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Development of ferroelectric solar cells of barium strontium titanate ($Ba_xSr_{1-x}TiO_3$) for subtituting conventional battery in LAPAN-IPB Satellite (LISAT)

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Abstract

Semiconductor based solar cell or photovoltaic cell can be defined as a device that used to convert solar radiation into electrical energy directly. In this study, BST (Barium Strontium Titanate) semiconductor has been manufactured by sol-gel method and with spin coating process. Various mole fractions (x) of 0.5, 0.6, 0.7, and 0.8 were conducted in this study. Annealing hold time was conducted for 29 hours at constant temperature of 850°C. After the BST film formation is completed, it would be followed by optical characteristics testing, electrical conductivity measurement and current-voltage photovoltaic testing of the BST ferroelectric solar cells. The efficiency of BST ferroelectric solar cells was calculated through the computation program, which was developed by using Matlab. In the program, the *Psi*, ε_0, c_p, and *C* values of BST are input data in the Matlab's command window. As the results, the BST has *Psi*, ε_0, c_p, and *C* values of 7.66 μC.cm^{-2}, 8.854 x 10^{-16} C^2.N^{-1}.cm^{-2}, 2.5 x 10^6 J.m^{-3}.K^{-1}, and 1300°C or 1.573 x 10^3 K, respectively. Regarding to the values, the efficiency of BST ferroelectric solar cell was 6.2%. Moreover, in the laboratory, the efficiency of ferroelectric solar cells of BST was 0.000014285%, so it needs several developments for improving the efficiency. However, the BST ferroelectric solar cell has potential application in satellite technology for subtituting conventional battery.

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Keywords: BST; ferroelectric solar cell; battery; Lapan-IPB Satellite (LISAT).

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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).

Nowadays, a lot of discoveries that have been found by many researchers are associated to the utilization of renewable energy technologies. One of such invention is a solar cell, which is an electronic device that converts directly photons from the sun's energy into electrical energy. This conversion process is known as the photovoltaic effect. Photovoltaic technologies that exist today can be considered to have grown rapidly due to several reasons, such as oil and natural gas limited sources as well as the fact that the energy of photons supplied by the sun. The energy, which is received by the earth's surface, is actually approximately 3 x 1024 joules per year where if converted into electric power will produce about 1,017 watts which is equal to 10,000 times the world energy consumption [1]. However, this technology has not yet optimally used for human's welfare due to the lack of conversion technology. Recently, only a few countries that have been able to utilize the sun energy using the existing technologies [2].

The limitations of solar energy utilization are the difficulty in manufacturing solar cell and high cost to produce the prototype [3]. Therefore, it is needed an easy and inexpensive manufacturing process as well as the use of materials and processing tools that can be obtained easily. This challenge can be initiated from the selection of materials which are suitable and easy to obtain.Manufacturing of solar cells in the form of crystals with a material derived from ferroelectric materials is an alternative approach [3, 5]. The various ferroelectric materials composed of complex chemical compounds can be utilized as a solar cell due to its availability in the market. Several ferroelectric materials that available namely Triglycine Sulphate (TGS), Lithium Tantalate ($LiTaO_3$), Lithium Niobate ($LiNbO_3$), Sodium Nitrite ($NaNO_2$), Barium Titanate ($BaTiO_3$), Strontium Titanate ($SrTiO_3$), and Barium Strontium Titanate (BST) [3, 5].

In this study, Barium Strontium Titanate (BST) is utilized as a potential ferroelectric material in solar cells and expected to be applied as battery in satellite technology. The BST is easy to be applied due to its chemical and mechanical aspects, which is more stable and has a curie temperature close to the room temperature rather than other ferroelectric materials [6]. Moreover, the BST also has energy gap, which is required as a minimum photon energy to stimulate an electron from the valence to the conduction level, of 2.58 eV [4,7]. The efficiency of sunlight energy conversion into electrical energy from a ferroelectric solar cell can be calculated using equation (1), namely:

$$\eta_m = \frac{P_{si}^2}{\varepsilon_0\, c_p\, C}\left[x_m + x_0\left(\frac{D_m}{D_i}\right)^2\right]^2\left(\frac{D_m}{D_i}\right)^2 \quad (1)$$

Where P_{si} is the spontaneous polarization, ε_0 is the vacuum permittivity, c_p is specific heat at constant pressure, C is a constant curie, X_m is the electric displacement at its maximum value, and X_0 is the initial electric displacement. For high heating rates and resistance values (R), the X_0<<1 so that it can be considered zero, the X_m value → 1 and $\left(\frac{D_m}{D_i}\right)^2$ are $\frac{1}{\exp(1)}$. So that equation (1) is transformed into Equation (2) in the maximum condition [10].

$$\eta_{\mathrm{m,max}} = \frac{1}{\exp(1)}\,\frac{P_{si}^2}{C\, c_p\, \varepsilon_0} \quad (2)$$

While the efficiency of ferroelectric solar cell is influenced by electric displacement value (X_0), then the relationship between the efficiency (η) and the electric displacement (X_0) can be seen in Equation (3) [10].

$$\eta \cong \frac{\eta_{\mathrm{m,max}}}{1+X_0} \text{ x } 100\% \quad (3)$$