

# Bioelectrochemical Systems From Extracellular Electron Transfer To Biotechnological Application Integrated Environmental Technology

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## HUFFMAN TAPIA

*Electron-Based Bioscience and Biotechnology* Frontiers Media SA

This volume discusses both the latest experimental research in bioelectrosynthesis and current applications. Beginning with an introduction into the "electrification of biotechnology" as well as the underlying fundamentals, the volume then discusses a wide range of topics based on the interfacing of biotechnological and electrochemical reaction steps. It includes contributions on the different aspects of bioelectrochemical applications for synthesis purposes, i.e. the production of fine and platform chemicals based on enzymatically or microbially catalyzed reactions driven by electric energy. The volume finishes with a summary and outlook chapter which gives an overview of the current status of the field and future perspectives. Edited by experts in the field, and authored by a wide range of international researchers, this volume assesses how research from today's lab bench can be developed into industrial applications, and is of interest to researchers in academia and industry.

*Fundamentals and Applications* John Wiley & Sons

This book covers the principles, underlying mechanisms, thermodynamic functions, kinetics and modeling aspects of sustainable technologies, particularly from the standpoint of applying physical, chemical and biological processes for the treatment of wastewater polluted with heavy metals. Particular emphasis has been given to technologies that are based on adsorption, electro-coagulation, bio-precipitation, bio-solubilization, phytoremediation and microbial electrolysis. Metal contamination in the environment is one of the persisting global issues. The adverse health effects of heavy metals on human beings and its impact on the environment has been well-documented. Several physico-chemical and biological technologies have been successfully implemented to prevent and control the discharge of industrial heavy metal emissions. On the contrary, metal resource depletion has also accelerated dramatically during the 20th century due to rapid advances in industrial engineering and medical sciences, which requires large amount of raw materials. To meet the global metal demand, in recent years, novel research lines have started to focus on the recovery of metals from metal contaminated waste streams. In order to conflate both metal removal and recovery, new technologies have been successfully tested, both at the lab and pilot-scale. The target audience of this book primarily comprises of research experts, practicing engineers in the field of environmental/chemical technology and graduate students.

*From Laboratory Practice to Data Interpretation* Frontiers Media SA

There are a large number of books available on fuel cells; however, the majority are on specific types of fuel cells such as solid oxide fuel cells, proton exchange membrane fuel cells, or on specific technical aspects of fuel cells, e.g., the system or stack engineering. Thus, there is a need for a book focused on materials requirements in fuel cells. Key Materials in Low-Temperature Fuel Cells is a concise source of the most important and key materials and catalysts in low-temperature fuel cells. A related book will cover key materials in high-temperature fuel cells. The two books form part of the "Materials for Sustainable Energy & Development" series. Key Materials in Low-Temperature Fuel Cells brings together world leaders and experts in this field and provides a lucid description of the materials assessment of fuel cell technologies. With an emphasis on the technical development and applications of key materials in low-temperature fuel cells, this text covers fundamental principles, advancement, challenges, and important current research themes. Topics covered include: proton exchange membrane fuel cells, direct methanol and ethanol fuel cells, microfluidic fuel cells, biofuel

cells, alkaline membrane fuel cells, functionalized carbon nanotubes as catalyst supports, nanostructured Pt catalysts, non-PGM catalysts, membranes, and materials modeling. This book is an essential reference source for researchers, engineers and technicians in academia, research institutes and industry working in the fields of fuel cells, energy materials, electrochemistry and materials science and engineering.

*Principles and Engineering* Springer

This book presents the state of the art technologies and solutions to tackle the critical challenges faced by the building and development of the WSN and ecological monitoring system but also potential impact on society at social, medical and technological level. This book is dedicated to Sensing systems for Sensors, Wireless Sensor Networks and Ecological Monitoring. The book aims at Master and PhD degree students, researchers, practitioners, especially WSN engineers involved with ecological monitoring. The book will provide an opportunity of a dedicated and a deep approach in order to improve their knowledge in this specific field.

**Microbial Electrochemical Technologies** CRC Press

Current research fields in science and technology were presented and discussed at the EKC2008, informing about the interests and directions of the scientists and engineers in EU countries and Korea. The Conference has emerged from the idea of bringing together EU and Korea to get to know each other better, especially in fields of science and technology. The focus of the conference is put on the topics: Computational Fluid Dynamics, Mechatronics and Mechanical Engineering, Information and Communications Technology, Life and Natural Sciences, Energy and Environmental Technology.

**Biofilms in Bioelectrochemical Systems** Bentham Science Publishers

Biomass, Biofuels, Biochemicals encompasses the potential of microbial electrochemical technologies, delineating their role in developing a technology for abating environmental crisis and enabling transformation to a sustainable future. The book provides new and futuristic methods for bioelectrogenesis, multiple product synthesis, waste remediation strategies, and electromicrobiology generation which are widely essential to individuals from industry, marketing, activists, writers, etc. In addition, it provides essential knowledge transfer to researchers, students and science enthusiasts on Microbial Electrochemical Technologies, detailing the functional mechanisms employed, various operational configurations, influencing factors governing the reaction progress and integration strategies. With these key topics and features, the book generates interest among a wide range of people related to renewable energy generation and sustainable environmental research. Depicts the holistic view of the multiple applications of Microbial Electrochemical Technologies (METs) in a unified comprehensible manner Provides strategic integrations of MET with various bioprocesses that are essential in establishing a circular biorefinery Widens the scope of the existing technologies, giving up-to date, state-of-the-art information and knowledge on research and commercialization Contains topics that are lucid, providing interdisciplinary knowledge on the environment, molecular biology, engineering, biotechnology, microbiology and economic aspects Includes more than 75 illustrations, figures, diagrams, flow charts, and tables for further study

**Wastewater Treatment** IWA Publishing

This book serves as a manual of research techniques for electrochemically active biofilm research. Using examples from real biofilm research to illustrate the techniques used for electrochemically active biofilms, this book is of most use to researchers and educators studying microbial fuel cell and bioelectrochemical systems. The book emphasizes the theoretical principles of bioelectrochemistry, experimental procedures and tools useful in quantifying electron transfer processes in biofilms, and mathematical modeling of electron transfer in biofilms. It is divided into three sections: Biofilms: Microbiology and microbioelectrochemistry - Focuses on the microbiologic

aspect of electrochemically active biofilms and details the key points of biofilm preparation and electrochemical measurement Electrochemical techniques to study electron transfer processes - Focuses on electrochemical characterization and data interpretation, highlighting key factors in the experimental procedures that affect reproducibility Applications - Focuses on applications of electrochemically active biofilms and development of custom tools to study electrochemically active biofilms. Chapters detail how to build the reactors for applications and measure parameters

**Immobilised Biocatalysts for Bioremediation of Groundwater and Wastewater** John Wiley & Sons

This timely book will introduce its readers to the

**Bioelectrochemical Systems** Springer

This book focuses on value addition to various waste streams, which include industrial waste, agricultural waste, and municipal solid and liquid waste. It addresses the utilization of waste to generate valuable products such as electricity, fuel, fertilizers, and chemicals, while placing special emphasis on environmental concerns and presenting a multidisciplinary approach for handling waste. Including chapters authored by prominent national and international experts, the book will be of interest to researchers, professionals and policymakers alike.

*Current Challenges and Future Perspectives on Emerging Bioelectrochemical Technologies* Elsevier

Nitrogen containing compounds produced by industrial processes are pollutants which pose a significant environmental and health hazard. There are a number of processes that have been devised for removing nitrogen compounds from wastewater. This reference book summarizes different denitrification methods for wastewater processing. The book introduces readers to toxic nitrogen compounds responsible for water pollution. This introduction is followed by chapters which explain different nitrogen removal methods including conventional methods, biological methods, food industry wastewater treatment and new approaches towards environmental pollution remediation: Bio Electrochemical Systems (BESs). This book is a handy reference guide for industrial and environmental engineers and students learning about wastewater management and industrial denitrification.

*From Extracellular Electron Transfer to Biotechnological Application* Springer

Microbial Biodegradation and Bioremediation: Techniques and Case Studies for Environmental Pollution, Second Edition describes the successful application of microbes and their derivatives for bioremediation of potentially toxic and relatively novel compounds in the environment. Our natural biodiversity and environment is in danger due to the release of continuously emerging potential pollutants by anthropogenic activities. Though many attempts have been made to eradicate and remediate these noxious elements, thousands of xenobiotics of relatively new entities emerge every day, thus worsening the situation. Primitive microorganisms are highly adaptable to toxic environments, and can reduce the load of toxic elements by their successful transformation and remediation. This completely updated new edition presents many new technologies and techniques and includes theoretical context and case studies in every chapter. Microbial Biodegradation and Bioremediation: Techniques and Case Studies for Environmental Pollution, Second Edition serves as a single-source reference and encompasses all categories of pollutants and their applications in a convenient, comprehensive format for researchers in environmental science and engineering, pollution, environmental microbiology, and biotechnology. Describes many novel approaches of microbial bioremediation including genetic engineering, metagenomics, microbial fuel cell technology, biosurfactants and biofilm-based bioremediation Introduces relatively new hazardous elements and their bioremediation practices including oil spills, military waste water, greenhouse gases, polythene wastes, and more Provides the most advanced techniques in the field of bioremediation, including insilico approach, microbes as pollution indicators, use of bioreactors, techniques of pollution monitoring, and more Completely updated and expanded to include topics and techniques such as genetically engineered bacteria, environmental health, nanoremediation, heavy metals, contaminant transport, and in situ and ex situ methods Includes theoretical context and case studies within each chapter

**Electrochemically Active Microorganisms** Springer

This book introduces the 3R concept applied to wastewater treatment and resource recovery under a double perspective. Firstly, it deals with innovative technologies leading to: Reducing energy requirements, space and impacts; Reusing water and sludge of sufficient quality; and Recovering resources such as energy, nutrients, metals and chemicals, including biopolymers. Besides targeting effective C,N&P removal, other issues such as organic micropollutants, gases and odours emissions are considered. Most of the technologies analysed have been tested at pilot- or at full-scale. Tools and methods for their Economic, Environmental, Legal and Social impact assessment are described. The 3R concept is also applied to Innovative Processes design, considering different levels of innovation: Retrofitting, where novel units are included in more conventional processes; Re-Thinking, which implies a substantial flowsheet modification; and Re-Imagining, with completely new conceptions. Tools are presented for Modelling, Optimising and Selecting the most suitable plant layout for each particular scenario from a holistic technical, economic and environmental point of view.

*Principles and Applications* John Wiley & Sons

This book serves as a manual of research techniques for electrochemically active biofilm research. Using examples from real biofilm research to illustrate the techniques used for electrochemically active biofilms, this book is of most use to researchers and educators studying microbial fuel cell and bioelectrochemical systems. The book emphasizes the theoretical principles of bioelectrochemistry, experimental procedures and tools useful in quantifying electron transfer processes in biofilms, and mathematical modeling of electron transfer in biofilms. It is divided into three sections: Biofilms: Microbiology and microbioelectrochemistry - Focuses on the microbiologic aspect of electrochemically active biofilms and details the key points of biofilm preparation and electrochemical measurement Electrochemical techniques to study electron transfer processes - Focuses on electrochemical characterization and data interpretation, highlighting key factors in the experimental procedures that affect reproducibility Applications - Focuses on applications of electrochemically active biofilms and development of custom tools to study electrochemically active biofilms. Chapters detail how to build the reactors for applications and measure parameters

*From Bioelectrorespiration to Bioelectrodegradation* Elsevier

Introduces basic principles and mechanisms, covers new developments, and provides a different view of the main facets of bioelectrosynthesis Bioelectrosynthesis represents a promising approach for storing renewable energy or producing target chemicals in an energy-sustainable and low-cost way. This timely and important book systemically introduces the hot issues surrounding bioelectrosynthesis, including potential value-added products via bioelectrochemical system, reactor development of bioelectrosynthesis, and microbial biology on biofilm communities and metabolism pathways. It presents readers with unique viewpoints on basic principles and mechanisms along with new developments on reactor and microbial ecology. Beginning with a principle and products overview of bioelectrosynthesis, Bioelectrosynthesis: Principles and Technologies for Value-Added Products goes on to offer in-depth sections on: biogas production and upgrading technology via bioelectrolysis; organic synthesis on cathodes; chemical products and nitrogen recovery; external electron transfer and electrode material promotion; and the microbiology of bioelectrosynthesis.

Topics covered include: hydrogen production from waste stream with microbial electrolysis cell; microbial electrolysis cell; inorganic compound synthesis in bioelectrochemical system; microbial growth, ecological, and metabolic characteristics in bioelectrosynthesis systems; microbial metabolism kinetics and interactions in bioelectrosynthesis system; and more. \* Comprehensively covers all of the key issues of bioelectrosynthesis \* Features contributions from top experts in the field \* Examines the conversion of organic wastes to methane via electromethanogenesis; methane production at biocathodes; extracellular electron transport of electroactive biofilm; and more Bioelectrosynthesis: Principles and Technologies for Value-Added Products will appeal to chemists, electrochemists, environmental chemists, water chemists, microbiologists, biochemists, and graduate students involved in the field.

*Principles and Technologies for Value-Added Products* IWA Publishing

Wastewater Treatment: Cutting-Edge Molecular Tools, Techniques and Applied Aspects reports new findings in existing molecular biology strategies, including their limitations, challenges and potential application to remove environmental pollutants through advancements made in cutting edge tools. In addition, the book introduces new trends and advances in environmental bioremediation with thorough discussions on recent developments in this field. Describes the application of different omics tools in wastewater treatment plants (WWTPs) Describes the role of microorganisms in WWTPs Points out the reuse of treated wastewater through emerging technologies Includes the recovery of resources from wastewater Emphasizes the need for the use of cutting-edge molecular tools

*Vol.1 Principles and Processes* Springer

The increasing demand for energy worldwide, currently evaluated at 13 terawatts per year, has triggered a surge in research on alternative energy sources more sustainable and environmentally friendly. Bio-catalyzed electrochemical systems (BESs) are a rapidly growing biotechnology for sustainable production of bioenergy and/or value-added bioproducts using microorganisms as catalysts for bioelectrochemical reactions at the electrode surface. In the last decades, this biotechnology has been intensively studied and developed as a flexible and practical platform for multiple applications such as electricity production, wastewater treatment, pollutants remediation, desalination and production of biogas, biofuels, or other commodities. BESs could have a critical impact on societies in many spheres of activity and become one of the solutions to reform our petroleum-based economy. However, BESs research has so far been limited to lab scale with the notable exceptions of pilot scale microbial fuel cells for brewery and winery wastewater treatment coupled with electricity generation. In general, more knowledge has to be acquired to overcome the issues that are stymieing BESs development and commercialization. For example, it is critical to understand better microbial physiology including the mechanisms responsible for the transfer of electrons between the microbes and the electrodes to start optimizing the systems in a more rational manner. There are many BES processes and for each one of them there is a multitude of biological and electrochemical specifications to investigate and adjust such as the nature of the microbial platform, electrode materials, the reactor design, the substrate, the medium composition, and the operating conditions. The ultimate goal is to develop highly energy efficient BESs with a positive footprint on the environment while maintaining low cost and generating opportunities to create value. BESs are complex systems developed with elements found in multiple fields of science such as microbiology, molecular biology, bioinformatics, biochemistry, electrochemistry, material science and environmental engineering. Given the high volume of research activities going on in the field of BESs today, this e-book explores the current challenges, the more recent progresses, and the future perspectives of BESs technologies. The BESs discussed here include microbial fuel cells, microbial electrolysis cells, microbial electrosynthesis cells, microbial electroremediation cells, etc.

*Phosphorus: Polluter and Resource of the Future* Royal Society of Chemistry

In the context of wastewater treatment, Bioelectrochemical Systems (BESs) have gained considerable interest in the past few years, and several BES processes are on the brink of application to this area. This book, written by a large number of world experts in the different sub-topics, describes the different aspects and processes relevant to their development. Bioelectrochemical Systems (BESs) use micro-organisms to catalyze an oxidation and/or reduction reaction at an anodic and cathodic electrode respectively. Briefly, at an anode oxidation of organic and inorganic electron donors can occur. Prime examples of such electron donors are waste organics and sulfides. At the cathode, an electron acceptor such as oxygen or nitrate can be reduced. The anode and the cathode are connected through an electrical circuit. If electrical power is harvested from this circuit, the system is called a Microbial Fuel Cell; if electrical power is invested, the system is called a Microbial Electrolysis Cell. The overall framework of bio-energy and bio-fuels is discussed. A number of chapters discuss the basics - microbiology, microbial ecology, electrochemistry, technology and materials development. The book continues by highlighting the plurality of processes based on BES technology already in existence, going from wastewater based reactors to sediment based bio-batteries. The integration of BESs into existing water or process lines is discussed. Finally, an outlook is provided of how BES will fit within the emerging biorefinery area.

*Bioremediation and Bioenergy* John Wiley & Sons

This book encompasses the most updated and recent account of research and implementation of Microbial Electrochemical Technologies (METs) from pioneers and experienced researchers in the field who have been working on the interface between electrochemistry and microbiology/biotechnology for many years. It provides a holistic view of the METs, detailing the functional mechanisms, operational configurations, influencing factors governing the reaction process and integration strategies. The book not only provides historical perspectives of the technology and its evolution over the years but also the most recent examples of up-scaling and near future commercialization, making it a must-read for researchers, students, industry practitioners and science enthusiasts. Key Features: Introduces novel technologies that can impact the future infrastructure at the water-energy nexus. Outlines methodologies development and application of microbial electrochemical technologies and details out the illustrations of microbial and electrochemical concepts. Reviews applications across a wide variety of scales, from power generation in the laboratory to approaches. Discusses techniques such as molecular biology and mathematical modeling; the future development of this promising technology; and the role of the system components for the implementation of bioelectrochemical technologies for practical utility. Explores key challenges for implementing these systems and compares them to similar renewable energy technologies, including their efficiency, scalability, system lifetimes, and reliability.

*Biofilms in Bioelectrochemical Systems* Bioelectrochemical Systems From Extracellular Electron Transfer to Biotechnological Application

An introduction to the fundamental concepts and rules in bioelectrochemistry and explores latest advancements in the field Bioelectrochemical Interface Engineering offers a guide to this burgeoning interdisciplinary field. The authors—noted experts on the topic—present a detailed explanation of the field's basic concepts, provide a fundamental understanding of the principle of electrocatalysis, electrochemical activity of the electroactive microorganisms, and mechanisms of electron transfer at electrode-electrolyte interfaces. They also explore the design and development of bioelectrochemical systems. The authors review recent advances in the field including: the development of new bioelectrochemical configurations, new electrode materials, electrode

functionalization strategies, and extremophilic electroactive microorganisms. These current developments hold the promise of powering the systems in remote locations such as deep sea and extra-terrestrial space as well as powering implantable energy devices and controlled drug delivery. This important book: • Explores the fundamental concepts and rules in bioelectrochemistry and details the latest advancements • Presents principles of electrocatalysis, electroactive microorganisms, types and mechanisms of electron transfer at electrode-electrolyte interfaces, electron transfer kinetics in bioelectrocatalysis, and more • Covers microbial electrochemical systems and discusses bioelectrosynthesis and biosensors, and bioelectrochemical wastewater treatment • Reviews microbial biosensor, microfluidic and lab-on-chip devices, flexible electronics, and paper and stretchable electrodes Written for researchers, technicians, and students in

chemistry, biology, energy and environmental science, Bioelectrochemical Interface Engineering provides a strong foundation to this advanced field by presenting the core concepts, basic principles, and newest advances.

**Bioelectrosynthesis** CRC Press

Artificial or constructed wetlands are an emerging technology particularly for tropical areas with water scarcity. For big cities, the sustainable management of water resources taking into account proper use is always challenging. The book presents case studies illustrating the above. As plants and microorganisms are a fundamental part of the correct functioning of these systems, their contribution to the degradation of the organic matter and to the removal and transformation of the pollutant compounds present in the wastewaters is also a highlight of this book.

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