

Real time measurement of water transport in polymer electrolyte fuel cell

Ryosuke Shimokawa^a, Hidekazu Nagai^a, Yukihiro Sugawara^a, Hisashi Minakuchi^b, Masao Sudoh^a

^aDepartment of Materials Science and Chemical Engineering, Shizuoka University

3-5-1 Johoku, Hamamatsu, Shizuoka 432-8561, Japan

^bDepartment of Mechanical Systems Engineering, Faculty of Engineering,

University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan

1. Introduction

Water management of the polymer electrolyte fuel cell (PEFC) is one of the factors that are crucial for a high performance and durability. The proton conductivity in polymer electrolyte membranes (PEMs) such as Nafion[®] depends on the water content. Therefore, PEM must be hydrated in order to maintain high proton conductivity. But excessive liquid water in the cathode or anode catalyst layer and gas diffusion layer limited reactant gas diffusion and leading to a performance drop. Hence, it is very important to maintain an optimal water balance during the operation of PEFC.

Water balance in the PEFC lies in the interactions of two different mechanisms of water transport, back diffusion (BD) and electro-osmotic drag (EOD). BD is caused by the difference in water concentration between the anode and cathode. EOD occurs when proton pulls water molecules when transferring through the membrane. To maintain an optimal water balance in the PEFC, it is necessary to reveal the water transport condition during operating of PEFC.

In this study, we used humidity sensors to measure the water content inlet and outlet gases during operating. We determined the real-time net water transport coefficient α during operating of PEFC from the humidity change in inlet and outlet gases, and investigated the effect of reactant gas flow rates on the real-time α behavior and performance of PEFC.

2. Experimental

2.1 Preparation of Membrane Electrode Assembly (MEA).

The membranes were Nafion 115, 117 or 212 which are pretreated. The anode and cathode gas diffusion electrode used carbon paper (TORAY TGPH-060) with 1.0 mg cm⁻² platinum catalyst loading. The membrane and electrodes were sandwiched and hot pressed at 1 MPa, 398 K, 2 min. The active area of MEA is 2.3 × 2.3 cm².

2.2 Real-time measurement of relative humidity of inlet and outlet gases.

Four humidity sensors were used to measure the relative humidity in anode and cathode inlet and outlet gases. The fuel cell works at the temperature of 80 °C, relative humidity of both supplying gasses was set at 40 % and gas flow rates were 50-500 ml min⁻¹. The water content ($\dot{n}_{in\ or\ out}$ [mol/s]) in humidified gases calculated from gas flow rates, relative humidity and the temperature. Net water transport coefficient α was calculated from \dot{n} with following expressions. The α was defined as the ratio between the net amount of water transported from the anode to the cathode per proton [H₂O/H⁺].

$$\dot{n}_{in\ or\ out} = \frac{\dot{n}_{others} [RH \cdot P_{sat}(T)/P]}{1 - RH \cdot P_{sat}(T)/P} \quad (1)$$

$$\dot{n}_{gen} = \frac{iA}{2F} \quad (2)$$

$$\alpha_a = \frac{\dot{n}_{in,a} - \dot{n}_{out,a}}{iA/F}, \quad \alpha_c = \frac{\dot{n}_{out,c} - \dot{n}_{in,c} - \dot{n}_{gen}}{iA/F} \quad (3)$$

3. Result and discussion

Fig. 1 shows the real-time α_a and α_c . Water transport condition passed through three steps (①-③) from start-up to shut down²⁾. After current turned on (①), α_a was quickly increased and α_c was decreased. This means that water moves to center of membrane at start-up process. At anode side, the effect of EOD the water moves to cathode side. At cathode side, the water produced at catalyst layer and diffused to anode side. After 200 s (②), α converged at steady value because of the effect of EOD and diffusion interact with each other. After current turned off (③), α_a was quickly decreased and α_c was increased, as the opposite from step ①. This means that water moves to the outside of membrane at shut down process.

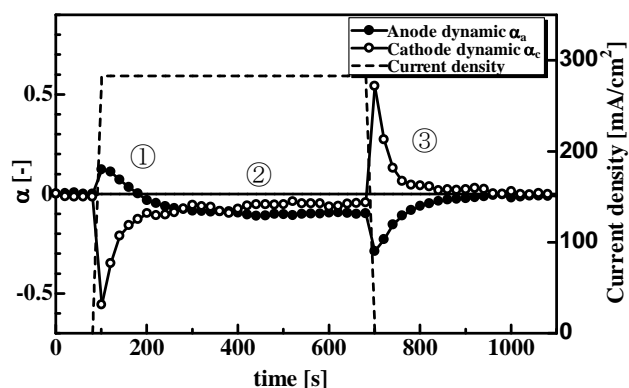


Fig. 1 Real time α for Nafion 212 at 1.5 A (284 mA/cm²), A (Anode)/C (Cathode) RH=40/40%.

Fig. 2 shows the steady state values of α at various membrane thicknesses and O₂ gas flow rates. As the effect of BD was enhanced, the α obtained to be lower values at thinner membrane¹⁾. The α increased with O₂ gas flow rate increased in all of membranes.

We investigated the water transport at start-up process for various gas flow rates. Water transport at start-up process related to the transient response of cell voltage. At high gas flow rate, both the α and voltage spike at start-up was approached to steady state in short time.

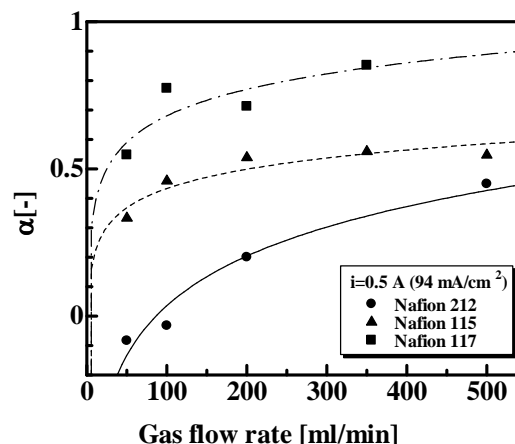


Fig. 2 Steady state values of α at various gas flow rates and membrane thicknesses.

4. Reference

- 1) G. J. M. Janssen and M. L. J. Overvelde, *J. Power Sources*, **101** 117-125 (2001)
- 2) G. He, K. Shibata, Y. Yamazaki and A. Abudula, *Int. J. Hydrogen Energy* **36** 7183-7190 (2011)