Chapter I
INTRODUCTION

The increase of world energy consumption and the rapid depletion of fossil fuels have created enormous interests in alternative energy sources, such as solar, wind, nuclear, biofuels, and hydrogen, which are possible candidates to substitute the fossil or petroleum fuel. The ideal alternative energy source should be easily accessible, environmental friendly, and cost competitive compared to the existing energy supplies. In this regard, fuel cell technology is attractive because they provide an innovative alternative energy, have higher efficiency and a lower environmental cost (DeLuca *et al.*, 2006). A fuel cell is an electrochemical device, which continuously converts chemical reaction to electrical energy. Fuel cell is usually classified by the electrolyte used in the cell such as the Polymer Electrolyte Membrane Fuel Cell (PEMFC), the Alkaline Fuel Cell (AFC), the Phosphoric Acid Fuel Cell (PAFC), the Molten Carbonate Fuel cell (MCFC) and the Solid-oxide Fuel Cell (SOFC).

Direct Methanol Fuel Cell (DMFC), one type of PEMFC, is a promising power source for portable electronic devices because the liquid methanol is much easier to store compared to hydrogen which needs high pressure or low temperature. Moreover, the energy density of methanol is much higher than that of compressed hydrogen (Li, 2009). Therefore, DMFC is simply safe to handle, and of low cost. The DMFC mainly consists of an anode, a cathode, and a membrane. The membrane is the proton exchange membrane employed as an electrolyte. The membrane should have the required properties such as high proton conductivity which is the most important, good mechanical and chemical stabilities under the operating temperature. The membrane should be able to resist swelling, has good interface with the catalyst layer, has a low methanol crossover, and relatively low cost compared to the commercial membranes (Carrette *et al.*, 2001).

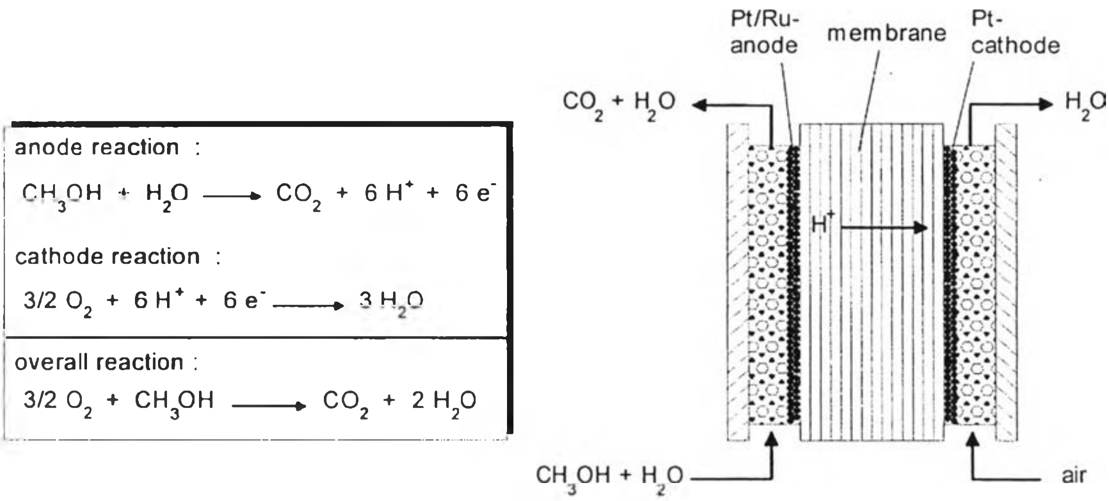

Figure 1.1 Schematic representation of a DMFC single cell (Baldauf and Preidel, 1999).

The basic structure of all fuel cells is similar: the fuel cell consists of two electrodes, separated by the electrolyte, which are connected to an external circuit. For the DMFC, methanol is directly fed as a fuel into the anode side and oxidized in a catalyst layer to protons, electrons, and carbon dioxide in the presence of water. While the electrons transport through the external circuit, the generated protons move from the anode to the cathode through the proton conducting membrane. At the cathode side, the supplied oxygen or air is reduced with protons to produce water molecules (Li, 2009).

The reactions, which take place in DMFC system, show in the equation (1.1), (1.2), and (1.3), represent the oxidation, reduction and overall reaction respectively

$$\text{Oxidation: } CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^- \quad (1.1)$$

$$\text{Reduction: } 3/2\ O_2 + 6H^+ + 6e^- \rightarrow 3H_2O \quad (1.2)$$

$$\text{Overall reaction: } CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O \quad (1.3)$$

Nafion, a perfluorosulfonic acid polymer produced by Dupont, is widely used as the membrane in DMFC. Nafion exhibits excellent proton conductivity (~0.1

S/cm) at ambient temperature (Qiao *et al.*, 2005), mechanical and chemical stabilities (Wootthikanokkhan *et al.*, 2006). However, its high cost, high methanol crossover and low cell performance under low humidity or high temperature have limited its commercialization (Devrim *et al.*, 2009). Therefore, various alternative polymer membranes have been developing for replacing Nafion membrane. Several research works have been reported on sulfonated polymers used as a PEM. The sulfonation process enhances the hydrophilic pathway for proton transfer within a polymer matrix by attaching sulfonic groups (-SO_3H) on its polymer backbone. There are many sulfonated polymers such as poly (ether ether ketone) (Macksasitorn *et al.*, 2012), poly(phenylene) (Ghassemi *et al.*, 2004; Kobayashi *et al.*, 1998), poly(arylene ether) (Gao *et al.*, 2005; Wang *et al.*, 2001), polyimides (Chen *et al.*, 2007; Miyatake *et al.*, 2007), polysulfone (Unnikrishnan *et al.*, 2012), and polyvinylidene (Macksasitorn *et al.*, 2012).

Polysulfone (PSF) is widely used in various utilizations such as tubing, printed circuit boards, and battery separator. PSF is an amorphous polymer and possesses excellent mechanical, thermal, and chemical stability. PSF can be easily sulfonated by various sulfonating agents. Therefore, sulfonated polysulfone (S-PSF) is expected to improve the DMFC performance by sulfonation process (Unnikrisnan *et al.*, 2012) and the incorporation of inorganic fillers to modify the membrane.

In this work, a novel composite membrane was fabricated by using S-PSF as a polymer matrix and zeolite Y and sulfonated graphene oxide (S-GO) as an inorganic filler. It was characterized in terms of proton conductivity, mechanical and thermal stability, and methanol permeability to study the effects of zeolite Y and S-GO contents.