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CHARACTERIZATION OF GDE FOR POLYMER ELECTROLYTE FUEL CELLS

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ABSTRACT

Gas Diffusion Electrodes (GDE), applied in Polymer Electrolyte Fuel Cells (PEFCs), are composed by a multi-layers structure, containing porous carbon materials and noble metal catalyst.

Gas diffusion layer (GDL), a GDE component, consists of a thin layer of carbon black mixed with an organic binder, frequently polytetrafluoroethylene (PTFE), that is coated onto a sheet of macro-porous carbon backing cloth or paper. GDL serves as current collector that allows ready access of fuel and oxidant to the anode and the cathode catalyst surfaces, respectively.

In this work, the effects of different fabrication methods and composition of gas diffusion layer are investigated and discussed in the light of gas permeability, thermal analysis, morphology and electrical resistance. Besides, performances in H_2/air fed cell at 50°C were discussed. A comparison with own products and commercial GDLs was carried out.

1. INTRODUCTION

GDE consists in a tree layers structure: a macroporous layer, a microporous layer (MPL), a catalytic layer.

Although in the past several years more attention has been dedicated to the catalytic layer, GDL optimization is now receiving an increasingly interest, regarding its structure and composition.

In particular, GDL properties as porosity , porosity distribution, pore size distribution [1] has been investigated by many researchers. Moreover, a lot of works has been published about PTFE content, GDL thickness, different carbon backing. It is also clear that the compression during MEA preparation process represent a critical parameter for GDE performances. Electrical resistance [2] and alternative preparation methods [3] have been studied.

In current study, the need of realize highly reproducible GDLs, requires at first raw materials study and commercial products investigation. Experimental evidences obtained are very important, because information about preparation process and characteristics of commercial GDLs are not easily available. In particular, while for GDL BC31-SGL the main properties are reported in its technical schedule, for Carbel none of them are presented. For this reason, we tried to determine these unknown characteristics analyzing Carbel GDL by means of different techniques. So, we obtained significant results to better understand its properties and its electrochemical behaviour, different from the other GDLs. Particular attention has been paid to traditional and new GDL preparation processes. Moreover, chemical and physical parameters, necessary to GDLs characterization and to better understand their performances, has been recognized and discussed. Permeability measurements, electrical resistances and thermal analysis, in conjunction with morphology and electrochemical characterizations have been used to determine the in-house and commercial GDLs behaviour.

2. EXPERIMENTAL

The first part of this research attempts to provide an alternative method to GDL production. So, in order to improve reproducibility, materials loss and the ease of preparation process, GDLs were prepared by spraying, hand coating, rolling and screen printing techniques.

Carbon paper (Toray) and carbon powder (SuperP), mixed with different amount of PTFE, were used as backing layer and MPL. After preparation, our *in-house* GDLs were compared with the following commercial products: Carbel^{TM} (Gore-Tex) and BC31 (SGL). Structural and morphological characterizations were carried out by optical (Olympus TL2) and FEG-SEM (LEO mod.1530) microscopy. Air permeability measurements, thermo gravimetric and differential thermo gravimetric analysis, contact resistence studies were performed. Finally, *in-house* and commercial GDLs, previously characterized, were covered by a catalytic layer (20% wt. Pt/C E-Tek, 0.5 mg_{Pt} cm^{-2}, approximately, and 15%wt. ionomer Nafion solution) and used as anodes In a MEA assembly.

At last, these MEAs were tested in single fuel cell station. The cell temperature was maintained at 50°C, but anodic and cathodic temperatures were varied the former between 25 and 60°C and the latter between 25 and 55°C, in order to simulate different humidity conditions.

3. RESULTS AND DISCUSSION

About the different deposition methods, it is clear that only cold rolling process likely seems to be the most feasible to realize well-done GDLs. In fact, in this way, we obtained good results in term of reproducibility and stability.

Simultaneous TGA/DTA experiments were carried out to obtain important information about PTFE contents, which plays a decisive role in water management, and to analyze GDL components separately. In conclusion, it is worth to be noticed that the presence of about 5%wt of PTFE in carbon support and 25%wt of PTFE is shown from TGA and DTA analysis on commercial GDLs. Permeability values decrease lowering the % of PTFE ,is noticeable that it is possible to vary permeability behaviours simply changing the %PTFE.

In Fig.1, an optical image (4X) of each type of in-house and commercial GDLs is reported. The similar morphology between sprayed GDL and BC31-SGL and between in-house rolled GDL and Carbel is clear.

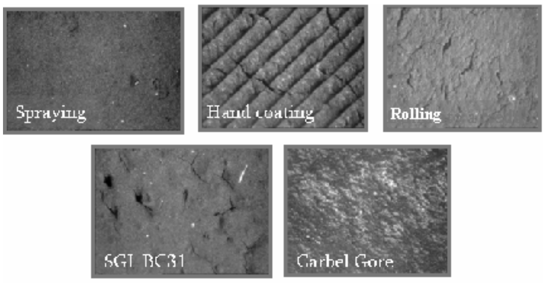
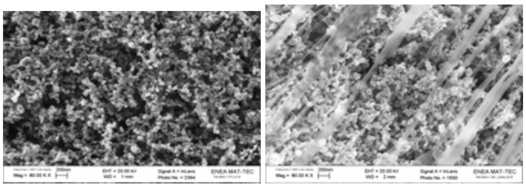


Fig.1: OPTICAL IMAGES (4X) FOR IN-HOUSE AND COMMERCIAL GDLs.

Furthermore, it is possible to note that Carbel GDL, after rolling, was probably undergone a pulling and pressing step to improve surface uniformity, as shown in Fig.2.



a) b)

Fig.2: SEM MICROGRAPHS (80.00KX) OF a) IN-HOUSE ROLLED GDL, b) CARBEL.

In addition, further SEM pictures of carbon paper used for our GDLs and commercial products, allow to establish that in commercial GDLs the carbon backing layer was pre-treated with PTFE (around 5%, as confirmed by thermal analysis). Clearly, the purpose of this treatment consists in an improvement of water management behaviour. Moreover, is also evident that SGL carbon paper is slightly different from the others: in fact, carbon fibre diameters are around 20 µm whereas Toray and Carbel Gore are less than 15 µm. The carbon fibres show also a particular curvilinear shape and a less regular and close-packed distribution.

The electrochemical characterization of GDLs was performed in the single fuel cell device. Voltage vs current curves of BC31-SGL, Carbel and *in-house* GDls were recorded. In Fig. 3, the polarisation curves related to the particular conditions of high humidity, with anodic temperature at 60°C and cathodic at 55°C, are presented It could be interesting to note that Carbel performances decrease, in particular for current density higher then 200 mA cm^{-2}, increasing the humidity. This evidence could be explained considering that the Carbel structure is extremely close and characterized by a very low permeability, this kind of structure is not able to remove water produced

At the opposite BC31-SGL and in-house sprayed GDL present an higher permeability, allowing an easy water evaporation so avoiding an electrode flooding.

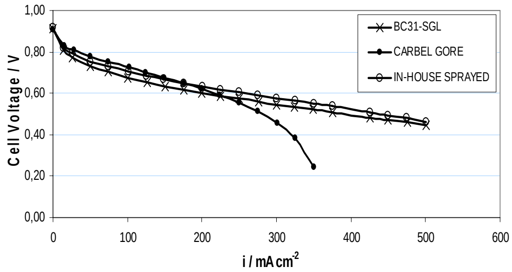


Fig.4: POLARISATION CURVES AT HIGH HUMIDITY.

4. CONCLUSIONS

Current literature on Gas Diffusion Layer properties is often contradictory and these arguments are still under debate. For this reason, the aim of this work is to better understand the GDLs characteristics related to their electrochemical behaviour, giving a particular attention to the manufacturing process. In fact, the results obtained show that, changing deposition method, GDls could be at will tailored. In particular, by means of spray deposition process it is possible to realize porous and high permeable systems, attaining good performances especially in medium and high humidity conditions. Cold rolling method, instead, allows to produce more close structures with low permeability, extremely suitable in low humidity condition. Therefore, with both deposition processes above mentioned, it is possible to produce GDLs with good reproducibility and excellent electrochemical performances, comparable with commercially available systems. From thermal analysis, it is clear that, in commercial GDLs, carbon support (CP) is pre-impregnated with about 5%wt of PTFE, likely improving their water management properties, while the % of PTFE in the microporous layer is roughly equal to 25%wt. Moreover, also carbon paper type used as support influences GDLs properties. Morphological analysis confirm the results above presented.

Anyway, further investigation is necessary to know more thoroughly GDLs properties, especially in term of vapour and liquid water permeability, that certainly influences transport mechanism through GDLs porous structure.

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