Optimizing Electron Transport Layer Thickness for Enhanced Efficiency in Dye Sensitized Solar Cells

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Abstract- In 1991, Michael Gratzel invented dye-sensitized solar cells (DSSCs), a major solar cell technical advance. These cells have exceptional organic and inorganic solar cell qualities. A detailed empirical investigation of Dye-Sensitized Solar Cell design, material synthesis, and characterization is presented in this thesis. This work aims to improve Dye-Sensitized Solar Cells (DSSCs) design to raise stability and efficiency above the 4% benchmark attained in traditional labs. This study found that nano-porous Titania layer thickness affects dye-sensitized solar cell performance. Device efficiency increases with nano-porous Titania layer thickness. However, efficiency decreases when the nano porous Titania dense layer thickness exceeds 20 nanometers. Electrons are trapped in the high-density layer, preventing them from crossing the active layer. Electric current in the solar cell depends on this movement. Electrical characterization is crucial for assessing Dye-Sensitized Solar Cells (DSSCs). A variety of electrical and optical characterization techniques are used to evaluate the device's electrical and optical features. These methods use current-voltage (IV) curves, transmittance spectra, and absorbance spectra to determine device attributes. The surface morphology of DSSCs is also assessed using SEM images of the deposited layers. Experimental values match literature data, validating the study's conclusions' robustness and trustworthiness. This study adds to the scientific knowledge of dye-sensitized solar cells (DSSCs) and its potential to improve solar energy conversion.

Index Terms- Dye Sensitized Solar Cell, Nano porous Titania, Electron Transport Layer

I. INTRODUCTION

The The domain of photovoltaic (PV) power generation is of considerable significance and plays a pivotal role within the domain of sustainable energy sources. The efficacy of solar panels, a crucial element within the realm of sustainable energy, is considerably influenced by the attributes of photoactive materials and the intricacies inherent in their manufacturing processes. Recent developments in the field of photovoltaics have shown great potential, as it has been demonstrated that semiconducting polymers could serve as a viable alternative to traditional inorganic materials. These polymers offer several advantages, including cost-effectiveness and ease of manufacturing. The aforementioned polymers have exhibited favorable power conversion efficiencies, indicating their potential for practical application in energy conversion systems. The year 1991 holds significant importance in the historical

accounts of solar energy due to a seminal breakthrough achieved by O' Regan and Gratzel [1, 2]. The authors' groundbreaking contribution presented a novel framework within the realm of photovoltaics, commonly referred to as the Dye-sensitized solar cell (DSSC). These devices offer a dual benefit by reducing manufacturing costs and promoting environmental consciousness. The exceptional degree of efficiency demonstrated by these solar cells, which closely approximates the direct conversion of sunlight into electrical power, has garnered considerable attention within the research community. The fundamental principle underlying dye-sensitized solar cells (DSSCs) involves the utilization of a monolayer of molecular dye sensitizer to capture photons emitted by the sun. The dye sensitizer is effectively immobilized onto the surface of a nonporous semiconducting film, typically composed of TiO2 or ZnO2, as illustrated in Figure 1. The photovoltaic process is initiated through photo-excitation, which is induced by the absorption of light by the dye. The outcome of this phenomenon is the introduction of energized electrons into the conduction band of the oxide layer. The process of electron-hole recombination within the film is effectively suppressed, leading to the unhindered diffusion of electrons towards transparent conductive oxide films like ITO and FTO [3]. Consequently, the electrons are able to establish electrical contact, thereby contributing to the external circuit. The process of restoring the dye to its original state is simultaneously facilitated by the electron contribution from the electrolyte. This is commonly achieved by utilizing the I-/I3- redox pair in organic solvents. Currently, the Dye-Sensitized Solar Cells (DSSCs) have demonstrated a maximum efficiency of approximately 11-12% [3-5]. Ongoing research endeavors are actively focused on augmenting the stability and efficacy of dye-sensitized solar cells (DSSCs), while concurrently tackling challenges related to electrolyte loss arising from leakage or volatility. To accomplish the aforementioned objective, a diverse array of dyes has been developed with the intention of augmenting the efficacy of Dye-Sensitized Solar Cells (DSSCs). Extensive research has been conducted to explore the potential of various categories of dyes in dye-sensitized solar cells (DSSCs), including organic metal complexes, natural dyes, and organic dyes [4-7]. It is noteworthy to acknowledge that Ruthenium (Ru)-based dyes, particularly N3 and N-719, have emerged as prominent selections within the realm of dye-sensitized solar cells (DSSC) [1-7]. This study aims to explore the process of sensitization in a recently identified

dye, specifically 2,9-bis(2,4-difluorophenyl). The compound of interest is -5,6,12,13-tetrakis (p-tolyloxyAnthra is a term that refers to a class of organic compounds known as anthracenes. These compounds The provided text appears to contain a combination of numbers and characters. Specifically, it includes the sequence [2The compound in question is diisoquinoline-1,3,8,10(2H, The compound under investigation, commonly known as tetraene or 2,4 DFP, is being studied for its potential utilization in solar cell technology. Furthermore, this research endeavor entails the production of dye-sensitized solar cells (DSSCs) through the process of fabrication, employing a diverse range of dyes. The primary objective of this investigation is to perform a comprehensive comparative analysis. The findings derived from our research indicate that the utilization of the innovative 2,4 DFP-based dye in solar cells yields lower efficiency in comparison to solar cells employing N-719 or Z-907-based dyes. It is important to acknowledge that the open circuit voltages exhibited by the distinct 2,4 DFP dye are comparable to those observed in N-719 devices. The fill factor (FF) of devices incorporating the novel dye exhibits a significant performance, achieving a value of 73%. This surpasses the fill factor values of devices utilizing N-719 and Z-907, which are reported as 56.8% and 29.4% respectively. Dye-sensitized solar cells (DSSCs) frequently employ wide band gap semiconductor materials, such as titanium dioxide (TiO2), for their photoanode. Since their inception in 1991 by Gratzel, dye-sensitized solar cells (DSSCs) incorporating titanium dioxide (TiO2) have garnered significant attention as a viable avenue for the progression of photovoltaic technologies [1]. Dye-sensitized solar cells (DSSCs) demonstrate a complex amalgamation of various components, including a transparent electrode (ITO, FTO) that is coated with a nano porous layer composed of wide band gap semiconductors such as TiO2 or SnO2 [2,3]. The ensemble is comprised of an electrolyte that incorporates a suitable redox couple, along with a counter-electrode that is coated with either platinum or carbon, as depicted in Figure 2. The fundamental operational principle of dye-sensitized solar cells (DSSCs) is based on the generation of photoexcited electrons within the dye molecule following the absorption of sunlight. The transfer of energetic electrons occurs as a result of the transition from excited dye molecules to the conduction band of titanium dioxide (TiO2). This process initiates the transportation of electrons towards the external load, facilitated by the nano porous and dense TiO2 layer. The electrolyte solution, commonly containing iodide/tri-iodide, facilitates the electron donation process to the dye, thereby facilitating its regeneration.
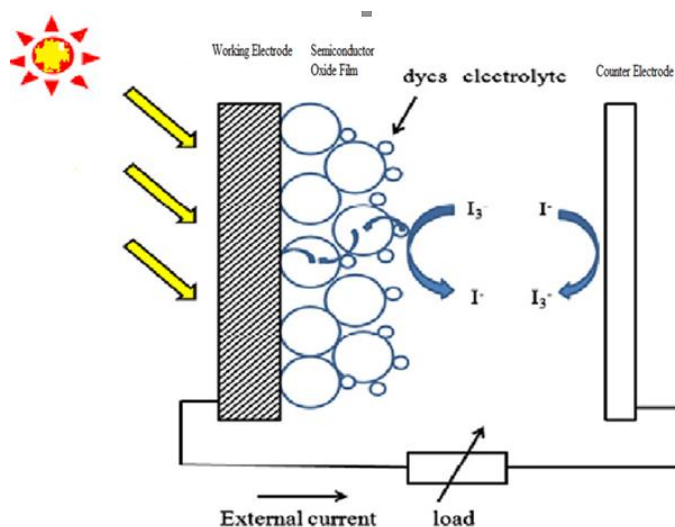

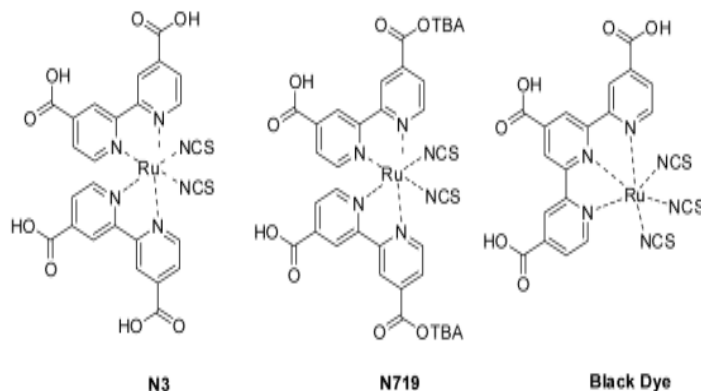Figure 1: A schematic showing how a dye-sensitized solar cell operates [2]

Figure 2: Dye structures for Black, N3, and N719.

The process of refilling electron vacancies in iodide involves the transfer of electrons from the counter electrode. It is noteworthy to mention that dye-sensitized solar cells (DSSCs) incorporating both thick and nano porous titanium dioxide (TiO2) layers have exhibited impressive conversion efficiencies, with reported values as high as 11% [4, 5]. However, the ongoing quest for enhanced conversion efficiencies necessitates further scientific inquiry aimed at enhancing the device's design, stability, and structural integrity [8]. As illustrated in Figure 1, the sensitized nano porous titanium dioxide (TiO2) layer, which is a crucial component of dye-sensitized solar cells (DSSCs), exhibits a multitude of minuscule pores that facilitate the direct interaction between the electrolyte and the working electrode. To mitigate the occurrence of undesired charge leakage, a strategically positioned high-density layer of titanium dioxide (TiO2) is employed as a blocking layer. The layer in question is situated between the conductive electrode and the sensitized nano porous TiO2 layer. The presence of a compact titanium dioxide (TiO2) layer effectively impedes the electron transfer from the

electrolyte to the indium tin oxide (ITO) electrode by impeding direct physical contact. Previous research has extensively investigated the utilization of various materials and film thicknesses in the fabrication of the titanium dioxide (TiO2) dense layer, commonly referred to as blocking layers [6-12]. The objective of this study is to examine the influence of the thickness of the TiO2 dense layer on the efficiency and functionality of dye-sensitized solar cells (DSSCs) [9]. This study utilizes TiO2 nano porous layers and Z907 dye to fabricate dye-sensitized solar cells (DSSCs). The fabrication process of dye-sensitized solar cells (DSSCs) involves the deposition of blocking layers with varying thicknesses onto indium tin oxide (ITO) glass substrates through the utilization of the spin-coating technique. The objective of this study is to investigate the optical, photovoltaic, and structural properties of dye-sensitized solar cells (DSSCs). Through comparative analyses, this research aims to offer valuable insights into these characteristics.

II. EQUIPMENT FABRICATION

The compound denoted as 2,4-difluorophenyl-5,6,12,13-tetrakis(p-tolyloxy) anthra[2,1,9 def:6,10,14,18]tetraene is a chemical entity of interest.The diisoquinoline-1,3,8,10(2H,9H)-tetraone (2,4 DFP) dye underwent a sensitization procedure employing a modified variant of the PTCDI dye, known as Energy Relay Dyes. The aforementioned alteration is graphically depicted in Figure 2. The dye being examined exhibits a HOMO energy level of -4.4653 eV and a LUMO energy level of -2.9593 eV, resulting in a narrow band gap of 0.506 eV. A comprehensive analysis was undertaken to assess the effectiveness of a recently developed dye in Dye Sensitised Solar Cells (DSSCs) [10-12]. This evaluation involved comparing the performance of DSSCs incorporating the new dye with those incorporating the widely utilised N719 and Z907 dyes. The fabrication procedure was initiated by subjecting the substrates coated with Indium-doped Tin Oxide (ITO), which exhibited a surface resistance of 150Ω/sq, to a thorough cleaning process. The experimental procedure entailed submerging the substrates into a detergent solution within an ultrasonic bath for a precisely timed duration of 10 minutes. Following the experimental procedure, the substrates underwent a comprehensive rinsing process utilising de-ionized (DI) water in order to effectively eliminate any remaining contaminants that may have been present. After the initial procedure, the indium tin oxide (ITO) substrates underwent immersion in ethanol and isopropyl alcohol (IPA) solutions. This was followed by a sonication period of 10 minutes and a subsequent blow-drying step. An integral component of the fabrication procedure involved the application of a compact TiO2 layer onto the indium tin oxide (ITO) substrate. The dense layer was meticulously fabricated by employing a solution comprising 20 millilitres of tri-isopropoxide, 14 millilitres of acetyl acetone, and 52 millilitres of ethanol. The careful and precise manipulation of the substrate led to notable improvements in its electron transport characteristics. The fabrication process of the essential TiO2 nanoporous layer involved the preparation of a specialised Ti-nanoxide paste. The experimental procedure entailed the meticulous combination of 5.5 grammes of TiO2 powder P25 (Degussa), 120 millilitres of ethanol, 0.5 millilitres of

Ti-isopropoxide, and a minute amount of Triton x-100. The effective implementation of the doctor blade technique facilitated the consistent deposition of Ti-nanoxide paste onto the ITO conductive glass, leading to the creation of a nanoporous TiO2 layer [13]. The thickness of the layer under investigation was determined to be 35 µm, with the layer exhibiting coverage over a surface area of 5 cm2. The subsequent annealing procedure was carried out at a temperature of 450°C for a duration of 60 minutes with the aim of attaining the desired structural and electrical characteristics of the TiO2 film. The indium tin oxide (ITO) electrodes, coated with titanium dioxide (TiO2) through a meticulous engineering process, were subsequently submerged in three distinct dye solutions. Each solution was meticulously prepared with careful attention to detail, incorporating one of the dyes (2,4 DFP, N719, Z907). Ethanol was utilised as the solvent at a concentration of 3×10^{-4} M. The duration of the sensitization process extended over a period of 12 hours. Simultaneously, the counter electrode (CE) was systematically prepared by depositing a carbon coating onto the conductive surface of an extra indium tin oxide (ITO) glass substrate [14]. The final stage of the fabrication procedure for the Dye-Sensitized Solar Cell (DSSC) involves the insertion of a redox (I−/I3−) electrolyte solution between the titanium dioxide (TiO2) electrode sensitised with dye and the counter electrode (CE) coated with carbon. The electrolyte solution was prepared with great attention to detail, involving the dissolution of potassium iodide (KI) at a concentration of 0.10 M and iodine (I2) at a concentration of 0.015 M in ethylene glycol. The present study involved a meticulous approach in order to achieve the highest level of electron transport and charge transfer properties within the solution. The detailed arrangement and structural composition of the meticulously engineered Dye-Sensitized Solar Cell (DSSC) are prominently depicted in Figure 3, effectively demonstrating the seamless integration of diverse materials and components aimed at enhancing the solar cell's efficiency [15].
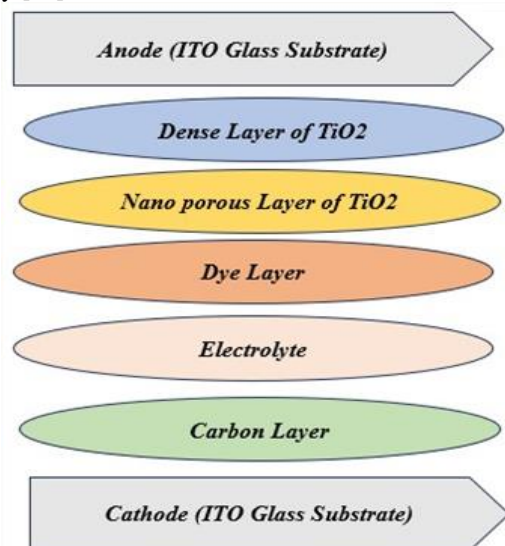

Figure 3 (a): Steps for Fabrication of DSSC

Figure 3 (b): Fabricated Dye-sensitized solar cells

III.   METHODOLOGY & DEVICE CHARACTERIZATION

Following the meticulous fabrication process of the Dye Sensitized Solar Cells (DSSCs), a comprehensive evaluation was performed utilizing established characterization techniques, extensively elucidated in the preceding chapter dedicated to photovoltaic devices. The comprehensive process of characterizing was effectively partitioned into two discrete components. The initial aspect of the study involved a meticulous exploration of spectroscopic and optical phenomena, which were effectively utilised to unravel the intricate mechanical complexities associated with Dye-Sensitized Solar Cells (DSSCs). The second aspect, in stark contrast, meticulously highlights the electrical dimensions, thereby elucidating the fundamental electrical properties associated with these photonic phenomena. The diligent characterizations yield a range of parameters, which will be discussed in detail in the subsequent section. In the realm of electrical characterization, the devices that were fabricated underwent a series of pivotal measurements, prominently encompassing:

i.   The short-circuit current (Isc) refers to the current that flows through a cell while there is no voltage across it.

ii. Open-Circuit Voltage (Voc): Effectively encompassing the entire voltage spectrum from zero to the highest attainable voltage, with Isc measured prior to calculating the associated Jsc.

iii. Maximum Current in the Circuit: Signifying the peak level of electric current within the circuit.

iv. Peak Voltage: The highest level of voltage seen across the gadget.

The fill factor is a crucial metric that encompasses the overall performance of a cell.
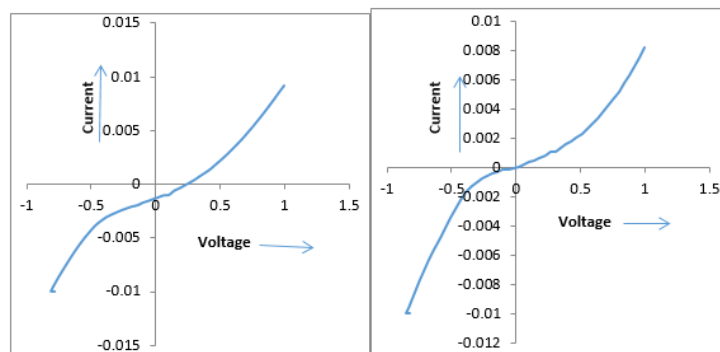

Figure 4. A Curve in the Absence of Light (a), light-measured curve (b).

The device's ability to convert solar energy into electricity depends on cell efficiency. It's the device's crowning glory, demonstrating its conversion expertise. IV measurements under standardized solar spectrum circumstances reveal intricate factors that determine these solar cells' efficiency. Note that the luminous spectrum closely resembles sunlight, and the lamp is calibrated at 1000 W/m². The Newport solar simulator and Keithly Source meter were essential to this extensive study. The output current was carefully determined by selectively applying voltage to the working and counter electrodes. The Open Circuit Voltage (Voc) was measured systematically across the voltage spectrum, commencing from zero voltage, where the Short Circuit Current (Isc) was meticulously recorded for subsequent computation of the Current Density (Jsc). The methodical scanning procedure, conducted with meticulous attention, afforded the equipment the prospect of a resolute restoration. The current-voltage (I-V) curve, as denoted in scholarly discourse, is the outcome of meticulous endeavor, representing a distinct manifestation of the diligent exertion invested in this undertaking.
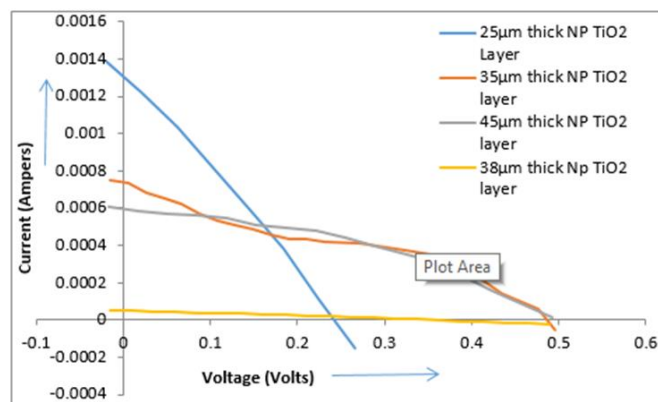

Figure 5. A Comparison of Four DSSCs for Evaluation

Figure 5 effectively demonstrates the intricate relationship between current and voltage, as observed under varying light conditions. A meticulous analysis of the current-voltage (I-V) characteristics has unveiled a pivotal element, specifically the quantification of photocurrent (Jph). The aforementioned result was achieved through a meticulous procedure involving the

subtraction of the dark current curve from the I-V curve under the influence of radiant illumination. In an optimal scenario, it is desirable for the photocurrent of a solar cell to exhibit a consistent behavior, unaffected by any potential fluctuations within the cell. Utilizing a comprehensive understanding of the underlying topic, we conducted a meticulous inquiry, resulting in the acquisition of four distinct samples of Dye-Sensitized Solar Cells (DSSC). The samples utilized in this study demonstrated minor discrepancies in their respective characteristics. The initial specimen was furnished with a nano porous titania layer measuring 25 μm in thickness. The second specimen exhibited a marginally increased thickness, measuring 35 μm. The third sample exhibited a notable increase in thickness, measuring 45 μm. Finally, the fourth sample exhibited a distinctive composition characterized by a compact titania layer measuring 40 nm in thickness. This composition deviated from the preceding three samples, where the compact titania layer had a thickness of only 20 nm. The examination of the obtained I-V curves, as illustrated in Figure 3.8, unveiled a variety of open circuit voltage (Voc) values, specifically 0.2650 V, 0.4760 V, 0.490 V, and 0.3640 V, along with their corresponding short-circuit current (Isc) values of 1.220 mA, 0.7440 mA, 0.540 mA, and 0.510 mA, respectively. The aforementioned findings have been visually depicted in Figure 5, thereby offering a comprehensive exhibition of meticulously recorded observations.

IV.   EXPERIMENTAL RESULTS

The present study meticulously fabricated Dye Sensitized Solar Cells (DSSCs) employing indium-doped tin oxide glass substrates as conductive substrates, N719 ruthenium dye as the sensitizer, titania nanoparticles for sensitization, I/I3 electrolyte, and carbon-based counter electrodes. Every dye-sensitized solar cell (DSSC) possesses a uniform active area measuring 5 cm². The Dye-Sensitized Solar Cells (DSSCs) under investigation exhibited short-circuit current densities of 0.244, 0.148, 0.108, and 0.102 mA/cm² for their respective cell samples. The open-circuit voltages of the four cells were measured to be 0.2650V, 0.4760V, 0.49V, and 0.3640V, respectively. The sectored spectrophotometry technique was employed to obtain transmission and absorbance spectra for each of the four solar cells, as well as the Indium Tin Oxide glass substrate. In order to ensure uniformity, all cells were standardized to possess an active area measuring 5 cm². The thickness of the Titania nonporous layer was precisely regulated through the utilization of aluminum foil, leading to the acquisition of measured thickness values of 25 μm, 35 μm, 45 μm, and 25 μm for the four respective cells. Precision was upheld through the implementation of rigorous error control measures. In order to maintain consistency and standardization, meticulous adjustments were made to the temperature, illumination intensity, and pressure levels during the measurement process. The sheet resistance of the sample was consistently maintained at a value of 13.4726 Ω/sq throughout the experiment, employing a four-probe measurement system. In order to evaluate the electrical performance of a solar cell under low light conditions, a digital multimeter was employed in conjunction with a computer to precisely measure and analyze the photocurrent. The measurements were conducted using a solar cell simulator that provided an irradiance of 100 W/cm². Table 1 presents a comprehensive summary of the metrics pertaining to the

thickness of the Titania layer. The findings of this study indicate a positive correlation between the thickness of the Titania nonporous layer and the increase in voltage and fill factor. Consequently, the efficiency of the Dye-Sensitized Solar Cells (DSSCs) is improved.
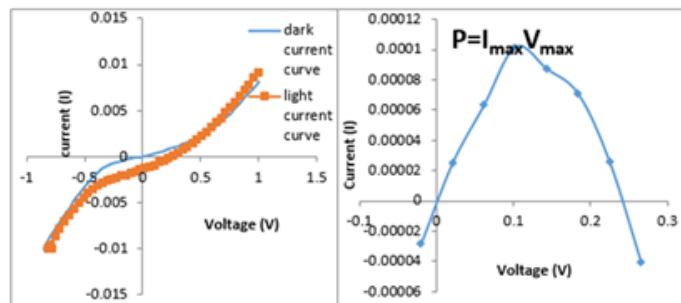

Figure 6. Current voltage curve Vs Real Power

25 nm Nano Porous Layer Dye-Sensitized Solar Cell

The present study aimed to modulate the absorption range and bandgap characteristics of semiconductors, building upon prior research that emphasized the efficacy of inorganic semiconductor nanoparticles owing to their notable absorption coefficients and adjustable size attributes. To accomplish this objective, dye-sensitized solar cells (DSSCs) were fabricated with a thickness of 25 micrometers, employing the methodology described in the preceding section. The present study involved the characterization of dye-sensitized solar cells (DSSCs) under controlled laboratory conditions. The voltage and current characteristics of the Dye-Sensitized Solar Cell (DSSC) are visually depicted in Figure 6, illustrating different lighting conditions. In the absence of illumination, the initiation of current flow necessitates the application of a forward bias voltage surpassing the open-circuit voltage (Voc). The generation of maximum photocurrent occurs when light is present, as depicted in Figure 6 (I), where the current flows under the short-circuit condition. According to the findings depicted in Figure 6 (II), it can be observed that under a flat-band condition, the absence of any current generation is evident. In this particular scenario, the fourth sector serves as the primary source of power generation. The product of voltage and current results in the determination of the maximum power point (MPP). A constant incident light intensity of 1000 W/m2 was employed to replicate the solar power experienced on Earth.

The present investigation involved an examination of the optical characteristics of a Dye Sensitized Solar Cell (DSSC) featuring a Nano Porous Layer measuring 25 nm. This was accomplished through a comprehensive analysis of transmittance and absorbance data. In order to facilitate comparison, a substrate composed of Indium Tin Oxide (ITO) glass with a transmittance value of 100% was employed as the initial reference point. The subsequent measurements conducted revealed that a significant proportion of the sun's energy, specifically 95%, was observed to be transmitted through a dense layer with a thickness of 20 nm. This observation strongly indicates that the energy transmitted through this layer is utilized in the generation of electron-hole pairs. The findings presented in Figure 7 illustrate the outcomes of supplementary investigations conducted on a Nano Porous Layer with a thickness

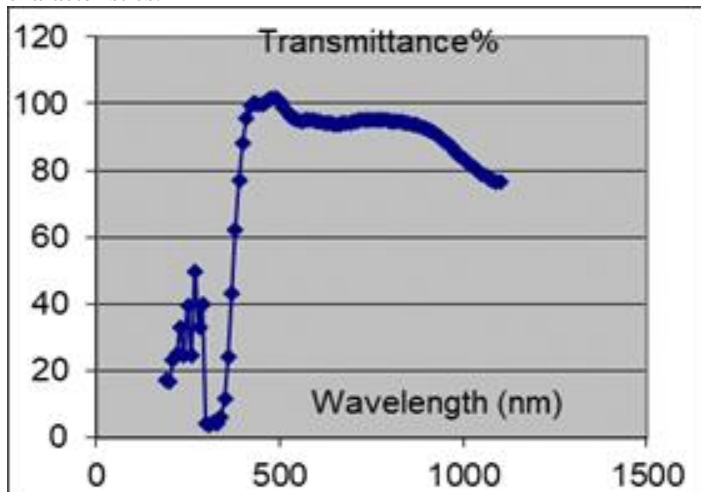of 25 m, showcasing its absorbance and transmittance characteristics.

Figure 7(a): Transmittance Graph

The Nano porous titania layer demonstrates a high degree of efficacy in promoting the transmission of light wavelengths, while the layer with a thickness of 25μm exhibits a notable propensity for absorbing this specific spectrum. The active layer of the system exhibits enhanced functionality due to the inclusion of the N719 dye. The present configuration maximises the efficacy of photovoltaic cells by effectively harnessing solar radiation to facilitate the movement of electrons and holes.
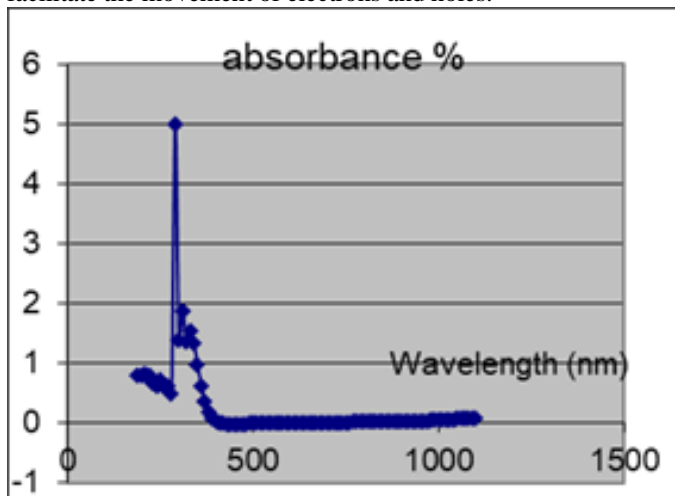

Figure 7(b): Absorbance Graph

Nano porous DSSCs with a 35 m Thickness

The manufacturing and characterization procedures utilized for the second batch of dye-sensitized solar cells, which integrated a Nano porous titania layer measuring 35μm in thickness, were conducted in a manner consistent with the methods employed for the initial batch. Figure 8 depicts the electrical characterization of the dye-sensitized solar cell (DSSC) under standard test conditions, specifically showcasing the current-voltage (I-V) characteristics.
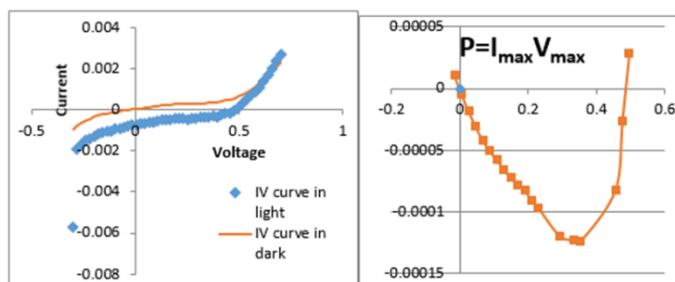

Figure 8. graph of actual power versus voltage output

The optical characterization of the Dye-Sensitized Solar Cell (DSSC) with a Nano porous layer, measuring 35μm in thickness, was conducted under controlled test conditions to evaluate transmittance and absorbance. Based on the existing body of literature, it has been established that there exists an inverse relationship between transmittance and absorption. Specifically, high transmittance is indicative of low absorption, while low transmittance corresponds to high absorption. Dye-sensitized solar cells (DSSCs) necessitate the presence of an active layer that is responsible for absorbing light, while the window layer is designed to facilitate the transmission of light. The findings of the Dye-Sensitized Solar Cell (DSSC) experiment indicate that the Titania dense layer exhibits a high photon transmission rate of 95%, thereby establishing its role as the window layer. Conversely, the Titania Nano porous layer, in conjunction with the dye, demonstrates a significant photon absorption capacity. The transmission and absorption spectrum for the 35μm Nano porous layer is depicted in Figure 9.
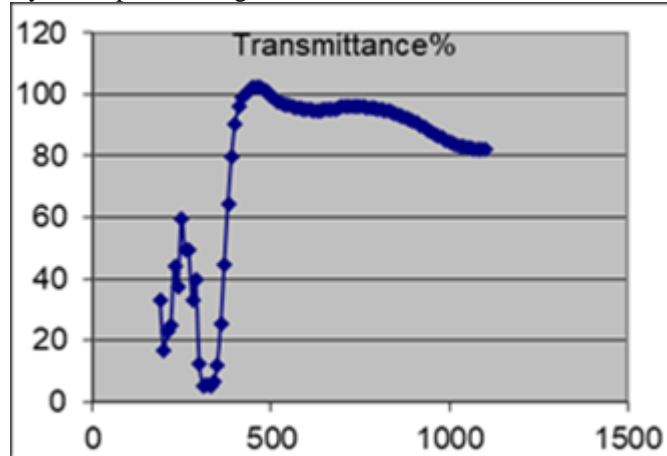

Figure 9 The manufactured devices' measured transmittance and absorption spectra

Titania solar cell with a 45 m dye layer thickness

The fabrication process for the third dye-sensitized solar cell (DSSC) sample involved incorporating a Titania layer with a thickness of 45μm.

Figure 11. The constructed device's absorbance curve was measured alongside its transmission curve.

Dense-layer 40 nm-thick dye-sensitized solar cell

A strategic realignment has been executed, wherein the focus has been redirected towards the modification of the active layer rather than the Nano porous layer. The primary objective of this shift is to investigate the impact of such modifications on both the electrical and optical characteristics. The present study investigates the effects of varying the thickness of the dense layer, specifically up to 40 nm. In the initial phase, an evaluation of the electrical properties of the Dye Sensitized Solar Cell is conducted through the acquisition and analysis of current and voltage measurements. The evaluation was conducted under two distinct conditions: one in a dark environment and the other in a well-lit environment, while strictly adhering to established test parameters. The Dye Sensitized Solar Cell (DSSC) is characterized by a dense layer thickness of 40nm. The graphical representations of the present values of current, voltage, and power are visually depicted in Figure 12, as illustrated below.

Figure 12. Current, Voltage and Power Curve

Similar to earlier experimental findings, it is noticed that no electrical current is present in the absence of light. However, when the sample is exposed to illumination, the maximum current is recorded.
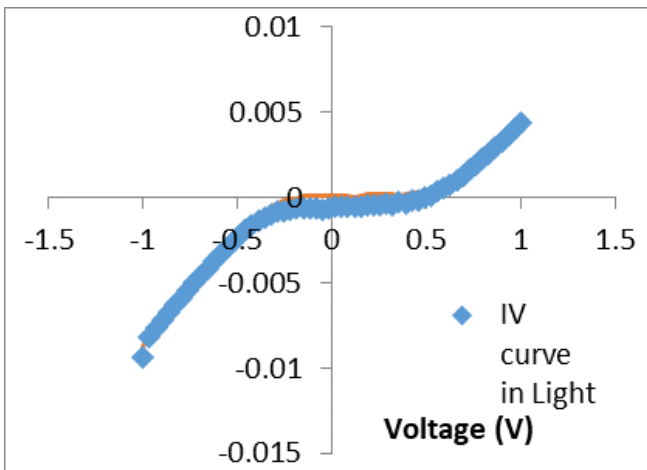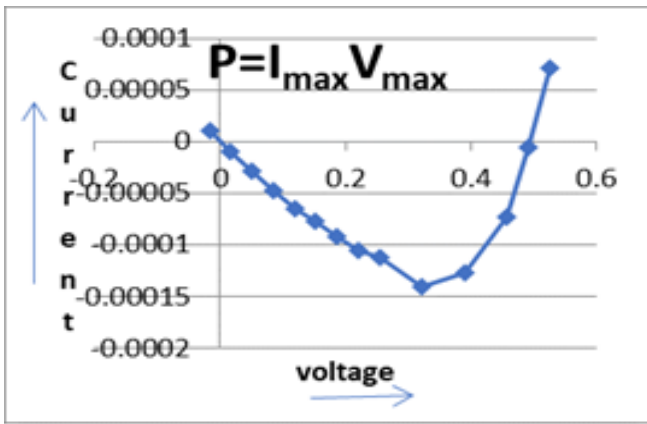

Figure 10. Current, Voltage and Power Curve

This sample was created using the same procedure as the previous cells, with careful attention to maintaining consistent temperature and pressure conditions. The experimental procedure for electrical characterization encompassed the collection of current and voltage data, as depicted in Figure 10. The I-V curve was employed as a means to calculate additional electrical parameters, such as fill factor, current density, and solar cell efficiency. The values of these parameters have been provided accordingly. The optical properties of the photovoltaic device in this particular situation exhibit a strong correlation with the statistics pertaining to transmittance and absorbance. In the preceding chapter, we examined the transmittance and absorbance curves of the Titania dense layer with a thickness of 20nm. However, our present focus is directed towards the Nano porous layer and its influence on the efficiency and optical characteristics of the fabricated solar cells. Figure 11 presents the statistics on transmittance and absorbance for the produced cells. The absorption spectra depicted above yields an estimated band gap of 3.3eV. The majority of the sun spectrum is absorbed, resulting in the excitation of electrons in the semiconductor to the highest energy band of Titania.
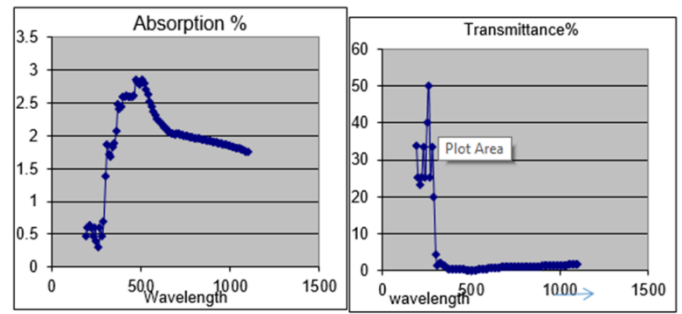
V_{oc}(Volt)	I_{sc}(mA)	V_{max}(volt)	I_{max}(mA)	J_{sc}(mA/cm^2)	F.F%	Efficiency%	DL thickness	NP layer thickness
0.2650	1.220	0.11	0.990	0.2440	30.81	1.990	20nm	25μm
0.476	0.744	0.39	0.33	0.148	36.6	2.59	20nm	35μm
0.49	0.54	0.32	0.43	0.108	56.8	3.005	20nm	45μm
0.364	0.51	0.16	0.025	0.102	2.25	0.83	40nm	25μm

Several methods can explain how Titania thickness affects Dye-Sensitized Solar Cell (DSSC) efficiency. Dye-sensitized solar cells carry electrons via Titania. A lower thickness of 25μm may have led to insufficient carriers for charge transmission. Increased Titania layer thickness may increase carrier numbers and cell efficiency. Another reason is micro-pores, which help transfer electrons. Thicker Titania layers are connected with more micro-pores in the cell's active layer. The study shows that larger Titania layers reduce cell formation. The N719 dye solution is between semiconductor and carbon electrodes in the experiment. This setup stimulates dye molecules by absorbing light. Photons pass through Titania before reaching dye molecules. This layer strongly absorbs or blocks photons, preventing them from reaching dye molecules. Thus, theoretical studies suggest that if Titania is endlessly thick, the solar cell's output may drop to zero due to photon transmission issues with dye molecules. Based on the data and patterns, it seems unlikely that increasing the Titania layer thickness or conducting more experiments would significantly improve efficiency. Table 5.1 shows that Titania layer thickness increases production. Specifically, increasing Titania layer thickness from 25μm to 45μm leads to higher production. Titania and a dye were used to build the Dye-Sensitized Solar Cell (DSSC) technology in two phases. The final step examined the electrical and optical properties of nonporous titanium oxide and carbon-coated solar cells, focusing on their association with dye-sensitized solar cells. My tests show that dye-sensitized solar cells need a nonporous TiO2 layer. Also highlighted are the effects of overcoating the window layer and the decrease in cell output caused by photon occlusion. A 45μm thickness is suitable for the nonporous Titania layer in my case. Increasing the Nano porous layer thickness from 25μm to 45μm increases charge carriers and experimental output. This experimental investigation confirms prior findings and was published in a reputable journal. Due to resource limits, I was unable to experiment with multiple dyes or study the effect of temperature on dye-sensitized solar cells. Future studies should examine solar cell heating and efficiency. The effects of different dyes on solar cell parameters need additional study, and heating experiments can confirm patterns. Future research can use these criteria for controlled experiments.
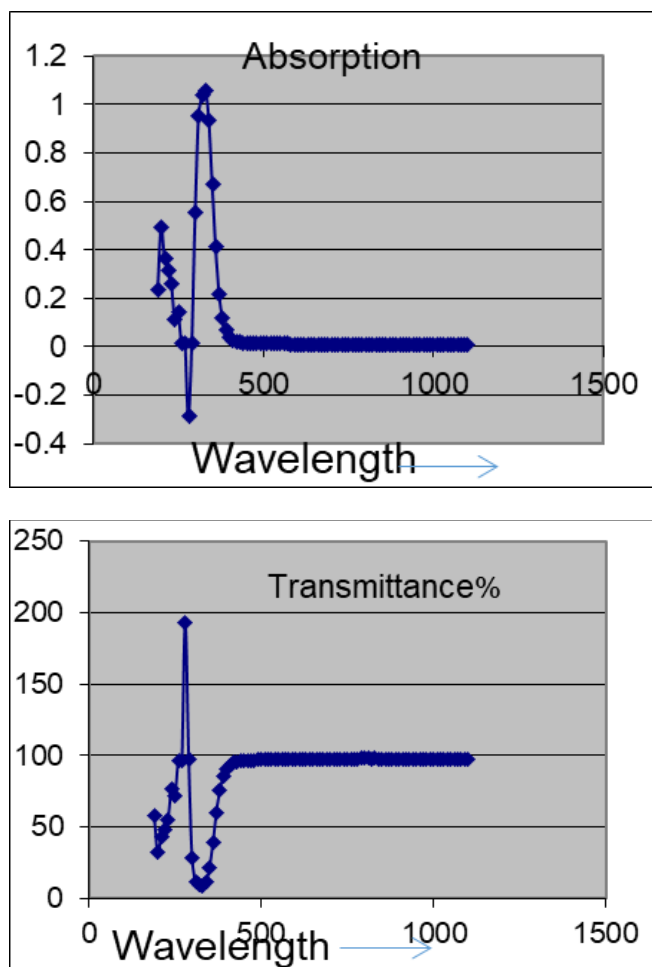

Figure 13. Absorption and Remittance Graph VS Wavelength

It is important to highlight that in the present sample, altering the width of the window layer, also referred to as the dense layer, rather than the active layer, leads to a reduction in the efficiency of the dye-sensitized solar cell (DSSC). The decline in efficiency can be attributed to the window layer's absorption of a significant portion of solar spectrum wavelengths. This absorption impedes the efficient transfer of energy to the active layer, hindering the formation of electron-hole pairs. The graphical representation in Figure 13 illustrates the absorption and transmittance spectra of a window characterized by a thickness of 40nm.

V. CONCLUSION

All experiments were performed under controlled conditions, with a steady pressure of 1 atmosphere and a stable temperature of 50 degrees Celsius. The duration of carbon coating on the ITO glass exhibited a consistent pattern, ranging from 40 to 45 seconds, which closely approximated the duration for which the ITO glass was subjected to the presence of a lit candle. Prior to application to the cells, the dye solution was saturated with ethanol, while the electrolytic solution consisted of a 2% aqueous solution of potassium iodide with iodine (KI/I2). The findings of these trials are comprehensively explained in the following summary.

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