CHAPTER 3

DESIGN AND EXPERIMENTS

3.1 Design of Single Micro-DMFC

The single DMFC cosmists of two acrylic plates, hydrophilic glass, stainless steel flow field plate, and anode meshed collector (see Fig. 3-1, provided by Industrial Technology Research Institute, Materials and Chemical Engineering), gasket, and membrane electrode assembly, as shown in Fig. 3-2.

In the edge of flow field plate, there is a beam as part of the current collector. The cathode acrylic plate is designed to hold the stainless steel flow field plate and the hydrophilic glass plate covering the stainless steel plate. The process of water condensation and removal in the cathode channels can be observed through the glass plate. There are two holes (Fig. 3-3) in the edge of cathode acrylic plate. Air and water vapor can be allowed to discharge from these holes. At the bottom, there is a water-storage tank with capillary structure to absorb liquid water. The MEA, the stainless steel flow field plate at the cathode, and the meshed collector at the anode are clipped tightly with the two acrylic plates. The ribs on the anode acrylic plate (Fig. 3-4) were used to fix anode meshed collector. The channels between the ribs are used as the flow path for the fuel as well as the product carbon dioxide bubbles.

3.2 Design of Flow Field

A modification of multi-section parallel channels, proposed in [21] with uniform distribution, no flooding, low pressure drop, and water recyclability is shown in Fig. 3-5. It comprises three parts: (1) two holes for air-inlet, (2) parallel channels for air flow and water collection, and (3) the region for water recycling and gas discharging. Each part is described as follows:

(1) Air-inlet:

Air is provided from a steel cylinder via silica gel pipe. The air flow rate is measured by a rotameter. A buffer zone is designed to allow air into the channels. Each hole has dimension of 4φ.

(2) Parallel channels:

The dimensions of channel are designed about 500μm x 1000μm which is small enough to generate capillarity for uniform reactant distribution and water collection. It is expected that most of the water will be collected at the corners of the micro-channels. The rids (width of each rib is 500μm) are used to fix the MEA and as the collecting electrode.

(3) The region for water collector:

Because metal mesh has good capillary pumping force, it is employed at the end of channels to retrieve excessive water.

The single-cell micro-DMFC is clamped with high pressure in order to reduce the contact resistance. Furthermore, the surface of stainless steel plate can generate more significant capillary force due to better hydrophility according to Eq. (2-11). Therefore, we choose stainless steel (SS316) as the material of flow flied in stead of silicon. The flow field is fabricated by electrical discharge machining.

3.3 Experimental Method and Apparatus

3.3.1 Apparatus

1. Oven: (*DENG YNG DOS60*) to modulate experimental temperature.
2. Micro-Flow meter: (*OMEGA Model FL-220)* to provide precision non-preheated and non-humidified airflow.
3. Micro-pump: (*GRUNDFOS DME*) to provide micro flow rate of methanol solution.
4. Electronic load system: (*PRODIGIT C3310*) used to measure the current variation with fixed voltage and the polarization curve.
5. Torque wrench: (*KANON 30QLK*) to screw the integral DMFC.
6. Image capture system:
   i. Digital video (*Sony, DCR PC330*) to record the flow process and capture images.
   ii. Microscope (*Optem® zoom 125*): Ocular: 2X; Object lens: 0.6X ~ 6.5X.
   iii. CCD camera (Chip size: 1/2") to provide about 50X amplification factor in 14" monitor, with clear μm-level structure images.

The rotameter (*OMEGA Model FL-220* precision rotameter assemblies, glass float, and nominal flow rate from 0.2 to 90*ml/min* for air) is calibrated using a bubble meter; each reading is the average of three runs. The calibration curve is shown in Fig. 3-6.

3.3.2 Experimental Method

The experimental studies focused on the visualization of cathode of the single DMFC with different methanol concentrations and temperatures. The stainless steel multi-section flow field will be integrated into a DMFC single cell. The flow field with through channels is horizontally positioned and bottom of the flow filed is covered with the hydrophilic glass. The torque wrench (*KANON 30QLK*) is employed to screw the integral DMFC for uniform pressure. The torque of every screw is 30 Kgf·cm. When the anode of the DMFC is facing upward, CO_2 bubble can be eliminated by buoyancy and convection force. Additionally, a CCD camera with a microscopic lens is used to observe and record the water transport phenomena in the channels (Fig. 3.7).

The DMFC operated at different temperatures modulated by the constant-temperature oven. The methanol solution is provided by the micro-pump via the silica gel pipes, with the flow rate of 0.1 to 30 ml/min. Finally, the surplus methanol is discharged to the recycling tank.

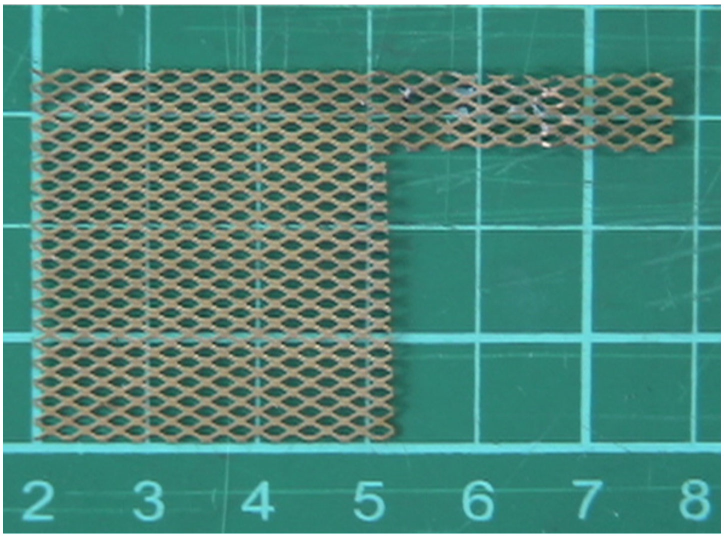


Fig. 3-1 Schematic of the anode meshed collector

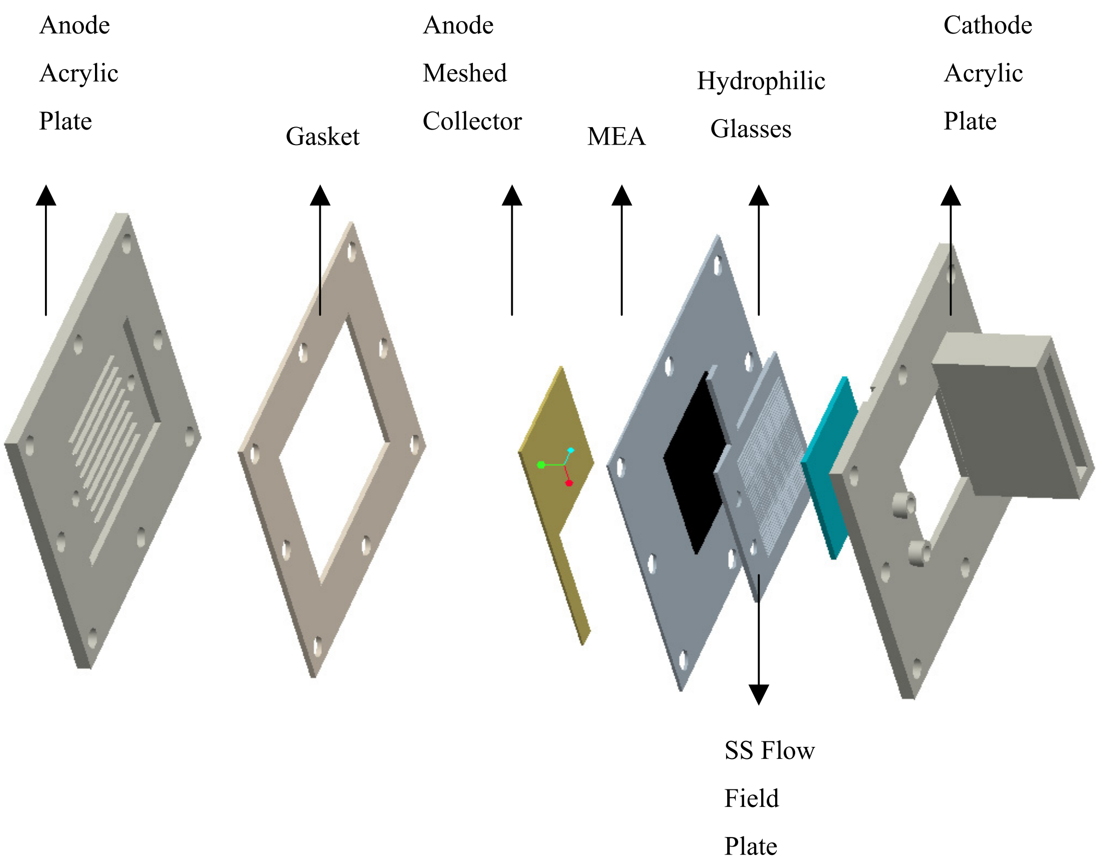


Fig. 3-2 Schematic of the single micro-DMFC

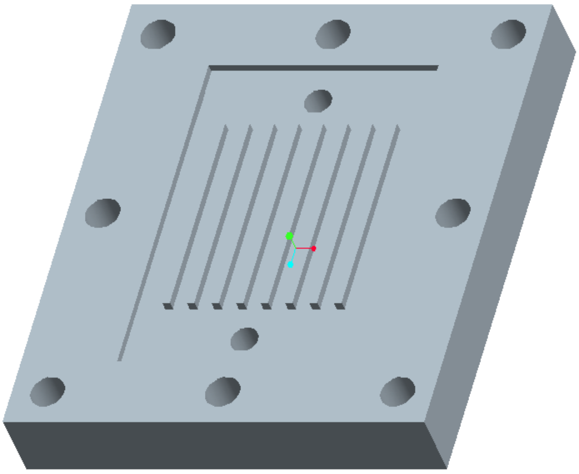


Fig. 3-2 (a)

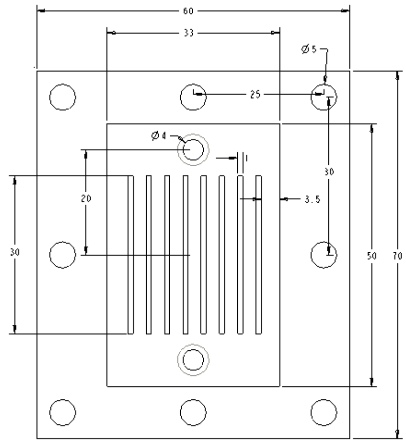


Fig. 3-2 (b)

Fig. 3-3(a) Schematic of the anode acrylic plate

Fig. 3-3(b) Dimensions of the anode acrylic plate

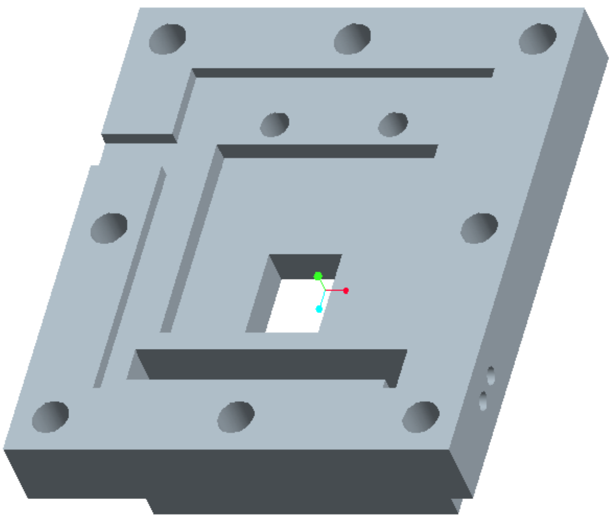


Fig. 3-3 (a)

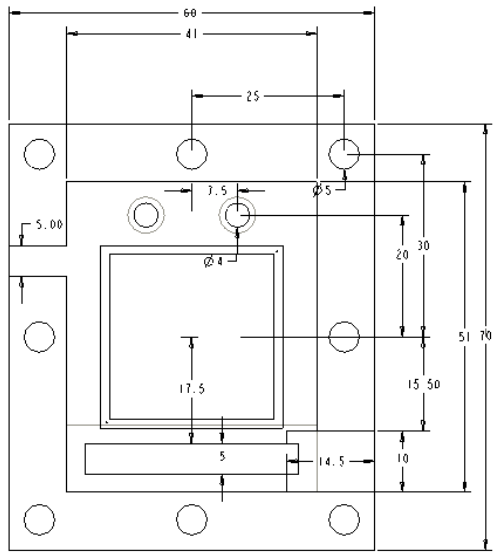


Fig. 3-3 (b)

Fig. 3-4(a) Schematic of the cathode acrylic plate

Fig. 3-4(b) Dimensions of the cathode acrylic plate

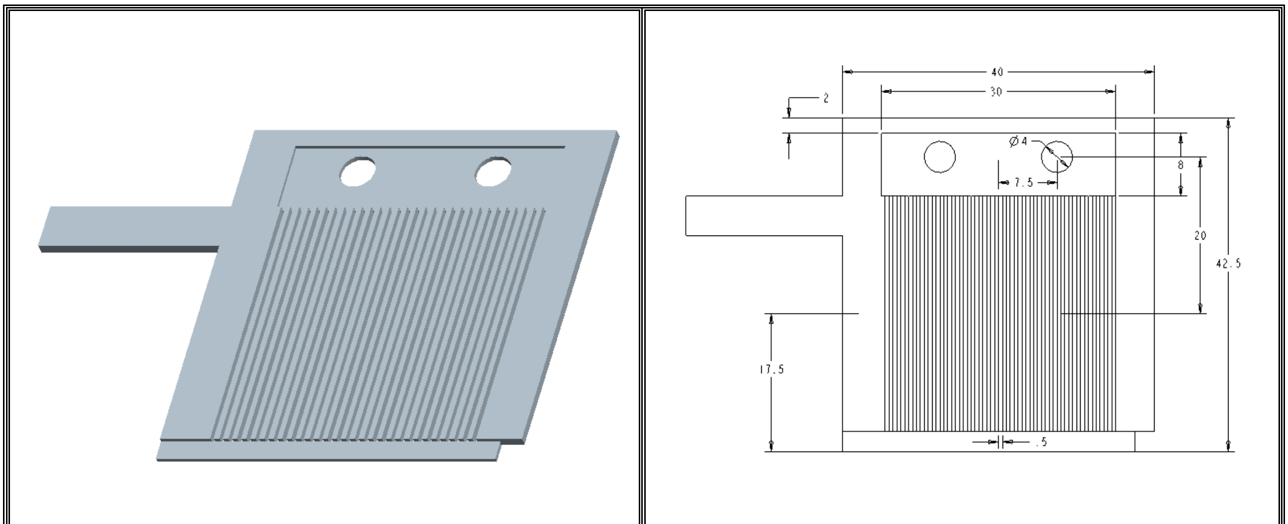
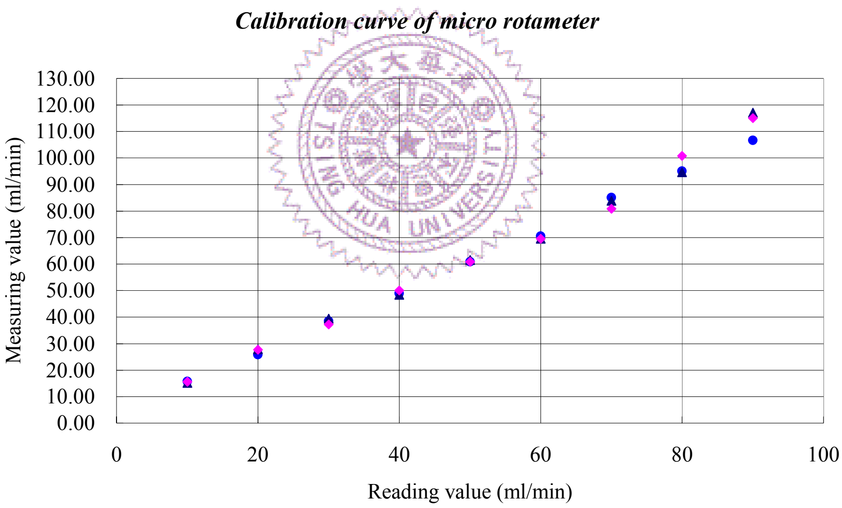


Fig. 3-3 (a) Fig. 3-3 (a)

Fig. 3-5 (a) Schematic of the stainless steel multi-section flow field

Fig. 3-5(b) Dimensions of the stainless steel multi-section flow



Reading Value *(ml/min)*	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Measuring Value I *(ml/min)*	*15.73*	*25.77*	*38.47*	*48.92*	*60.85*	*70.59*	*85.11*	*95.09*	*106.67*
Measuring Value II *(ml/min)*	*15.14*	*27.86*	*39.42*	*48.45*	*61.57*	*69.57*	*83.92*	*94.64*	*117.07*
Measuring Value III *(ml/min)*	*15.59*	*27.66*	*37.27*	*50.02*	*60.91*	*69.52*	*80.81*	*100.76*	*115.05*
Mean Value *(ml/min)*	***15.49***	***27.10***	***38.39***	***49.13***	***61.11***	***69.89***	***83.28***	***96.83***	***112.93***

Fig. 3-6 Calibration curve of micro rotameter

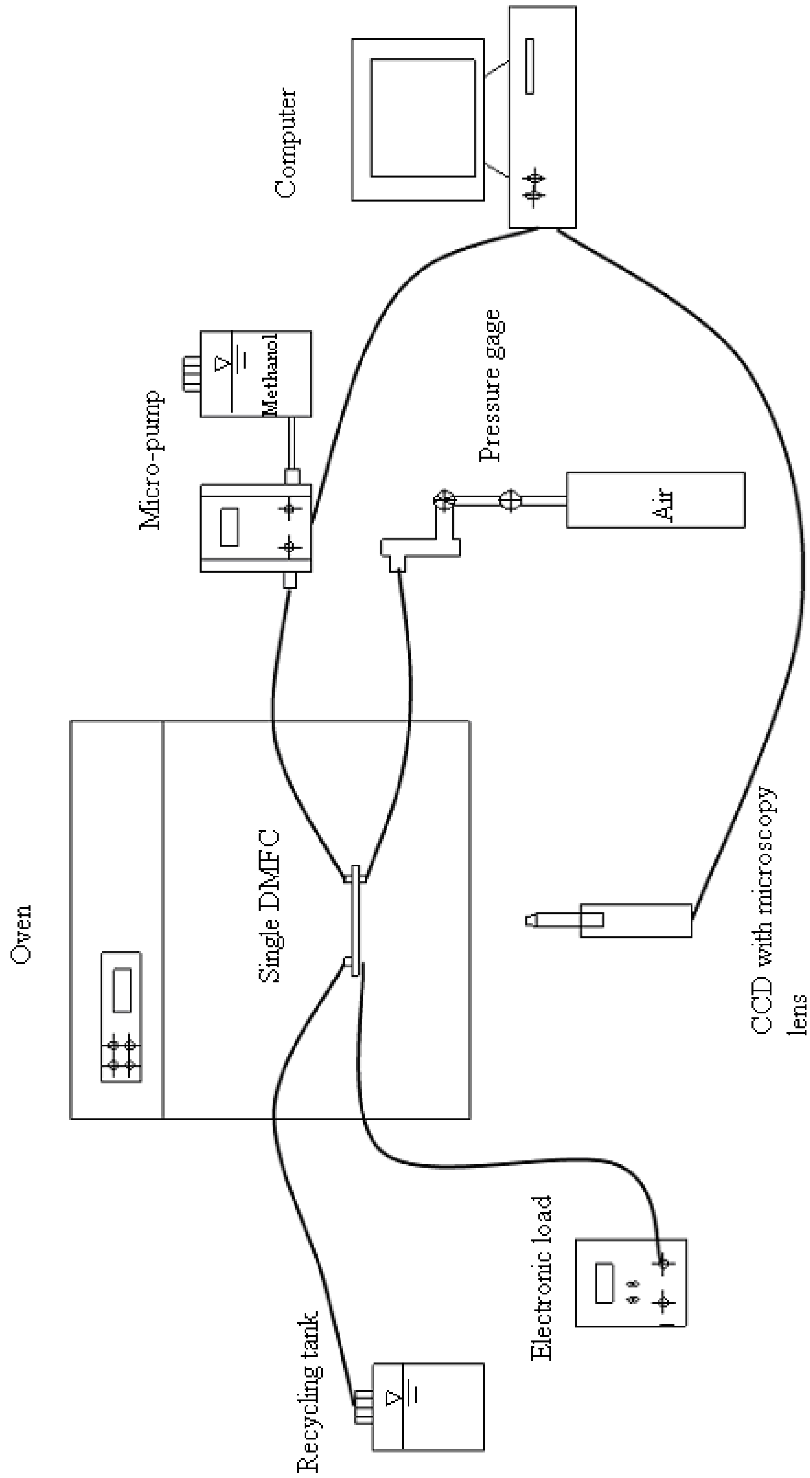


Fig. 3-7 Experimental equipment setup for multi-section parallel channels