EFFECT OF GAS FLOW CHANNEL PATTERN WITHOUT CATHODE HUMIDIFICATION ANALYZED WITH ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

Yasutaka Takazono[1], Hironori Nakajima[2], Tatsumi Kitahara[2], Kohei Ito[2]
[1]Department of Mechanical Engineering Science, Graduate School of Engineering, Kyushu University, Fukuoka, Japan
[2]Department of Mechanical Engineering, Faculty of Engineering, Kyushu University, Fukuoka, Japan

SUMMARY

We have investigated the effect of gas flow channels without cathode humidification using Electrochemical Impedance Spectroscopy (EIS). Performance tests and EIS were conducted with triple-serpentine and the serpentine-interdigitated hybrid flow channels that we had developed [1]. The performance obtained with the hybrid flow channel is better than the triple-serpentine flow channel. Moreover, the EIS result indicated that the dehydration of the membrane proceeded gradually with the triple-serpentine flow channel. In the case of the hybrid flow channel, however, the dehydration of the membrane did not occur. These result said that the serpentine-interdigitated hybrid flow channel is more suitable for PEFC operation without cathode humidification than the triple-serpentine flow channel. The reason for these results is possibly that the hybrid flow channel uniformized current distribution because of the interdigitated flow channel structure and the serpentine flow channel structure supplied water vapor along the flow channel.

INTRODUCTION

To operate PEFCs stably, the membrane has to be wetted in moderation. In order to achieve a good water balance and a hydrated membrane, the inlet gases are commonly humidified. However, from the point of view of the total efficiency of a PEFC and the cost, humidifiers should be removed. In particular, the humidifier on the cathode side should be removed because water is generated at the cathode side with the oxygen reduction reaction. To achieve this objective, several researches have been conducted [2].On the other hand, we have developed novel gas flow channel aiming at higher performance than conventional gas flow channels. The novel gas flow channel, named serpentine-ingerdigitated hybrid pattern gas channel, had high pressure interdigitated channel and low pressure serpentine channel. In this paper, we clarify the effect of the flow channels on the PEFC performance without cathode humidification.

EXPERIMENT/DISCUSSION

Flow channels

Triple-serpentine, interdigitated and serpentine-interdigitated hybrid pattern gas channels were prepared. Figures 1(a) and (b) show the design of the respective channels. In the hybrid channel, the reactant gas flows through the high pressure interdigitated channel and then flows through the gas diffusion layer under the landing. The gas then flows though the low pressure serpentine channel and is exhausted from the cell.

Experimental conditions

Cell performance tests were carried out without cathode humidification. The cell temperature was set at 75℃. The utilization of hydrogen at the anode was 70% and that of air at the cathode was set at 50%. The relative humidity of the fed gas at the anode was set at 100%. No back pressure was applied. The active area of the membrane electrode assembly (MEA; Japan Gore-Tex Inc., PRIMEA 5580, Catalyst: 0.4mg Pt cm^{-2}, thickness: 30μm) was 4.2cm^2. Electrochemical impedance spectroscopy was performed for the full cell in a frequency range between 5000 and 0.1 Hz. Impedance spectra variations with time were measured at 0.1A/cm^2. Test conditions are summarized in Table 1.

DISCUSSION

Figure 1 illustrates the Nyquist plots for the three channels at 0.1A/cm^2. Two arcs are observed for the three flow channels. The higher frequency arc corresponds to the proton transport and charge transfer process and the lower frequency arc corresponds to the diffusion process. The real axis intercept represents the ohmic resistance of the cell. The diameter of the high frequency arc for the serpentine flow channel is larger than that for interdigitated and the hybrid flow channels. This phenomenon indicates that the serpentine flow channel has higher resistances than the other flow channels. The diameter of the low frequency arc for the serpentine flow channel is also larger than the others. The oxygen permeation seems to decrease because of the dehydration of the catalyst layer.

Fitting was conducted. The results indicate that the proton transport resistance (R_p) is dominant. R_{ohm} is considerably different among the three channel. Its value for the serpentine flow channel is larger than that of interdigitated flow channel by 2.4 times. Moreover, it is larger than that of the hybrid flow channel by 3.4 times. This phenomenon indicates that the membrane is dehydrated when serpentine flow channel was used. However, the dehydration of membrane was mitigated when interdigitated and the hybrid flow channel were used. This reason is probably that the interdigitated design can distribute reactant gas to each flow channel uniformly. This means that the oxygen concentration is uniform on the active area. Thus, the interdigitated design can uniform the current distribution[3]. On the other hand, serpentine design has non-uniform oxygen distribution [4], that is, current distribution is not uniform[3]. For that reason, the water distribution is different and the dehydration level of the membrane is different.

Table 1: Experimental conditions

CELL TEMPERATURE	CURRENT DENSITY	ANODE UTILIZATION	CATHODE UTILIZATION
75℃	0.1A/cm^2	70%	50%

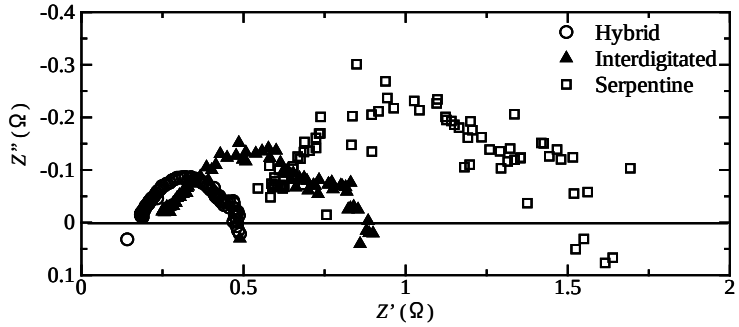

Figure 1: Nyquist plots for the three flow channel at 0.1A/cm^2.

CONCLUSION

The influence of channel design on the PEFC performance without cathode humidification was investigated and the following conclusions were reached.

(1) A serpentine-interdigitated hybrid pattern gas flow channel achieves higher performance than the triple-serpentine flow channel.
(2) At low current density (0.1A/cm^2), the dominant resistance is the proton transport resistance for each flow channels. Its value for the hybrid flow channel is the lowest of the three flow channels. This phenomenon indicates that the hybrid flow channel is suitable for the PEFC operation without cathode humidification because of its uniform current distribution and re-humidifying ability attributed to the low pressure serpentine flow channel.

ACKNOWLEDGEMENT

One of the authors, Y.T., thanks Japan Society for the Promotion of Science for the financial support of a research fellowship.

REFERENCES

[1] Y.Takazono, K.Tsuda, etc, “Development of a PEFC with serpentine-interdigitated hybrid pattern gas channels”, ECS transactions 33(1), (2010), pp927-935.

[2] Z.Jianlu, T.Yanghua, etc, “PEM fuel cells operated 0% relative humidity in the temperature range of 23-120 ℃”, Electrochemica Acta. 52(15), (2007), pp5095-5101.

[3] G.Zhang, L.Guo, etc, “Comparison of current distributions in proton exchange membrane exchange fuel cells with inteterdigitated and serpentine flow fields”, J. Power Sources, 188, (2009), pp.213-219.

[4] J.Inukai, K.Miyatake, etc, “Direct Visualization of Oxygen Distribution in Operating Fuell Cells”, Angew. Chem. 120, (2008), pp.2834-2837.