Microelectronic Engineering 119 (2014) 159–163

Contents lists available at ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

Stainless steel fiber felt as the anode diffusion backing and current collector for μ-DMFC

Rui Xue, Shengtian Sang, Hanchen Jin, Qian Shen, Yufeng Zhang *, Xiaowei Liu, Xuelin Zhang *

MEMS Center, School of Astronautics, Harbin Institute of Technology, Harbin 150001, China

ARTICLE INFO

Article history:
Received 27 October 2013
Received in revised form 29 January 2014
Accepted 7 February 2014
Available online 11 March 2014

Keywords:
Direct methanol fuel cell
Stainless steel fiber felt
Methanol crossover
Polarization loss

ABSTRACT

In this paper, a membrane electrode assembly (MEA) that uses a stainless steel fiber felt (SSFF) to replace the anode current collector and backing layer is designed and fabricated for a micro-direct methanol fuel cell (DMFC). At the same time, a conventional MEA with carbon paper (CP) as the support layer of the anode gas diffusion layer was fabricated as a contrast experiment. To study the effect of the novel structure on the anode or cathode electrode process, a reference electrode was built inside a single cell. The results show that the novel MEA has a smaller cathode polarization by reducing the methanol crossover and provides a smaller anode polarization by improving the methanol transportation.

1. Introduction

A direct methanol fuel cell (DMFC) has obvious advantages in the field of portable energy due to its high fuel efficiency, high energy density and environmentally friendly features [1–5]. By eliminating liquid pumps and gas fans/blowers, a DMFC cell can possess a much simpler structure, smaller volume and higher energy density [6]. In this passive system, the supply of fuel and oxygen only relies on diffusion and natural convection, which causes it to provide a poorer performance than those systems running in active mode, due to poor mass transportation. To achieve the commercialization of a passive DMFC cell, various passive DMFCs were proposed and extensively investigated to improve cell performance over the past decade [7–9].

Recently, metallic porous materials such as stainless steel fiber felt (SSFF) and metal foam have been used in several passive DMFCs as a flow field, gas diffusion layer, backing layer and current collector [10–13]. Considering their high mechanical strength and good conductivity, porous metal materials were used to replace both the cathode gas diffusion backing and the current collector by Chen and Li [11–12]. The results show that the novel structure not only simplifies the cell structure but also increases the cell performance by improving oxygen transportation and water management and by decreasing methanol crossover. However, a similar work has not been performed on the fabrication and study of the anode gas diffusion electrode. Liu applied SSFF as an anodic gas diffusion backing [13], but the anode current collector was not replaced. Moreover, Liu did not provide a detailed study on how SSFF affects the anode or cathode electrode process.

As one of the main aspects that deteriorate the performance of a passive DMFC cell, methanol crossover can be controlled by optimizing the MEA structure, and research has been performed on this aspect [14–17]. In our previous work, SSFF was used to replace the cathode current collector and backing layer of a micro-DMFC cell, and the results show that the novel structure can reduce the methanol crossover dramatically [12]. In this paper, SSFF was used to replace the anode current collector and backing layer to fabricate a novel MEA for a micro-DMFC cell. At the same time, a reference electrode was built inside a single cell to study the effect of the novel structure on the anode or cathode electrode process. The fabricated micro-DMFC cell was tested in a half-cell measurement using polarization at different methanol concentrations and constant-current discharging and was compared with a normal DMFC cell as a reference.

2. Experiment

A 316L stainless steel fiber felt (SSFF) was used as the anode gas diffusion backing and current collector to fabricate a MEA for a micro-DMFC cell. The novel membrane electrode assembly with an active area of 1 cm^2 was fabricated in-house using the following procedures. To decrease the contact resistance, a 200-nm Au layer was deposited onto the SSFF using magnetic sputtering technology.

* Corresponding authors. Tel.: +86 0451 86413442; fax: +86 0451 86413441.
E-mail addresses: yufeng_zhang@hit.edu.cn (Y. Zhang), zhangxuelin@hit.edu.cn (X. Zhang).

http://dx.doi.org/10.1016/j.mee.2014.02.006
0167-9317/

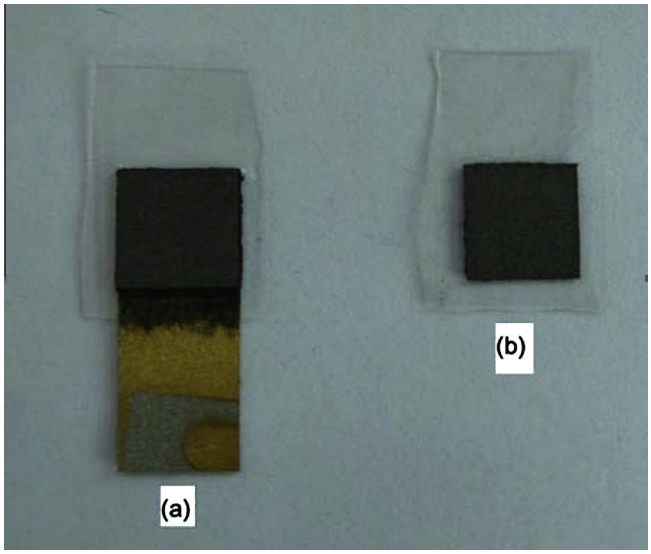

Fig. 1. Photographs of MEAs made from SSFF (a) and carbon paper (b).

A mixture of 80 wt.% XC-72 and 20 wt.% Nafion was sprayed onto the surface of the SSFF and served as a micro-porous layer with a carbon loading of 4 mg cm^{-2}. A carbon-supported catalyst of 60 wt.% PtRu/C (Pt:Ru = 1:1 in atomic ratio, Johnson Matthey Corp.) was used for the fabrication of the anode catalyst layer. The anode catalyst ink was well mixed and sprayed onto the carbon-coated SSFF to obtain an anode gas diffusion electrode (GDE). The catalyst loading was approximately 4 mg cm^{-2} with 20 wt.% Nafion as the bonding agent. Along with the manufacture of the novel anode GDE, a conventional anode GDE with carbon paper (TGPH060) as the backing layer was also built for reference. The Nafion 117 membrane was adopted to fabricate the MEA, which was pretreated in deionized water at 3 wt.% H_2O_2, 3 wt.% H_2SO_4 and once more in deionized water for 1 h in each solution. A commercial cathode gas diffusion electrode (purchased from Johnson Matthey, Inc.) and a homemade anode gas diffusion electrode were attached to the Nafion membrane using hot-pressing at 408 K and 18 MPa for 180 s to form an MEA. The prepared MEAs made from SSFF and carbon paper are shown in Fig. 1. In the following, the two MEAs fabricated with carbon paper and SSFF were named CP-MEA and SSFF-MEA, respectively, to simplify the description.

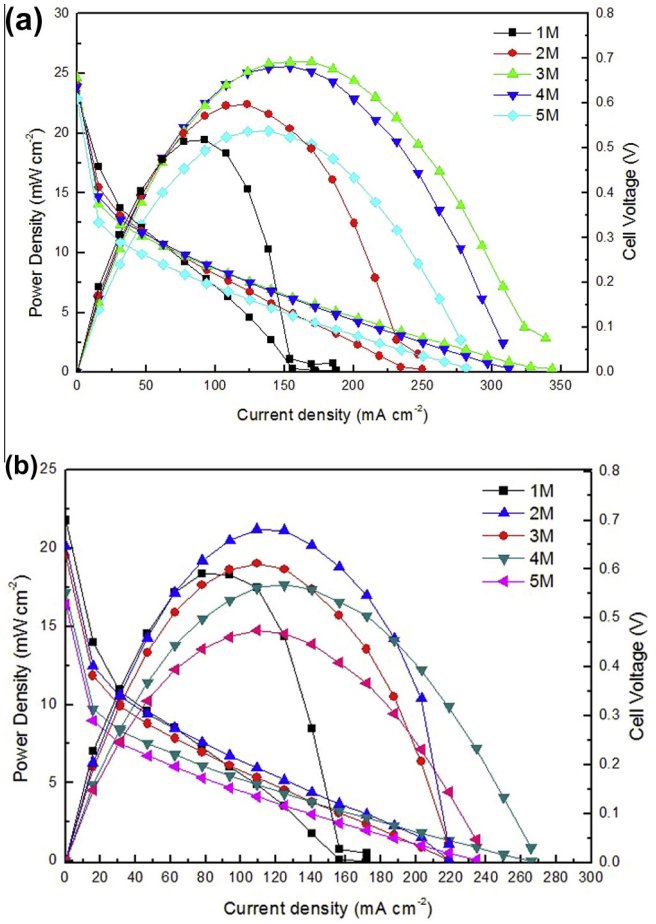

Fig. 3. Power density curves of SSFF-MEA (a) and CP-MEA (b) measured at 298 K with different methanol concentrations.

For an SSFF-MEA, only a cathode current collector is required for single cell assembly, which has a perforated flow field with an open ratio of 40.7%. For a CP-MEA, an anode current collector is still required, which has parallel channels with an open ratio

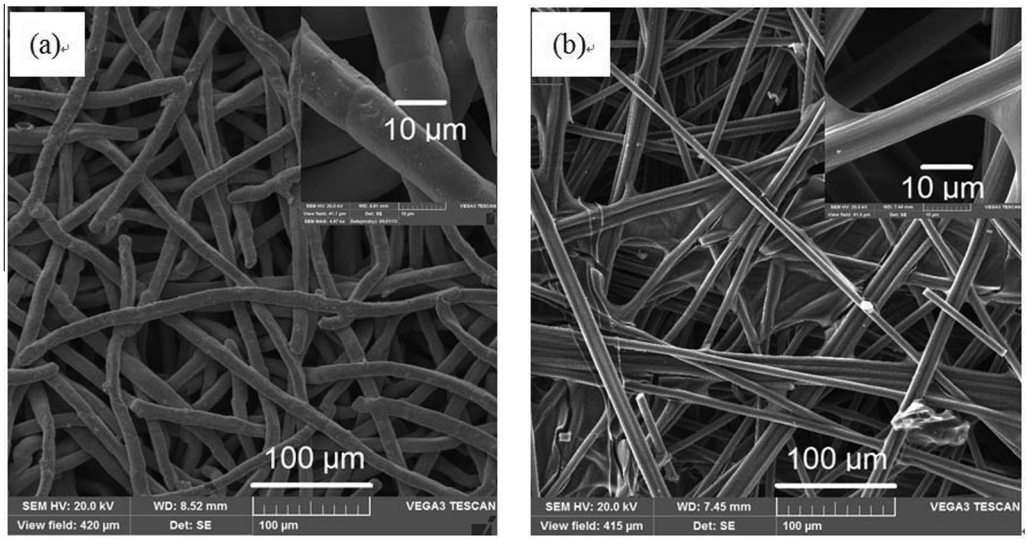

Fig. 2. SEM views of SSFF (a) and carbon paper (b).