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Transparent Dye-Sensitized Solar Cell Using Titanium Dioxide Thin Film

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Abstract: On an FTO glass substrate, titanium dioxide (TiO_2) thin films have been created and deposited. Utilizing the spin coating process, TiO_2 solution is deposited on the substrate. TiO_2 solution containing 5ml, 7ml, and 10ml TTIP that has been stirred overnight without pre-heating is used to create the TiO_2 thin films. In a single hour, 450°C is used to anneal all thin films. Field Emission Scanning Electron Microscopy has been used to analyse the thin film's surface morphology (FESEM). The X-Ray Diffraction (XRD) technique analysis, which revealed that the TiO_2 thin film is in the nanocrystalline anatase phase, was used to demonstrate the crystallinity of TiO_2. The optical transmittance of the thin films was measured using a UV-Vis spectrophotometer with a wavelength range of 300 nm to 1000 nm. UV filters out light. The sample can absorb a lot of light if there is a lot of light entering it. The DSSC's performance increases as a result of its capacity to hold a lot of light. I-V measurements have been used to determine electrical characteristics. According to the results, increasing the film thickness can enhance dye molecule adsorption. According to the results of the trials, the TiO_2 thin film with 7ml TTIP achieves the best efficiency, which is 0.0222%, when compared to 5ml & 10ml TTIP.

Keywords: TiO_2, FTO, Spin Coat method

1. Introduction

The most recent energy source is the solar cell, which was discovered in 1839 by a researcher named Alexandre Edmond Becquerel. According to his study, the photovoltaic principle can turn the energy contained in light into electricity. The direct conversion of sunlight to electricity is known as photovoltaic. A solar cell, also known as a photovoltaic cell, is an electrical device that converts light energy directly into electricity using the photovoltaic effect, a physical and chemical phenomenon [1]. In 1972, the University of Delaware's Energy Conversion Department developed thin-film photovoltaic and thermal system technologies.

Since silicon solar cells are the most common and widely used, they face competition from polymers, copolymers, and the production of various organic and hybrid photovoltaics due to high

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production costs and electrical and photo transmission problems [2]. Solar energy is predicted to be one of the most promising alternative energy sources in the next years. Light shining on a solar cell generates both a current and a voltage, which is used to generate electricity [3]. Silicon solar cells presently rule the photovoltaic market. To survive the energy crisis, it slowly increased the demand for renewable energy technology development and research, especially solar energy [2]. Aside from wind turbines, hydropower, wave and tidal power, solar cells, solar thermal, and photovoltaic technology, which uses solar energy, are regarded as the most promising of all renewable energy technologies. Electricity can be generated using various photovoltaic designs, such as Dye-Sensitized Solar Cells (DSSC) [4].

1.1 Dye-Sensitized Solar Cell (DSSC)

Dye-Sensitized Solar Cell (DSSC) is claimed to be the most promising and inexpensive route to sunlight gathering, according to Professor M. Gratzel's study in 1991. For DSSCs using ruthenium complex dyes (N719), the maximum power conversion efficiency (PCE) reported was 11–12% [5]. Long-term stability is one of the most challenging for DSSCs. The essential criteria influencing cell stability are dye desorption, electrolyte leakage and dye degradation [6].

1.2 Titanium Dioxide (TiO_2)

Transparent oxide thin films are a common material in new generation solar cells. Titanium dioxide (TiO_2) thin films provide numerous benefits, including a wide band gap, a high refractive index, a high dielectric constant, and negligible toxicity [7]. Due to their unique hybrid energy storage system supporting interesting optoelectronic phenomena, the possibility of low-cost scale-up of the associated synthesis technique, as well as its relevance for diffuse light harvesting [8].

2. Materials and Methods

2.1 Preparation of TiO_2 thin film

Cleaning of glass substrates, preparation of TiO_2, and deposition of TiO_2 solution onto FTO glass substrates are the three parts of the TiO_2 thin film preparation process.

2.2 Cleaning of glass the substrate

The substrate used in this experiment is FTO glass. The FTO glass was immersed in acetone, ethanol and deionized (DI) water first. After that, the glass substrates were immersed in an ultrasonic bath for 10 minutes. Figure 1 and Figure 2 show the chart of cleaning the substrate and the machine that was used to clean the glass substrate for 10 minutes in an ultrasonic bath.

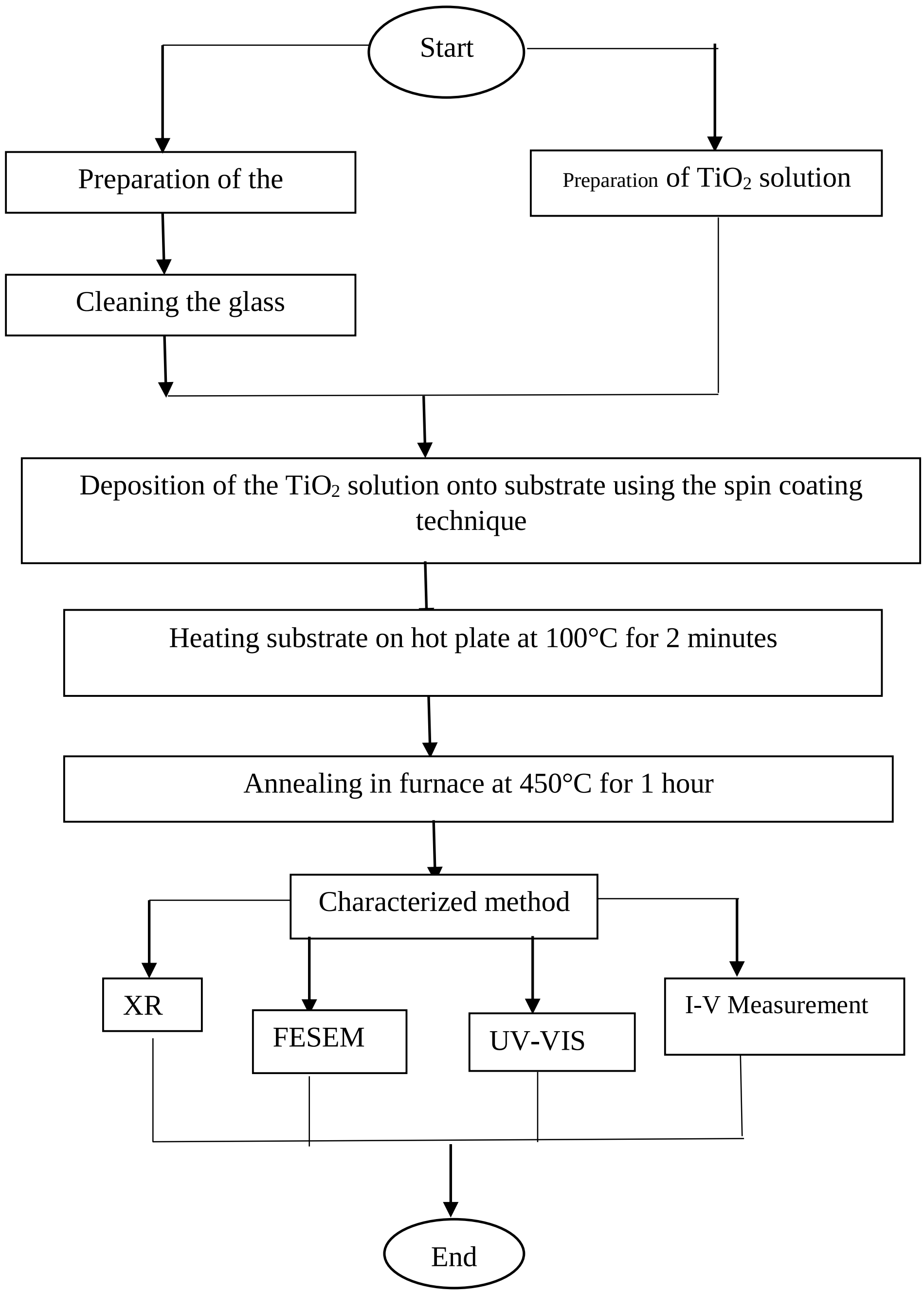


Figure 1: Flowchart of preparation and characterization method of TiO_2 thin film

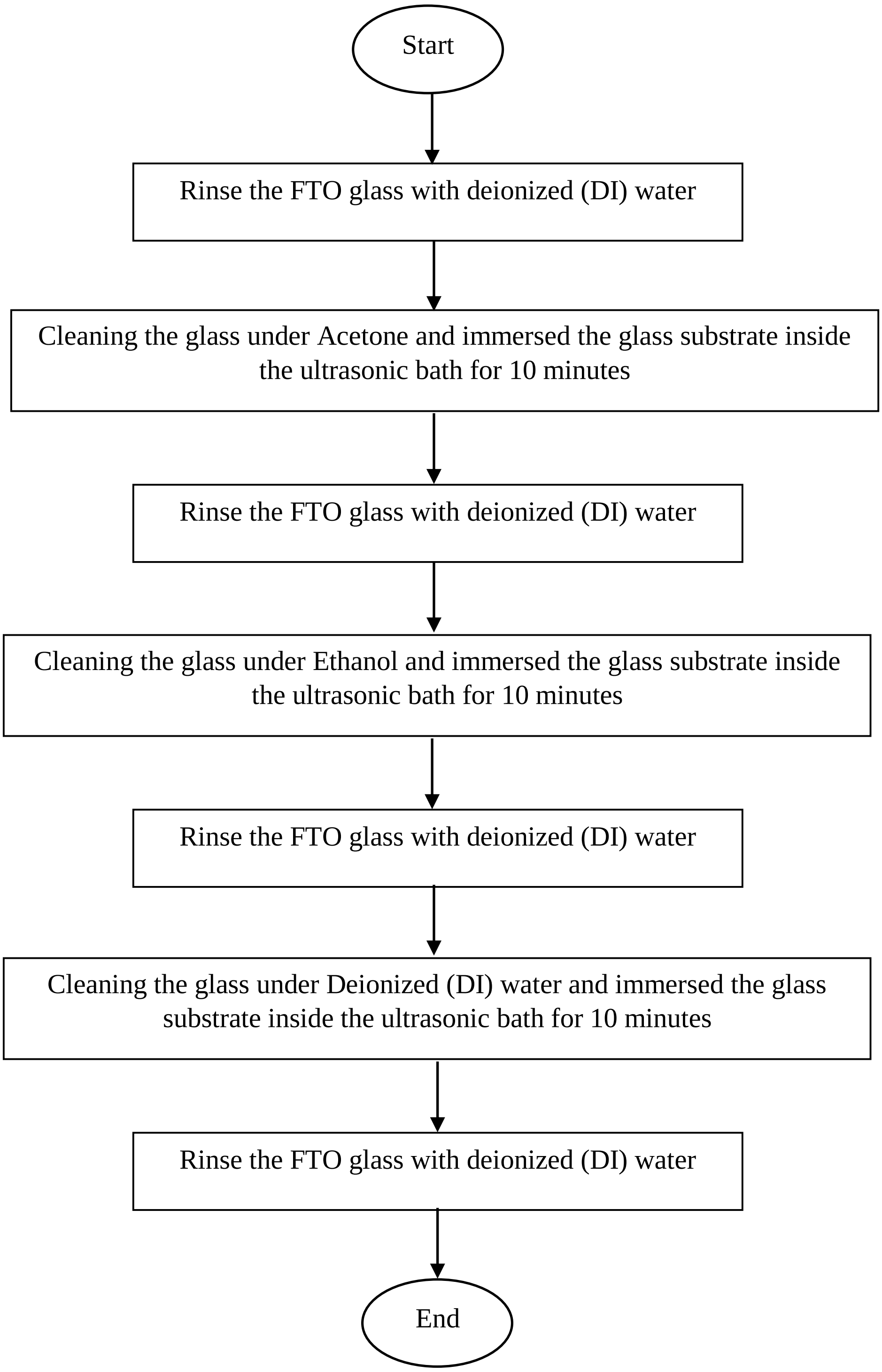


Figure 2: Flowchart of cleaning substrate

2.3 Preparation of TiO_2 solution

Table 1 shows chemical the used to prepare the TiO_2 solution. 10ml of 2-Propanol was measured using a measuring cylinder and poured inside a reagent bottle. Then, 5ml, 7ml, and 10ml of TTIP are added inside the bottle followed by 5.5ml of acetic acid. After that, add 2 drops of Triton X-100 and 3ml (drop by drop) of Deionized (DI) water into the solution using the dropper. Lastly, the solution is left to be stirred with a magnetic stirrer on a hot plate for 24 hours without preheating.

Table 1: Chemical used in preparing the TiO2 solution

Type of chemical	Quantity
2-Propanol	10ml
Titanium (IV) Isopropoxide (TTIP)	5ml, 7ml, 10ml
Acetic Acid	5.5ml
Triton X-100	2 drops
Deionized (DI) water	3ml (drop by drop)

2.4 Deposition of TiO_2 thin film

The spin coating machine is wrapped entirely with aluminum foil. The spin coating machine is turned on and the mode of the machine is set to Recipe C (3000rpm for 40 seconds). A sample of the glass substrate is placed into the middle of the spin coating machine. After that, the lid of the spin coating machine is closed and wrapped along with the aluminum foil. 10 drops of TIO_2 solution are added at 3000rpm using the dropper. After the sample is spun for 40 seconds, the sample is taken out and placed directly on a pre-heated hot plate at 100C for 2 minutes. Upon finishing the experiment, the spin coating machine is cleaned with Ethanol. The sample is placed into the furnace oven. The temperature of the furnace oven is set at 450°C within 1 hour. All the processes are shown in Figure 3 and Figure 4.

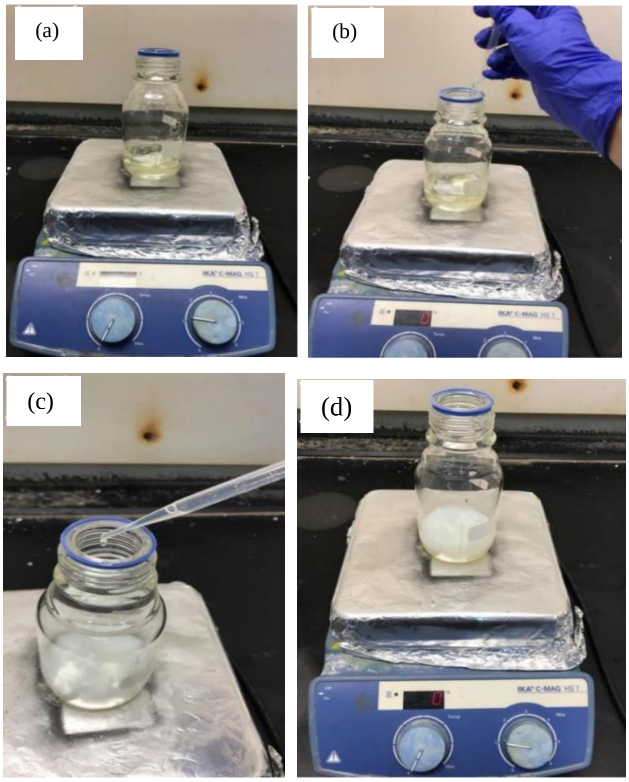


Figure 3: (a) 2-propanol, TTIP and acetic acid in the reagent bottle. (b) 3ml of DI water is added to the reagent bottle using a dropper. (c) 2 drops of triton x-100 were added to the reagent bottle. (d) The solution is left to be stirred for 24 hours without the pre-heating (50°C)

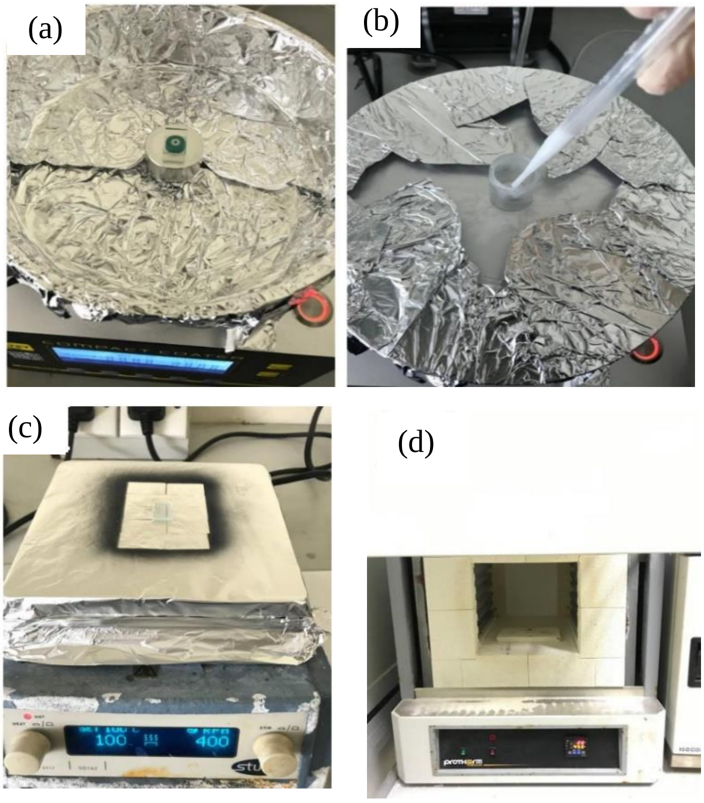


Figure 4: (a) Sample is placed into the middle of the spin coating machine. (b) Drop the TiO_2 solution at 3000rpm. (c) The sample on a hot plate at 100C for 2 minutes. (d) The sample is placed into the furnace oven at 450°C within 1 hour.

3. Results and Discussion

FESEM and XRD were used to evaluate the surface morphology, and a UV-Vis spectrophotometer was used to determine the optical properties. The TiO_2 thin film produced by the multiple layers of TiO2 solution will have varying thicknesses. As a result, the samples are predicted to be TiO_2 with varying porosity structures. Surface morphology, optical characteristics, and electrical qualities will all be altered. Lastly, the efficiency of the DSSC was measured by using Solar Simulator.

3.1 XRD

Figure 5 show the XRD pattern of TiO_2 thin films deposited on FTO-coated glass substrates at 450°C with three different thicknesses based on different amounts of TTIP (5ml, 7ml, 10ml). TiO_2 thin films show an anatase structure with the preferred (101) orientation.

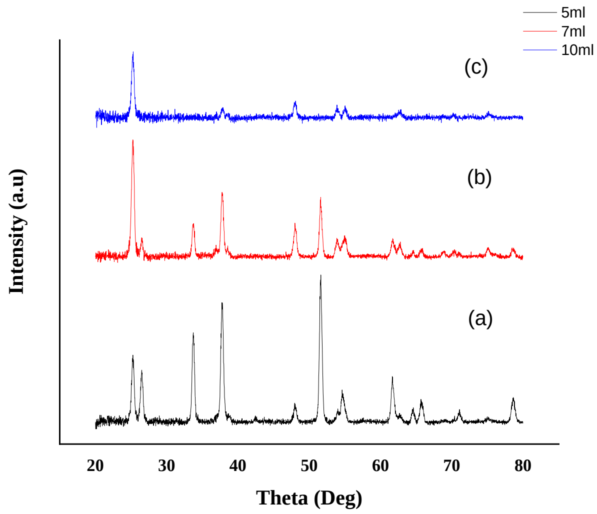
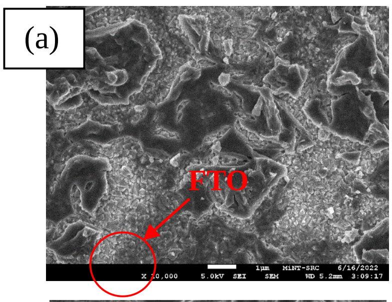


Figure 5: TiO2 thin film XRD pattern with various thicknesses

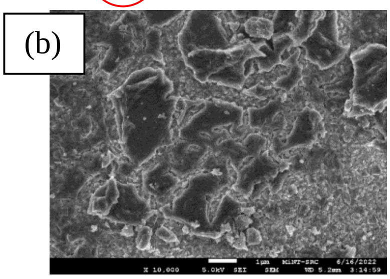
The three samples were tested for an XRD examination in order to establish the presence of TiO_2. The XRD patterns of the TiO_2 sample, 5ML, 7ML, and 10ML, are shown in Figure 5 (a)–(c). TiO_2's XRD pattern is quite similar to the Joint Committee on Powder Diffraction Standards' anatase phase card no. 21-1272. (JCPDS). The 2θ angle of the diffraction peaks correspond to the crystal planes 25.198 (101), 36.963 (103), 37.770 (004), 38.468 (112), 48.016 (200), 53.830 (105), 55.116 (211), 62.681 (204), and 75.021 (215). Figure 5 (b) shows that 7 ml has a high intensity than others (5 and 10 ml). Peak width or broadening often increases as crystallite size decreases.

3.2 FESEM

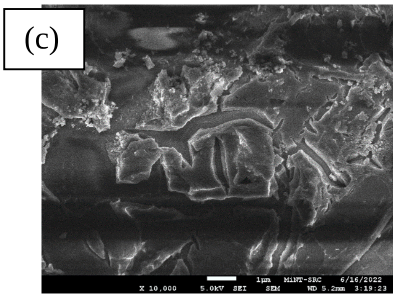
Figure 6 shows the surface morphology of TiO_2 thin films with different amounts of Titanium (IV) Isopropoxide (TTIP). Figure 6 (a), (b), and (c) show the TiO_2 thin film with 5ml, 7ml, and 10ml, respectively, magnified to a scale of 10,000 times. There were many lump points at the moment of coating, therefore, TiO_2 nanoparticles were irregularly distributed and not at the same size [9], as seen in Figure 6 (b). The lump point of TiO_2 emerges as an impurity, which is influenced by a non-homogeneous coating process. TiO_2 particle size is unable to display due to the low resolution. Because it is related to the rising efficiency of light obtained during the process [10] the uniformity of the TiO_2 layer on the FTO substrate significantly impacts its electrical characteristics [11].



Under a 10,000 magnification scale, (a) the surface morphology of a TiO_2 thin film with a 5 ml TTIP. The TiO_2 particles are so thin that the FTO glass substrate may be seen clearly through them. The TiO_2 solution didn't entirely cover the glass substrate's surface.



(b) the surface morphology of a TiO_2 thin film with 7 ml of TTIP under a 10,000 magnification scale. TiO_2 nanoparticles were irregularly distributed and not at the same size



(c) The surface morphology of a TiO_2 thin film with 7 ml of TTIP under a 10,000 magnification scale. It is obvious that the sample with 10ml TTIP is too thick, causing the surface of the sample to fracture.

Figure 6: Surface morphology of TiO_2 thin film with different amounts of TTIP

3.3 UV-Vis

Electrons from dye molecules will obtain energy from light in order to use DSSC. The thin film's conduction band will then be excited by an electron with sufficient energy. As a result, the dye molecule must absorb as much light as possible, and the TiO_2 thin layer must have a low transmittance value. Figure 7 shows the absorbance and transmittance spectra of TiO_2 films of different thicknesses using wavelengths ranging from 300 to 1000 nanometers. Between 300 nm and 350 nm wavelengths, the transmittance of a thin film with 5ml, 7ml, and 10ml TTIP drops steadily. They have an average transmittance from 400nm to 800nm. The transmittance of the thin film with 5 ml TTIP increases slightly from 360 nm to 1000 nm. Thin film with 5ml TTIP has a higher optical transmittance than other thin films. Light is absorbed by UV. If there is a lot of light entering the sample, it can absorb a lot of light. As a result of its ability to hold a large amount of light, the DSSC's performance improves.

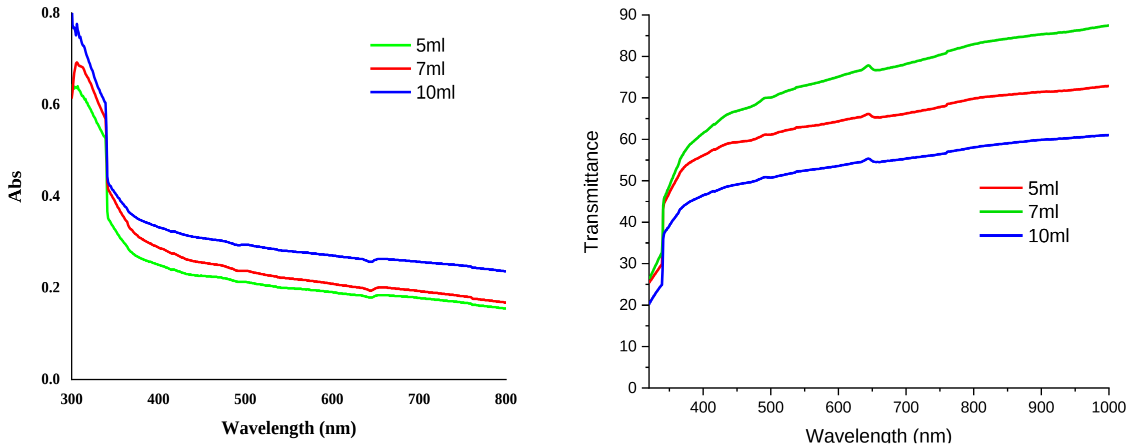


Figure 7: Absorbance and transmittance of TiO_2 films with 5ml, 7ml and 10ml of TTIP

3.4 I-V Measurement

Current-voltage measurement (I-V) is carried out on TiO_2 thin film structures to determine their electrical properties. Figure 8 shows an illustration of the assembly of TiO_2 thin film (sandwiches)

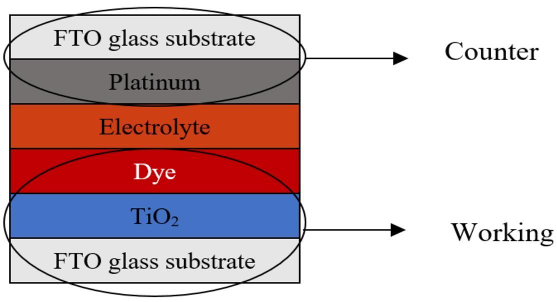


Figure 8: Illustration of assembly of TiO_2 thin film

The assembly of a TiO_2 thin film is represented in Figure 8. Platinum is an essential component of dye-sensitized solar cells since it is utilized to generate counter electrodes. In DSSCs devices, highly electrocatalytic materials such as platinum (Pt) are employed to decrease I3- to I- at the electrolyte/CE interface to maintain current flow and replenish molecules of the oxidized sensitizer.

The DSSC was tested by I-V measurement and using TiO_2 thin films of three different thicknesses, FTO glass and dye as working electrodes Figure 9 shows that the TiO_2 thin film with 10ml TTIP produces the lowest electric current compared to the other thin films. The thin film with 7ml TTIP had the best efficiency of 0.0222%, followed by thin films with 5ml and 10ml, which had 0.0158% and 0.0035%, respectively. Table 2 shows the various DSSC parameters for different thin film thicknesses.

From the result obtained, it can be seen that sample with 7ml TTIP has the highest efficiency because the absorption of the dye molecule on the TiO_2 particle is higher. This 7ml sample can store a significant amount of light capacity. It could keep a lot of light, and the performance of the DSSC would get higher. This has been proven through IV Measurement. However, the efficiency of the 10ml sample was the lowest because the surface is cracked & there is no porous so it cannot absorb the light, preventing the dye from absorbing well. As a result, its efficiency is minimal. From FESEM, it can be seen that the thickness of the sample with 10ml TTIP is too thick, which causes the sample to crack. That is why the efficiency is the lowest. The TiO_2 thin film fabricated using 7ml of TTIP performs better with 0.0222% efficiency. It has the highest values of V_{OC} and J_{SC}, which are 0.0909V and 0.0215mA/cm2, respectively.

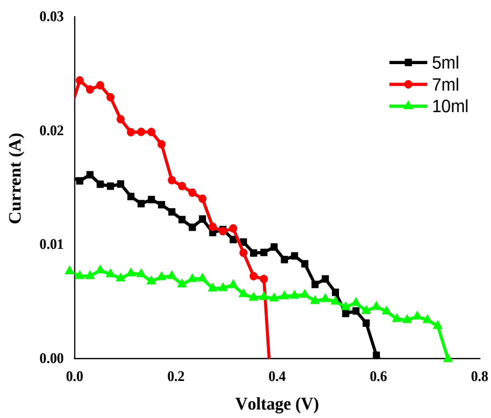


Figure 9: I-V measurement of TiO_2 thin film with different thickness

Table 2: DSSC parameters with three different film thicknesses

Sample	Voltage	Jsc	Fill Factor	Efficiency	Area
5ml TTIP without pre-heating	0.0505	0.0157	41.69	0.0158	0.25
7ml TTIP without pre-heating	0.0909	0.0215	66.93	0.0222	0.25
10ml TTIP without pre-heating	0.0101	0.00286	30.02	0.0035	0.25

4. Conclusion

Three different thicknesses of titanium dioxide thin films have been successfully created. The sol-gel spin coating process was used to deposit the thin film. The quantity of TTIP (5ml, 7ml, or 10ml) used to develop the TiO_2 solution determines the thickness of the thin film. FESEM has been used to analyze the thin film's surface shape, and X-ray diffraction analysis has been used to show the crystallinity of TiO_2. In addition, I-V measurement is used to determine the electrical characteristics of

TiO2. A UV-Vis spectrometer was used to measure the optical transmittance of the thin layer. Lastly, in order for the thin films of TiO2 to have a nanocrystalline anatase structure and absorb the dye molecule as much as possible, the thickness of the thin film is essential in improving the DSSC's performance.

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