

Preface

Organic–Inorganic Composite Polymer Electrolyte Membrane: Preparation, Properties and Fuel Cell Applications is intended to explore the recent developments in the area of polymer electrolyte membranes for high-temperature polymer electrolyte membrane fuel cells. This book presents a unified viewpoint of the operating principles of fuel cells, fuel cells thermodynamics and efficiency, various methodologies used for the fabrication of polymer electrolyte membranes, issues related to the chemical and mechanical stabilities of the membranes. Special attention is paid to the fabrication of electrospun nanocomposite membranes.

This book discusses the developments in the fast-growing and promising area of PEM materials obtained by using hygroscopic inorganic fillers, solid proton conductors, titanium oxide, zirconia and sulphated zirconia, silica, zeolite, montmorillonite, heterocyclic solvents, ionic liquids, anhydrous H_3PO_4 blends, heteropolyacids, etc.

This book is of great importance not only to the learners but also to the more experienced fuel cell researchers, enabling a deep understanding of the organic–inorganic membranes for fuel cells, methods for the fabrication of membranes as well as properties and applications. Based on thematic topics, the book edition contains the following 17 chapters:

Chapter 1 deals with the use of ionic liquids (ILs) as fuel cell electrolytes. ILs with good mechanical properties and high conductivity has great potential to fabricate polymer membranes. This chapter focuses on the recent advances in the application of ionic liquid-based polymer membranes for the development of fuel cell technology. The key factors affecting membrane performance have been nicely discussed.

In Chap. 2, a review on the recent developments about organic/ TiO_2 nanocomposite membranes is presented. The unique properties, such as electrical property and processability together with thermal and chemical stabilities as well as high proton conductivity at high temperatures of organic–inorganic composite systems are highlighted.

In Chap. 3, the importance of nanoscience and nanotechnology for producing new materials with enhanced properties and potential applications are discussed. Among the variety of nanoparticles (NPs), silica NP is considered of a particular interest due to its ease of synthesis, functionalization and precise controlling of size and distribution of particles. Superior features of polymeric membranes are summarized.

Chapter 4 describes the basic requirements of polymer electrolyte membrane (PEM) fuel cells. This chapter is divided into seven sections. The first section presents some statistical data of publications concerning fuel cell, PEM fuel cells (PEMFC) and PEMFC with zeolites. The second section exhibits some concepts about zeolites types, structure, properties, and industrial applications. The third section presents the role of the zeolite properties on the performance of the PEMFC. The fourth section describes the main technique used for producing zeolite/polymer nanocomposite membrane for PEMFCs. The two following sections outline the state of the art of using the zeolite for PEMFC applications, being the fifth and sixth sections dedicated to the synthetic and natural polymers, respectively.

Chapter 5 covers the use of heteropolyacids (HPAs) in the preparation of proton exchange membranes (PEM) for polymer electrolyte membrane fuel cells (PEMFCs). The fundamental aspects of HPAs and their corresponding salts in addition to various structural configurations such as Keggin, Wells–Dawson, and Lacunar are discussed. The use of HPAs for preparation of membranes for high-temperature PEMFC and direct methanol fuel cell (DMFC) based on the immobilization on various substrates including perfluorinated sulfonic acids (PFSA), aromatic hydrocarbons, poly(vinyl alcohol) (PVA), and polybenzimidazole (PBI) are reviewed.

In Chap. 6, organic/montmorillonite nanocomposite membrane and membrane fabrication techniques are discussed. The fabrication technique, properties of the fabricated membranes, and performance are explained in detail and compared.

In Chap. 7, the application of electrospun nanofibers from organic, inorganic, and composite organic–inorganic is extensively reviewed. The interesting features of electrospun nanofibers to improve fuel cell performance in terms of power density, ionic conductivity, interfacial resistance, and chemical stability, as well as mechanical strength are discussed. The development and evolution of fuel cells as one of the advanced energy conversion systems is suggested.

Chapter 8 describes the basic overview of fuel cell technology in order to understand the construction and the working principle of this eco-friendly technology. The fuel cells thermodynamics and efficiency are discussed in detail.

Chapter 9 presents an overview of the commonly used polymer hosts and inorganic additives. The available literature on sulfated zirconia ($S\text{-ZrO}_2$) nanohybrid membrane technology is discussed in view of catalyzing the future research to develop more suitable polymer electrolyte membranes for fuel cell.

In Chap. 10, literature data on the promotional role of under-rib convection for polymer electrolyte membrane fuel cells (PEMFCs) fueled by hydrogen and

methanol have been structured and analyzed, with the aim of providing a guide to improve fuel cell performance through the optimization of flow field interaction.

Chapter 11 presents a brief overview of various techniques used for the preparation of organic–inorganic nanocomposite polymer electrolyte membranes for fuel cells and discusses the encountered challenges, the problems to be overcome, the major findings and guidance for future developments. With the advances in nanomaterials and polymer chemistry, the innovative nanocomposite membranes with superior properties can be designed by blending of nanoparticles in a polymer matrix, doping or infiltration and precipitation of nanoparticles and precursors, self-assembly of nanoparticles, layer-by-layer fabrication method, and nonequilibrium impregnation-reduction.

In Chap. 12, important attributes of PEM, such as chemical and mechanical stabilities, are described and reviewed. Efforts have been made to highlight the responses of chemical and mechanical stabilities of membrane at different temperatures and relative humidities of the fuel cell operation that lead to cell failure. A literature review regarding the chemical and mechanical degradation of membrane as well as the mitigation for the membrane degradation is also presented.

The focus of Chap. 13 is on the membrane of polymeric fuel cells and the methods of using electrospinning process to prepare these membranes. Three important objectives of this chapter with respect to using electrospinning in membranes of polymeric fuel cells include reducing methanol crossover, improving proton conductivity, and suppressing water swelling.

Chapter 14 summarizes the various fabrication techniques for the development of polymer electrolyte membrane fuel cells (PEMFC). A brief overview of different fabrication techniques, such as plasma method, phase inversion method, sol-gel method, direct copolymerization, ultrasonic coating technique, ultra-violet polymerization, in situ reduction, decal transfer method and catalyst coated membrane method, is presented in this chapter.

Chapter 15 reviews structure and property of chitosan with respect to its applications in fuel cells. In addition, different synthetic strategies to prepare chitosan-based polymer electrolyte membranes and their properties for the use in fuel cells are critically examined. These strategies include chemical modifications of chitosan, blending with other polymers and their composites for polymer electrolyte membranes among fuel cell applications. Recent achievements and prospect of its applications have also been discussed in this chapter.

Chapter 16 emphasizes about the basics information of fuel cells. It also summarizes the available information details about the types of fuel cells, the design and constructions of fuel cells, catalysts in fuel cells, materials and the methods used for preparation of fuel cells.

Chapter 17 presents details about fuel cell technology and production of proton exchange membranes developed through electrospinning technique along with recent progress made in research of new materials, such as Nafion, poly(vinylidene fluoride) (PVDF), poly(ethylene oxide) (PEO), and poly(vinyl alcohol) (PVA).

Composite membranes composed of highly conductive and selective layer-by-layer (LbL) films and electrospun fiber mats have been examined for mechanical strength and electrochemical selectivity. The present status and future prospectus of electrospun nanofibres for fuel cell applications are highlighted.

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