Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 24 (2015) 324 – 328

Procedia Environmental Sciences

The 1st International Symposium on LAPAN-IPB Satellite for Food Security and Environmental Monitoring

Characterizations of electrical and optical properties on ferroelectric photodiode of barium strontium titanate ($Ba_{0.5}Sr_{0.5}TiO_3$) films based on the annealing time differences and its development as light sensor on satellite technology

Johan Iskandar[a,*], Heriyanto Syafutra[b], Jajang Juansah[b], Irzaman[b]

[a]*Post Graduate of Biophysics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia*
[b]*Department of Physics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia*

Abstract

Photodiode of $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) film has successfully been created by growing BST on the surface of p-type Si (100) substrate with chemical solution deposition (CSD) method and spin coating technique at a speed of 3000 rpm for 30 seconds. BST films were made with concentration of 1 M and annealing process at the temperature of 850°C for 8, 15, 22, and 29 hours. Characterizations of electrical and optical properties of the films were then conducted. I-V characterization was conducted in dark and bright conditions with green, yellow, and red filters. The results showed that the films had photodiode characteristic. Characterizations of optical properties were the absorbance and the reflectance. The obtained absorbance curve showed that the most absorbed and reflected wavelengths were in the range of 400-500 nm and 570-600 nm respectively. Data of film reflectance can be used to calculate band gap energy (E_g). The electrical and optical properties indicate which the BST film has a prospect to be used as a light sensor on the satellite.

Selection and peer-review under responsibility of the LISAT-FSEM Symposium Committee

*Keywords:*BST; annealing; electrical properties; optical properties

* Corresponding author. Tel.: +62-251-8625-728.
E-mail address :johan_iskandar@live.com.

Selection and peer-review under responsibility of the LISAT-FSEM Symposium Committee
doi:10.1016/j.proenv.2015.03.042

1. Introduction

Nowadays, ferroelectric materials have been developed for various purposes in the field of microelectronic devices [1, 10]. Ferroelectric materials and its composites in thin film form have attracted an immense interest due to their vital role in advanced electronic technology with their wide variety of applications as ferroelectric devices. Many kind of ferroelectric materials such as, Barium Titanate ($BaTiO_3$), Barium Strontium Titanate (BST), Lithium Niobate ($LiNbO_3$), Lead Zirconate Titanate (PZT) [9, 15, 15].

Composite Material used in this experiment was Barium Strontium Titanate (BST).The material is a typical ABO_3 perovskite structure with many advantages, such as high dielectric constant, low dielectric loss, low leakage current, large dielectric adjustable range, and high pyroelectric coefficient [2, 12, 13, 17, 20]. Furthermore, its desirable ferroelectric, pyroelectric, and piezoelectric properties can be utilized for a variety of applications such as capacitor, dynamic random access memory (DRAM), integrated microwave devices, infrared detector, delay lines, filters, and phase shifters for steerable antennas [1, 3, 4, 5, 6, 7, 8, 9, 11, 16].

There are several technique which can be used to grow thin film such as sol-gel, screen printing, chemical solution deposition (CSD), Metal-organic decomposition (MOD), reactive sputtering, metalorganic chemical vapor deposition (MOCVD), ion beam assisted deposition (IBAD) and pulsed laser deposition (PLD) [13, 18, 19, 21].

The aim of this study was to investigate the annealing time effect on the electrical and optical properties.

2. Experimental Method

The materials used in this experiment were barium acetate powder [$Ba(CH_3COO)_2$, 99%], strontium acetate powder [$Sr(CH_3COO)_2$, 99%], titanium isopropoxide [$Ti(C_{12}O_4H_{28})$, 97.999%], methanol pro analysis, 2–methoxy ethanol, dye water, HF (fluoride acid), and p-type Si (100) as substrate.

The concentration of barium acetate and strontium acetate were 0.5 M and 0.5 M respectively. Both were mixed to titanium isopropoxide with 1 M of concentration and 2-methoxy ethanol with 2.5 ml of volume to obtain BST solution. Chemical solution deposition (CSD) and spin coating technique were the method used to grow BST solution on the surface of the substrate [18, 19]. Afterwards, the BST films were annealed at the temperature of 850 ^{0}C for 8 hours, 15 hours, 22 hours, and 29 hours.

3. Results and Discussion

I-V characterization was conducted in dark and bright conditions with green, yellow, and red filters with 405 lux of intensity. The results showed that the films were sensitive to light because a shift in the curve occurred when the voltage was given from -10 volt to +10 volt and these are shown in Fig. 1.

The electric current generated in bright condition was greater than that of less lighting because the films became more conductive. The conductive properties are caused by photon that was absorbed by electrons of the film. In this condition, the photon has a tendency to provide some energy for diffusion of electrons, and it causes the recombination of electrons and increase of holes [18, 19, 22].

I-V characterization was conducted to find out the sensitivity which occurs to any wavelengths. The results showed a shift in I-V curve. Fig. 1 showed that each film had a different sensitivity to various wavelengths, and this was caused by a shifting in the internal structure of the BST crystals when it was being heated so which it affects electrical and optical properties. From the results, the longer in holding time of annealing causes sensitivities of the films decrease. In summary, the films which had been made possessed photodiode properties.

Optical properties characterization was conducted to obtain absorbance and reflectance spectrum. Those are very important to claim the films which had been made were sensitive to light, so it is very helpful when applied to satellite devices.

Fig. 2 shows that the holding time of annealing caused the optical properties of the film to change, where the longer annealing time improved the performance of the film to absorb visible light. The curve showed that the holding time of annealing was most optimum at 22 hours because when the annealing time was increased to 29 hours its performance was down.

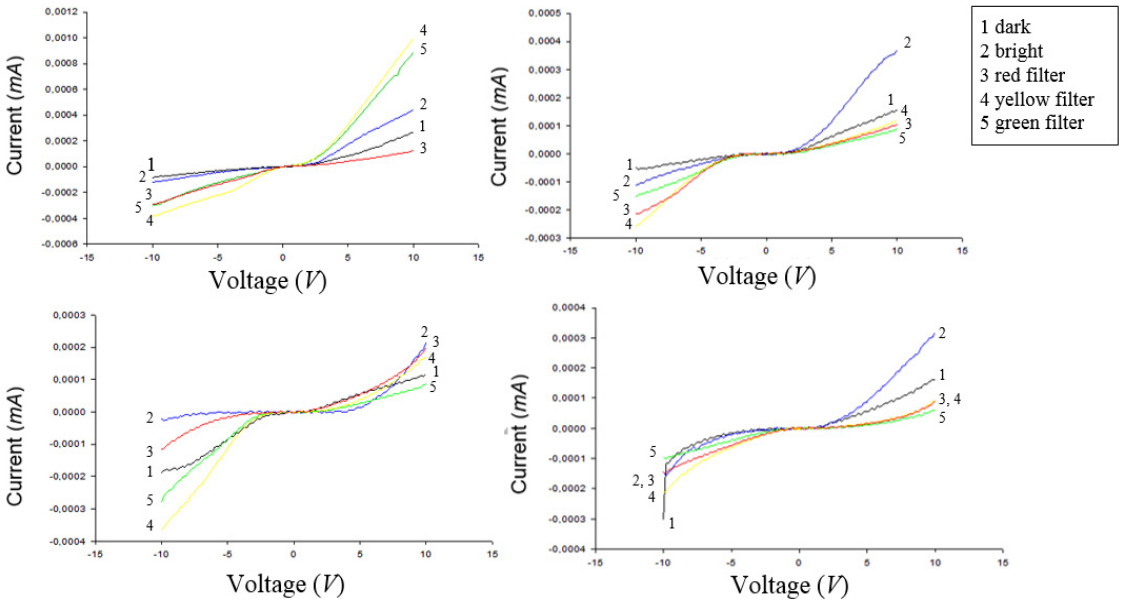

Fig. 1. I-V characteristic of BST with annealing time of (a) 8 hours; (b) 15 hours; (c) 22 hours; (d) 29 hours

Table 1. Band gap energy of films

BST films (hours)	*Band gap Eg* (eV)
8	2,54
15	3,12
22	2,97
29	3,19

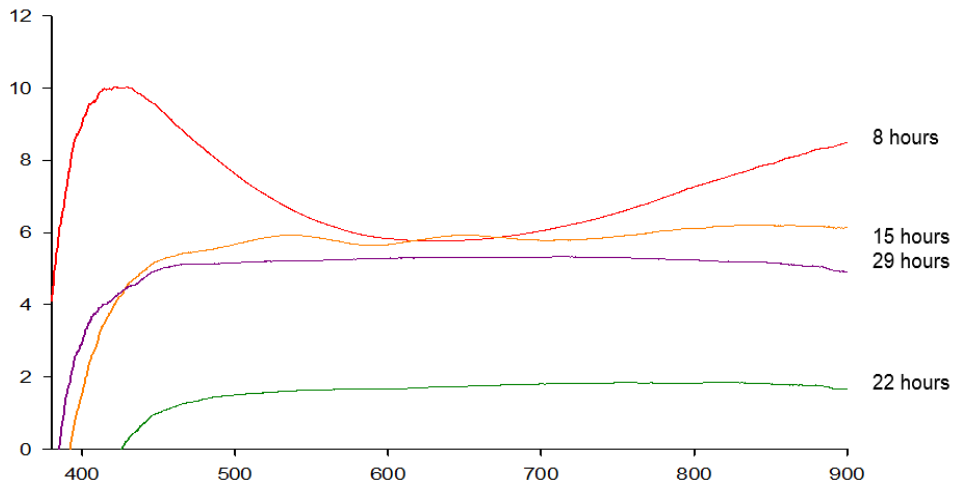

Fig. 2. Reflectance spectrum

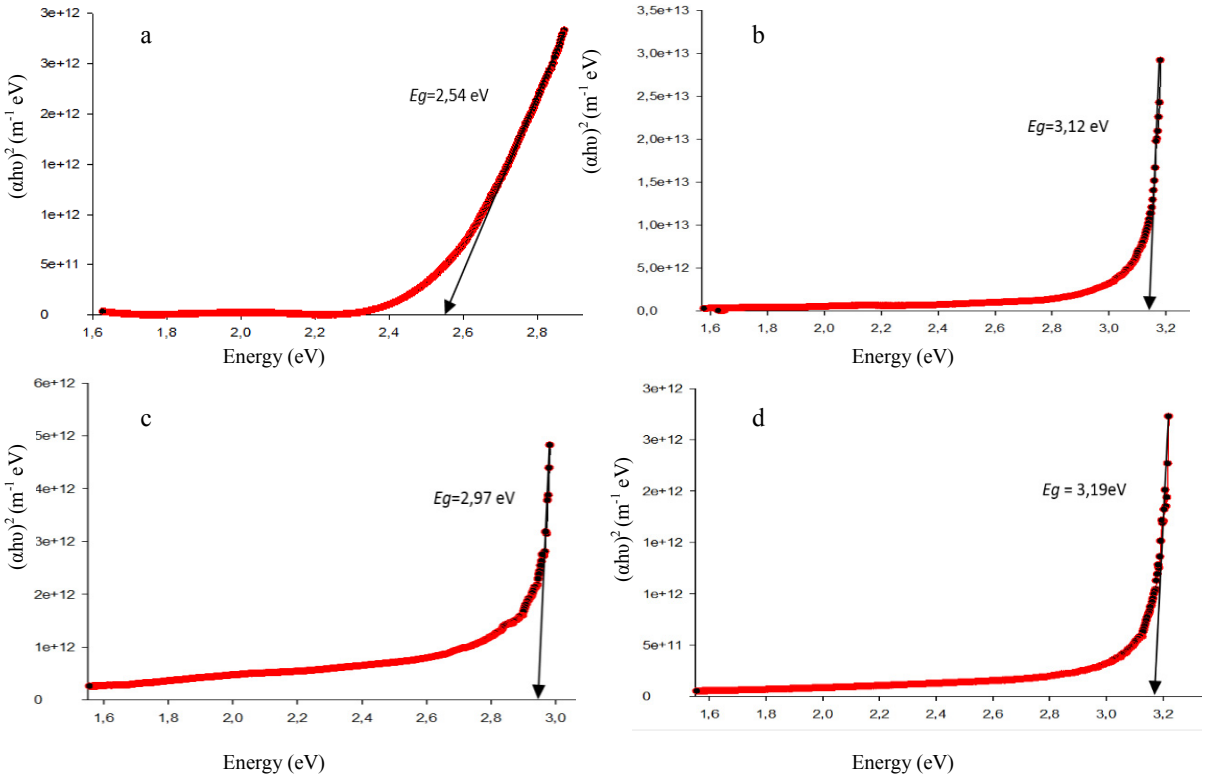

Fig. 3. Band gap energy determination using reflectance spectrum of BST with annealing time of (a) 8 hours; (b) 15 hours; (c) 22 hours; (d) 29 hours

It is interesting to learn about the relationship of optical properties to band gap energy of each films because it is important to prove which the film made was semiconductor material. The data of reflectance spectrum in Fig. 2 were used to determine band gap values. Tauc Plot is one of simple method which can be used to determine band gap energy. The method is just plotting a curve of $(\alpha hv)^2$ versus *Energy* as shown in Fig. 3. Treatment of annealing time tends to increase the values of the band gap energy as shown in Table 1. In this study the results of the band gap energy is still within in the range of semiconductor band gap value. From these results, it seems that if the annealing time is increased, there will be an increase or even a decrease in the band gap energy with the value outside of the semiconductors range.

4. Conclusion

BST films have successfully been prepared by annealing time of 8 hours, 15 hours, 22 hours, and 29 hours at a constant temperature of 850 °C. The results of the characterization of the electrical properties of the film showed that the film was a photodiode. From the results of optical properties characterization, BST films with annealing time of 22 hours could absorb the most visible light, but they were not sensitive to different wavelengths. The BST films with annealing time of 8 hours were good to differentiate wavelength of visible light than others although they had the lowest absorbance intensity. The band gap values of the films showed that they were in the range of semiconductors value. The results of the electrical and optical properties characterization indicates that the BST films are very capable to be used as a light sensor on any devices which work based on optical properties such as camera and satellite technology.

Acknowledgement

This work was supported by Incentive Grant of SINAS KMNRT, Republic of Indonesia under contract No. 38/SEK/INSINAS/PPK /I/2014 and National Strategic Research of Directorate General of Higher Education, Ministry of National Education, Republic of Indonesia under contract No. 134/SP2H/PL/Dit.Litabmas/V/2014.

References

1. Ala'edin AS, Ramli N, Poopalan P. 2010. AFM study of multilayer sol-gel $Ba_xSr_{1-x}TiO_3$ thin films. *J Jordan of Phys* 2010; **3** (2): 61-8.
2. Bonghoon K. Optical and dielectric properties of reduced $SrTiO_3$ single crystals. *J of the Korean Ceramic Soc* 2011; **48** (4): 278-81.
3. Subrat KB, Choudhary RNP, Singh AK. Ac impedance spectroscopy and conductivity studies of $Ba_{0.8}Sr_{0.2}TiO_3$ ceramics. *J Adv Mat Lett* 2011; **2** (6): 419-24.
4. Burcu E. The overview of electrical properties of barium titanate. *J American J of Eng Res* (AJER) 2013; **2** (8): 1-7.
5. Mao-Yan F, Sheng-Lin J. Influence of La-Mn-Al Co-doping on dielectric properties and structure of BST Thick film. *J of Elect Sci and Technol of Chn* 2009; **7** (3): 281-5.
6. Ibrahim NB, Yusrianto E, Zalita Z, Ibrahim Z. Effect of annealing temperature of sol-gel TiO_2 buffer layer on microstructure and electrical properties of $Ba_{0.6}Sr_{0.4}TiO_3$ films. *J Sains Malaysiana*. 2012; **41** (3): 339-44.
7. Ibrahim NB, Yusrianto E, Ibrahim Z. Effect of different TiO_2 preparation techniques on the performance of the dielectric bolometer $Ba_{0.6}Sr_{0.4}TiO_3$ as a distance sensor. *J Sains Malaysiana* 2012; **41** (8): 1029-35.
8. Ionescu D, Apreotesei G. A novel simulational approach: electromagnetic parameters determinations for some ferrite-ferroelectric nanocomposites. *J Romanian Reports in Phys* 2013; **65** (4): 1328-47.
9. Neeraj K, Rabinder N. Ferroelectric properties of potassium nitrate-polymer composite films. J Pure Appl & Ind Phys 2010;1(1):21-35.
10. Neeraj K, Rabinder N. Evidence of ferroelectric polarization switching in potassium nitrate composite thick films. J Mater Environ Sci 2010;2(4):379-386.
11. Rajesh K, Subba R . High-k gate dielectrics of thin films with its technological applications. *J Int Pure Appl Sci Technol* 2011; **4** (2): 105-14.
12. Xiuyun L, Denis R, Nossikpendou S, Ying C, Chaoliang M, Xianlin D, Genshui W. Dielectric, ferroelectric and piezoelectric properties of 100-oriented $Pb_{0.4}Sr_{0.6}TiO_3$ thin films puttered on $LaNiO_3$ electrode. *J of Crystal Growth* 2012; **347** : 15-8.
13. Liu GJ, Hu WC, Shen YD. Dielectric characteristics of $Ba_{0.65}Sr_{0.35}TiO_3$ thin films by sol-gel method. *J of Elect Sci and Tehnol of Chn* 2007; **5** (1): 47-9.
14. Morintale E, Scarisoreanu N, Dinescu M, Rotaru P. Thermal stability of BST in a vast range of temperature. *J Phys AUC* 2010; **20** (1): 83-9.
15. Muravov SA, Gordiyko NA, Bogorosh AT, Bubulish A, Voronov A. The study of ferroelectric thin films on silicon substrates. *J of Measur in Eng* 2013; **1** (1): 23-7.
16. Novizal, Azwar M. Microstructural studies of (barium strontium hexaferrite-barium strontium titanat) composite system by mechanical alloying process. *J Int of Sci and Res* (IJSR) 2014; **3** (1): 253-6.
17. Sabah M, Ali R, Rawa AH. Studying the dielectric and structural properties of $Ba_xSr_{1-x}TiO_3$ (BST) ferroelectric system prepared by using oxalic acid route. *J Eng & Tech* 2010; **28** (10): 2015-28.
18. Irzaman, Heriyanto S, Rancasa E, Nuayi AW, Rahman GN, Nuzulia NA, Supu I, Sugianto, Tumimomor F, Surianty, Muzikarno, and Masrur. The effect of Ba/Sr ratio on electrical and optical properties of $Ba_xSr_{(1-x)}TiO_3$ (x = 0.25; 0.35; 0.45; 0.55) thin film semiconductor. *J Ferro Taylor & Francis* 2013; **445** (1): 4-17.
19. Irzaman, Heriyanto S, Ardian A, Husin A, Hilaluddin MN, Ade K, Johan I, Dahrul M, Agus I, Dani Y, Aminullah, Prasetyo LB, Yusuf A, and Kadri TM. Formation of solar cells based on $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) ferroelectric thick film. *Proc AIP Conf* 1586 2014; 23-34.
20. Ala'edin AS, Nurhafizah R, Poopalan P. Leakage current behavior of $Al/Ba_{0.5}Sr_{0.5}TiO_3$ thin film capacitor. *J Solid State Sci and Technol* 2011; **19** (1): 150-4.
21. Sinaga P. Pengaruh temperatur annealing terhadap struktur mikro, sifat listrik dan sifat optik dari film tipis oksida konduktif transparan ZnO:Al yang dibuat dengan teknik screen printing*: J Pengajaran MIPA* 2009; **14** (2): 51-7.
22. Wijaya SK.Optoelektronika. Depok: Fisika FMIPA UI; 2010.