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Short communication

Aluminate cement/graphite conductive composite bipolar plate for proton exchange membrane fuel cells

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Abstract

Aluminate cement/graphite conductive composite bipolar plate for proton exchange membrane fuel cells (PEMFC) was prepared by mold pressing at room temperature. The effect of size of graphite particles on the conductivity and the flexural strength of composite bipolar plate were discussed. Resistance to acid corrosion, thermal property and pore size distribution of this composite bipolar plate were also investigated in this paper. The experiment results show that the conductivity and the flexural strength of this composite bipolar plate can be improved by choosing uniform size graphite as conductive fillers. The corrosion current is about $10^{-4.5}$ A cm^{-2} from polarization curves of this composite bipolar plate, which shows that this composite bipolar plate is acid corrosion-resistant. Al and Ca ions may leach from this composite bipolar plate after 1 M H_2SO_4 acid corrosion. But Al and Ca ions leaching from this composite bipolar plate are only a little percentage of the total Al and Ca ions content in the composite bipolar plate after acid corrosion at 30 °C. This composite bipolar plate is also thermally stable from room temperature to 400 °C. The large amount of pore in this composite bipolar plate is gel capillary pores because of the hydration and solidification of aluminate cement, which make it possess humidifying function during the PEMFC operating.

Keywords: Aluminate cement; Graphite; Corrosion; Fuel cell; Bipolar plate

1. Introduction

The performance of machined graphite bipolar plate is excellent and it is adopted extensively in the construction of proton exchange membrane fuel cell (PEMFC). However, its manufacturing technology is relatively complicated and, especially, its flow channels can be only machined, so its cost is very high and account for about 45% of fuel cell stack cost [1]. The US Department of Energy (DOE) requires that the cost of a fuel cell stack system must be reduced from US$ 800 to US$ 35 kW^{-1} to become a commercial success in automobile use. Other stack designs consider the use of metal hardware such as stainless steel [2]. However, a number of disadvantages are also associated with stainless steel, including high cost of machining and especially possible corrosion in the fuel cell environment, which is very difficult to be resolved at present.

In the light of these difficulties, much of the recent work on fuel cell bipolar plate materials has concentrated on a molded composite graphite bipolar plate [3–7], which offer the potential advantages of lower cost, lower weight and greater ease of manufacture than traditional graphite bipolar plates, for instance, flow fields can be molded directly into these composites. So, a molded composite graphite bipolar plate is inexpensive and performs as well as machined graphite bipolar plates.

In addition, because NAFION membrane of DUPONT Company is used in PEMFC extensively, it is very essential to humidify the membrane in the course of operating the PEMFC. Humidifying through external equipment is generally adopted at present, which increase the volume and the cost of the fuel cell stack directly [8]. So, it is a considerable direction to humidify the NAFION membrane through internal equipment. In recent years, world wide research efforts have been addressed to remove the externally humidifying unit from the PEMFC system by endowing the membrane electrode assembly (MEA) with self-humidifying ability [9]. Differently, Institute of Gas

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Technology and International Fuel Cells give bipolar plate self-humidifying function by changing the materials or structure of bipolar plate [10,11]. In this way, the volume and weight of the fuel cell stack can be reduced and it is favorable to be integrated.

So, aluminate cement/graphite composite bipolar plate, which has self-humidifying function, have been developed in our laboratory.

2. Experimental

2.1. Materials

Aluminate cement/graphite composite bipolar plates were prepared according to literatures [12]. The flow fields were carved using numerical control (NC) machine tool of Beijing Carving Technological Co. Ltd. The sample pictures are shown in Fig. 1. All the conductive composite bipolar plates were not broken during machining flow fields. The flow channels are very clear and the ridges of flow fields don't collapse.

2.2. Measurements of conductivity

The electrical resistance (R) of composite samples was measured using a TH 2512 type testing apparatus of low resistance of direct current (Changzhou). The average electrical resistance of each sample was obtained from three repeated measurements at different locations on the sample. The resistivity (ρ) was calculated as: $\rho = RWT/L$ and the conductivity (σ) was calculated as: $\sigma = 1/\rho = L/W/T/R$, where L, W and T are length, width and thickness of the sample, respectively. The contact resistance between bipolar plates and gas diffusion layer (GDL) in PEM fuel cells is also very crucial, which will be tested in the future experiments.

2.3. Measurements of flexural strength

The flexural strength of composite bipolar plates was investigated by Instron 5548 micro tester. The width and thickness of sample are 5 and 2.5 mm, respectively. The adjusted span is 22 mm. The rate of displacement is 0.5 mm min^{-1}.

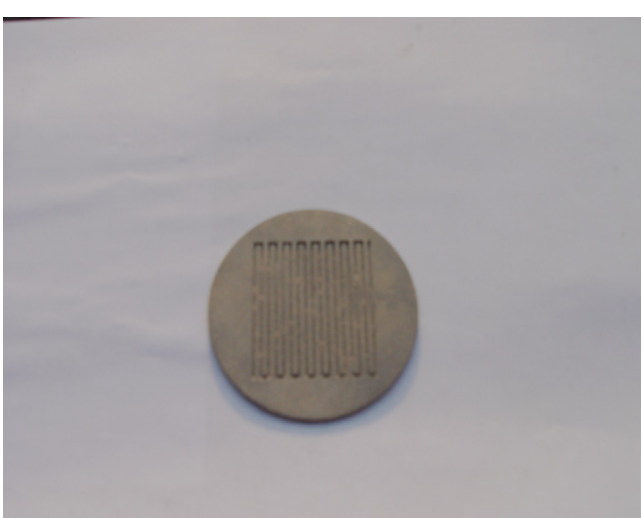

Fig. 1. The picture of aluminate cement/graphite composite bipolar plate.

2.4. Characterizations of resistance to acid corrosion

The resistance to acid corrosion of composite bipolar plate samples was examined with Potentiostat Galvnostat, Autolab of Eco Chemie Inc., Netherlands. A conventional three-electrode system was used in the electrochemical measurements, in which a platinum sheet acted as the counter electrode, a saturated calomel electrode (SCE) as the reference electrode and the composite bipolar plate sample as the working electrode. A scanning rate of 1 mV s^{-1} was selected for linear sweep voltammetry measurements. Plots of voltage versus current were recorded. Tafel plots were used to determine the corrosion current density.

In addition, metal ions possibly leach from this composite bipolar plate, which is will significantly reduce the conductivity of the proton exchange membrane. So, metal ions content in corrosion solution also need to be measured. The composite bipolar plate sample is immersed in 1 M H_2SO_4 solution. After 1 h, metal ions content in the solution was measured by inductively coupled plasma atomic emission spectrometry (ICP-AES) of Perkin-Elmer Inc., US.

2.5. Thermogravimetric analysis (TGA)

Thermal degradation of composite bipolar plates was measured by DSC–TG instrument (NETZSCH STA 449C) from room temperature to 400 °C with a heating rate of 10 °C min^{-1}.

2.6. Porosity analysis

The pore size in the composite bipolar plates was also measured by PM 33 Mercury Intrusion Porosimeter from Quantachrome Instruments.

3. Results and discussion

3.1. The effect of graphite size on the conductivity and the flexural strength of composite bipolar plate

Four kinds of graphite powder with size of <45, 45–65, 65–90 and >90 μm were divided using sample sifter and the effect of graphite size on the conductivity and the flexural strength of composite bipolar plate were investigated. The experimental result is shown in Tables 1 and 2.

Table 1
The effect of graphite size on the conductivity of composite bipolar plate with 60 wt% graphite content

Graphite powder size (μm)	The conductivity of composite bipolar plate (S cm^{-1})
<45	367.54
45–65	386.98
65–90	428.17
>90	467.61