Journal of Power Sources 196 (2011) 2750–2753

Contents lists available at ScienceDirect

Journal of Power Sources

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

Short communication

Single passive direct methanol fuel cell supplied with pure methanol

Ligang Feng, Jing Zhang, Weiwei Cai, Liangliang, Wei Xing*, Changpeng Liu

State Key Laboratory of Electro-analytical Chemistry, Changchun Institute of Applied Chemistry, Jilin Province Key Laboratory of Low Carbon Chemical Power, Graduate School of the Chinese Academy of Sciences, 5625 Renmin Street, Changchun, Jilin 130022, PR China

ARTICLE INFO

Article history:
Received 26 October 2010
Received in revised form
22 November 2010
Accepted 22 November 2010
Available online 27 November 2010

Keywords:
Passive direct methanol fuel cell
Pervaporation membrane
Pure methanol
Power density

ABSTRACT

A new single passive direct methanol fuel cell (DMFC) supplied with pure methanol is designed, assembled and tested using a pervaporation membrane (PM) to control the methanol transport. The effect of the PM size on the fuel cell performances and the constant current discharge of the fuel cell with one-fueling are studied. The results show that the fuel cell with PM 9 cm^2 can yield a maximum power density of about 21 mW cm^{-2}, and a stable performances at a discharge current of 100 mA can last about 45 h. Compared with DMFC supplied with 3 M methanol solution, the energy density provided by this new DMFC has increased about 6 times.

1. Introduction

The DMFC is a promising power source for portable applications due to its high energy density, long life and so on [1–4]. The theoretical specific energy and energy density of pure methanol are about 6100 Wh kg^{-1} and 4800 Wh L^{-1}. In practice, the fuel supplied at the anode of passive DMFC must be a low methanol concentration (less than 5 M). Therefore, this will lead to a short runtime of the fuel cell, and the specific energy and energy density will be largely decreased. In order to increase the operation time, several efforts [5–8] have been carried out to develop advanced DMFC technology. Abdelkareem et al. [5,9,10] employed a porous carbon plate to increase the mass transport resistance on the anode and realized to supply the fuel cell with high methanol concentration over 20 M. Kim et al. [11,12] used the hydrogels to control the methanol transport from the fuel reservoir to the anode even at high fuel concentration.

Pervaporation membrane (PM) was employed for the separation of mixture of liquids and several new membranes were reported to separate the small molecular substances such as methanol, ethanol, and water and so on [13–15]. Based on the properties of PM, in our experiment, the work was tentatively to introduce the PM into a single passive DMFC and to check if it can be used to control the methanol transport on the anode. Therefore, in this communication, a new fuel cell structure was proposed with PM to control the methanol transport when the fuel was supplied with pure methanol. The experiment results demonstrated that the passive DMFC with the proposed new structure can successfully operate with pure methanol. Under the same condition, the discharge time of the proposed DMFC supplied with pure methanol at a constant current was much longer than that of the conventional fuel cell supplied with methanol solution.

2. Experimental

2.1. Membrane electrode assembly

Pt–Ru and Pt black catalysts (Johnson Matthey) were used as anodic and cathodic electrocatalysts, respectively. The carbon papers (TGP-H-60, Toray) with 20% and 40% polytetrafluoroethylene (PTFE) content were used as anodic and cathodic backing layers, on which carbon black (Vulcan-XC 72) with PTFE content of about 20% and 40% as the micro-porous layer had been pre-coated with a loading of 2 mg cm^{-2} respectively. Nafion®-117 membrane (DuPont Co., USA) was pretreated before use [16,17]. The catalyst ink consisted of the catalyst, deionized water, isopropyl alcohol and Nafion solution (5 wt.%, DuPont Co., USA) was coated on the carbon backing layer to fabricate the electrodes. The catalyst loading as high as 8 mg cm^{-2} is used on each electrode to achieve high performance. The Nafion ionomer loading in the catalyst was 10 wt.% for the cathode and 15 wt.% for the anode, defining by the ratio that dry ionomer takes up in the catalyst layer. The MEA, area of 9 cm^2, was fabricated by sandwiching the membrane between the anode and the cathode, and then it was hot-pressed at 408 K and 5 MPa for 3 min.

* Corresponding author. Tel.: +86 431 85262223; fax: +86 431 85685653.
E-mail address: xingwei@ciac.jl.cn (W. Xing).

0378-7753/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.jpowsour.2010.11.125

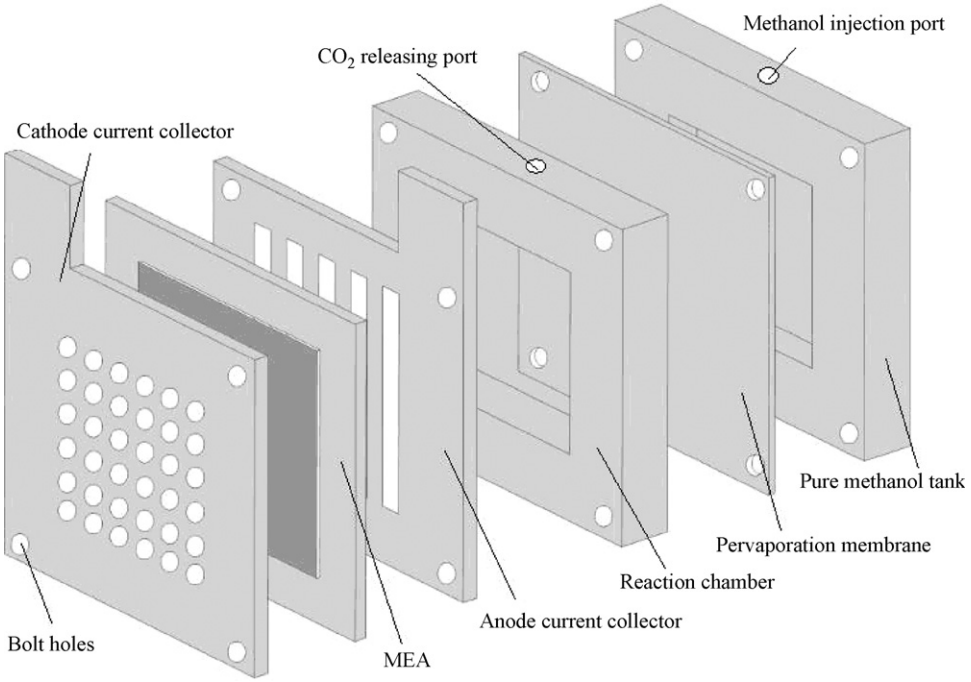

Fig. 1. Schematic diagram of the structure for the DMFC-P.

2.2. Fuel cell design and test

The single fuel cell structure is shown in Fig. 1, which is a modification for the conventional fuel cell structure [18]. The fuel tank is divided into two tanks: a pure methanol tank and a low methanol concentration tank (reaction chamber). The PM of 0.17 mm thick was bought from Beijing Hongzhi Jiahe Technology Co., China and used as-received. The PM was fixed between the two tanks to control the methanol transport. The fixing of the PM was not clear in Fig. 1, here, it was further explained. In order to easily change the effective PM size, the PM was sandwiched between two polycarbonate sheets (0.5 mm thick). The apparent PM size was close to that of the polycarbonate sheet and an open size of the desired effective PM area was machined on the polycarbonate sheet. The fringe of the open size was covered by adhesive-sealant silicone and then the PM was sandwiched between the two polycarbonate sheets. The PM sandwiched between the polycarbonate sheets was fixed between the pure methanol tank and reaction chamber at the anode. The low methanol concentration tank was the reaction chamber for the anodic oxidation of methanol and it was about 3 mm in thickness. The volumes of the reaction chamber and the pure methanol tank were about 2.7 mL and 5 mL, respectively. Other components such as current collectors, fuel cell body were the conventional parts used in fuel cell [19,20].

The polarization curves of the single fuel cell were measured during discharge process with a Fuel Cell Test System (Arbin Instruments Co.). The discharge curves of voltage vs. time were also tested at a constant current to record the voltage. For comparison, the MEA prepared in the same patch was also tested in a conventional single fuel cell with a dilute methanol solution. The designed fuel cell supplied with pure methanol was denoted as DMFC-P, and the conventional fuel cell supplied with a dilute methanol solution was denoted as DMFC-S. For the DMFC-S, the volume of the fuel tank was about 7.7 mL, which equaled to the sum of the volume of the reaction chamber and the pure methanol tank of the DMFC-P. The fuel cell was tested at ambient conditions (20–25 °C).

3. Results and discussion

Prior to testing the DMFC-P, a small amount of water of about 2 mL was syringed into the reaction chamber to wet the anode of the fuel cell. According to the anodic oxidation of methanol, the water is necessary for the reaction. Therefore, the syringed water can be used to dilute the penetrated methanol for the initial anodic methanol oxidation. The water needed for the reaction during the fuel cell operation was obtained from the water created on the cathode [20–22]. According to our experiment, if the MEA has been soaked in the water, the foregoing step could be omitted. The pure methanol was injected and the injection port was sealed completely during the operation. Before testing, the voltage of open circuit was recorded until the stable high voltage was reached; the process lasted for several minutes. For the purpose of comparison, the DMFC-S fed with a dilute methanol solution was tested in the same conditions.

3.1. Effect of pervaporation membrane size

In order to know the effect of the PM size on the performances of the DMFC-P and to find an optimal PM size, the PM with apparent area of about 9, 6, 3 and 1 cm^2 was employed. Because of the difficulty to measure the methanol concentration in the anodic catalyst layer, the polarization curves of the DMFC-S supplied with different methanol solution were tested and according to the similar curves, the methanol concentration of the DMFC-P was obtained by a rough estimate. The polarization curves and power density curves are shown in Fig. 2. The features of the curve for the DMFC-S were consistent with the results published elsewhere [23,24]. When the methanol concentration was increased, the performance became much better and the maximum power density was about 22 mW cm^{-2} for the DMFC-S with 3 M methanol solution. For the DMFC-P, the performance of PM with 9 cm^2 was about 21 mW cm^{-2}, which was close to the performance of the DMFC-S with 3 M methanol solution. When the PM size was decreased, it was evident from Fig. 2 that the maximum power density was also decreased. The cell performance of PM with 6 cm^2 was between