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Optical and electrical characterizations of niobium-doped $Ba_{0.25}Sr_{0.75}TiO_3$ (BSNT) on p-type silicon and corning glass substrates and its implementation as photodiode on satellite of LAPAN – IPB

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Abstract

Niobium-doped Ba0.25Sr0.75TiO3 (BST) thin films with one layer coating have been manufactured on p-type silicon and corning glass substrates using chemical solution deposition and spin coating techniques with a rotational speed of 3000 rpm for 30 seconds. BST thin films were prepared with concentration of 1 M and annealing temperatures of 850°C, 900°C, 950°C on p-type silicon substrate and temperatures of 400°C, 450°C, and 500°C on corning glass substrate. Characterizations of optical by using UV-Vis spectrophotometer and electrical Characterizations were performed I-V meter, respectively. The aim of this research is to characterize optical and electrical of BSNT implementation as photo sensor that can be used satellite control switch. Thin films also have photodiode properties due to its appeared current were faster in light condition of 60 watt then the dark condition. The optical result showed the value of gap energy was 3.31 eV, 3.29 eV, and 3.21 for BST and 2.93 eV, 2.85 eV and 2.80 eV for BSNT. The electrical result showed voltage knee 2.1 Volt, 1.8 Volt, and 0.5 Volt for BST and 0.4 Volt, 1.5 Volt and 0.3 Volt for BSNT. The results showed that the photo sensor characteristics of BSNT thin films can be used for satellite control switch.

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Keywords: niobium-doped BST; optical,electical; photodiode,photo sensor; energy gap; satellite of LAPAN IPB

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1. Introduction

Thin film is a material that gives new hope in the development of solar cells device to meet the requirements, including low cost and good material stability [1]. Making the thin layer has been developed by using certain methods. Method for making thin layers are generally grouped into two: the method of vacuum and non-vacuum. Vacuum method consists of PVD, laser ablation, Ion Planting, and CVD. As for the non-vacuum methods are electrodeposited, Dip Coating, Spin Coating, Electrophoresis, Screen Printing, and Spray Pyrolysis [2]. The method used in this study is non-vacuum i.e. CSD (Chemical Solution Deposition).

The thin film that was developed as a solar cell device has a fairly good efficiency. Based on the obtained data, the efficiency of the manufacture of solar cell and silicon materials is above 20% [3]. Tools that can generate the photovoltaic effect is basically a matter of semiconductor materials.

BST has been implemented as Sensor Devices [4], Immuno Sensor [5], Microwave Devices [6], CMOS [7], Dynamic Random Access Memory (DRAM) [8], Ferro-electrics Varactor [9], Capacitor Devices [10], Electrical Conductor [11], Semiconductor Devices [12], Micro Electric Devices [13], Tunable Filters and Antenna Devices [14], Nano-sized Photo Catalyst [15], Methods to Improve Adaptive Impedance Matching [16], and Other Applications [17]

2. Materials and Methods

Materials that used in this study is Barium Acetate powder $Ba(CH_3COO)_2$, 99%], Titanium Isopropoxide [$Ti(C_{12}O_4H_{28})$, 99.999%], Niobium Oxide, 2-metoksietanol solvent [$H_3COCH_2CH_2OH$, 99%], Si substrate (100) p-type, corning glass substrate, aquabides, HF (fluoride acid), slide glass, and aluminum foil. Thin film $Ba_{0.25}Sr_{0.75}TiO_3$ that is overgrown on top of p-type silicon substrate and corning glass with CSD method is created by using barium acetate [$Ba(CH_3COO)_2$, 99%] + strontium acetate [$Sr(CH_3COO)_2$, 99%] + titanium isopropoxide [$Ti(C_{12}O_4H_{28}$ 99.99%] + material (for BSNT) as precursor and 2-metoksietanol [$H_3COOCH_2CH_2OH$, 99.9%] is used as a solvent material [12]. After the ingredients are mixed, the solution was shaken a few minutes. After that, the solution was filtered to obtain a homogeneous solution the substrate that used is a p-type Si substrate (100) and corning glass. The cleanliness of the substrate as a thin film growth needs to be maintained so that the thin film can grow well and evenly. The substrate is cut to form a rectangle with a size of 1 cm x 1 cm.

The substrate which has been cleaned is placed on top of the disk spin coater reactor which has been on the outboard with insulation in the middle, then the substrate is etched with a solution of BST and BSNT as much as 1 drop. Then do the spin coater reactor playback which is set at 3000 rpm for 30 seconds. The next process is annealing that is heating the substrate at a high temperature which is at a temperature of 950°C, 900°C, and 850°C for the Si substrate (100) and 400°C, 450°C, and 500°C for the cornong glass substrate for 15 hours which aims to diffuse BST and BSNT solution with substrate.

The process of heating the substrate which has been overgrown with a thin layer at high temperatures or annealing process is performed by using a Naberthem furnace models. P-type Si substrate (100) at different annealing at temperature of 850°C, 900°C, and 950°C whereas for corning glass substrate at a temperature of 400°C, 450°C, and 500°C. Annealing process is carried out in stages. Heating is started from room temperature then raised to the desired annealing temperature. After a rise in temperature for 9 hours and then heater is adjusted to a constant annealing temperature for 15 hours. Furthermore, the furnace cooling until back to room temperature for 12 hours.

3. Result and Discussion

3.1. Film optical properties of BST and BSNT

The addition of doping in thin films led to changes in the transmittance percentage. Although the changes that caused by doping was not too significant, but small changes affected the absorption coefficient (α) of the thin film. The value of the energy gap was affected by the value of coefficient absorption (α).

The value of absorption coefficient (α) that obtained from the calculation is varies for certain wavelengths. The obtained value of absorption coefficient (α) for determining the energy gap is 103 cm-1, Based on that result, The value of the energy gap for thin film can be calculated. The value of gap energy can be searched by plot Touc method.