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Erik Kjeang

Microfluidic Fuel Cells and Batteries



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Microfluidic Fuel Cells And Batteries Springerbriefs In Energy

Erik Kjeang



Microfluidic Fuel Cells And Batteries Springerbriefs In Energy:

Microfluidic Fuel Cells and Batteries Erik Kjeang, 2014-06-14 Microfluidic fuel cells and batteries represent a special type of electrochemical power generators that can be miniaturized and integrated in a microfluidic chip Summarizing the initial ten years of research and development in this emerging field this SpringerBrief is the first book dedicated to microfluidic fuel cell and battery technology for electrochemical energy conversion and storage Written at a critical juncture where strategically applied research is urgently required to seize impending technology opportunities for commercial analytical and educational utility the intention is for this book to be a one stop shop for current and prospective researchers in the general area of membraneless microfluidic electrochemical energy conversion As the overall goal of the book is to provide a comprehensive resource for both research and technology development it features extensive descriptions of the underlying fundamental theory fabrication methods and cell design principles as well as a thorough review of previous contributions in this field and a future outlook with recommendations for further work It is hoped that the content will entice and enable new research groups and engineers to rapidly gain traction in their own laboratories towards the development of next generation microfluidic electrochemical cells

Bioelectrochemical Interface Engineering R. Navanietha Krishnaraj, Rajesh K. Sani, 2019-09-24 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

High Performance Fuel-Breathing Microfluidic Fuel Cells Yifei Wang, 2017-01-26 This dissertation High

Performance Fuel breathing Microfluidic Fuel Cells by Yifei Wang was obtained from The University of Hong Kong Pokfulam Hong Kong and is being sold pursuant to Creative Commons Attribution 3.0 Hong Kong License The content of this dissertation has not been altered in any way We have altered the formatting in order to facilitate the ease of printing and reading of the dissertation All rights not granted by the above license are retained by the author Abstract Abstract of the thesis entitled HIGH PERFORMANCE FUEL BREATHING MICROFLUIDIC FUEL CELLS Submitted by Yifei Wang for the degree of Doctor of Philosophy at The University of Hong Kong in September 2016 Fuel cells are broadly regarded as one of the most promising power sources A fuel cell is generally composed of a thin membrane electrolyte sandwiched by two porous electrodes which has a similar structure with batteries Fuel cells are very advantageous considering their high energy density uninterrupted operation and environmental friendliness To date the application of this technology is vigorously promoted by the government and industry especially for large power applications As for applications with small rated power the progress is however impeded by their high cost leading to less competitiveness against the mature battery technology To lower down the cost microfluidic fuel cell MFC also known as the membraneless fuel cell or laminar flow fuel cell has been proposed recently A MFC generally utilizes two laminar flows in parallel as electrolyte instead of any solid membrane therefore lowering the fabrication cost To prevent the flows from violent mixing micro channel normally with characteristic length less than 1mm is requisite In this manner the mixing process is dominated by slow diffusion forming a flow interface in the middle of the channel as a virtual membrane Despite of its cost advantage there are still many unsolved problems in MFCs such as poor energy density trade off between cell performance and fuel utilization complex fluidic management etc In this thesis research works on MFC development have been done to improve their cell performance energy efficiency energy density long term stability etc In addition a novel MFC stacking strategy has been proposed which was proved to be competent for practical applications First conventional liquid feed MFCs with either co flow or counter flow configuration were studied Their cell performance and fuel utilization were optimized which were used as benchmarks in subsequent studies To solve the intractable restrictions in liquid feed MFCs vapor feed MFCs were proposed which breathed fuel vapor from outside the cell instead of acquiring dissolved fuel from the inside electrolyte therefore 2 achieving both high power density 55 4mW/cm² and high energy efficiency 9.4% at the same time To better understand the mechanism behind its performance numerical R simulation on vapor feed MFCs was also conducted using COMSOL 4.2 To achieve practical power output a circular stacking strategy was proposed which was especially suitable for fuel breathing MFCs A six cell stack was designed and tested proving that such a stacking strategy was not only highly efficient but also potentially robust to external flow disturbance The same stacking strategy was also applied to H₂ fueled MFCs to further improve the power output By utilizing Al-H₂O reaction for H₂ generation 2.2 the proposed Al feed MFC stack achieved a peak power output of 530mW Meanwhile difficulties in hydrogen storage and waste electrolyte management were eliminated In MFCs with enlarged

electrode areas cathode flooding was inevitably aggravated and cell performance dropped significantly By cracking the cathode catalyst layer this problem was greatly alleviated leading to a m

Enzymatic Microfluidic Fuel Cells Ma José González Guerrero, 2015 Esta tesis presenta el desarrollo y la fabricación de pilas de combustibles microfluídicas para aplicaciones portátiles de baja potencia En concreto pilas biológicas que utilizan las enzimas en la degradación de la glucosa El trabajo está dividido en dos secciones dependiendo de si los dispositivos fabricados son activos es decir los reactivos son suministrados a la micropila por bombeo Capítulo 2 y 3 O si por el contrario los reactivos fluyen sin necesidad de mecanismos externos los dispositivos serán pasivos Capítulo 4 y 5 En el primer capítulo de la tesis se ha llevado a cabo la primera aproximación en el desarrollo de micro pilas de combustible glucosa O_2 con el objetivo de hacer posible las primeras medidas electroquímicas con enzimas La pila microfluídica fue construida sobre un sustrato de vidrio en el cual se grabaron electrodos de oro mediante técnicas de microfabricación Por otro lado se utilizó fotolitografía suave para la fabricación de los canales con forma de Y en PDMS Esta forma de canal permite fluir dos soluciones en paralelo usando una bomba de jeringa Como primera aproximación las enzimas se encontraban fluyendo de manera continua a través del canal Eso provocaba experimentos caros y dificultaba su posible aplicación portátil De este modo el siguiente aspecto en abordarse fue la inmovilización de los biocatalizadores sobre los electrodos de la micro pila El Capítulo 2 presenta la fabricación de una pila de combustible que posee los biocatalizadores inmovilizados en la superficie de los electrodos lo cual hace que los biocatalizadores sean aprovechados más eficientemente que en la anterior pila Los electrodos se han fabricado utilizando resina pirolizada y se han usado por primera vez con éxito en pilas microfluídicas enzimáticas de este tipo La pila está compuesta por diferentes capas de material plástico laminado que han sido cortadas usando un plotter de corte Esto hace que la fabricación del dispositivo sea rápida barata y compatible con la manufacturación a gran escala El canal microfluídico se ha definido también sobre este tipo de material plástico evitando el largo proceso litográfico relacionado con el PDMS Por otro lado el canal en forma de Y permite optimizar la potencia que obtenemos de la pila cuando bombeamos dos soluciones diferentes Por otro lado el dispositivo necesita ser simplificado para finalmente obtener una fuente de energía portátil Con este objetivo se abordó la siguiente fase de la tesis El Capítulo 4 describe la fabricación de una pila microfluídica implementada utilizando sustratos de papel a través de los cuales fluyen los reactivos de manera pasiva por efecto capilar Los componentes de la pila se cortaron utilizando un plotter de corte lo que permite fabricar dispositivos con mucha rapidez Se probó el buen funcionamiento de una pila de combustible de papel y enzimática obteniendo valores de potencia similares a los presentados en el Capítulo 3 donde las soluciones eran bombeadas A partir de aquí el trabajo se centró en aproximar la pila de papel a la simplicidad de los tests de flujo lateral Así que la micro pila fue adaptada y operada con éxito usando una única solución generando energía de una bebida comercial El Capítulo 5 presenta una micropila de combustible fabricada en papel mucho más sofisticada y pequeña que la del capítulo anterior Se probó satisfactoriamente una nueva combinación de biocatalizadores

que permiti trabajar utilizando muestras a pH neutro Adem s el tama o compacto del sistema abri la posibilidad de operar la pila de combustible con fluidos fisiol gicos como por ejemplo la sangre Finalmente se ha demostrado que es posible tener una pila preparada para alimentar dispositivos que requieran poca demanda de energ a Sin embargo todav a se deben hacer esfuerzos para acercar esta pila a un mundo real debido principalmente a que el tiempo de vida de las enzimas es todav a limitado

Advances in Microfluidics Xiao-Ying Yu,2016-11-23 Increasing innovations and applications make microfluidics a versatile choice for researchers in many disciplines This book consists of multiple review chapters that aim to cover recent advances and new applications of microfluidics in biology electronics energy and materials sciences It provides comprehensive views of various aspects of microfluidics ranging from fundamentals of fabrication flow control and droplet manipulation to the most recent exploration in emerging areas such as material synthesis imaging and novel spectroscopy and marriage with electronics The chapters have many illustrations showcasing exciting results This book should be useful for those who are eager to learn more about microfluidics as well as researchers who want to pick up new concepts and developments in this fast growing field

Membraneless Microfluidic Fuel Cells Kamil S. Salloum,2010 Portable devices rely on battery systems that contribute largely to the overall device form factor and delay portability due to recharging Membraneless microfluidic fuel cells are considered as the next generation of portable power sources for their compatibility with higher energy density reactants Microfluidic fuel cells are potentially cost effective and robust because they use low Reynolds number flow to maintain fuel and oxidant separation instead of ion exchange membranes However membraneless fuel cells suffer from poor efficiency due to poor mass transport and Ohmic losses Current microfluidic fuel cell designs suffer from reactant cross diffusion and thick boundary layers at the electrode surfaces which result in a compromise between the cell s power output and fuel utilization This dissertation presents novel flow field architectures aimed at alleviating the mass transport limitations The first architecture provides a reactant interface where the reactant diffusive concentration gradients are aligned with the bulk flow mitigating reactant mixing through diffusion and thus crossover This cell also uses porous electro catalysts to improve electrode mass transport which results in higher extraction of reactant energy The second architecture uses porous electrodes and an inert conductive electrolyte stream between the reactants to enhance the interfacial electrical conductivity and maintain complete reactant separation This design is stacked hydrodynamically and electrically analogous to membrane based systems providing increased reactant utilization and power These fuel cell architectures decouple the fuel cell s power output from its fuel utilization The fuel cells are tested over a wide range of conditions including variation of the loads reactant concentrations background electrolytes flow rates and fuel cell geometries These experiments show that increasing the fuel cell power output is accomplished by increasing reactant flow rates electrolyte conductivity and ionic exchange areas and by decreasing the spacing between the electrodes The experimental and theoretical observations presented in this dissertation will aid in the future design and commercialization

of a new portable power source which has the desired attributes of high power output per weight and volume and instant rechargeability

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Abstract Abstract of the thesis entitled HIGH PERFORMANCE FUEL BREATHING MICROFLUIDIC FUEL CELLS Submitted by Yifei Wang for the degree of Doctor of Philosophy at The University of Hong Kong in September 2016 Fuel cells are broadly regarded as one of the most promising power sources A fuel cell is generally composed of a thin membrane electrolyte sandwiched by two porous electrodes which has a similar structure with batteries Fuel cells are very advantageous considering their high energy density uninterrupted operation and environmental friendliness To date the application of this technology is vigorously promoted by the government and industry especially for large power applications As for applications with small rated power the progress is however impeded by their high cost leading to less competitiveness against the mature battery technology To lower down the cost microfluidic fuel cell MFC also known as the membraneless fuel cell or laminar flow fuel cell has been proposed recently A MFC generally utilizes two laminar flows in parallel as electrolyte instead of any solid membrane therefore lowering the fabrication cost To prevent the flows from violent mixing micro channel normally with characteristic length less than 1mm is requisite In this manner the mixing process is dominated by slow diffusion forming a flow interface in the middle of the channel as a virtual membrane Despite of its cost advantage there are still many unsolved problems in MFCs such as poor energy density trade off between cell performance and fuel utilization complex fluidic management etc In this thesis research works on MFC development have been done to improve their cell performance energy efficiency energy density long term stability etc In addition a novel MFC stacking strategy has been proposed which was proved to be competent for practical applications First conventional liquid feed MFCs with either co flow or counter flow configuration were studied Their cell performance and fuel utilization were optimized which were used as benchmarks in subsequent studies To solve the intractable restrictions in liquid feed MFCs vapor feed MFCs were proposed which breathed fuel vapor from outside the cell instead of acquiring dissolved fuel from the inside electrolyte therefore achieving both high power density 554 mW/cm² and high energy efficiency 9.4% at the same time To better understand the mechanism behind its performance numerical R simulation on vapor feed MFCs was also conducted using COMSOL 4.2 To achieve practical power output a circular stacking strategy was proposed which was especially suitable for fuel breathing MFCs A six cell stack was designed and tested proving that such a stacking strategy was not only highly efficient but also potentially robust to external flow disturbance The same stacking strategy was also applied to H₂ fueled MFCs to further improve the power output By

utilizing $\text{Al H}_2\text{O}$ reaction for H_2 generation the proposed Al feed MFC stack achieved a peak power output of 530mW. Meanwhile difficulties in hydrogen storage and waste electrolyte management were eliminated. In MFCs with enlarged electrode areas cathode flooding was inevitably aggravated and cell performance dropped significantly. By cracking the cathode catalyst layer this problem was greatly alleviated leading to a m

Comprehensive Numerical Study of Microfluidic Fuel Cells, 2008 The microfluidic fuel cell or laminar flow based fuel cell is a membraneless fuel cell which typically consists of two electrodes mounted within a T or Y shaped microchannel. Aqueous fuel and oxidant are introduced from the two inlets of the channel and flow together side by side toward the end of the channel. The Reynolds number in the microchannel is low and hence viscous forces are dominant over the inertial forces. This causes the anolyte and catholyte form a co laminar flow inside the microchannel which is required to maintain the separation of the fuel and oxidant and limit the reactions to the appropriate electrodes. In this work a comprehensive numerical model of the microfluidic fuel cell is developed using COMSOL Multiphysics. This model accounts for the mass and momentum transport phenomena inside the device as well as the electrochemical reaction kinetics which are described by the Butler Volmer equations. Potential equations are used to model both the ionic conduction in the electrolyte and the electrical conduction in the solid electrodes. The validity of the developed model is first checked by verifying it against the numerical and experimental results previously reported in the literature. The model is then used to assess the effect of different modifications which have been applied on the microfluidic fuel cell since its advent by calculating the polarization curves associated with each modification. In this thesis a novel design of microfluidic fuel cell with a tapered channel is also proposed. Using the numerical model it is shown that the tapered geometry improves the fuel utilization by up to four times in addition to a substantial improvement in the power density. A similar numerical model is developed to study the performance of a microfluidic fuel cell with flow through porous electrodes. Using this model the effect of porosity on the net power output of the fuel cell is investigated and an optimum value for porosity is calculated.

Th Microfluidics in Membraneless Fuel Cells Jesus A. Diaz-Real, 2016 In the 1990s the idea of developing miniaturized devices that integrate functions other than what normally are carried out at the laboratory level was conceived and the so called lab on a chip LOC devices emerged as one of the most important research areas. LOC devices exhibit advantages related to the use of microfluidic channels such as small sample and reagent consumption, portability, low power consumption, laminar flow and higher surface area volume ratio that enhances both thermal dissipation and electrochemical kinetics. Fuel cells are electrochemical devices that convert chemical energy to electrical energy. These are considered as one of the greener ways to generate electricity because typical fuel cells produce water and heat as the main reaction byproducts. The technical challenges to develop systems at the microscale and the advantages of microfluidics exhibited an important impact on fuel cells for several reasons mainly related to avoid inherent problems of gaseous based fuel cells. As a result the birth of a new type of fuel cells as microfluidic fuel cells MFCs took place.

The first microfluidic fuel cell was reported in 2002. This MFC was operated with liquid fuel oxidant and had the advantage of the low laminar flow generated using a Y microfluidic channel to separate the anodic and cathodic streams resulting in an energy conversion device that did not require a physical barrier to separate both streams. This electrochemical system originated a specific type of MFCs categorized as membraneless also called colaminar microfluidic fuel cells. Since that year numerous works focused on the nature of fuels oxidants and anodic cathodic electrocatalysts and cell designs have been reported. The limiting parameters of this kind of devices toward their use in portable applications are related to their low cell performances, small mass activity and partial selectivity, durability of electrocatalysts. On the other hand it has been observed that the cell design has a high effect on the cell performance due to internal cell resistances and the crossover effect. Furthermore, current technology is growing faster than last centuries and new microfabrication technologies are always emerging allowing the development of smaller and more powerful microfluidic energy devices. In this chapter the application of microfluidics in membraneless fuel cells is addressed in terms of evolution of cell designs of miniaturized microfluidic fuel cells as a result of new discoveries in microfabrication technology and the use of several fuels and electrocatalysts for specific and selective applications.

Scale Up Solutions for Liquid Based Microfluidic Fuel Cell Bernard Ho, 2012

A microfluidic fuel cell is a microfabricated device that produces electrical power through electrochemical reactions involving a fuel and an oxidant. In this study vanadium redox electrolytes will be used as reactants. Microfluidic fuel cell systems exploit colaminar flow on the microscale to separate the fuel and oxidant species in contrast to conventional fuel cells employing an ion exchange membrane for this function. In order to maintain this regime specific to microscale the size of the device is limited which directly impacts the power output. In this study scale up methods are investigated. In order to keep the microfluidic colaminar flow regime flow distribution over the whole active area is the main challenge. Two approaches have been investigated: a multiplexing approach and a dimensional scale up approach. For both solutions prototypes have been designed, built, tested with Vanadium electrolytes as reactants and compared with the performance of a unit cell. With the multiplexing approach we managed to get performance on par with the unit cell. With the dimensional scale up we managed to have a total power output of 130mW, the highest power output reported yet for microfluidic fuel cells.

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