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Crossover effects of the land/channel width ratio of bipolar plates in polymer electrolyte membrane fuel cells

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ABSTRACT

The crossover effect of the land/channel width ratio of bipolar plates in polymer electrolyte membrane fuel cells is experimentally investigated in this study. To isolate the effect of the land/channel width ratio, three different types of bipolar plates of a fixed sum and channel width are specially prepared. With three different bipolar plates, measurements are taken of electrochemical performance, inlet pressure, and hydrogen crossover rate. When the stoichiometric ratio of hydrogen is 1.5, the standard type of bipolar plate, BP2 (land width = 0.75 mm, channel width = 1.05 mm) show the best performance. However, according to increasing stoichiometric ratio of hydrogen, BP3 (land width = 1.12 mm, channel width = 0.68 mm) has the best performance, especially at the medium and high current range. For the crossover rate, the biggest amount of hydrogen gas crossover to the cathode in BP3. This is because of the anode inlet pressure caused by the largest land/channel ratio of BP3.

Introduction

The fuel cell has been highlighted to manage problems related to environmental contamination and insufficient energy sources ever since the first prototype was made in the 1960s. Among several kinds of fuel cells, the eco-friendly and highly efficient polymer electrolyte membrane fuel cell system is the most powerful candidate for next-generation vehicles [1]. As commercialization of fuel cell vehicles is close at hand, research into improving system durability becomes very important [2–5].

Since a polymer electrolyte membrane fuel cell system was suggested as a new power source, the problem of material durability in fuel cell stacks has been constantly brought up. Lately, much thinner membranes have been used in the system because they can improve its performance by decreasing contact resistance and managing water content properly. Also increased clamping pressure has been applied to reduce contact resistance. However, it makes the durability deteriorate in the same time [6–8]. To break this barrier, the crossover phenomenon, which is implicated with the degeneration of system efficiency and durability shown in Fig. 1, becomes one of the most significant issues to be solved. Furthermore,

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Nomenclature

T	temperature, °C
P	pressure difference, kPa
RH	relative humidity, %
SR	stoichiometric ratio
I	current, A
V	voltage, V
C	concentration, ppm
Superscript	
AN	anode side
CA	cathode side
Subscript	
i	inlet
e	outlet
H_2	hydrogen gas

because of the importance of this crossover, much research has been conducted not only into polymer electrolyte membrane fuel cells but also into other types of fuel cells. In case of the crossover phenomenon in the direct methanol fuel cell, many studies have been done and many ideas for reducing the crossover rate are suggested [9–12]. In the case of polymer electrolyte membrane fuel cells, however, further studies are needed.

Because the research into the crossover phenomenon has begun to reveal why the open circuit voltage was different from the ideally expected value, the parameters which affect the crossover have been studied actively [6,8,13–15]. The relation between parameters and the crossover together with the possible problems has been analyzed actively [13,16–18]. Through this research, the mechanism of reactions initiated by crossed-over gases was suggested and reaction products of fluoride ion, hydrogen peroxide, etc. were determined. Nowadays, there are many efforts to measure crossover rates more accurately, and techniques for measuring the permeability coefficient have been proposed. For example, Sakai et al. used a volumetric method while Chiou et al. tried a time-lag method to analyze the permeability of membranes [19,20]. Lately, many researchers are using improved methods such as an electrochemical method or a direct detection method which needs unique detecting equipment [6,8,21–24].

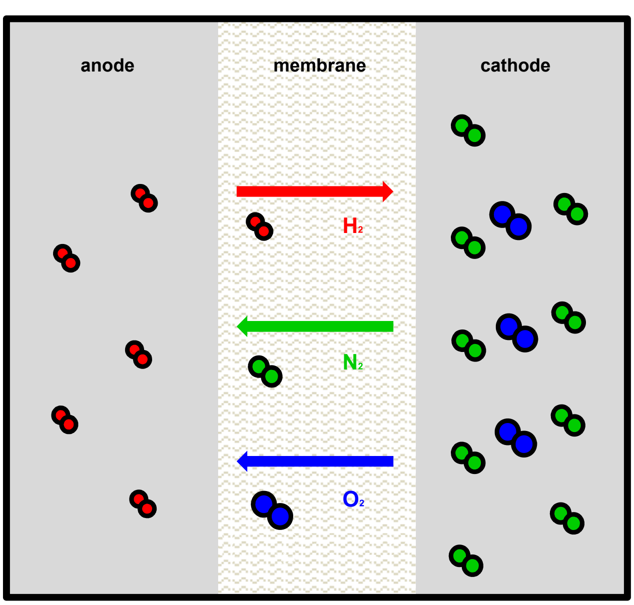

Fig. 1 – Schematic diagram of crossover through the membrane in a single cell.

Among the diverse materials which comprise the fuel cell stack, a bipolar plate is a key component that influences the total weight and manufacturing cost thereof [25,26]. Although there have been dramatic changes in bipolar plates in the last several years, the most critical one is that the main material has changed from graphite to metals or composites [27]. Research into new manufacturing processes and efficient coating methods for metals or composites has been conducted actively [28–32]. Furthermore, the introduction of new materials allows many different designs of bipolar plates. Many attempts to improve system performance by designing flow channels or diverse cross sections are tested through numerous simulations and experiments [25,33–35].

The relationships between the crossover phenomenon and various operating parameters such as temperature and relative humidity have been studied actively [6,8,13–15]. However, the effects of the physical properties of bipolar plates on crossover have never been studied. Lu et al. studied the effects of various channel surface wettability and geometry on water management [39]. Owejan also studied only the effects of different flow field geometry on water accumulation [40]. Therefore, in this study, the effects of the land/channel width ratio of bipolar plates on crossover were experimentally investigated with different channel size of bipolar plates.

Experimental method

Bipolar plates

To show the effect of the land/channel width ratio of bipolar plates on the crossover phenomenon, three different types of bipolar plates were designed. Every bipolar plate is made of 316L stainless steel (SS) without a gold layer coating as shown in Fig. 2. All bipolar plates have four multi-channel flow fields with serpentine flow. The shape of the cross-section of each bipolar plate is rectangular. The cross-sectional view of three different bipolar plates is shown in Fig. 3.

The land width of each bipolar plate varies from 0.38 to 1.12 mm and the channel width of each bipolar plate varies from 0.68 to 1.42 mm. All geometrical characteristics of these bipolar plates are in Table 1. To isolate the effects of the land/channel width ratio, the pitch which is the sum of the land and channel width is kept the same for all cases. Because of the mass flow rate between anode and cathode, the channel depths are different from each other. The channel depth of the anode side is 0.40 mm and that of the cathode side is 0.60 mm.

Single fuel cell preparation

A single fuel cell with an active area of 25 cm^2 was used in this study. It consists of a membrane, gas diffusion layers, gaskets,