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ORIGINAL PAPER

Fabrication of a micro-direct methanol fuel cell using microfluidics

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A direct-methanol fuel cell containing three parts: microchannels, electrodes, and a proton exchange membrane (PEM), was investigated. Nafion resin (NR) and polystyrene-*block*-poly(ethylene-*ran*-butylene)-*block*-polystyrene (PS) were used as PEMs. Preparation of PEMs, including compositing with other polymers and their solubility, was performed and their proton conductivity was measured by a four point probe. The results showed that the 5 % Nafion resin has lower conductivity than the 5 % PS solution. The micro-fuel cell contained two acrylic channels, PEM, and two platinum catalyst electrodes on a silicon wafer. The assembled micro-fuel cells used 2 M methanol at the flow rate of 1.5 mL min^{-1} in the anode channel and 5 × 10^{-3} M $KMnO_4$ at the flow rate of 1.5 mL min^{-1} in the cathode channel. The micro-fuel cell with the electrode distance of 300 μm provided the power density of 59.16 μW cm^{-2} and the current density of 125.60 μA cm^{-2} at 0.47 V.

Keywords: microfluidics, micro-direct methanol fuel cell, micro-fuel cell, electrochemical process

Introduction

Direct-methanol fuel cell (DMFC), a type of fuel cell, is an alternative energy source directly generating electricity without fuel combustion (Hogarth & Hards, 1996). DMFCs are useful for portable electronic devices because of their many advantages such as high energy density, green alternative energy, quick recharge rate, low volume and mass, easy transportation, and fuel flexibility with a wide choice of feeds. Also, their efficiency is not a function of the cell size (Shah et al., 2004). Miniaturization of DMFCs leads to μDMFCs and microfluidic technologies can be applied in the fabrication of microchannel structures (Kamitani et al., 2008). However, commercial requirements on micro-fuel cells have to be considered in terms of materials, costs, volume, power performance, etc. (Hogarth & Hards, 1996; Kobayashi et al., 2003; Kamarudin et al., 2007).

In the microfabrication technologies for microelectro–mechanical systems (MEMS) and integrated circuits (IC), a single micro-fuel cell with anodic and cathodic channels formed on a single silicon substrate was introduced (Motokawa et al., 2004; Kjeang et al., 2007, 2009; Chen et al., 2008; Kamitani et al., 2008, 2009; López-Montesinos et al., 2011). A micro-fuel cell can be constructed as a micro proton exchange membrane fuel cell or a membraneless micro-fuel cell. Sung and Choi (2007) introduced a membraneless micro-fuel cell on a single substrate which was performed with the fuel mixture of KOH + CH_3OH + H_2O_2. Their results showed that small distance between the anode and the cathode results in higher output compared to that of the membraneless micro-fuel cell. López-Montesinos et al. (2011) fabricated a membraneless micro-fuel cell with a reduced diffusion zone between the anode stream and the cathode stream. Their membraneless micro-fuel cell with a bridge-

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