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

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.

This brief introduces the structural and functional characterization of this important group of proteins. The content of each chapter is aimed at the non-specialist so that key concepts, methodologies and applications can be presented in a "snapshot" style volume. Multiheme cytochromes are ever more important now that it is possible to obtain genome sequences of microorganisms which have major biotechnological and environmental implications. There is a tremendous profusion of multiheme cytochromes which have great potential as targets for bioremediation and bioenergy applications. This brief gives a glimpse of an intriguing and fast-moving field.

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.

This book presents specific key natural and artificial systems that are promising biocatalysts in the areas of health, agriculture, environment and energy. It provides a comprehensive account of the state of the art of these systems and outlines the significant progress made in the last decade using these systems to develop innovative, sustainable and environmentally friendly solutions. Chapters from expert contributors explore how natural enzymes and artificial systems tackle specific targets such as: climate change, carbon footprint and economy and carbon dioxide utilisation; nitrogen footprint and fixation and nitrous oxide mitigation; hydrogen production, fuel cells and energy from bacteria; biomass transformation and production of added-value compounds, as well as biosensors development. This book provides an important and inspiring account for the designing of new natural and artificial systems with enhanced properties, and it appeals not only to students and researchers working in the fields of energy, health, food and environment, but also to a wider audience of educated readers that are interested in these up-to-date and exciting subjects. Chapter "Carbon Dioxide Utilisation—The Formate Route" is available open access under a Creative Commons Attribution 4.0 International License via link.springer.com.

Phosphorus: Polluter and Resource of the Future

Electron-Based Bioscience and Biotechnology

Innovative Wastewater Treatment & Resource Recovery Technologies: Impacts on Energy, Economy and Environment

Biofilms in Bioelectrochemical Systems

Fundamentals and Applications

Raw Materials from Biotechnology

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.

Some microorganisms dynamically alter their metabolic states in response to changes in the environmental conditions, such as availability of compatible electron donors and acceptors. A prominent example is nitrate, which is the most energetically favorable electron acceptor in the absence of oxygen and often dominantly controls microbial reactions taking place in anoxic systems. Solid electrodes present another substrate that can regulate microbial reactions, serving as an electron donor and/or electron acceptor for microbes capable of extracellular electron transfer (EET). Electrode-mediated microbial metabolisms are central in bioelectrochemical systems (BESs), an emerging technology with a variety of potential applications, including a novel experimental platform to study the dynamic change of microbial metabolisms with real-time monitoring under controlled conditions. A better characterization of microbial reactions associated with such key substrates has important implications to understand microbial reactions in anoxic environments and also developing biological processes that exploit relevant microbial metabolisms. This research investigated the capabilities and constraints of microbial metabolisms at the nexus of electrode- and nitrate-mediated respirations relevant to wastewater treatment processes. The facultative metabolic shift between anode electrode reduction and nitrate reduction was investigated in anode-reducing biofilms to study the effects of alternative metabolic options on exoelectrogenic biofilms in BESs. This has important implications not only to explain the fundamental ecology and performance of these systems, but also to develop reliable integrated nutrient removal strategies in BESs, which potentially involve nitrate that can support/induce alternative metabolisms. Using the exoelectrogenic nitrate reducer Geobacter metallireducens, the critical conditions controlling those alternative metabolisms were investigated in two-chamber, potentiostatically controlled BESs at various anode potentials, biofilm thicknesses, and nitrate concentrations. Results showed that anode-reducing biofilms preferentially reduced nitrate at all tested anode potentials (-150 to + 900 mV vs Standard Hydrogen Electrode) with a rapid metabolic shift, despite the fact that the biofilms had no prior nitrate exposure. The critical nitrate concentration that triggered a significant decrease in BES performance was a function of anode biofilm thickness but not anode potential. This indicates that these alternative metabolisms were controlled by the availability of nitrate, which is a function of nitrate concentration in the bulk solution and its diffusion into an anode-reducing biofilm. Coulombic recovery decreased as a function of nitrate dose due to electron-acceptor substrate competition, and nitrate-induced suspended biomass growth decreased the effluent quality. This nitrate-induced metabolic shift of anode-reducing biofilms was further investigated in the context of a shift between two different electrode-mediated metabolisms, electrode reduction and electrode oxidation. The characterization of metabolic shifts among different electrode-mediated reactions such as anode reduction and cathode oxidation is important to understand EETs in natural settings and also to develop stable BESs. This part of the research investigated the capability of anodically-grown G. metallireducens biofilms to shift from anode reduction to cathode oxidation. In tests with potentiostatically controlled graphite electrodes, G. metallireducens biofilms demonstrated a quick and alternative shift between anode reduction and cathode oxidation as a function of electrode potential and availability of the co-substrates nitrate and acetate. Cathodic electrode oxidation was coupled with nitrate reduction by metabolically active biofilms with a large cathodic current of ~ 3.68 A/m2. This metabolic shift from anode reduction to nitrate reduction took place quicker than the metabolic shift from ferric reduction to nitrate reduction. The presence of nitrate-reducing enzyme in the anode-reducing biofilms cells in the absence of nitrate, measured as specific in-vitro nitrate-reducing enzyme activity, was thought to enable such a quick metabolic shift to start nitrate reduction. Cyclic voltammetry and the analysis of its first derivative provided insights into the electron transfer mechanisms of these biofilms. Finally, the potential occurrence of dissimilatory nitrate reduction to ammonium (DNRA), a microbial nitrate-reducing metabolism that involves the sequential reduction of nitrate to nitrite and then nitrite to ammonium, was investigated in two full-scale wastewater treatment plants. DNRA in biological wastewater treatment systems and BESs is largely unstudied despite its potential impacts on system performance. This part of the research examined differential expression and diversity of nrfA, a key marker gene for DNRA, in activated sludge from full-scale domestic wastewater treatment plants with one designed for enhanced biological phosphorus removal (EBPR). Expression of nrfA, which encodes the penta-heme nitrite reductase NrfA catalyzing the nitrite ammonification step of DNRA, was observed in anaerobic and anoxic mixed liquor, but not in aerobic mixed liquor samples. The expression of nrfA under anaerobic and anoxic conditions suggests an overlooked potential for DNRA activity to occur in biological wastewater treatment systems. Some retrieved nrfA sequences were related to sequences associated with a microbial community with anammox activity, and the nrfA diversity in this wastewater treatment system differed from that observed in soil systems. Retrieved nrfA sequences both in genomic DNA and transcript samples were dominated by sequences associated with Actinobacteria, which are often abundant in EBPR processes. These results suggested potential occurrence of DNRA in wastewater activated sludge and encourage further studies in different types of wastewater treatment systems and with chemical tracer analyses to obtain comprehensive understanding of DNRA in this context. This research investigated dissimilatory nitrate reduction in electrode-respiring biofilms and full-scale wastewater treatment processes. Elucidating the dynamics of nitrate-dependent reactions of electrode-respiring G. metallireducens in the contexts of a competitive reaction to anode reduction and an alternative electrode-mediated reaction have implications for BES development. Moreover, the experimental frameworks that were developed to address those problems would be applicable to study other electrode-mediated microbial metabolisms. Findings of nrfA expression and its diversity in full-scale wastewater treatment processes indicated potential occurrences of DNRA in wastewater treatment processes, which would have implications for energy and chemical utilization in these systems, and broadened the representation of diversity in the rather limited nrfA database.

This volume presents the fundamentals and advances in state-of-the-art catalytic nanoscale interventions to improve the efficiency of bioelectrochemical systems. These systems are used in a number of applications in the water-energy nexus. Contributed chapters describe and build on useful strategies to use and reference when dealing with an important environmental issue: the final disposal of heavy metal catalysts. Summarizing basic and translational research, these chapters are valuable for researchers in energy, nanotechnology, and catalysis.

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.

Materials for Low-Temperature Fuel Cells

Microbial Extracellular Electron Transfer

Advances in Chemical Bioanalysis

From Bioelectrorespiration to Bioelectrodegradation

Study of Electron Transfer Mechanism in Biofilms

Microbial Community and Electrochemistry of Bioelectrochemical Systems

This timely book will introduce its readers to the

This book reviews the latest advances in the bioelectrochemical degradation of recalcitrant environmental contaminants. The first part introduces readers to the basic principles and methodologies of bioelectrochemical systems, electron-respiring microorganisms, the electron transfer mechanism and functional electrode materials. In turn, the second part addresses the bioelectrochemical remediation/treatment of various environmental pollutants (including highly toxic refractory organics, heavy metals, and nitrates) in wastewater, sediment and wetlands. Reactor configuration optimization, hybrid technology amplification and enhanced removal principles and techniques are also discussed. The book offers a valuable resource for all researchers and professionals working in environmental science and engineering, bioelectrochemistry, environmental microbiology and biotechnology.

This book is the first in a two-volume set devoted to bioelectrochemical systems (BESs) and the opportunities that they may offer in providing a green solution to growing energy demands worldwide. In this first volume, established research professionals explain the underlying principles and processes of BESs, providing a thorough introduction to these systems before proceeding to address the roles of cathode catalysts and biocatalysts, biofilms, heterotrophic denitrification, and nanotechnology approaches. This volume forms a sound foundation for understanding the potential industrial applications of this technology, which include in particular the generation of high-value chemicals and energy using organic wastes. These applications are the focus of the second volume, where readers will find up-to-date information on microbial fuel cells and the use of microbial biofilm- and algae-based bioelectrochemical systems for bioremediation and co-generation of valuable chemicals. The book is designed for a broad audience, including undergraduates, postgraduates, energy researchers/scientists, policymakers, and anyone else interested in the latest developments in this field.

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.

Current Challenges and Future Perspectives on Emerging Bioelectrochemical Technologies

Waste to Wealth

Electrochemically Active Microorganisms

Immobilised Biocatalysts for Bioremediation of Groundwater and Wastewater

Microbe-electrode Interactions: The Chemico-physical Environment and Electron Transfer

Bioelectrosynthesis

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, experimer 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 techniqu 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 measur parameters

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 a 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 biorefiner 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 stu

This book offers a comprehensive introduction to electron-based bioscience, biotechnology, and biocorrosion. It both explains the importance of electron flow during metabolic processes in microorganisms and provides valuable insights into emerging applications in various fields. In the opening section, readers will find up-to-date information on topics such as electron transfer reactions, extracellular electro transfer mechanisms, direct interspecies electron transfer, and electron uptake by sulfate-reducing bacteria. The focus then shifts to state-of-the-art advances and applications in the field of biotechnology. Here, the coverage encompasses e.g. progress in understanding electrochemical interactions between microorganisms and conductive particles, enzymatic reactions and their application in the bioproduc useful chemicals, and the importance of redox balance for fatty acid production. In closing, the book addresses various aspects of the complex phenomenon of microbiologically induced corrosion, highlighting novel insights from the fields of electromicrobiology and electrochemistry and their implications.

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.

Bioelectrochemical Interface Engineering

Novel Catalyst Materials for Bioelectrochemical Systems

Waste Valorization and Waste Biorefinery

Multiheme Cytochromes

Principles and Technologies for Value-Added Products

Microbial Biofilms in Bioremediation and Wastewater Treatment

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 produ 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-dep 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, ecolo characteristics in bioelectrosynthesis systems; microbial metabolism kinetics and interactions in bioelectrosynthesis system; and more. * Comprehensively covers all of the key issues of biolelectrosynthesis * 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 m 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.

Microbial fuel cell (MFC) is a major type of bioelectrochemically systems (BESs) that focus on the direct electricity production from biodegradable materials. Furthermore, applications have been developed through utilizing this electrical current to produce H2 (microbial electrolysis cells, MECs), or driving water desalination (microbial desalination cells, MDCs). However, one major challenge for widespread integration of MFCs or BESs is the generated. Instead of optimizing of the fuel cell design or scaling-up electrode area to enhance the output energy of MFCs, the key factor for improving the electricity production in MFCs is to understand the extracellular electron transfer (EET) mechanism, metabolic activities and metabolism of the microbes used in such MFCs and BESs. Chapter 2 introduces dissimilatory metal-reducing bacteria, such as Shewanella oneidensis MR-1 and from metabolism. We demonstrate an on-chip electrochemical system to study the EET pathway on both Shewanella oneidensis MR-1 and Geobacter spp under aerobic and anaerobic conditions. Chapter 3-4 explores electron transfer from an electrochemically active bacteria (EAB) to an insoluble substrate such as Fe(III), Mn(IV) and U(VI) can occur by direct or mediated electron transfer pathway. However, it is critical to understand the E metabolism of the microbes in biofilms which used in MFC. By exploring the specific interaction between Shewanella oneidensis MR-1 and insoluble substrate, the remarkable chemical factor has been discovered to influence the recognition, motion attachment/detachment and colonization between Shewanella oneidensis MR-1 and Fe2O3 substrate. We also developed a method for studying the EET pathway, metabolic activities status an current production in the microfluidic flow system. The dissimilatory metal-reducing bacteria (DMRB) Shewanella oneidensis MR-1 wild type (WT), mtrC omcA and bfe mutant cells are the model organisms for in-situ real time electrochemical current measurement. Our goal is to develop a novel bioelectronic device to study the EET mechanism, bacteria behavior in single cell level, metabolic activities status, bacteria behavior for maximal ele artificial modification or coloration process.

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 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 m 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 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.

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, Engineering, Information and Communications Technology, Life and Natural Sciences, Energy and Environmental Technology.

From Extracellular Electron Transfer to Biotechnological Application

Characteristics, Analysis and Control

A Suitable Technology for Sustainable Water Management

Natural and Artificial Systems in Health, Agriculture, Environment and Energy

One-Carbon Feedstocks for Sustainable Bioproduction

Bioelectrochemical Systems as Tools to Study Subsurface Biogeochemical Processes

The European project MINOTAURUS explored innovative bio-processes to eliminate emerging and classic organic pollutants. These bio-processes are all based on the concept of immobilization of biocatalysts (microorganisms and enzymes) and encompass bioaugmentation, enzyme technology, rhizoremediation with halophytes, and a bioelectrochemical remediation process. The immobilization-based technologies are applied as engineered ex situ treatment systems as well as natural systems in situ for the bioremediation of groundwater, wastewater and soil. The selection and application of tailored physico-chemical, molecularbiological and ecotoxicological monitoring tools combined with a rational understanding of engineering, enzymology and microbial physiology is a pertinent approach to open the black-box of the selected technologies. Reliable process monitoring constitutes the basis for developing and refining biodegradation kinetics models, which in turn improve the predictability of performances to be achieved with technologies. Immobilised Biocatalysts for Bioremediation of Groundwater and Wastewater delivers insight into the concepts and performance of a series of remediation approaches. A key strength of this book is to deliver results from lab-scale through to piloting at different European reference sites. It further suggests frameworks for structuring and making evidence-based decisions for the most appropriate bioremediation measures.

This book offers a comprehensive review of the latest developments, challenges and trends in C1-based (one-carbon based) bioproduction, and it presents an authoritative account of one-carbon compounds as promising alternative microbial feedstocks. The book starts with a perspective on the future of C1 compounds as alternative feedstocks for microbial growth, and their vital role in the establishment of a sustainable circular carbon economy, followed by several chapters in which expert contributors discuss about the recent strategies and address key challenges regarding one or more C1 feedstocks. The book covers topics such as acetogenic production from C1 feedstocks, aerobic carboxydotrophic bacteria potential in industrial biotechnology, bioconversion of methane to value-added compounds, combination of electrochemistry and biology to convert C1 compounds, and bioprocesses based on C1-mixotrophy. Particular attention is given to the current metabolic engineering, systems biology, and synthetic biology strategies applied in this field.

Microbes capable of extracellular electron transfer have been identified, characterized, and isolated from a wide variety of environments, including many soils and sediments. These uniquely-adapted microbes have been extensively studied in bioelectrochemical systems, such as microbial fuel cells, microbial electrolysis cells, and microbial three-electrode systems. These bioengineered systems capitalize on their ability to respire with insoluble electron acceptors, including solid-state electrodes. However, the role that these microbes play within the microbial community and biogeochemistry of the soils and sediments in which they are naturally found is less clear. Subsurface microbial communities perform many functions, including: degrading organic matter, controlling carbon and nutrient availability for primary producers, producing greenhouse gases, and mitigating anthropogenic pollutants. Therefore, it is critical to understand the complex community dynamics that govern soil microbiome structure in subsurface environments, and to link microbial processes with landscape level ecosystem function. To this end, I developed a cost-effective and field-ready potentiostat, capable of long-term operation in remote areas with poised subsurface electrodes and measuring respiration of iron- and humic acid-reducing microbes. I integrated these systems with measurements of greenhouse gas emission from soils and characterization of microbiome structure to link the microbial and landscape scales. I applied these techniques to two environments: (1) Arctic peat soils outside Barrow, Alaska to study the impacts of dissimilatory metal-reduction and microbial community structure on greenhouse gas emissions; and (2) sediments in a riparian zone near Ithaca, New York to study differences in biogeochemistry across hydrologic and spatial gradients. In the Arctic, potentiostatic monitoring of bacterial respiration revealed a correlation with soil temperature and the activation of microbes at deeper depths as the thaw progressed. Furthermore, bioelectrochemical manipulation altered microbial community structure, enriching for proteobacteria, bacteroidetes, and verrucomicrobia phyla, and these changes impacted landscapescale processes by increasing methane emissions 15-43%. This work demonstrates a new technique for linking the microbial and landscape scales, the fragility of carbon-rich high latitude soils, and the potential for increased methane emissions in response to small shifts in biogeochemistry. In riparian zones, which are often critical to the mitigation of anthropogenic nitrogen and phosphorus pollution in aquatic ecosystems, I found that microbial processes are highly variably across relatively small spatial gradients (~50 m). One location had lower methane emissions which did not change as a result of bioelectrochemical manipulation; however, at another site which had higher control methane emissions (factor of 2), bioelectrochemical manipulation severely (50%) inhibited methane emissions. Despite these differences in landscape scale response, microbial community structure at both sites was altered by manipulation. The work from both locations (Arctic and New York State) demonstrates the complexity of subsurface microbial community dynamics, their ability to be influenced by small changes in conditions, and the tangible impact that these processes have on landscape-scale processes. Understanding the links between the microbial and landscape scales will be essential to predicting response to external stimuli, such as anthropogenic pollution and climate change.

Expert authors provide critical, in-depth reviews of available methods for retrieving selective information out of complex biological systems. Sensors, probes and devices are present and future tools of medicinal diagnostics, environmental monitoring, food analysis and molecular biology. These are based on fluorescence, electrochemistry and mass spectrometry. Coverage of this volume includes sensor development for the detection of small analytes, monitoring of biomolecular interactions, analysis of cellular function, development of diagnostic tools.

Microbial Fuel Cell

Biofilms in Medicine, Industry and Environmental Biotechnology

The Autotrophic Biorefinery

A Techno-Economic Approach

MEET Applications for Biotechnology

The depletion of fossil resources and an ever-growing human population create an increasing demand for the development of sustainable processes for the utilization of renewable resources. As autotrophic microorganisms offer numerous metabolic pathways for the fixation of carbon dioxide and the metabolic utilization of light, electricity and inorganic energy donors, they are expected to play a pivotal role in an emerging carbon neutral society. This text-book presents the metabolic principles of autotrophy and current efforts for their utilization in biotechnology, including photoautotrophic, chemolithoautotrophic and electroautotrophic organisms. It outlines how modern molecular biology and process engineering create technologies that allow to use industrial off-gases and inorganic energy for the synthesis of bio-based plastics, materials and other chemical products. The text-book is ideally suited for students in advanced graduate and master courses and offers a reference for PhD students, engineers, chemists, biologists and all with an interests in biotechnology and renewable resources.

Biofilms represent the natural living style of microbial communities and play a pivotal role in biogeochemical cycles and natural attenuation. Biofilms can be engineered for biodegradation and biotransformation of organic and inorganic contaminants, for both in situ bioremediation and ex situ treatment in bioreactors. This book focuses on microbial biofilms and their potential technological applications for sustainable development. It covers recent advances in biofilm technologies for contaminant remediation coupled to recovery of resources and serves as a complete reference on the science and technology behind biofilm mediated bioremediation and wastewater treatment.

Bioelectrochemical SystemsFrom Extracellular Electron Transfer to Biotechnological ApplicationIWA Publishing

This comprehensive book provides an up-to-date and international approach that addresses the Motivations, Technologies and Assessment of the Elimination and Recovery of Phosphorus from Wastewater. This book is part of the Integrated Environmental Technology Series.

EKC 2009 Proceedings of EU-Korea Conference on Science and Technology

Microbial Electrochemical Technologies

Bioelectrochemistry Stimulated Environmental Remediation

Biofuels and Bioenergy

Biomass, Biofuels, Biochemicals

A Bioelectrochemical System that Converts Waste to Watts

Biofuels and Bioenergy: A Techno-Economic Approach provides an in-depth analysis of the economic aspects of biofuels production from renewable feedstock. Taking a biorefinery approach, the book analyzes a wide range of feedstocks, processes and products, including common biofuels such as bioethanol, biobutanol, biooil and biodiesel, feedstocks such as lignocellulosic biomass, non-edible feedstocks like vegetable oils, algae and microbial lipids, and solid and liquid wastes, performance assessments of biodiesel in diesel engine, and the latest developments in catalytic conversion and microbial electrosynthesis technologies. This book offers valuable insights into the commercial feasibility of biofuels products for researchers and students working in the area of bioenergy and renewable energy, but it is also ideal for practicing engineers in the biorefinery and biofuel industry who are looking to develop commercial products. Focuses on an in-depth, techno-economic analysis of biofuel and bioenergy products, including all important feedstocks, processes and products, all of which are supported by industry case studies Includes environmental impacts and lifecycle assessments of biofuels production alongside techno-economic analyses Provides a critical guide to assessing the commercial viability and feasibility of bioenergy production from renewable sources

This book addresses electro-fermentation for biofuel production and generation of high-value chemicals and biofuels using organic wastes. It covers the use of microbial biofilm and algae-based bioelectrochemical systems (BESs) for bioremediation and co-generation of valuable chemicals, including their practical applications. It explains BES design, integrated approaches to enhance process efficiency, and scaling-up technology for waste remediation, bio-electrogenesis, and resource recovery from wastewater. Features: Provides information regarding bioelectrochemical systems, mediated value-added chemical synthesis, and waste remediation and resource recovery approaches. Covers the use of microbial biofilm and algae-based bioelectrochemical systems for bioremediation and co-generation of valuable chemicals. Explains waste-to-energy related concepts to treat industrial effluents along with bioenergy generation. Deals with various engineering approaches for chemicals production in eco-friendly manner. Discusses emerging electro-fermentation technology. This book is aimed at senior undergraduates and researchers in industrial biotechnology, environmental science, civil engineering, chemical engineering, bioenergy and biofuels, and wastewater treatment.

This thesis presents studies that examine microbial extracellular electron transfer that an emphasis characterizing how environmental conditions influence electron flux between microbes and a solid-phase electron donor or acceptor. I used bioelectrochemical systems (BESs), fluorescence and electron microscopy, chemical measurements, 16S rRNA analysis, and qRT-PCR to study these relationships among chemical, physical and biological parameters and processes.

Bioelectrochemical Systems (BESs) are innovative and sustainable devices. They combine biological and electrochemical processes to engineer sensors, treat wastewater and/or produce electricity, fuel or high-value chemicals. In BESs, scientists have managed to incorporate biological catalysts, i.e. enzymes and/or microorganisms, and make them work in advanced electrochemical cells. BESs operate under mild conditions — at close to ambient temperature and pressure and at circumneutral pH — and represent a sustainable alternative to precious metal-based systems. Incorporating biological catalysts into devices while maintaining their activity and achieving electrical communication with electrode surfaces is a critical challenge when trying to advance the field of BESs. From implantable enzymatic biosensors to microbial electrosynthesis, and from laboratory-scale systems and fundamental studies to marketed devices, this book provides a comprehensive overview of recent advances related to functional electrodes for BESs. Suitable for researchers and graduate students of chemistry, biochemistry, materials science and environmental science and technology. Contents: Fundamentals: Fundamentals of Enzymatic Electrochemical Systems (Victoria Flexer and Nicolas Brun)Fundamentals of Microbial Electrochemical Systems (Stefano Freguia, Kun Guo, and Pablo Ledezma)Continuum in Enzymatic and Microbial Bioelectrocatalysis (Frédéric Barrière)Electron Transfer Between Bacteria and Electrodes (Lucie Semenec, Sanja Aracic, Elizabeth R Mathews, and Ashley E Franks)Electrodes for Enzymatic Electrochemical Systems: Architectures of Enzyme Electrodes Using Redox Mediators (Victoria Flexer, Antonin Prévoteau, and Nicolas Brun)Functional Electrodes for Enzymatic Electrosynthesis (Lin Zhang, Mathieu Etienne, Neus Vilà, and Alain Walcarius)Redox Hydrogels as an Efficient Strategy for Immobilization of Enzymes at Electrode Interfaces (Joshua W Gallaway, and Scott Calabrese Barton)Conducting Polymer Hydrogels and Their Applications as Electrode Materials (Yu Zhao, Lanlan Li, Lijia Pan, Guihua Yu, and Yi Shi)Nanocarbon-Based Enzymatic Electrodes (Nicolas Brun, Mohammed Baccour, and Victoria Flexer)Carbonaceous Electrodes Featuring Tunable Mesopores for Use as Enzyme Electrodes (Seiya Tsujimura)Electrodes for Microbial Electrochemical Systems: Materials and Their Surface Modification for Use as Anode in Microbial Bioelectrochemical Systems (Kun Guo, Antonin Prévoteau, Sunil A Patil, and Korneel Rabaey)Electrodes for Cathodic Microbial Electrosynthesis Processes: Key-Developments and Criteria for Effective Research and Implementation (Ludovic Jourdin and David Strik)Non-Carbonaceous Electrodes for Microbial Electrochemical Systems (Hernán Romeo, Diego Massazza, Rodrigo Parra, and Juan Pablo Busalmen)Imaging and Characterization of Bioelectrodes: Imaging and Characterization of Microbial Electrodes (Yang Lu and Bogdan C Donose)Spectroscopic Methods for Characterizing Redox Chemistry at Metalloprotein-Modified Electrodes (Philip A Ash and Kylie A Vincent)Spectroelectrochemistry of Microbial Biofilms (Diego Millo and Bernardino Virdis)Scanning Electrochemical Microscopy: A New Tool for Studying Enzymatic Reactions (Dodzi Zigah and Olivier Fontaine) Readership: Suitable for researchers, postgraduate and graduate students of chemistry, biochemistry and environmental sci

Microbial Dissimilatory Nitrate Reduction in Bioelectrochemical Systems with Electrode-respiring Biofilms and Wastewater Treatment Processes

Bio-Electrochemical Systems

Functional Electrodes For Enzymatic And Microbial Electrochemical Systems

Vol.1 Principles and Processes

From Laboratory Practice to Data Interpretation

Bioelectrochemical Systems

This book represents a novel attempt to describe microbial fuel cells (MFCs) as a renewable energy source derived from organic wastes. Bioelectricity is usually produced through MFCs in oxygen-deficient environments, where a series of microorganisms convert the complex wastes into electrons via liquefaction through a cascade of enzymes in a bioelectrochemical process. The book provides a detailed description of MFC technologies and their applications, along with the theories underlying the electron transfer mechanisms, the biochemistry and the microbiology involved, and the material characteristics of the anode, cathode and separator. It is intended for a broad audience, mainly undergraduates, postgraduates, energy researchers, scientists working in industry and at research organizations, energy specialists, policymakers, and anyone else interested in the latest developments concerning MFCs.

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.

Microbial electrochemical systems (MESs, also known as bioelectrochemical systems (BESs) are promising technologies for energy and products recovery coupled with wastewater treatment, and have attracted increasing attention. Many studies have been conducted to expand the application of MESs for contaminants degradation and bioremediation, and increase the efficiency of electricity production by optimizing architectural structure of MESs, developing new electrode materials, etc. However, one of the big challenges for researchers to overcome, before MESs can be used commercially, is to improve the performance of the biofilm on electrodes so that 'electron transfer' can be enhanced. This would lead to greater production of electricity, energy or other products. Electrochemically active microorganisms (EAMs) are a group of microorganisms which are able to release electrons from inside their cells to an electrode or accept electrons from an electron donor. The way in which EAMs do this is called 'extracellular electron transfer' (EET). So far, two EET mechanisms have been identified: direct electron transfer from microorganisms physically attached to an electrode, and indirect electron transfer from microorganisms that are not physically attached to an electrode. 1) Direct electron transfer between microorganisms and electrode can occur in two ways: a) when there is physical contact between outer membrane structures of the microbial cell and the surface of the electrode, b) when electrons are transferred between the microorganism and the electrode through tiny projections (called pili or nanowires) that extend from the outer membrane of the microorganism and attach themselves to the electrode. 2) Indirect transfer of electrons from the microorganisms to an electrode occurs via long-range electron shuttle compounds that may be naturally present (in wastewater, for example), or may be produced by the microorganisms themselves. The electrochemically active biofilm, which degrades contaminants and produces electricity in MESs, consists of diverse community of EAMs and other microorganisms. However, up to date only a few EAMs have been identified, and most studies on EET have focused on the two model species of Shewanella oneidensis and Geobacter sulfurreducens.

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.

Microbial Electrochemical Technology: Sustainable Platform for Fuels, Chemicals and Remediation

Enzymes for Solving Humankind's Problems

Motivations, Technologies and Assessment of the Elimination and Recovery of Phosphorus from Wastewater

Artificial or Constructed Wetlands