

Electrochemical Properties of Novel Metal Powder Electrodes for Polymer Electrolyte Membrane Electrolysis

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Abstract

The electrochemical properties of novel metal powders were investigated for the electrode materials of polymer electrolyte membrane electrolysis. Two types of Pt black and IrO₂ powder electrodes were hot-pressed on the polymer electrolyte membrane to form membrane electrode assembly. The galvanodynamic polarization method was used to characterize the electrochemical properties of both electrodes. From the experimental results, we concluded that the IrO₂ powder electrode exhibits better electrochemical performance than Pt black as cathode material for the electrolysis.

Keywords : Novel metal powder, Polymer electrolyte membrane, Electrolysis, Electrochemical property

1. Introduction

Hydrogen will gradually take charge of the future energy supply because of the rapid depletion of the fossil fuels. In order to control the supply and demand of electricity, energy storage medium are necessary and this could be solved by the combination of water electrolysis and fuel cell.

At present hydrogen production technology status, water electrolysis is the most promising method for mass hydrogen production. 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 cost, safety, reliability, compactness. In this regard, much attention has been paid into the development of PEM electrolysis systems.

The constituents of PEM electrolysis systems are classified into electrodes, polymer electrolyte membrane, and current collectors. And it is well known that the performance and cost of the PEM electrolyzer is crucially influenced by the electrode materials. In the present study, we investigated the electrochemical properties of the novel metal powders used as the electrode in polymer electrolyte membrane electrolysis.

2. Experimental and Results

Commercially available Pt black (Aldrich, USA) and IrO₂ (Kojima, Japan) powders were used for the fabrication of electrode materials. The electrodes were prepared from the mixture of powders, 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. 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 D.I. water for 24 h

Fig. 1 shows the temperature dependence of electrolysis cell with Pt black (cathode) and IrO₂ (anode) powder electrodes. 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. This implies 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 that the anode materials exhibit much higher overvoltage than cathode materials and hence, we proceed to test effect of anode on the cell performance by leaving the effect of cathode out of consideration, which is shown in Fig. 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.

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.

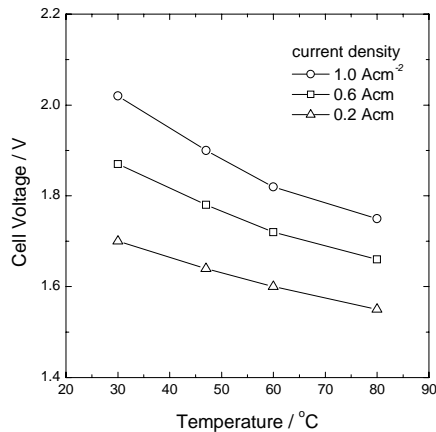


Fig. 1. Temperature dependence of electrolysis cell with Pt black (cathode) and IrO₂ (anode) powder electrodes.

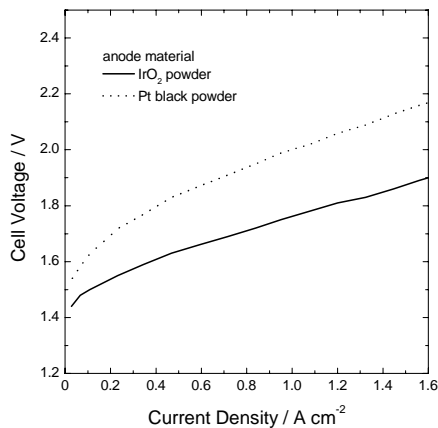


Fig. 2. Galvanodynamic polarization curves measured on the electrolysis cells with different anode powder electrodes at 80 °C. The cathode was Pt black powder.

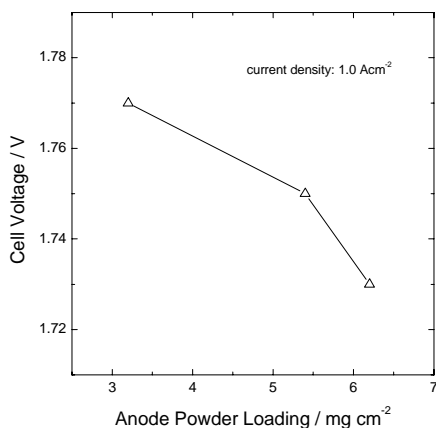


Fig. 3. Plot of cell voltage vs. anode powder loading measured on the electrolysis cell at 80 °C.

Fig. 3 demonstrates the effect of anode powder loading on the electrolysis cell performance. The cell voltage was decreased with increasing the amount of IrO₂ powder. From the results, it can be said that the IrO₂ loading in anode material crucially influences the electrolysis cell performance.

3. Summary

The electrolysis cell performance was enhanced with increasing cell temperature. However, owing to the thermal stability of the polymer electrolyte membrane, the optimum cell temperature was limited to the 80 °C. IrO₂ powder electrode exhibited much higher catalytic activity for oxygen evolution reaction as compared with Pt black powder electrode. Moreover, the higher the amount of IrO₂ powder loading was, the better resulted in the electrolysis cell performance.

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4. References

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