GDL Design & Function

AvCarb's GDL and Electrode Newsletter

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INSIDE THIS ISSUE

Introduction

By Guy Ebbrell

Welcome to the first issue of GDL Design and Function, AvCarb's newsletter for Gas Diffusion Layer (GDL) technology!

The goal of this newsletter is to help fuel cell engineers, scientists and businesspeople address issues that they are facing that relate to the GDL.

Each edition will address important GDL technical and commercial topics as they relate to the commercialization of reliable PEM fuel cells.

AvCarb welcomes collaboration with academia and industry to improve GDL designs to meet next generation design goals.

We hope that these newsletters will both inform fuel cell industry and academic participants and solicit feedback about AvCarb's products, projects, and product development initiatives.

Enjoy!

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Moving Energy with Carbon Fiber

Role of the GDL in a Fuel Cell

By Reyhan Taspinar, Ph.D.

The GDL is comprised of a highly porous non-woven carbon substrate that is treated with PTFE (Teflon) to make it hydrophobic, and then coated with one or more microporous layers (MPLs) to form a 2-layer graded porous structure. A 3-D rendering of the structure is shown schematically on Fig.1, with the macroporous carbon paper substrate shown in green, PTFE coating in yellow, and the microporous top coat layer shown in blue.

The GDL is characterized by the following five key features, each of which requires specific, sometimes competing, GDL properties for desired performance:

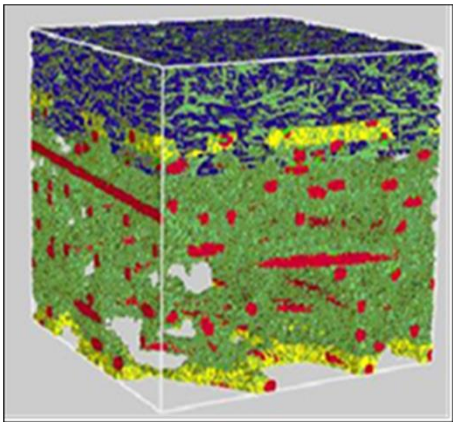

Figure 1. 3D rendering of GDL structure

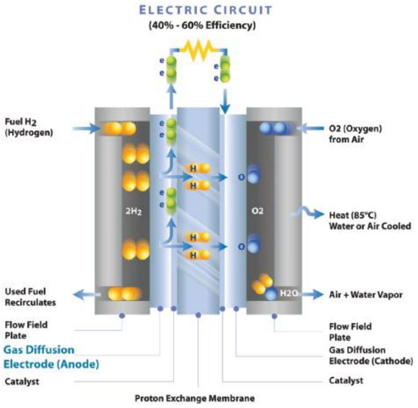

Figure 2. Schematic of fuel cell operation

1) Reactant Diffusion: This should be as high as possible to ensure an adequate supply of reactants (O_2/H_2), especially oxygen from air, to the catalyst layer so that the performance is limited by electrode kinetics, not by reactant transport. This requires the GDL to be macroporous and largely free of liquid water.

2) Product Diffusion: This should be high to remove water to the flow field effectively and prevent it from building up at the cathode catalyst layer (CCL), thereby blocking the reactant access to the catalyst. On the other hand, it should not be so high as to lead to membrane drying, which would reduce the proton conductivity of the membrane.

3) Electrical Conductivity: This parameter should be as high as possible to minimize Ohmic losses by effectively conducting electrons between the catalyst layer and the current collectors via the bipolar plate. However, it is reduced by increased porosity and PTFE content of the GDL, necessary for high reactant and product diffusion.

4) Thermal Conductivity: This should be high to effectively remove the heat from the membrane electrode assembly (MEA) to the bipolar plates, where cooling is available, and maintain the MEA at a uniform temperature. The heat effects are mainly associated with the cathode reaction, the Ohmic losses in the membrane, and water evaporation/condensation.

5) Mechanical Support: The GDL must provide robust mechanical support to protect the membrane and catalyst layer, to prevent damage from any pressure differentials across the MEA, and to avoid deflection into the flow field channels during cell compression.

GDL Property Focus: MPL Thickness

By Jason Morgan, Ph.D.

The MPL thickness plays a crucial role in fuel cell performance by strongly influencing the product transport rate, the electrical conductivity (contact resistance) and the mechanical support (surface roughness). Here, we will examine the influence of different MPL loadings on all 3 effects.

1. Product Transport Rate

In this study, three MPL loadings were examined (10, 30 and 60 g/m^2) using same micro particles under both wet (>70% RH) and dry (<30% RH) operating conditions. The MPLs were comprised of the same particles, the PTFE content was held constant and the MPLs were coated on the same base substrate material. The resulting GDL samples were tested in a 50 cm^2 single cell test station with double-pass serpentine flow channels on the anode and triple-pass serpentine channels on the cathode. The cell was operated at 70 °C and 12 psig back pressure, with both anode and cathode flows held at 2x stoichiometric flow.

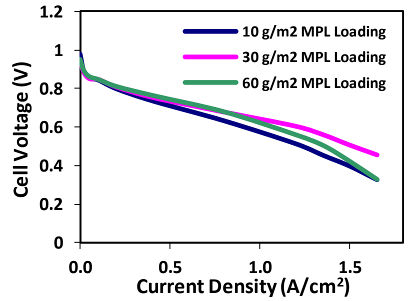

Figure 3. Influence of MPL loading on cell performance under dry operating conditions (< 30% RH)

The results (Fig. 3) show that under dry conditions an increase in the MPL loading will improve performance. This is because the thicker MPL prevents the membrane from drying out, while also providing lower contact resistance and reducing Ohmic losses. At very high loadings, however, the mass transport limitations in the GDL begin to dominate, as evident from the mass transport knee. Whereas under wet conditions (Fig. 4) the performance is best with the thinnest MPL. Since there is so much water present, the membrane remains well humidified and the thicker MPLs show higher mass transport resistance. In designing a GDL, it is important to balance the improved conductivity associated with keeping the membrane adequately hydrated and transport limitations associated with flooding of the catalyst with too much water.

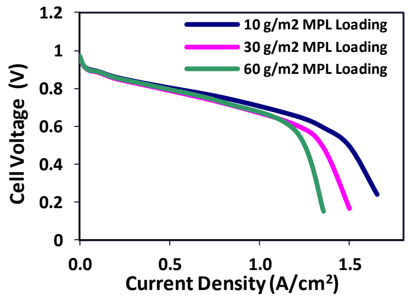

Figure 4. Influence of MPL loading on cell performance under wet operating conditions (> 70% RH)

2. Contact Resistance

In this study the contact resistance of the GDL was determined via the transmission line method (TLM) utilizing copper pads that were placed at various distances across the width of the GDL. A series of GDLs with different MPL loadings (8, 15, 30, 50 g/m^2) were constructed and tested. The contact resistance (Fig. 5) drops very quickly as loadings approach 30 g/m^2 and then begins to flatten at higher loadings. In general, MPL loadings at or below 15 g/m^2 risk having poor contact resistance and high Ohmic resistance.

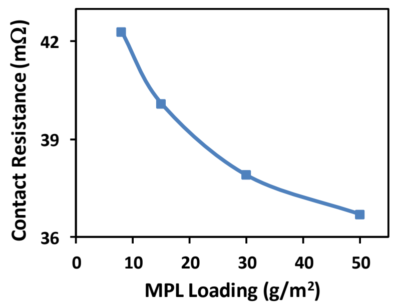

Figure 5. Influence of MPL loading on contact resistance as measured via TLM

3. Surface Roughness

Similar to contact resistance, we see (Fig.6) a sharp decrease in RMS Roughness (Rq) as the MPL loading is increased from 8 to 30 g/m^2 and the surface images on Fig. 6 show the coverage of the GDL surface fibers at each loading.

The coverage of surface fibers will become increasingly important as cell designers shift towards thinner GDLs and CCMs in next generation stacks. If there is not adequate MPL coverage on the fibers then there is the potential for fibers to create pinholes in the membrane and for performance to suffer.

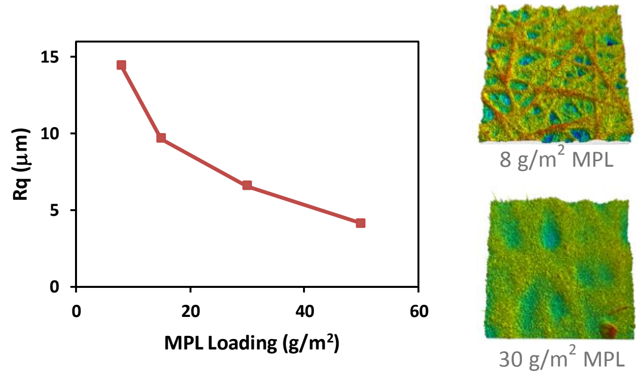

Figure 6. Influence of MPL loading on surface roughness

Product Spotlight

By Thomas Rabbow, Ph.D.

TYPICAL PROPERTY	AvCarb® MB-30
Base Material	**AvCarb EP40**
Nominal Thickness (µm)	
(@ 5.0 N/cm^2)	205
(@ 1MPa)	150
Nominal Basis Weight (g/m^2)	55
Break Strength (N/m)	
Machine direction	2800
Stiffness (Taber Units)	
Machine direction	12.5
Cross machine direction	7.0
Bulk Density (g/cm^3)	
(@ 0.69 N/cm^2)	0.27
Through-Plane Electrical Resistivity (mΩcm^2)	
(@ 1 MPa)	10
Water Vapor Diffusivity (D/D_0)	0.33

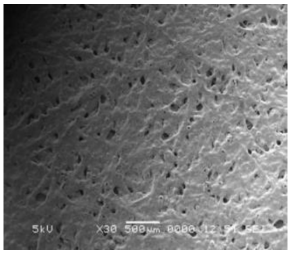

Figure 7. Typical properties and SEM image of MB-30

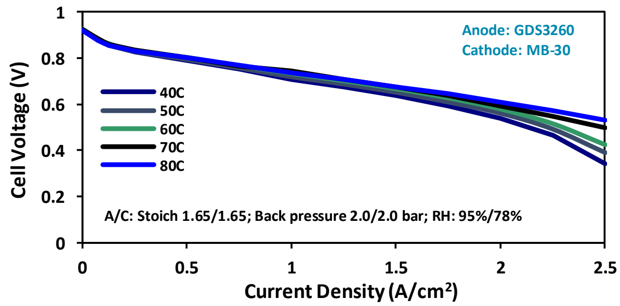

Figure 8. Single cell polarization curves at different operating temperatures

AvCarb GDS MB-30

AvCarb GDS MB-30 is a highly engineered GDL that provides enhanced water management through controlled porosity in the MPL (Fig. 7). It was first developed in 2010 and has been successfully used in various applications for over 10 years.

MB-30 is best used on the cathode side of the fuel cell in high humidity (>70%) applications with narrow flow field channels (<1.2 mm). Although it can be used on the anode side as well, it removes water so effectively that it can cause membrane drying in some designs. If membrane drying is seen, it can pair very well with GDS3260 on the anode to provide over 0.5V at 2.5 A/cm^2 in single cell testing (Fig. 8)!

Additionally, MB-30 has been shown to provide wet limiting current densities of over 6 A/cm^2 and very high durability (>35,000 hrs continuous operation in some systems). Over 300,000 m^2 of MB-30 has been used in production fuel cell designs over the past 10 years and it is the centerpiece of the AvCarb GDL portfolio.