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Elimination of water flooding of cathode current collector of micro passive direct methanol fuel cell by superhydrophilic surface treatment

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HIGHLIGHTS

- The cathode current collector was treated by plasma electrolytic oxidation.
- Superhydrophilic coating was formed on the cathode current collector.
- Water flooding of cathode current collector was solved.
- The micro passive DMFC showed better performance and extremely high stability.

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ABSTRACT

To solve the water flooding problem of micro passive direct methanol fuel cell (DMFC), plasma electrolytic oxidation (PEO) was adopted to prepare a superhydrophilic coating on the surface of an aluminum-based cathode current collector which contacts with air. Results data show that liquid water spreads quickly as a plane on the surface of the porous PEO coating that is composed of Al_2SiO_3 and Al_2O_3. As a result, water droplet can be prevented from accumulating along the air-breathing channels of the PEO-treated cathode current collector, and thus the water flooding problem of the micro passive DMFC is effectively solved. The cell fabricated with the novel cathode structure gives excellent stability.

1. Introduction

Direct methanol fuel cells (DMFCs) can convert directly the chemical energy stored in methanol into electricity, which makes it an attractive and a leading candidate power source in replacing batteries in portable electronic device applications [1–3]. By eliminating liquid pumps and gas fans/blowers, a DMFC can be operated under a passive mode [4–6], as shown in Fig. 1(a), where the supply of fuel and oxygen only relies on diffusion and natural convection. This kind of passive DMFC not only provides the advantage of simple and compact structure but also eliminates the parasitic power loss that is required to power ancillary devices [6]. However, the passive DMFC gives worse performance than that running in active mode due to poor mass transportation [4]. As such, many passive DMFC prototypes have been proposed and widely studied over the past decade to boost the output performance [2–4].

At present, several critical technical problems restrain the practical application of DMFC, such as cathode water flooding [7,8], slow reaction kinetics of methanol oxidation [9,10], and methanol crossover from the anode to the cathode [11,12]. Among them, one of the critical issues in the design of a passive DMFC is how to enhance oxygen transport and water removal at the cathode [2,4]. In a passive DMFC, liquid water generated by cathode reaction, along with that crosses from the anode, can form liquid droplets along the air-breathing channels of the cathode current collector and thus blocks the oxygen transportation from ambient air to the cathode catalyst layer [8], as shown in Fig. 1(b). It is necessary for a quick removal of the water droplets to maintain high oxygen transportation. But under a passive operation, the removal of these droplets mainly relies on gravitational forces [4]. Such a passive operation mode can result in serious accumulation of liquid water inside the air-breathing channels, which constrains significantly oxygen transport and leads to a so-called water flooding problem [8,13]. Especially in a micro passive DMFC, the

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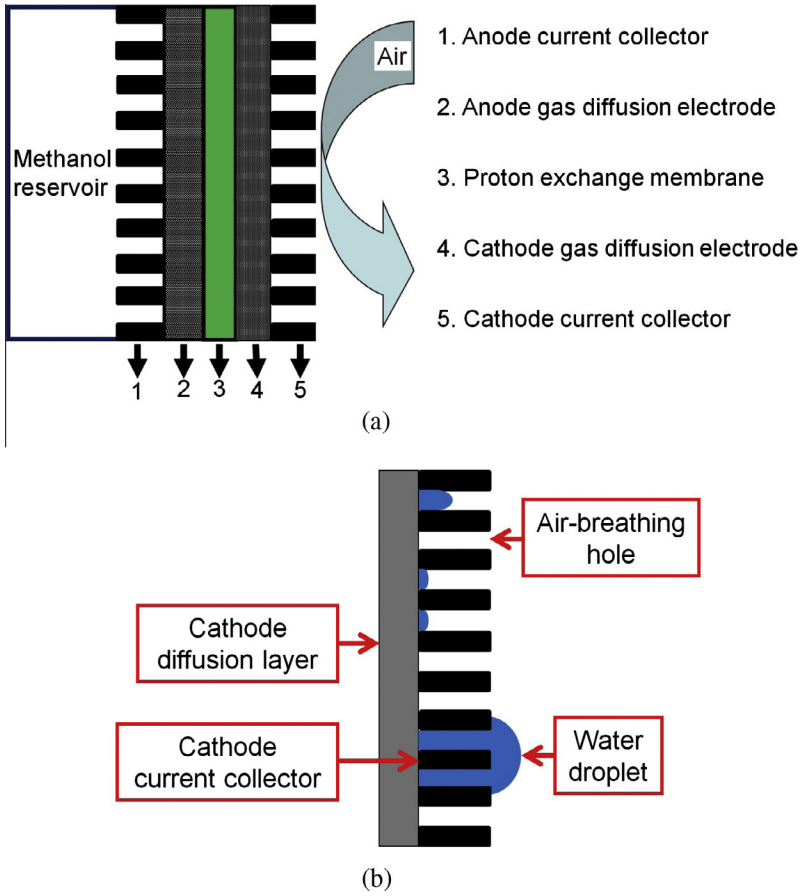

Fig. 1. Schematic of a micro passive direct methanol fuel cell (a) and water flooding of the cathode current collector (b).

influence of water flooding can be worse because the small size of air-breathing channels, ranging from several millimeters to several hundred microns, makes it more difficulty to remove water droplets from the air-breathing channels.

To improve oxygen transportation, some efforts have been done to accelerate the water-removal rate by optimizing the structure of cathode current collector. A parallel structure is better than a perforated one in terms of water removal [14], but the ribs tend to accumulate liquid water and reduce the cathode area exposed to ambient air. A faster water removal rate can be achieved by using a porous cathode current collector [15–17], but it still cannot avoid the water accumulation along the open channels. A careful design of the structure of silicon-based cathode current collector can ease water flooding problem [8,18], but its structure is quite complicated and not suitable for metal-based current collector. Up to now, water flooding of the cathode current collector is still one of the main challenges that hamper the performance of a passive micro DMFC. In this paper, a novel cathode structure was fabricated to solve water flooding problem of the cathode current collector by avoiding water clogging up the air-breathing channels.

2. Mechanism and design

Aluminum alloy LY12 was used to fabricate a perforated cathode current collector. The surface of the current collector, which contacts directly with the cathode gas diffusion electrode, was coated with an Au layer to reduce the contact resistance [19]. The rest surface was treated by plasma electrolytic oxidation to form an insulated, protective and hydrophilic coating [20]. The PEO treatment was carried out for about 30 min in a sodium silicate solution by a homemade 5 kW AC power supply with the frequency of 1000 Hz. More detailed experiment procedures can be found in some Refs. [21,22].

After PEO treatment, a gray PEO coating was formed on the surface of the cathode current collector, as shown in Fig. 2. The phase composition and surface morphology of the coating were characterized respectively by scanning electron microscopy and X-ray diffraction, and the results are shown in Fig. 3. X-ray pattern shows that the coating is composed of Al_2SiO_3 and Al_2O_3. SEM result shows that the coating gives a typical crater-like porous structure

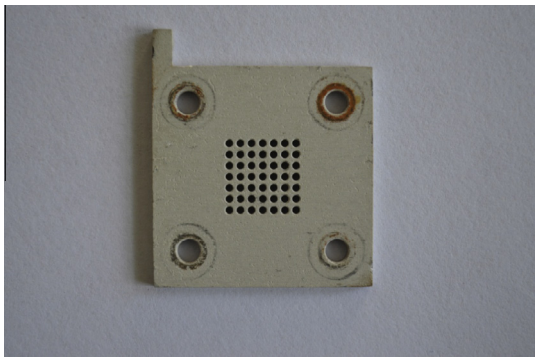

Fig. 2. Picture of the cathode current collector treated by plasma electrolytic oxidation.