Design of a New Micro Direct Methanol Fuel Cell Using MEMS Technology

Xiuling Ji and Wenzhong Lou
School of Aerospace Science and Engineering
Beijing Institute of Technology
5 South Zhongguancun Street, Haidian District, Beijing 100081
CHIINA

Abstract: In this paper, a special micro DMFC using MEMS technology is designed to work in a circumrotating condition, which providing power using inertia over-load. The designed cell is a cylinder, anode channel is inside, cathode is outside and exposes to the air. When the overload exceeds the critical value, the liquid inside reserve tank will splash and comes into the two electrodes, and then the cell will be activated. The voltage, current density and work time of DMFC are calculated, and the DMFC performance of serpentine and parallel flow fields is analyzed preliminary. Furthermore, cathode and anode plates are fabricated using a MEMS technology--3D KOH- etching. Although there are many experimental works to do to testify its performance, it is true that the flow field simulation is authentic and the primary design is feasible.

Key-Words: μDMFC, MEMS, design, KOH-etching, flow fields, circumrotating

1 Introduction

The research efforts and interests in fuel cell technology and development are increasing rapidly. Governments, companies and universities worldwide are gradually adapting to this new technology [1-4]. Due to high efficiency and low emissions, fuel cells display a great variety of potential applications. The absence of moving parts and an extremely simple mechanism make fuel cells very competitive for small-scale applications. Moreover, because of easily stored and instantly refueled of liquid fuels [5,6]], direct methanol fuel cells (DMFCs) have significant potential to become a leading technology for energy conversion in a variety of applications .

The proposed DMFC using MEMS technology design is to satisfy special condition, such as slightly circumrotating condition, providing power using inertia over-load [7]. The cell is a cylinder, anode channel is inside, cathode is outside and exposes to the air. When the overload exceeds the critical value, the liquid inside reserve tank will splash and come into the two electrodes. Then the cell will be activated.

2 Design

2.1 Modeling and design

In order to satisfy the work condition, the DMFC is designed as a cylinder, its physical parameters and performance is shown in Table 1.

Table 1 Parameter of DMFC

Diameter (mm)	41
Height (mm)	34
Thickness (mm)	1
Voltage (V)	1.3-2.0
Current (mA)	≥350
Work time (s)	200
Active time (ms)	≤100
Channel / rib width (μm)	400 (anode)
Channel depth (μm)	200 (anode)

1) Voltage

As we know, the ideal voltage of monomer DMFC is 1.184V, but it is only above 0.4V at normal temperature, so the amount the monomer cells is,

$$\text{Amount}=\frac{1.3\sim 2.0}{0.4}=3\sim 5\ \text{unit}$$

We design 4 monomer cells in series to obtain the design voltage. Because the monomer cell is very thin, it will not increase the volume largely to enhance the voltage.

2) Current

The discharge current density i_0 of DMFC is as high as 36mA/cm^2, the current of whole area is,

$$I=i_0 \cdot A \tag{1}$$

where, A is the area of membrane electrode.

$$A=\pi \cdot R \cdot h \tag{2}$$

Here, R is the diameter of cylinder membrane electrode, h is the height of membrane electrode.

Because the diameter and height of DMFC is 41mm and 34mm respectively, we design the size of cylinder membrane electrode is 30mm diameter, 25mm height.

So, the area is calculated,

$$A=\pi \cdot 30 \cdot 25 \approx 2356 \text{ mm2}=23.56 \text{ cm}^2$$

$$I \approx 848 \text{ mA} > 350 \text{ mA}$$

It should be found that the current of MDFC stack is much higher than required, even if the cell declines, it still satisfy the demand.

3) Work time

Work time is determined by the volume of reserve tank and methanol concentration mainly. So in order to calculate the work time, the volume of reserve tank should be determined first.

As we know, designed dimension of cylinder membrane electrode is 30mm diameter and 25mm height, the dimension of reserve tank should be smaller than it so as to install inside the cell. The diameter of reserve tank suggested is 20mm, height is 15mm.

So the volume of reserve tank is

$$V=\pi r^2 h=4712.4\text{mm}^3=4.7124\text{ml} \qquad (3)$$

The methanol concentration suggested is 2mol/L, so the quality of active matter reaction f ully is

$$m_0=0.002\times4.7124\times32\approx0.30159\text{g} \qquad (4)$$

So, the ideal capacity of cell is

$$C_0=26.8\text{n}\frac{m_0}{M}=\frac{1}{q}m_0=26.8\times6\frac{m_0}{32}$$

$$=\frac{m_0}{0.199}\approx1.5155\text{Ah} \qquad (5)$$

Where, C_0 -ideal capacity;

m_0 -quality of active matter reaction fully;

M -mol of active matter;

n- electron amount of gain or loss

q-electrify quality of active matter.

thus,

Work time $t=C_0/I\approx1.79\text{h}>>200\text{s}$

As calculated above, work time is larger than required 200s greatly, the performance of design DMFC satisfies demand, and so it is feasible theoretically.

2.2 Flow Field Design

To design the anode, flow fields of two different channels, parallel and serpentine, were studied in the model. The result shown in Fig. 1 indicates that the output power of the serpentine flow field is similar in most cases to that of parallel channels, but higher under high current density, so we choose the parallel flow field to simplify the design, as shown in Fig.2.

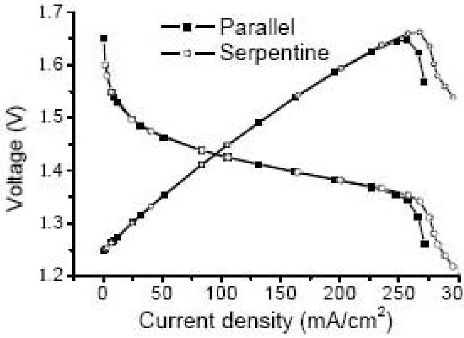


Fig. 1 DMFC performance curves of serpentine and parallel flow fields.

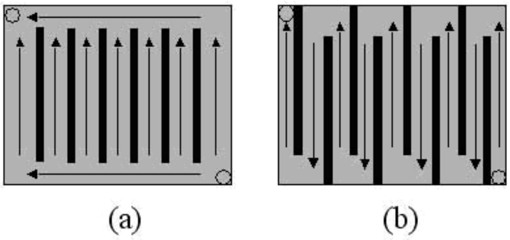

(a) (b)

Fig.2 Parallel and serpentine flow fields

Furthermore, we choose binding fuel cell to satisfy the need, as shown in Fig.3. Because it is plane membrane electrode, four monomer cells are placed in series on the membrane. The main advantages of the binding design are as follows;

1) Suit to small power.

2) Flexible sculpt.

3) Border cells can share airproof area, decrease the area of airproof.

4) Use common plastic to made the shell.

5)Share air channel, simplify manufacture techniques.

The core part of this design is membrane electrode, 4 membrane electrodes can be preparation inside one cylinder PEM, along with the bipolar plate, constitute the 4-cell unit. Polar plate is made from cover-metal plate, and 4 membrane electrodes are designed in series, all these make it come into true to require higher or other different voltage not need more enhancing voltage circuit, as shown in Fig.4.

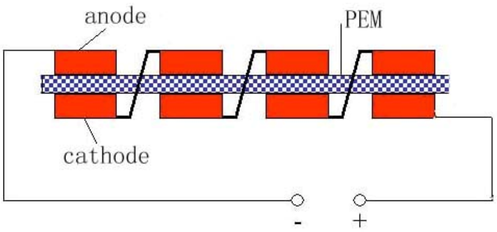


Fig.3 Binding fuel cell design

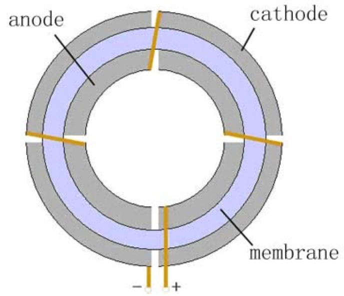


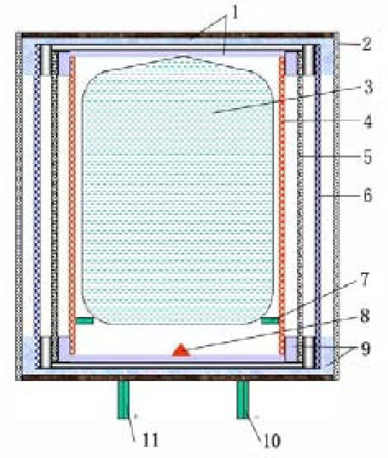
Fig.4 Electrode of DMFC

2.3 Configuration of DMFC

A design drawing of the DMFC fuel cell stack, including seated active framework, fuel reserve tank and feed system, is shown in Figure 5, and the assembled configuration is shown in Fig.6. The wall of cylinder shell is made of lacunaris material, which will expose the cathode to the air effectively in order to supply enough oxygen when reaction needed. Two plastic cylinder poles made membrane electrode into cylinder, so as the cell has the maximal discharge area to ensure the cell work stably for a long time under the loose discharge current. At the same time, it ensures the cell has the maximal interior space to place the glass reserve tank and other complement unstintedly, and ensures the cell performance.

The whole cell is a cylinder, the centre is glass reserve tank, storing up concentration certain methanol liquid, holed by sustained ears and fixed by groove. Near the reserve tank is cylinder fuel polar plate, the outer is air pole. Between the air pole and polar plate is membrane electrode suit. The threediscreteness are insulated fixed to the shell and airproof wholly. Each of Fuel pole and air pole has cathode and anode.

The actuator is modeled into the shell of cell. When system provide power using inertia over-load, it will work automatically，whereas it doesn't move due to the sustained ears at equability. When the overload exceeds the critical value, glass reserve tank will suffer from the recoil then press the sustained ears and drop from the safe position, breaking up simultaneity. Liquid will splash and come into two electrodes through inner anode, and the cell is actuated. The cell begins to discharge, and it will work for 200s continuously or longer time.



1-insulated fixed piece, 2-lacunaris shell, 3-reverve tank, 4- polar plate; 5-MEA, 6-air pole, 7-sustained ears, 8-prominency of sustained ears, 9-insulated fixed piece, 10-cathode,11-anode

Fig.5 Structure of the fuel cell

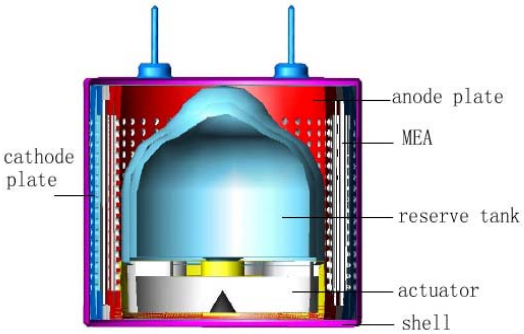


Fig.6 Assembled configuration of DMFC

3 Fabrication using MEMS technology

A new method is proposed to address these issues. This method has been implemented by first using double-sided lithography to transfer different but interrelated patterns (designed according to certain considerations) onto each side of the cathode plate, and then using KOH timed etching to etch through the wafer. Thus a unique 3D KOH-etched cathode structure is formed.

The MEMS fabrication process of the silicon plates, shown in Fig. 7, was modified and optimized on the basis of the previous process[8]. The detailed steps are as follows:(a)Thermal oxide and PCVD SisNa were deposited as mask layers on both sides of a 400μm double-polished silicon wafer; (b) Double-sided lithography was used to form the patterns of microchannel and feeding holes(for the anode) or patterns contacting the MFA(for the cathode) on the front side of the silicon wafer(top side of the wafer in Fig.7, at the same time form aligned feeding holes(for the anode) or the patterns exposed to the air(for the cathode); (c) KOH timed etching was used to anisotropically etch the wafer until the feeding holes were etched through; (d) Finally 0. 8μm Ti/Cu and 0. 2μm Au were sputtered onto the front side of the silicon wafer to form the current collecting layers.

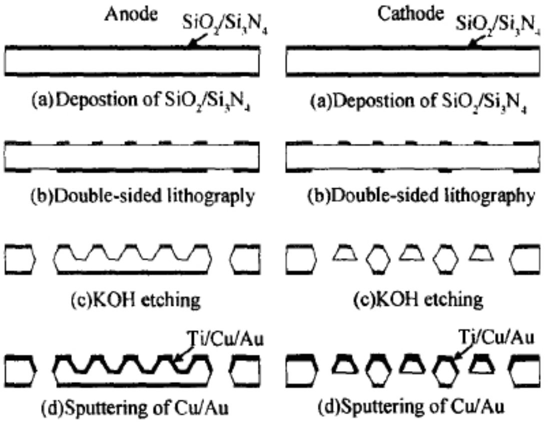


Fig.7 Fabrication process of the anode and cathode plates

Unfortunately, the experiment of the power densisy of MEMS prototype is not done yet.

4 Conclusion

In this paper, a new micro DMFC is designed to work in special condition such as slightly circumrotating condition, providing power using inertia over-load. The voltage, current density and work time of DMFC are calculated, and the DMFC performance of serpentine and parallel flow fields is analyzed preliminary. Furthermore, cathode and anode plates are fabricated using a MEMS technology--3D KOH- etching. Although there are many experimental works to do to testify its performance, it is true that the field simulation of cathode side is authentic and the primary design is feasible.

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