Effect of Counter Electrode from Waste Carbon in Factory for Dye-Sensitized Solar Cell

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Abstract. *The incomplete combustion of coal fuels produces smoke that is emitted outside, which uses a wet scrubber process to reduce smoke. The waste produced by this process is carbon. This waste carbon can be used as a film material on the counter electrode layer of a dye-sensitized solar cell (DSSC). The effect of a counter electrode made from waste carbon in factory for dye-sensitized solar cell (WCFCE-DSSC) is presented in this study. For the counter electrode, transparent conductive oxide (TCO) glass was coated with the waste carbon in factory. X-ray diffraction (XRD) was confirmed by crystalline structure of the waste carbon in the factory, which shows peak intensity at the carbon (002) plane and 27.33° (2θ). At AM 1.5 and 600 W/m*^{2}*, the result was that the open-circuit voltage (*V_{OC}*) and the short-circuit current density (*J_{SC}*) of the WCFCE-DSSC were 0.59 V and 14.7 mA/cm*^{2}*, the filter factor (FF) and the energy conversion efficiency (η) were 0.87 and 1.27%, respectively. The *V_{OC}* was lower than all material counter electrodes when compared to the research group using counter electrodes. The energy conversion efficiency is lower because waste carbon in factory may contain impurities that reduce the redox reaction and decrease electron atoms. The use of carbon waste from the factory to be applied to the counter electrode of commercial dye-sensitized solar cells can reduce the amount of waste from the factory and also reduce pollution.*

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1. Introduction

At present, there are many methods for generating electricity such as hydroelectric power generation, wind power generation and generates electricity with heat from fuel or geothermal energy. For example, countries with fuel resources often use energy from fuel to generate electricity. [1]-[4] The use of fuel as raw material in the electricity production process is based on the principle of heating to produce steam to drive turbines to spin as a power source for generators. Most of the fuel used to generate electricity comes from coal, diesel oil, and natural gas, all of which cause air pollution. In addition, the cost of fuel is high. resulting in the switch to more renewable energy sources such as wind, water, solar, etc. Solar energy is clean energy and does not cause air pollution. Therefore, the researchers developed a device to generate electricity called "solar panels." Currently, solar cells have developed a variety of devices, including types of monocrystalline silicon solar cells and polycrystalline silicon solar cells, which are these types of solar cells.

The raw materials are also expensive, and the production process is complicated and time consuming. However, there is another type of solar cell that is classified in the group of organic solar cells, which is a dye-sensitized solar cell (DSSC). It has a simple, uncomplicated production process coupled with low production costs. This is due to the use of natural dyes sensitized that facilitate the excitation through the semiconductor that allows electrons to pass through. By focusing on naturally dye-sensitized substances, DSSC research has classified the manufacturing process. [5]-[8] The structure of DSSC is divided into two electrodes: the counter electrode (+), consisting of carbon and platinum, and the working electrode (-), consisting of titanium dioxide (TiO_2).

Generally, the counter electrode or the positive electrode (carbon or platinum) is mainly used. However, platinum is expensive, carbon derived from alkaline batteries is preferred. graphite obtained from ink carbon from black copy paper. [9]-[11] The problem with using carbon as an auxiliary electrode is the area of the electrode with good electrical conductivity that research has found.

The use of alkaline batteries, which contain charcoal, has a small amount of carbon, resulting in poor thickness of the conductive area. There is also carbon from other parts that may be used as counter electrodes. Therefore, the authors used the carbon from the incomplete combustion of coal to capture smoke by using water (Wet Scrubber) [12]-[13] until it forms carbon deposits that fall into the dye industry, it was called “Waste Carbon in Factory”. It could be used as a waste carbon-assisted counter electrode layer in DSSC.

In this paper, we present an effect of using a counter electrode from the carbon from the incomplete combustion of coal (waste carbon in factory: WCF) for dye-sensitized solar cells. It consists of a layer of working electrode, counter electrode and electrolyte by being overlap in layers as follows: transparent conductive oxide (TCO) glass/ titanium dioxide (TiO_2) paste/ dye sensitized / electrolyte/ WCF paste/ TCO glass. The use of carbon from the incomplete combustion of coal as counter electrodes could have significant implications for increasing the efficiency of dye-sensitized solar cells.

2. Experimental Setup

In designing and building a DSSC using electrodes assisted by the waste carbon from the incomplete combustion of coal consist of a working electrode and counter electrode. It is overlap, including TCO glass/TiO_2 past /N719 dye/ I_3/I^- electrolyte/WCF paste/TCO glass as shown by Fig. 1.

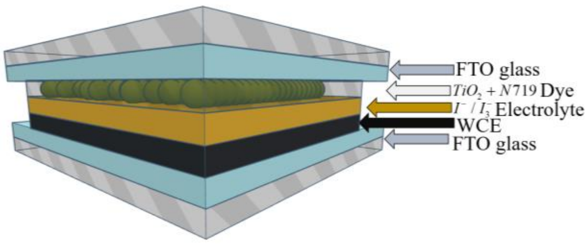

Fig. 1 Natural dye-sensitized solar cell structure using coal waste carbon-assisted electrodes.

2.1 Preparation of Working Electrode

In this step for preparation of working electrode, a solution used to make the working electrodes is prepared. Titanium dioxide (TiO_2) paste, dye-sensitized and electrolytes. TiO_2 paste by from Dyesol Chemistry Co., Ltd. Model 18 NR – Transparent Titania Paste. N719 dye was used dye-sensitized which is the same company.

Then prepare transparent conducting oxide (TCO) glass. In this study, Fluorine Tin Oxide (FTO) was used TCO glass will be cut to the length of 2x3 cm^2, ultrasonic cleaning by immersing in acetone for 45 min to remove grease and inorganic residues from the glass. TiO_2 paste was coated on FTO glass 1x1 cm^2 using Doctor-Blading technique. After that, it was dried at 450 °C for 1 h or until the film is transparent.

The final step was to prepare the N719 dye dissolved in deionized water at 1 g of water per 10 ml of water. After that, the glass coated with TiO_2 was soaked in the prepared solution for 1 night or 24 h which was responded a reddish purple color.

2.2 Preparation of Counter Electrode

To prepare the counter electrodes of the DSSC using the counter electrodes from waste carbon in factory by removing the carbon from the flue using a water spray nozzle to reduce the amount of waste smoke coming out of the flue. Caused by burning coal at 900 °C, this type of carbon is a waste carbon that cannot be disposed of outside the factory, show in Fig. 2(a).

The waste carbon in factory was dried at 150 °C for 1 h. to remove moisture from the carbon. The acetone was washed with waste carbon by clean ultrasonic for 45 minutes, filtered with 20 µm filter paper, and washed twice with DI water until black powder was obtained. The obtained carbon powder was dried by bath evaporation. After that, carbon powder was ground thoroughly and mixed into the surfactant (Triton X-100: Kem Aus) at 10 g : 10 ml of surfactant to form a homogeneous substance, shown in Fig. 2(b).

(a) (b)

Fig. 2 (a) waste carbon generated by incomplete combustion in the plant (b) waste carbon paste.

Finally, take the FTO glass and measure the ohmmeter to find the polarity side. Take a piece of transparent tape with a thickness of 6 µm and cover it in a square shape with a center area of 1x1 cm^2. The mixed carbon was coated on the glass using Doctor-Blading technique at 230 °C for 45 min.

2.3 Preparation of DSSC Using Counter Electrode from Waste Carbon in Factory

The preparation of electrolyte solutions, [9] in this project will consist of a substance that consists of sodium iodide (NaI), iodine (I_2), lithium carbonate (Li_2CO_3) and acetonitrile solution. The solutions have a concentration ratio of NaI : I_2 : Li_2CO_3 = 0.5 : 0.05 : 0.5 mol or NaI : I_2 : Li_2CO_3 = 745 : 127 : 0.185 mg and add to 10 ml of Acetonitrile solution mix all solutions until homogeneous to have a dark brown.

Preparation of natural dye-sensitized solar cells using a counter electrode made from waste coal after the working electrode, counter electrode, and electrolytes. The side coated with TiO_2 + dye sensitized (N719) and the side coated with waste carbon are straightened and overlapped. The FTO glass will be stacked on top of each other to visible the electrodes on both sides. show inset Fig. 4.

Then use a plastic seal 10 µm thick, place the area around the coated area with a hole for an electrolyte drop, and clamp it in the oven at 100 °C for 15 min to be welded together.

3. Experimental Setup

The crystallization structure of the waste carbon in factory was tested using X-Ray Diffractometer (SmartLab: Rigaku), as shown in Fig. 3. The factory carbon waste had a peak intensity of 27.33° (2θ) response carbon (002) plane and 15.61° response carbon (100) plane shows that waste carbon in factory contains many carbon components.

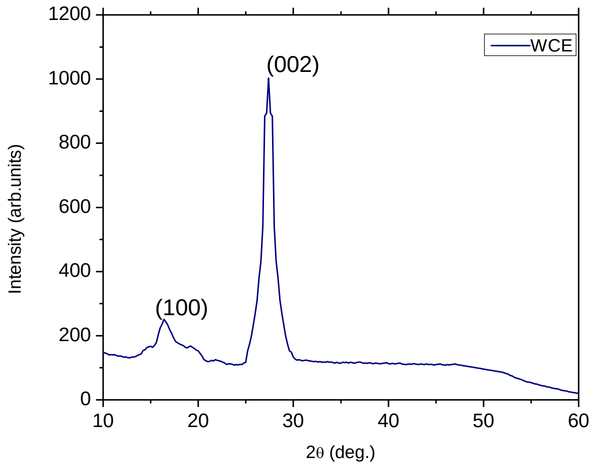

Fig. 3. X-ray Diffraction of waste carbon in factory powder.

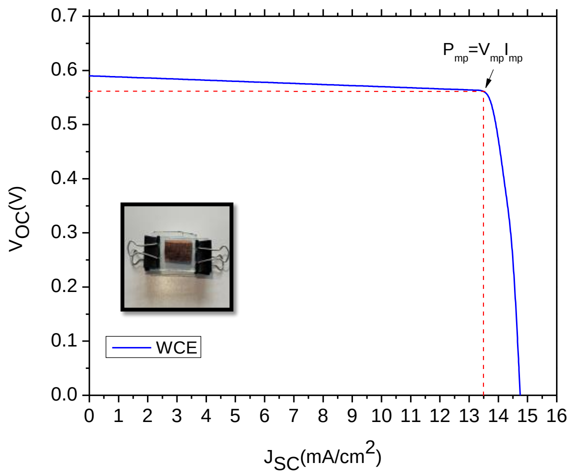

Fig. 4. I-V curve of the counter electrode from waste carbon in factory for dye-sensitized solar cell.

Fig. 4 shows I-V curve between the open-circuit voltage (V_{OC}) and the short-circuit current density (J_{SC}) of the waste carbon in factory counter electrode (WCFCE) for dye-sensitized solar cells, measured by a solar simulator (XES-301S: SAN-EI ELECTRIC). According to the air mass standard AM 1.5, the has a light intensity of 600 W/m^2, 380 °C (311 °K). For experimental result was found that the J_{SC} of 14.7 mA/cm^2 and V_{OC} of 0.59 V. The maximum point power (P_{mp}) of 0.0867 W. The obtained J_{SC} and V_{OC} can determine the filter factor (FF) and the energy conversion efficiency (η), which can be calculated as equations (1) and (2) [14]–[15].

$$FF = \frac{V_{mp} I_{mp}}{V_{OC} I_{SC}} \quad (1)$$

The energy conversion efficiency defined as

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}} \quad (2)$$

When, V_{mp} is maximum point voltage. I_{mp} is maximum point current. P_{in} is input power for efficiency.

Equations (1) and (2) show the filter factor (FF) and energy conversion efficiency (η) of the dye-sensitized solar cells of the counter electrode from waste carbon in factory were found that 0.87 and 1.27%, respectively. When compared with the research group using counter electrode materials such as carbon, graphite, platinum, and others, the results are shown in Table 1.

Counter Electrode Materials	**V_{OC} (V)**	**I_{SC} (mA/cm^2)**	***FF***	**η (%)**
Carbon [14]	0.77	8.5	0.54	3.53
Graphite [15]	0.717	1.4	0.51	0.56
Platinum [16]	0.66	1.4	0.7	4.07
Waste Carbon Copy paper [17]	0.687	7.8	0.38	9.44
MnO_2:C [18]	0.65	14.5	0.44	4.12
Cu:MnO_2 [19]	0.781	14.8	0.43	5.83
WCFCE (This work)	0.59	14.7	0.87	1.27

Table 1 Compared photoelectrochemical parameters of DSSCs at difference counter electrode material

Table 1, WCFCE found that the V_{OC} was lower than all the difference counter electrode materials. Due to the use of different electrolytes, oxidation and reduction reactions are different. I_{SC} of WCFCE was higher than the carbon, graphene, platinum, and waste carbon copy at same surface area (1x1 cm^2). The fill factor of WCFCE was higher than all the difference counter electrode materials. The efficiency of WCFCE was lower than all the difference counter electrode materials because the waste carbon in factory come from the incomplete combustion of coal and obtained carbon that has been contaminated by the wet scrubber process. It is not purity carbon. Therefore, the reduction of the redox reaction results electron is decreased.

4. Conclusion

The effect of a counter electrode layer made from waste carbon in a factory for dye-sensitized solar cells (WCFCE-DSSC) is investigated in this study. The X-ray diffraction shows the crystallization structure of the waste carbon in the factory. The open circuit voltage (V_{OC}) and short circuit current density (J_{SC}) of WCFCE-DSSC were 0.59 V and 14.7 mA/cm^2. The fill factor and energy conversion efficiency of WCFCE-DSSC were 0.87 and 1.27%, respectively. Compared with another counter electrode material, the energy conversion efficiency and open circuit voltage of WCFCE-DSSC were lower than those of the other counter electrode material. While WCCE-DSSC had a higher current density than all other counter electrode materials. The use of waste carbon in the factory as a counter electrode layer in dye-sensitized solar cells can significantly reduce plant waste. If wanting to apply commercially, it can eliminate waste from the factory and help reduce pollution as well.

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