Preparation and Characterization for Carbon Composite Gas Diffusion Layer on Polymer Electrolyte Membrane Fuel Cells

JOONGPYO SHIM1†, CHOONSOO HAN1, HOJUNG SUN2, GYUNGSE PARK3, JIJUNG LEE4, HONGKI LEE4

1Department of Nano & Chemical Engineering, Kunsan National University, Jeonbuk, 573-701, Korea
2Department of Material Science & Engineering, Kunsan National University, Jeonbuk, 573-701, Korea
3Department of Chemistry, Kunsan National University, Jeonbuk, 573-701, Korea
4Fuel Cell Regional Innovation Center, Woosuk University, Jeonbuk, 565-701, Korea

Abstract >> Gas diffusion layers (GDLs) of carbon composite type in polymer electrolyte fuel cells were prepared by simple and cheap manufacturing process. To obtain the carbon composite GDLs, carbon black with polymer binder was mixed in solvent, rolled to make sheet, and finally heat-treated at 340℃. The performance of fuel cell using composite GDLs was changed by PTFE content. The physical properties of composite GDLs for pore, conductivity and air permeability were analyzed to compare with the variation of fuel cell performance. The conductivity of composite GDLs was very similar to carbon paper as commercial GDL but pore properties and air flux were considerably different. The porosity, PTFE content and conductivity for composite GDLs did not have an influence on the cell performance much. The increase of pore diameter and air flux led to enhance cell performance.

Key words : Polymer electrolyte membrane fuel cell(고분자 전해질 연료전지), Gas diffusion layer(기체확산층), Carbon composite(탄소복합체), Electrode(전극), porosity(기공도)

1. Introduction

Polymer electrolyte membrane fuel cells (PEMFCs) are good power sources for electronic devices because of their high efficiency, high power density, low emissions, low operation temperature, and low noise1). Although PEMFCs have many advantages, there are still many obstacles to commercialization such as the high cost of materials and low durability. A membrane electrode assembly (MEA), which is the heart of a PEMFC, consists of a catalyst, a polymer electrolyte membrane and a gas diffusion layer (GDL).

The functions of the GDL are to act as a gas
diffusion media, provide mechanical support, provide an electrical pathway, and channel product water away from the electrodes\(^2\). The GDL should have high conductivity\(^3\), appropriate hydrophobicity\(^4,5\), high air permeability\(^6\) and sufficient mechanical strength\(^7-9\). GDLs are typically carbon-based materials, and usually in cloth or paper form\(^10,11\). They are manufactured using huge and high-cost processes of carbonization or fabrication. Only a few researches studies on the preparation of GDLs without carbon paper or carbon cloth have been reported. Hayashi et al.\(^12\) and Chen-Yang et al.\(^13\) reported a process for obtaining diffusion media from a combination of carbon materials and polytetrafluoroethylene (PTFE). They showed that the performance of a PEMFC containing such GDLs changed depending on the composition of the carbon materials and PTFE.

In this study, the carbon composite GDLs were prepared by mixing carbon black with a polymer binder, namely PTFE. The main properties of GDLs that affect fuel cell performance are hydrophobicity, electrical conductivity, pore size distribution, and air permeability. We investigated the role of each of these properties in cell performance.

2. Experimental

To prepare the carbon composite GDL, carbon black (Vulcan XC-72, Cabot, Boston, MA, USA) and a PTFE suspension (60% solid, DuPont, Wilmington, DE, USA) were mixed in a water/isopropyl alcohol (IPA) solvent. The solution was agitated to make a paste-like gum, and then rolled on a glass plate until it formed a thin sheet. The carbon composite GDL sheet were dried at 80°C for 6h and then heat-treated at 340°C for 1h to remove surfactant contained in the PTFE suspension. The GDL thickness was from 150 to 200 mm and its PTFE content was from 20% (PF2) to 50% (PF5). Fig. 1 shows the manufacturing process for the carbon composite GDL.

The weights of carbon and binder were measured by thermal gravimetric analysis (TGA; SDT Q600, TA Instrument, New Castle, DE, USA), and the surface morphologies of the GDLs were observed by scanning electron microscopy (SEM; S-4800, Hitachi, Tokyo, Japan). The porosity and pore size distribution were measured using mercury porosimeter (AutoPore 9500, Micromeritics, Norcross, GA, USA).

Air flux through a plane (along the z direction) of the GDLs was measured with a laboratory-made instrument using the Gurley method (ASTM D737). This instrument, a permeometer, measured air flow per minute at 1.27 cm (0.5 inch) water pressure drop between the gas inlet and outlet. Single-phase flow through a porous medium is described by Darcy’s law\(^14\):

\[
-\nabla P = \mu \nu K
\]

where \(K\) is the absolute permeability of the porous material, \(\mu\) is the viscosity (1.85 x 10\(^{-5}\) Pa·s for air) of the flowing fluid, \(\nu\) is the superficial velocity of the fluid and \(P\) is the pressure. Solution of Darcy’s law for the one-dimensional flow of a compressible fluid results in the following equation\(^15\):