Optimisation of PEMFC Gas Diffusion Layer  

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ABSTRACT:  
Among the components of the Membrane Electrode Assemblies (MEA) of Proton Exchange Membrane Fuel Cells, much interest has been put on the membranes and on the active layers. Less attention has been paid to the Gas Diffusion Layer (GDL) whereas it is essential to have an efficient link between the bipolar plates and active layers. Studies have been performed in order to optimise this component using different manufacturing processes developed at CEA. Microporous layers have been made by spraying or coating on a carbon felt and compared in various operating conditions. These GDL have been compared to commercial product based on the same carbon support. The main conclusions are that it has been possible to enhance the performance by optimising the microporous layer and that the manufacturing process has an important influence on the MEA performance, particularly at low pressure and relative humidity.

KEYWORDS: PEMFC, Gas Diffusion Layer, Composition, Process, Optimization.

1. INTRODUCTION

Proton Exchange Membrane Fuel Cells (PEMFC) can be used in operating conditions differing in temperature, pressure and gas humidification, depending on the application. The Membrane-Electrode Assembly (MEA), composed of the polymer electrolyte membrane, two Active Layers (AL) and Gas Diffusion Layers (GDL), is a key component and has to be optimised for given operating conditions. More often, a GDL is made of a microporous layer, composed of carbon and some hydrophobic agent, sprayed or coated on a carbon fibres based support, such as cloth, felt or paper. The microporous layer insures a good electrical contact between the carbon support and the active layer. It also homogenizes the reactants' distribution onto the catalytic sites since it makes a porosity gradient between the carbon support and the active layers. This layer brings a protection to the membrane avoiding the direct contact with the possible broken carbon fibres of the support.

The right use of the GDL is not easy since it has numerous functions, namely to supply the active layers with reactants, to collect the current and to remove heat and water from the MEA. These functions are controlled by physical-chemical properties, namely gas permeability, electronic and thermal conductivities, porosity and hydrophobicity, which depend on the composition and the manufacturing process.

The influence of composition and deposition process of the GDL microporous layer on electrochemical performance has been studied in different conditions of temperature, pressure and gas humidification. The comparative has been studied performed on a commercial product and on GDLs developed at CEA on the same carbon support.

2. EXPERIMENTAL

The experiments have been conducted on home-made 5-layers MEAs obtained by hot-pressing 3-layers with the different GDL materials. The active layers have been coated onto Nafion® 112 membranes using 20wt% Pt/C on Vulcan XC72 with Pt loadings 0.3 mg/cm².

The same GDL have been pressed on both sides of the 3-layers at 100 kg/cm² and 150°C during a few minutes. These parameters are supposed to be adapted to all kinds of GDLs.

GDLs are composed of a microporous layer sprayed or coated on a commercial carbon felt containing 10 wt% of PTFE (similar to the support of the “commercial” GDL) and are heat treated for PTFE sintering. Two carbon loadings have been tested: 0.5 and 0.9 mg/cm² with a fixed ratio of 23 wt% of PTFE. The name,
composition and manufacturing process of each GDL are summarized in Table 2. The standard product from the felt supplier is named “Commercial” in the following.

MEAs have been tested in 25 cm² single cells made of impregnated graphite plates with machined flow fields. The stress applied on the MEAs is about 3 MPa and is controlled by adjusting the tightening torque of the cell’s screws and the type of gasket. The gas flow rates, the cell temperature, the gas pressures, the current and the relative humidity both on cathode and anode sides are controlled by the test bench.

Before recording the polarisation curves in the different operating conditions, the MEA is kept in stationary conditions during 24 hours at 80°C, at 1000 mA/cm² with fully humidified hydrogen and oxygen at 4 absolute bars in order to reach maximum and stable performance.

<table>
<thead>
<tr>
<th>Conditioning step (24 hours)</th>
<th>Tests conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (° C)</td>
<td>80</td>
</tr>
<tr>
<td>Pressure (barsa)</td>
<td>4</td>
</tr>
<tr>
<td>Cathode feeding gas</td>
<td>O₂</td>
</tr>
<tr>
<td>Gas humidification (%RH)</td>
<td>100</td>
</tr>
<tr>
<td>Oxidizer Stoichiometry</td>
<td>1.5</td>
</tr>
<tr>
<td>Fuel Stoichiometry</td>
<td>1.2</td>
</tr>
<tr>
<td>Current density (mA/cm²)</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Table 1:** Operating conditions during the conditioning step and during the performance tests.

<table>
<thead>
<tr>
<th>Deposition process</th>
<th>Composition (mg/cm² of carbon)</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating</td>
<td>0.5</td>
<td>C₀.₅</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>C₁.₀</td>
</tr>
<tr>
<td>Spraying</td>
<td>0.5</td>
<td>S₀.₅</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>S₀.₉</td>
</tr>
</tbody>
</table>

**Table 2:** Deposition process, micro porous layer composition and name of the home-made GDLs.

3. REALISATIONS AND RESULTS

At 80°C and 4 bars, with fully hydrated hydrogen and oxygen, the cell voltages at the working point (1000 mA/cm²) at the end of the conditioning step range between 660 and 700 mV (Figure 1). So, when comparing the performance at fixed current density, they seem quite similar. However, considering the current density at 700 mV, that is to say the power at a given efficiency, it appears that the results are quite different (Figure 1). In the following, the different MEAs will be compared in this latter way in order to be more representative of stack specifications.

**General comparison of commercial and CEA components**

The MEAs performance logically decrease when using fully hydrated air instead of pure oxygen since the oxygen activity is reduced. However, these two high pressure operating conditions lead to the same classification of the tested GDL when considering their performance at 700 mV (Figure 1).

At 4 bars, with fully hydrated gases, the MEA and especially the membrane are well hydrated and as a consequence, their conductivity is maximised. Moreover, the activity of the oxygen is high and as a consequence, the activation and diffusion overpotential are minimised. So these conditions are not really adapted to compare different MEAs or to correlate the performance to the physical properties of the GDLs. Moreover, these conditions are not representative of the applications.

So in order to have a more objective comparison, the performance of the GDLs developed at CEA have been compared to commercial component also at low pressure and relative humidity (Figure 3). These results show that as at high pressure, it has been possible to enhance the performance at low relative humidity by optimising the microporous layer.

**Influence of the microporous layers properties**
Concerning the influence of the microporous layers (making process and composition), the influence of temperature and relative humidity on the performance has been particularly studied at low pressure: 1.5 and 1.2 barsa. Only the results obtained at 1.5 barsa are presented since the conclusions are the same at 1.2 barsa (Figure 3 and Figure 4).

At 60°C, and low Hydrogen and Air pressures, coated GDL have allowed obtaining better performance than sprayed GDL both with fully humidified gases and with gases only humidified at 50%.

At 80°C, coated GDL, with microporous layers carbon loadings around 0.9 mg/cm², present better performance than sprayed GDL in all the conditions of pressure and humidification tested, whereas for carbon loadings of only 0.5 mg/cm², sprayed GDL present higher performance at low relative humidity (50%). For sprayed GDL, the performance decrease as the microporous layer thickness increases for all the operating conditions. This is probably due to an increase in the whole transverse resistance of the component and to a decrease in its permeability.

For coated GDL, this is also true at 60°C but at 80°C, thicker coated microporous layers allow to reach higher performance in particularly drying conditions: for example, at low pressure, 50%RH and for the lowest current densities studied. In this case, a thick microporous layer is maybe necessary to allow storing enough water to optimise the performance. This behaviour could be related to the pore structure of the sprayed microporous layers which is probably more open.

These results show the strong influence of the GDL structure and hence, of the manufacturing process, on the local water management in order to obtain a good balance between 3-layers hydration and gas feeding.

![Figure 1](image_url)

**Figure 1:** Performance at (left) 1000 mA/cm² and (right) 700 mV of the MEAs made with the different GDL materials. Conditions: 80°C, H₂/O₂, 4 barsa, 100%RH.
**Figure 2:** Performance at 700 and 500 mV of the MEAs made with the different GDL materials. Conditions: 80°C, H₂/Air, 4 bars, 100%RH.

**Figure 3:** Performance at 700, 500 and 300 mV of the MEAs made with the coated and sprayed GDL materials. Conditions: 80°C, H₂/Air, 1,2 bars, (left) 100%RH and (right) 50%RH.
4. CONCLUSION

The optimisation of the microporous layer has allowed to obtain better results with sprayed and coated GDL than with the similar commercial product on a standard felt. This is a promising result since even best results have been obtained with a new plain commercial support that could also be modified with an optimised microporous layer to further enhance its performance.

For the GDL developed at CEA best performance at low pressure and relative humidity have been obtained with a carbon loading of 0.5 mg/cm² for sprayed GDL and with a carbon loading of 0.9 mg/cm² for coated GDL.

The results obtained in this study should be correlated to the properties of the GDL (permeability, the electrical conductivity and hydrophobicity) in order to better understand their particular behaviour in some operating conditions. However, it can already been concluded that the manufacturing process has an important influence on the structures of these components and therefore on their performances due to a very different water management.

Many characterizations have been conducted on various GDL to evaluate their behaviour in terms of performance. Our following studies will also include durability aspects: the objectives are to characterize the degradation of this component during long term operation and also to evaluate the impact of its degradation of the durability of the whole MEA. The main objective concerning the development and manufacturing of GDL is to adapt the processes and compositions to produce GDL adapted to the innovations performed in parallel for the MEA as well for the active layers (new catalysts and/or new processes) as for the whole assembly (in particular polymers for High Temperature and Low Relative Humidity operation).