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Effect of Oxygen Utilization on PEM Fuel Cell Performance Investigated by Numerical Simulation

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Overview

Recently, visualization studies have been more important to understand the mechanism in PEM fuel cell under various operating, structural conditions. In order to visualize inside PEM fuel cell, we have been developed a numerical simulation tool calculating the cell performance and physical distributions using in-situ measured data. In this study, as for the first step of the modeling development, the effect of oxygen utilization on the fuel cell performance was investigated by numerical simulation.

Numerical Modeling

Inside PEM fuel cell, multi-physical and multi-scale of phenomena such as multi-component gas, liquid water and heat transport inside the flow channel and the GDL, electrochemical reactions and proton/water transport in the MEA are nonlinearly coupled [1]. These phenomena require too much calculation cost to be solved by fully 3D equations based on computed fluid dynamics (CFD), so it is necessary to apply simplified models to some extent. In our simulation, macroscopic models are applied for microscopic phenomena in the MEA such as electrochemical reactions and proton/water transport. Furthermore, these models are coupled with heat and mass transport equations in which effective parameters such as gas diffusion coefficient and permeability in the GDL and pressure drop coefficient in the flow channel are included.

Results

At first, the performance of 25cm^2 test cell with single serpentine channel was carried out. The operating condition is that hydrogen and air flow rate is 300ml/min, relative humidity is 60%RH, cell temperature is 353K and back pressure is 1atm, respectively.

The distribution of oxygen partial pressure in cathode flow channel at oxygen utilization 30% (220mA/cm^2), 60% (430mA/cm^2) and 80% (580mA/cm^2) is shown in Fig. 1 compared to the measured data by a nondestructive visualization system for oxygen [2]. The simulation result is good agreement with the measured data and indicates that the peak of current density shifts toward upstream area as oxygen utilization increases. As seen Fig.2, compared to the result of segmented cell, current density in the inlet area is higher than that near outlet. Thus, the numerical model is valid for different oxygen utilization conditions.

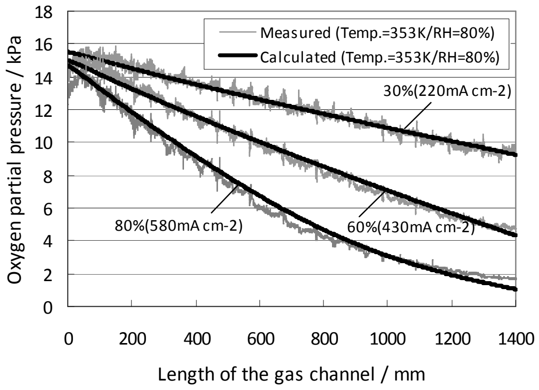


Fig.1: The distribution of oxygen partial pressure in cathode flow channel

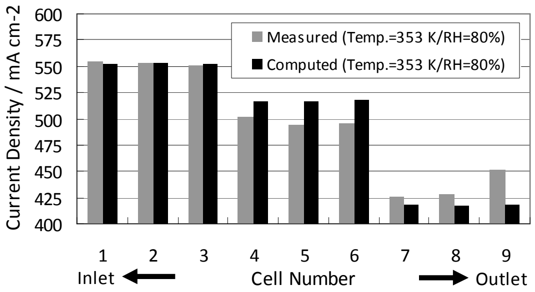
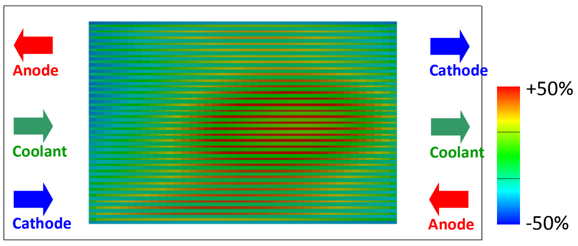
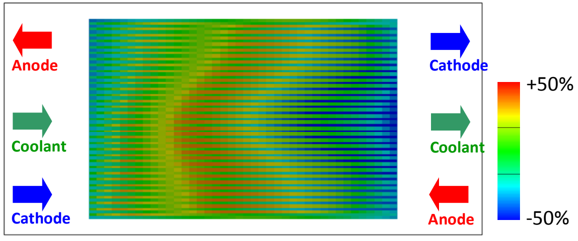


Fig.2: The distribution of local current density compared to segmented cell

Applying the validated model, effect of oxygen utilization on the commercial-sized 260cm^2 PEM fuel cell performance was investigated. Fig.3 shows local current density distribution at 500mA/cm^2. At low oxygen utilization (30%), the current density under the flow channel is lower than that under the rib, because MEA under flow channel dehydrates caused by the high velocity of air-flow in the cathode. On the other hand, at high oxygen utilization (80%), the current density in the down stream area remarkably decreases especially under the rib caused by liquid water flooding. As seen Fig.4, the distribution of gas flow rate for each flow channel becomes heterogeneous as oxygen utilization increases, because liquid water accumulates in the down stream area.



(a) Oxygen Utilization=30%



(b) Oxygen Utilization=80%

Fig.3: The distribution of local current density in the 260cm^2 PEM fuel cell at 500mA/cm^2

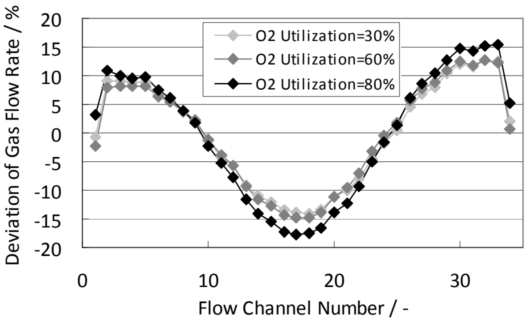


Fig.4: Deviation of gas flow rate for each straight flow channels at 500mA/cm^2

References

1. C.Y. Wang, *Chem. Rev.*, **104**, 4727-4766, (2004).
2. J. Inukai et al., *Angew. Chem, Int. Ed.*, **47**, 2792 (2008).