Preface

Fuel cell is considered to be one of the most promising clean energy sources since it does not generate toxic gases and other hazardous compounds. It is currently an important research topic in all leading automobile and energy industries. Fuel cells will provide an urgently needed solution to the increasing impact of vehicles pollution. Among various kinds of fuel cells, polymer electrolyte membrane fuel cells (PEMFC) are easy to be miniaturized and suited as energy sources for automobiles as well as domestic applications and potable devices. Fuel cell is also currently considered as reaching the threshold of commercialization. The center of PEMFC is the polymer electrolyte membrane, as it defines the properties needed for other components of fuel cell and is the key component of a fuel cell system. The membrane component of a fuel cell stack may account for as much as 30% of the total material cost. Their properties are paramount to the successful operation and commercialization of fuel cells. The most widely used solid polymer electrolyte membranes in fuel cells are perfluorosulfonic acid membranes such as Nafion, Acipex and Flemion. However, they have some drawbacks that should be overcome before their practical applications will be achieved. The most significant drawbacks of these membranes are their relatively high cost in the range of US $ 800/m^2, and their limited stability at temperatures substantially in excess of 100°C. Moreover, there is a problem of methanol crossover when used in direct methanol fuel cell. Hence, there is a need to develop less expensive polymeric membranes with improved performance. More specifically, it is currently targeted to develop membranes with high proton conductivity (above 10^{-2} S cm^{-1} at 120°C), preventing excessive methanol crossover, and with durability of 5000 hours for transportation and 4000 hours for stationary devices.

During the past two decades many attempts have been made all over the world to improve the performance of presently available membranes and develop new ones for PEMFC. The fuel cell membrane field is growing with such a fast pace that it will emerge as one of the most important membrane technologies. A literature search on fuel cell membranes over the years 1990–2006 revealed more than 2500 patents only in addition to thousands of journal publications, which clearly indicate the importance of the subject. It seems most timely to summarize the results of such research efforts. Hence, this book is focused on the development of polymeric and polymeric/inorganic hybrid membranes for PEMFC.

Although each chapter is independent from the other chapters, attempts were made to give some cohesiveness between chapters.

The first five chapters are general description of the strategies adopted to improve the membrane properties and status of the PEMFC technology.

Chapter 1 and 2 outline the principle of PEMFC and its desired properties. The general trend in recent R & D efforts and the future outlook is also summarized. It would be a good start to read these two chapters before entering any other chosen chapter.

Chapter 3 presents an overview of fuel cell technology, potential applications of fuel cell technology, current research and development in fuel cells, key technology players in fuel cells, and provides directions for fuel cell research.

Chapter 4 presents an overview of the synthesis, chemical properties, and polymer electrolyte fuel cell applications of new proton-conducting polymer electrolyte membranes based on sulfonated poly(arylene ether ether ketone) polymers and copolymers.

In chapter 5, a comprehensive review was made of the attempts to prepare alternative proton conductive membranes (PCMs) by radiation-induced graft polymerization.

Chapters 6 and 7 deal with the hydrocarbon polymers and composites targeted for high temperature PEM fuel cell applications. Specifically, chapter 6 deals with a series of high molecular weight, highly sulfonated poly(arylenethioethersulfone) (SPTES) polymers synthesized by polycondensation. They were characterized by different methods and tested for proton conductivity. Finally, membrane electrode assemblies (MEAs) were fabricated.

Chapter 7 emphasizes polymer/inorganic composite membranes to increase thermal stability. More specifically, polymers include perfluoronated polymers, sulfonated poly(arylene ether)s, polybenzimidazoles (PBIs), and others. The inorganic proton conductors are silica, heteropolyacids (HPAs), layered zirconium phosphates, and liquid phosphoric acid.

In the next five chapters more specific classes of macromolecules and other materials are shown for the design of improved PCMs.

Chapter 8 describes a strategy to improve the membrane properties by blending polymer electrolytes with other polymers. Different types of interactions are involved when cross-linking between polymers is formed.

In chapter 9 the general strategy involved in the preparation of organic-inorganic membranes for fuel cell applications is described and its advantages and disadvantages are discussed.

In Chapter 10 efforts have been made to highlight the response of thermal and mechanical properties with variation of different parameters characteristic of a typical fuel cell environment.

Chapter 11 also includes the polymer inorganic membranes consisting of Nafion and zirconium phosphates, heteropolyacids, metal hydrogen sulfates and metal oxides. Moreover, this chapter includes the design of thin film electrodes for MEA.

Chapter 12 deals with carbon nanotube (CNT) filled membranes for PCMs. CNT-filled polyethylene terephthalate was blended with various polymers, injection molded and characterized by different methods.

The next four chapters are for direct methanol fuel cells (DMFC).

In Chapter 13 critical issues for the commercialization of DMFCs are discussed thoroughly. Functions, current status and technical approaches have been discussed in terms of proton conductivity, methanol permeability, water permeability, life cycle and processing cost as well as the interaction with other compartments.

Chapter 14 presents a brief literature survey of such modifications, along with recent experimental results (membrane properties and fuel cell performance curves) for: (i) thick Nafion films, (ii) Nafion blended with Teflon®-FEP or Teflon®-PFA, and (iii) Nafion doped with polybenzimidazole.

Chapter 15 is a general overview of DMFC research to develop membranes with low methanol permeability without sacrificing other important qualities.

Chapter 16 presents a unique membrane design and development using the concept of pore-filling. The membranes are used for both polymer electrolyte membrane fuel cells (PEMFCs) and direct methanol fuel cells (DMFCs).

And finally, chapter 17 was written to summarize the whole chapters. Attempts were also made to show the future direction of the fuel cell R & D.

The editors believe that this book is the first book exclusively dedicated on fuel cell membranes in which the experts of the field are brought together to review the development of polymeric membranes for PEFC in all their aspects. The book was written for engineers, scientists, professors, graduate students as well as general readers in universities, research institutions and industry who are engaged in R & D of synthetic polymeric membranes for PEMFC. It is therefore the editors' wish to contribute to the further development of PEMFC by showing the future directions in its R & D.

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