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Fabrication and Characterisation of Titanium Dioxide (TiO_2) with Different Synthesis Temperatures for Solar Cell Applications

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In this investigation, the effects of various synthesis temperatures of titanium dioxide (TiO_2) on the structural, optical, and electrical properties of Dye-Sensitised Solar Cell (DSSC) were investigated. As an organic dye for DSSC, Beetroot plant was chosen. The TiO_2 solution was prepared using the sol-gel method and deposited on glass using the spin coating technique. Several compounds, including absolute ethanol, Titanium Isopropoxide (TTIP), Glacial Acetic Acid (GAA), Triton X-100, and deionised water, were combined to create the TiO_2 solution. Using a Scanning Electron Microscope (SEM), an Ultraviolet-Visible (UV-Vis) spectrometer, and a Keithely 2450 Sourcemeter, the structural, optical, and electrical properties of TiO_2 were determined. The results indicate that the TiO2 thin film synthesised at a temperature of 60°C has the most porous structure and the smallest particle size when compared to others. This temperature also produces TiO_2 with the sharpest peak absorption of 0.40 at a wavelength of 575.50 nm, resulting in a bandgap energy of 3.10 eV. Furthermore, it has a higher Field factor (FF) value that results in the highest energy conversion efficiency, η of 0.34 %.

Keywords: Dye-Sensitised Solar Cell (DSSC); Titanium dioxide (TiO_2); band gap energy; energy conversion efficiency; sol-gel method

I. INTRODUCTION

Population growth is driving a significant increase in the worldwide energy consumption rate. This subsequently led to a rise in demand for natural resources such as petroleum and natural gas. However, the rising demand for these natural resources may result in an increase in harvesting costs. This generation has relied on fossil fuels to generate a respectable amount of energy, but their emissions of harmful gases contaminate the environment and contribute to global warming and climate change. Therefore, individuals began to utilise other energy sources. The solar cell, which is also known as a photovoltaic cell, is one of the most environmentally friendly energy sources. A solar cell is recognised as a clean energy device because it does not produce carbon dioxide and is renewable. Dye-Sensitised Solar Cell (DSSC) was first developed by O'Regan and Gratzel in 1991, a new type of photochemical solar cell (Grätzel, 2005). DSSC is a low-cost solar cell with a simpler fabricating process. Because of these advantages, the DSSC has become a promising alternative solar cell. To fabricate DSSC, a semiconductor electrode is the most crucial one. One of the major factors in fabricating the DSSC is to choose the

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photoanode materials (Song *et al*., 2014). Many researchers have found semiconductor materials such as Graphene, reduced Graphene Oxide (rGO), Zinc Oxide (ZnO), and Titanium dioxide (TiO_2) for DSSC application (Casaluci *et al.*, 2016; Wei *et al.*, 2016; Zhang *et al.*, 2018). TiO_2 was widely used in DSSC due to its larger band gap, relatively nontoxic material and has higher photoactivity (Zulkifli *et al*., 2015). However, the lower efficiency of DSSC is caused by the lower electron transfer in TiO_2 which is due to less optimal contact between particles (Trihutomo *et al*., 2019). In addition, the fabrication techniques are the utmost important to improve the performance of DSSCs (Song *et al.,* 2014). Improved performance of DSSC can be achieved by depositing a good quality of TiO_2 on the film. Many parameters should be taken into account to produce high-quality TiO_2 film. It has been reported that the potential application of titania nanomaterial are affected by the particle size and morphology (Shang *et al.,* 2009; Chen *et al.,* 2007). Several processes have been studied and investigated to develop titania nanoparticles (Baek *et al.,* 2009; Simonsen *et al.,* 2010). Sol-gel method is one of the preparation methods that has been extensively used to prepare TiO_2 nanoparticles (Ojstrsek *et al.,* 2013). Theoretical and experimental showed that the size of particle has been influenced by temperature, pH solution and metal precursor (Zhang *et al.,* 2008). In addition, it was confirmed that the process temperature of sol-gel method has an impact on the nucleation growth of TiO_2 nanoparticles (Morteza *et al.,* 2017). In addition, a combination of organic dye and TiO_2 showed a promising result. Our previous research showed the turn-on voltage increases from 0.2 V to 1.2 when integrating turmeric and TiO_2 for DSSC application (Sahari *et al.,* 2017).

Therefore, this study aims to investigate the effects of different synthesis temperatures of TiO_2 on the structural properties of TiO_2. The correlation between structural properties and performance of DSSC was further investigated from optical and electrical characteristics. The structural properties of TiO_2 thin film was characterised by Scanning Electron Microscopy (SEM), while the optical properties were measured by UV-Visible spectroscopy (UV-Vis). Meanwhile, the electrical properties (I-V characteristic) was measured by Keithely 2450 Sourcemeter.

II. MATERIALS AND METHOD

A. Synthesis of Titanium Dioxide (TiO_2) by Sol-Gel Method

The fabrication process of DSSC is illustrated in Figure 1. First, the photoanode was prepared from TiO_2. The TiO_2 film was prepared by depositing the TiO_2 solution on the substrate. The TiO_2 solution was prepared by mixing ethanol or ethyl alcohol (C_2H_6O), Glacial Acetic Acid (GAA), titanium isopropoxide (TTIP), distilled water and Triton X-100 in a Schott Bottle Blue Cap.

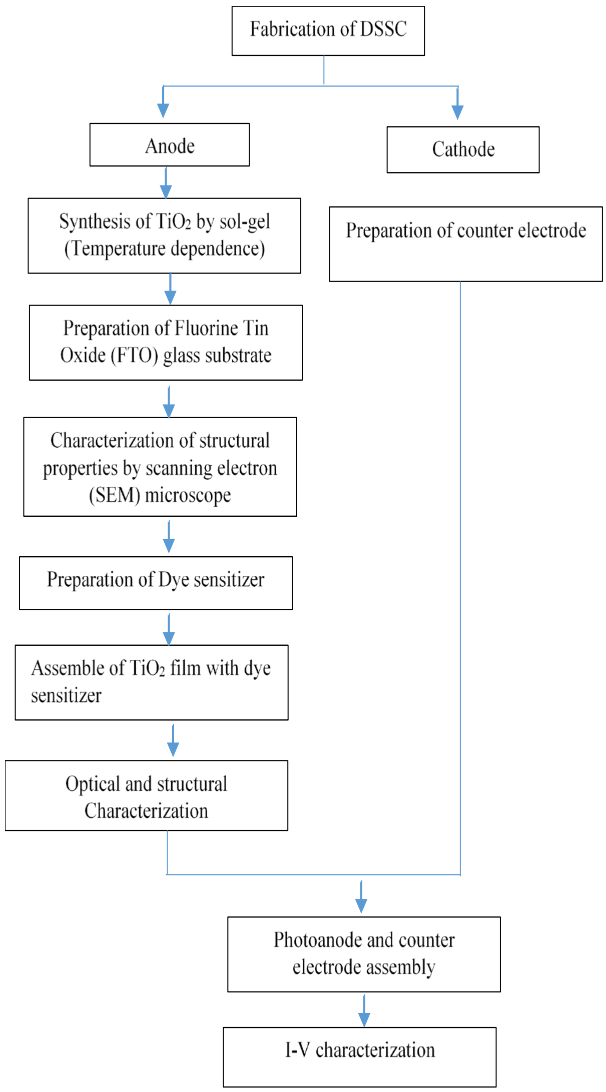

Figure 1. The flow process of DSSC fabrication.

The solution was continuously stirred for two hours at different synthesis temperatures (50 °C, 60 °C or 70 °C) at 600 rpm. The stirring process at a certain temperature (50 °C, 60 °C or 70 °C) in 2 hours is very important to break the carbon chain and to avoid from agglomeration (Vaiciulis *et al.,* 2012). In this method, TTIP was used as a precursor, ethanol