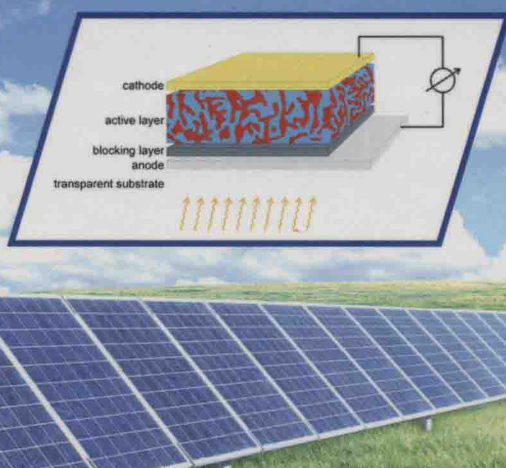
Polymer Science and Plastics Engineering

POLYMERS FOR ENERGY STORAGE AND CONVERSION



Edited by
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Scrivener Publishing

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Polymers for Energy Storage and Conversion

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Scrivener
Publishing

WILEY

Co-published by John Wiley & Sons, Inc. Hoboken, New Jersey, and Scrivener Publishing LLC, Salem, Massachusetts.
Published simultaneously in Canada.

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Cover design by Russell Richardson

Library of Congress Cataloging-in-Publication Data:

ISBN 978-1-118-34454-5

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Polymers for Energy Storage and Conversion

Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Polymer Science and Plastics Engineering

The "Polymer Science and Plastics Engineering" series publishes both short and standard length monographs, textbooks, edited volumes, practical guides, and reference works related to all aspects of polymer science and plastics engineering including, but not limited to, renewable and synthetic polymer chemistry and physics, compositions (e.g. blends, composites, additives), processing, characterization, testing, design, and applications. The books will serve a variety of industries such as automotive, food packaging, medical, and plastics as well as academia.

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Preface

Polymers are increasingly finding applications in the areas of energy storage and conversion. A number of recent advances in the control of the polymer molecular structure control which allows the polymer properties to be more finely tuned, have led to these advances and new applications. This book is an attempt to assimilate these advances in the form of a comprehensive text which includes the synthesis and properties of a large number of polymer systems for applications in the areas such as lithium batteries, photovoltaics, solar cells.

Chapter 1 introduces the structure and properties of polymer hydrogel with respect to its applications for low to intermediate temperature polymer electrolyte-based fuel cells. In recent years, there has been extensive research on the development of high performance electrochemical devices which can generate and store energy at low cost. Fuel cells have been receiving attention due to their potential applicability as a good alternative power source. Chapter 2 describes PVAc-based polymer blend electrolytes for lithium batteries. Among the different kinds of batteries, Li-ion secondary batteries play a key role in the development of modern technologies especially in the portable electronic devices and in heavy electrical vehicles because of advantages such as high theoretical capacity, improved safety, lower material costs, ease of fabrication into flexible geometries, and the absence of electrolyte leakage. Chapter 3 reviews the lithium polymer batteries based on ionic liquids. A very promising approach for overcoming the existing drawback is represented by the addition of ionic liquids, as co-salts, into the polymer electrolytes. Ionic liquids, molten salts at room temperature, have very interesting properties such as high chemical, thermal and electrochemical stability, high conductivity, no measurable vapor pressure and non-flammability. In Chapter 4, the concept of the solar cell with the organic multiple quantum dots (MQDs) is proposed. Next, molecular layer deposition (MLD) processes for the polymer MQDs and the molecular MQDs are described, and experimental results of absorption spectra and surface potential are presented to confirm that designed MQD structures are constructed by MLD actually. In Chapter 5, solvent effects in polymer-based organic photovoltaic devices are discussed. The example of using solvents with different boiling points (choice of solvent) to control the morphology and crystallinity due to the evaporation rate and interaction with the polymers are discussed. Moreover, solvent molecules remaining inside the active layer are presented. Chapter 6 suggests that conjugated polymer-inorganic semiconductor composite has come a long way and still remains a matter of research interest, so as to exploit unique properties of conjugated polymers and inorganic semiconductors in single and tandem devices. Numerous challenges still exist to obtain device performance matching to polymer-fullerene counterpart cells. However, with further engineering of polymer and inorganic materials, followed by effective device design and processing steps, there is still room to raise device performance with new breakthroughs. Chapter 7 provides an overview of the properties of the polymers which factor into their use for solar power, whether for niche applications or for large scale harvesting. Chapter 8 reviews the use of macroporous organic polymers as promising materials for energy gas storage with the distinguished advantage in the diversity in synthetic chemistry and versatility in post-modifications.

Vikas MITTAL
Abu Dhabi
February 20, 2013

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1

High Performance Polymer Hydrogel Based Materials for Fuel Cells

Yogeshwar Sahai and Jia Ma

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Abstract
In recent years, there has been extensive research on the development of high performance electrochemical devices which can generate and store energy at low cost. Fuel cells have been receiving attention due to its potential applicability as a good alternative power source. Polymer hydrogel electrolyte is prospective material to deliver high performance at low cost in fuel cells which use polymer membrane as electrolyte and separator. This chapter introduces structure and properties of polymer hydrogel with respect to its applications for low to intermediate temperature polymer electrolyte-based fuel cells.

Keywords: Fuel cell, polymer hydrogel, electrolyte

1.1 Introduction

A fuel cell is an electrochemical device that produces electrical energy via electrochemical reactions between the fuel and the oxidant. Unlike a battery, which stores a finite amount of energy, a fuel cell continues to produce energy as long as the oxidant and the fuel are fed into it. Energy generation from combustion in a heat engine is intrinsically inefficient and also causes environmental problems. On the contrary, a fuel cell is inherently energy efficient, environmentally friendly, and silent.

The polymer electrolyte-based fuel cell employs a polymer membrane as the electrolyte. Compared to other types of fuel cells, it

Vikas Mittal (ed.) Polymers for Energy Storage and Conversion, (1–26)

is capable of achieving reasonably high power performance at relatively low working temperatures, and thus is considered a promising power supply for transport, stationary, and portable applications. The major component of a fuel cell is the membrane electrode assembly (MEA) which consists of solid polymer electrolyte membrane (either a cation exchange membrane (CEM) or an anion exchange membrane (AEM)) sandwiched between an anode and a cathode. An electrode generally consists of a catalyst layer and a diffusion layer. The catalyst layer must have facile transport of reactants and products as well as good ionic and electronic conductivity. Therefore, the catalyst layer should have high porosity and large electrochemically active surface area. The solid polymer electrolyte membrane should have good ionic conductivity and no electronic conductivity. For such an application, an ideal solid electrolyte membrane should fulfill a number of requirements including high ionic proton conductivity, long-term chemical and mechanical durability under heated and humidified conditions. A primary goal is to find stable polymer-based materials with ionic conductivities within the range of mS cm^{-1} at temperatures up to 100°C [1]. Ionic conductivity of many polymeric membranes, increases with its water content, and thus hydration is of significance to achieve high conductivity, especially at high temperatures. Perfluorinated ionomers, such as Nafion, with fluoroalkyl ether side chains and sulphonic acid end groups on polytetrafluoroethylene backbones, have been the most commonly used polymer electrolyte membrane so far. Nafion material is also used as an electrode binder which facilitates ionic conduction, provides mechanical support for catalyst particles, and enhances dispersion of catalyst particles in the catalyst layer. Nafion possesses many desirable properties as a polymer electrolyte, and yet it is very expensive and loses ionic conductivity if not sufficiently hydrated. For application in a polymer electrolyte-based fuel cell using methanol as the fuel or direct methanol fuel cell, solid polymer electrolyte membrane also needs to have low methanol permeability. However, Nafion membrane has relatively high methanol crossover.

Research has been going on in the development of high-performance, cost-effective polymer-based membrane electrolyte as an alternative to Nafion for use in polymer electrolyte-based fuel cells. Hydrogel polymer electrolyte has high potential for applications in fuel cells. This chapter introduces structure and properties of polymer hydrogel electrolyte with respect to its applications in fuel cells.