

Molecular Catalysts for Energy Conversion

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Preface

Over the past decade the topic of energy and environment has been acknowledged among many people as a critical issue to be solved in 21st century since the Kyoto Protocol came into effect in 1997. Its political recognition was put forward especially at Heiligendamm in 2007, when the effect of carbon dioxide emission and its hazard in global climate were discussed and shared universally as common knowledge. Controlling the global warming in the economical framework of massive development worldwide through this new century is a very challenging problem not only among political, economical, or social circles but also among technological or scientific communities. As long as the humans depend on the combustion of fossil for energy resources, the waste heat exhaustion and CO₂ emission are inevitable.

In order to establish a new era of energy saving and environment benign society, which is supported by technologies and with social consensus, it is important to seek for a framework where new clean energy system is incorporated as infrastructure for industry and human activities. Such a society strongly needs innovative technologies of least CO₂ emission and efficient energy conversion and utilization from remaining fossil energies on the Earth. Energy recycling system utilizing natural renewable energies and their conversion to hydrogen may be the most desirable option of future clean energy society. Thus the society should strive to change its energy basis, from fossil-consuming energy to clean and recycling energy.

In the future “clean energy society,” a closed hydrogen cycle consisting of hydrogen generation, storage, transmission, and usage that are driven by a solar energy as the energy source is to be established. For such purpose, water photoelectrolysis, photosynthesis from CO₂ to bioenergy, electrochemical solar cells, and fuel cells should be the most important combinations of technologies. In this sense, a dream of humans toward sustainable energy society should be realized with hydrogen-mediated energy conversion systems.

Technological background for such dream is being enforced by a wide spectrum of researches in above-mentioned fields. Fuel cells and artificial photosynthesis are the most developing fields in the last few decades. One of the key

technologies for such developments should be the electrocatalysts for electrochemical energy conversion. The efficiency and utilization of energy conversion highly depend on the electrocatalysts that determine the reaction route, energy barrier through the rate-controlling process, and frequency factor. The history of electrocatalysts dates back to the beginning of 20th century, when electrode kinetics started to be investigated with the language of the “current and overpotential.” For an energy conversion system, Sir William R. Grove first proposed a model of fuel cell in 1839 using hydrogen and oxygen gases with platinum electrocatalysts. Today many researchers aim to invent and investigate new electrocatalysts for variety of electrochemical reactions, and such trend will continue to look for the most efficient and cost-competitive catalyst materials.

A new possibility of electrocatalysts is proposed in this context, which would assist in developing vast field of electrocatalysts. The organic complex catalysts for energy conversion, which are emerging technologies in the last several decades, are the main topic of the book focusing on energy and environment technologies. Such molecular catalysts have wide variety of applications in the field of fuel cell technology, electrochemical solar cells, artificial photosyntheses, and so on. Since these molecular catalysts have many potential advantages over inorganic or metal-alloy catalysts due to their cost performance, capability of manipulating structures through molecular design and synthesis, variety of immobilization processes on the catalyst substrate, etc., a firm strategy for their design and application is awaited to cope with the expeditious solution of the latest energy and environment issues.

This book aims to provide a scientific and technological basis for the design and application of molecular catalysts for energy conversion and environment protection, and to establish a method of efficient processing, manufacturing, and development. This book is expected to be beneficial for those people who are studying, researching, or developing molecular catalysts as the electrocatalysts or photocatalysts in energy conversion systems.

Chapter 1 introduces the historical overview and the underlying designing concepts of molecular catalysts with the scope of new developing field. Chapters 2 through 3 give fundamental aspects of the elementary reactions associated with the electrocatalytic processes and measuring techniques of molecular catalysts. From Chaps. 4 to 7, developing fields of molecular catalysts in fuel-cell energy conversion systems are discussed with variety of examples in the anode and the cathode of the reacting gas systems. Chapters 8 through 10 give another new field of molecular catalysts, and electrochemical solar cells and photosynthesis technology are presented with examples of dye-sensitizers for photochemical reactions, nano-materials for photoelectrodes and charge-transport media. Chapters 11 and 12 discuss new applications of molecular catalysts in environmental cleaning and in sensor technology. Chapters 13–15 provide fundamental knowledge for the catalyst researches, which are indispensable tools for understanding elementary molecular processes in the electrocatalytic and photocatalytic processes. Finally Chap. 16 gives the summary

and future prospects of molecular catalysts in the energy conversion technology in various possible fields of applications.

This book is contributed by many of the renowned authors in the related field of researches, and chapters are arranged through intent discussions and interplay of authors and editors. It is carefully planned so that all the chapters keep good balances and therefore provide the readers with adequate state-of-the-art technologies and knowledge concerning the newly emerging field of molecular catalysts for energy conversion. Lastly we would like to express our hearty acknowledgments to all the contributors and to the staff of Springer Verlag for their willing interest and generous assistance, without which this book would not have been published in success.

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