



APPLICATION OF CURRENT PULSES TO WATER ELECTROLYSIS SYSTEMS

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Hydrogen obtained from renewable energy resources is a virtually unlimited, environmentally benign energy source that could meet most of our future energy needs. The “Blow Jet” is a Wave Energy Conversion (WEC) device, which is currently being tested in a wave flume. The Proton Exchange Membrane Electrolyzer (PEME) can be coupled to WEC to obtain the necessary electricity for splitting the water. This work shows a chrono-potentiometric study. The experiments are carried out by applying the current pulse and determining the potential as a function of time. The Membrane Electrode Assemblies (MEA) were prepared from the mixture of electro-catalysts (RuO_2 and IrO_2 were used as anode and Pt/C was used as cathode) and Nafion 115 membrane. The PEME was designed and in-home built. It is connected to a galvanostat in order to obtain its response characteristics ($V-t$). Chrono-potentiometric experiments were recorded in the current range of 20 to 500 mA at 300s.

Key words: Chronopotentiometric, PEM Electrolyzer, Wave Energy Conversion



1. INTRODUCTION

Hydrogen obtained from renewable energy resources is a virtually unlimited, environmentally benign energy source that could meet most of our future energy needs. The “Blow Jet” is a Wave Energy Conversion (WEC) device, which is currently being tested in a wave flume. The aim of this device is to concentrate the energy of a wave train and offer it in a more readily available form, as a jet, capable of powering a turbine generator. It generates a current pulse with a specific voltage [1,2]. The electrolysis of water has been recognized as the only current practical method for the production of hydrogen from renewable energy sources [3,6]. The Proton Exchange Membrane Electrolyzer (PEME) can be coupled to WEC to obtain the necessary electricity for splitting the water. Water and electrical energy can be regenerated later by using a fuel cell, thus completing the hydrogen-electricity cycle.

The performance of the PEME mainly depends on the structure and the electrochemical characteristics of the oxygen electrode. It is well known that the oxygen evolution reaction (OER) is the slowest step in water electrolysis [7]. In a PEME system is believed that the OER is the main source of energy loss due to the complexity of its reaction pathway that involves absorbed species on the catalyst surface blocking the surface sites where they are going to be oxidized. In addition, the oxygen electrode should be resistant to anodic corrosion during OER. In consequence, the development of efficient electrocatalysts for the oxygen electrode is a technological challenge for the PEME commercialization. It has been reported that noble metals and metal oxides have been used as electrocatalysts on the oxygen electrode. Therefore, several studies have shown that noble metal oxides, such as iridium oxide (IrO_2) and ruthenium oxide (RuO_2), exhibit good performance for OER [8-10]. Nonetheless, it is recognized that the use of mixed metals can lead to synergetic effects that could improve the kinetics for the OER and the stability/selectivity of the oxygen electrode. This work shows a chronopotentiometric study to determine the voltage-current response of electrolyzer. The Membrane Electrode Assemblies (MEA) were prepared from the mixture of electrocatalysts (RuO_2 and IrO_2 were used as anode and Pt/C was used as cathode) and Nafion[®] 115 membrane.

The Membrane Electrode Assembly (MEA the electrochemical processor) was prepared by using carbon cloths as gas diffusion medium. The catalytic ink was prepared with ethylic alcohol and 5% Nafion solution (Aldrich), it was sprayed over a membrane. The mixture of electrocatalysts (75RuO₂-25IrO₂ (Aldrich 99.99%) were used as anode and Pt/C was used as cathode) and Nafion 115 membrane. The membrane was previously treated with H₂O₂ and H₂SO₄ as reported in literature [12].

The MEA of 4 cm² geometric surface area was prepared by hot-pressing of the catalysts-membrane and carbon cloths using a 5% Nafion solution (Aldrich) as a binder, in order to prevent ohmic resistance and to form good contact between the electrodes and the polymer membrane. The chosen proton conductive binder (identical with the polymer electrolyte) ensures the mechanical stability of the MEA. It was performed stepwise in the regime of gradual pressure decrease, starting at 50 kg cm⁻² and 120 °C for 5 s, and ending at 11 kg cm⁻² and 120 °C for 2 min.

All electrochemical measurements were carried out at 25°C and all potentials are referred to Normal Hydrogen Energy (NHE). The amount of hydrogen produced was determined by water displacement in a burette, the time was register to determine the yield. The theoretical yield of hydrogen is calculated using Faraday laws.

3. RESULTS AND DISCUSSION

3.1 Chronopotentiometric

The experiments are carried out by applying the controlled current (current pulse) and determining the voltage as a function of time. The voltage response of MEA after applying current of different magnitude is shown in Figure 2. The current pulses length is chosen to be sufficiently long that the voltage remains constant. After 80 mA the voltage remains constant following to 50 sec.

Figure 2 shows chronopotentiometric curves obtained when current pulses are applied during 300 sec. The constant voltages are suggesting the reproducibility of electrochemical processes occurring on its surface.

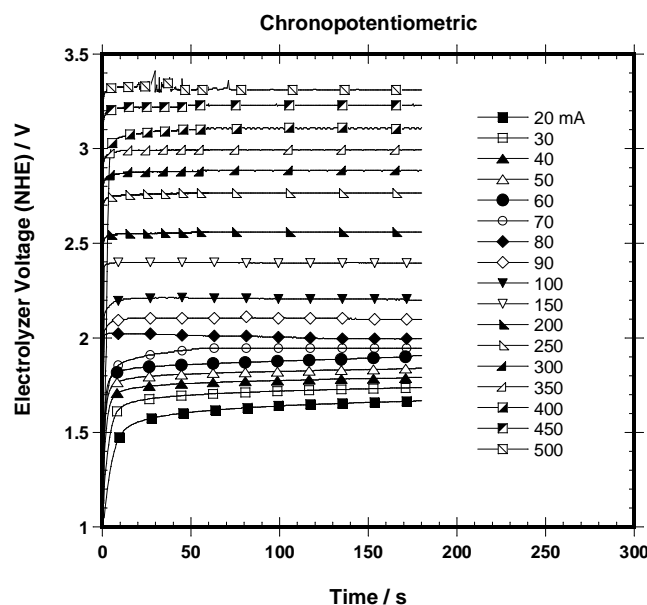


Figure 2. Electrode potential response during the application of pulses of different current at 25°C.

Figure 3 shows the galvanostatic polarization curve (V-I) of the electrolyzer experimentally measured, containing the assemblies with Pt as cathodes and anodes of 75RuO₂-25IrO₂ at atmospheric pressure and 25 °C. The polarization curve was obtained from figure 2. The electrochemical performance of the electrolyzer is reproducible and stable, after operated for around 5 h. This behavior is attributed to the homogeneity of the ink deposition. The experimental results show that at a current of 0.2 A and 2.5 V, the electrolysis of water produce 69 cm³ min⁻¹ of hydrogen. The current efficiency is defined as the ratio of electrons used for generating hydrogen, calculated using the following equation [11-12].

$$\eta_1 = \frac{\text{Real H}_2 \text{ product}}{\text{Theoretical H}_2 \text{ product}} = \frac{2 \times 96500 \text{ V}^0}{I \times 3600 \times 24.4} 100 \quad (1)$$

The theoretical hydrogen product is derived by assuming that the hydrogen is an ideal gas and the pressure is corrected by the atmospheric pressure where the experiment was performed. V^0 is the volume of hydrogen produced under standard conditions.

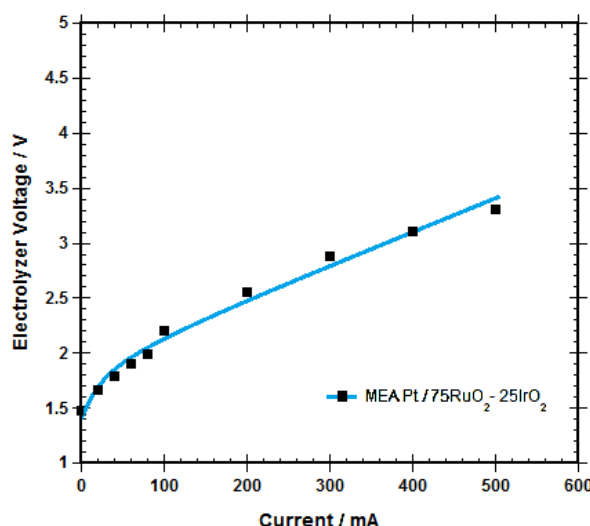


Figure 3. The polarization curves of MEA.

The current efficiency could be enhanced by the cell temperature and the operating pressure, because hydrogen dissociation, proton transfer reactivity in the Nafion membrane and the partial pressure of hydrogen, all increase with temperature and pressure.

The current efficiency deduced for the production of $69 \text{ cm}^3 \text{ min}^{-1}$ of hydrogen was up to 76% indicating that only the hydrogen evolution reaction occurs in the cathode side and oxygen in the anode compartment.

4. CONCLUSIONS

The PEME can work with a current pulse with a voltage larger than 1.5 V, preferably with a time larger than 5 seg. A system of electrolysis will be coupled to the Blow Jet through the turbo-generator, in order to store the energy captured chemically, in the form of hydrogen. The preliminary results presented here demonstrate the compatibility of the two devices and suggest a promising possibility for future wave energy conversion.

5. ACKNOWLEDGEMENTS

This work has been supported by the IPN under project SIP-20113593 and CONACYT project 130254.

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