

C45. The Effect of Photoconductive Mole Fraction Based on Thin Film $BaxSr1-xTiO3$ ($x = 0.000; 0.125; 0.250;$ $0.375; 0.500$) on Electrical Properties and Diffusivity Coefficient

by Mochamad Zakki Fahmi

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Irzaman^{1*}, Vania Rahmawaty¹, Endah Kinarya Palupi¹, Nazopatul Patonah¹, Tony Sumaryada¹, Ridwan Siskandar², Husin Alatas¹, Muhammad Iqbal³, Brian Yulianto³, Mochammad Zakki Fahmi⁴, Febdian Rusydi⁵, Widagdo Sri Nugroho⁶

¹ Department of Physics, Faculty of Mathematics and Science, Bogor Agricultural University, Meranti Street, Dramaga, Bogor, West Java, 16680, Indonesia

² Computer Engineering Study Program, College of Vocational Studies, IPB University, Bogor, West Java 16151, Indonesia; ridwansiskandar@apps.ipb.ac.id (R.S.);

³ Department of Engineering Physics, Industrial Engineering Faculty, Bandung Institute of Technology, Bandung, West Java 40132, Indonesia; iqbal@tf.itb.ac.id (M.I.); brian@tf.itb.ac.id (B.Y.);

⁴ Department of Chemistry, Faculty of Science and Technology, Airlangga University Surabaya, East Java 60115, Indonesia; m.zakki.fahmi@fst.unair.ac.id (M.Z.F.);

⁵ Department of Physics, Faculty of Science and Technology, Airlangga University Surabaya, East Java 60115, Indonesia

⁶ Department of Veterinary Public Health, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia; weesnugroho@ugm.ac.id (W.S.N.);

* Correspondence: irzaman@apps.ipb.ac.id;

Scopus Author ID 7409571162

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Abstract: Barium Strontium Titanate ($\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$) thin films have been fabricated for mole fraction ($x = 0.000; 0.125; 0.250; 0.375; 0.500$) on p-type silicon (100) substrate using Chemical Solution Deposition (CSD) method and spin coating technique. The film annealed at 850 °C for 8 hours with an increasing rate of 1.67 minute. The BST thin film was characterized using an LCR meter that the film is given a different light intensity (0 lux, 4000 lux, 8000 lux). Data obtained from the LCR meter is conductance, capacitance, and impedance. Different mole fractions on Barium produce different electrical properties that show the value of electric conductivity, dielectric constant, impedance, and diffusion coefficient.

Keywords: $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$; mole fraction; electrical properties; diffusivity coefficient; LCR meter.

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1. Introduction

In recent years, increasing attention has been paid to the synthesis and characterization of barium strontium titanate (BST) because its uniqueness lies in its mole fraction, which can be varied and cause new chemical and physical properties. Partial substitution of Ba ions in pure $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ strongly affects the ferroelectric-paraelectric phase transition temperature [1]. BST as a ferroelectric material has various technical advantages such as chemical stability, high permittivity, high dielectric constant, good thermal stability, and high tunability [2–7].

BST thin film is found in the perovskite family with general formula ABO_3 , which is the compositional modification in solid solution, substitution, and/or dopants. The addition of Ba atoms to the SrTiO_3 lattice substitutes the Sr atoms, influencing the crystalline structure and its properties⁶. Variation of BST mole fraction made is SrTiO_3 , $\text{Ba}_{0.125}\text{Sr}_{0.875}\text{TiO}_3$; $\text{Ba}_{0.25}\text{Sr}_{0.75}\text{TiO}_3$; $\text{Ba}_{0.375}\text{Sr}_{0.625}\text{TiO}_3$; and $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$. Many techniques can be applied to

prepare BST thin film, one of that is chemical solution deposition [3,8–16]. BST data retrieval is done using an LCRmeter to get the impedance, capacitance, and conductance data of BST measured with 3 variations, in dark conditions (0 lux) and light conditions (4000 lux and 8000 lux).

2. Materials and Methods

In the substrate preparation, the p-type silicon (100) substrate was cut to form a rectangle with a size of 1 cm² then washed using double distilled water [11,12,17–20]. The materials used in the synthesis of BST with different Ba ratio (x = 0.000; 0.125; 0.250; 0.375; 0.500) were barium acetate [Ba(CH₃COO)₂, 99%], strontium acetate [Sr(CH₃COO)₂, 99%], titanium isopropoxide [Ti(C₁₂O₄H₂₈), 99.999%]. The chemicals were calculated and weighed, corresponding to the stoichiometrical composition of Ba_xSr_{1-x}TiO₃. This material is dissolved with acetic acid [CH₃COOH, 100%] and ethylene glycol [C₂H₆O₂]. All of the materials are dissolved with a magnetic stirrer at a speed of 240 rpm. Thin-film BST was overgrown above the p-type silicon substrate with a spin coating technique at 8000 rpm for 30 seconds repeated 3 times. Then, BST films were annealed at 850 °C in the furnace model Vulcan™ with an increasing rate of 1.67 °C for 8 hours [14,20–28].

After that, a thin film is prepared to make an MFS layer. 2 holes in the BST part and 2 holes in the silicon substrate part will be made in contact, the remaining part will be covered with aluminum foil. Making contacts aims to install cables that can be used for characterization using LCR. Each cable is attached to each hole using silver paste [26,29,30].

3. Results and Discussion

The characterization was carried out under 3 different conditions, in the darkroom (0 lux), with lights 4000 lux and 8000 lux. Characterization using LCRmeter produces the value of conductance, capacitance, impedance, etc. The value of conductance can be used to calculate the electric conductivity. Electrical conductivity is represented by σ and is defined as the inverse of the resistivity as shown in equations 1, 2, 3 [12,15,28,31–37].

$$\sigma = \frac{1}{\rho} \quad (1)$$

$$\rho = \frac{RA}{l} \quad (2)$$

$$\frac{1}{R} = G \quad (3)$$

The value of conductance can be used to calculate electric conductivity by equation 4.

$$\sigma = \frac{Gl}{A} \quad (4)$$

where G is conductance obtained from the LCR meter.

The electric conductivity of Ba_xSr_{1-x}TiO₃ thin films under LCR characterization is shown in Figure 1.

Figure 1 shows that the electric conductivity tends to increase with increasing frequency. The various mole fraction produces various electric conductivity. Electric conductivity is also greater when it is given the greater intensity of light. This is due to the valence band to conduction band electrical conductivity increase. More electrons are excited into the conduction band due to irradiated light that causes the current to rise [10,20,32].

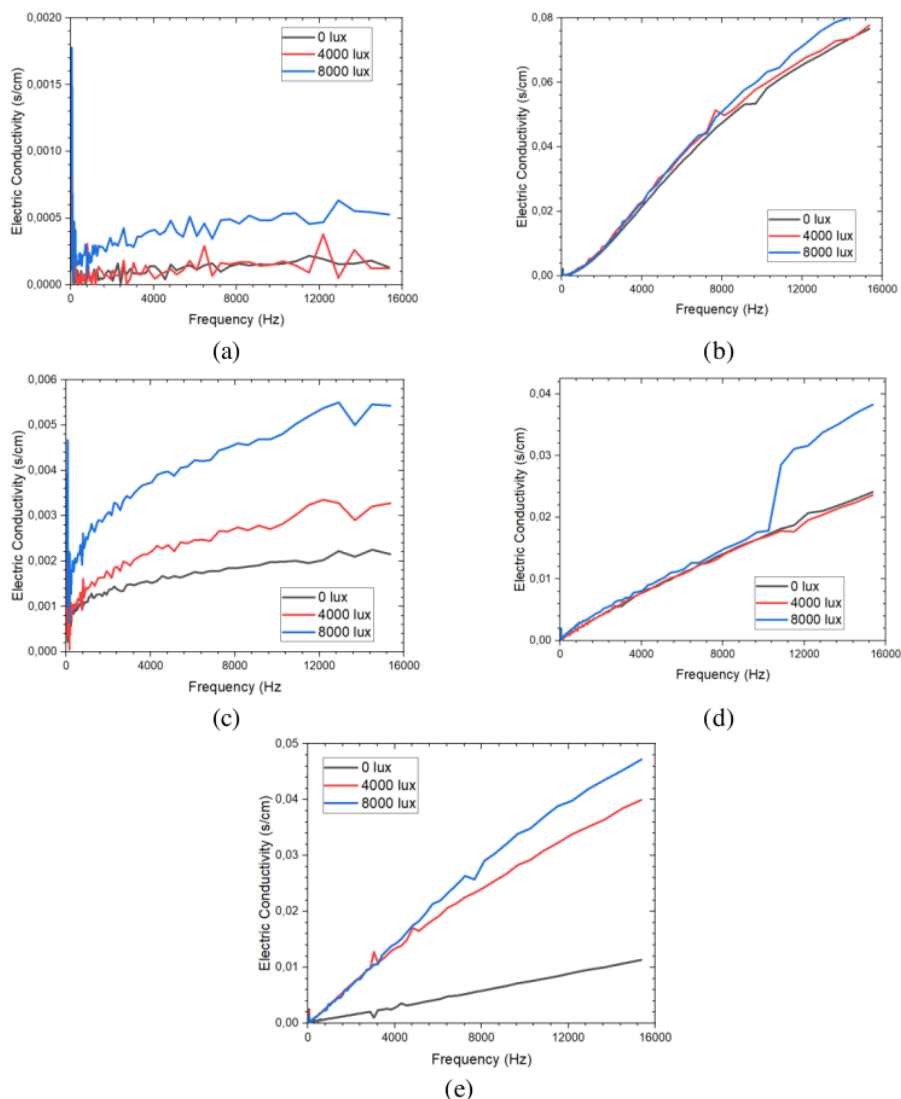


Figure 1/ Electric conductivity as a function of frequency for various mole fraction of BST: (a) $x = 0.000$; (b) $x = 0.125$; (c) $x = 0.250$; (d) $x = 0.375$; (e) $x = 0.500$.

Thus, the amount of light intensity indicates the energy given to films so that the light intensity will vary directly with electric conductivity.

The capacitance (C) was measured on the LCR meter used to get the dielectric constant (ϵ) that calculated using equation [1,12,37–40]:

$$\epsilon = \frac{Cd}{\epsilon_0 A} \tag{5}$$

where ϵ_0 is the permittivity of free space (8.85×10^{-12} F/m), A is the electrodes' area, and d is the sample's thickness.

The graphs below show the relationship between the dielectric constant and the frequencies that tend to be inversely proportional. Variation of the mole fraction produces different dielectric constant graphs. The dielectric constant's value tends to go up from the mole fraction from 0 to 0.25 and down to the mole fraction from 0.375 to 0.5.

The dielectric constant of $Ba_xSr_{1-x}TiO_3$ thin films from LCR characterization is shown in Figure 2.

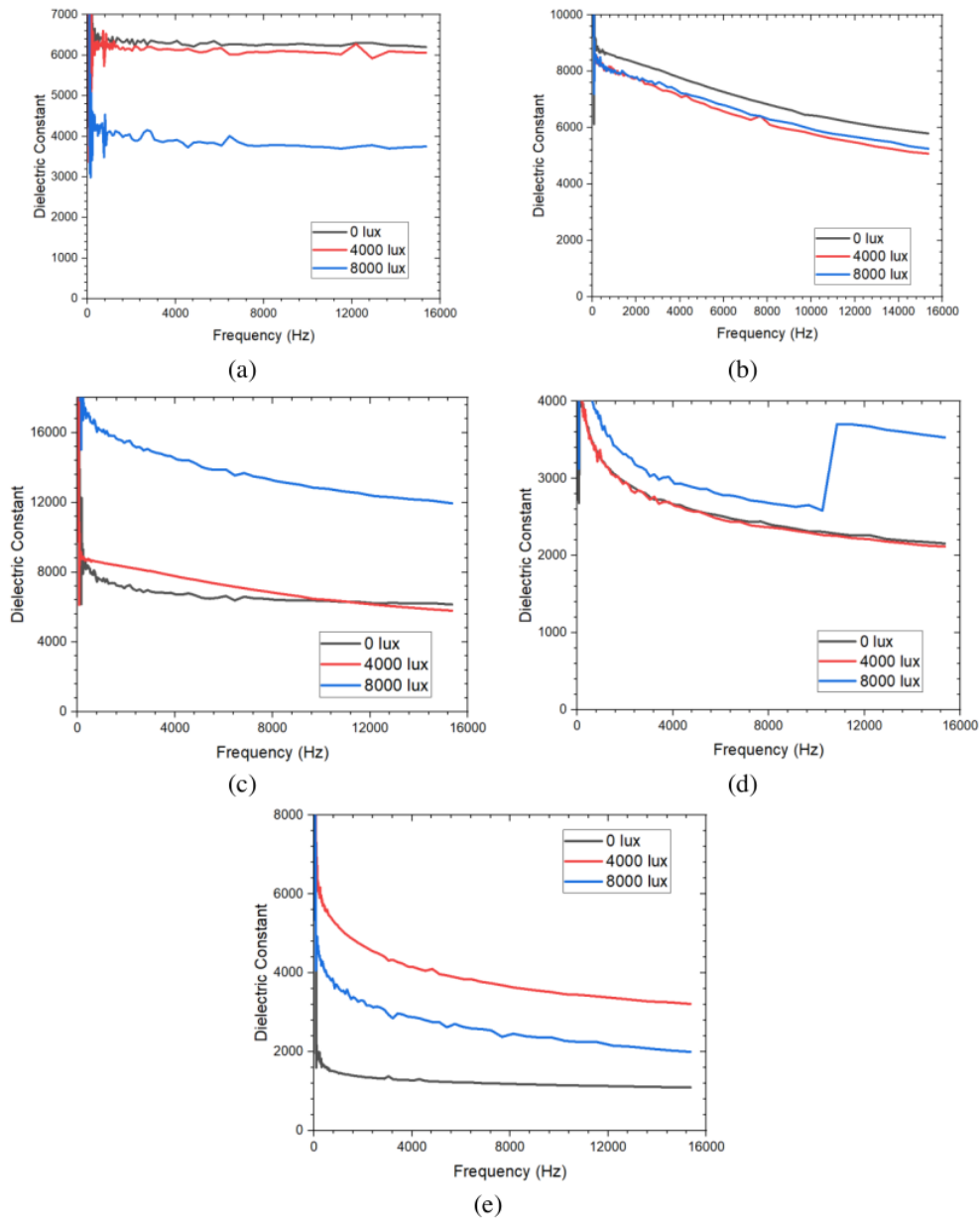


Figure 2. Dielectric constant as a function of frequency for various mole fraction of BST: (a) $x=0.000$; (b) $x=0.125$; (c) $x=0.250$; (d) $x=0.375$; (e) $x=0.500$.

The electric conductivity obtained from Eq. 4 can be used to calculate the diffusion coefficient by the equation below [12,32,41]:

$$D = k \frac{KT}{Cq^2} \sigma \tag{6}$$

σ is the electrical conductivity, C and q is the charge of the concentration and imperfections, k depends on the kinds of imperfections; $k = 1$ for the interstitial ion, k and T are the Boltzmann constant and temperature.

The diffusion coefficient of $Ba_xSr_{1-x}TiO_3$ thin films from LCR characterization is shown in Figure 3.

Figure 3 shows that the diffusion coefficient tends to increase with increasing frequency. That is because the diffusion coefficient depends on the electric conductivity value, which is directly proportional to the frequency, and that also causes this figure to have the same pattern as Figure 1.

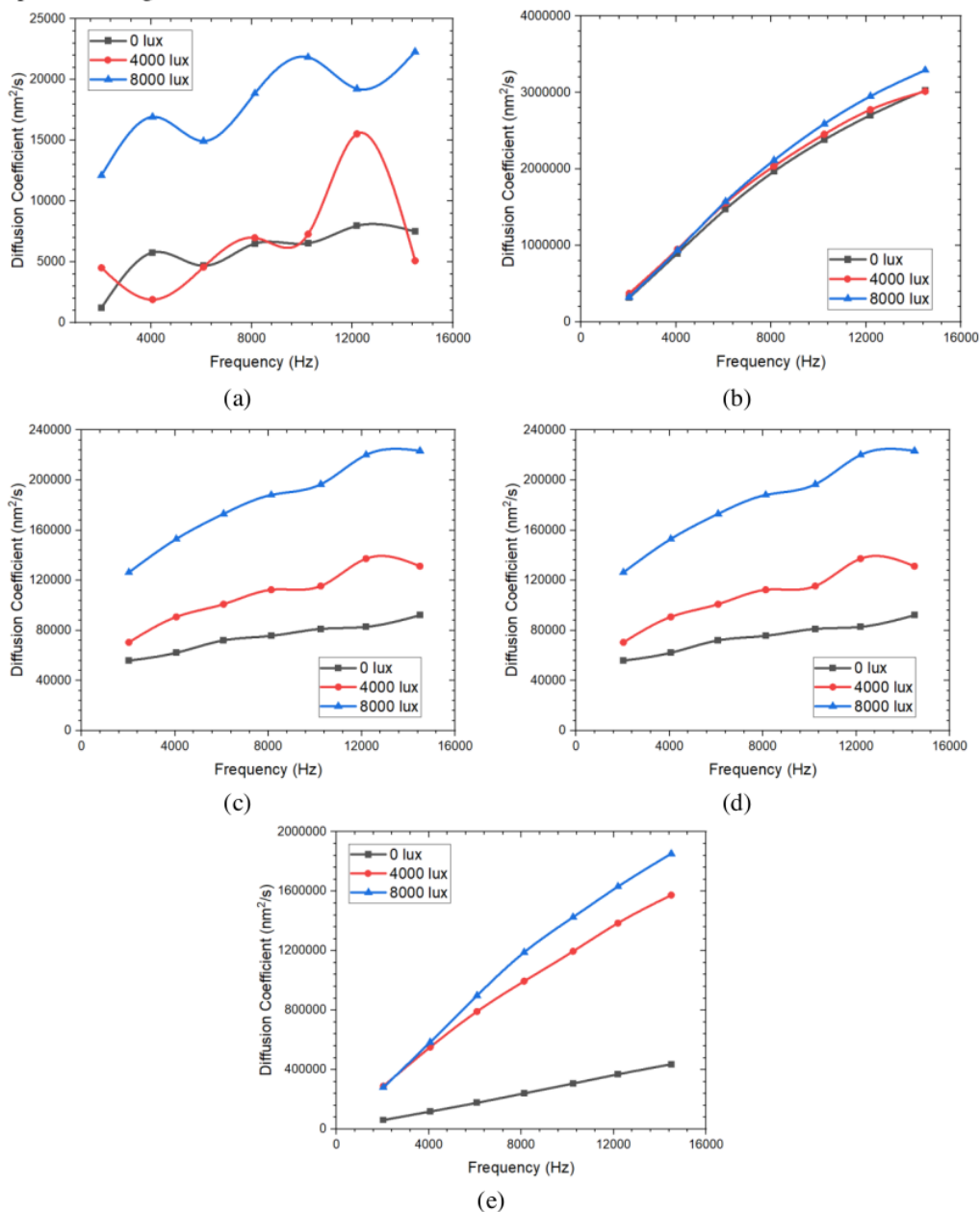


Figure 3. Diffusion coefficient as a function of frequency for various mole fraction of BST: (a) $x=0.000$; (b) $x=0.125$; (c) $x=0.250$; (d) $x=0.375$; (e) $x=0.500$.

4. Conclusions

Has succeeded in making thin films based on thin film $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ ($x = 0.000; 0.125; 0.250; 0.375; 0.500$) with the effect of photoconductive mole fraction and its characterization on electrical properties and diffusivity coefficient.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the study's design, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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