An Electrical Model of a Solid Polymer Electrolyte Cell

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Abstract. Solid polymer electrolyte (SPE) produces hydrogen and oxygen from pure water uses electrochemical reaction, and this process is believed to be the most promising and efficient way to produce hydrogen. For application and simulation, the electrical model of SPE is absolutely required, we intend to develop an electrical model. Where the model has been constructed based on the structure and characteristics of SPE. The electrical model of SPE battery like that consists of a voltage and resistance, that fulfil the equation $v=1.936+0.0183I-0.012T$, to ensure that this model is close to the character of the SPE, we conducted an experiment to validate it, based on the correlation analysis method we obtained those results of the experiment and results of calculation of the model have a correlation is > 0.9988, this meaning that the model is valid.

Introduction

Currently our attention is focused on environmental problems, global warming and the energy crisis. One way to overcome this is to produce clean energy. One of the clean energies that has promising ease of production is hydrogen. Where hydrogen can be produced using an electrolysis process that converts water into hydrogen and oxygen. In addition, Hydrogen has advantages in environmental friendliness and safety, and is considered as a universal energy carrier for the future. [1-5]

Electrolysis of water using cells with solid polymer electrolytes (SPE) is a very efficient way to produce hydrogen. And this technology has demonstrated a high degree of efficiency and higher current density capability than conventional alkaline water electrolyzes, and the use of SPE to produce hydrogen is considered a promising method for large-scale hydrogen production in the future [6-9].

Hydrogen production process using SPE through an electrolysis process by passing direct current through two electrodes. The water molecules split apart, producing oxygen at the anode (positive electrode) and hydrogen at the cathode (negative electrode).

In this work, we present an electrical model of a solid polymer electrolyte, this model constructed based on structure of cell, chemical and electrical characteristics. We show that we can evaluate the model compared with results of experiment.

Structure and Chemical Reaction of SPE

Figure1 show SPE that used in our laboratory, where the dimension and diagram of the SPE shown in Figure 2. The SPE is composed of a membrane, cathode and anode as shown in Fig. 2. [6], where effective area is 50 cm^2, and operating voltage 6-9V. The SPE electrolysis produces hydrogen by providing pure water to one side of polymer ion exchange film, which is put between anode and cathode. The electrochemical conversions at the anode and cathode of SPE are as follows:
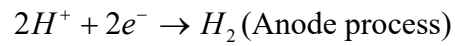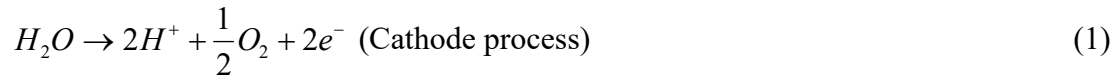
$$H_2O \rightarrow 2H^+ + \frac{1}{2}O_2 + 2e^- \text{ (Cathode process)} \qquad\qquad (1)$$

$$2H^+ + 2e^- \rightarrow H_2 \text{ (Anode process)}$$
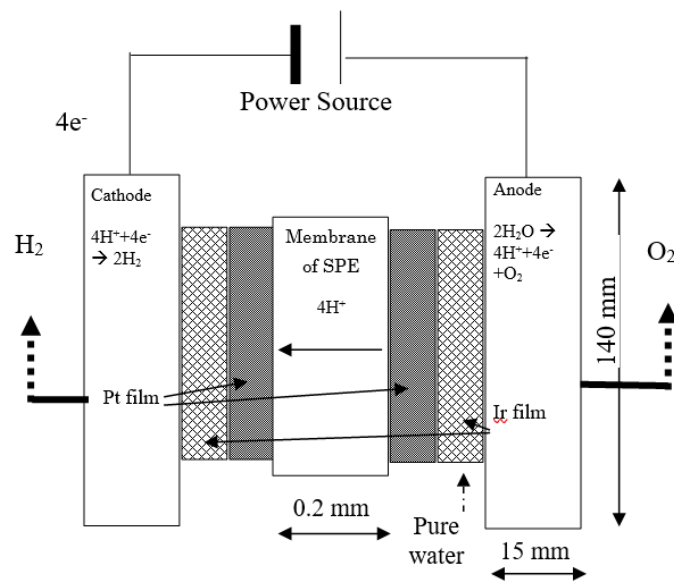

Fig. 1: Solid polymer electrolyte cell

Fig. 2: Diagram of solid polymer electrolyte cell

Construction the Electrical Model

Based on Figure 2 and based on some report [7, 10] show that the structure of the SPE is similar to a battery, then we can propose a simple of electrical model as shown in Figure 3.
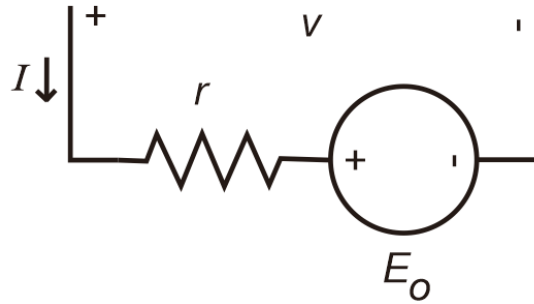
Fig. 3: The electrical model of SPE

Based on kirchoff voltage law, we can calculate the voltage of SPE cell of circuit in Figure 3 is as follows:

$$v = E_o + Ir \tag{2}$$

Where v is SPE cell voltage, E_o is the theoretical dissociation voltage dependent on absolute temperature of cell T in Celcius. The standard electrode potential for platinum is 1.188 V [11] and Iridium 0.748V [12], and total of the standard electrode potential is 1.936V at the temperature is 25 °C. Where the value of E_o is

$$E_o = 1.936 - 0.0012T \tag{3}$$

And r is the total resistance of the membrame and electodes, where the value of r based on experiment is 0.00183 ohm.   I is the current that flows through the SPE.
If we combinate the equation (2) and (3), we can get, the generale equation of SPE as follow:

$$v = 1.936 + 0.0183I - 0.012T \tag{4}$$

Results and Discussion

The mathematical model of SPE Cell in Equation (4) the we plot in a graph as v=f(T,I), as shown in Figure 4. Where in Fig. 4 shows independently the cell voltage as function of cell current in difference temperature. First, we can see with increase the temperature the cell voltage decrease as temperature gives coefficient negative against cell voltage. Second, we can see that with increase the cell current will make the cell voltage increase rapidly.

To make sure this model appropriate with the SPE cell, then we conduct a experiment to measure the cell voltage, the cell current and the cell temperature., to arrange this measurement, we connected the SPE cell with a variable power supply, and we measure the current and voltage of the circuit use ampere meter and voltmeter respectively.

To obtain data about change the cell temperature against the voltage of SPE cell, then we change the cell temperature at 30, 60 and 90ºC the relation between electrolysis voltage was measured at various currents which results are illustrated in Figure 5.
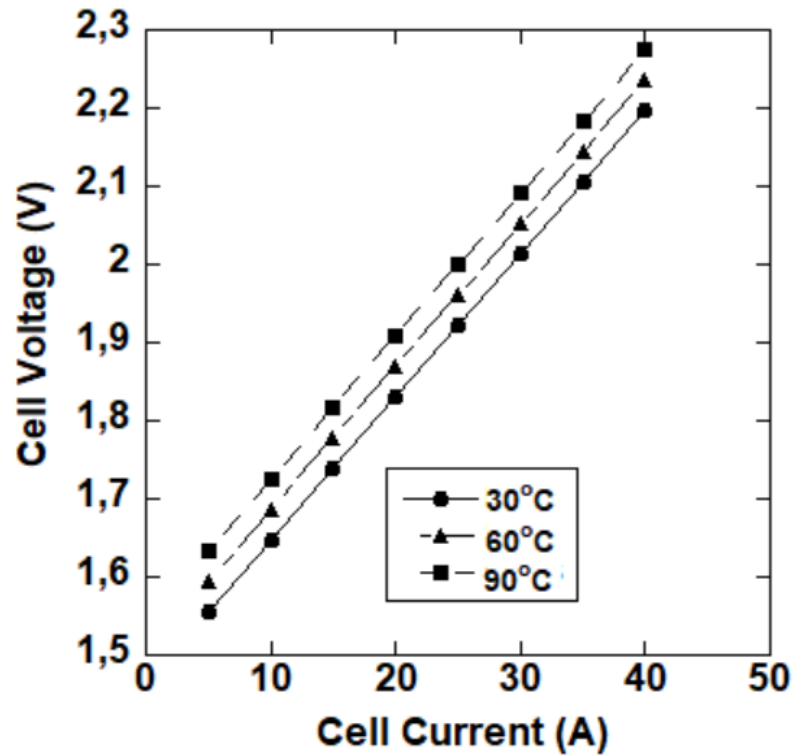
Fig. 4: Calculation the cell voltage as a function of the cell current and the cell temperature based on model equation.
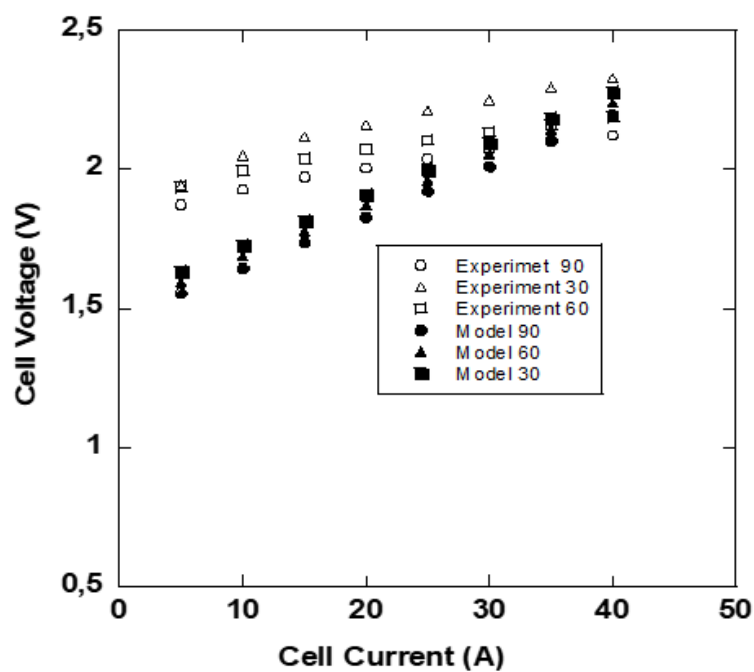

Fig. 5: Comparison between experiment and the model of the cell voltage as a function of the cell current and the cell temperature based on model equation.

In Figure 5, shows result of experiment of a SPE cell as a function of variation the cell current and the cell temperature, as well as in same figure we plot value of the cell voltage based on the model. In this picture we can make comparison between results of the cell voltage based on experiment and the cell voltage based on model. We can compare and we can see that the calculated data of model tends to follow the results of experiment especially in high cell current. We can see that slope of the both cell voltage from experiment and the model tend to similar.

To validate the data between results of the experiment and results of calculation of the model, then we do the correlation analysis between results of the experiment and results of calculation of the model. As shown in table 1. Where we obtained that the results of the data between results of the experiment and results of calculation of the model shows the correlation is > 0.9988, this meaning that the model is valid.

Table 1 The correlation between results of calculation of electric model of SPE and result of experiment of SPE with variation of temperature.

No	Item 1	Item 2	Correlation
1	Experiment 90	Model 90	0,998828248
2	Experiment 60	Model 60	0,998277838
3	Experiment 30	Model 30	1

It feels incomplete if this SPE experiment is not equipped with its ability to produce hydrogen, then we conduct experiment to measure the productivity of hydrogen use SPE As shown in Fig. 6. The relation between the production rate of hydrogen was measured at various current and under the SPE cell temperature at 30ºC, 60ºC and 90ºC. From the figure we can conclude that the production rate of hydrogen is proportional with the SPE current and the changing of the water temperature of SPE not so changes the production rate of hydrogen.
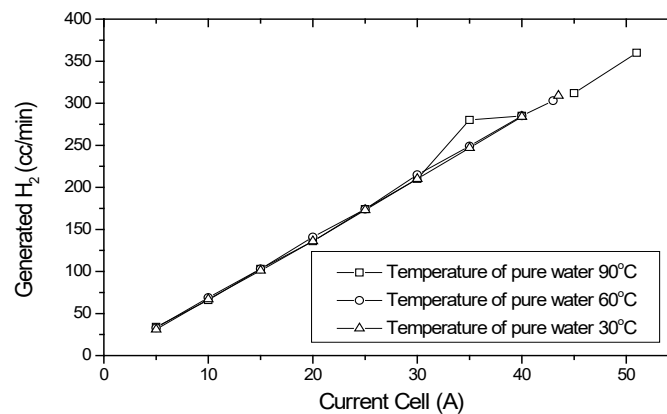

Fig. 6: Effect of current against the production rate of hydrogen

Conclusions

An electrical model of A cell of Solid Polymer Electrolyte has been developed and validated use the data of experiment. The electrical model of SPE shows the strong correlation with data of experiment (>0.998), where we can proof that the model is appropriate with real cell of SPE. We show that the cell of SPE can produce the hydrogen where the production of hydrogen is proportional with supply current to cell. This model can be used to make design of SPE in simulation circuit.

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