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Fabrication and evaluation of membrane electrode assemblies by low-temperature decal methods for direct methanol fuel cells

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ABSTRACT

In this study, a low-temperature decal transfer method is used to fabricate membrane electrode assemblies (MEAs) and the MEAs are tested for application in a direct methanol fuel cell (DMFC). The low-temperature decal transfer uses a carbon-layered decal substrate with a structure of ionomer/catalyst/carbon/substrate to facilitate the transfer of catalyst layers from the decal substrates to the membranes at a temperature as low as 140 °C, and also to prevent the formation of ionomer skin layer that is known to be formed on the surface of the transferred catalyst layer. The DMFC performance of the MEA (with carbon layer) fabricated by the low-temperature decal transfer method is higher than those of MEAs fabricated by the same method without a carbon layer, a conventional high-temperature decal method, and a direct spray-coating method. The improved DMFC performance of the MEA fabricated with carbon layer by the low-temperature decal transfer method can be attributed to the absence of an ionomer skin on the catalyst layer, which can streamline the diffusion of reactants. Furthermore, the intrinsic properties of the MEA fabricated by the low-temperature decal transfer method are elucidated by field-emission scanning electron microscopy (FESEM), electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV) techniques, and cathode CO_2 analysis.

1. Introduction

Direct methanol fuel cells (DMFCs), as promising power sources for portable electronic devices and small-scale vehicles, generate electricity through the electrochemical reactions of methanol oxidation and oxygen reduction. The DMFC is very compact, exhibits high energy density, and the fuel methanol has a superior chemical stability [1,2]. Nevertheless, factors such as the sluggishness of the methanol oxidation reaction, methanol crossover to the cathode, un-optimized structure of membrane electrode assembly (MEA) and high fabrication cost are obstacles to the commercialization of DMFCs. Hence, the importance of MEA fabrication, which determines mainly the performance and cost of the cell, has been highly emphasized in the literature [3,4]. In order to improve MEA performance, various strategies such as different MEA fabrication methods, modification of the MEA structure and operating conditions have been adopted [5–12]. Although the issues of slow kinetics of methanol oxidation reaction and methanol crossover to the cathode can be addressed through the use of a high surface-area PtRu catalyst and development of new types of polymer electrolyte membranes, fabrication of an optimized structure of the MEA can also mitigate these issues. Many attempts have been made to improve the fabrication process and structural parameters of the MEA to enhance its DMFC performance.

Conventional methods to fabricate MEAs are divided into two groups [5,9,13–16]. One is the catalyst-coated substrate (CCS) method and the other is the catalyst-coated membrane (CCM) method. In the CCS approach, catalysts are coated on the gas-diffusion layer (GDL), which is made from carbon paper, felt or cloth, and then hot-pressed with the membrane electrolyte to form the MEA. This method is suitable for the fabrication of large-scale MEAs and for mass production. In the CCM method the catalysts are directly coated on the membrane and subsequently hot-pressed with the GDL. The MEA made by CCM method has an improved catalyst|membrane interface [16], better utilization of catalysts [9]

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