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Solar Driven Photocatalytic Fuel Cells: an Environmentally Friendly Innovation of Power Plant Technology as Energy Source

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Abstract

Nowadays, the demand of energy in Indonesia is still dominated by fossil fuel. In 2013, fossil fuel contributed 94.3 % of the total energy. Production of fossil fuel or conventional energy sources such as coal, oil, and gas that are widely used to fulfill the energy needs in the world has been decreasing very significantly. One of energy supply problems resulting from the deficiency of fossil fuel energy is unequal distribution of electricity in areas of Indonesia. To overcome the energy supply issues, hence hydrogen can be used as energy supplier because it has been proven to be potential and prospective alternative energy source. The hydrogen resulted from water electrolysis can be used as the main component of fuel cells technology. Fuel cells technology is a kind of renewable energy that is clean and safe. It also has high energy efficiency. Power plant using fuel cells technology is then used as energy supplier for public street lighting in the remote areas which lack of electricity supply from Electricity Company or PLN. However, those areas should have abundant sources of water to be converted into hydrogen. Here we explore the idea of designing Solar Driven Photocatalytic Fuel Cells. The first step is to synthesize nitrogen dopped titanium dioxide (N-TiO_2) nanotubes/dye by using hydrothermal method on Fluorine Tin Oxide (FTO) substrate. Then use it as a photoanode, Silicon (Si) is used as cathode by putting the metal into Hydrofluoric acid (HF) liquid. The hydrogen will be generated from water electrolysis. Then use the hydrogen as a fuel. The fuel cells can generate electricity without combustion of fuel and produce zero pollution.

Keywords: fuel cells; power plant technology; street lighting.

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1. Introduction

Nowadays, the demand for energy in Indonesia is still dominated by fossil energy. With the growth of high energy consumption and energy consumption per capita is still low, the electrification ratio becomes uneven in Indonesia. Energy infrastructure is also not optimal. As an illustration, with a population about 250×10^6 people, generating electricity provided only 45 Giga Watts (GW). Refinery capacity could not meet all the needs of fuel, while the natural gas infrastructure is still limited [1, 2].

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Conventional energy sources like coal, oil, and gas that is widely used to meet the energy needs of the world production decreased very significantly. This sparked the emergence of a challenge to produce new alternative fuel. Hydrogen is one of the potential options to answer these challenges and can be a major energy source for the future of environmentally friendly [3]. One of the alternatives offered to produce hydrogen is the using of sunlight and water as a photocatalyst. [4]. A study of hydrogen production based on the renewable natural materials has been done, both of which are based on the electrical work (electrolysis), photocatalyst, and electro photocatalyst [5].

Sunlight is a natural resource that is always available in every season and every places such as beaches, plains, plateaus, hills and mountains. Solar energy is renewable energy (renewable) means always exist, are inexhaustible, and available freely. The process utilizes photon energy and the use of semiconductor. As we know, the electrons and holes of a semiconductor will be separated under light illumination and there will be a photovoltage. For n-type semiconductor under light illumination photogenerated holes are the majority for oxidation. In contrast, for ptype semiconductor under light illumination photo-generated electrons are the majority for reduction. Semiconductors are known have an important advantage, especially for the application of production hydrogen from water, such as, has a high stability, corrosion resistance, the availability is abundant in nature, and relatively cheap price [6]. Nevertheless, the photocatalyst process using TiO_2 has a low function because a large band gap that is less responsive to visible light. Therefore, needed an efforts to improve the performance photocatalysts in producing hydrogen from water.

Alternatively, photocatalytic fuel cell (PFC), which is an integration of photocatalysis and fuel cell technologies, is a more promising approach. The photoanode of PFC is deposited with a thin layer of active photocatalyst (*e.g.* TiO_2). When the photoanode is exposed to light irradiation, photo-induced electrons (e^-) and holes (h^+) are produced at the photocatalytic sites. The holes can oxidize OH- to produce hydroxyl free radicals (.OH) or oxidize photodegradable organic substances in the solution to form CO, electrons and protons.Electrons generated from photocatalysis and oxidation of organics at the anode side can movethrough the external circuit to the cathode side, where reduction reaction occurs. Taking Pt/C catalyst as an example, the reaction varies depending on the availability of oxygen. In case oxygen is absent, the reduction reaction involved is hydrogen evolution reaction. On the other hand, if oxygen is present in the solution, the reaction is oxygen reduction to produce water. Therefore, it is feasible to convert organic substances including pollutants into electricity and/or hydrogen fuel [7, 8]. Solar photocatalytic fuel cell (PFC) is a promising technology for environmental-friendly wastewater treatment and simultaneous production of electricity. Photocatalytic fuel cell is recently regarded as a remerging research field . The architecture can be categorized into singlecompartment or two-compartment cell.

Most of previous studies were based on single-compartment cell because the simple design is of high potential for commercialization. The two-compartment cell configuration requires additional separator, such as proton exchange membrane (Nafion that will increase the cost of the PFC. The key components of PFC include photoanode, cathode and photodegradable organic substances in the supporting electrolytes. [9].

2. Methods

2.1. Literature and data sources

This paper uses library research (literature). Library research is a writing method using an object of research studies that focus on literature and observation in the object area in Pliken, Pekalongan City, Indonesia.

3. Results and Discussion

An implementation plan for the design of Solar Driven Photocatalytic Fuel Cells will be carried out in pilot villages is Pliken, Village Pungangan, Pekalongan City, Indonesia. Current conditions of villages are untouched by electricity and the only people who have money get the facility of electrical energy in the form of windmills on the river [10]. Pliken is suitable for the pilot because of the difficulty of obtaining energy and needs a touch of alternative energy as well as geographic hamlet Pliken support. The weather in this hamlet is stable and has never experienced a drought or flood.

The process of splitting water molecules with the help of sunlight requires photoanode and photocathode. Both of these electrodes can be prepared from a variety of semiconductor materials and the transparent electrode in order to facilitate the absorption of light. FTO electrode can be used as a substrate because it is transparent and can conduct electricity. As mentioned in the previous chapter, the activity of TiO_2 is affected by the surface area of the material. It makes it possible to increase its activity, TiO_2 be grown on the FTO substrate by means of hydrothermal.

Before designing solar driven photocatalytic fuel cells, first step is preparation N-TiO_2 Nanotubes/Dye, and it started from the process of synthesis the anode of N-TiO_2 nanotubes by hydrothermal method with substrate Fluorine Tin Oxide (FTO).Synthesis is done by modifying the synthesis conducted by Wang et al. [7]. Preparation of TiO_2 nanotubes with FTO substrates with a size of 10 cm × 10 cm, beforehand the substrate is cleaned with deionized water, acetone and 2-propanol for 30 min, and then dried. Furthermore, FTO substrate is placed next to a teflon stainless steel autoclave with added 15 mL H_2O, 15 mL of 37 % HCl and 0.5 mL of Ti (OBu)4 (titanium isobutoxide). Then it was put in the oven for 150 °C for 24 h. Next, a thin layer of TiO_2 film

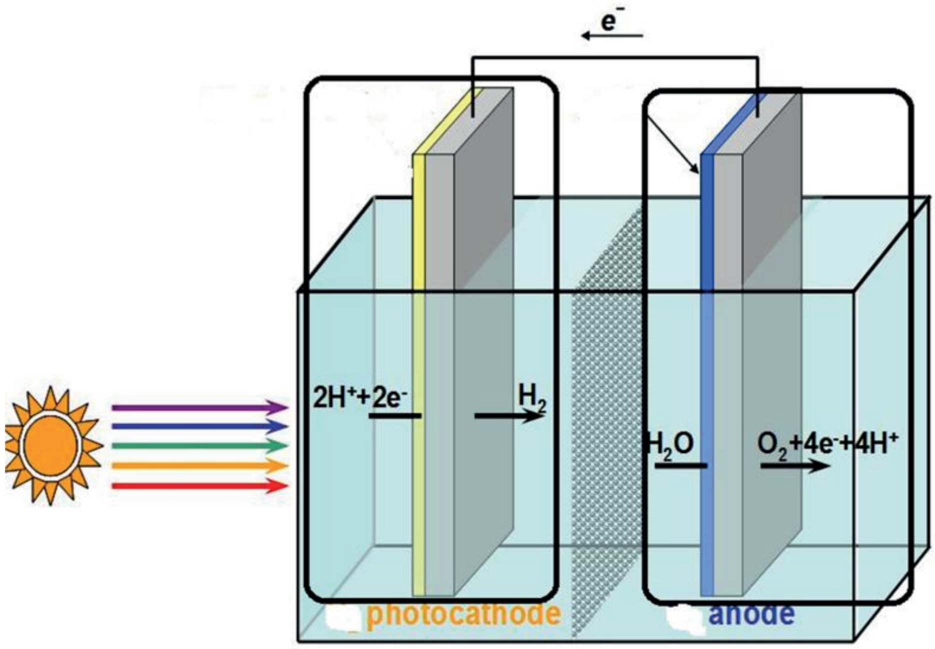

Figure 1: Solar Driven Photocatalytic Fuel [7].

that deposited on the FTO substrate is washed with absolute ethanol and deionized water to clean organic pollutants. Then nitrogen (N) is deposited into the TiO_2-FTO substrate based on the research conducted by Valentina [8], the method of dopant N-TiO_2 nanotubes photocatalyst by soaking in NH4OH. The phases are TiO_2 nanotubes-FTO substrate soaked in a solution of 0.5M NH_4OH for 24 h and then dried in an oven at 130 °C for 1 h [8].

Hydrogen is distributed to the anode of fuel cells, while oxygen is pumped into the cathode, with the membrane or electrolyte, the hydrogen gas will not mix with oxygen. In anode, there is a layer of platinum that functions as a catalyst that is able to break up the hydrogen atoms into electrons and protons. Protons flow through the electrolyte, while the electrons are still in the anode, so the electrons will accumulate in the anode. As the cathode, there is accumulation of positive charged ions. Furthermore, H^+ ions pass through the electrolyte to binds with oxygen to produce water with the help of platinum contained in the cathode as a catalyst. This reaction will take place if there are electrons. If the anode and cathode are connected, the electrons will flow and produce electricity. Solar Photocatalytic Fuel Cells generates electricity without combustion of fuel, so there is no pollution. The result is a prototype of generator solar power systems and water, convertible system, so it can easily be carried to remote areas (farthest). It means that it can be dismantled, reassembled, and portable (carried or moved places). Therefore it can be installed in areas that have not installed the flow of electricity yet. Construction of this generator is independent or stand on your own (standalone). The number of cells (cell) made as much as 10 pieces assuming the hydrogen produced

0.032 mol · s^{-1} with an output per cell is 1.2 V so for 10 cells (cells) is 12 V. Fuel cells has an efficiency about 40 % to 70 % depend on the various of fuel cells.

The investment cost for Solar Driven Photocatalytic Fuel Cells technology is around IDR 14 636 000. There are several implementation stages to carry out the technology. Firstly, the area conditions: number of citizens who lived in the area and street condition, are analyzed. This is, then, followed by socializing implementation planning to the citizens. After getting government approval, several trial tests are carried out and evaluated to derive final properness decision of implementation.

4. Conclusions

The initial process of making Solar Driven Photocatalytic Fuel Cells starts from photoanode synthesis of N-TiO_2 nanotubes/dye and assemble the components of photoanode and photocathode with a membrane to produce H_2 and O_2 which will be converted into electrical energy.

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