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Ruthenium (N719) Optimization to Improve Dye Sensitized Solar Cell Efficiency

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Abstract: The study aims to characterize and optimizing of Ruthenium as a photosensitizer in dye-sensitized solar cells (DSSC). Samples are made in the structure of the working electrode pair Sandwich and the opponent electrode. Sample absorbency test using UV-Visible LAMBDA 25 spectrophotometer and test current and voltage characterization (I-V) using Keithley 2602A. The results of the study showed that the maximum absorbency in the high dye ruthenium appeared at the two peaks at = 448 nm and = 580 nm. These results show that higher concentrations of ruthenium dye can increase the value of the resulting efficiency. Ruthenium has been prepared using various methods immersion and various intensity with technic deposition use spin coating. The purpose of this research is to obtain optimal efficiency results. Ruthenium can be used as an absorbent material in solar cell applications. The photovoltaic parameters are studied and the power conversion efficiency can reach 0.2%.

Keywords: N719, Solar cell, Efficiency, Improvement.

1 Introduction

The rapidly growing renewable energy in the world today is wind energy and solar energy [1]. The source of wind and solar energy is a source of renewable energy that is clean and freely available [2]. The main problem with these two types of energy is that it is not continuously available. Solar energy is only available during the day [3] when the weather is sunny (not cloudy or rainy). While wind energy is available at times that are often unpredictable (sporadic), and fluctuate heavily depending on weather or season [4]. To address the above problems, hybrid engineering is widely used to incorporate several types of power plants, such as wind, solar, and diesel energy generation, wind, and solar energy generators, wind, and diesel power generation [5]. In this hybrid technique, the battery is generally used as temporary energy storage, and a controller is used to optimize the energy consumption of each source and battery, adapted to the load, and availability of energy from energy sources used [6]. The most widely used solar cells today are silicon solar cells, as the first generation (1st) solar cells [5].

Although solar cells are now dominated by silicone materials, the cost of silicone production makes the consumption cost more expensive than fossil energy sources [4]. Cheap solar cells can be made from organic semiconductor materials [7]. This is because organic semiconductors can be in large quantities of synthesis [8]. Nevertheless, the efficiency is far below the silicon solar cells. Therefore, research on organic material as material from solar cells still needs to be developed.

A dye-sensitized solar cell (DSSC) is the third generation solar cell that utilizes the photoelectrochemical principle [9]. This type of solar cell is believed to provide alternative energy concepts with a more affordable production cost and with simpler fabrication technology compared to its predecessor silicon crystal-based solar cells [10]. The preparation of various types of thin films was highlighted, and power conversion efficiency was discussed as well [11]. On the other hand, the dye was produced by extraction from various natural materials as described.

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Gratzel in 1991 found that titanium dioxide (TiO_2) which was sensitized by the dye in electrolyte solution can produce electric current with 7.1% efficiency [12]. The thickness of the TiO_2 layer affects the number of dye that can be absorbed [13]. The thicker the TiO_2 layer will be more and more of the colored substances are absorbance [14]. As the TiO_2 particles increase, more dye will be bound to the TiO_2 particles, so this will affect the performance of the DSSC cells created. Dye absorption of colorants is done by conducting immersion against thin layers of TiO_2 for a certain period. Various methods to make a thin layer of TiO_2 using the technique of spin coating [15], electrophoresis chemical vapor deposition (CVD), and others [16].

One of the factors that are still a problem in the manufacture of DSSC solar cells is the use of the type of electrolytes both gels and solutions that have an important role in converting light energy into electrical energy in the solar cells [17]. Because of its form in general in the form of a solution, many problems arising related to the use of electrolytes, as well as leakage, evaporation of the possibility of corrosion on the counter-electrode, and so forth. Most of the problems above are related to the problem of stable cell performance in the long term [18]. Moreover, the selection of the right type of electrolyte solution is one of the factors that are still studied by researchers.

Besides, the dye-photosintezer is an important factor in determining the DSSC performance, such as its photosensitivity absorption properties, which directly determines the photo response range of solar cells [19]. Dye serves to absorb visible light, pumping/instruction of electrons into the semiconductor, receiving electrons from the redox pair in the solution, and so on in a cycle, so that dye plays a molecular electron pump. The dye must have a high anthocyanin content, have strong absorption in the area of visible light, high stability, and reversibility in its oxidized form. The dye used in DSSC has conjugated chromophore groups that allow electron transfer [20].

This study used ruthenium as a dye. Ruthenium is one of the chemical elements with atomic number 44. This element is in group 8 with the emblem of Ru. Ruthenium is a silvery-color transition metal, is hard, and has a melting point or high boiling point [21]. The most common compounds for this element are ruthenium trichloride. This compound is shaped in red solids and is widely used as a synthetic chemical. The use of this compound is known in the form of ruthenium dioxide combined with lead and bismuth ruthenate as a thin-film resistor [22].So that ruthenium is a good catalyst for improving solar cell efficiency [23].

Nowadays there have been many researchers who develop DSSC various types of dye obtained from natural ingredients that are plant extracts. Some of which have been developed include dye extracts or plant pigments such as chlorophyll extract, Anthocyanin [24], beta carotene [25]. The development of technology sensitization of organic natural materials is interesting to learn because of the availability of abundant nature. Dye-sensitizer molecules from natural compounds or plant pigments are an organic material that is very promising to be used as a material to manufacture solar cells. One of the conditions for dye can serve as a sensitizer, it must be able to be the transfer medium of electric charge carrier as a result of the absorbed photons.

Based on the results of previous studies [26], synthesis, optical, electrochemical and photovoltaic properties of natural organic dyes and donor-modified N719 for dye-sensitized solar cell applications (DSSC) stating that N719 can be applied to solar cells. This research is an advanced study of our previous research. In this study can explain the variation of the old method of immersion ruthenium and obtained the optimization of the light intensity variation of the halogen lamp to obtain an optimal increase in efficiency results. The purpose of this research is to obtain optimal efficiency results.

2 Experimental Details

The TiO_2 used in this study is Titanium (IV) nanoparticles with a size of 21 nm. TiO_2 as much as 0.5 gr is dissolved in 2 ml of absolute ethanol stirred for 30 minutes using a vortex styrer. TiO_2 is superimposed on the Fluorine Tin Oxide (FTO) conductive glass with the depositor of 2 cm x 1,5cm to use the spin coating method. The deposition layer of TiO_2 is heated at 500°C for 60 minutes above the hot plate. This study used ruthenium dye which was dissolved using Iopropanol where previous research uses ethanol solvent [8]. After stirring then it is allowed to sit for 24 hours at room temperature. The DSSC construction used is a sandwich system. The working electrode in the form of FTO conductive glass that has been coated with TiO_2, which has been soaked with the ruthenium dye. The opponent's electrode is FTO conductive glass that has been coated with thin coating Pt (Hexachloroplatinic (IV) acid 10%). Electrolytes are made from I_2/KI which is dissolved in PEG which is then transmitted between the opponent electrode and the working electrode is given a barrier keyboard protector so that no short circuit occurs. The working electrode and the opponent's electrode that has been transmitted by the electrolyte are then stacked and pinned using the Clipboard. The DSSC Sandwich was then characterized by its current and voltage.

3 Results and Discussions

Research on using ruthenium dye dissolved in isopropanol while previous research using ethanol solvent [8]. Then tested absorbance using Spectrophotometer UV Visible Shimadzhu 1601 PC and current-voltage measurements use I-V meter/Elkahfi 100 from I-V meter to determine the value of electrolyte and dye conductivity. Ruthenium Absorbance measured using UV-Vis Spectroscopy at a wavelength range of 200-800 nm. Figure 1 shows a graphic absorption of Ruthenium with a variety of immersion variation for 18 hours and 24 hours.

Figure 1 describes the difference between the absorption of 18 hours of inundation and 24 hours of submersion in the absorption of the cell in an 18-hour submersion over 24 hours. This is because dye substation within a long time can cause dye particles to rise from sell or prototypes. Automatically, the particles in the sell are less and the absorption is less. Ruthenium's absorption in the study has an absorption peak at a wavelength range of 200-600 nm. The same results were obtained at the research of Gratzel [27, 28,29], Ruthenium can absorb light on the wavelength range of visible light (visible). Current-Voltage(I-V) is a method of knowing the performance of the dye-sensitized solar cells (DSSC) which is how much DSSC capability can convert light into electrical energy the I-V measurements are done in dark and light conditions namely under the illumination of the halogen lamp with variations in intensity. The DSSC conductivity value of ruthenium with variations in intensity can be seen in Figures 2 and 3.

Based on the results of the "I-V Dye" Ruthenium characterization, it obtained the I-V curve in dark and bright conditions. The current value of Ruthenium dye is increased linearly when the voltage value increases. As the amount of Ruthenium dye concentration increases, more Ruthenium dye molecules will produce free electrons [30]. This is a free electron that will produce a flow of charge, so it will generate currents [31]. These characteristics appear in both dark and light conditions. Experimental results showed that the ruthenium dye can produce good electrical current [32]. DSSC Performance Testing a variation of Ruthenium dye concentration was performed to see the effect of concentration on the performance produced by DSSC. This test is done on the condition of using platinum as an opponent electrode. The efficiency produced by DSSC using Ruthenium with treatment on TiO_2 is presented in Table 1. DSSC generates efficiency.

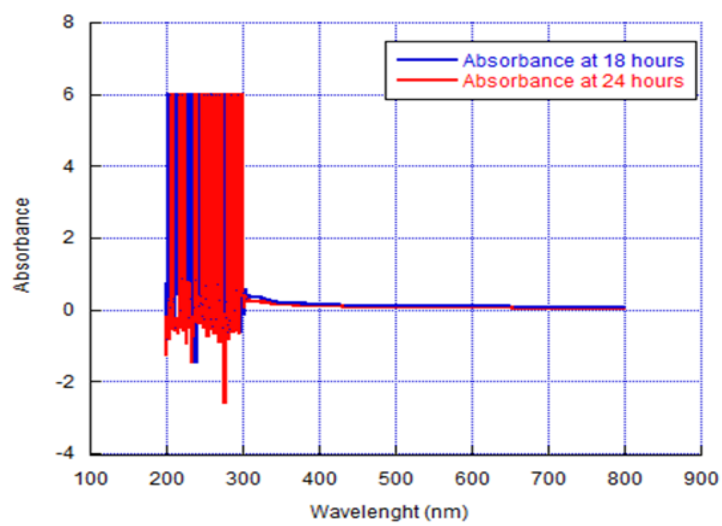
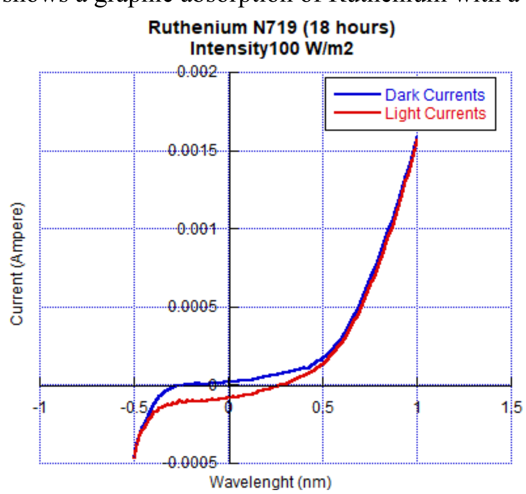
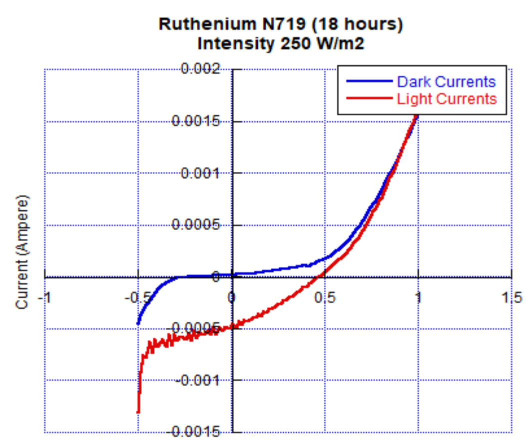


Fig.1: shows a graphic absorption of Ruthenium with a variety of immersion variation for 18 hours and 24 hours.





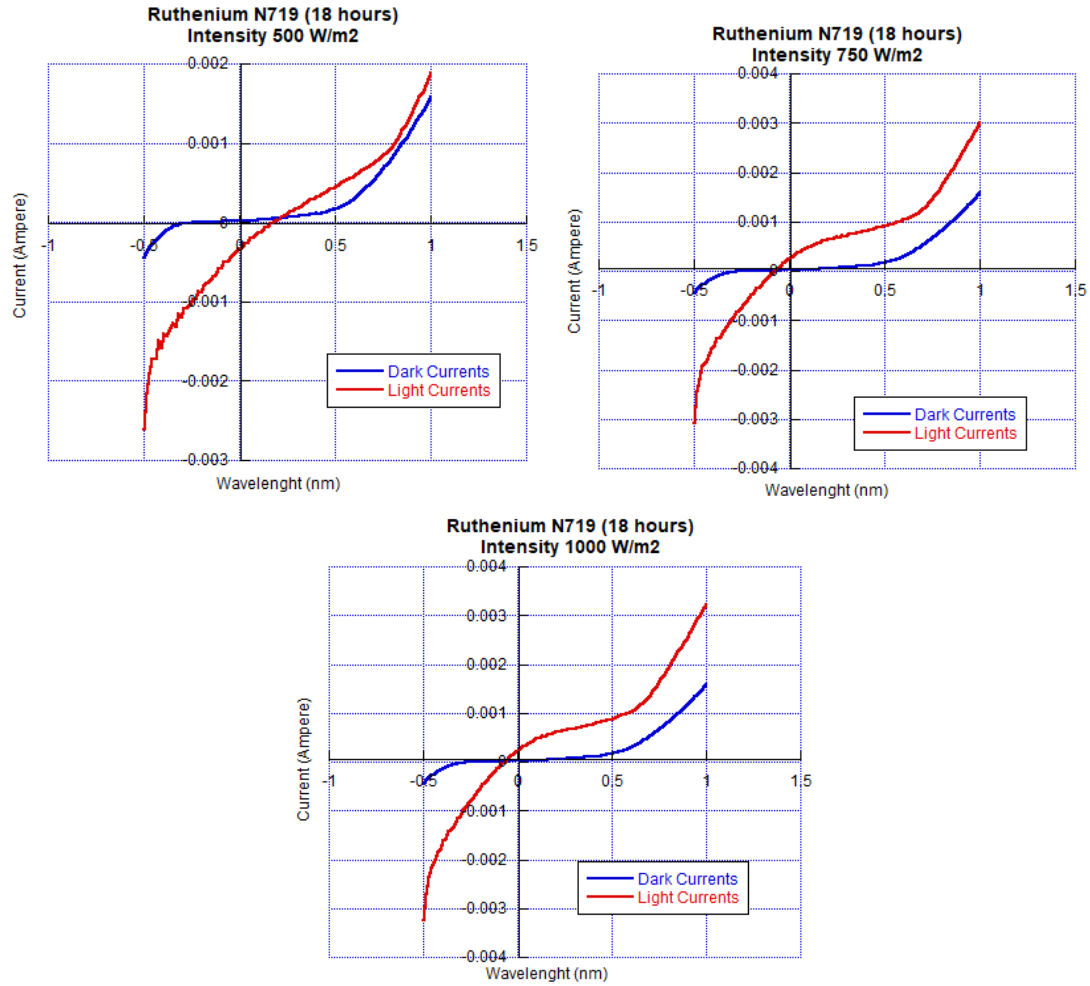
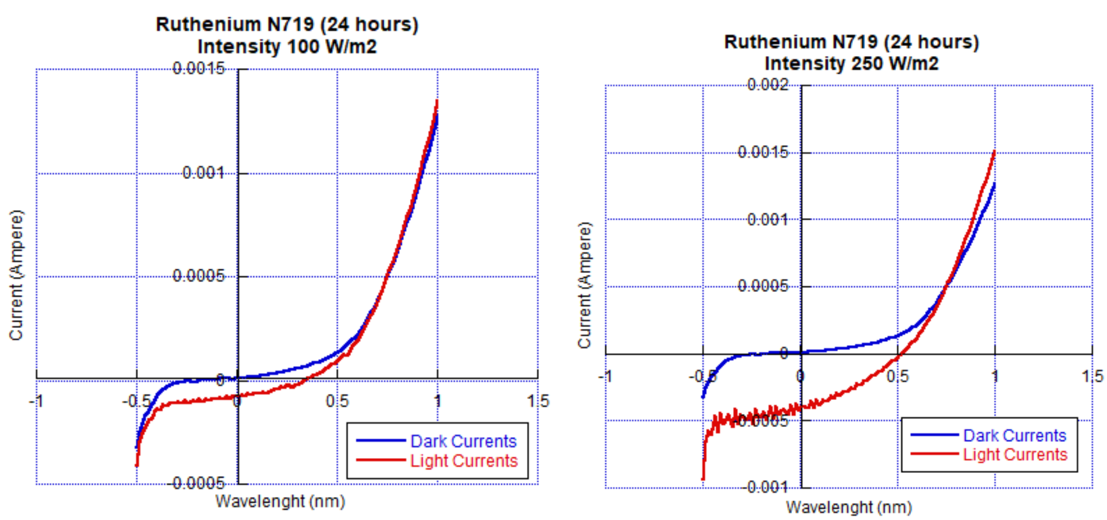


Fig. 2: Chart conductivity at 18 hours immersion.



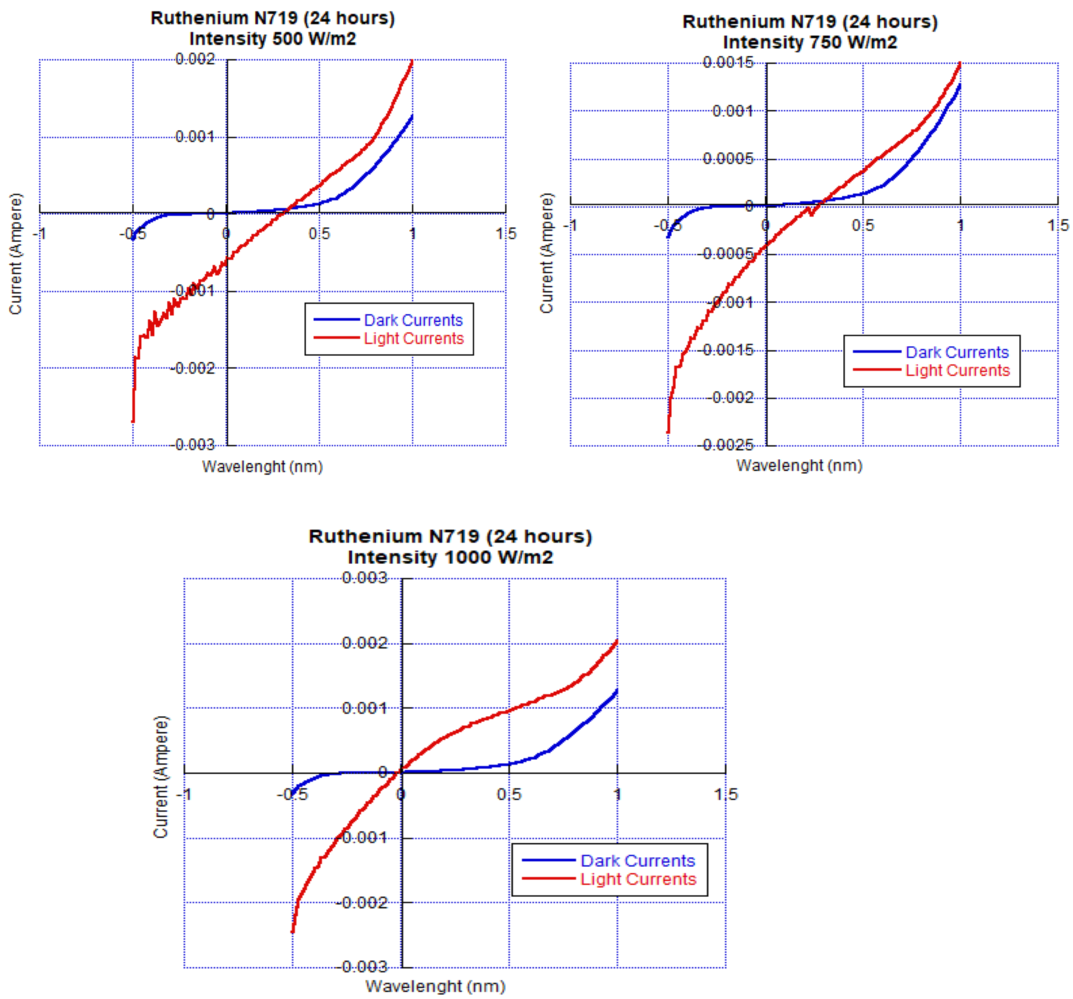


Fig. 3: Chart conductivity at 24 hours immersion.

Table 1: DSSC generated efficiency.

Method immersion	Intensity (W/m2)	Imax (Ampere)	Vmax (Volt)	Isc (Ampere)	Voc (Volt)	Fill Factor	Efficiency (%)
18 hours	100	3.3×10^{-6}	0.28	8.2×10^{-6}	0.28	2.7×10^{-10}	0.034
	250	1.2×10^{-5}	0.46	4.5×10^{-4}	0.46	5.8×10^{-9}	0.125
	500	1.3×10^{-5}	0.16	3.2×10^{-4}	0.16	4.4×10^{-9}	0.012
	750	1.8×10^{-4}	0.28	2.8×10^{-4}	0.38	1.4×10^{-7}	0.184
	1000	5.7×10^{-4}	0.17	2.5×10^{-4}	0.23	1.0×10^{-7}	0.060
24 hours	100	1.1×10^{-5}	0.37	7.9×10^{-5}	0.37	8.7×10^{-10}	0.004
	250	3.6×10^{-6}	0.52	3.9×10^{-4}	0.52	1.4×10^{-9}	0.028
	500	1.6×10^{-5}	0.31	5.6×10^{-4}	0.31	9.0×10^{-9}	0.021
	750	2.7×10^{-5}	0.28	3.9×10^{-4}	0.28	1.1×10^{-8}	0.010
	1000	4.8×10^{-4}	0.17	7.5×10^{-5}	0.32	1.9×10^{-8}	0.101

The results of the optimization showed the efficiency gained in this study is 0.184% using dye Ruthenium (N719) in table 1, using Pt (Hexachloroplatinic (IV) acid 10%) As an opponent electrode. From Table 1 can be explained that the longer the immersion process can result in the ruthenium dye injection process towards TiO_2 scrape the surface of the electrode so that the resulting efficiency is unstable.

Figure 2 and figure 3 showed illumination of the halogen lamp with variations in intensity at 18 hours and 24 hours. Variation of intensity [100, 250, 500, 750 and 1000 W/m2] show conductivity cell. Conductors of 18 hours are higher than 24-hour conductivity. This is because the electron that flows on the 18-hour cell is relatively stable, so the currents that result in more than the intensity of the 24-hour cell.

4 Conclusions

Measurement and analysis of the absorption spectral of Ruthenium dye have been performed with varying intensity and immersion. The results showed that Ruthenium dye had a spectrum of absorption in wavelengths between 200 – 600 nm, thereby Ruthenium was able to absorb light at a wavelength range of visible light (visible). The higher the concentration then the higher the efficiency is generated. This makes ruthenium materials need to be investigated as a DSSC sensitizer material. Long immersion ruthenium dyes may affect DSSC performance. Awarding of Pt (Hexachloroplatinic (IV) acid 10%) On the opponent's electrode provides better performance on DSSC. Pt (Hexachloroplatinic (IV) acid 10%) Catalyzes accelerating the redox reaction with electrolytes. The resulting efficiency is 0.2%.

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