STUDY OF GAS DIFFUSION LAYERS IN PEM FUEL CELLS

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Fuel cells are electrochemical devices which convert chemical energy of a reacting fuel directly into electricity with high efficiency and no pollution. Proton Exchange/ Polymer Electrolyte Membrane (PEM) fuel cells are likely to be among one of the most promising energy sources for transportation, heating and power generation. Some of the key materials used in PEM fuel cells are catalysts, membranes, gas diffusion layers (GDLs), and bipolar plates. There is a need for the development of woven fabric GDLs which can be tailored for continuous commercial scale production of membrane electrode assemblies (MEAs) to reduce the labor cost of fuel cell manufacture. At the University of New Hampshire research is being conducted on the development of fabric GDL made of carbon fibers (called UNH GDL).

This investigation focuses on the study of Gas Diffusion Layers (GDLs), which are an integral part of the Membrane Electrode Assembly (MEA) of a PEM fuel cell system. The importance of this work is the development and evaluation of the MEAs prepared from the GDL samples supplied by a local company. Name is withheld due to proprietary reasons. These GDLs are made of a fabric woven with carbon fibers. The fabric is wetproofed by coating one side with carbon and polytetra-fluoroethylene (PTFE). The operating experimental parameters such as cell temperature, gaseous humidity and other details were studied and the optimum experimental conditions were established for the best cell performance. The cell performance was based on voltage-current data. The amounts of various materials used in the preparation of the MEAs from the GDLs were varied to optimize the cell performance. These GDLs unlike the commercially available paper based GDLs, are robust and can be tailored to the continuous commercial scale production of MEAs. The surface characteristics and gas permeabilities were studied to characterize and compare the GDL samples with commercially available GDLs.

PEM fuel cell (5 cm^2 single cell) operating on hydrogen and air was used in this investigation. Membrane used was Nafion 112. The effect of experimental parameters such as cell temperature, humidity and composition of the reactant gases and composition of catalyst was studied to maximize the cell performance. Operating the cell at 60 ^oC with hydrogen humidified at 75 ^oC and with dry air gave the best results. The performance of the GDL was optimized by varying the PTFE (Teflon) content and coating pattern of the carbon layer. Nafion and platinum amounts in the catalyst layer were also varied. Multi-layer coating, PTFE content of 7mg/cm^2, Nafion loading of 1.5 mg/cm^2 and catalyst loading of 2 mg/cm^2 (20% Pt/C) resulted in maximum performance. Comparative studies with other woven and non-woven commercially available GDLs were also made. Efforts were made to characterize the GDLs by evaluating the surface and cross-sectional SEM scans and air permeability data. Our results show that fabric UNH GDLs can provide good cell performance with proper water management.

Gas diffusion layer is of vital importance to the performance and durability of a PEM fuel cell. For portable systems like cell phones and laptops, flexible and more durable fabrics GDLs are preferred over the paper GDLs. Several commercial GDLs are also available catering to the specific needs of the users. A comparative study was made and the results are discussed.

V I and P I data

The MEA prepared with locally manufactured UNH GDL was compared with other commercially available GDLs: GDL-A (fabric), GDL-B (paper) and GDL-C (paper). The catalyst and Nafion loadings were kept at 2mg/cm^2 and 1.5 mg/cm^2, respectively for all the MEAs prepared with the above GDLs. Hydrogen saturated at 75 ^oC was used as anode gas and dry air was used as cathode gas. The cell temperature was maintained at 60 ^oC for all the experiments. Figure 1 shows the cell performance curves for all the four GDLs along with the cell performance of a commercial MEA (called MEA-T) as evaluated in our lab.

SEM scans

Scanning Electron microscope (Amray 3300 FE) was used to study the surface characteristics of the various GDLs. Surface scans of both the sides (carbon coated side that faced the membrane and uncoated side that faced the gas flow channels) for all the GDLs were taken. Cross sectional views of the MEAs were prepared by cutting the MEAs with a sharp blade and mounting the samples in a vertical position. These MEA samples were the ones that had been used in the fuel cell system for several hours. All the samples were randomly chosen.

Fabric GDLs

UNH GDL and GDL-A are made of carbon fabrics. Both GDLs have a carbon layer on the side facing the membrane. Both the GDLs gave a maximum power output of about 0.37 W/cm^2. However, the cell performance with GDL-A was distributed over a wide range of current densities up to about 1.1 A/cm^2. The performance curve with UNH GDL showed diffusion overpotential at higher current density with a sudden drop in voltage at about 0.7 A/cm^2. However, the air permeability data taken for both the GDLs showed that the UNH GDL had higher air permeability (5.32 cm^3/cm^2/s) than that of GDL-A (0.58 cm^3/cm^2/s).

The SEM scans showing the surface characteristics were studied to understand the reason for the high diffusion overpotential encountered inspite of the greater air permeability of UNH GDL compared to GDL-A. The carbon coated surface scan showed that GDL-A surface had almost no cracks. Moreover, the scan of the uncoated side, which faced the reactant gases, showed that even the small openings between the weaving patterns had been blocked by the carbon layer coating. UNH GDL showed cracks on carbon-coated surface indicating the presence of large crevices within this layer of the GDL.

The carbon layer in a GDL is basically microporous and hydrophobic. It enhances the electrical conductivity of the GDL and also diffuses the gases uniformly to the surface of the

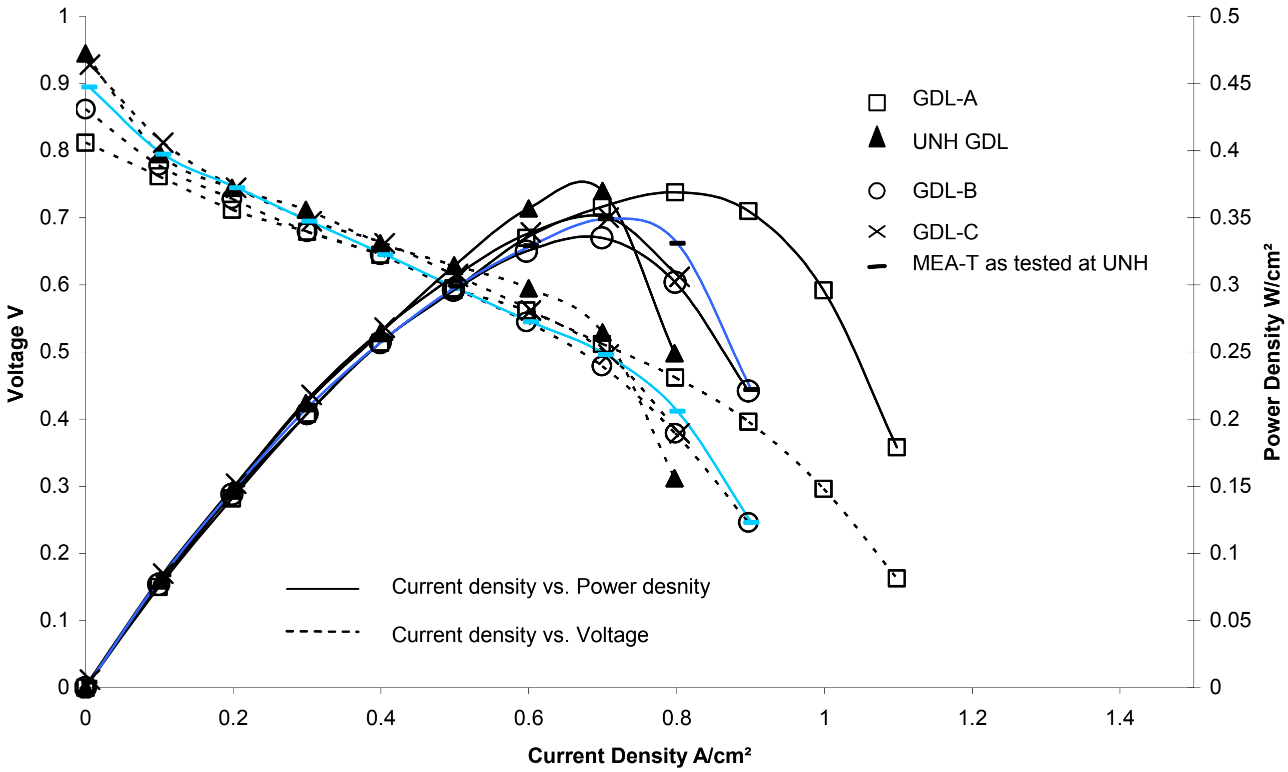

Figure 1 Performance comparison of UNH GDL with commercial GDLs

catalyst. This layer helps in proper water management in the membrane and catalyst layers by rejecting the excess water formed at the cathode or by retaining water for proper membrane hydration.

Paper GDLs

GDL-B and GDL-C are made of carbon paper. GDL-B has a carbon layer on one side of the GDL while GDL-C does not have any. The cell performance of both the GDLs is almost the same as shown in Figure 1.

GDL-B coated with carbon layer and GDL-C with the higher amounts of wetproofing material probably exhibits similar water repelling properties. Both the GDLs could hold the water formed at the cathode from entering the GDL to the same extent. However, during the course of the experiments and from the performance curves, it was observed that these paper GDLs do not appear to have as much water repelling property as that of GDL-A.

Conclusions

Performance of UNH GDL has been optimized by varying the amounts of materials such as PTFE, Nafion, and catalyst used in the GDL and MEA preparations. The GDL is found to be robust, flexible and durable. And its performance compares favorably with those available in the market.

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References

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