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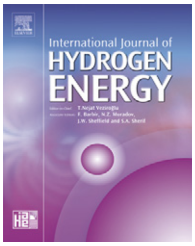

Technical Communication

A preliminary study of a six-cell stack with dead-end anode and open-slits cathode

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ABSTRACT

A practical air-breathing stack consisting of six cells was fabricated as a stair configuration for the integrated series connection of proton exchange membrane fuel cells. All the six cathodes of the stack contacting the ambient air through the open slits presented highly efficient (uniform and sufficient) oxygen supply for each cell. Hydrogen was supplied in series and circulated inside the stack to enhance the hydrogen utility and to improve the sufficiency of hydrogen supply to each cell of the stack. Polarization curves of the stack were measured without water-heat management. Gradual change processes of both the cells' temperature and voltage from the startup to equilibrium were recorded and analyzed. The cells produced the maximum power density of 350 mW/cm^2 at 650 mA/cm^2 averagely. The preliminary experimental results show the practicability of the design configuration due to both the high efficient oxygen supply to each cell and the hydrogen circulation inside the stack.

1. Introduction

In recent years, considerable attention has been focused on air-breathing fuel cells due to their minimization of auxiliary oxygen supply and simplified water-heat management [1,2]. Both the presence of micro-hydrogen generator [3] and dead-end anode operation [4] make the air-breathing fuel cells more compact and more suitable for portable applications.

Compared with other fuel cells, performances of air-breathing fuel cells are more affected by the ambient conditions. Much work has been conducted on the effect of temperature, humidity and natural convection therefore. Jeong et al. studied the dependence of net-water transfer in air-breathing fuel cell on the ambient temperature and humidity [5]. Zhang et al. reported that the performance of air-breathing fuel cells can be improved by increasing the hydrogen pressure and the ambient humidity [6,7]. Fabian et al. studied the dead-end anode operation at ambient temperature 10–40 °C and relative humidity 20–80%; the nature air-convention around the cathode was visualized and analyzed by shadowgraphy [8]. Noponen et al. obtained the optimal performance at 60 °C for the air-breathing fuel cell [9]. Pan et al. improved oxygen transfer by hydrophobic treatment of the cathode diffusion layer [10].

The cathode separator structure of air-breathing fuel cells can be mainly designed into two types to facilitate oxygen supply, open-slit type and channel type. In open-slit-type structure, parallel rectangular open-slits are machined on the cathode separator, air is supplied through the slits and reached the cathode vertically. Great efforts have been

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devoted to the dependence of the fuel cell performance on the slit configuration [11–16].

In the channel-type structure, straight vertical channels with two open ends are designed, through which the ambient air flows into the stack from the bottom end of the channels and flows upward by buoyancy. Some work has been conducted to investigate the cells with this channel-type cathode. Morner and Nopponen investigated the effect of humidity on the current distribution [9,17]; Himanen and Litster studied the water and oxygen transfer in the MEA [4,18].

Tabe et al. compared the two types of cathode separators mentioned above; they confirmed that both the uneven contact resistance in the open-slit-type structure and the insufficient natural convection inside the channels in the channel-type configuration were inevitable [19]. However, the type of open-slit structure attracted more attention than the channel-type configuration due to the larger open contact area with the ambient air and the more unhindered oxygen supply [2,13,20–24]. Apparently, the oxygen supply is more important in air-breathing fuel cells. Many researchers introduced air-fan into the stack or cells to enhance the oxygen supply. The air flow rate was controlled according to the stack operation conditions such as power output, ambient temperature and humidity [9,25–27]. Santa et al. determined the dependence of air temperature at the cathode outlet on the driving voltages of air-fans and confirmed the favorable function of the air-fan [25].

Almost all the experimental research about the air-breathing fuel cells was focused on the operation conditions [28,29], the theory studies were conducted on the water and oxygen transfer [30–32]. Our previous paper has provided a 3-cell stack fabricated as a stair structure, hydrogen was supplied in series [33]. This paper reports on the preliminary work of a six-cell stack, the configuration was based on the work of Ref. [33], the hydrogen was supplied in series and circulated by the fans built in the stack. The six-cathode separators are designed in the open-slits structure, hence the oxygen supplies of the six cells are separate. The characteristics of both the temperature variations and the discharge performance of the stack were determined and analyzed.

2. Experimental

2.1. Design of stack

The stack in our experiment consisted of six cells. The electro-connect was in series as well as hydrogen supply. The configurations of the stack and the cathode separators are presented in Fig. 1A. The circulation route of hydrogen and temperature detecting sites are shown in Fig. 1B. The hydrogen was supplied and circulated by the hydrogen fans in the stack. The oxygen was obtained directly from the ambient air through the open slits. The open-slit type cathode separator has opening slits of 10 mm × 1 mm at 1 mm intervals. The area of every MEA was 5 cm^2. The stack can be considered as two 3-cell substack locating at both sides of the hydrogen fans, the electric-connection between the two substacks was realized by Pt wire. The substack was designed into the stair configuration to feed sufficient and uniform oxygen to each cell. The stack was placed vertically to the ground, the hydrogen inlet was machined at the bottom of the stack and the outlet was fabricated on top of the stack. The assembled stack is shown in Fig. 1C. The outlet was used to drive air or other impurities before each experiment, which was shut when the stack was operating.

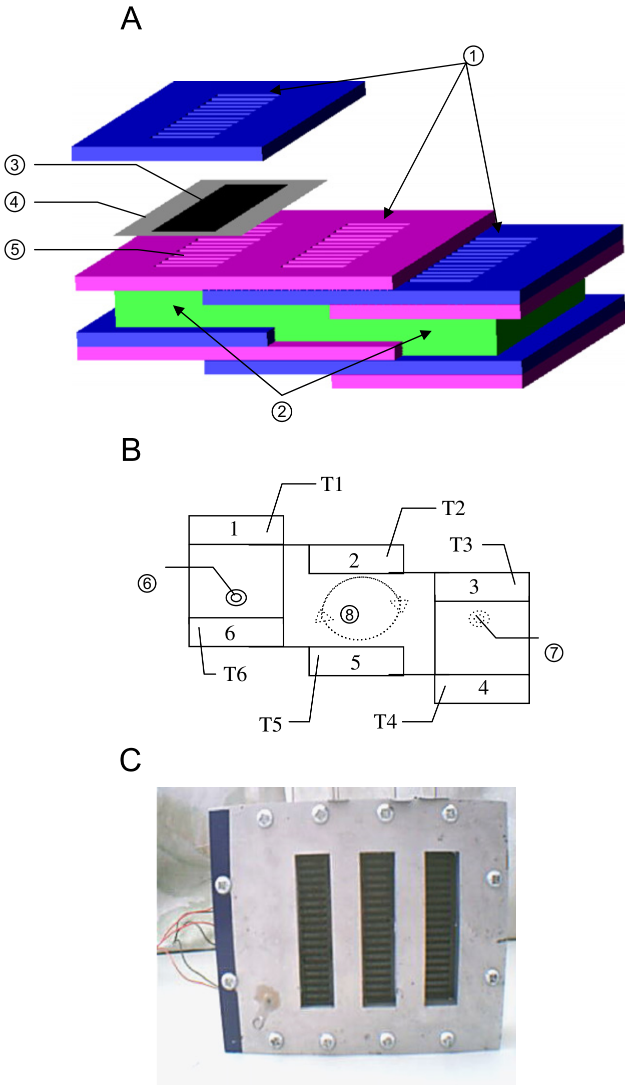

Fig. 1 – Air-breathing six-cell stack: (A) stack and cathode separators configurations; (B) hydrogen circulation route and temperature measuring site; and (C) assembled stack. ① Open-slit cathode, ② hydrogen fans, ③ cathode diffusion and catalyst layers, ④ electrolyte membrane, ⑤ anode field channels, ⑥ hydrogen inlet, ⑦ hydrogen outlet and ⑧ hydrogen circulation direction. T1–T6 present the temperature of 6 cells, measured by inserting the thermocouple into the anode channels.

2.2. MEA fabrication and stack assembly

The membrane electrode assembly (MEA) was prepared by pressing the anode, proton exchange electrolyte membrane