CHAPTER I
INTRODUCTION

A fuel cell is a device that converts the chemical energy of a fuel such as hydrogen, natural gas, methanol and gasoline including an oxidant, air or oxygen into the electricity. In principle, a fuel cell operates similarly to a battery. Conversely, a fuel cell can be differentiated from a battery in term of lifetime or recharging. Thus, it also produces electricity and heat as long as fuel and an oxidizer are supplied. Commonly, the batteries and the fuel cells are electrochemical devices. For instance, both have a positively charged anode, a negatively charged cathode, and an ion-conducting material called an electrolyte. Therefore fuel cells are classified by their electrolyte materials. The electrochemical devices generate electricity without the combustion of the fuel and the oxidizer according to the traditional methods of electricity generation.

Particularly, Vanadium Redox Battery, or VRB, is a type of rechargeable flow battery as an energy storage system. The benefits of VRB are for many applications: storage in renewable energy systems; wind and solar and uninterruptable power supplies. The VRB energy is stored chemically in different ionic forms of vanadium in a dilute sulfuric acid electrolyte. The function of a membrane is not only preventing the cross mixing of the positive and negative electrolytes but also allowing the transport of ions to complete the circuit during the passage of current (Mohammadi and Skyllas-Kazacos, 1995). For a VRB system, the ideal membrane should possess low permeability of vanadium ions and low water transport properties to obtain a higher Coulombic efficiency and a long circle life, and high proton conductivity to obtain higher voltage efficiency (Teng and Zhao, 2009). Consequently, the significant advantages of the vanadium redox battery are; they offer almost unlimited capacity simply by larger storage tanks; left completely discharged for long periods with no effects; can be recharged simply by replacing the electrolyte if no power source is available to charge it; and when the electrolytes are accidentally mixed the battery does not suffer any permanent damage.

Purposely, the proton exchange membranes are mostly commercially developed for the industrial separation of cations and anions rather than a specific ion. For instance, Nafion® is a perfluorosulfonic polymer commonly used as a proton exchange membrane material in VRB system because its high proton conductivity and good chemical stability; but its cost is very expensive compared to others (Luo *et al.*, 2008). The vanadium ions, however, are easy to penetrate through the Nafion membrane amidst the operation of the VRB because the selectivity of Nafion membrane is not high enough. In addition, preferential water transfer across the membrane can result in the precipitation of vanadium salt and cause the flooding of the solution tanks and ultimately cause the operational difficulties in commercial systems.

Therefore, a sulfonation is a well-known and alternative way for developing a new membrane in VRB system. Generally, the sulfonation is an electrophilic substitution reaction in which one of hydrogen ion on aromatic rings is substituted by sulfonic acid group ($-SO_3H$). The presence of the sulfonic acid group constitute the S-Polymer becomes highly hydrophilic enable it to perform the high proton conductivity. The sulfonated aromatic poly(ether ether ketones) (S-PEEK) based membranes have been studied because their good mechanical properties, thermal stability, and conductivity (Li *et al.*, 2005). Furthermore, poly(1,4-phenylene ether ether sulfone) (PPEES) has been used as a backbone aromatic polymer. Thus, the aromatic rings can be sulfonated with electrophilic sulfonation agents.

In this research, the degree of sulfonation (DS) is controlled by varying reaction time, instead of varying the reaction temperature. PEEK and PPEES are selected for the sulfonation in order to compare properties with those of Nafion®. Subsequently, the effects of DS of S-PEEK and S-PPEES on polymer features and membrane performances will be considered.