Available online at www.sciencedirect.com

SCIENCE DIRECT®

Journal of Power Sources 145 (2005) 702–706

JOURNAL OF POWER SOURCES

www.elsevier.com/locate/jpowsour

Short communication

Hydrogen production with integrated microchannel fuel processor for portable fuel cell systems

Gu-Gon Park [a], Sung-Dae Yim [a,*], Young-Gi Yoon [a], Won-Yong Lee [a], Chang-Soo Kim [a], Dong-Joo Seo [b], Koichi Eguchi [c]

[a] *Fuel Cell Research Center, Hydrogen and Fuel Cell Research Department, Korea Institute of Energy Research, 71-2 Jang-dong, Yuseong-gu, Daejeon 305-343, Republic of Korea*
[b] *Conversion Process Research Center, Hydrogen and Fuel Cell Research Department, Korea Institute of Energy Research, 71-2 Jang-dong, Yuseong-gu, Daejeon 305-343, Republic of Korea*
[c] *Department of Energy and Hydrocarbon Chemistry, Graduate School of Engineering, Kyoto University, Nishikyo-ku, Kyoto 615-8510, Japan*

Abstract

An integrated microchannel methanol processor was developed by assembling unit reactors, which were fabricated by stacking and bonding microchannel patterned stainless steel plates, including fuel vaporizer, heat exchanger, catalytic combustor and steam reformer. Commercially available Cu/ZnO/Al_2O_3 catalyst was coated inside the microchannel of the unit reactor for steam reforming. Pt/Al_2O_3 pellets prepared by 'incipient wetness' were filled in the cavity reactor for catalytic combustion. Those unit reactors were integrated to develop the fuel processor and operated at different reaction conditions to optimize the reactor performance, including methanol steam reformer and methanol catalytic combustor. The optimized fuel processor has the dimensions of 60 mm × 40 mm × 30 mm, and produced 450sccm reformed gas containing 73.3% H_2, 24.5% CO_2 and 2.2% CO at 230–260 °C which can produce power output of 59 Wt.

Keywords: Polymer electrolyte membrane fuel cells; Portable fuel cells; Hydrogen production; Fuel processor; Methanol reformer; Methanol combustor

1. Introduction

Small polymer electrolyte membrane fuel cells (PEMFCs) can be an attractive power sources for portable electronic devices. In order to apply fuel cell systems to portable devices, it is essential to develop a small and lightweight hydrogen supplier. Several systems including metal hydrides, chemical hydrides and hydrocarbon fuel reformers have been investigated as small hydrogen suppliers. Among them fuel processors have received great attention because of their high energy density and instant recharge of liquid fuel. However, fuel processors involve complex reactions for hydrogen production from hydrocarbons resulting in high reactor volume for the chemical reactions. Hence, the concept of the microchannel reactor was employed to miniaturize the complicated chemical plant, mainly due to its advantages such as high surface to volume ratio, which is several orders of magnitude higher compared to traditional chemical reactors, and low linear dimensions, which enhance heat transfer and mass transfer in the reactor [1]. There are several hydrocarbon fuels as potential hydrogen sources for PEMFC systems. Among them methanol is an attractive fuel for the fuel processor because of its low reforming temperatures, low steam to carbon ratio, good miscibility with water and low content of sulfur compounds [2].

Recently, several investigations have been reported on the microchannel fuel processor using methanol as fuel for portable PEMFC applications. Pacific Northwest National Laboratory (PNNL) demonstrated 40W equivalent microchannel fuel processor consisting of a vaporizer, steam reformer and recuperative heat exchanger [3].

* Corresponding author. Tel.: +82 42 860 3548; fax: +82 42 860 3309.
E-mail address: jimmyim@kier.re.kr (S.-D. Yim).

0378-7753/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jpowsour.2005.01.080

Recently, they also reported sub-watt methanol processors revealing high thermal efficiencies up to 33% and low carbon monoxide below 100 ppm [4]. Motorola labs disclosed an integrated fuel cell system with ceramic methanol processor comprising fuel vaporizer, heat exchanger, reformer and catalytic combustor. The system was operated for 1 week generating 0.7 W electrical power [5]. Reuse et al. fabricated an integrated fuel processor with methanol steam reformer and methanol combustor employing two independent passages using microstructured stainless steel plates. In the microchannel reactor, kinetic models for steam reforming and complete combustion were also developed [6]. These previous studies revealed that the performance of micro fuel processors strongly depends on the reactor fabrication processes including microchannel design, material choice, catalyst coating method and reactor integration. Hence, they employed a variety of reactor construction processes and evaluated the integrated reactor performance to develop more a compact and more efficient hydrogen generator.

In this study, we developed an integrated methanol processor consisting of fuel vaporizer, heat exchanger, catalytic combustor and reformer based on our own reactor design, fabrication process and integration. Microchannels were patterned on the stainless steel plates and fabricated to make unit reactors. Catalyst was deposited inside the microchannel of the reformer unit. Granular combustor catalyst was packed inside cavity reactor. The catalytic combustor provided heat for the endothermic reforming reaction and the vaporization of liquid fuel. Vaporizer, heat exchanger, catalytic combustor and reformer units were integrated to make a unitized hydrogen supplying system. The performance of integrated reactor was evaluated and the maximum throughput of the fuel processor was also determined.

2. Experimental

2.1. Fabrication of microchannel reactor

A stainless steel plate was used to fabricate unit microchannel reactors and integrated fuel processor. Microchannels were patterned on the stainless steel plates with 500 μm thickness using a wet chemical etching. Two different types of patterned plates with mirror image were prepared as shown in Fig. 1. The plates can be used as a co-current or counter-current heat exchanger in which the reforming and combustion reactions can be performed separately. A manifold plate has two holes for flow path and two triangular manifolds for uniform distribution of flow through each microchannel. Designing of microchannel shape was performed based on the simulation data of the channel. The plate has 34 straight microchannels which are 300 μm wide, 200 μm deep and 34 μm long as shown in Fig. 1. All stainless steel plates were stacked together and bonded by brazing to make unit reactors such as fuel vaporizer, heat exchanger and reformer as shown in Fig. 2.

The unit reactor for methanol steam reforming should be coated by reforming catalyst. For the catalyst coating to stainless steel plates, all plates were precoated by Al_2O_3, before bonding the microchannel plates, to enhance the adherence of the catalyst layer on the microchannel walls. Then a commercial $Cu/ZnO/Al_2O_3$ catalyst (ICI Synetix 33–5) was coated inside microchannel reformer by slurry coating method. The

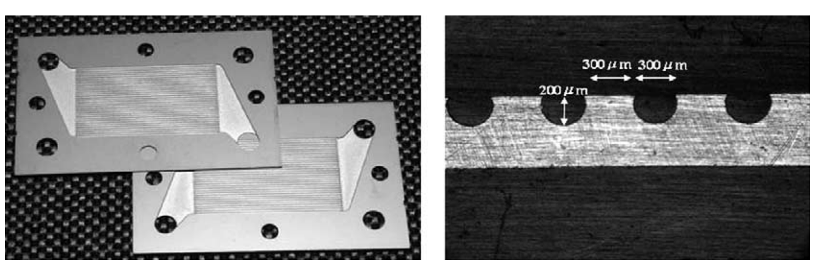

Fig. 1. Microchannel plates (left) and cross-sectional shape of the microchannel (right).

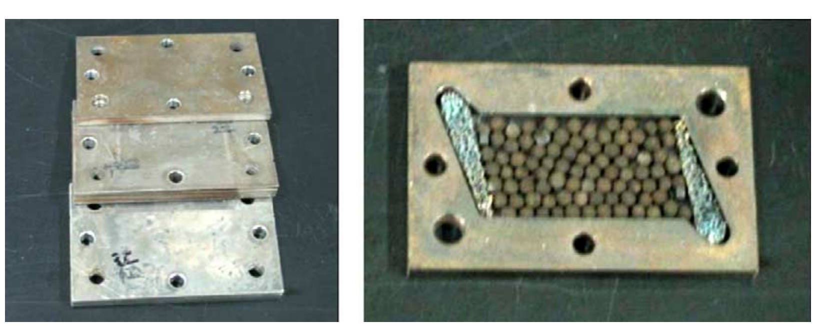

Fig. 2. Unit reactors fabricated by stacking and bonding of several microchannel plates (left) and catalytic combustor filled with Pt/Al_2O_3 pellets (right).