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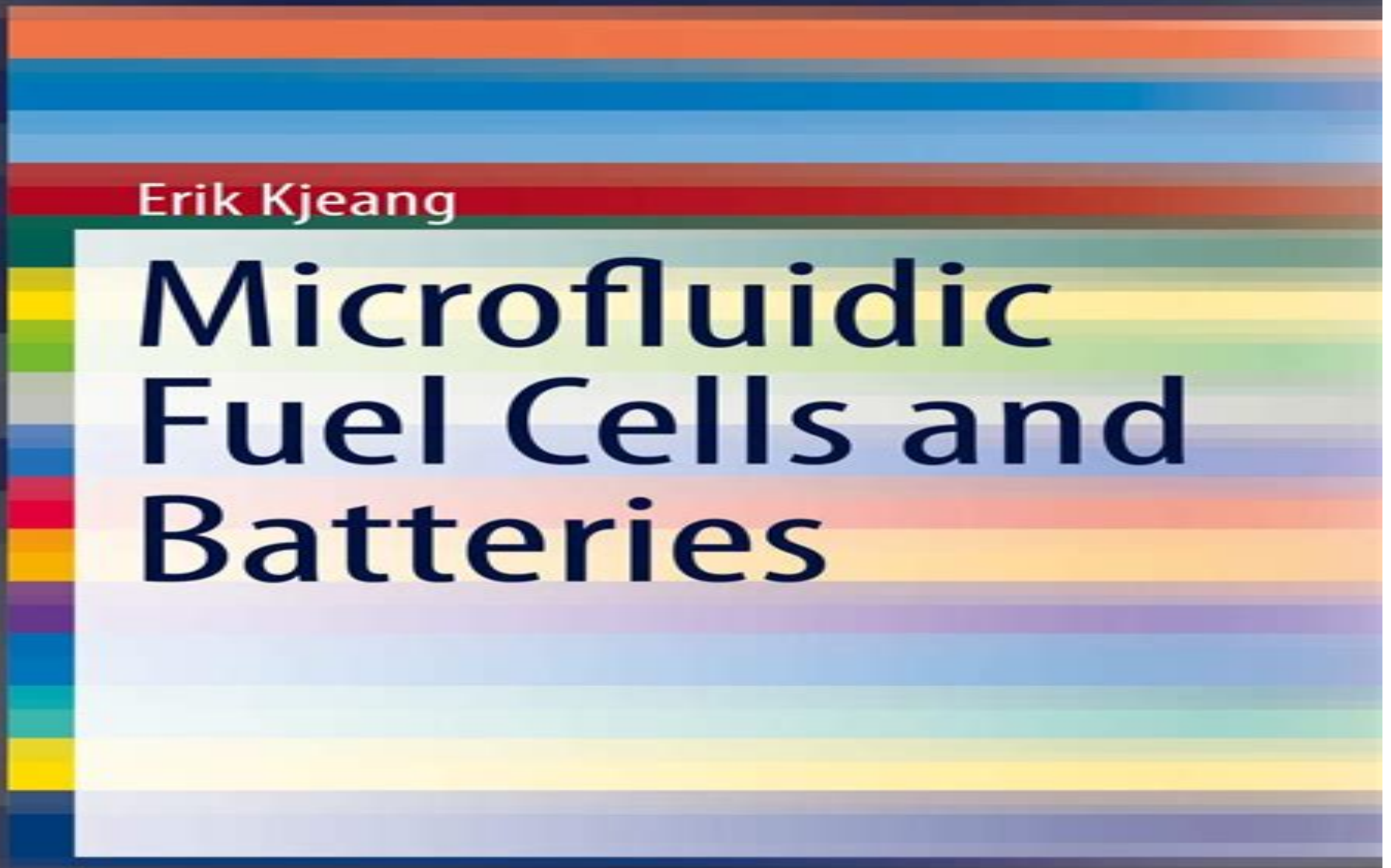

Erik Kjeang

Microfluidic Fuel Cells and Batteries

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Microfluidic Fuel Cells And Batteries Springerbriefs In Energy

Yicheng Fang

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 4mWcm 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 H fueled MFCs to further improve the power output By utilizing Al H O reaction for H 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 **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

Enzymatic Microfluidic Fuel Cells Ma José González Guerrero,2015 Esta tesis presenta el desarrollo y la fabricaci n de pilas de combustibles microflu dicas para aplicaciones port tiles de baja potencia En concreto pilas biol gicas que utilizan las enzimas en la degradaci n de la glucosa El trabajo est dividido en dos secciones dependiendo de si los dispositivos fabricados son activos es decir los reactivos son suministrados a la micropila por bombeo Cap tulo 2 y 3 O si por el contrario los reactivos fluyen sin necesidad de mecanismos externos los dispositivos ser n pasivos Cap tulo 4 y 5 En el primer cap tulo de la tesis se ha llevado a cabo la primera aproximaci n en el desarrollo de micro pilas de combustible glucosa O2 con el objetivo de hacer posible las primeras medidas electroqu micas con enzimas La pila microflu dica fue construida sobre un sustrato de vidrio en el cual se grabaron electrodos de oro mediante t cnicas de microfabricaci n Por otro lado se utiliz fotolitograf a suave para la fabricaci n de los canales con forma de Y en PDMS Esta forma de canal permiti fluir dos soluciones en paralelo usando una bomba de jeringa Como primera aproximaci n las enzimas se encontraban fluyendo de manera continua a trav s del canal Eso provocaba experimentos caros y dificultaba su posible aplicaci n port til De este modo el siguiente aspecto en abordarse fue la inmovilizaci n de los biocatalizadores sobre los electrodos de la micro pila El Cap tulo 2 presenta la fabricaci n de una pila de combustible que posee los biocatalizadores inmovilizados en la superficie de los electrodos lo cual hace que los biocatalizores sean aprovechados m s eficientemente que en la anterior pila Los electrodos se han fabricado utilizando resina pirolizada y se han usado por primera vez con xito en pilas microflu dicas enzim ticas de este tipo La pila est compuesta por diferentes capas de material pl stico laminado que han sido cortadas usando un plotter de corte Esto hace que la fabricaci n del dispositivo sea r pida barata y compatible con la manufacturaci n a gran escala El canal microflu dico se ha definido tambi n sobre este tipo de material pl stico evitando el largo proceso litogr fico 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 energ a port til Con este objetivo se abord la siguiente fase de la tesis El Cap tulo 4 describe la fabricaci n de una pila microflu dica

implementada utilizando sustratos de papel a trav s 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 permit a fabricar dispositivos con mucha rapidez Se prob el buen funcionamiento de una pila de combustible de papel y enzim tica obteniendo valores de potencia similares a los presentados en el Cap tulo 3 donde las soluciones eran bombeadas A partir de aqu el trabajo se centr en aproximar la pila de papel a la simplicidad de los test de flujo lateral As que la micro pila fue adaptada y operada con xito usando una nica soluci n generando energ a de una bebida comercial El Cap tulo 5 presenta una micropila de combustible fabricada en papel mucho m s sofisticada y peque a que la del cap tulo anterior Se prob satisfactoriamente una nueva combinaci n 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 **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 *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 4mWcm 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 H fueled MFCs to further improve the power output By utilizing Al H O reaction for H 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

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

Microfluidic Fuel Cells as Analytical Platforms Fikile R. Brushett,2009 *Microfluidics for Fuel Cell Applications* Ian Stewart,2011 In this work a microfluidics approach is applied to two fuel cell related projects the study of deformation and contact angle hysteresis on water invasion in porous media and the introduction of bubble fuel cells This work was carried out as collaboration between the microfluidics and CFCE groups in the Department of Mechanical Engineering at the University of Victoria Understanding water transport in the porous media of Polymer Electrolyte Membrane fuel cells is

crucial to improve performance One popular technique for both numeric simulations and experimental micromodels is pore network modeling which predicts flow behavior as a function of capillary number and relative viscosity An open question is the validity of pore network modeling for the small highly non wetting pores in fuel cell porous media In particular current pore network models do not account for deformable media or contact angle hysteresis We developed and tested a deformable microfluidic network with an average hydraulic diameter of 5 m the smallest sizes to date At a capillary number and relative viscosity for which conventional theory would predict strong capillary fingering behavior we report almost complete saturation This work represents the first experimental pore network model to demonstrate the combined effects of material deformation and contact angle hysteresis Microfluidic fuel cells are small scale energy conversion devices that take advantage of microscale transport phenomena to reduce size complexity and cost They are particularly attractive for portable electronic devices due to their potentially high energy density The current state of the art microfluidic fuel cell uses the laminar flow of liquid fuel and oxidant as a membrane Their performance is plagued by a number of factors including mixing concentration polarization ohmic polarization and low fuel utilization In this work a new type of microfluidic fuel cell is conceptualized and developed that uses bubbles to transport fuel and oxidant within an electrolyte Bubbles offer a phase boundary to prevent mixing higher rates of diffusion and independent electrolyte selection One particular bubble fuel cell design produces alternating current This work presents to our knowledge the first microfluidic chip to produce bubbles of alternating composition in a single channel class of fuel cells that use bubbles to transport fuel and oxidant and fuel cell capable of generating alternating current **Micro Fuel Cells** Tim Zhao,2009-07-07 Today s consumers of portable electronics consumers are demanding devices not only deliver more power but also work healthy for the environment This fact alone has lead major corporations like Intel BIC Duracell and Microsoft to believe that Microfuel Cells could be the next generation power source for electronic products Compact and readable Microfuels Principles and Applications offers engineers and product designers a reference unsurpassed by any other in the market The book starts with a clear and rigorous exposition of the fundamentals engineering principles governing energy conversion for small electronic devices followed by self contained chapters concerning applications The authors provide original points of view on all types of commercially available micro fuel cells types including micro proton exchange membrane fuel cells micro direct methanol fuel cells micro solid oxide fuel cells and micro bio fuel cells The book also contains a detailed introduction to the fabrication of the components and the assembly of the system making it a valuable reference both in terms of its application to product design and understanding micro engineering principles An overview of the micro fuel cell systems and applications A detailed introduction to the fabrication of the components and the assembly of the system Original points of view on prospects of micro fuel cells **Advanced Materials and Technologies for Fuel Cells** Massimo Viviani,Antonio Barbucci,Maria Paola Carpanese,Sabrina Presto,2021-08-31 Fuel cells are expected to play a relevant role in the transition towards a sustainable

energy driven world Although this type of electrochemical system was discovered a long time ago only in recent years has global energy awareness together with newly developed materials and available technologies made such key advances in relation to fuel cell potential and its deployment It is now unquestionable that fuel cells are recognized alongside their possibility to work in the reverse mode as the hub of the new energy deal Now the questions are why are they not yet ready to be used despite the strong economic support given from the society What prevents them from being entered into the hydrogen energy scenario in which renewable sources will provide energy when it is not readily available How much are researchers involved in this urgent step towards change This book gives a clear answer engaging with some of the open issues that explain the delay of fuel cell deployment and at the same time it opens a window that shows how wide and attractive the opportunities offered by this technology are Papers collected here are not only specialist oriented but also offer a clear landscape to curious readers and show how challenging the road to the future is **Microfluidic Fuel Cells** Boming Zhu,2010 **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

Scalable Model-Based Energy Management Strategies for Hybrid Mobile Systems Powered by Fuel Cells and Batteries Hujun Peng,2023 **Boosting Performance of Membraneless Microfluidic Fuel Cells Via Cell Architecture Optimization and Flow Management** □□□,2023 Practical Advances in Microfluidic Electrochemical Energy Conversion

Omar Ibrahim,2018 Micro fabrication technologies has enabled the inexpensive production of microchannels which has been utilized in electrochemical flow cells like fuel cells and flow batteries These offer simplicity and cost benefits as they utilize co laminar flow for flowing streams separation rather than a physical separator or membrane This thesis aims to identify practical applications for viable utility of microfluidic flow cells and suggests their potential use for analytical platforms disposable power sources or combined electrolyte functionalities such as cooling and powering of electronics All advances reported in this work leverage microfluidic cell architectures with flow through porous electrodes to achieve competitive performance with simplified inexpensive device solutions A previously reported microfluidic redox battery design is modified to form an analytical cell that is applied throughout this dissertation The analytical cell designs have two separate cell portions which when connected in parallel enable in situ characterization of the dual pass design allowing deeper understanding of the reactant conversion and crossover When the two portions are connected in series quantifying possible losses in flow cell arrays such as shunt current is allowed The technology is also applied to explore flow cells with non aqueous electrolytes which generally enable higher cell voltages but have limited performance from high membrane resistance The proposed membrane less cell with non aqueous electrolytes shows comparable performance with aqueous vanadium electrolytes Moreover a chemistry evaluation framework is applied to assess redox reactants and supporting electrolytes selection for biodegradable primary batteries The selected quinone redox chemistry is demonstrated in a novel 1 V paper based capillary flow cell with flow through porous electrodes that is proven to be powerful cheap scalable and biodegradable and demonstrated to directly substitute a coin cell battery for powering a water quality sensor This new class of batteries thus holds great promise to radically change the portable battery paradigm from considering it a harmful waste to a source of biodegradable materials that could even nurture the environment by enriching soil and water beyond its life cycle Lastly a scaled co laminar flow cell is shown for the first time and embedded in a printed circuit board for the application of simultaneous thermal and power management of mounted electronics This demonstration has advantages in future high density computers and enables new perspectives for near term adoption **Microfluidic Platforms for the Investigation of Fuel Cell Catalysts and Electrodes** Fikile R. Brushett,2011 A clear need exists for novel approaches to producing and utilizing energy in more efficient ways in light of society0 9s ever increasing demand as well as growing concerns with respect to climate change related to CO2 emissions The development of low temperature fuel cell technologies will continue to play an important role in many alternative energy conversion strategies especially for portable electronics and automotive applications However widespread commercialization of fuel cell technologies has yet to be achieved due to a combination of high costs poor durability and system performance limitations Chapter 1 Developing a better understanding of the complex interplay of electrochemical transport and degradation processes that govern the performance and durability of novel fuel cell components particularly catalysts and electrodes within operating fuel cells is critical to designing robust

inexpensive configurations that are required for commercial introduction Such detailed in situ investigations of individual electrode processes are complicated by other factors such as water management uneven performance across electrodes and temperature gradients Indeed too many processes are interdependent on the same few variable parameters necessitating the development of novel analytical platforms with more degrees of freedom Previously membraneless microfluidic fuel cells have been developed to address some of the aforementioned fuel cell challenges Chapter 2 At the microscale the laminar nature of fluid flow eliminates the need for a physical barrier such as a stationary membrane while still allowing ionic transport between electrodes This enables the development of many unique and innovative fuel cell designs In addition to addressing water management and fuel crossover issues these laminar flow based systems allow for the independent specification of individual stream compositions e g pH Furthermore the use of a liquid electrolyte enables the simple in situ analysis of individual electrode performance using an off the shelf reference electrode These advantages can be leveraged to develop microfluidic fuel cells as versatile electro analytical platforms for the characterization and optimization of catalysts and electrodes for both membrane and membraneless fuel cells applications To this end a microfluidic hydrogen oxygen H2 O2 fuel cell has been developed which utilizes a flowing liquid electrolyte instead of a stationary polymeric membrane For analytical investigations the flowing stream i enables autonomous control over electrolyte parameters i e pH composition and consequently the local electrode environments as well as ii allows for the independent in situ analyses of catalyst and or electrode performance and degradation characteristics via an external reference electrode e g Ag AgCl Thus this microfluidic analytical platform enables a high number of experimental degrees of freedom previously limited to a three electrode electrochemical cell to be employed in the construct of working fuel cell Using this microfluidic H2 O2 fuel cell as a versatile analytical platform the focus of this work is to provide critical insight into the following research areas 0 Identify the key processes that govern the electrode performance and durability in alkaline fuel cells as a function of preparation methods and operating parameters Chapter 3 0 Determine the suitability of a novel Pt free oxygen reduction reaction catalyst embedded in gas diffusion electrodes for acidic and alkaline fuel cell applications Chapter 4 0 Establish electrode structure activity relationships by aligning in situ electrochemical analyses with ex situ microtomographic MicroCT structural analyses Chapter 5 0 Investigate the feasibility and utility of a microfluidic based vapor feed direct methanol fuel cell VF DMFC configuration as a power source for portable applications Chapter 6 In all these areas the information garnered from these in situ analytical platforms will advance the development of more robust and cost effective electrode configurations and thus more durable and commercially viable fuel cell systems both membrane based and membraneless *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 co laminar 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 co laminar 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 **Microfluidic Fuel Cell Lacking a Proton Exchange Membrane** Eric Raymond Choban,2002

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