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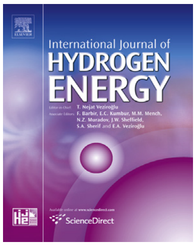

Water control by employing microgrooves inside gas channel for performance improvement in polymer electrolyte fuel cells

Ryo Koresawa [a], *Yoshio Utaka* [b,*]

[a] *Graduate School of Engineering, Yokohama National University, 79-5 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan*

[b] *Faculty of Engineering, Yokohama National University, 79-5 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan*

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ABSTRACT

Further performance improvement in polymer electrolyte fuel cell (PEFC) and their popularization face several problems even though they have been commercialized. The water behavior in PEFCs is closely related to cell performance. To enhance the cell performance, it is necessary to effectively remove the generated water. In this study, to improve the water control in gas channels, a novel gas channel with microgrooves, which are fabricated inside the channel walls, is applied. The generated water is removed through the microgrooves to facing side of the gas channel by capillary and shear forces from air flow. The performance of the PEFC with and without microgrooves was examined in various experimental conditions: cell temperature, relative humidity of gas, and air velocity. It was shown that the PEFC with microgrooves showed better performance than conventional PEFC without microgrooves. In particular, value of current density increased by approximately 16% when the air velocity was 8.0 m/s.

Introduction

Moisture management is very important for improving the performance of polymer electrolyte fuel cells (PEFCs). In particular, at a high current density, the generated water increases and accumulates in the gas diffusion layer (GDL) and gas channel at the cathode side. The cell performance decreases significantly because of the generated water, which blocks the oxygen transport. To improve the cell performance, it is necessary to efficiently remove the generated water.

Many attempts have been made to improve the moisture control and removal performance of water at the cathode side; that is, the application of a surface treatment or finish in the GDL or on the inner surface of the gas channel wall has been tested for water management in PEFCs. For example, in studies concerning GDL, hydrophobic material, such as polytetrafluoroethylene (PTFE) and fluorinated ethylene propylene (FEP), have been used to investigate the hydrophobic treatment of GDL [1–4]. Furthermore, the effects of PEFCs with and without a micro-porous layer (MPL), change in the PTFE content [5–7], and the component fraction of hydrophobic and hydrophilic materials [8–10] were also examined. In addition

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[*] *Corresponding author*. Tel./fax: +81 45 339 3909.
E-mail address: utaka@ynu.ac.jp (Y. Utaka).

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Nomenclature

d	Width of gas channel or microgroove, mm
θ	Crossing angle between microgroove and gas flow
h	Depth of microgroove, mm
V	Cell voltage
P	Pitch of microgroove, mm
Q	Water supply

Subscripts

g	Gas channel
ave	Average
1	Side wall of gas channel
min	Minimum
2	Upper wall of gas channel
max	Maximum
$I = 2.0$	Current density of 2.0 A/cm^2
$I = 4.0$	Current density of 4.0 A/cm^2

to the hydrophobic treatment of the GDL and coating on the MPL, moisture control using the GDL perforated with laser-cut holes [11,12] and the multi-layer of hydrophobic and hydrophilic MPLs [13,14] have been examined. Moreover, to enhance oxygen gas diffusion, the control of water movement using the GDL with planar-distributed wettability has been proposed and examined [15,16]. Furthermore, the effects of the gas channel and various flow channels - such as parallel, serpentine, interdigitated, and hybrid - have been investigated [17–26]. Considering the special configuration of the flow channel, passive water removal by capillary droplet actuation [27] and the effect of channel wall wettability [28] have also been investigated.

Results of previous report and objective of this study

To reduce the accumulation of water on the GDL surface, Okabe and Utaka [29] proposed a method in which thin microgrooves, with an axis tilted at an angle with respect to the air flow, are arranged at both side walls and at the upper wall inside the gas channel composed of the GDL surface and separator walls, and excluded its effect. Fig. 1 shows the schematic view of water distribution in the case of the proposed method. As shown in Fig. 1(a), in the case of a normal separator, a liquid–gas two-phase flow is formed. Water tends to accumulate on the GDL surface with a large amount of water generation. To reduce the accumulation of water on the GDL surface, the water on the GDL surface and from upstream of the gas channel moves through the opposing surface of the microgrooves to the GDL owing to the capillary and shear forces of the air flow; that is, as shown in Fig. 1(b), microgrooves with an axis tilted at an angle toward the gas flow direction were arranged inside the walls and the upper wall of the gas channel, which is composed of separator inner walls and the GDL surface. The experimental apparatus, which simulates water production by chemical reaction, is shown in Fig. 2. In this apparatus, microgrooves, with a tilted axis, were arranged toward the gas flow direction on the side walls and the upper wall of the gas channel. Two gas channels with a rectangular cross section of $d_g = h_g = 1.0$ and 2.0 mm were prepared. The microgrooves at both side and upper walls were used with a rectangular cross section with a width and depth of $d_1 = 0.2$ mm, $h_1 = 0.2$ mm and $d_2 = 0.3$ mm, $h_2 = 0.2$ mm for two gas channels with cross sections of 1.0 and 2.0 mm, respectively. The crossing angle between the microgrooves and the gas flow direction and pitch of microgrooves are expressed as θ and P, respectively. Experiments were performed under inclination angles of 20, 30, and 45°. The surface velocity of water flow in the microgrooves was measured to clarify the water behavior in microgrooves using the laser-induced fluorescence method (LIF). Fig. 3 shows the surface velocity of the water in the mid-height of microgrooves at the side wall. The positive velocity indicates that the water was removed from the GDL surface. The surface velocity of the water was measured at total length of 200 mm at tilt angle $\theta = 20^\circ$ in the case of water supply rate $Q_{I=2.0}$, which denotes that I is 2.0 A/cm^2 in PEFC power generation. Therefore, the arrangement of the microgrooves was confirmed to be effective throughout the gas channel at a total length of 200 mm, which shows that it is possible for microgrooves to be used for actual stack dimensions of PEFCs.

However, because these investigations were focused on the effect of water movement, it is necessary to confirm the effectiveness of microgrooves on the performance of an actual PEFC, in which various phenomena such as generation of

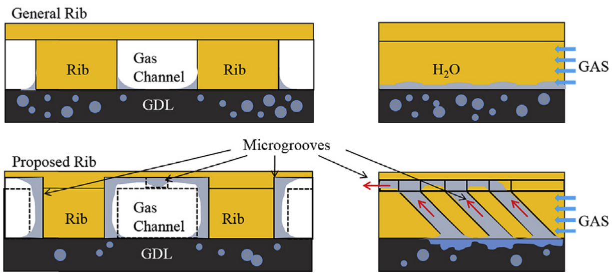

Fig. 1 – Schematic of water behavior through microgrooves from GDL.

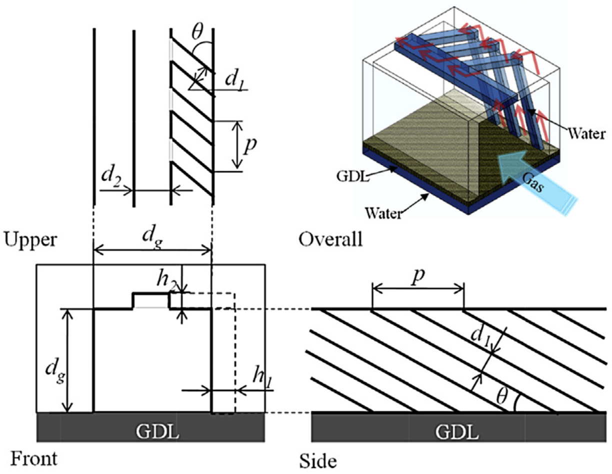

Fig. 2 – Details of microgroove structure.