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Segmented cell approach for studying uniformity of current distribution in polymer electrolyte fuel cell operation

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ABSTRACT

In this study, the current distribution of a polymer electrolyte fuel cell (PEMFC) with a large active area is investigated using a segmented cell system. A specially designed printed circuit board (PCB)-type segmented cell is applied to a single-cell PEMFC. By using the segmented system, the effects of clamping pressure uniformity between the components of the PEMFC and the fuel injection direction are examined. The pressure uniformities of the two different types of endplates are measured using pressure indicating films (PIFs). A curved endplate is used to improve the pressure uniformity. The pressure uniformity is found to significantly influence the current distribution in a PEMFC with a large active area. Two types of gas feeding modes, parallel and cross injection, are tested. The results show that the clamping pressure uniformity and gas feeding configuration affect the current distribution and overall PEMFC performance.

Introduction

Alternative power solutions such as wind power, solar power, and fuel cells have emerged owing to the growing demand for clean and renewable energy. Among these, polymer electrolyte membrane fuel cell (PEMFC) technology has attracted considerable attention as a mobile power solution owing to its relatively low operating temperature and suitable power range for vehicles [1].

However, the performance and durability of PEMFCs must be improved further before they can be commercialized. Generally, PEMFCs mainly suffer power loss owing to the contact resistance between the bipolar plates and the gas diffusion layers (GDLs) [2].

The contact resistance depends on the clamping pressure, gas pressure, current density, and temperature [3]. In Refs. [3], Ihonen et al. simultaneously measured the clamping pressure and contact resistance using a specially designed single cell. They validated the relationship between the contact resistance and other parameters through a comparison of in-situ and ex-situ measurements.

Zhou et al. investigated the effect of the clamping force on the interfacial contact resistance and porosity of a GDL [4]. They suggested an optimal rib design for a gas channel for a reasonable combination of low interfacial contact resistance and good GDL porosity.

Recently, pressure indicating films (PIFs) have been adapted to measure the pressure distribution. A PIF indicates

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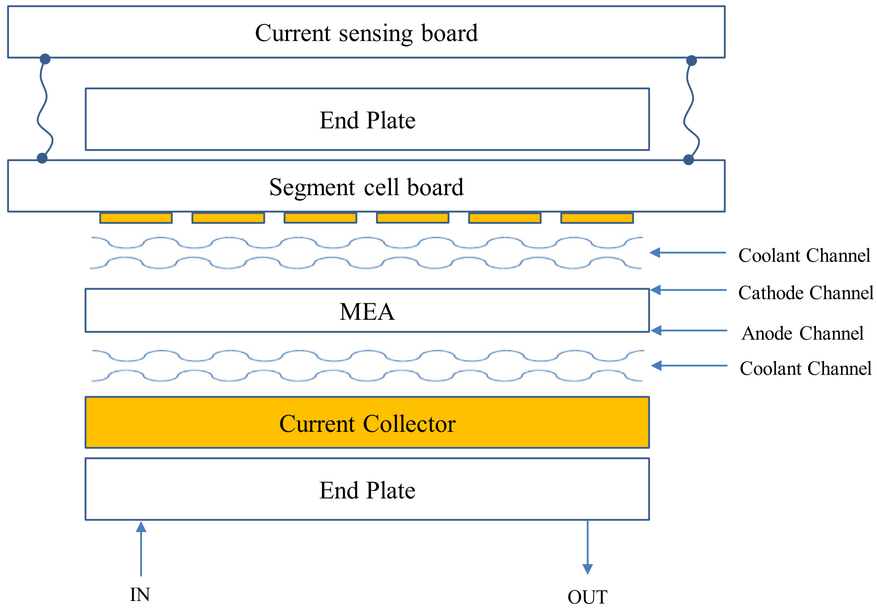
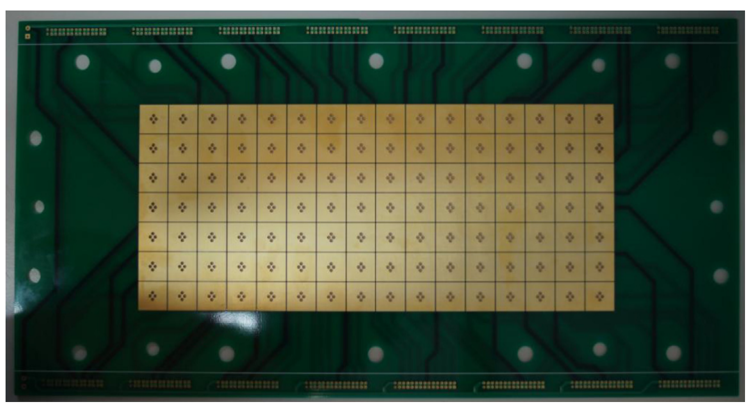


(a) Configuration of segmented PEMFC



(b) Photograph of PCB board

Fig. 1 – Segmented PEMFC. (a) Configuration of segmented PEMFC. (b) Photograph of PCB board.

applied pressure differences through color density variations, allowing the pressure distribution to be measured using software. Wen et al. investigated the fuel cell performance for different clamping torques and bolting configurations using PIFs. They found that a larger mean contact pressure leads to higher maximum power and uniformity of the contact pressure distribution. Furthermore, the ohmic resistance and mass transport limit current showed highly linear correlations with the mean contact pressure [5].

Yu et al. used a PIF to measure the pressure distribution in a single-cell PEMFC [6]. Instead of metals, they employed composite materials as endplates to increase the uniformity of the pressure distribution. They used composite endplates with a pre curvature created by thermal fabrication. These endplates red uced the stack weight without compromising the performance.

In this study, PIF was used to measure the pressure distribution in a single-cell PEMFC. A curved endplate was used to achieve high pressure uniformity. The effect of the pressure distribution was analyzed based on the current distribution. We adapted a printed circuit board (PCB)-type segmented cell to visualize the current distribution. Segmented cells were generally used to measure the current distributions [7,8]. Three techniques were used to realize a segmented cell system: PCB, resistor network, and Hall effect sensors [9]. Cleghorn et al. [7] first adapted the PCB-based measuring technique, in which a segmented flow field and a current collector were used. Wieser et al. [10] first introduced the Hall effect sensor for indirect current sensing. They investigated the relation between the uniformity of the pressure and the current distribution using a PCB-type segmented cell.

As mass transport is one of the most significant phenomena in PEMFCs owing to the electrochemical reaction, many studies have investigated efficient flow configurations through numerical as well as experimental methods [11]. However, only a