Studies on a Single Cell Unitized Regenerative Fuel Cells

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Abstract: – Conventional fuel cell can generate DC power and water by react hydrogen and oxygen, while electrolyzer function reversely by splitting water to hydrogen and oxygen with the assist of external power source mostly from renewable resources such as solar and wind. The unitized regenerative fuel cell (URFC) is a unique cell can function as fuel cell and electrolyzer within same cell at different modes. In contrast to conventional Fuel cell the URFC membrane catalyst need a delicate choosing because the highly performance catalyst for electrolysis may function poorly at fuel cell mode and vice versa. Selecting the URFC catalysts need a delicate compromise. In this study a single cell URFC was assembled, the catalysts for the membrane electrode assembly was Ru with loading rate of 1.25 mg/cm² for oxygen side and Pt with loading rating of 1 mg/cm². The results gained from the study show a satisfactory performance for both electrolyzer and fuel cell mode and the required voltage for water splitting through the electrolyzer mode increased significantly with increasing the operating current and leads to increase the amount of hydrogen generated. For fuel cell mode, the output voltage decreases when the operating current increasing.

Key-Words: – Fuel cell; bipolar plate; Unitized; titanium; membrane; catalyst.

1 Introduction

Fuel cell based power plants offer one of the most lucrative possibilities for future power generation and the fuel cell is also found to be potentially more efficient than the conventional plants since the fuel reacts electrochemically instead of combustion. In this way there is far less air, thermal, and noise pollution issues to be considered. A conventional fuel cell is an electrochemical device that produces electricity by separating the fuel (generally hydrogen gas) via a catalyst. The protons flow through a membrane and combine with oxygen to regenerate water with the help of the catalyst used while the electrons flow from the anode to the cathode to create electricity.

An electrolyzer operates reversely to the fuel cell which splits water into hydrogen and oxygen by the power supplied. To make a hydrogen system self dependent energy source, an electrolyzer should exist to generate gases which then be consume to generate power through the fuel cell. For some applications a specific weight (power per unit weight) is an important issue to be considered, thus researches succeed in getting one cell to function as electrolyzer and fuel cell in one cell at different modes. This cell is known as a unitized regenerative fuel cell (URFC).

Fig.1 Electrochemical reaction in the URFC

The URFC works logically in the electrolyzer mode first to store hydrogen and then use it in the fuel cell mode, thus the URFC behaves like a battery as a...
self independent power source but in contrast to the battery system, the URFC is unaffected by the depth of the discharge or length of the cycle duration. In the URFC, energy and power are not linked i.e. the cell is sized for power but the storage tank is sized for energy[1]. A diagram of the electrochemical reaction that occurs in the proton exchange membrane (PEM) of the URFC is shown in Figure 1.

URFC uses different catalyst than the conventional fuel cell uses .the conventional fuel cell normally use Pt as a catalyst for both oxygen and hydrogen side ,while in URFC Ir, IrOx,Rh or Ru was uses to enhance the reaction in the oxygen side. Hari [2] tested a URFC with Pt: C ratio 20:80 at a loading of 1 mg/cm² as an electrode for the hydrogen side and Pt/Ir-on-C with a 20% iridium content and impregnated with 5% Naftion at approximately 0.5 mg/cm² as an electrode for the oxygen side. The data collection for the regenerative is first from the fuel cell mode and then the electrolyzer shows better electrolysis performance and finally as it slightly lowers for Pt/Ir-on-C than those for Pt-on-C electrodes.

Swette et al. [3] tested different oxygen electrode catalyst materials and different decompositions and compared the results with the baseline electrode with Pt at both the hydrogen and oxygen side. The results show that the regenerative PEM fuel cells display an efficient bifunctional performance that can be fabricated with the traditional Pt for the hydrogen side and Pt-Ir catalyst if the electrode structures are properly designed. This investigation has also identified RuOx as a catalyst with a good potential for improving the O₂-evolution component of a bifunctional positive electrode. Ledjeff et al. [4] shows the manufacturing procedure of coating Naftion117 membrane with a variety of different noble catalysts such as Ru and Ir. The resulting electrodes are very thin and show a high performance.

Ioroi [5] showed that the preparation procedure of the IrO₂/Pt catalyst can affect the performance of the URFC, comparing the result of catalyst prepared by mixing IrO₂/Pt and the one with deposited IrO₂/Pt. The deposited method shows 2-3 % improvement of the roundtrip efficiency and this enhancement is due likely to the microstructure of the electrocatalyst. Chen et al.[6]prepared electrode arrays containing 715 unique combinations of five elements (Pt, Ru, Os, Ir, and Rh) by the Borohydride reaction of aqueous metal salts. Catalysts that showed high activity for both reactions and good resistance to anodic corrosion have been identified in the Pt–Ru rich region of the Pt–Ru–Ir ternary. The ternary catalyst Pt₁₄.₅Ru₄Ir₀.₅ (subscripts indicate atomic ratios) is significantly more active than the previously described Pt₁Ir₁ bifunctional catalyst for both reactions.

2 Experimental Setup

In the single cell URFC, the MEA have been sandwiched between two current collectors and two flow field plates. The flow field plate used in the single cell URFC from clear Acrylic Plastic while the current collector was made from copper .Figure 2 shows the aforementioned components of the cell. A silicon gasket was used on each side of the cell of the MEA to assure a gas tight seal between the membrane and the flow field plate upon compression .This seal prevents the gases and the water from leaking from the cell or crossing over from one side to the other.
3 Results and Observations

The test start on electrolyzer mode at which the deionized water supplied to the cell with the supplying of DC power. The water starts splitting to hydrogen and oxygen and stored in the gases cylinders. As expected, it was found that increasing the operating current lead to increase the required splitting voltage and consequently the amount of the gases generated increased accordingly. In the fuel cell mode, the operation was completely reversed. The variable resistor work as external load and the gases stored in the cylinders supplied to the URFC, it was found that the higher operating current the lower output voltage generated by the cell was observed. Figure 5 showed one complete cycle (electrolyzer mode, purging and fuel cell mode) at which the operating voltage and current for each mode was shown.

The cell tested base on 10 min. interval for electrolyzer mode and fuel cell mode and 1 min. for purging the accumulated gases and water before each mode starting. The hydrogen volumetric flow rate produced through the electrolyzer mode was achieved at fix operating current (0.8-0.86 Amp.), while for the fuel cell mode the hydrogen volumetric flow rate was consumed at fix operating current of (0.5 Amp.). Since the room temperature was 25 °C as well as the pressure was atmospheric pressure, the measured volumetric flow rate assumed to be at standard conditions and a standard milliliter per min was used as a measured unit. Figure 6 shows the volumetric flow rate for both modes.

The URFC performance under different current values. As expected the higher operating current leads to decrease the output voltage for cell at fuel cell mode. Similarly for electrolyzer mode, high amount of voltage was achieved at higher operating
currents. The single cell URFC performance under various current ranges is shown in figure 7.

![Fig.7 Performance of single cell URFC (ambient temperature and pressure)](image)

4 Conclusions
From the gained results and the observations from this study, the following conclusion can be drawn.
1. A satisfactory cell performance for both electrolysis and fuel cell mode was achieved by implemented a MEA with 1.25 mg/cm$^2$ of Ru as a catalyst for oxygen side and 1 mg/cm$^2$ Pt for the hydrogen side.
2. The higher operating current for electrolyzer mode leads to generate more hydrogen but the required voltage was higher accordingly. For fuel cell mode the higher withdrawal amperage from cell tends to decrease the operating voltage.

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