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Characterization process to measure the electrical contact resistance of Gas Diffusion Layers under mechanical static compressive loads

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ABSTRACT

Recent research has identified the mechanical properties of the fuel cell internal components (in particular, the Gas Diffusion Layers – GDLs) as key-parameters to obtain high final performances of the generator. The mechanical compression modulus of these components, the stability of their mechanical properties with respect to temperature and humidity, and their ability to interact with water have an impact on the electrical contact resistances in the stack and, by consequence, on the overall performance of the electric generator. Reducing the losses by contact resistance is an objective necessary to optimize the fuel cells in operation. The study of GDL electrical behavior under various internal operating conditions provides a suitable database to better understand their effects on the overall stack performance.

This paper describes an experimental method for measuring the electrical contact resistance versus the static mechanical pressure applied to the GDLs. A nonlinear behavior of the electrical contact resistance versus the mechanical stress is observed. The PTFE and MPL additions modify the electrical contact resistance.

Introduction

Fuel cell (FC) is one of the most promising solutions to generate power with high efficiency, portability and near zero-emissions [1,2]. Proton Exchange Membrane Fuel Cell (PEMFC) or Polymer Electrolyte Fuel Cell (PEFC) is the most mature and promising FC technology due to the solid nature of its electrolyte, low start-up temperature and high efficiency. The PEMFC performance is fully related with the properties of its components, especially with the MEAs (Membrane Electrode Assemblies), with the assembly process to build a stack, and the operating conditions. The widespread success of this technology in the industry field is linked with the high

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performance provided by the stacks and the stable mechanical behaviors of the assemblies under both operating and environmental excitations. To reach suitable PEMFC performance levels and durability targets, it is essential to study both the electrical, thermal and mechanical behaviors of each MEA element under temperature and humidity variations [3]. Indeed, the coupling between the different physical phenomena inside the MEA leads to complex effects and interactions on the performance results. In particular, the compressive strength of the elements, the stability of their mechanical properties versus temperature, humidity, as well as their capabilities to interact with water have some direct effects on the electrical contact resistances inside the FC assembly, and thus, on the global performance of the whole generator. The decrease of the contact resistance losses is obviously required to optimize the global behavior of the PEMFC technology [4–12].

Gas Diffusion Layer (GDL) is known as a key-component of the MEA [13], due to its role in the gas diffusion and in the water flushing/management, high thermal and electrical conductivity, hydrophobicity, and mechanicals properties. Thus, understanding the compressive behavior of the GDL is required for further improvements of the PEMFC technology.

In the next part, we will present the different components of a PEMFC in terms of material and properties, allowing us to expose the operation mode of this generator in details and to highlight the strong mechanical/electrical interactions existing at the GDL/bipolar plate interfaces. The conclusions of section The key-role of the GDL/bipolar plate interface will underline the essentials points that have motivated us to realize this study focusing on the determination of the electrical contact resistances between gas flow field plates and Gas Diffusion Layers subjected to mechanical static compressive loads.

With this article, we intend to propose a better understanding of the GDL mechanical behavior as well as some guidelines for the ex-situ measurement of GDL electrical contact resistances. The work presented in this article is a step towards the more complex analysis of the mechanical – electrical GDL properties under real FC operating conditions including thermal and humidity variations.

The key-role of the GDL/bipolar plate interface

The FC assembly and its components

A PEMFC has four main components: the polymer electrolyte or membrane, the electro-Catalyst Layers (CLs), the Gas Diffusion Layers (GDLs), and the Flow Field Plates (FFPs) (or bipolar plates, gas distribution plates). Fig. 1 shows the classical architecture of a PEMFC. The Membrane Electrode Assembly (MEA) is built in an additive manner. The membrane is coated with Catalytic Layers (CLs) and assembled between two GDLs. In order to collect the electrons, the MEA and the GDLs are inserted between two bipolar plates. The reactants reach the cathode and anode sides through the channels of the FFPs and the GDLs. This minimal assembly is called cell. Each cell component is designed to realize specific functions in the MEA.

To generate a useful electric power, several cells are stacked and mechanically constrained by applying a clamping pressure

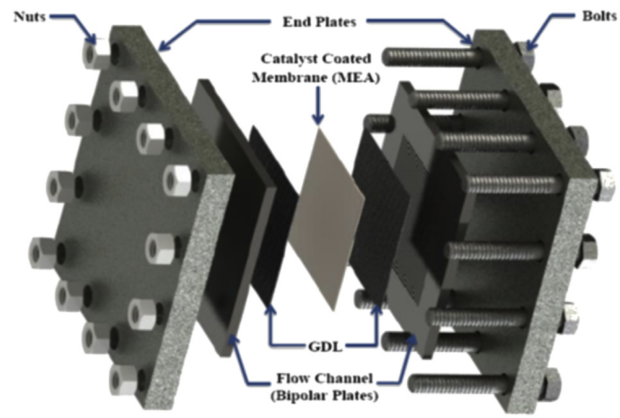

Fig. 1 – Classical architecture of a PEMFC [16].

from the terminal plates, usually with fasteners (bolts and nuts) [3,14,15]. As described by Jason Millichamp et al. in Ref. [10], various techniques used to put stacks into compression can now be found in the literature and be obtained from FC stack suppliers: standard tie rod setup, tie rods through gas/water manifolds, bands, crimps, straps/curved endplate, leaf-spring, tie rod springs, dynamic fluid compression plate.

Polymer electrolyte membrane

PEM, also called a Proton Exchange Membrane, is an organic material providing the proton selectivity and forcing the electrons generated by Reaction (1) to travel along an external electric circuit to the cathode side; this is the key of the FC technology. Other substances passing through the electrolyte would tend to disrupt the chemical reaction.

Catalyst layers

A catalyst layer is added on both sides of the membrane at the anode and cathode sides, and lead to the MEA. Conventional PEMFC catalytic layers include particles of platinum dispersed on a high-surface-area of carbon support. This supported platinum catalyst is mixed with an ion-conducting polymer sandwiched between the membrane and the GDLs. The FC powers are generated by oxidizing hydrogen atoms into protons and electrons at the anode electrode (Reaction (1)), and by reducing oxygen atoms with protons at the opposite side (Reaction (2)).

$$H_2 \leftrightarrow 2H^+ + 2e^- \quad (1)$$

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \leftrightarrow H_2O \quad (2)$$

Gas Diffusion Layers

The MEA is sandwiched between two GDLs. These elements provide the flow of reactants to catalytic sites, as well as the removal of product water. Each GDL is typically composed of a sheet of carbon paper in which the carbon fibers are partially coated with polytetrafluoroethylene – PTFE (note that metal-sheet GDLs also exist [14]). Gases rapidly diffuse through the pores of the GDL. These pores are kept open by the hydrophobic PTFE, which prevents excessive water buildup. In many cases, the GDL is coated with a thin layer of high-surface-area

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