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Short communication

The role of flow-field layout on the conditioning of a proton exchange membrane fuel cell

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ABSTRACT

The importance of membrane electrode assembly (MEA) conditioning for proton exchange membrane (PEM) fuel cells under various operating conditions, such as reactant flow and cell voltage-current combination, has been well recognized, but few studies have considered the impact of the cell hardware design. In this study, the impact of flow-field layout on the conditioning of MEAs has been experimentally investigated. It is shown that the MEAs conditioned with serpentine flow-field layouts on both the anode and cathode side have better performance than the MEAs conditioned with straight-parallel flow-field layouts, and that the peak power density can be increased from 0.83 W/cm^2 to 0.93 W/cm^2 (about 12% increase) for the MEAs tested under the same operating condition of using humidified hydrogen and air at atmospheric pressure. This performance improvement is mainly due to the under-rib convection of the reactant gases in serpentine flow-field layouts that provides more uniform conditioning of the entire MEAs, compared with the MEAs conditioned with straight-parallel flow-field layouts for which the portion of the MEAs under the rib is not well conditioned, due to the lack of the reactant flow there.

1. Introduction

Proton exchange membrane (PEM) fuel cells have garnered considerable attention, particularly in automotive, stationary and portable applications, due to their unique characteristics, such as high energy-conversion efficiency, quick start-up and shut-down, fast response to instantaneous load changes, environmental benignity, and the ability to operate without moving parts [1,2]. Extensive efforts on all aspects of PEM fuel cell technology have advanced and brought the technology very close to commercial viability, together with remaining technical and scientific challenges to be overcome [3–5]. For instance, after being manufactured, a PEM fuel cell does not immediately reach its maximum performance, since the electrochemical reactions do not fully take place in the initial cell start-up. Thus, a long-lasting conditioning/break-in/incubation procedure is primarily required to activate the cell [6].

The conditioning procedure is typically carried out to initiate the newly manufactured membrane electrode assembly (MEA), and it may last hours and even days depending on the specifications of the MEA and the type (e.g., on/off line conditioning) and conditions of the procedure (e.g., cell temperature, pressure, and relative humidity of reactants) [7,8]. During this procedure, the performance obtained from the cell increases progressively, and then reaches a “plateau” and stabilizes as well. Various theories have been proposed to account for conditioning procedure-dependent performance enhancements [9–11]. According to these theories, the MEA conditioning procedure enhances cell performance in a time-dependent manner by (i) facilitating the removal of impurities that are typically introduced into the MEA during its fabrication, (ii) activating the electrochemically inactive catalyst sites, (iii) forming pathways for the transport of reactants and by-products from/to the triple-phase boundary, (iv) ensuring an effective hydration for initially dry membrane, thus enhancing its ionic conductivity, and (v) facilitating hydration of the polymeric binder embedded in the anode and cathode electrodes, thus building up a well-connected network for proton transport.

Over the last decade, MEA conditioning has been actively investigated, having mainly centered on understanding the potential mechanisms behind MEA conditioning [12], influences of various activation procedures [13], and alternative techniques for MEA conditioning either prior to or following cell assembly [14]. These studies have provided a good basis for further investigation by revealing the

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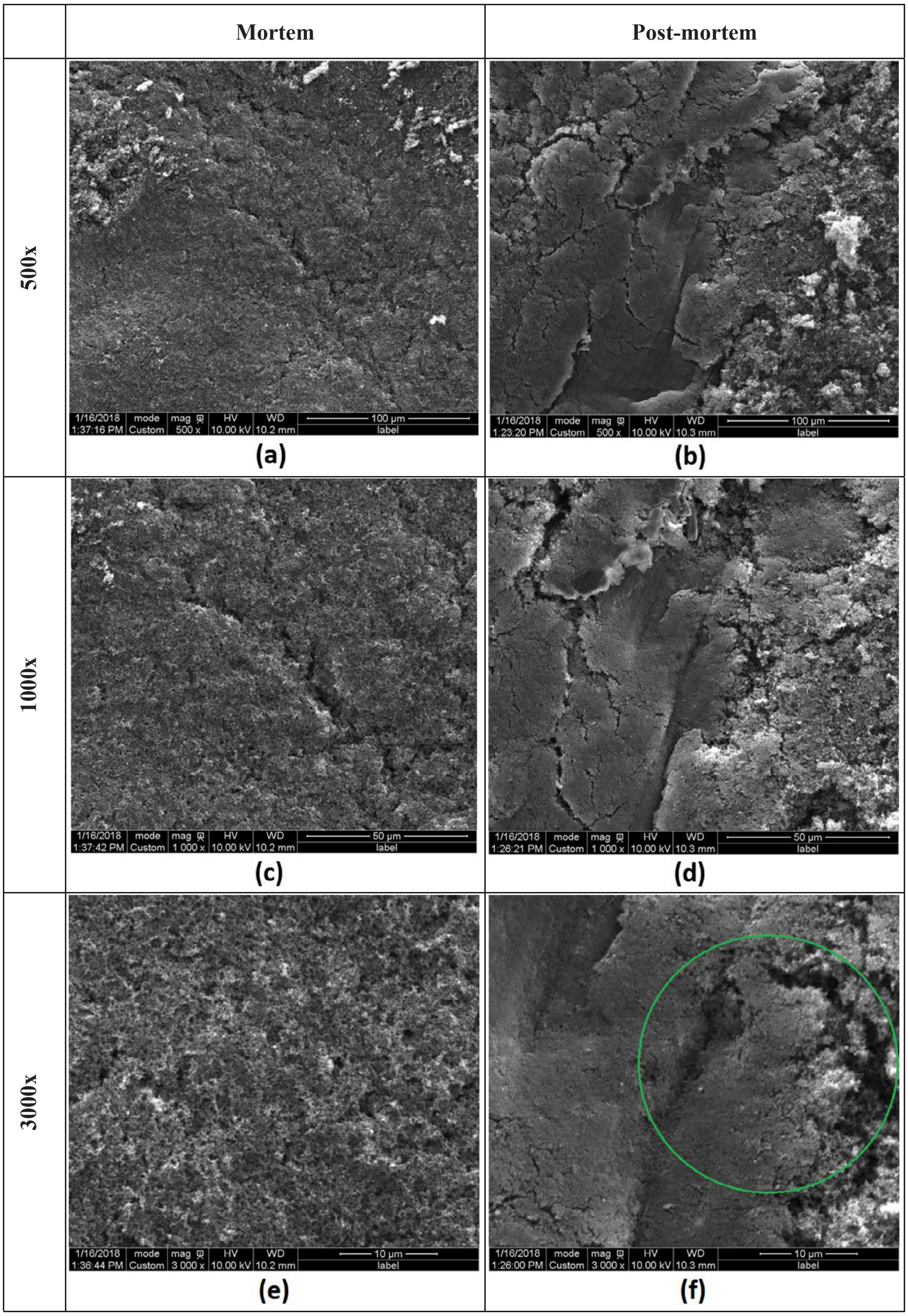

Fig. 1. SEM images of the *mortem* and *post-mortem* GDLs: (a), (c), (e), and (g) face views of the *mortem* GDL (before conditioning), the images showing the crack- and damage-free surface morphology; (b), (d), (f), and (h) face views of the *post-mortem* GDL (after conditioning), the images showing the crashed and compacted morphology. The region captured by the green and red circles showing the morphological differences between the under-rib and under-channel regions, while the region captured by the yellow circle showing the crashed and compacted morphology underneath the ribs.

performance-enhancing effects of modifications to the existing conditioning procedure and/or by revealing those of various conditioning parameters on overall cell performance. However, the effects of cell hardware (i.e., anode and cathode flow-field layouts) on the MEA conditioning procedure and, thus overall cell performance, still remain unexplored.

The objective of this study is therefore to investigate the impact of cell hardware, especially anode and cathode flow-field layouts, on the conditioning of MEAs, thus developing a simple-to-perform MEA conditioning methodology that is effective in improving MEA performance. To achieve this objective, similarly manufactured MEAs are conditioned in a single-cell assembly with different anode and cathode flow-field layouts under the same operating conditions. The first set of MEAs is conditioned in the single cell with serpentine anode and cathode flow-field layouts, while the second set of MEAs is conditioned in the cell with straight-parallel anode and cathode flow-field layouts. Performance testing for all the MEAs is carried out in the cell with straight-parallel anode and cathode flow-field layouts. *Mortem* and *post-mortem* characterizations of porous cell components, such as catalyst layers (CLs) and gas diffusion layers (GDLs), are performed to examine the changes in morphological and microstructural characteristics upon conditioning and performance tests. In this manner, the influence of the