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Current and clamping pressure distribution studies on the scale up issues in direct methanol fuel cells

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ABSTRACT

The focus of the present study is to obtain the performance on a larger area (45 cm^2) equivalent to that obtained on a smaller area (4 cm^2) single cell DMFC overcoming performance losses associated with scale-up of single cell DMFCs due to uneven clamping pressure distribution on MEA through the end-plates and non-uniform distribution of reactants to MEA. The current distribution profile along the cathode flow field channel is measured using a segmented current measurement plate to understand the influence of uneven clamping pressure distribution on the MEA. Uniform current distribution in a single cell DMFC with 45 cm^2 electrode area is achieved using angular ribbed end-plates. Also, in the present study performance of conventional DMFC is compared with that of mixed-reactant (MR), i.e. methanol and air. Performance of DMFC operating on mixed reactant (MeOH + air) at anode and air at cathode is superior compared with DMFC operating on aqueous methanol at anode and air at cathode. A power density of 55 mW cm^{-2} at 0.3 V is obtained for a DMFC single cell with an effective area of 45 cm^2 using angular ribbed end-plates and MR at anode and air at cathode under ambient conditions. Pressure film test is conducted to obtain the clamping pressure distribution and cyclic voltammetry is performed to obtain the electrochemical surface area of small and large area electrodes.

1. Introduction

Direct methanol fuel cell (DMFC) is one of the most promising energy conversion devices for low-power applications due to its system simplicity and use of methanol as a high energy density liquid fuel [1–3]. Owing to its complicated reaction kinetics and methanol crossover problem, the simulation becomes more difficult for DMFCs in comparison with PEMFCs. However, there is some simulation models reported in the literature recently [4–8]. While the cathodic reaction appears to be fairly straightforward, the complete mechanism for the anodic reaction is still not well understood [9]. Mass transport of methanol in a DMFC is one of the major issues in improving the performance of the single cell or stack. A number of papers have reported on the study of CO_2 bubble behavior in the anode flow field of conventional DMFCs with relatively large area MEAs [10–12] and on the effect various flow field designs in regard to the transport of methanol and carbon dioxide [13,14]. In the present study, we have focused on the influence of mixed reactants in mitigating the mass transfer effects. In DMFCs, methanol and water react to produce carbon dioxide, electrons and protons at the anode, the electrons and protons which are transferred via external circuit and electrolyte membrane, respectively, react with oxygen to produce water at the cathode. One of the main problems in the development of DMFCs is non-uniform current distribution during scale-up of single cell and stacks. Generally, most of the published data on DMFCs under ambient conditions were obtained with small single cells [15–20]. Non-uniform current distribution occurs due to the inhibition of methanol flow on the anode side by CO_2 bubbles causing concentration decrease of the reactants across the active area along the flow field channels and uneven compaction pressure. These effects lead to a pronounced non-uniform current distribution as well as to a power loss of the fuel cell. It has been shown through modeling studies using finite element analysis that flat end-plates structure is inferior in terms of the compaction pressure distribution in relation to ribbed structure [21].

Usually, formation of carbon dioxide at anode in DMFCs leads to hindrance of reactant pathway resulting in mass-diffusion problems. Thus, modified operating conditions are needed to lessen the mass-diffusion problems and increase the cell performance in DMFCs. Shukla et al. [20] reported that a DMFC operating with mixed-reactant at anode exhibits superior performance in relation

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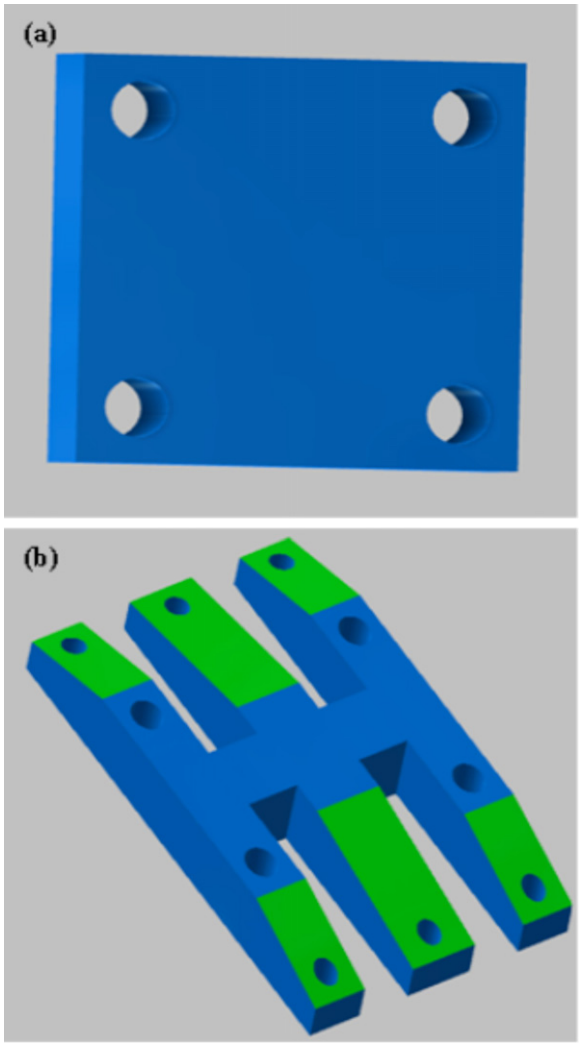

Fig. 1. Three-dimensional view of end-plates of (a) design-1 and (b) design-2.

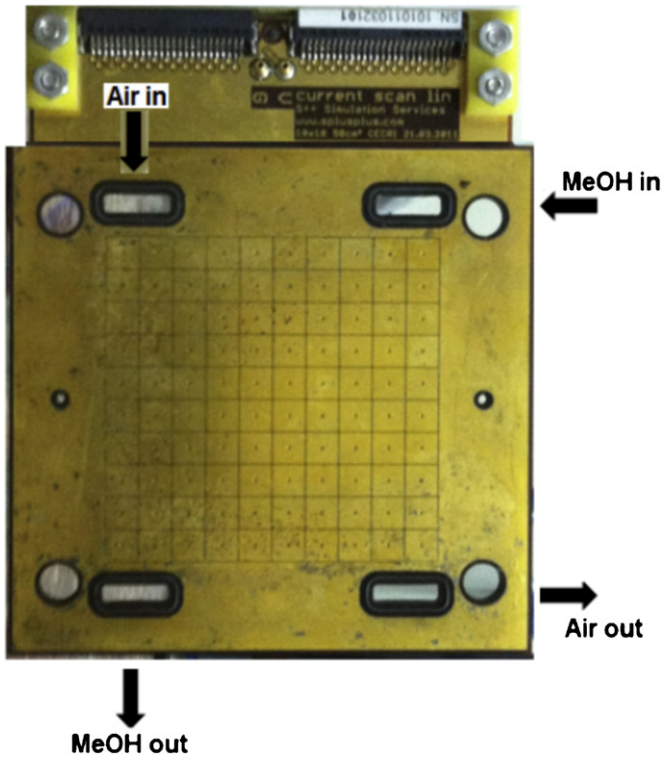

Fig. 2. Image of the current distribution sensor plate.

to conventional DMFC and it is suggested that this improvement is due to a higher liquid saturation in the anode diffusion layer of the DMFC and faster removal of carbon dioxide at its anode.

In order to understand current density variations in a fuel cell, it is very important to measure the current distribution. The reactant concentration varies along the flow channels; it causes variations in current density, water content, and temperature [22–24]. In many cases the goal of the fuel cell development is also to achieve an even current density profile under a variety of operating conditions. The areal variations of the cell current give information

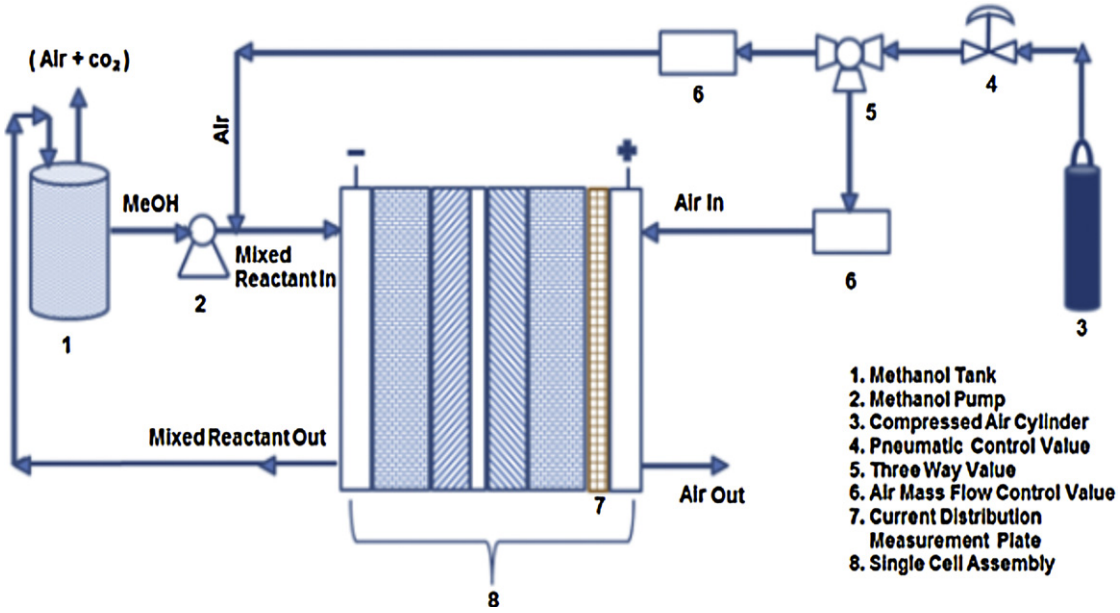

Fig. 3. Flow chart of the fuel cell current distribution measurement system and experimental setup of conventional and mixed-reactant operation of DMFCs.