Making Photodiode

by Johansah Liman

Chapter 15

Making Photodiode Based on $Ba_{0.5}Sr_{0.5}TiO_3$ Thin Film on P-type Si (100) Substrate with Chemical Solution Deposition (CSD) Method

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Abstract. Ferroelectric thin film has been used in variety of applications for electronic and optical electricity. One of the material could be used in making a thin film is barium stronsium titanat (BST). BST can be made using simple device, with a cheaper cost and in a relatively short time. The making of Ba0.5Sr0.5TiO3 solution that grown on the type-p Si(100) substrat surface was done with Chemical Solution Deposition (CSD) method. Annealing Process with temperature 850 oC during 22 hours will produce different BST thin film characterisation in crystal structure, thickness and particle size. Photodiode based on BST on p-type Si(100) Substrat surface characteristic, on the test with Ketley 2400 I-V meter, show that photo diode is sensitive to light (Dark room: 2 Lux, Light room: 400 Lux).

Keywords: Photodiode, thin film, BST , CSD , I-V.

I. Introduction

There are three main advantages of Barium Strontium Titanate (BST)-based thin film light sensor. First, the ferroelectric BST material has high responsivity towards heat and light as compared to materials like LiTaO3 or NaNO2. Second, the operating condition range of such sensors is in room temperature condition and hence, the production process can be carried out in simple laboratories as it does not require any cooling system, this is unlike HgCdTe with its operating temperature of 77K, which is the temperature of liquid nitrogen. Third, commercially available sensors on the market are typically made of amorphous silicon material, therefore, the idea of production of sensors in crystallite form with ferroelectric BST material is very attractive and promising. The synthesis of BST material can be done with relatively simple devices, low cost and in a short time. This BST-based material has the potential to replace SiO2 in Metal Oxide Semiconductor (MOS) circuits [1,2].
Among the aforementioned ferroelectric materials above, BST is very attractive as it has very low optical loss, high dielectric constant and high load storage capacity [1], so it can used for Dynamic Ferroelectric Random Access Memory (DRAM) with the capacity of piezoelectric and piroelectric that allows storage capacity of up to 1Gbit [1-4]. Piezoelectric and piroelectric allows BST to be used for sensor applications [5]. At the same time, its electro-optic behaviour can be used in infra-red thermal switches [1]. These advantages of BST attract a lot of interest for it to be developed for new generation devices [6].

There are a number of techniques to create BST, e.g. Chemical Solution Deposition (CSD), Pulsed Laser Deposition (PLD), sputtering and Metallo Organic Chemical Vapour Deposition (MOCVD) [2,4,6,7]. Chemical Solution Deposition is known as a semiconductor film deposition method since 1869. In this method, thin film is made by depositing chemical solution on a substrate and then prepared by spin coating at a specific speed. The advantages of this method are that it is economical, simple, low temperature and faster processing time [2,4]. The main problem with this method is the stability of the solution as precipitation sometimes happen during storage.

The application of ferroelectric material for optoelectronics devices such as solar cells, photosensors and color sensors requires the optical characteristics data of the material, such as the absorbance and transmittance [2]. In this paper, the creation process of thin layer Ba0,5Sr0,5TiO3 (BST) is presented. The process involved the dripping of BST onto type-p silicone substrate using the Chemical Solution Deposition (CSD) method, followed by the spin coating process at a speed of 3000 rev/min for 30 seconds and annealing process at 8500C for 22 hours. The resulting thin film's optical properties were then characterised through measurement of its absorbance and reflectance. The objective of this study is to analyse the optical properties of BST thin film on a type-p Si (100) substrate in measurement of energy gap and refraction index.

II. Methodology

2.1. *Equipment and Materials*

Equipment used in this study include an analytic Sartonius BL6100 weighing machine, a spin coater, the UV-Vis Ocean Optics USB4000 spectroscope, a VulcanTM-3000 furnace and a Branson 2510 ultrasonic machine. The materials used include powder form of Barium Acetate [Ba(CH3COO)2, 99%], Strontium Acetate [Sr(CH3COO)2, 99%], Titanium Dioxide [TiO2, 97.999%] and the solvent 2-Metoksietanol [H3COCH2CH2OH, 99%]. All chemicals were obtained from Sigma Aldrich. Aqua bidest and p-type Si (100) substrate.

3.1. *Thin Film Preparation*

In this study, the substrate was Si (100) type-p that was cut using a glass cutter to 1x1 cm2 size. The substrate was then washed by using an aqua bidest for 30 seconds.

4.1. *Making Ba0.5Sr0.5TiO3 solution*

The BST solution that was grown on the surface of the Si substrate was made using the Chemical Solution Deposition (CSD) method, which is by mixing Barium Acetate, Strontium Acetate and Titanium Dioxide and was diluted in 2.5 ml 2-Metoksietanol. The molar fraction of the Barium Acetate was 0.5, the Stronsium Acetate was 0.5 and the Titanium Dioxide was 1. Next, the solution was homogenised with the ultrasonic machine for 90 minutes to get a homogeneous BST solution.

5.1. *Thin Film Growing Process*

The BST solution was then dripped onto the Si (100) type-p substrate and spun using a spin coater for 30 seconds with a speed of 3000 rpm. The coating process of BST on the Si (100) type-p substrate was done 3 times with spinning times of 30 seconds each and a 1-minute in-between breaks.

6.1. *Annealing Process*

The annealing process was done using the VulcanTM-3000 Furnace to form BST solution crystals on the substrate. The annealing process on the Si (100) type-p substrate was done in a temperature of 8500C for 22 hours with a temperature increase of 1.670C/minute.

7.1. ***Contact Deposition Process***

After the annealing process, the next step was to prepare the contact deposition that included the closing of the film sample using aluminium foils and to leave a part that was to be installed the contact in the shape of a 2x2 mm2 square. The material of the contact used in this study was aluminium 99.999%. The deposition process was carried out with the metal oxide chemical vapour deposition (MOCVD) method.

8.1. ***G I-V Test***

I-V test was carried out to observe the current-voltage curve of the film and its sensitivity to lights. The I-V test was carried out with the Keithley 2400 I-V meter with voltage source range of -10 to 10 V.

III. Result and Discussions

The I-V tests were carried out in 2 conditions, namely dark (2 Lux) and bright (400 Lux). The results show that the BST film was sensitive to light. This was shown by the existence of curve shifting when tested on the different conditions, as shown in Fig. 1.

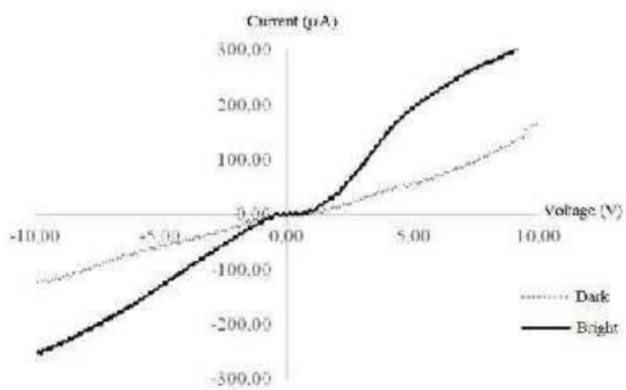

Fig. 1. F Curve I-V BST thin film in Dark and Bright condition.

From the Fig. , the current in dark condition was smaller than in bright condition. This was because the thin film's resistance was higher in dark condition and vice versa. This was because when the thin film was given energy in the form of light, electrons escaped from the valence band to the conduction band so the charge carrier number and the electrical conductivity increased.

The produced BST film was a combination of 2 types of semiconductor, namely the type-p and type-n semiconductors. The silicone substrate used was of the type-p semiconductor while the BST solution that was growth on the substrate was of type-n semiconductor. The combining was done during the crystal growth phase, which is during the annealing process. The pattern of the I-V curve in Fig. 1 shows that the produced BST thin film was a diode because the curve profile was similar to that of a diode curve. This shows that the basic principle of combining of p and n was working.

The results of the I-V tests showed that the knee voltage or the voltage when the current was beginning to increase was found to be 0.8 V as shown in table 1.

Table 1. Knee voltage thin film BST on dark and bright condition

Condition	*Knee voltage (Volt)*
Bright	0,8
Dark	0,8

IV. Conclusions

$Ba_{0.5}Sr_{0.5}TiO_3$ (BST) thin film was successfully made by growing it on a Si (100) type-p substrate using the CSD method. The patter on Curve I-V shows that the produced BST thin film was a diode because the curve profile is similar to the characteristics of a diode curve. Testing showed that the BST thin film was sensitive to light so it can be applied for the next generation light sensor with a potential application as a switch**.**

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