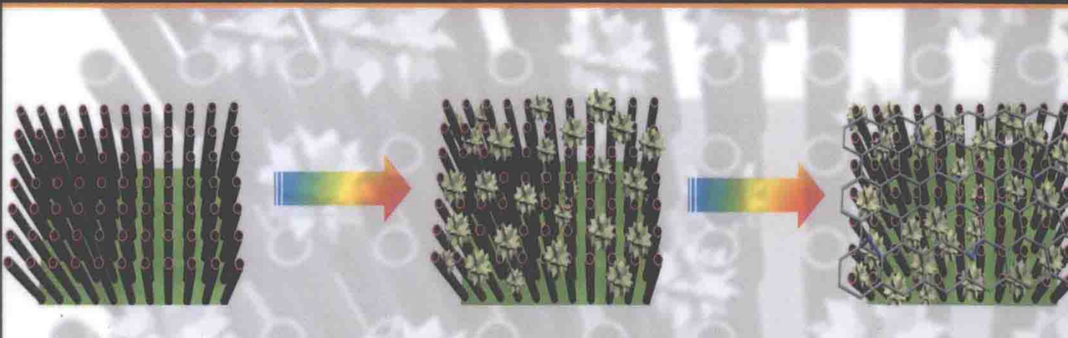
Advanced Materials Series

ADVANCED ELECTRODE MATERIALS



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Preface

Among the hot topics concerning advanced materials are recent advances in electrode materials because of their importance not only in developing new biosensors but also in designing efficient batteries, fuel cells and, of course, energy storage and conversion systems. Therefore, we have tried to compile various valuable aspects of this hot topic as a part of the Advanced Materials Series.

In this book, a narrative is presented of recent advances in electrode materials and their novel applications, which are a cross section of advanced materials. Electrochemistry is a widely used branch of chemistry which combines chemical and electrical effects. It provides the advantages of high sensitivity, high performance and low cost. In electrochemistry, a well-designed electrode material is the key to many applications. Therefore, we have summarized different electrodes used in various fields for enhancing the quality of electrochemical systems. We begin with a chapter regarding advances in electrode materials, particularly those based on energy storage, since an electrode is one of the important parts of electrochemical capacitors as well as energy storage and conversion products. The major classes of suitable electrode materials used for capacitors are commonly activated nanoporous carbon, graphene, carbon nanotubes, conducting polymers, metal oxides and polymer composites, which have been extensively reported on in the literature.

Diamond-based electrodes have garnered great attention for use in electrochemical systems. Therefore, detailed techniques used in chemical vapor deposition (CVD) to generate polycrystalline and nanocrystalline diamond layers are also covered, along with methodologies employed to dope the diamond phase in order to obtain an electrically conductive material. Then, the use of diamond-based layers for the assembly of electrodes is summarized to inform readers in areas related to the environment and renewable energies, including food and pharmaceutical analysis, soil and water purification, supercapacitors, Li-ion cells and fuel cells. Recent advances in tungsten oxide/conducting polymer hybrid assemblies for electrochromic applications have taken place which emphasize the importance of developing new technologies that can be used for electrochromic applications. Tungsten oxide (WO_3) has emerged as one of the key materials for electrochromic devices since it exhibits the best electrochromic activity among transition metal oxides. The introduction of WO_3/conducting polymer-based hybrid materials has prompted the development of nanocomposites with properties unmatched by conventional counterparts. The interdisciplinary research involving materials science, bioelectrochemistry and electrochemistry is still the hallmark of many technological and fundamental breakthroughs. The effectiveness of surfactant-free metal nanoparticles as "abiotic" catalysts in biotechnology are outlined, based on systems harvesting energy from biological sources for various sensing and wireless information-processing devices for biomedical, homeland and environmental monitoring applications. In another chapter, polyoxometalates (POMs) based on concepts of biosensors for renewable energy applications are summarized. POMs are a well-known class of discrete early transition metal-oxide clusters with a variety of sizes, shapes, compositions and physical and chemical properties, which undergo reversible multivalence reductions/oxidations. Electrochemical sensors based on ordered mesoporous carbons are also highlighted since they provide high sensitivity and selectivity.

Conducting polymer-based electrochemical DNA biosensing is also detailed in the book. Electrode materials for fuel cells lead to important reactions such as oxygen evolution reactions (OER), hydrogen evolution reactions (HER), and oxygen reduction reactions (ORR). In metal-air batteries and fuel cells, the most sluggish reaction is the ORR reaction, which is the bottleneck of numerous electrochemical reactions. Key electrocatalytic reactions occur at the cathode of a proton exchange membrane fuel cell (PEMFC). Therefore, inexpensive materials that have high activity, stability, and resistance to methanol crossover effects for ORR-HOR and OER reactions have been summarized in one of the chapters. In another chapter, a study of phosphate polyanion electrodes and their performance with glassy electrodes for potential application in lithium-ion solid-state batteries is presented in order to stress the importance of new generation solid-state batteries. Then, in a related area, conducting polymer-based hybrid nanocomposites for lithium batteries are given. In this chapter, host-guest and core-shell hybrid nanocomposites based on conducting conjugated polymers and inorganic compounds, which are considered active components of the lithium batteries, are reported. Later on, electrode materials for fuel cell applications are categorized and evaluated in two separate parts as catalyst supports and anode/cathode catalysts. Platinum (Pt)-based catalysts make fuel cell technology less cost-effective due to the limited supply

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and high cost of Pt. Thus, research on the cost reduction of fuel cells is dealt with either by optimization of existing Pt catalysts or development of Pt or non-Pt alloy catalysts with new and improved electronic structures. Novel photoelectrocatalytic electrode materials for fuel cell reactions are also summarized, with the main focus of the chapter being the recent progress of novel photoresponsive electrodes as anode catalysts for improving the photoelectrocatalytic activity of low molecular weight alcohols oxidation under light irradiation. Finally, advanced nanomaterials for the design and construction of anode materials for microbial cells are detailed at the end of the book.

The invaluable efforts of distinguished researchers from ten different countries with seventeen different affiliations have helped build a comprehensive book from the perspective of advanced materials. By including information presented by such a wide range of authors we hope to contribute to the understanding of students and researchers as well as industrial partners from different fields.

Editors
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September 2016

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Part 1

STATE-OF-THE-ART ELECTRODE MATERIALS

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