

Hydrogen Production from Water using Polymer Electrolyte Membrane

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1. Introduction

Hydrogen has been considered as promising future energy carriers to replace current fossil fuels. In producing hydrogen in conjunction with renewable energy source, water electrolysis has taken great interest as a most rosy technology. Among three types of alkaline, polymer electrolyte membrane (PEM), and high temperature electrolysis technologies, PEM electrolysis has demonstrated it advantageous over the other electrolysis systems from a view point of efficiency, safety, reliability, compactness. In this regard, much attention [1,2] has been paid into the development of PEM electrolysis systems.

The constituents of PEM electrolysis systems are catalogued as electrodes, solid polymer electrolyte, and current collectors. And it is well known [3] that the performance of the PEM electrolyzer can be improved by developing these constituents. In the present study, we fabricated the electrodes by controlling their composition and then investigated the effect of the electrocatalysts. Moreover, the effects of the cell temperature and the types of the current collectors were examined.

2. Experimental

Pt black (Aldrich, USA) and IrO₂ (Kojima, Japan) were used as electrocatalysts. The electrode materials were prepared from the mixture of electrocatalyst, Nafion ionomer (Aldrich, USA), and PTFE binder (Aldrich, USA) in an iso-propyl-alcohol. The mixture slurry was thoroughly agitated under ultrasonic condition for 30 min and then poured into the 5 × 5 cm mould. The slurry was dried in a forced convective oven at 30 °C for 4 h to form the electrode material.

The Nafion 117 (Du Pont, USA) was used as a polymer electrolyte membrane. The membrane was pretreated by boiling in 3 wt.% H₂O₂ solution for 1 h, followed by boiling in 0.5 M H₂SO₄ for 1h. Thereafter, the membrane was placed in boiling water for 1 h, and the procedure was repeated at least twice to remove completely the sulfuric acid.

In order to form the membrane-electrode assembly (MEA), the electrode, a polymer electrolyte membrane (Nafion 117), and a counter electrode were hot-pressed together at 120 °C with 100 kg_f cm⁻² for 7 min. Prior to the electrochemical measurements, the MEA was soaked in deionized water for 24 h.

3. Results and discussion

Fig. 1. shows galvanodynamic polarization curves experimentally measured from the electrolysis cell with Pt black cathode and IrO₂ anode as a function of temperature. As cell temperature increased from 30 to 80 °C, the cell voltage decreased from 2.04 to 1.76 V at the current density of 1 A cm⁻². Moreover, the voltage increment with current density was lowered with increasing cell temperature.

This is because high temperatures reduce the amount of electrical energy required to split the water molecules from a thermodynamic standpoint and hence electrical energy demand ΔG for water electrolysis decreases with increasing temperature [4]. Furthermore, high temperature operation quite generally favors reaction kinetics decreasing activation overvoltage.

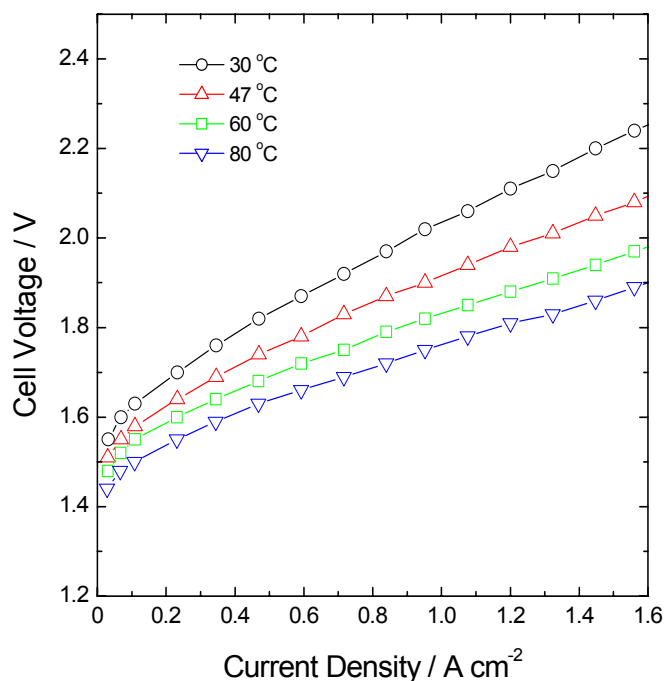


Fig. 1. Plots of (a) cell voltage against current density with different cell temperatures. The cathode material consisted of 5 mg cm⁻² Pt black, 10 wt.% Nafion ionomer, and 10 wt.% PTFE. The anode material comprised 5 mg cm⁻² IrO₂, 10 wt.% Nafion ionomer, and 10 wt.% PTFE.

In this respect, it is assured that high temperature operation is advantageous for water electrolysis. However, considering the thermal stability of Nafion membrane, optimum cell temperature was selected as 80 °C. If not specifically indicated, all the electrochemical measurements in the present study were carried out at 80 °C.

It was reported [5] that the anode materials exhibit much higher overvoltage than

cathode materials and hence contributing to most voltage loss in solid polymer electrolyte water electrolysis. The voltage loss crucially depends on the kinds of electrocatalysts [6]. In this regard, we proceed to test effect of anode electrocatalyst on the cell performance by leaving the effect of cathode catalyst out of consideration, which is shown in Fig. 2. As anode electrocatalyst, two types of Pt black and IrO₂ were prepared. Both anode catalyst loadings were exactly same as 4.5 mg cm⁻².

As can be seen in Fig. 2, the cell voltage of Pt black increased more rapidly than that of IrO₂ at low current densities below 0.3 A cm⁻². However, at intermediate current densities, the rate of cell voltage increase was almost same for both electrocatalysts.

It is well known [7] that the voltage losses at low current densities are ascribed to the activation overvoltage, which is caused by the slowness of the reactions taking place on the surface of the electrode. On the other hand, at intermediate current densities, the voltage losses are mainly due to the ohmic losses of the electrolyte between two electrodes.

Under the circumstances, it can be said that the catalytic activity of the IrO₂ for oxygen evolution reaction was much higher than that of the Pt black. In this study, aside from the IrO₂, Pt-Ru alloy was also tested. However, owing to the poor stability of Pt-Ru alloy, the result was not displayed in this figure.

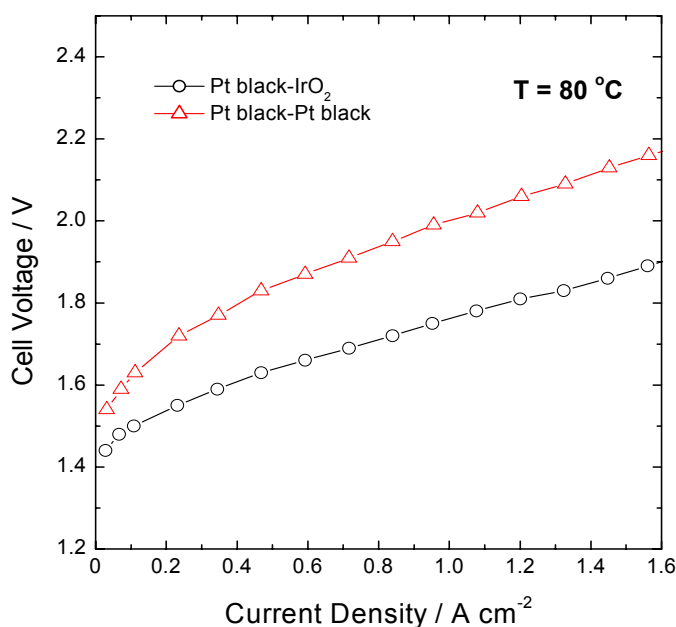


Fig. 2. Plots of cell voltage against current density for Pt black-IrO₂ and Pt black-Pt black electrodes at the cell temperature of 80 °C. Both anode catalyst loadings were exactly same as 4.5 mg cm⁻².

Fig. 3. presents plots of cell voltage against current density for the cells with three

types of Pt mesh, sintered Ti powder mat, and sintered Ti fiber mat current collectors. Ti mesh exhibited much lower overvoltage than both sintered Ti powder mat, and sintered Ti fiber mat, especially at high current densities. Since the voltage losses at high current densities are primarily attributable to the mass transfer limitations of the involved species [7], it is reasonable to say that mass transport of water inlet and gases outlet through Ti mesh was much more facilitated than those through both Ti mats. This could be due to fact that the pores consisting of Ti mesh were larger than those of Ti mats.

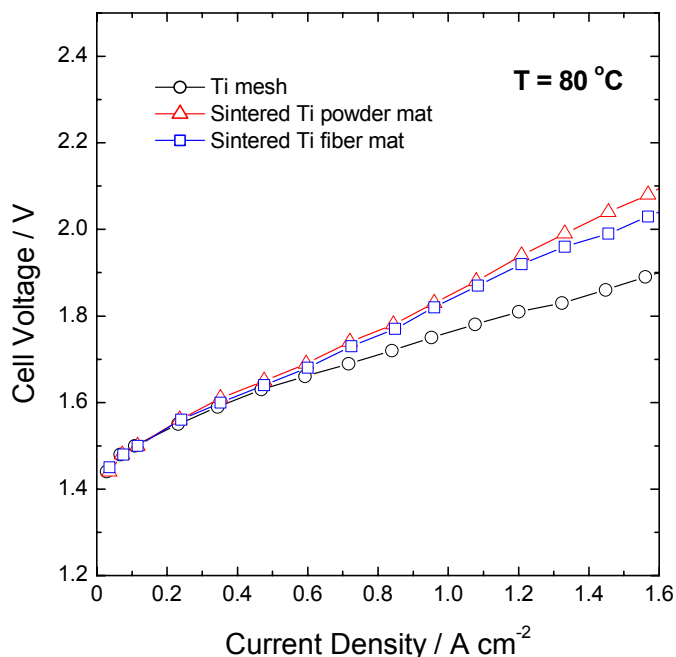


Fig. 3. Plot of cell voltage against current density for the cells with different current collectors at the cell temperature of 80 °C.

4. References

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