Investigation for Water Propagation at PEMFC with Single Channel by Neutron Imaging Technique

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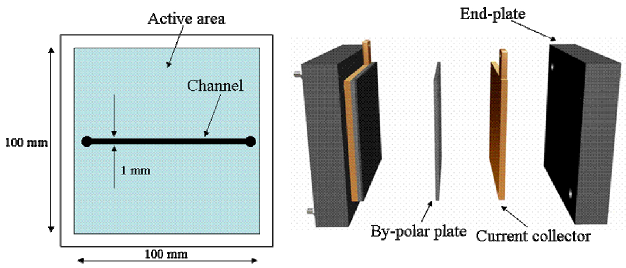
1. Introduction

Effective water management increases performance and durability of the Polymer Electrolyte Membrane Fuel cell(PEMFC). The membrane in PEMFC must be sufficiently hydrated because its conductivity relies primarily on the humidity state of the membrane. Since water is generated as a by-product when the fuel cell is generating power, this water source can be said to be a "disturbance" to any water management system, which is trying to maintain proper humidity level without flooding. Since water is generated throughout the active area, the downstream area can be flooded even when the upstream area is under-saturated. This creates a challenging environment for water management, which adversely affects the efficiency and reliability in the operation of the PEMFC [1]. Although there are many researches for the water management [1-7], their interests are limited on the performance. However, the fundamental information of water propagation characteristics is needed to make a scheme for water management. In this study, we used specially designed PEMFC with only single channel, and the water propagation was investigated according to the channel location by neutron imaging technique.

2. Experimental Setup

2.1 Test Section

The specially designed PEMFC as sketched in Fig. 1 was used to investigate the water propagation characteristics with an active area of 100 cm^2/single-cells. Its width and depth is both 1 mm. The flow fields were directly machined into a carbon-graphite block. Since fuel was supplied only into the limited area of active area, small area nearby channel is directly reacted and most part of active area plays a role as a reservoir.

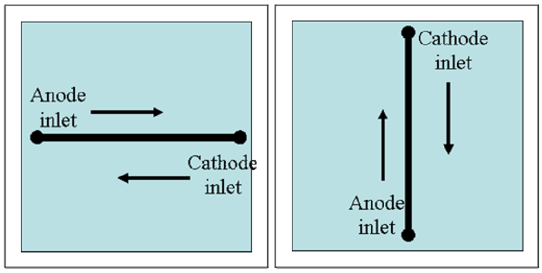


a) b)

Fig. 1. Schematic diagram of test section, a) front view and b) side view

2.2 Test condition

Test was performed with two kinds of channel location, horizontal and vertical cases as shown at Fig. 2, with counter-current flow. The flow rates of anode and cathode were fixed at 0.8 and 2.6 lpm, respectively. The relative humidity and temperature of hydrogen and air are 100 % and 65℃.



a) b)

Fig. 2. Schematic diagram of channel location, a) horizontal and b) vertical cases

2.3 Neutron Imaging Facility and Process

All the experiments described above were performed at NRF, HANARO. The neutron flux and collimation ratio of NRF is 2×10^7 n/cm^2s and 200, respectively. The detecting system of this study consists of a neutron-sensitive scintillator and a CCD camera with a 16-bit with 1340 by 1300 pixels housed in a light tight box. The neutron beam is converted into light by the scintillator. The light is reflected by a mirror and then measured by the CCD camera. This design protects the camera against a neutron beam. The exposure time was 5 second.

Two kinds of image were taken to emphasize the water behavior from the raw neutron images, usually called dry and wet images. The typical process is like as:

(1) Capture images of PEMFC without water (***dry***)

$$I_{dry} = I_{o\_dry} \exp(-\sum_i \mu_i t_i) \quad (1)$$

(2) Capture images of PEMFC with water (***wet***)

$$I_{wet} = I_{o\_wet} \exp(-(\sum_i \mu_i t_i + \mu_{water} t_{water})) \quad (2)$$

(3) Divide the ***wet*** image by ***dry*** image and take the negative natural log to get the value of μt.

$$T = -\ln\left(\frac{I_{wet}}{I_{Dry}}\right) = -\ln\left(\frac{I_{o,wet}\exp(-(\sum_i \mu_i t_i + \mu_{water} t_{water}))}{I_{o,dry}\exp(-\sum_i \mu_i t_i)}\right)$$

$$= -\ln\left(\frac{\Phi_{o,wet}}{\Phi_{o,dry}}\right) + \mu_{water} t_{water} \quad (3)$$

At steps (1) and (2) we must consider the white spots which are caused by the gamma radiation hitting the CCD chip. For this purpose, a smoothing filter like a 3x3 median filter is applied to the whole data set. This technique consists of replacing the pixel value with the median of the neighboring pixel values. And a temporal non-uniformity of the neutron beam flux is corrected by any position of the outside test section.

3. Results and discussion

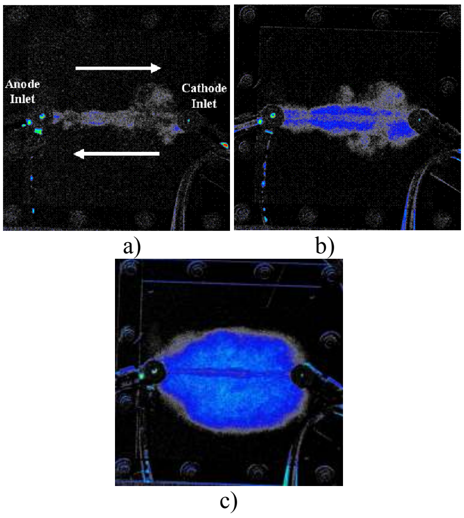


Fig. 3. Test result of horizontal case, a) before supplying, b) after 1000 sec, and c) after 5400 sec

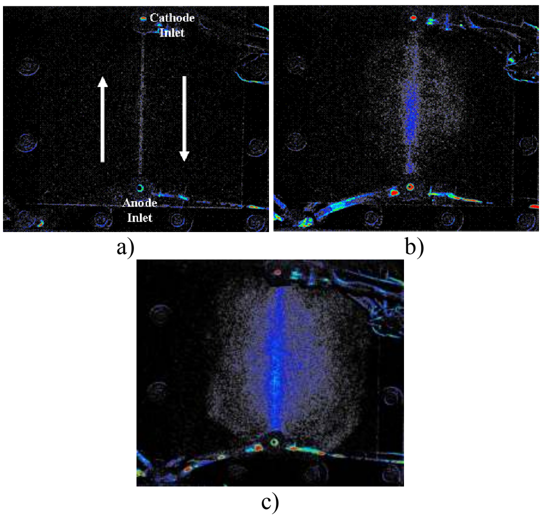


Fig. 4. Test result of vertical case, a) before supplying, b) after 1000 sec, and c) after 6300 sec

Figs.3 and 4 are test results of horizontal and vertical cases, respectively. They are processed as described at Section 2.3. Black area at processed neutron image means low water and blue means high water. Although there exists some water before supplying the hydrogen and air into PEMFC as shown as Fig.3-a), the water propagation was well visualized from channel to MEA by neutron imaging technique when comparing from Figs.3-a), 3-b) to 3-c). Especially since the thickness of MEA is less than 300 μm, the maximum thickness of water at MEA is less than 300 μm and the water distribution and behavior was well measured. It shows the power of neutron imaging technique.

When checking the Fig.3-c), the propagation length between higher part and lower part is different. The propagation length of lower part is bigger than that of higher part. It seems that the gravitational force might affect the water distribution and propagation. These results conform by the Fig.4-c). Since gravitational force is same between right and left part for the vertical case, the propagation length is similar.

4. Conclusion

A series of measurement has been conducted to investigate the water propagation characteristics according to the channel location. For the horizontal case water at lower part was better propagated than higher part due to gravitational force. For the vertical case, there isn't gravitational effect. It would be interesting to study the fundamentals of these phenomena based on the measurements presented in this work. It was also shown that neutron imaging technique is a powerful tool to visualize the PEMFC.

ACKNOWLEGMENT

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