Artificial Photosynthesis From Basic Biology To Industrial Application

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RANDALL FORD

Photosynthesis CRC Press
This technical book explores current and future applications ofsolar power as an unlimited source of energy that earth receivesevery day. Photosynthetic organisms have learned to utilizethis abundant source of energy by converting it into high-energybiochemical compounds. Inspired by the efficient conversionof solar energy into an electron flow, attempts have been made toconstruct artificial photosynthetic systems capable of establishinga charge separation state for generating electricity or drivingchemical reactions. Another important aspect ofphotosynthesis is the CO2 fixation and the production of highenergy compounds. Photosynthesis can produce biomass usingsolar energy while reducing the CO2 level in air. Biomass canbe converted into biofuels such as biodiesel and bioethanol. Undercertain conditions, photosynthetic organisms can also producehydrogen gas which is one of the cleanest sources of energy.
Handbook of Porphyrin Science (Volumes 6 – 10): With Applications to Chemistry, Physics, Materials Science, Engineering, Biology and Medicine Emereo Publishing
Jules Verne (1828-1905), author of Around the World in Eighty Days (1873) and Journey to the Center of the Earth (1864), wrote in 1875 “I believe that water will one day be used as a fuel,

because the hydrogen and oxygen which constitute it, used separately or together, will furnish an inexhaustible source of heat and light. I therefore believe that, when coal (oil) deposits are oxidised, we will heat ourselves by means of water. Water is the fuel of the future" Solar energy is the only renewable energy source that has sufficient capacity for the global energy need; it is the only one that can address the issues of energy crisis and global climate change. A vast amount of solar energy is harvested and stored via photosynthesis in plants, algae, and cyanobacteria since over 3 billion years. Today, it is estimated that photosynthesis produces more than 100 billion tons of dry biomass annually, which would be equivalent to a hundred times the weight of the total human population on our planet at the present time, and equal to a global energy storage rate of about 100 TW. The solar power is the most abundant source of renewable energy, and oxygenic photosynthesis uses this energy to power the planet using the amazing reaction of water splitting. During water splitting, driven ultimately by sunlight, oxygen is released into the atmosphere, and this, along with food production by photosynthesis, supports life on our earth. The other product of water oxidation is "hydrogen" (proton and electron). This 'hydrogen' is not normally released into the atmosphere as hydrogen gas but combined with carbon dioxide to make high energy containing organic molecules. When we burn fuels

we combine these organic molecules with oxygen. The design of new solar energy systems must adhere to the same principle as that of natural photosynthesis. For us to manipulate it to our benefit, it is imperative that we completely understand the basic processes of natural photosynthesis, and chemical conversion, such as light harvesting, excitation energy transfer, electron transfer, ion transport, and carbon fixation. Equally important, we must exploit application of this knowledge to the development of fully synthetic and/or hybrid devices. Understanding of photosynthetic reactions is not only a satisfying intellectual pursuit, but it is important for improving agricultural yields and for developing new solar technologies.

Today, we have considerable knowledge of the working of photosynthesis and its photosystems, including the water oxidation reaction. Recent advances towards the understanding of the structure and the mechanism of the natural photosynthetic systems are being made at the molecular level. To mimic natural photosynthesis, inorganic chemists, organic chemists, electrochemists, material scientists, biochemists, biophysicists, and plant biologists must work together and only then significant progress in harnessing energy via “artificial photosynthesis” will be possible. This Research Topic provides recent advances of our understanding of photosynthesis, gives to our readers recent information on photosynthesis research, and

summarizes the characteristics of the natural system from the standpoint of what we could learn from it to produce an efficient artificial system, i.e., from the natural to the artificial. This topic is intended to include exciting breakthroughs, possible limitations, and open questions in the frontiers in photosynthesis research.
Photosynthesis World Scientific Publishing
Artificial photosynthesis, in broad terms, is the process for converting solar energy into a useful fuel for storage and mobile use, as photosynthesis in plants and algae does. Replication of the photosynthetic process would mark a significant achievement in the production of clean energy while also reducing CO2 in the atmosphere. Artificially replicating the process however, presents several challenges and thus far, extensive efforts have been devoted to water splitting to produce hydrogen as a solar fuel in heterogeneous photocatalysis. The molecular-based mimicry of the fundamental processes occurring in photosynthesis have attracted much attention including: light harvesting, charge separation, water oxidation, NAD(P)+ reduction and CO2 fixation. Each of these processes, however, have been researched separately in their respective fields of study. This textbook aims to provide a unified view, and future perspective, of artificial photosynthesis while discussing and reviewing all of the artificial molecular processes together. This textbook is an

ideal single-source reference for any student or early career researcher interested in the study of molecular-based artificial photosynthesis systems.
Photosynthesis and Bioenergetics John Wiley & Sons
Discover a new generation of organic nanomaterials and their applications Recent developments in nanoscience and nanotechnology have given rise to a new generation of functional organic nanomaterials with controlled morphology and well-defined properties, which enable a broad range of useful applications. This book explores some of the most important of these organic nanomaterials, describing how they are synthesized and characterized. Moreover, the book explains how researchers have incorporated organic nanomaterials into devices for real-world applications. Featuring contributions from an international team of leading nanoscientists, Organic Nanomaterials is divided into five parts: Part One introduces the fundamentals of nanomaterials and self-assembled nanostructures Part Two examines carbon nanostructures—from fullerenes to carbon nanotubes to graphene—reporting on properties, theoretical studies, and applications Part Three investigates key aspects of some inorganic materials, self-assembled monolayers, organic field effect transistors, and molecular self-assembly at solid surfaces Part Four explores topics that involve both biological aspects and nanomaterials such as biofunctionalized surfaces Part Five

offers detailed examples of how organic nanomaterials enhance sensors and molecular photovoltaics Most of the chapters end with a summary highlighting the key points. References at the end of each chapter guide readers to the growing body of original research reports and reviews in the field. Reflecting the interdisciplinary nature of organic nanomaterials, this book is recommended for researchers in chemistry, physics, materials science, polymer science, and chemical and materials engineering. All readers will learn the principles of synthesizing and characterizing new organic nanomaterials in order to support a broad range of exciting new applications.

Principles and Applications of Artificial Photosynthesis National Academies Press

This comprehensive book systematically covers the fundamentals in solar energy conversion to chemicals, either fuels or chemical products. It includes natural photosynthesis with emphasis on artificial processes for solar energy conversion and utilization. The chemical processes of solar energy conversion via homogeneous and/or heterogeneous photocatalysis has been described with the mechanistic insights. It also consists of reaction systems toward a variety of applications, such as water splitting for hydrogen or oxygen evolution, photocatalytic CO2 reduction to fuels, and light driven N2 fixation, etc. This unique book offers the readers a broad view of solar energy utilization based on chemical processes and their

perspectives for future sustainability.
Design, Concepts and Applications
Springer Science & Business Media
MOLECULAR MECHANISMS OF PHOTOSYNTHESIS Rediscover the foremost introduction to molecular photosynthesis on the market today In the comprehensively revised Third Edition of Molecular Mechanisms of Photosynthesis, distinguished researcher and professor Robert E. Blankenship delivers a brand-new update to the most authoritative textbook on the subject of photosynthesis. In addition to thorough coverage of foundational topics in photosynthesis, the book discusses cutting-edge advances in research in this area, including new structures and new information about the mechanism of oxygen production. The author also describes advancements in the understanding of the regulation of photosynthesis and the critical process of photoprotection, as well as newly discovered pigments and organisms that extend oxygenic photosynthesis deeper into the near infrared spectral region. Readers will also benefit from the inclusion of a fulsome appendix that incorporates a detailed introduction to the physical basis of photosynthesis, including thermodynamics, kinetics, and spectroscopy. A companion website offers downloadable figures as PowerPoint slides ideal for teaching. The book also includes: Thorough introductions to the basic principles of photosynthetic energy storage, photosynthetic organisms and organelles, and the history and early

development of photosynthesis An expansive discussion of photosynthetic pigments, including their structure and spectroscopy Explorations of antenna complexes, energy transfer processes, reaction centers, and electron transport pathways in anoxygenic phototrophs and oxygenic photosynthetic organisms Comprehensive treatments of chemiosmotic coupling, ATP synthesis, and carbon metabolism Authoritative discussions of the evolution of photosynthesis and artificial photosynthesis Perfect for advanced undergraduate and beginning graduate students in biochemistry and biophysics, Molecular Mechanisms of Photosynthesis will also earn a place in the libraries of students studying plant biology and seeking a one-stop resource in the field of molecular photosynthesis.

Chemical Energy Storage John Wiley & Sons

“Photosynthesis: Plastid Biology, Energy Conversion and Carbon Assimilation” was conceived as a comprehensive treatment touching on most of the processes important for photosynthesis. Most of the chapters provide a broad coverage that, it is hoped, will be accessible to advanced undergraduates, graduate students, and researchers looking to broaden their knowledge of photosynthesis. For biologists, biochemists, and biophysicists, this volume will provide quick background understanding for the breadth of issues in photosynthesis that are important in research and instructional settings. This volume will be of interest to advanced

undergraduates in plant biology, and plant biochemistry and to graduate students and instructors wanting a single reference volume on the latest understanding of the critical components of photosynthesis.

250 Scenarios from Classical to Modern Times Artificial PhotosynthesisFrom Basic Biology to Industrial Application

Sustainable Materials and Green Processing for Energy Conversion provides a concise reference on green processing and synthesis of materials required for the next generation of devices used in renewable energy conversion and storage. The book covers the processing of bio-organic materials, environmentally-friendly organic and inorganic sources of materials, synthetic green chemistry, bioresorbable and transient properties of functional materials, and the concept of sustainable material design. The book features chapters by worldwide experts and is an important reference for students, researchers, and engineers interested in gaining extensive knowledge concerning green processing of sustainable, green functional materials for next generation energy devices. Additionally, functional materials used in energy devices must also be able to degrade and decompose with minimum energy after being disposed of at their end-of-life. Environmental pollution is one of the global crises that endangers the life cycles of living things. There are multiple root causes of this pollution, including

industrialization that demands a huge supply of raw materials for the production of products related to meeting the demands of the Internet-of-Things. As a result, improvement of material and product life cycles by incorporation of green, sustainable principles is essential to address this challenging issue. Offers a resourceful reference for readers interested in green processing of environmentally-friendly and sustainable materials for energy conversion and storage devices Focuses on designing of materials through green-processing concepts Highlights challenges and opportunities in green processing of renewable materials for energy devices

Solar Energy for Life CABI

This book covers the field of solar production of hydrogen by water photo-splitting (photoelectrolysis) using semiconductor photoanodes. The emphasis of the discussion is on the use of nanotechnology in the field. The theories behind photocatalysis and photoelectrochemical processes responsible for hydrogen production are given in detail. This provides a state-of-the-art review of the semiconductor materials and methods used for improving the efficiency of the processes. The book also gives an account of the techniques used for making the nanostructures.

Synthesis, Characterization, and Device Applications Edward Elgar Publishing

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treatment touching on most of the processes important for photosynthesis. Most of the chapters provide a broad coverage that, it is hoped, will be accessible to advanced undergraduates, graduate students, and researchers looking to broaden their knowledge of photosynthesis. For biologists, biochemists, and biophysicists, this volume will provide quick background understanding for the breadth of issues in photosynthesis that are important in research and instructional settings. This volume will be of interest to advanced undergraduates in plant biology, and plant biochemistry and to graduate students and instructors wanting a single reference volume on the latest understanding of the critical components of photosynthesis.

Molecular Solar Fuels John Wiley & Sons
The new best thing Artificial photosynthesis. There has never been a Artificial photosynthesis Guide like this. It contains 36 answers, much more than you can imagine; comprehensive answers and extensive details and references, with insights that have never before been offered in print. Get the information you need--fast! This all-embracing guide offers a thorough view of key knowledge and detailed insight. This Guide introduces what you want to know about Artificial photosynthesis. A quick look inside of some of the subjects covered: Green electricity, World peace - Economic norms theory, Sustainability - Human relationship to nature, Water splitting - Electrolysis, Futures studies - Science and technology for

sustainability, Photoelectrochemical cell - Photogeneration cell, List of solar energy topics - A, Uneconomic growth - The role of technology, and Jevon's paradox, Water splitting - Photoelectrochemical water splitting, Steady state economy - Policies for the transition, Thomas Alured Faunce - Sustainable energy research, Conscience - World conscience, Andrew B. Bocarsly - Carbon Dioxide Conversion Research / Liquid Light inc., Peidong Yang, Nathan Lewis, Sustainocene - Artificial photosynthesis powering the sustainocene, California Institute of Technology - 21st century, Common heritage of humanity - Controversies about the principle, Thomas Alured Faunce - Career, Climate change in popular culture - Fiction, David Wendell, Joint Center for Artificial Photosynthesis, Sustainocene - Correlation with geophysics, World Future Society - The Futurist, Hydrogen economy - Photoelectrochemical water splitting, Solar chemical, Peidong Yang - Career, Dan Nocera - Career, Rights of Nature - Future Developments, Conscience - Evolutionary biology and physics, Solar fuel, Clean energy, Renewable energy, Lord Howe Island - Climate change, and much more...

Photochemical Modes Royal Society of Chemistry

This study aims to address the deficiencies of the Marcus model of electron transfer (ET) and then provide modifications to the model. A confirmation of the inverted energy gap law, which is the cleanest verification so

far, is presented for donor-acceptor complexes. In addition to the macroscopic properties of the solvent, the physical properties of the solvent are incorporated in the model via the microscopic solvation model. For the molecules studied in this dissertation, the rate constant first increases with cooling, in contrast to the prediction of the Arrhenius law, and then decreases at lower temperatures. Additionally, the polarizability of solute, which was not considered in the original Marcus theory, is included by the Q-model of ET. Through accounting for the polarizability of the reactants, the Q-model offers an important design principle for achieving high performance solar energy conversion materials. By means of the analytical Q-model of ET, it is shown that including molecular polarizability of C60 affects the reorganization energy and the activation barrier of ET reaction. The theory and electrochemistry of Ferredoxin and Cytochrome c are also investigated. By providing a new formulation for reaction reorganization energy, a long-standing disconnect between the results of atomistic simulations and cyclic voltametery experiments is resolved. The significant role of polarizability of enzymes in reducing the activation energy of ET is discussed. The binding/unbinding of waters to the active site of Ferredoxin leads to non-Gaussian statistics of energy gap and result in a smaller activation energy of ET. Furthermore, the dielectric constant of water at the interface of neutral and charged C60 is

studied. The dielectric constant is found to be in the range of 10 to 22 which is remarkably smaller compared to bulk water(80). Moreover, the interfacial structural crossover and hydration thermodynamic of charged C60 in water is studied. Increasing the charge of the C60 molecule result in a dramatic structural transition in the hydration shell, which lead to increase in the population of dangling O-H bonds at the interface.

Learning from Nature John Wiley & Sons

At a time when the world's food supplies are increasingly unable to meet the needs of a burgeoning population, there is significant diversity of opinion concerning the benefits and perceived dangers of the application of biotechnology to food production. Plants, Biotechnology and Agriculture provides the reader with a guide to plants as both organisms and resources. The first half of the book gives an overview of plant biology, suitable for students of plant biology and agriculture as well as those without a biology background. This is followed by an outline of the human exploitation of plants, from domestication to scientific manipulation. Further chapters describe the technologies that are now being used to improve crops, society's responses to these technologies, and how they are being modified as a result. The book concludes with a discussion of future challenges for biotechnology in the face of rapid population growth, depletion of non-renewable resources and climate change.

Fundamentals of Nanotechnology Academic Press
Modern technological development has been both rapid and fundamentally transformative of the means and methods of warfare, and of the broader environment in which warfare is conducted. In many cases, technological development has been stimulated by, and dedicated to, addressing military requirements. On other occasions, technological developments outside the military sphere affect or inform the conduct of warfare and military expectations. The introduction of new technologies such as information technology, space technologies, nanotechnology and robotic technologies into our civil life, and into warfare, is expected to influence the application and interpretation of the existing rules of the law of armed conflict. In this book, scholars and practitioners working in the fields critically examine the potential legal challenges arising from the use of new technologies and future directions of legal development in light of the specific characteristics and challenges each technology presents with regard to foreseeable humanitarian impacts upon the battlespace.
Current challenges in photosynthesis: From natural to artificial Springer Science & Business Media
Energy – in the headlines, discussed controversially, vital. The use of regenerative energy in many primary forms leads to the necessity to store grid dimensions for maintaining continuous supply and enabling the replacement of

fossil fuel systems. Chemical energy storage is one of the possibilities besides mechano-thermal and biological systems. This work starts with the more general aspects of chemical energy storage in the context of the geosphere and evolves to dealing with aspects of electrochemistry, catalysis, synthesis of catalysts, functional analysis of catalytic processes and with the interface between electrochemistry and heterogeneous catalysis. Top-notch experts provide a sound, practical, hands-on insight into the present status of energy conversion aimed primarily at the young emerging research front.
Solar Power as an Energy Source World Scientific
Photosynthesis has been an important field of research for more than a century, but the present concerns about energy, environment and climate have greatly intensified interest in and research on this topic. Research has progressed rapidly in recent years, and this book is an interesting read for an audience who is concerned with various ways of harnessing solar energy. Our understanding of photosynthesis can now be said to have reached encyclopedic dimensions. There have been, in the past, many good books at various levels. Our book is expected to fulfill the needs of advanced undergraduate and beginning graduate students in branches of biology, biochemistry, biophysics, and bioengineering because photosynthesis is the basis of future advances in producing more food, more biomass,

more fuel, and new chemicals for our expanding global human population. Further, the basics of photosynthesis are and will be used not only for the above, but in artificial photosynthesis, an important emerging field where chemists, researchers and engineers of solar energy systems will play a major role.

Solar-to-Chemical Conversion Springer

Artificial PhotosynthesisFrom Basic Biology to Industrial ApplicationJohn Wiley & Sons

Handbook of Porphyrin Science (Volumes 16 – 20): With Applications to Chemistry, Physics, Materials Science, Engineering, Biology and Medicine Elsevier

"Chromic phenomena, or those produced by materials which exhibit colour in response to a chemical or physical stimulus, have increasingly been at the heart of 'high-tec' developments in a variety of fields in the last decade. Many of the newer technologies, which are at the cutting edge of research, are multi-disciplinary, involving researchers from areas as diverse as physics, biology, materials science and electronic engineering. Chromic Phenomena covers five main areas: * Colour change materials, such as photochromic, thermochromic and electrochromic materials * Materials which absorb and reflect light - the classical dyes and pigments * Luminescent phenomena, including phosphorescence, fluorescence and electroluminescence * Materials which absorb light and transfer energy, eg photosensitisers, infra-red absorbers and laser-addressable compounds *

Phenomena involving the manipulation of light by chemicals, such as liquid crystals, lustre pigments, optoelectronics and photonics Providing an entry point both for new researchers and for established ones, this book, with its emphasis on the technological applications of these chromic phenomena, develops and investigates new applications for colour chemistry. It will be of interest to industrialists and professionals in the biological, medicinal, electronics/telecommunications and colorant industries, as well as academics in these fields."

Science at the Frontier Academic Press

The maturation of nanotechnology has revealed it to be a unique and distinct discipline rather than a specialization within a larger field. Its textbook cannot afford to be a chemistry, physics, or engineering text focused on nano. It must be an integrated, multidisciplinary, and specifically nano textbook. The archetype of the modern nano textbook, Introduction to Nanoscience and Nanotechnology builds a solid background in characterization and fabrication methods while integrating the physics, chemistry, and biology facets. The remainder of this color text focuses on applications, examining engineering aspects as well as nanomaterials and industry-specific applications in such areas as energy, electronics, and biotechnology. Also available in two course-specific volumes: Introduction to Nanoscience elucidates the nanoscale along with the societal

impacts of nanoscience, then presents an overview of characterization and fabrication methods. The authors systematically discuss the chemistry, physics, and biology aspects of nanoscience, providing a complete picture of the challenges, opportunities, and inspirations posed by each facet before giving a brief glimpse at nanoscience in action: nanotechnology. Fundamentals of Nanotechnology surveys the field’s broad landscape, exploring the physical basics such as nanorheology, nanofluidics, and nanomechanics as well as industrial concerns such as manufacturing, reliability, and safety. The authors then explore the vast range of nanomaterials and systematically outline devices and applications in various industrial sectors. Qualifying instructors who purchase either of these volumes (or the combined set) are given online access to a wealth of instructional materials. These include detailed lecture notes, review summaries, slides, exercises, and more. The authors provide enough material for both one- and two-semester courses. Frontiers E-books
WINNER 2009 CHOICE AWARD OUTSTANDING ACADEMIC TITLE! Nanotechnology is no longer a subdiscipline of chemistry, engineering, or any other field. It represents the convergence of many fields, and therefore demands a new paradigm for teaching. This textbook is for the next generation of nanotechnologists. It surveys the field’s broad landscape, exploring the physical basics such as

nanorheology, nanofluidics, and nanomechanics as well as industrial concerns such as manufacturing, reliability, and safety. The authors then explore the vast range of nanomaterials and systematically outline devices and applications in various industrial sectors. This color text is an ideal companion to Introduction to Nanoscience by the same group of esteemed authors. Both titles are also available as the single volume Introduction to Nanoscience and Nanotechnology Qualifying instructors who purchase either of these volumes (or the combined set) are given online access to a wealth of instructional materials. These include detailed lecture notes, review summaries, slides, exercises, and more. The authors provide enough material for both one- and two-semester courses.