Performance of Dye-sensitized Solar Cells based on Gel Electrolyte

Kinerja Sel Surya *Dye-sensitized* berbasis Elektrolit Gel

Lia Muliani [*], Natalita M. Nursam, and Jojo Hidayat

Pusat Penelitian Elektronika dan Telekomunikasi, Lembaga Ilmu Pengetahuan Indonesia
Komplek LIPI Gedung 20 Lantai 4, Jl Sangkuriang, Bandung 40135, Indonesia

Abstract

Electrolyte is one of the crucial elements in dye sensitized solar cells (DSC) due to the reduction-oxidation reactions take place in this area and it has the function as the charge transfer medium. An electrolyte solution contains redox couple such as I^-/I_3 is filled up into a space between the photo-anodes and the counter electrode. Usually, the DSC employs a liquid electrolyte which using organic solution because easy preparation. But it has disadvantage, solvent evaporation occurs and this can decrease the cell performance. One of way to solve this problem is change liquid electrolyte to gel electrolyte. This paper describes fabrication of DSC based on gel electrolyte. Performance of the DSC is compared to the cell which using a liquid electrolyte. The result shows that the energy conversion efficiency of the solar cells based on gel electrolyte was lower than liquid electrolyte solar cell that is 1.51% and 2.23% respectively. Based on life time investigation obtained the performance of gel electrolyte solar cell is much stable than liquid electrolyte solar cell.

Keywords*: dye sensitized solar cell (DSC), gel electrolyte, liquid electrolyte, I-V curve, life time.*

Abstrak

Elektrolit merupakan salah satu komponen penting dalam sel surya berbasis *dye-sensitized* (DSC), karena reaksi reduksi dan oksidasi terjadi di sini dan berfungsi juga sebagai media transfer muatan. Suatu elektrolit terdiri dari pasangan redoks I^-/I_3 *yang* disuntikkan melalui celah antara fotoanoda dan elektroda pembanding. Biasanya DSC mengaplikasikan larutan elektrolit yang mengunakan pelarut organik karena preparasinya mudah. Tetapi elektrolit ini memiliki kelemahan, larutan mengalami penguapan yang dapat menurunkan kinerja sel surya. Salah satu cara untuk mengatasinya adalah dengan menggantikan larutan elektrolit dengan elektrolit berupa gel. Tulisan ini menguraikan pembuatan DSC berbasis elektrolit gel. Kinerja sel dibandingkan dengan sel yang menggunakan larutan elektrolit. Hasil pengukuran menunjukkan bahwa efisiensi konversi energi sel surya berbasis elektrolit gel lebih rendah dari pada larutan elektrolit, secara berurutan yaitu 1,51% dan 2,23%. Sedangkan berdasarkan penelitian *life time* diketahui kinerja sel menggunakan elektrolit gel lebih stabil.

Kata kunci: sel surya berbasis *dye-sensitized* (DSC), elektrolit gel, elektrolit cair, kurva I-V, *life time.*

I. INTRODUCTION

The high energy demand has been promote scientists and researchers to create alternative energy source. Photovoltaic cell is a device that is able to convert solar energy into electrical energy. Dye-sensitized solar cell (DSC) is expected as a promising photovoltaic device in the future as green solar cell and environmentally friendly because low fabrication cost, simple manufacturing processing and using no toxic materials [1], [2]. This solar cell is a new generation which is based on the mechanism of a regenerative photo electrochemical process and the original model cell was reported by Gratzel in 1991[1].

The components of DSC composed of a photo electrode, dye-sensitized, a redox electrolyte and counter electrode. They are very important materials that affect performance of cells [3] - [5]. Figure 1 show the physical structure of a standard DSC that consist of two transparent conductive oxide glass (TCO) that arranged like sandwiched. One of glass has function as photo electrode layer which coated semiconducting Titanium dioxide nano crystalline (nc-TiO_2) layer. Photosensitive dye molecules are attached on the surface nc-TiO_2 layer. The counter electrode is made up of catalyst material usually is Platinum that attached to another piece of conducting glass. An electrolyte containing the iodide/tri-iodide redox couple is filled between the photo electrode and counter electrode [2], [5], [6]. Dye molecules absorb light and inject electron into the conduction band of TiO_2. The Electron passes through the porous nano crystalline TiO_2 to transparent conductive oxide and then moves along an external load to the counter electrode. The dye molecule is regenerated by the redox reaction. In this process, the electron is transferred to tri-iodide to yield iodide according to $I_3^- + 2e^- \rightarrow 3I^-$ and when iodide diffuses to dye sensitized porous TiO_2 electrode, it reduces the oxidized dyes (S^+) following $2S^+ + 3I^- \rightarrow 2S + I_3^-$ [7].

* Corresponding Author.
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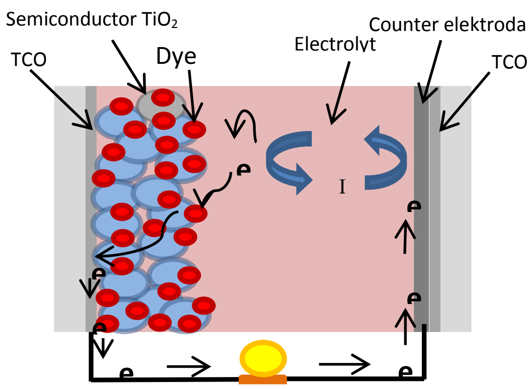


Figure 1. The Physical Structure of a Standard DSC

Electrolyte is one of the crucial components in DSC due to the reduction-oxidation reactions take place in this area and it has the function as the charge transfer medium between the photoanode and the counter electrode [8]. The cell usually employs a liquid electrolyte which using volatile solution because easy preparation. In DSC based on liquid electrolyte had achieved conversion efficiency of 11% [9]. However, the presence of liquid electrolytes in modules may result in some practical limitations of sealing and long-term stability [10]. During long-term operation, the solvent occur evaporation, higher temperatures cause the liquid to expand, making sealing the cells a serious problem. All of that can cause of a decrease in cell performance. One of way to solve this problem is replacing the liquid electrolytes by solid-state or quasi-solid-state electrolytes such as gel electrolyte [9].

This paper describes fabrication of DSC based on gel electrolyte. Performance of the DSC that using gel electrolyte was studied and compared to the cell which using a liquid electrolyte.

II. Experimental

This research aims to study the performance of DSC based on gel electrolyte. Characteristic I-V of the DSC was compared to the cell which using a liquid electrolyte. An electrolyte solution used Dyesol products are EL-SGE for gel electrolyte and EL-HSE for liquid electrolyte.

In this project, fluorine-doped tin-oxide (FTO) with thickness of 3.24 mm and sheet resistance of 15Ω/□ was used as a TCO substrate. FTOwas cleaned with detergent and then washed with deionized water and isopropyl alcohol using ultrasonic cleaner. In this experiment, TiO_2 paste (18NR-AO, Dyesol) as photo electrode was deposited onto FTO by screen printing technique using nylon screen. Thickness of TiO_2 film was performed based on the optimum results from our previous work [10]. The glass coated nc-TiO_2 was preheated at 120 ^oC for 10 minutes and sintered on a conveyor-belt furnace at 500 ^oC for 15 minutes. All samples were subsequently immersed on a solution consisting Ruthenium complex dye $RuL_2(NCS)_2$:2 TBA (L = 2,2'-bipyridil-4,4'-dicarboxylic acid; TBA = tetrabutylammonium) [11] known as N719 (Dyesol) for 24 hours on a dark place and continued all samples were rinsed on ethanol to remove the dye residues.

Platinum layer as counter electrode was deposited onto FTO by DC-sputtering processing for 20 minutes with an initial pressure of $6.6x10^{-3}$ Pa, argon gas pressure of $5.3x10^{-1}$ Pa, rotation speed 5 rpm and power 50 W.

Dyesol gel electrolyte EL-SGE was lubricated onto photo electrode layer while Dyesol liquid electrolyte EL-HSE was injected into the assembled samples. Both photoelectrode and counter-electrode were assembled into a sandwich structure and clipped both edge. The characteristics of I-V curve of 1x2 cm^2 sized cells were measured using direct Sun Simulator Oriel AM 1.5 with the light intensity of 40 $mWatt/cm^{-2}$.

III. Results and Discussion

Figure 2 shows the photograph of our cell prototype which using gel electrolyte and liquid electrolyte.

Figure 2. Prototype of DSC Based on Gel Electrolyte (left) and Liquid Electrolyte (right)

Figure 3 indicates photocurrent density–voltage characteristics of cells with liquid electrolyte and gel electrolyte. The performance parameters of solar cells were summarized in Table 1. The best conversion efficiency of device was obtained of 1.51% and 2.23% for gel electrolyte and liquid electrolyte respectively. Overall those data show that DSC based on liquid electrolyte had larger short-circuit current density (Jsc), open circuit voltage (Voc), fill factor (FF) and conversion efficiency (η) than that based on gel electrolyte. Both electrolytes contain same additive materials and solvent (3-methoxypropionitrile) [12]. The difference is the gelling agent in gel electrolyte. Although polymers of some kinds could change the liquid electrolyte become gel effectively, they can give a negative influence on the photovoltaic performance and stability of the DSC. The gel network may hinder the charge transport in the electrolyte, also there is a possibility that the gelators may react with the components of the electrolyte [11].

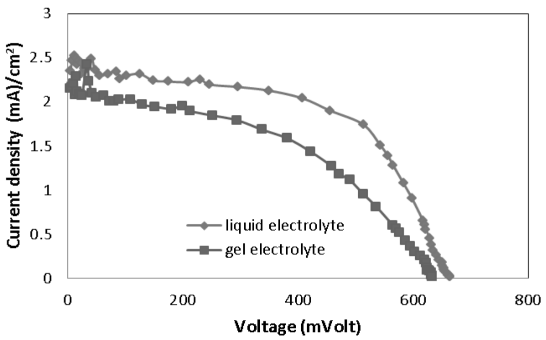


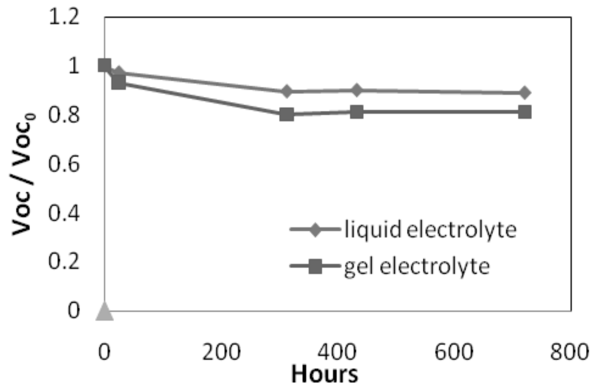
Figure 3. I-V Curve of Cells With Different Elecrolyte Solution

TABLE I
THE PERFORMANCE PARAMETERS OF SOLAR CELLS

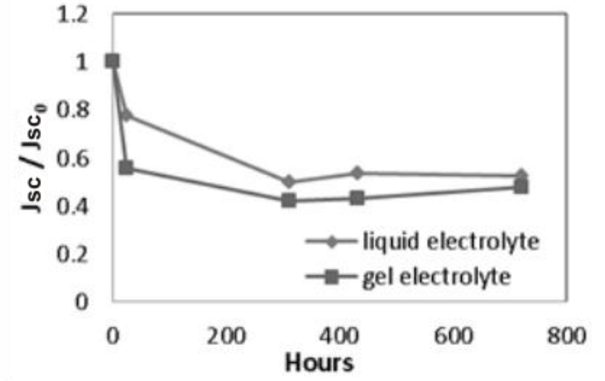
Characterstics	Gel Electrolyte (EL-SGE)	Liquid Electrolyte (EL-HSE)
V_{oc} (mV)	678	643
J_{sc} (mA/cm^2)	2.07	2.30
P_m (mWatt)	1.79	1.21
FF	0.46	0.57
η (%)	1.51	2.23

To know long-term stabilities of DSC stability of DSC based gel electrolyte, characteristics I-V of cells was measured periodically for 750 hours. Figure 4 presents the detailed behavior of device parameters during the aging tests. Each of these parameters is the data of relative changes to the initial measurement data. Figure 4 shows that the general performance of DSC decreased very large after aging time for 24 hours. This condition can due to the work mechanism of DSC not yet optimal. Parameters of open voltage (Voc) are more stable than others (Figure 4 (a)). Conversion efficiency (η) parameter has the same behavior as the current density (Jsc). Figure 4 (b) and Figure 4 (d) shows that in long term Jsc and η will decrease. This may be caused by the evaporation of solvent during the observation period so that the electrolyte is degraded. Matsui [2] reported dependence of Jsc on concentration of I^-/I_3^- redox couples. Jsc increased with increasing concentration of I^-/I_3^- to maximum value and after that Jsc decreased. The decreased current is result of the decreased transparency of electrolyte which caused by increasing of light absorption of I^-/I_3^-[2] so that concentrations become high. The high concentrations may reduce light absorption by the dye [9].

Figure 4 (b) shows the change of gel electrolyte Jsc which is lower than of liquid electrolyte. Parameter of Fill Factor (FF) describes quality of solar cells that can easily be visualised by drawing the area of the maximum possible rectangle under the I-V. Teoritically, FF is affected by parasitic resistances i.e. the series and parallel resistances within the cell itself. Figure 4 (c) indicated that DSC device that obtained has good enough performances. Overall, the performance of DSC based gel electrolyte and liquid electrolyte decreased during long-term. Based on life time investigation known the performance of gel electrolyte dye-sensitized solar cell is much stable than liquid electrolyte.



(a)



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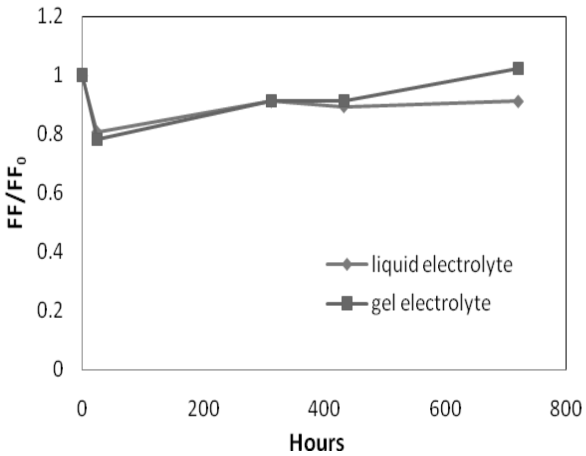
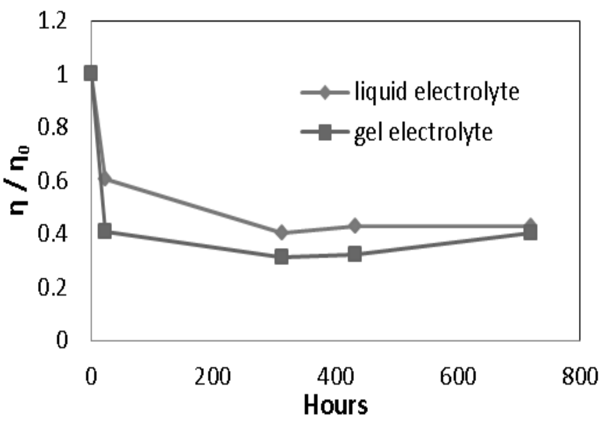


(c)



(d)

Figure 4. Long-term Stabilities of DSC With Liquid Electrolyte and Gel Electrolyte Based on Change of Voltage (a), Current Density (b), Fill Factor (c), and Efficiency (d).

CONCLUSIONS

Study of the performace of dye-sensitized solar cell based on gel electrolyte has been done. The performance of DSC based gel electrolyte and liquid electrolyte decreased during longterm. The performance parameter of DSC based on liquid electrolyte had larger than that based on gel electrolyte. The best efficiency of the cell obtained was 1.51% and 2.23% for gel electrolyte and liquid electrolyte, respectively. The performance of solar cell based on gel electrolyte more stable than liquid electrolyte.

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