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Dual exchange membrane fuel cell with sequentially aligned cation and anion exchange membranes for non-humidified operation

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ABSTRACT

To realize effective polymer electrolyte fuel cell (PEFC) operation under non-humidified conditions, a new self-humidifying dual exchange membrane fuel cell (DEMFC) was designed and evaluated. The DEMFC was fabricated using sequentially aligned membrane electrode assemblies (MEAs) consisting of an anion exchange membrane (AEM) and a cation exchange membrane (CEM). In this system, water simultaneously generated by the half-cell reactions at both the anode and the cathode is then supplied to the other MEA through the gas diffusion medium and the bipolar plate in the DEMFC under completely dry conditions, resulting in high cell performance. Also, durability of a DEMFC five-cell stack was tested by accelerated on/off operation under fully dry conditions. No cell degradation occurred over 50 cycles (200 h), indicating that this DEMFC design provides an effective approach for constructing practical miniaturized PEFCs that do not require external humidification systems.

1. Introduction

Significant climate change and environmental concerns require the development of alternative power devices. Hydrogen is an appealing fuel for polymer electrolyte fuel cells, which offer low cell operation temperature, low noise, high power density, and long operation time with a single fuel injection. Despite commercialization efforts, several obstacles remain, such as cost and durability of membranes and electrodes, which are affected by the requirements of complex water management processes.

In particular, water management is not only a critical issue for polymer membrane performance but also affects the durability of the entire system [1]. Several recent studies have examined water management for improving power efficiency under non-humidification

operation. Fig. 1 summarizes the cell performance achieved over the last decade under non-humidified operation in systems based on composite membranes [2–6], hydroscopic catalysts [7–10], water-retainable electrodes [11–13], hybrid membranes [14,15], and bipolar membranes (BPMs) [16]; all data are based on a current density of 0.6 V in i–V curves under dry hydrogen and oxygen. Performance has tended to increase as research has progressed.

Self-humidifying composite membranes based on various materials, including ionic liquids, functionalized graphene oxide, and hygroscopic metal oxides with fluorocarbon or hydrocarbon backbone membranes, have been investigated [2–6]. These composite materials aid self-humidification by absorbing and retaining water inside the membranes under dry conditions. However, they show unsatisfactory performance ($<400 \text{ mA cm}^{-2}$ at 0.6 V). The second approach utilizes

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