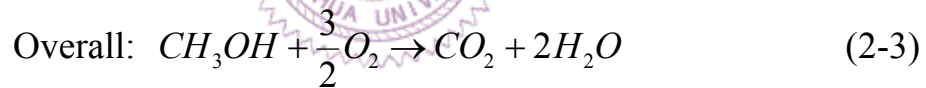
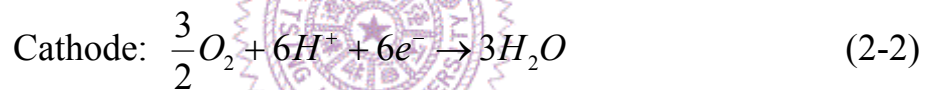
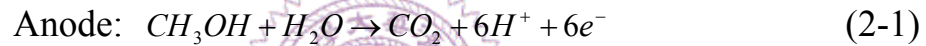


CHAPTER 2

FUNDAMENTAL

2.1 Principle of Operation

Fig. 2-1 illustrates the principle of DMFC power generation. These reactions occur at electrodes to which reactants are continuously fed. The anode is maintained by supplying a fuel such as methanol, whereas the cathode is maintained by the supply of air. At the anode, methanol and water combine to generate proton H^+ and CO_2 . At the cathode, a reaction takes place where H^+ , electron e^- , and oxygen in the air combine to form water. The basic reactions for a DMFC are:



2.2 Efficiency of Operation

The change of Gibbs free energy can be shown as

$$\Delta G = \sum G_{\text{reactant}} - \sum G_{\text{product}} \quad (2-4)$$

In addition, the net energy released from a fuel cell can be defined as the enthalpy difference between the reactants and the products. Thus

$$\Delta H = \sum H_{\text{reactant}} - \sum H_{\text{product}} \quad (2-5)$$

The intrinsic efficiency (η) is given by the maximum effective work of the enthalpy difference per unit mole of fuel under constant temperature and pressure at the standard state ($T = 298.15K$, $P = 1\text{atm}$).

Hence,

$$\Delta G = -167.91 \text{ Kcal/mol},$$

$$\Delta H = -173.67 \text{ Kcal/mol},$$

$$\eta = \frac{\Delta G}{\Delta H} = 96.7\% \quad . \quad (2-6)$$

The theoretical conversion efficiency of a DMFC is 96.7%, and at least 3.3% of energy converts into heat.

2.3 Structure of Direct Methanol Fuel Cell

The DMFC comprises the flow fields, the diffusion and reaction layers of both anode and cathode, and the polymer electrolyte membrane. This assembly is then sandwiched as shown in Fig. 2-2, with each term described as follows:

2.3.1 Membrane Electrode Assembly (MEA)

MEA is the heart of the fuel cell. A successful MEA for DMFC must not only conduct proton, but also prevent methanol cross-over. Each side of MEA is attached with a catalyst layer comprising typically of platinum (for cathode) or platinum/ruthenium (for anode).

Commercially available polymer electrolyte membranes, like Nafion117 of Dupont, typically have good proton conductivity. They are poor in resisting methanol crossover. This not only leads to fuel loss, but also adversely affects cathode performance.

2.3.2 Gas Diffusion Layer (GDL)

GDL is an essential component of DMFC. Figure 2-3 shows the scanning electron microscopy (SEM) images of commercial carbon-paper and carbon-cloth.

In general, each surface of the bipolar plate contains grooved channels with inlet and outlet as flow path of the fuel and oxidant,

respectively. The requirements of an ideal GDL include: effectively diffusing the gas reactants to the catalyst layers, having high electronic conductivity, having a surface with low electrical contact resistance and proper hydrophobicity for necessity.

2.3.3 Bipolar Plate (BP)

The bipolar plate is essentially a plate with channels for fuel flows and air flows on each side (flow fields). It uniformly distributes fuel and air, conducts electrical current from cell, removes heat from the active area, and prevents leakage of gases and coolant. BP also significantly contributes to the volume, weights and costs of DMFC. The BP has the following functions to perform:

- (1) to distribute the fuel and oxidant within the cell,
- (2) to facilitate water management within the cell,
- (3) to carry current away from the cell, and
- (4) to facilitate heat management.

2.4 Capillary Driving Force

2.4.1 Young's Law

A liquid droplet is on a solid surface at state steady shown is Fig. 1. There three surface, including γ_{la} , γ_{sl} and γ_{sa} acting at the interface satisfying Young's law as

$$\gamma_{sa} = \gamma_{sl} + \gamma_{la} \cos \theta_c \quad (2-7)$$

where θ_c is the contact angle.

2.4.2 Capillary Force

Liquid water in a channel forms meniscus and the effective surface tension force applied on the surface. For a rectangular channel, the whole

length of L , the wetting length of x , the width of g , and the height of h as shown in Fig. 2-4, the total energy of the capillary channel is expressed as

$$E_s = E_o + [A_T \gamma_{sa} + A_x (\gamma_{sl} - \gamma_{sa})], \quad (2-8)$$

where A_T is the total area with the length of L , and A_x is wetting area with the length of x . For a micro channel, the complex surface of capillary meniscus can be treated as a plane surface. Hence, the total energy can be expressed as

$$E_s = E_o + 2(g+h)[L \cdot \gamma_{sa} - x \cdot (\gamma_{sl} - \gamma_{sa})]. \quad (2-9)$$

Taking derivative of Eq. (2-9) with respect to x , we can obtain the equivalent force F applied on the capillary fluid column along the x direction.

$$F = -\frac{dE_s}{dx} = 2(g+h) \cdot (\gamma_{sa} - \gamma_{sl}) = \Delta P_{la} \cdot g \cdot h. \quad (2-10)$$

Finally, the pressure drop across the liquid-air interface can be written as

$$\Delta P_{la} = \frac{2(g+h) \cdot (\gamma_{sa} - \gamma_{sl})}{g \cdot h}. \quad (2-11)$$

It is demonstrated that capillary force is related to contact angle and channel dimensions via the above equations.

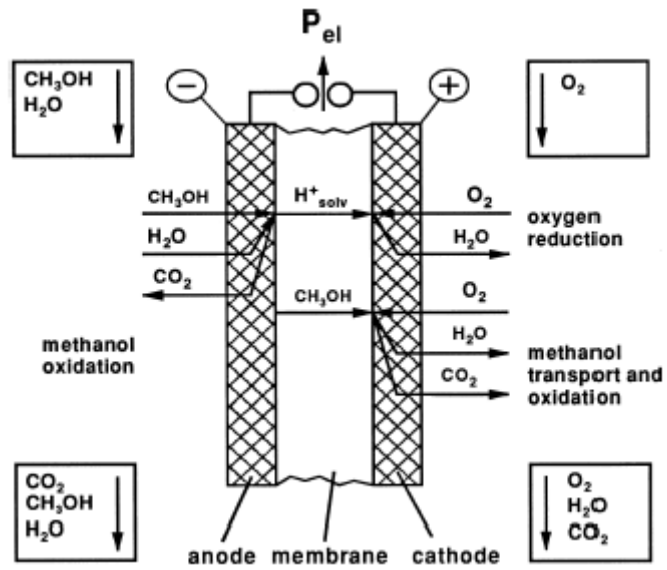


Fig. 2-1 Schematic diagram of the DMFC single cell with solid polymer electrolyte [20]

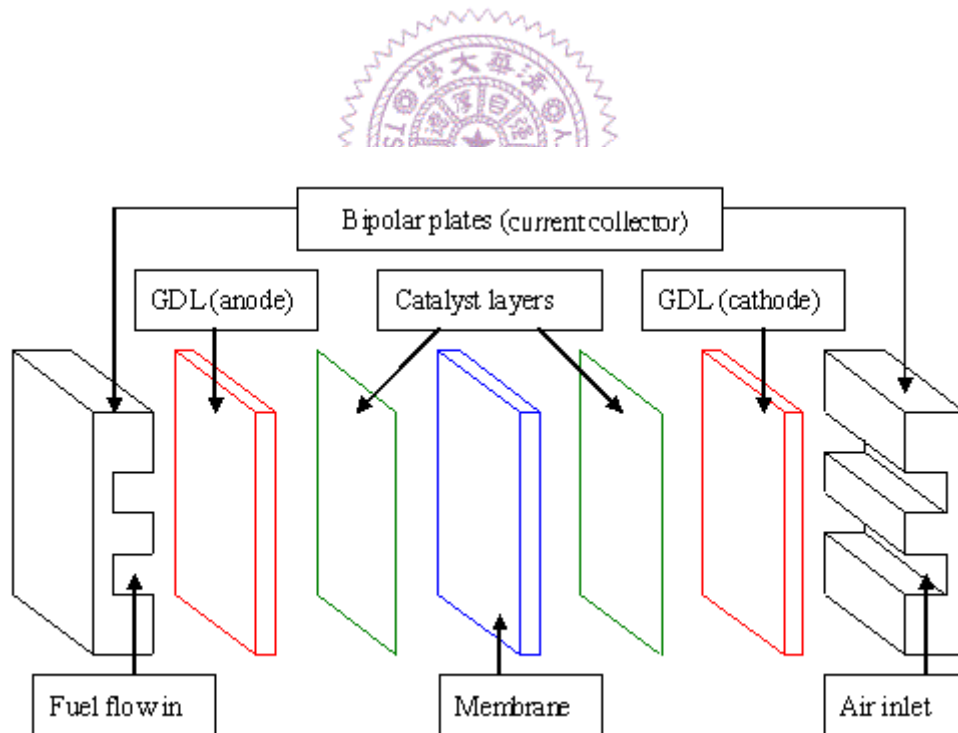


Fig. 2-2 Schematic diagram of the DMFC structure

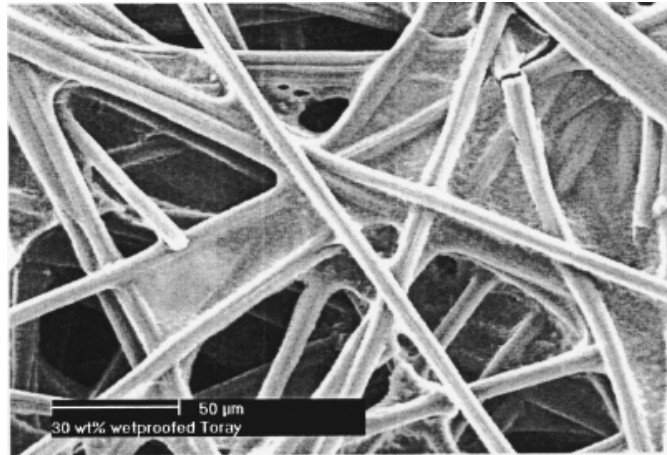


Fig. 2-3 Schematic diagram of (a) carbon paper [21]

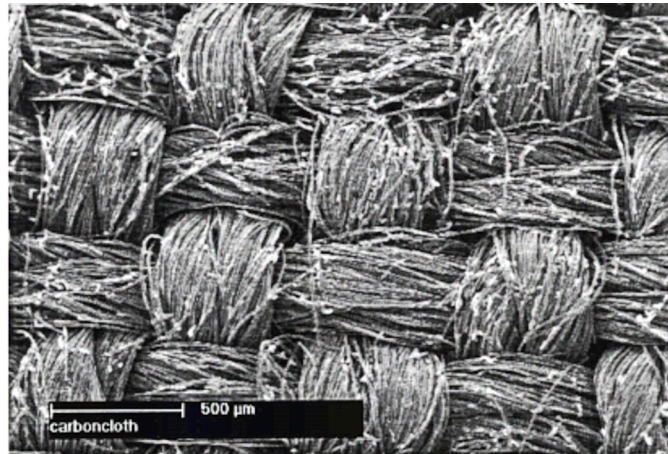


Fig. 2-3 (b) carbon clothes [21]

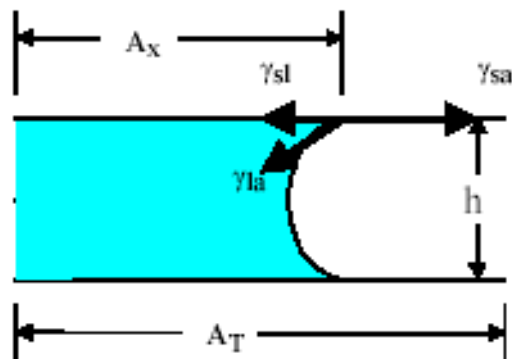


Fig. 2-4 configuration of a micro channel