



CHAPTER I INTRODUCTION

According to the problem of fossil fuel shortage in next few decades, the development of alternative sustainable energy production technologies are indispensable (Song, 2002). Among those technologies, fuel cell is one of the most possible choices which offers many advantages such as high energy conversion efficiency (50-70% conversion of fuel energy to electricity), applicability for fuels produced from plants, i.e., ethanol, low emission of green house gases (CO , CO_2 , NO_x , SO_2), and quiet operation (Stambouli *et. al.*, 2002). Polymer electrolyte membrane fuel cell (or proton exchange membrane fuel cell) (PEMFC) is one type of fuel cell which have received much expectation for being an electrical energy source of portable devices and also vehicles (Figure 1.1). The main advantages of this system over the other fuel cell systems are high current density, compact size, low operating temperature required, and short start-up time (Cropper *et. al.*, 2004).

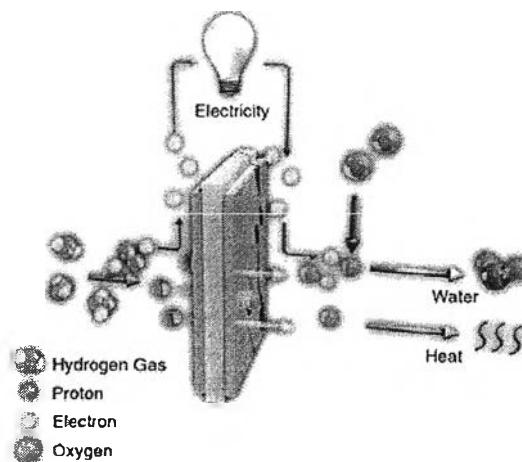


Figure 1.1 Flows and reactions in a simple fuel cell (www.plugpower.com).

However, there are many problems obstructing this technology from being introduced to industrial applications. Focusing on the electrolyte membrane part, the requirements of this component are high proton conductivity, low electron conductivity, low hydrogen and oxygen permeability, and chemically inertness, which has been satisfied in some certain level by the commercially available

polymer, i.e., Nafion[®] produced by DuPont. Unfortunately, the request of high humidification condition of the membrane caused significant limitations to fuel cell, i.e., limiting the operating temperature to be lower than 100 °C, requiring the system to release water flooding in the cell, difficulty in solving the problem of CO poisoned catalyst, requiring high purity H₂ feed gas, etc. (Kreuer, 2001). Therefore, many researches on low humidifying membranes or even the anhydrous systems have been proposed (Li *et al.*, 2003). In the case of anhydrous or water-free proton exchange membrane, heterocyclic resonance-structured compounds such as imidazole and benzimidazole were found to be able to function as proton carrier molecules (Kreuer *et al.*, 1998). The proton transferring mechanism, so-called proton transfer- and reorientation process, is under the resonance structure as proposed by Münch *et al.* (2001) (Figure 1.2).

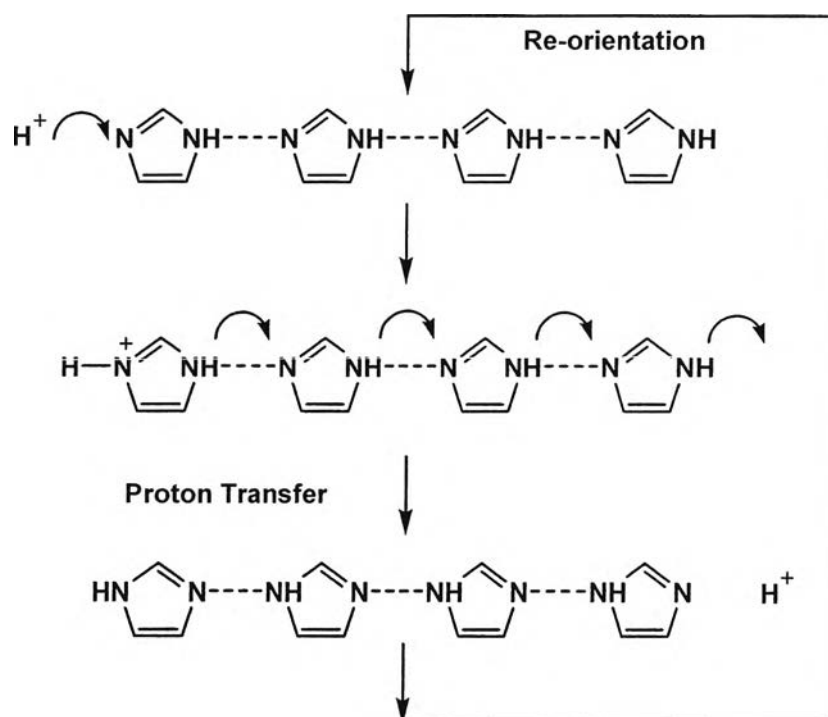


Figure 1.2 Proton transfer mechanism of imidazole.

However, most of the researches on heterocyclic structure-based membranes concern only incorporation of heterocyclic units into polymers as main chain (Kawahara *et al.*, 2000), side chain (Bozkurt *et al.*, 2001), or blending as additives

(Kreuer *et. al.*, 1998), without considering a systematical arrangement of the molecules. Therefore, in order to achieve the most proton transferring efficiency based on the favorable hopping mechanism, it is important to develop a well-arranged heterocyclic polymer and systematically study how the proton transfer efficiency related to the structure of the molecules and the hydrogen bond network either at the individual molecule basis and/or the morphological packing.

The present works, thus, concentrates on the molecular designs for model compounds by proposing the structure of molecules, syntheses, characterizations followed by the clarification of the packing structure and the hydrogen bond network. The work shows (i) the molecular design and synthesis of the benzimidazole-based model compounds (Chapters III and V), (ii) the systematical study on intermolecular interaction, molecular packing structure and hydrogen bond network of the benzimidazole-based model compounds (Chapters III and V), (iii) the demonstration of hydrogen bond network channels exhibited in the model compounds (Chapter IV), and (iv) proton conductivities derived by the model compounds (Chapter IV).