FABRICATION AND TESTING OF GLASS BIPOLAR PLATE FOR MICRO PEM FUEL CELL

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Abstract: A novel glass bipolar plate for the micro PEM fuel cell was proposed in the present study. The fabrication and testing of the micro PEM fuel cell using the glass bipolar plate are described. Advantages of the proposed bipolar plate are low fabrication cost, easy manufacture, and high chemical resistivity. The fabrication method of the bipolar plates done by anisotropic wet etching, metal layer deposition, thermal and UV bonding was established. From the results of performance evaluation, the power densities showed out to be adequate for the micro PEM fuel cell compared to current status of micro fuel cell technology.

Keywords: Bipolar plate, photosensitive glass, micro PEM fuel

INTRODUCTION

Micro proton exchange membrane (PEM) fuel cells are gaining great attention in portable power generation applications due to their higher energy density [1-2]. PEM fuel cells are characterized by their relatively low operation temperature, short start-up time, fast respond to load variation, and high efficiency making them suitable for mobile applications. The PEM fuel cell stack mainly consists of 3 components: the membrane, the gas diffusion layer (GDL), and the bipolar plate. Among them the bipolar plate collects and conducts the current from the anode to the cathode, while separately distributing the fuel and air over the anode and cathode surface respectively. Therefore, the bipolar plate must have properties such as good electric conductivity, thermal conductivity, impermeability for gases, and corrosion resistivity in the fuel cell environment. The bipolar plate actually comprises almost all the volume of the fuel cell, and nearly occupies more than 80% of the total weight of the fuel cell. Hence, to increase the energy density and lower the total cost, an appropriate material has to be chosen to manufacture the bipolar plate [3].

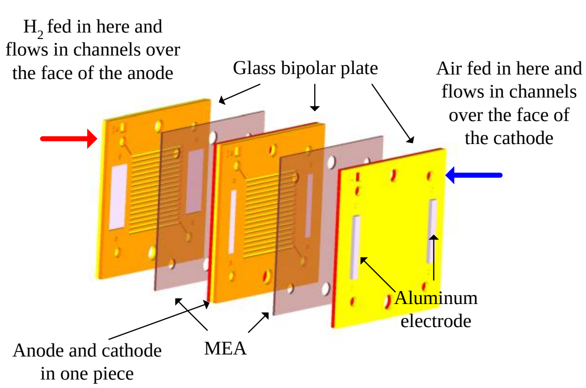

Fig. 1: Schematic of the micro PEM fuel cell stack.

Conventional graphite used for bipolar plates in contemporary PEM fuel cells has problems such as high crossover rates due to their porous nature. The high mass density of it also contributes to the low energy density of the fuel cell system. The fabrication takes a long time on an expensive machine. Therefore graphite is not appropriate for micro PEM fuel cells.

As an alternative for graphite, photosensitive glass has been proposed for the fabrication of bipolar plates in micro PEM fuel cell stacks. Photosensitive glass is readily manufactured by MEMS technology, mainly by anisotropic wet etching. Its low fabrication cost, easy manufacture, and high chemical resistivity also makes photosensitive glass a feasible material for the manufacture of bipolar plates in micro PEM fuel cells. In this study, a single PEM fuel cell using photo sensitive glass has been made and tested. The schematic of the micro PEM fuel cell stack is illustrated in figure 1. The detailed components of the bipolar plate are illustrated in figure 2. Silver was sputtered on each side of the anode and cathode to collect the current. Aluminum electrode was inserted to conduct the current from the anode to the cathode. It has been shown both qualitatively and quantitatively that the corrosion problems as well as energy density issues could be resolved by using glass for the bipolar plates.

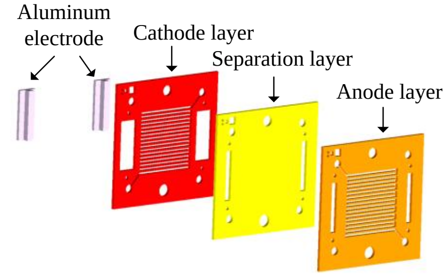

Fig. 2: Detailed components of the bipolar plate.

FABRICATION

Photosensitive glass is a useful material for the production of components for a wide variety of micro systems. High aspect ratio microstructures can be realized and relatively low fabrication costs are achievable. The advantages of photosensitive glass are impermeability for gases, good thermal insulation, and high chemical resistance. This makes it considerably compatible for micro PEM fuel cell systems. But compared with silicon, structure precision is certainly limited and assembly techniques are presently not provided to a high standard [4].

The fabrication process of the glass bipolar plate is shown in figure 3. A quartz wafer with a chromium absorber pattern was prepared for transmission at the required wavelength of 310 nm. Further, the substrate was exposed to UV light at the wavelength of 310 nm (figure 3(a)). The photosensitive glass was illuminated by UV light with an energy density of approximately 2 J/cm^2. During the UV exposure step, silver atoms were formed by a photochemical process in the illuminated section. Heat treatment (figure 3(b)) was achieved using a programmable furnace. The photosensitive glass was heated to 500 ℃ at a ramp rate of 3 ℃/min. Subsequently, it was reheated to 585 ℃ at a ramp rate of 1 ℃/min and then maintained at constant temperature of 585 ℃ for 1 h. Finally, the glass was cooled at a cooling rate of –3 ℃/min. During the heat treatment, the photosensitive glass crystallized around the silver atoms. The physical properties of the crystallized sections (glass-ceramic) were different from those of the glass itself. The final step of the fabrication was to etch the glass-ceramic (figure 3(c)). The etching was performed in diluted 10% HF. After the etching process, each layer of the fabricated glass wafer was polished and cleaned in the piranha solution (H_2SO_4:H_2O_2 = 3:1) for 10 min. The fabricated layers were then carefully aligned and pressed together at 1 kPa at 500℃ for 12 hours (Figure 3(d)) [5]. During this process, diffusion of atoms occurred at the interfacial surface of the bonded glass, leading to the formation of new chemical bonds. After the thermal bonding process the aluminum electrode and the integrated glass wafer were bonded by the UV curable

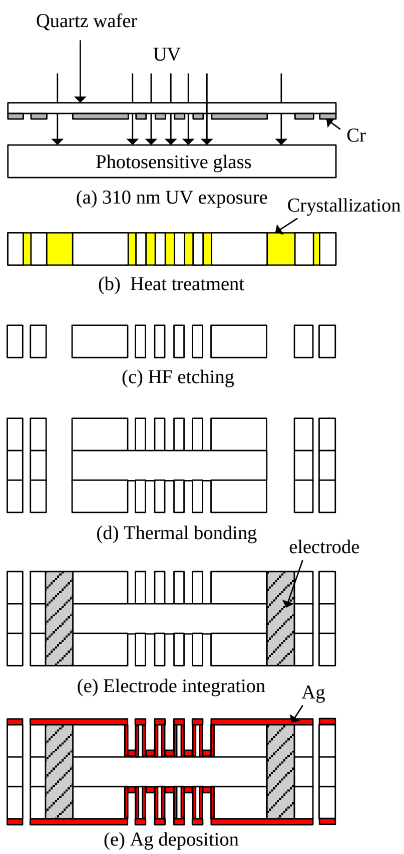

Fig. 3: Microfabrication process of the bipolar plate using glass wafer.

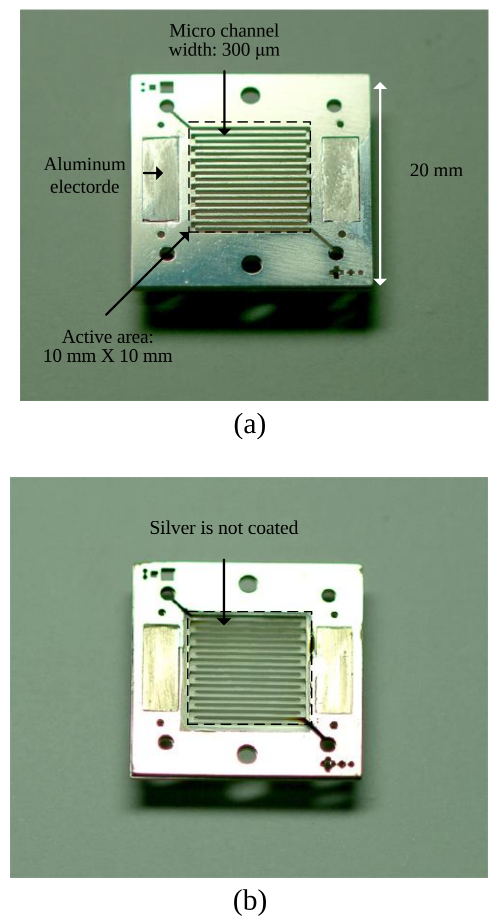

Fig. 4: Fabricated bipolar plate using glass wafer: (a) with silver deposited on the reactive area, (b) without silver deposited on the reactive area.

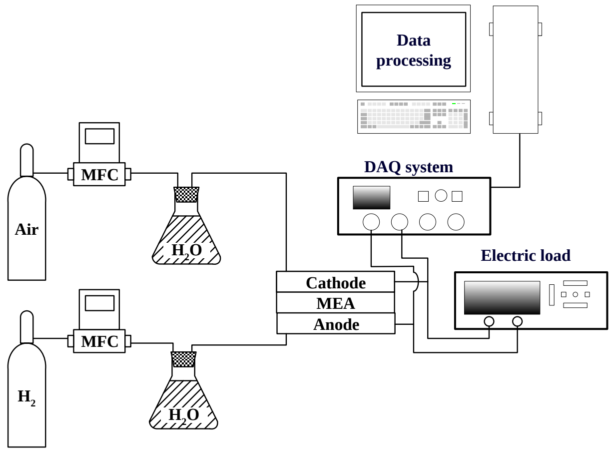

Fig. 5: Experimental setup.

glue (Figure 3(e)). The final step of the fabrication was the deposition of the metal layer that collects the current (Figure 3(f)). A chromium layer of thickness 2000 Å was deposited by sputtering in order to improve the Pt adhesion to the glass. A silver layer of thickness 10 μm was then deposited onto the Ti layer by sputtering.

The fabricated bipolar plates are shown in figure 4. Two cases of bipolar plates were fabricated to determine the effect of the silver coated area. One was that the whole surface of the plate was coated and another was that the reactive area was not coated. The dimensions of the bipolar plates were 20 mm × 20 mm × 1.5 mm with active area of 10 mm × 10 mm. The thickness of each layer was 500 μm. The width of the channel was 300 μm.

EXPERIMENTAL

The schematic of the test stand is shown in figure 4. Aluminum gaskets were used to fix the fabricated bipolar plates. The GDL was a product of the *BASF fuel cell* corporation located in Germany. 30% platinum catalyst was deposited on the GDL with a surface density of 0.0005g/cm^2.

99% hydrogen gas and air were supplied to the anode and cathode respectively from high-pressure external tanks kept at normal temperature. There was no separate heat source to control the operation temperature of the fuel cell or the gases. To humidify the PEM, hydrogen gas and air were both passed through water contained in a cylinder. The supply rates of H_2 and O_2 to the anode and cathode were 24sccm and 52sccm, respectively.

Prior to the cell tests, GDL activation was carried out in order to activate the cell. The increment of the load was 100mA on each step of GDL activation.

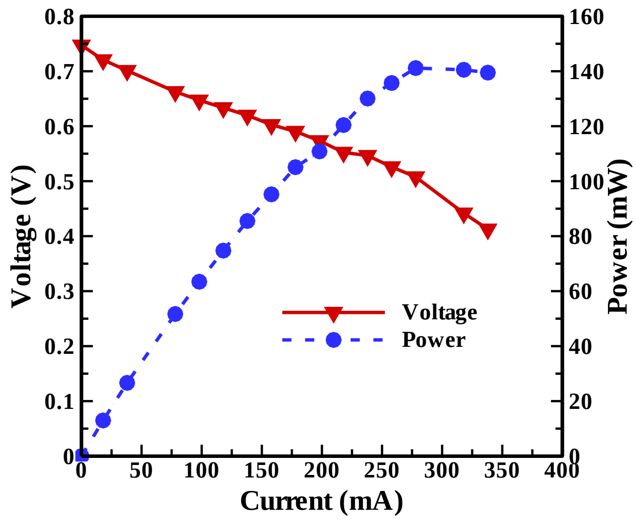

Fig. 6: The Polarization and power curve of the fuel cell with silver deposited on the reactive area

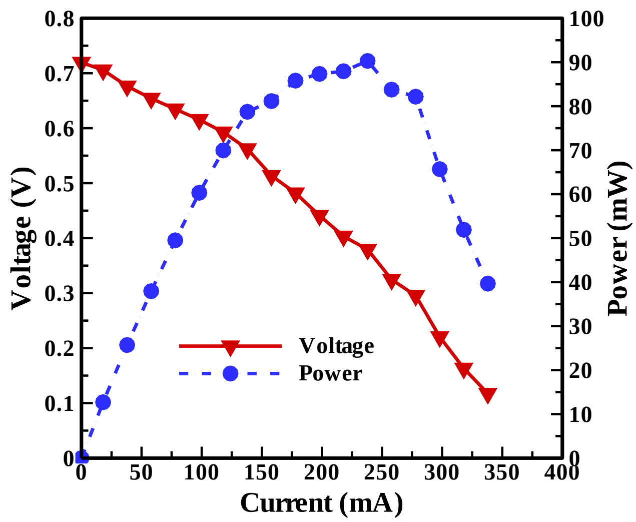

Fig. 7: The Polarization and power curve of the fuel cell without silver deposited on the reactive area

Between each load application of 10 minutes, there was a 5 minute load relief. The total activation process was thus carried out in an on-off manner until it reached its maximum current. Fuel cell testing was carried out afterwards.

Figures 6 and 7 show the results of cell testing for the fabricated fuel cells. The open circuit voltage (OCV), maximum current and peak power density was 0.74V, 340mA, 156mA respectively for the fuel cell with silver deposited on the reactive area and 0.688V, 340mA, 90mA respectively for the fuel cell without silver deposited on the reactive area.

CONCLUSIONS

A new glass bipolar plate for the micro PEM fuel cell was proposed in the present study. Advantages of the proposed bipolar plate are low fabrication cost, easy manufacture, and high chemical resistivity. We established the microfabrication process of photosensitive glass. The bipolar plates were fabricated by anisotropic wet etching, electric conductive metal layer deposition, thermal and UV bonding. Two cases of bipolar plates were tested to determine the effect of the silver coated area. The power densities of the two cases showed to be adequate for the micro PEM fuel cell compared to current status of micro fuel cell technology. The OCV was lower than typical fuel cells. This loss resulted from the waste of fuel passing through the electrolyte. This is a major problem that has to be solved. The fuel cell with silver deposited on the reactive area had better performance than the one without silver deposited on the reactive area. However, the fuel cell without silver deposited on the reactive area could have advantages in terms of corrosion problems. The present study demonstrated the feasibility of the glass bipolar plate. We will develop a micro PEM fuel cell stack integrated with hydrogen generation systems in the future.

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