EINSTEIN (e-Journal)
Jurnal Hasil Penelitian Bidang Fisika
Available online http://jurnal.unimed.ac.id/2012/index.php/einsten
e-issn: 2407 – 747x, p-issn 2338 – 1981

EFFECT OF DURATION OF ZnO PROTOTOTYPE DYE SENSITIZED SOLAR CELL LAYERS OF FAMBIR (UNCARIA) FRUIT EXTRACT AS A PHOTOSENSITIZER

Rahmatun Toyyibah[1], Abdul Rais[1]
[1]Department of Physics, Faculty of Mathematics and Natural Sciences, Medan State University
rahmatuntoyyibah.4201240009@mhs.unimed.ac.id

Submit: April 2026. Approved: May 2026. Published: June 2026.

ABSTRACT

DSSC research using organic dyes has been carried out by fabricating solar cells using dyes from gambir plants. The stages of this research are the manufacture of gambir fruit dye as a photosensitizer. This study aims to determine the effect of DSSC performance due to variations in soaking time. XRD test results show crystal sizes of 28.44536 nm, 7.66144 nm, 8.3061 nm, 2.93336 nm, and 19.97532 nm. SEM characterization of the ZnO layer on FTO glass looks uneven due to the difficulty of regulating the stability of the layer using the Doctor Blade method. UV-Vis characterization with a wavelength of 200-800 nm shows the results that the dye solution can work in invisible light to visible light with an absorbance value of 5.254 a.u. The current and voltage values in the immersion variation will be accumulated to determine the efficiency value of the DSSC. The efficiency values for 14 hours, 16 hours, and 18 hours are 0.0146%, 0.0192% and 0.0692%

Keywords: ZnO, DSSC, Doctor Blade Method, XRD, SEM, UV-Vis

INTRODUCTION

Energy is one of the important things to help in the continuity of human activities, energy consumption to meet the needs is increasing in all sectors. Based on data from the National Energy Council (DEN), Indonesia's energy needs in 2020 amounted to 290 million tons, an increase from the situation two years ago of 185 million tons or one percent of global consumption needs, but the government's target through the National Energy Policy (KEN) in 2022 that the use of oil energy will be less than 25% by 2025 and targets a reduction in energy efficiency by 1% per year to encourage savings in the use of fossil-derived energy in all sectors (Secretariat General of the National Energy Council (DEN), 2022).

One possible effort is to utilize sunlight to produce renewable energy. Solar cell is a photovaltaic device that can convert solar energy into electrical energy. The most widely used solar cells are first generation solar cells, second generation thin film solar cells and solar cells derived from non-organic materials and DSSC type solar cells. DSSC type solar cells are a type of third generation solar cells that apply photoelectrochemical principles as alternative energy with more affordable production costs and simpler fabrication technology (Hardani, 2020). DSSC functions to convert light energy into electrical energy based on semiconductor materials.

DSSCs are made from organic and inorganic materials by utilizing dyes to increase the sensitivity of solar cells. DSSC consists of three main components in its application to convert solar cell energy into electrical energy, namely working electrodes, opposing electrodes and electrolyte solutions. Semiconductors in DSCC are TiO2 (Titanium Oxide) and ZnO (Zinc Oxide) which have a mesoporous structure. TiO2 has an energy gap of 3.2 eV which can absorb light in the ultraviolet region. TiO2 and ZnO are good semiconductor materials used in solar cells as photovoltaic. ZnO thin layer preparation is carried out by various techniques, one of the techniques in the dissolution process is the doctor blade method which has the advantage of low cost, position control in applying the material layer, and intrinsic defects can be reduced (Hanavi, 2019).

Dye comes from organic compounds from leaves, fruits and flowers that contain anthocyanin compounds. Natural dyes have an important role to absorb photons from sunlight and convert them into electricity (Dwi Fahyuan et al, 2015). The working principle of DSSC that can convert light energy into electrical energy then when the dye attached to the surface of ZnO will absorb photons from sunlight, electrons will be excited into the conduction band of ZnO. One of the dyes derived from plants that can be used as a sensitizer in solar cells is gambir (Uncaria) fruit because of the content of certain chemical compounds in gambir that can act as a photosensitizer pigment. The color substance from gambir fruit functions as an electron conductor in DSSC. The use of gambier fruit in DSSC is as a pigment.

RESEARCH METHOD

Gambir fruit seeds were first cleaned, then cut into small pieces and dried in a furnace at 90°C for 2 hours. 30 ml of methanol solution, 4 ml of acetic acid and 20 ml of aquabidest were put into a beaker and stirred until smooth. Then, 20 grams of crushed gambier seeds were added to the mixed solution of methanol, aquabidest, and acetic acid, and stirred for 50 minutes. The stirred solution was put into a bottle and closed for maceration process for 24 hours at room temperature. The dye was then characterized by a Uv-Vis spectrophotometer to obtain the highest absorbance value and wavelength of the dye solution.

ZnO paste was made by dissolving 2 grams of ZnO powder into 16 ml of methanol in a beaker, heated and stirred using a hotplate magnetic stirrer for 50 minutes at 100 °C with a speed of 200 rpm, the ZnO solution was precipitated and then filtered to form a paste that would be placed on a 2 cm x 2 cm FTO glass using the doctor blade method. The ZnO paste deposited on the FTO glass was soaked with gambier fruit dye solution with 3 variations of time, namely 14 hours, 16 hours and 18 hours then the FTO glass was lifted and the glass side was cleaned using tissue.

In the manufacture of Counter Electrode with carbon coating, the conductive side of the FTO glass is shaded with a 7B pencil evenly and then the side is talented using wax until a carbon layer is formed. Then the glass that has been coated with carbon is heated at 400 °C for 10 minutes. The working electrode is attached to the glass coated with ZnO paste and attached to the glass that has been coated with carbon from burning the candle. Previously, both electrodes were dripped with two drops of electrolyte solution. This layer was then clamped with paper clips on both sides of the layer.

The sandwich layer is given an alligator clip as a contact to the cell. This layer is measured the current and voltage values using a multimeter with sunlight or lights. To measure the current and voltage of the DSSC assembled with a multimeter, the current and voltage on the DSSC layer that has been formed is measured by providing a 20 kΩ resistance. The light source used is sunlight, the light source is perpendicular to the cell surface.

RESULT AND DISCUSSION

UV-Vis *dye* Gambir

Gambir fruit extract was analyzed using a UV-Vis spectrophotometer to determine the absorbance value and wavelength of the gambir fruit dye. The absorbance spectrum of gambir fruit extract that has been caratecrystallized is measured with a wavelength range of 200-800 nm, shown in the graph below:

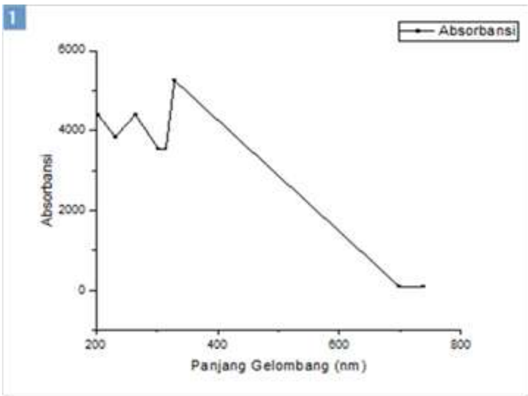

Figure 1. UV-Vis test results of Gambir dye

Based on Figure 1 shows that the dye solution of gambir fruit that has been carried out UV-Vis characterization works in invisible light to visible light. Based on research conducted by (Nurdin Siregar, 2019) the dye solution in DSSC works in visible light with a wavelength of 200-800 nm which is responsible for absorbing sunlight and converting it into electrical energy.

Based on the graph above, the absorbance peak of gambir dye is obtained with the following wavelengths:

Table 1. Absorbance Data of Gambir Fruit Extract

No	P/V	Wavelength (nm)	Absorbance
1	↑	739	0.087
2	↑	699	0.094
3	↑	329	5.254
4	↑	315	3.536
5	↑	303	3.536
6	↑	265	4.394
7	↑	232	3.843
8	↑	204	4.374

Based on table 1, the highest absorbance value is at a wavelength of 329 nm with a value of 5.254 a.u., and the lowest absorbance value is at a wavelength of 739 nm with a value of 0.087 a.u.. In table 4.1 above there is a P / V (Peak-to-Valley) ratio with an arrow generated in the study, namely an upward arrow that describes the ratio between the highest positive peak and the lowest negative valley in the absorbance spectrum.

XRD Characterization of ZnO Paste

XRD characterization of DSSC is carried out to determine the phase contained in the ZnO paste sample and to know the crystal size of the sample.

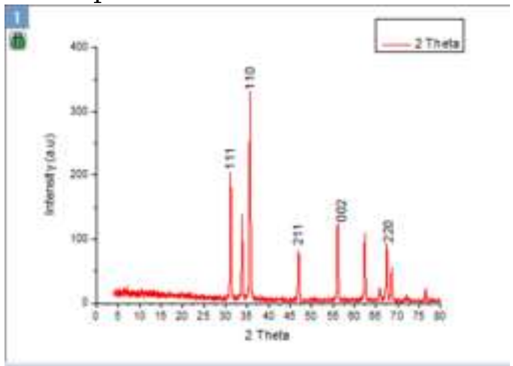

Figure 2. XRD characterization of ZnO paste

Based on the XRD characterization of ZnO paste as a semiconductor without soaking in Figure 2, there are 5 peaks at 2 Theta angles, namely: 31.22 ; 35.70 ; 47.02; 68.62; 56.08 with Mille Index (hkl): (110), (111), (211), (220), (002). This crystal peak is formed from Wurtzite Hexagonal phase, Wurtzite Hexagonal crystal phase is a stable ZnO crystal structure with a lattice constant of 3.25 Å (Amaliya, 2024). This phase is most common in DSSC applications because it can capture and move electrons. To determine the size of ZnO crystals at various peaks using the Scherer equation formula:

$$D = \frac{k\lambda}{\beta \cos \theta}.$$

XRD Characterization of ZnO Immersion 18 Hours

ZnO paste that has been coated on FTO glass and soaked for 18 hours in gambir fruit extract dye solution was characterized by XRD to determine the phase and crystal size. In this sample sandwich layer serves as a working electrode to capture light energy and convert it into electrical energy.

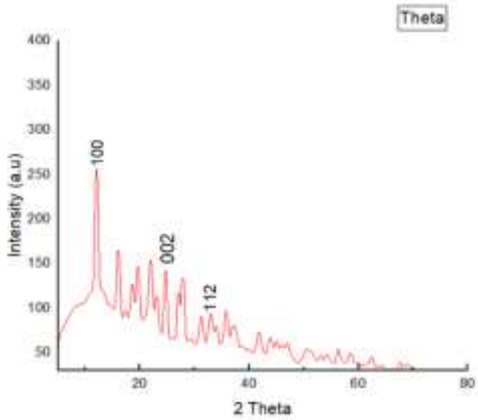

Figure 3. XRD Characterization of ZnO Immersion 18 Hours

Based on the characterization of ZnO with 18 hours of immersion in Figure 3 there are 3 peaks at angle 2 Theta, namely: 17.90 ; 21.09 ; 35.94 with Mille Index (hkl) which is (100), (002), (112). This Mille index serves as a parameter determinant that measures the efficiency of solar cells. The crystal phase in ZnO paste with dye solution immersion is Wurtzite HexagonSal. This phase is also found in ZnO paste without immersion. The crystal size of the sample was measured using the Scherer equation. The measurement results to determine the crystal size are presented in the following table below:

Table 2. 18-hour immersion ZnO crystal size data

No	Measurement Results			
	2 Theta	FWHM	D (nm)	Crystal Phase
1	12.08	0.4000	19.9715	*Wurtzite HexagonSal*
2	24.98	0.2800	28.0602	*Wurtzite Hexagonal*
3	35.94	2.7200	3.0704	*Wurtzite Hexagonal*

SEM Characterization Results

ZnO paste that has gone through the coating process with the Doctor Blade method on FTO glass is carried out Scanning Electron Microscope (SEM) characterization which aims to see the marfology and surface structure of ZnO paste on FTO glass.

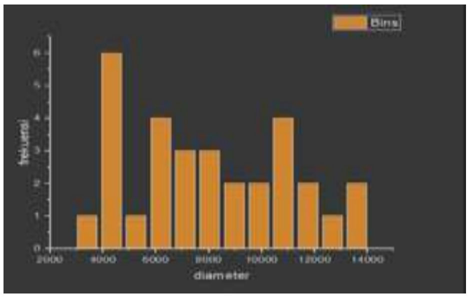

Figure 4. 2000x Magnification ZnO Paste Crystal Size Diagram

Figure 4 is the crystal size diagram of SEM characterization of ZnO paste. In determining the crystal size of 2000x magnification SEM characterization data is processed using image.j programming and graph making using origin programming. (Hernowo & Nurhasanah, 2019) stated that ZnO nanomaterials can have crystallization and various crystal sizes depending on the method and parameters of the synthesis. The resulting ZnO paste crystal size has a crystal size in the range of 3,000-4,000 nm. From Figure 4, it can be seen that the most crystal size is in the range of 4,000 nm and 11,000 nm. The results of ZnO paste marphology are presented in the figure below:

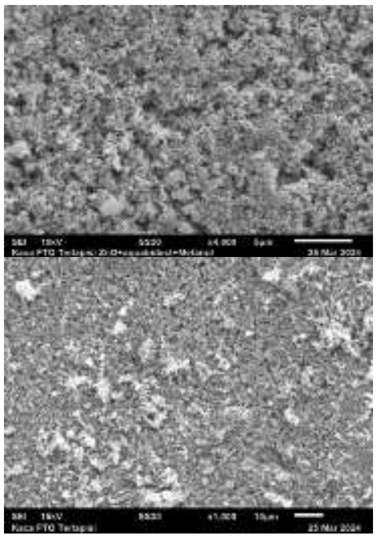

Figure 5. (a) SEM Characterization of ZnO Paste Magnification 4,000x, (b) SEM Characterization of ZnO Paste Magnification 2,000x.

Figure 5 (a) and (b) are SEM characterizations of ZnO paste with magnifications of 4,000x and 2,000x, at these magnifications the structure looks porous between particles but the ZnO paste in the layer looks unevenly distributed. In Figure 5 (b) at

2,000x magnification there is a light color and clumps which is a thick layer of ZnO paste. The factor causing the uneven distribution of ZnO paste is that during the coating process with the Doctor Blade method, the thickness of the ZnO paste on the FTO glass has difficulty in adjusting the thickness of the paste layer. As a result of the instability of the ZnO paste layer can affect the performance of DSSC. To produce good DSSC performance, the ZnO paste layer on FTO glass must be evenly distributed so as to produce many pores to absorb dye so that many electrons are excited when exposed to sunlight.

Current and Voltage Measurement Results

DSSC performance testing is done by making a sandwich layer consisting of several components, namely FTO glass that has been coated with ZnO then immersed in dye solution for 14 hours, 16 hours and 18 hours, and a comparison electrode in the form of FTO glass that has been coated with carbon from burning candles. This layer is arranged in the order of the carbon layer (comparison electrode) placed on the bottom side then the FTO glass coated with ZnO is placed in the upper position, then the two sides of the sandwich layer are given a paper clip.

Table 3. DSSC Performance Test of Gambir Fruit Extract

Soaking Time	Resistors kΩ	Voltage (V)	Current (A)	Power (W)
14 Jam	20 k Ω	0.308	15.4×10^{-6}	4.74×10^{-6}
16 Jam	20 k Ω	0.340	17×10^{-6}	5.78×10^{-6}
18 Jam	20 k Ω	0.399	19.95×10^{-6}	7.96×10^{-6}

Table 3 above is the result of the DSSC measurements that have been assembled. Current and voltage testing using sunlight intensity at 12:00 WIB at a temperature of 33 °C. In the measurement used a digital multimeter to measure the voltage that will be generated by DSSC. Then to find out the value of current and voltage, the ohm approach is used to analyze the measurement results. In table 3 above, the high current and voltage are produced from 18 hours of immersion with a current value of 0.399 Volts and a current of 19.95×10^{-6}.

To find the efficiency value of each DSSC layer at each immersion, formula 3.2 is used. The efficiency value produced in 14 hours immersion is 0.0146%, 16 hours immersion is 0.0192% and 18 hours immersion is 0.0692%. From the graph it can be seen that the longer the soaking time, the higher the efficiency value produced. The effect of the immersion time of the semiconductor layer that has been coated on the FTO glass which is immersed in the dye solution can affect the performance value of the DSSC. Based on research conducted by (Fernince Ina Pote, 2022) that the effect of the length of immersion variation on DSSC will affect the current strength and voltage produced. The longer the immersion time, the higher the efficiency results obtained. However, the length of immersion in DSSC also affects the semiconductor layer on FTO conductive glass. The addition of electrolyte solution to the DSSC sandwich layer also affects the results of DSSC performance because this solution functions as a conversion of solar energy into electrical energy. From the calculation of the efficiency value that has been obtained, the highest value occurs at the immersion time of 18 hours with an efficiency value of 0.0692%.

CONCLUSION AND SUGGESTION

Conclusion

Dye Sensitized Solar Cell (DSSC) using gambir fruit extract with ZnO semiconductor material as a photosensitizer has been produced. Based on UV-Vis testing that has been done on gambir fruit dye solution can work in visible light with the highest absorbance value of 5.254 a.u at a wavelength of 329 nm and UV-Vis test results on ZnO semiconductors can work in UV light. XRD characterization of ZnO paste samples without soaking there are peaks that have mille indices (110), (111), (211), (220), (002) with crystal sizes 28.0814 nm, 29.4590 nm, 36.0976 nm, 80.18 nm, 25.0022 nm with Hexagonal Wurtzite crystal phase. XRD characterization of the working electrode has mille index peaks (100), (002), (112), with crystal sizes of 19.9715 nm, 28.0602 nm, 3.0704 nm. SEM characterization of the ZnO layer on FTO glass looks uneven due to the difficulty of regulating the stability of the layer using the Doctor Blade method. In DSSC, the smaller the crystal size and the more pores in the ZnO layer produced, the easier it is for dye absorption. The results of DSSC performance are seen in the length of semiconductor immersion in dye solution. the longer the immersion in the dye, the higher the resulting efficiency value. From this study, the efficiency value produced at 14 hours of immersion is 0.0146%, 16 hours of immersion is 0.0192% and 18 hours of immersion is 0.0692%. The highest efficiency value is obtained at 18 hours of soaking.

Suggestion

Suggestions for further research are to use the spin coating method in research on dye sensitized solar cells to flatten the paste during deposition on FTO/ITO glass. SEM characterization should be carried out on FTO glass that has been coated with ZnO paste on dye solution immersion. FTO glass that has been coated with ZnO paste should be furnace for 30 minutes and stirrer for 30 minutes with a temperature of 200 ° C. To avoid loss or reduction of ZnO paste layer during immersion time.

REFERENCES

Amaliya, S. T. (2024). Zno nanoparticles using precipitation method with Ph-7. XII, 161-168.

Dwi Fahyuan, H., Samsidar, Farid, F., Heryanti, Napitupulu, S., & Pakpahan, S. (2015). Design of Dssc (Dye Sensitized Solar Cell) Prototype Graphite/Tio 2 Layer Based on Natural Dye. JoP, 1(1), 5-11.

Fernince Ina Pote (2022). Effect of Chlorophyll Soaking Time Variation of Natural Dye Extract on the Efficiency of Dye Sensitizer Solar Cell (DSSC). Magnetic: Research Journal of ..., 2(2), 156-161.

Hanavi. (2019). Synthesis of Zno Powder and its Use as a Photoanode in Color-Sensitized Solar Cells. Indonesian Journal of Materials and Energy, 9(01), 44. https://doi.org/10.24198/jmei.v9i01.24323

Hardani. (2020). DYE-SENSITIZED SOLAR CELL (DSSC) Theory and Application (L. M. Angraini (ed.); First). CV.Pustaka Ilmu Group Yogyakarta.

Hernowo, A., & Nurhasanah, I. (2019). CRISTALITY AND SIZE OF ZnO NANOPARICLES CALCIATED AT TEMPERATURES OF 100°C and 200°C. Physics Periodical, 22(4), 125-131.

Nurdin Siregar. (2019). Dye Sensitized Solar Cell (Dssc) Using Zno:B Thin Film and Dye Extract from Purple Sweet Potato. EINSTEIN E-JOURNAL, 7(1), 5-9. https://doi.org/10.24114/einstein.v7i1.12485

Rais, F. S. and A. (2021). Analysis of Dye Sensitized Solar Cell (DSSC) Prototype Making Using Anthocyanin from Kakoa Seed Dye as a Photosensitizer. Journal of Research Results in Physics, 16-22.

Secretariat General of the National Energy Council (DEN). (2022). Energy Policy; Renewable Energy Policy. In Energy Outlook Indonesia 2022.

Wibowo, A. (2022). Solar Electric Panel Installation. In Prima Agus Teknik Foundation Publisher (Dr. Joseph). STEKOM University.

Yuda Purwadi, A. (2017). Study of the Characteristics of the I-V and P-V Curves of the PLTS System Connected to the PLN Network One Phase 220 VAC 50 HZ using Tracking DC Logger and Low Cost Monitoring System. 174–183. https://doi.org/10.21063/pimimd4.2017.174-183