Measurement of Oxygen Gas Transport Resistance in Cathode Catalyst Layers of PEFC

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Introduction
Polymer electrolyte fuel cells (PEFCs) are a promising power sources for automotive use. For the commercialization, cost reduction is one of the most important issues. In order to reduce cost, the Pt-loading of a membrane electrode assembly (MEA) should be reduced. Many studies for this purpose have been done. As part of such studies, in-situ analytical methods for evaluating oxygen transport properties have been developed using limiting current measurements. It has been found that reactant gas transport resistance in CLs (R_m) was mainly consisted of two parts, Knudsen diffusion resistance (R_K) and diffusion resistance around Pt particles (R_p). And it has been found that the diffusion resistance around Pt catalyst R_p was significantly increased when Pt loading in CLs was reduced.

In this study, the oxygen diffusion resistances in CLs are measured not only the limiting current measurement method but also by the oxygen-nitrogen mutual diffusion method. The results are analyzed using the difference of oxygen diffusion pass in CLs with these two measurement methods.

Experimental
Table 1 shows the specifications of the MEAs used in this study. The MEA samples with an active area of 1cm² were fabricated by coating CLs consisting of catalysis powders (Pt/C) and Nafion® ionomer onto the perfluorosulfonated polymer membrane (Nafion® NR212). Pt-loadings of the samples for the working electrode were 0.50, 0.35, 0.20, 0.12, 0.07 mg cm⁻² respectively. In order to evaluate the reactant gas transport resistance in the CLs, limiting currents were measured in nitrogen balance gases. R_K and R_p were determined with the above-mentioned method and were compared.

Results and discussion
R_m was determined by limiting current measurement method is shown in Fig.1. In order to estimate R_K and R_p, Equation (1) was introduced with the analogy of porous electrode model and value was determined.

\[ R_{CL} = \sqrt{R_K R_p \ coth \left( \frac{R_p}{R_K} L \right)} \]  \hspace{1cm} (1)

R_K: Gas Diffusion resistance in CLs
R_p: Knudsen diffusion resistance in CLs
R_m: Diffusion resistance around Pt catalyst
L: Thickness of CLs

By changing L and measuring R_m, the values of R_p and R_K were determined (Fig. 2).

Another oxygen diffusion resistance measurement method which called oxygen-nitrogen mutual diffusion method have been proposed. The relation of the limiting current measurement method and the oxygen-nitrogen mutual diffusion method is represented in equation (2)

\[ R'_{CL} = R_K \times L \]  \hspace{1cm} (2)

The results are analyzed by this equation.

Table 1. MEA specification

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Working Electrode</th>
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<tr>
<td>Pt/C (TEC10E50E, 10%)</td>
<td>Pt/C (TEC10E50E, 10%)</td>
</tr>
<tr>
<td>Ionomer: Nafion® (DuPont)</td>
<td>Nafion® (DuPont)</td>
</tr>
<tr>
<td>Pt loading /mg cm⁻²</td>
<td>0.50, 0.35, 0.20, 0.12, 0.07</td>
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<tr>
<td>Ionomer to Carbon Ratio</td>
<td>0.7, 1.0, 1.3</td>
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<td>Active Area/cm²</td>
<td>1.0</td>
</tr>
<tr>
<td>Membrane</td>
<td>Nafion® (NR212-CS, Dupont)</td>
</tr>
</tbody>
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Fig.1 Other of ORR in the CLs

Fig.2 I/C vs Diffusion Resistance Parameters

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References