Dye-sensitized Solar Cell With Water Hyacinth (Eichhornia Crassipes) As Photosensitizer and Xanthan Gum As Thickening Agent in The Electrolyte

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Abstract. The dye-sensitised solar cell is a photoelectrochemical-based solar cell that uses a natural dye as the photosensitizer and an electrolyte as the charge transport medium. The volatility of the electrolyte is one of the causes of instability; therefore, a thickening agent was added to reduce the volatility. The aim of this study was to determine the electrical performance of a dye-sensitised solar cell using an extract of water hyacinth leaves as a photosensitizer and xanthan gum (XG) as a thickening agent in the electrolyte. Extraction of the dye from water hyacinth leaves using ultrasonic waves and deposition of TiO2 films on TCO using the squeegee method. The extracted dye contained 10.74 mg/L chlorophyll. The concentrations of XG were 1, 3 and 5 % (w/v). The highest efficiency (0.017%) was found with the addition of 5% GX, with the electrical output of Voc 0.721 V, Isc 0.0127 mA, Vmax 0.508 V, Imax 0.0102 mA, Pinput 29.7 mW, Poutput 0.005182 mV, FF 0.56588.

Keyword: Dye-sensitized Solar Cell, Water Hyacinth, Photosensitizer, Xanthan Gum, Electrolyte

1. Introduction

Indonesia, as a tropical country, has abundant sunlight with a stable sunlight intensity throughout the year [1]. Plenty of sunlight with a stable intensity can be used to generate electrical energy. To use the photovoltaic effect, a solar cell is needed that can convert sunlight directly into electrical energy. Solar cells are divided into three generations. The first generation is monocrystalline and polycrystalline silicon, the second generation is thin-film solar cells and the third generation is photochemical solar cells, which were introduced by Professor Gratzel in 1991. This third solar cell was called Dye Sensitised Solar Cell (DSSC). DSSC is able to convert solar energy into electrical energy by using organic substances (dyes) as sensitizers. Dye and electrolyte

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play an important role in generating electrical energy in DSSC. The weak point of DSSC is the instability of the electrical energy, as it is easily consumed when the dye and electrolyte dry out.

One of the potential dyes for DSSC is the chlorophyll of water hyacinth. Water hyacinth (Eichhornia crassipes) is one of the weeds commonly found in water bodies such as lakes and marshes. Water hyacinth contains a chlorophyll pigment that can be used as a photosensitizer in DSSC. The extraction method used in this study is ultrasound-assisted extraction (UAE). UAE has the advantage of providing optimal extraction results, saving time and solvent. Another advantage of UAE is the wider and optimal surface contact between the solid and the liquid due to the direct contact between the particles and the ultrasonic wave. Some previous studies reported the extraction of active compounds such as chlorophyll and carotenoids using UAE [2] [3].

DSSC is a photoelectrochemical-based solar cell that uses an electrolyte as a charge transport medium. However, the use of liquid electrolytes leads to unstable currents and voltages with a drastic drop in current in a short time. This is because the electrolyte evaporates more quickly or has a high evaporation rate due to its low viscosity, so it cannot be used for a longer period of time. The volatility of the electrolyte can be delayed by increasing the viscosity of the electrolyte by adding a thickening agent. The thickening agent used in this study was xanthan gum. Xanthan gum is inexpensive, water soluble and can be used as a thickening and stabilising agent [4]. The aim of this study was to determine the electrical performance of a dye sensitised solar cell (DSSC) using an extract of water hyacinth leaves as a photosensitizer and xanthan gum as a thickening agent.

2. Materials and Methods

2.1 Materials

The leaves of the water hyacinth come from the marshland in Inderalaya, South Sumatera. Transparent Conductive Oxide (TCO) glass surface of 2.5 cm x 2.5 cm, ITO substrate (Sigma Aldrich), 70% methanol as solvent, acetic acid 0.1N, and distilled water, xanthan gum.

2.2 Dye extraction

The fresh water hyacinth leaves were thoroughly washed of dirt. The leaves were cut into small pieces and 50 g weighed. Then 100 mL of distilled water was added to the leaves and pureed in a blender by adding 100 mL of distilled water to the blender. The liquid from the extraction was used as a photosensitizer.

2.3 TiO_2 preparation and thickening solution

One gramme of TiO_2 powder and 1.8 mL of acetic acid 0.1N were placed in a beaker and mixed to form a homogeneous paste. This paste was then applied to the TCO using the squeegee method. The thickening solution was prepared by weighing out an amount of xanthan gum (1, 3 and 5 g) and diluting in 100 mL of iodide electrolyte solution. The electrolyte was stirred with a magnetic stirrer to obtain a homogeneous thickening solution.

2.4 DSSC assembly

TCO coated with TiO2 paste was heated in an oven at 105oC for 30 minutes. Dye in an amount of 0.5 mL was added to the dried TiO2 paste on TCO. The dye was immersed in the TiO2 paste for ten minutes and then rinsed with distilled water and methanol. The TCO substrate coated with the dye was then sealed with a prepared carbon fibre TCO substrate. The two pieces of TCO substrate were clamped together with a clamp binder and then filled with an electrolyte to which xanthan gum was added. The resulting DSSC sandwich was further tested for electrical performance.

2.5 Measurement of electrical performance

The electrical output of the DSSC assembly was measured using a simulation device whose light source is a halogen lamp (50 W; average light intensity of 0.0062 W/cm2) at a distance of 10 cm from the DSSC. The parameters observed were Voc, Isc, FF and efficiency

3. Results and Discussion

3.1 Absorption spectrum of extracted dye

The extracted dye was measured at a visible light wavelength of 400 nm to 700 nm. Figure 1 shows the first absorption peak at a wavelength of 470 nm with an absorbance of 0.875 and the highest absorption peak at a wavelength of 650 with an absorbance of 0.918. The extracted dye from the water hyacinth leaves contained 10.74 mg/L chlorophyll. During photosynthesis in chlorophyll, the visible spectrum of visible light from violet at a wavelength of 380 nm to red at a wavelength of 750 nm is absorbed. The energy used is in the form of photons that come from the light spectrum, where the energy is inversely proportional to the wavelength. The blue light spectrum with a wavelength of 400-500 nm is maximally absorbed by carotenoids, while the red light spectrum with a wavelength of 600-700 nm is maximally absorbed by chlorophyll during photosynthesis [5]. The blue light spectrum has a short wavelength but a greater energy than the red light spectrum, which has a longer wavelength. The absorption of the extracted water hyacinth leaves is shown in Figure 1.

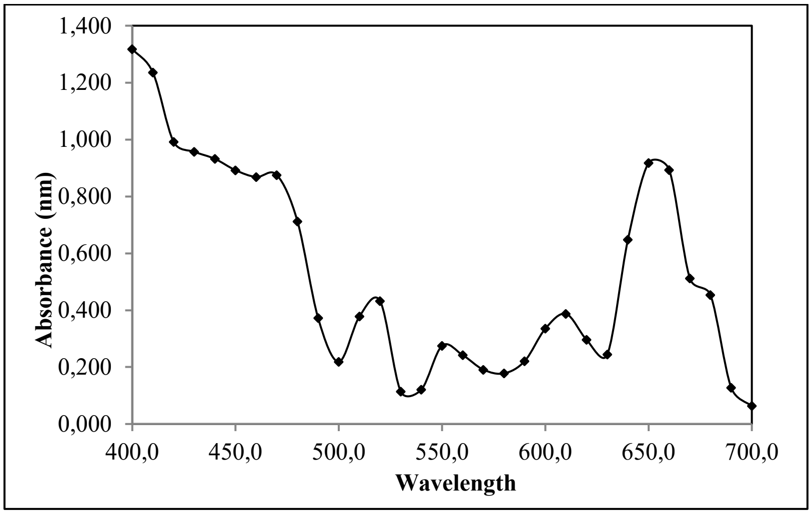


Figure 1. Absorbance of extracted water hyacinth leaves

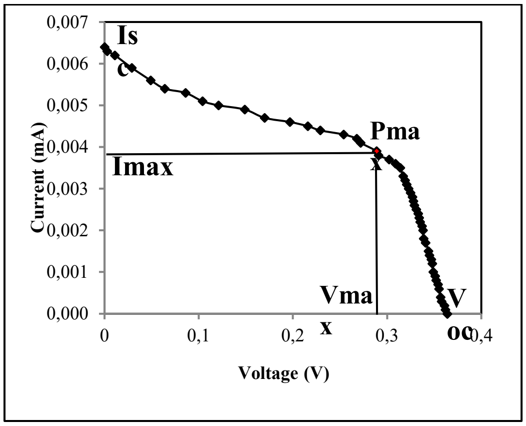
3.2 Characteristics of I-V on extracted water hyacinth leaves

Based on the current and voltage generated, the electrical characteristics was obtained including: 1) short circuit current (Isc), 2) open circuit voltage (Voc), 3) maximum current (Imax), 4) the maximum voltage (Vmax), 5) Fill Factor (FF), 6) maximum power (Pmax), and 7) DSSC efficiency are presented in Table 1.

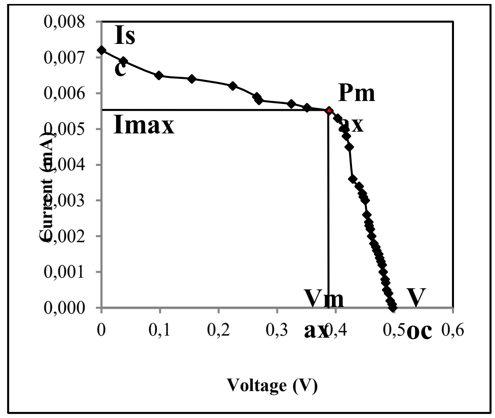
Table 1. Characteristics of DSSC with dye of water hyacinth and Xanthan gum as thickening agents

DSSC	Main and processed data							
	Voc (V)	Isc (mA)	Vmax (V)	Imax (mA)	Pinput (mW)	FF	Poutput (mW)	Efficiency (%)
Control	0.364	0.0064	0.289	0.0039	26.8	0.48382	0.001127	0.004
GX 1%	0.497	0.0072	0.389	0.0055	29.1	0.59789	0.000002	0.007
GX3%	0.547	0.0107	0.415	0.0088	27.3	0.62396	0.000004	0.013
GX 5%	0.721	0.0127	0.508	0.0102	31.2	0.56588	0.005182	0.017

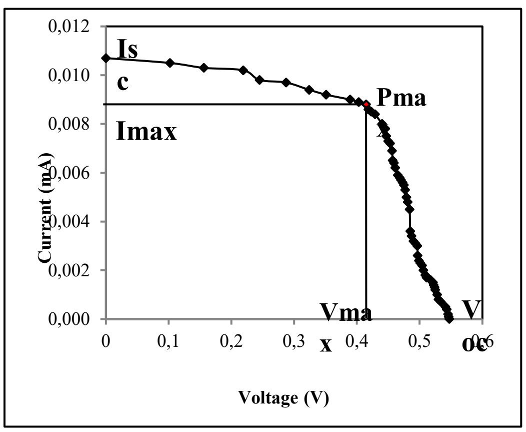
Electrical performance on DSSC without addition of thickening agent (control) was also carried out. The stability of the DSSC measurement for control was 9.75 minutes. The I-V characteristics on DSSC with the addition of GX 1%, 3% and 5% are presented in Figure 2.



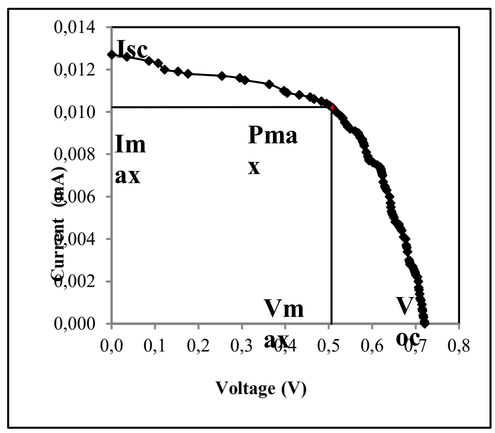
Control



XG 1%



c. XG 3%



XG 5%

Figure 2. I-V Characteristics curve of DSSC (control and XG addition)

The stability of the DSSC measurement when GX 1%, 3% and 5% were added was 13, 14.25 and 22.5 minutes, respectively. The increase in stability could be due to the increase in viscosity of the electrolyte trapping the liquid; therefore, the leakage of the electrolyte was delayed. This corresponds to increasing stability. Xanthan gum is a water-soluble polysaccharide consisting of a β-1,4-glycosidically linked main chain and a trisaccharide side chain containing successively mannose, glucuronic acid and mannose [6]. The structure of xanthan gum is able to form a three-dimensional hydrogel network with a thixotropic property; therefore, it can penetrate the mesopores of the TiO2 photoanode as a liquid. This condition could increase the stability of the DSSC.

4. Conclusions

An electrolyte based on xanthan gum was able to increase the efficiency and prolong the stability of DSSC with the dye of water hyacinth leaves as photosensitizer. The highest efficiency of DSSC (0.0017%) was achieved by adding 5% xanthan gum, and the stability of DSSC was 22.25 minutes.

References

[1] H. NA, "Potency of solar energy applications in Indonesia," International Journal of Renewable Energy Development, vol. 1, no. 2, pp. 33–38, 2012.

[2] W. Kong et al., "Optimization of ultrasound-assisted extraction parameters of chlorophyll from Chlorella vulgaris residue after lipid separation using response surface methodology," J Food Sci Technol, vol. 51, no. 9, pp. 2006–2013, 2014.

[3] D. P. Jaeschke, R. Rech, L. D. F. Marczak, and G. D. Mercali, "Ultrasound as an alternative technology to extract carotenoids and lipids from Heterochlorella luteoviridis," Bioresour Technol, vol. 224, pp. 753–757, 2017.

[4] S. Galliano et al., "Hydrogel electrolytes based on xanthan gum: green route towards stable dye-sensitized solar cells," Nanomaterials, vol. 10, no. 8, p. 1585, 2020.

[5] R. U. Arifah, S. Sedjati, E. Supriyantini, and A. Ridlo, "Kandungan klorofil dan fukosantin serta pertumbuhan Skeletonema costatum pada pemberian spektrum cahaya yang berbeda," Buletin Oseanografi Marina, vol. 8, no. 1, pp. 25–32, 2019.

[6] X. Hu et al., "Characterization and antioxidant activity of a low-molecular-weight xanthan gum," Biomolecules, vol. 9, no. 11, p. 730, 2019.