Studies on the Performance Enhancement of Polymer Electrolyte Fuel Cells

Gu-Gon PARK KOSEF - 10404

Researcher,
Polymer Electrolyte Fuel Cell Research Group, Korea Institute of Energy Research

Japanese Advisor : Koichi EGUCHI
Professor, Kyoto University

This thesis consists of 3 parts. Small size reformers, electro-catalysts and gas diffusion layers of PEFC are dealt at Part 1, Part 2 and Part 3, respectively.

In the Chapter 1 of Part 1, a proto-type microreformer was fabricated with microchannel patterned metal sheets. A methanol steam reformer and a vaporizer were integrated as a one unit. For this, electric heaters were used to provide heat for the endothermic reaction and the vaporization of aqueous methanol. The developed fuel processor could generate enough hydrogen for the power of 15We.

In the Chapter 2 of Part 1, two types of integrated microchannel methanol processors were fabricated by stacking and bonding microchannel patterned stainless steel plates, including fuel vaporizer, heat exchanger, catalytic combustor and steam reformer. In this reactor, commercially available $Cu/ZnO/Al_2O_3$ catalyst was coated inside of the microchannels of unit reactor for steam reforming and home-made Pt/Al_2O_3 pellets prepared by 'incipient wetness method' were filled in the cavity reactor for catalytic combustion. The comparison of two types of integrated reactors revealed that the fabrication process of reactor such as microchannel patterning, catalyst coating and microchannel bonding can significantly affect the reactor performance. Under well controlled operating condition, the microreformer could produce power output of 59 Wt.

In the Chapter 3 of Part 1, microchannel PrOx (Preferential Oxidation) reactor was developed to control the CO concentration level less than 10 ppm in the reformed gas. The reactor was developed based on previous studies on methanol steam reformer and the basic technologies on microchannel reactor including design of microchannel plate, fabrication process and catalyst coating method were applied to the PrOx reactor. The fabricated PrOx reactor was tested and evaluated on its CO removal performance.

In the Chapter 1 of Part 2, activated carbons were employed for the support material of catalyst in the direct methanol fuel cell (DMFC). An activated carbon was re-activated by chemical activation method with NaOH at various temperatures for the development of meso or/and macro pores. By using these pretreated activated carbons, Pt-Ru catalysts on the activated carbons (Pt-Ru/AC) which have various surface areas and porosities were prepared for the anode catalyst of DMFC. The performances of prepared Pt-Ru/AC catalysts were evaluated by using the typical air breathing type DMFC single cell. In this study, the optimum morphologies of catalyst in the aspect of performance were suggested by correlating the activity of catalysts with surface areas, pore sizes distributions, metal sizes and distances between active metals.

In the Chapter 2 of Part 2, Ketjenblack was used as a support material of anode catalyst for the polymer electrolyte fuel cells (PEFCs). Ketjenblack has more large surface area than Vulcan XC72 carbon black. This property can affect the catalytic activity of prepared catalysts. To understand the support effects on the catalysts, Ketjenblack was chemically pretreated in NaOH solution at various temperatures. Anode catalysts were prepared using these pretreated support materials and their physicochemical properties were characterized. The performance of prepared catalysts was evaluated by single cell test.

In the Chapter 3 of Part 2, the intention was to suggest principal design parameters of the electro-catalysts. Among various parameters, active metal size and inter-particle distance were intensively investigated in terms of electrode performance. In the present work, Ketjenblacks, as received and chemically treated, were used as the support materials of catalysts. The structures of electrodes as well as the morphologies of catalysts were examined to elucidate the relationship between cell performance and the above mentioned variables.

In the Chapter 1 of Part 3, water behavior in the gas diffusion layers of polymer electrolyte fuel cell (PEFC) was investigated analytically. To understand the water transportation phenomena systematically, the gas diffusion layers were divided into two parts. One is gas diffusion medium (GDM) and the other is micro-layer (ML). In this work, GDMs with different PTFE contents were intensively investigated at various single cell operation conditions.

In the Chapter 2 of Part 3, carbon nano-materials were applied to the gas diffusion layers of PEFC. Gas diffusion layers consist of gas diffusion medium and micro-layers. Carbon blacks, such as Vulcan XC72, have been widely used for the micro-layers. Main functions of gas diffusion layers are distribution of reactants to the active site of electrode, management of water supplied and/or generated and enhancement of electrical contact between the electrode and the bipolar plates. Carbon nano-tubes and carbon nano-fibers were mixed with commercial carbon blacks to make the micro-layers of GDLs. In this work, the GDLs which have carbon nano-fibers could enhance the cell performance by increasing the gas permeability and electric conductivity simultaneously maintaining the ability of water management.