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A performance study of methanol steam reforming microreactor with porous copper fiber sintered felt as catalyst support for fuel cells

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ABSTRACT

A porous copper fiber sintered felt (PCFSF) as catalyst support is used to construct a methanol steam reforming microreactor for hydrogen production. The PCFSF has been produced by solid-state sintering of copper fibers which is fabricated using the cutting method. The impregnation method is employed to coat Cu/Zn/Al/Zr catalyst on the PCFSF. In this study, the effect of the porosity and manufacturing parameters for the PCFSF on the performance of methanol steam reforming microreactor is studied by varying the gas hourly space velocity (GHSV) and reaction temperature. When the 80% porosity PCFSF sintered at 800 °C in the reduction atmosphere is used as catalyst support, it is found that the microreactor shows remarkable superiority in the methanol conversion and H_2 flow rate in comparison to the ones fabricated under other manufacturing parameters. Moreover, the microreactor with this catalyst-coated PCFSF also demonstrates the excellent stability of catalytic reaction in the methanol steam reforming process.

1. Introduction

Microreactor, a new efficient tool for reactor development, has been widely applied in chemical industry due to the advantages of efficient heat and mass transfer characteristics as well as the large interfacial area of multiphase reaction systems [15,6,28]. In recent years, the microreactors for hydrogen production fueled by hydrocarbons successfully provided the on-line hydrogen source for polymer electrolyte membrane fuel cells (PEMFCs). Therefore, the microreactors exhibit a promising way to provide hydrogen for microelectronics powder equipment. To date, many new-style microreactors for hydrogen production have been developed to meet different application requirements [9,10,19]. In general, the microreactors for hydrogen production are classified into packed-bed and microchannel reactors. For both microreactors, various catalysts are usually coated on the surface of microchannel and catalyst support by the methods of impregnation, chemical and physical vapor deposition, and sol–gel deposition [3,8,14]. However, microchannel reactors exhibit a series of disadvantages when the catalysts are coated on the surface of microchannel, such as low adhesion, easily shedding, and high machining cost [21,22,25,30]. Fortunately, Porous materials, which have three dimension

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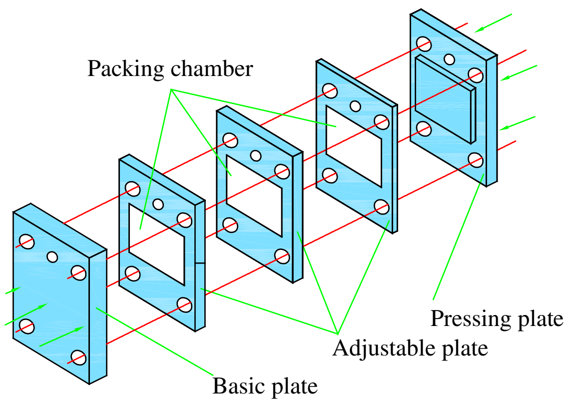

Fig. 1 – Assembling principle of the metal fiber mold pressing equipment.

porous structure and large specific surface area, can be uniformly coated with catalyst to form the microstructure catalyst. So, porous materials show a potential to become a new generation catalyst support of the microreactor for hydrogen production. In fact, foam metals [1,7,16,26,31], metal fiber porous materials [27,11,4,29], porous ceramics [20,23], and honeycomb monoliths [12] have been used as catalyst support in various chemical reaction systems.

Foam metal materials, fabricated by foaming technique, has the advantages of high porosity, low weight, and good permeability. Recently, the interesting works of foam metal used as the catalyst support for the microreactors have been made great progress, such as foam nickel [16], foam aluminum [1], foam steel [7,26], and foam copper [31]. However, the complex manufacturing process and high production cost for foam metal are the obstacle of practical large-scale applications. Metal fiber porous materials are a new type of porous metal materials, which were made of metal fibers. Nowadays, metal fiber porous material is behaving as an excellent candidate for catalyst support, due to their three-dimensional reticulated structure, interconnected pore, and high porosity. The previous works are mainly focused on exploring new manufacturing methods and

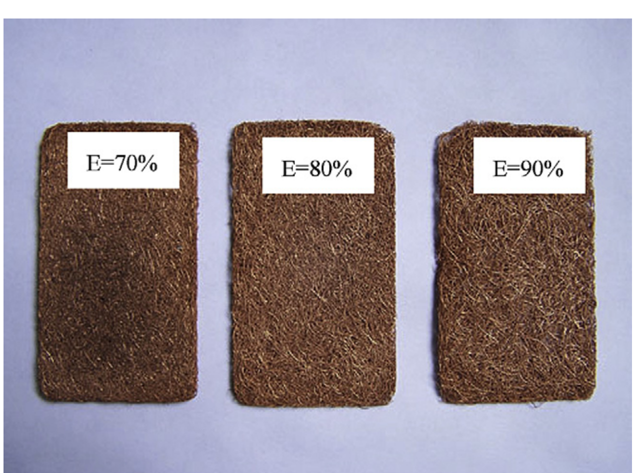

Fig. 2 – Optical image of PCFSFs with different porosities.

reliable production process [13]. Whereas, the research work for metal fiber porous materials used as catalyst support is reported in few literatures. Liu et al. [11] developed a composite bed microreactor for ammonia decomposition with the stainless steel fiber sintered felt as catalyst support. The microreactor was capable of producing 215 sccm hydrogen over per cm^3 bed volume with ammonia conversion of 99.5% at 650 °C. Chang et al. [4] used a nickel fiber porous metal to entrap small catalyst or sorbent particulates for high contacting-efficiency removal of trace contaminants including CO and H_2S from practical reformates for PEM H_2–O_2 fuel cells.

In this study, a porous copper fiber sintered felt (PCFSF) has been produced by solid-state sintering of copper fibers fabricated by the cutting method. The impregnation method was employed to coat the catalyst on the PCFSF. We investigated the effect of the porosity and manufacturing parameters of the PCFSF on the performance of methanol steam reforming microreactor. The optimal porosity and manufacturing parameters of PCFSF were proposed for the catalyst support of methanol steam reforming microreactor.

2. Experimental

2.1. *Processing procedure of the PCFSF*

The processing procedure of the PCFSF is divided into the following five steps: cutting fibers, mold pressing, sintering, cooling, and testing. First, continuous copper fibers were fabricated using a multi-tooth tool via the cutting method [32]. These copper fibers were then cut into fiber segments 10–20 mm in length. Later, the as-prepared copper fibers were first randomly packed into the predetermined packing chamber of the mold pressing equipment, and then a pressure from the bolts was employed to apply on the metal fibers. In this way, the semi-finished PCFSF with the same shape as predetermined packing chamber were obtained. The assembling principle of the metal fiber mold pressing equipment is shown in Fig .1. Moreover, the height and shape of the PCFSF can be adjusted by changing the design of the packing chamber in the mold pressing equipment.

The sintering process of PCFSF was carried out in a box-type furnace (No: FXL-12-11). And the sintering temperature has been controlled by a programmable temperature controller. To optimize the heating rate in the sintering process, we used the stage heating method. When the temperature was below 800 °C, the heating rate was kept at 300 °C/h, and when the temperature was above 800 °C, the heating rate was decreased to 200 °C/h. The sintering atmosphere included three kinds atmosphere of reduction, neutral, and oxidation. In the sintering process of reduction atmosphere, after the mold pressing equipment was put into the sintering furnace, nitrogen gas was used to flush the chamber. After the chamber had been purged of air, it was filled with hydrogen gas, which was later ignited. The pressure of the hydrogen gas in the furnace chamber was kept at 0.3 MPa. When the sintering was complete, the sample was moved and cooled to room temperature, at which point the mold pressing equipment could be disassembled. After a final test and