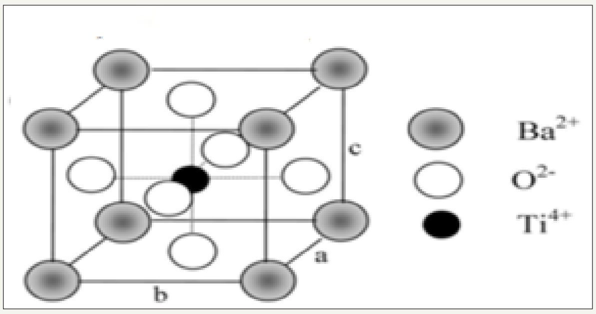

Figure 1: The perovskite structure of ferroelectric material [5].

The nature of the perovskite structure of the BST is due to a form with a concomitant with 3,951Å. This situation coincides with the $BaTiO_3$ crystalline structure (a = 3.991Å and c = 4.0108Å) and $SrTiO_3$ (a = 3.897Å) with Ba tau Sr being at zero. The Ti ion is at the center and the three oxygen atoms are at the center of the face. This structure will cause the Ba^{2+} ions in $BaTiO_3$ to be replaced by Sr^{2+} ions. Ti^{4+} ions and O^{2+} ions in $BaTiO_3$ will exchange places at the c-pipe where the Ba^{2+} ion is in an almost symmetrical position. Sr^{2+} ions, Ti^{4+} and O^{2+} ions in $SrTiO_3$ remain unchanged in the structure $SrTiO_3$ estimates [6]. CSD or sol gel techniques are one of the simplest and easiest ways of making nanoparticles. The usefulness of this method allows us to design the desired material at low temperatures and as an alternative to conventional methods [7].

These thin films will be characterized using X-ray Diffraction, FESEM and Impedance Spectroscopy, where the characterization using FESEM to obtain the thickness of the sample and characterization using impedance spectroscopy to obtain the value of the dielectric constant can be calculated using the equation:

$$\varepsilon' = \frac{c'd}{\varepsilon_0 A} \qquad (1)$$

The dielectric constant ε' is a measure of the ability of a material to store a relative charge in a vacuum chamber [8]. The value of complex capacitance (C*) at a given frequency is obtained through the relationship:

$$C^* = \frac{1}{j\omega Z^*} \qquad (2)$$

Research Methodology

This research is done by using some step experimental method. The sample was prepared using a sol-gel method placed on a glass substrate using a spin coater and annealing at temperatures of 600 °C, 650 °C and 700 °C while for BST capacitor characterization using XRD, FESEM and Impedance Spectroscopy. Figure 2 shows the flow diagram of the research conducted in the manufacture of BST capacitors. The structure of thin film of BST is shown in Figure 3.

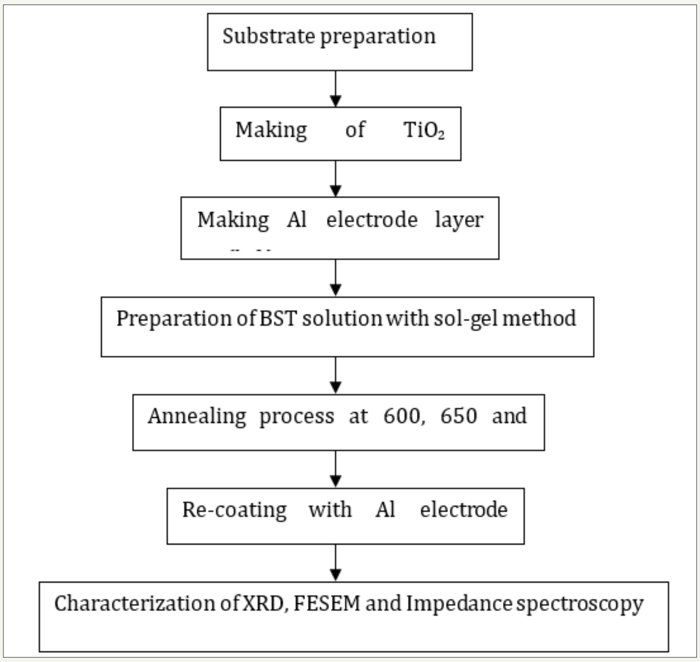

Figure 2: BST capacity building diagram.

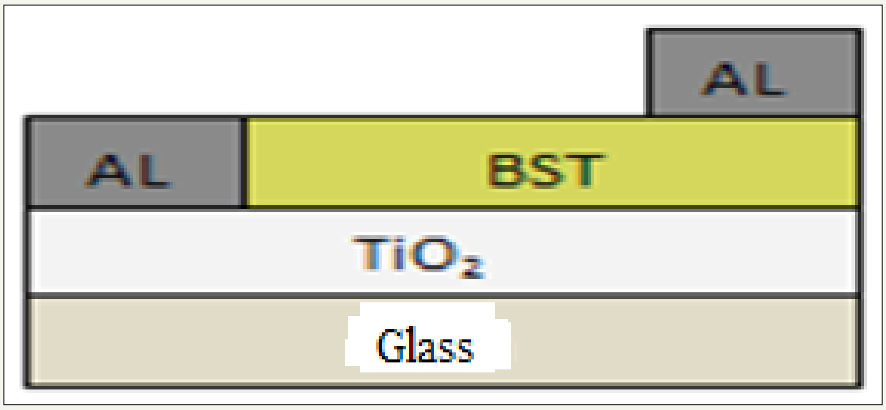

Figure 3: Thin film structure BST.

Results and Discussion

XRD characterization results can be seen in Figure 4 (a) shows the absence of the resulting diffraction peak against the 2θ angle. Without the temperature treatment the annealing structures can be amorphous. The sample has no crystal field but is amorphous [9]. The orientations (010) and (110) contained in the thin film $PbZr_{0,625}Ti_{0,375}O_3$ (PZT) were lost by treatment without annealing [10]. Figure 4b shows the resulting diffraction peak at a 2θ angle. Samples subjected to annealing temperature treatments have a crystal structure. Annealing temperature increases cause the atomic radius to increase in size so that the density becomes increased [11]. The intensity is proportional to the annealing temperature [12].

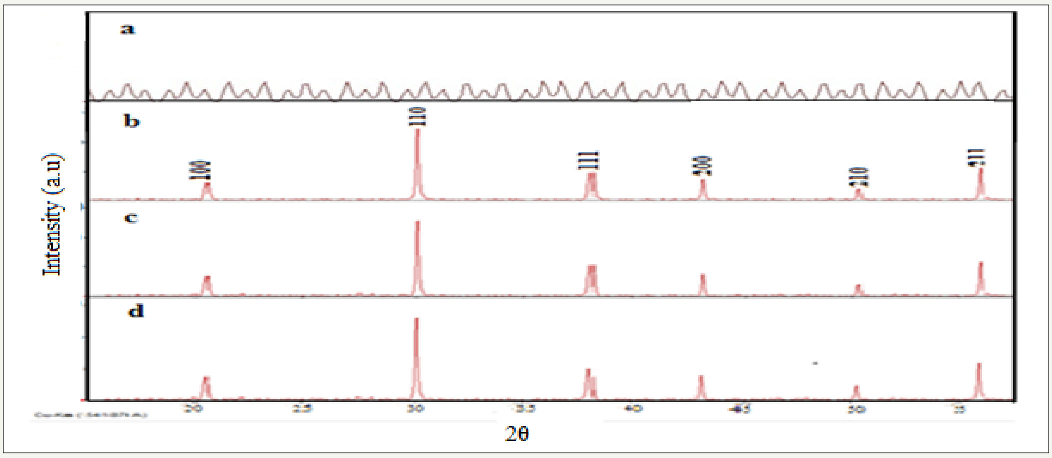

Figure 4: XRD characterization charts a.300 ; b.600, c.650 and d.700 °C temperatures.

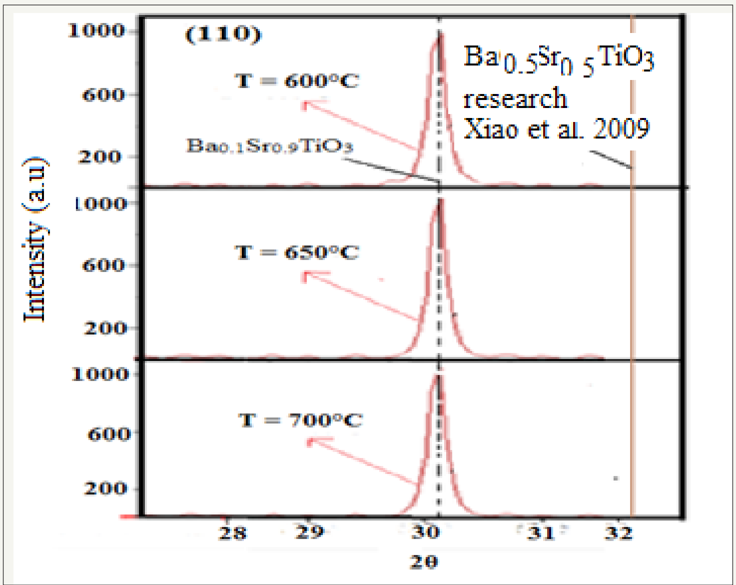

Figure 5: The magnification of the diffraction peak range (110).

Figure 5 represents the magnification of the range at the diffraction peak 110 against the angle 2θ. the image shows a angular distance difference due to the different compositions where (a) is the result of the study of thin film $Ba_{0.1}Sr_{0.9}TiO_3$ having an angle value of 2θ at the diffraction peak 110 (110) ie 30.1° with annealing temperature 600 °C, 650 °C and 700 °C, while (b) is the result of the study of the thin film $Ba_{0.5}Sr_{0.5}TiO_3$ having an angle value of 2θ at the diffraction peak (110) i.e., 32.1° with annealing temperature of 650 °C 700 °C and 800 °C [13]. The composition difference of x=0.4 resulted in an angle of 2θ having a difference of 2.1°. The result of data calculation using match3! shown in Table 1. Characterization using FESEM can be seen in the following Figure 6(a-c).

Table 1: Effect of annealing temperature on intensity at 2 theta.

No	2θ (°)	θ	d_{hkl} (Å)	Grid Parameters a (Å)	hkl	Intensity		
						600 °C	650 °C	700 °C
1	21.2	10.6	4,186	4,186	100	244	280	300
2	30.1	15.05	2,960	4,186	110	1045	1085	1105
3	37.16	18.58	2,417	4,186	111	373	393	410
4	43.22	21.61	2,092	4,184	200	302	312	320
5	50.63	25.3	1,812	4,159	210	152	182	199
6	55.6	27.22	1,665	4,127	211	456	486	498

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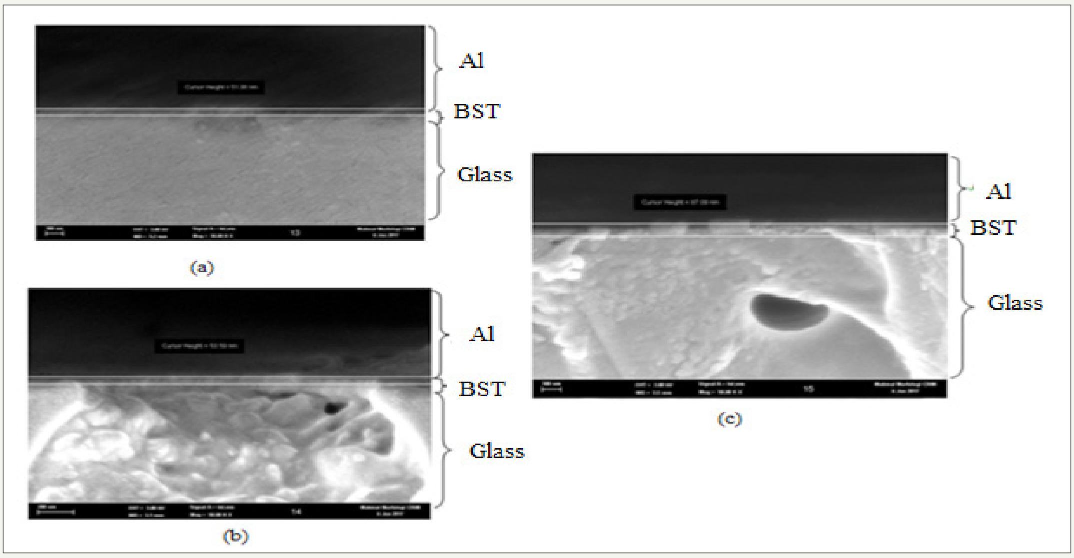

Figure 6: BST film thickness annealed at temperatures (a) 600 ^{0}C, (b) 650 ^{0}C and (c) 700 ^{0}C.

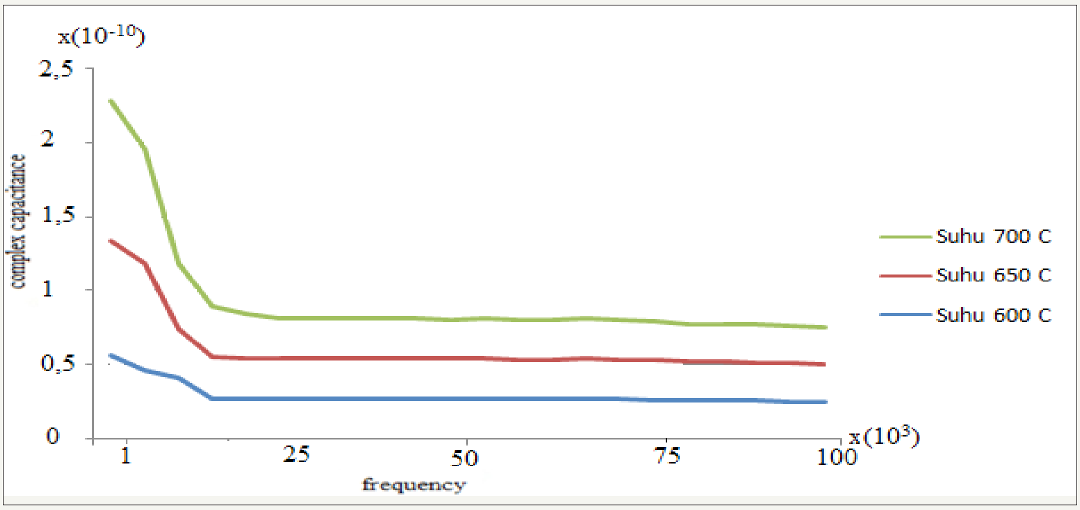

Figure 7: Graph of bode plot complex capacitance to frequency.

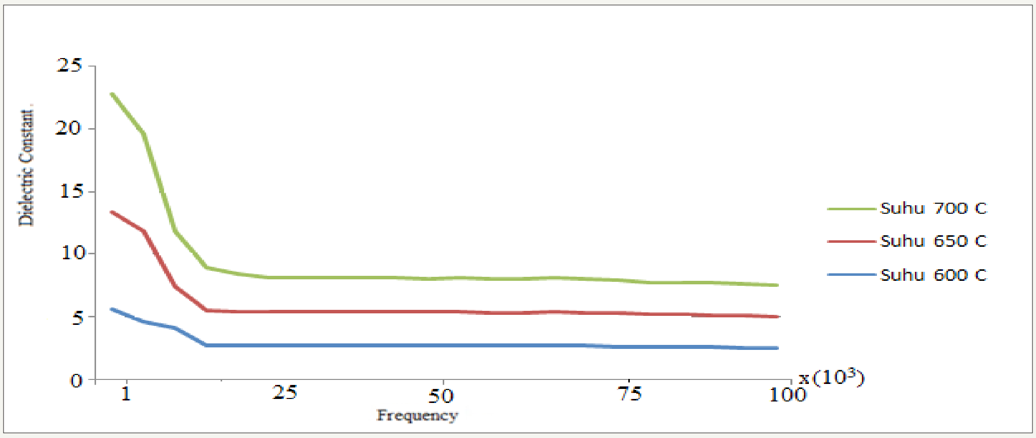

Figure 8: Graph of bode plot dielectric constant to frequency.

FESEM characterization of annealed samples at temperatures of 600 C, 650 °C and 700 °C produces thicknesses of $Ba_{0.1}Sr_{0.9}TiO_3$ capacitors. Figure 6(a-c) samples of BST annealing at temperatures of 600, m; 53.59nm and 87.09nm. Enhancement temperature annealing causes the size of BST layer thickness to be greater [14]. Annealing temperature increases cause the size of the BST constituent particles to be larger so that the atoms in it are more orderly and solid [15]. Characterization using Impedance Spectroscopy in order to know the value of complex capacitance, dielectric constant and dielectric loss. Values obtained at temperatures of 600 °C, 650 °C and 700 °C are shown in Figures 7-9 which are bode plot graphs ie the relationship between complex capacitance, dielectric constant and dielectric loss to frequency. Figures 7-9 are graphs of complex capacitance bode plot, dielectric constant and dielectric loss to frequency. Temperature 600 °C, 650 °C and 700 °C at 100Hz frequency of complex capacitance of 5.59x10^{-11}F, 15x10^{-11}F and 25 x10^{-11}F. The dielectric constant value is 6.32, 14.73 and 23.59. Dielectric loss value is 0.045; 0.11 and 016. The same frequency of complex capacitance values increases as a result of annealing temperature increases [16]. The dielectric constant increases with increasing annealing temperature from 550 °C to 800 °C [17]. The frequency rises from 100 Hz to 1MHz, dielectric decreases and dielectric losses increase sharply [18].

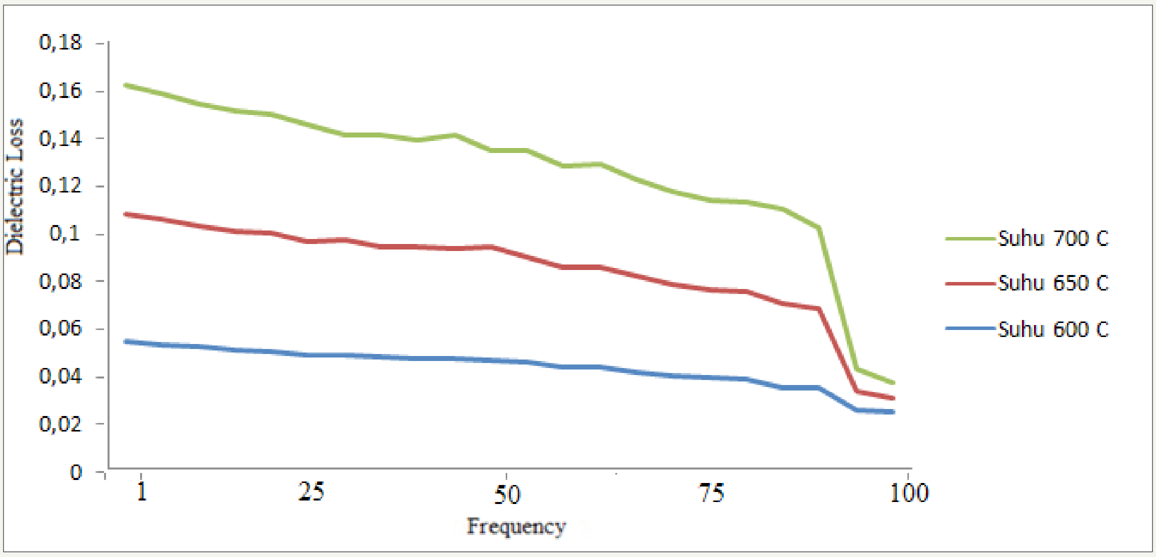

Figure 9: Graph of bode plot dielectric loss to frequency.

Conclusion

The XRD characterization shows intensity value increases with increasing annealing temperature and the resulting structure is cubic. FESEM characterization produces thickness. The thickness is directly proportional to the temperature. The characterization of impedance spectroscopy results in the value of complex capacitance, the dielectric constant inversely proportional to the frequency. Dielectric loss is directly proportional to frequency.

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