A DECADE OF GERMAN-CANADIAN COOPERATION IN FUEL CELLS

Looking back at our story so far

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29.09.2021

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Fraunhofer ISE

Who am I?

- Senior scientist in the Department Fuel Cell Systems at Fraunhofer Institute for Solar Energy Systems, ISE in Freiburg Germany since 2019
- Joined the department in 2011 first as an NSERC postdoctoral fellow after which I received a full contract
- Canadian citizen with all my education being completed at the University of Waterloo, ON, Canada in Mechanical Engineering
- Contributed to fuel cell development since 2005 with my work published in various research journals
- Active member of the research community; conference organization, advisory board membership, editorial duties, reviewing and student supervision
- Responsible for many industry projects

Fraunhofer Institute for Solar Energy Systems ISE

Research for the Energy Transformation

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Directors

Prof. Dr. Hans-Martin Henning

Prof. Dr. Andreas Bett

Staff

ca. 1300

Scientists, engineers, students

Budget 2019

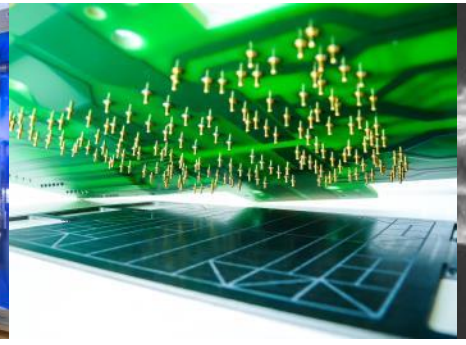
Operation	93,5 Mio. EUR
Investment	10,6 Mio. EUR
Total	104,1 Mio. EUR

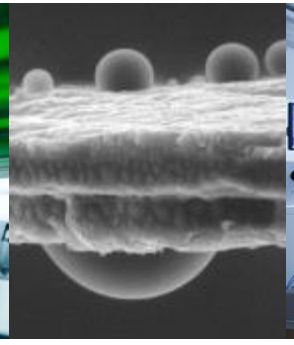
Fuel Cell Research at Fraunhofer ISE

Providing scientifically sound services to our customers

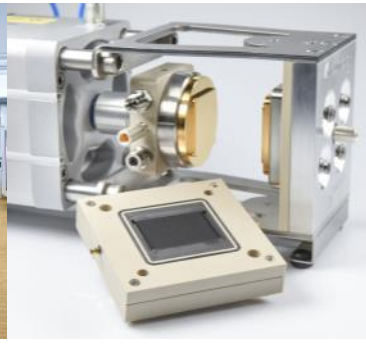
- > 25 years of fuel cell research
- > 20 researchers plus students
- 3.4 Mio € annual budget and 40% direct revenue by industry contract research (2020)
- >500 m² laboratory area with 10 single cell test stations, 4 short stack test stations, 1 system test site, 2 climate chambers (all fully automated for 24/7 operation)
- Focus on transport application (LT PEMFC)


stack testing


analysis of local effects


SEM analysis


MEA laboratory


test cell


environmental test of BoP

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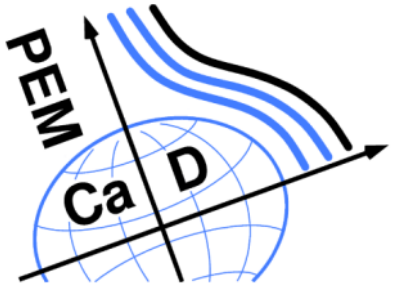
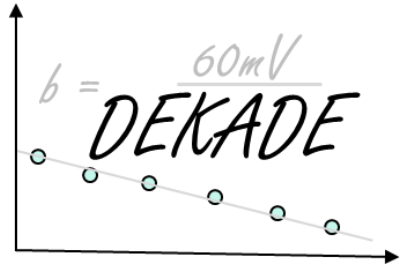
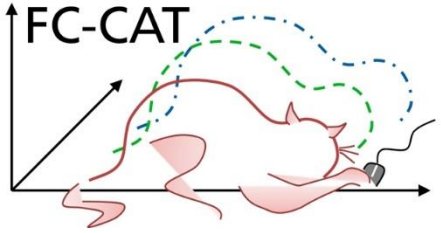
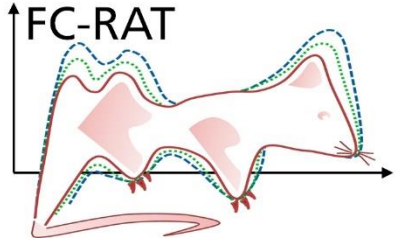
German-Canadian Cooperation on Fuel Cells Over the Years





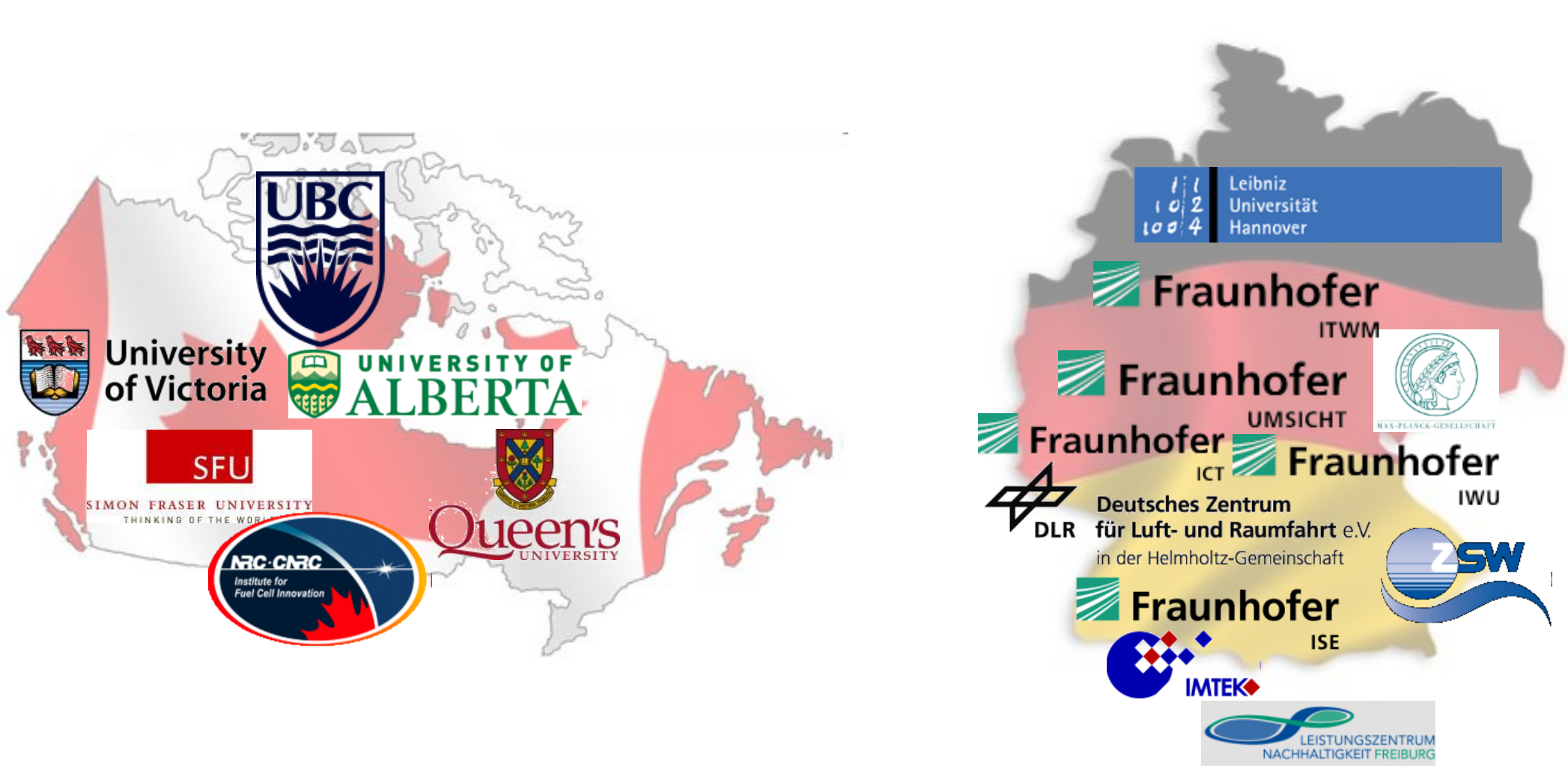




2009 - 2012	2013 - 2016	2017 - 2020	2019 - 2024	2021 - 2024
micro water management	novel characterization methods	component development	fuel cell CFD and Through-plane modeling	fuel cell realistic ageing trend modeling
■ DLR	■ Fraunhofer ICT	■ Fraunhofer ISE	■ Fraunhofer ISE	■ Fraunhofer ISE
■ Fraunhofer ISE	■ Fraunhofer ISE	■ Greenerity	■ AVL	■ AVL
■ Fraunhofer ITWM	■ MPI-DktS	■ Uni Freiburg - IAAC	■ Uni Freiburg – IMTEK	■ Uni Freiburg – IMTEK
■ Uni Freiburg - IMTEK	■ Uni Freiburg - IMTEK	■ Uni Freiburg – IMTEK		
■ ZSW	■ ZSW			

Scientific Success Story

A well-rounded scientific network



Scientific Success Story

Research staff exchange

Prof. Walter Merida, Prof. Fariborz Taghipour, Prof. David Wilkinson, Dr. Mada Zamel, Dr. Elham Safaei, Nigel David, Dave Todd, Kevin Holdcroft, Aleisha Cerny

Prof. Christian Dötsch, Dr. Christoph Ziegler, Dr. Robert Alink, Dr. Luisa Burhenne, Dr. Jan Haussmann, Dr. Max Sonnwager, Sebastian Prass, Dr. Matthias Klingele, Gabriel Sellbach & Dr. Matthias Breitwieser

Scientific Success Story

Joint conferences

- October 2020 & May 2021 — Canada-Germany Workshop Series
- September 2021 — f-cell
- September 2020 — f-cell
- September 2019 — f-cell — Canada-Germany Workshop Series
- September 2018 — f-cell — Canada-Germany Workshop Series
- July 2017 — EUROPEAN FUEL CELL FORUM
- February 2016
- March 2015 — ModVal 12
- September 2013 — f-cell
- March 2013

- May 2019 — f-cell•HFC
- February 2016 — FUEL CELL ELECTROCATALYSIS
- June 2017 — HFC2017 Hydrogen + Fuel Cells
- August 2015 — International Conference on Electrochemical Energy Science & Technology EEST2015
- June 2014 — Canadian Society for Chemistry | For Our Future — 97th Canadian Chemistry Conference and Exhibition — VANCOUVER, B.C. JUNE 1-5, 2014
- June 2013 — HFC2013 Hydrogen + Fuel Cells

Scientific Success Story

Multiple Scientific Papers and Awards


f-cell award
research & development

Im Wettbewerb „Innovationspreis Brennstoffzelle 2015" hat das

Institut für Mikrosystemtechnik (IMTEK) der Technischen Fakultät der Universität Freiburg mit dem Beitrag

„Direkt-Membran-Deposition für Hochleistungsbrennstoffzellen"

in der Kategorie „research & development" den f-cell award 2015 gewonnen.

Die Jury und die Veranstalter gratulieren zu diesem Erfolg.
Stuttgart, den 12. Oktober 2015

Franz Untersteller MdL
Minister für Umwelt, Klima und Energiewirtschaft des Landes Baden-Württemberg

Dr. Walter Rogg
Geschäftsführer der Wirtschaftsförderung Region Stuttgart GmbH

Baden-Württemberg

Wirtschaftsförderung Region Stuttgart

F-cell award 2015 for development in BMBF project GECKO


f-cell award 2020

Research & Development

f-cell STUTTGART 20 YEARS

In the competition "award for innovative hydrogen and fuel cell technology 2020" the **Fraunhofer Institute for Solar Energy Systems (ISE)** with the contribution

Through-Plane Ionomer Gradients in Fuel Cell Catalyst Layers for Enhanced Power Density

won the f-cell award 2020.

The judging panel and the hosts congratulate to this success.

Stuttgart, September 29, 2020

Minister Franz Untersteller MdL
Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg

Dr. Walter Rogg
Chief Executive of the Stuttgart Region Economic Development Corporation

Baden-Württemberg

Wirtschaftsförderung Region Stuttgart

F-cell award 2020 for development in BMBF project DEKADE

YEAR	TITLE/AUTHOR
2020	3D lattice Boltzmann modeling of droplet motion in PEM fuel cell channel with realistic GDL microstructure and fluid properties Hou, Y.; Deng, H.; Zamel, N.; Du, Q.; Jiao, K.
2020	Abschlussbericht für das Verbundvorhaben "Deutsch-Kanadische Brennstoffzellenkooperation: Diagnose und Entwicklung von Komponenten für automobile Brennstoffzellen" (Dekade*): Laufzeit: 01.01.2017-31.12.2019 Zamel, N.; Gerteisen, D.; Scherzer, A.-C.; Schneider, P.D.; Groos, U.
2020	Chemische Degradation von Brennstoffzellen-Membranen: Ex-situ Analyse in Fenton-Tests Prass, S.; Georg, A.; Zamel, N.
2020	Full Parametric Study of the Influence of Ionomer Content, Catalyst Loading and Catalyst Type on Oxygen and Ion Transport in PEM Fuel Cell Catalyst Layers Alink, Robert; Singh, Rajveer; Schneider, Patrick; Christmann, Kläre; Schall, Johannes; Keding, Roman; Zamel, Nada
2020	Fundamentals, Materials, and Machine Learning of Polymer Electrolyte Membrane Fuel Cell Technology Wang, Y.; Seo, B.; Wang, B.; Zamel, N.; Jiao, K.; Adroher, X.C.
2020	Impact of cyclic mechanical compression on the electrical contact resistance between the gas diffusion layer and the bipolar plate of a polymer electrolyte membrane fuel cell Bouziane, K.; Khetabi, E.M.; Lachat, R.; Zamel, N.; Meyer, Y.; Candusso, D.
2020	Production of Catalyst Coated Membranes for Low Temperature PEM Fuel Cells: Presentation held at International Conference on Energy and Al, Tianjin, China (R.O.), 09.01.2020-11.01.2020 Zamel, N.; Schneider, P.; Scherzer, A.-C.; Keding, R.; Singh, R.

Download at our website

https://www.ise.fraunhofer.de/en/business-areas/hydrogen-technologies-and-electrical-energy-storage/fuel-cell-systems.html

Scientific Success Story

Multiple Scientific Papers and Awards

A Decade of German-Canadian Cooperation in Fuel Cells

Die gemeinsame Forschung und Entwicklung von Brennstoffzellentechnologien zwischen Deutschland und Kanada hat eine Geschichte, die über ein Jahrzehnt zurückreicht. Die Erfolge der Kooperation gehen auf das besondere Engagement der Partnerinnen und Partner und eine hohe Transparenz zurück. Die deutsch-kanadischen Partnerschaften haben sich in mehrfacher Hinsicht als fruchtbar erwiesen: Ein Schwerpunkt lag auf Kostenreduktionen, während gleichzeitig die Lebensdauer der Brennstoffzellen verlängert wurde. Ein neues Kapitel wird demnächst durch die Schwerpunktsetzung auf Kommerzialisierung aufgeschlagen, insbesondere durch die Entwicklung von intelligenten Herstellungslösungen und neuen Analysemodellen.

Ulf Groos
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Department Fuel Cell Systems
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Freiburg, Germany

Dr. Nada Zamel
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Dr. Zamel, a Canadian scientist, carried out research in Canada between 2005 and 2011 before joining the Fraunhofer Institute for Industrial Mathematics ITWM and then moving to Fraunhofer ISE in Freiburg in 2011.

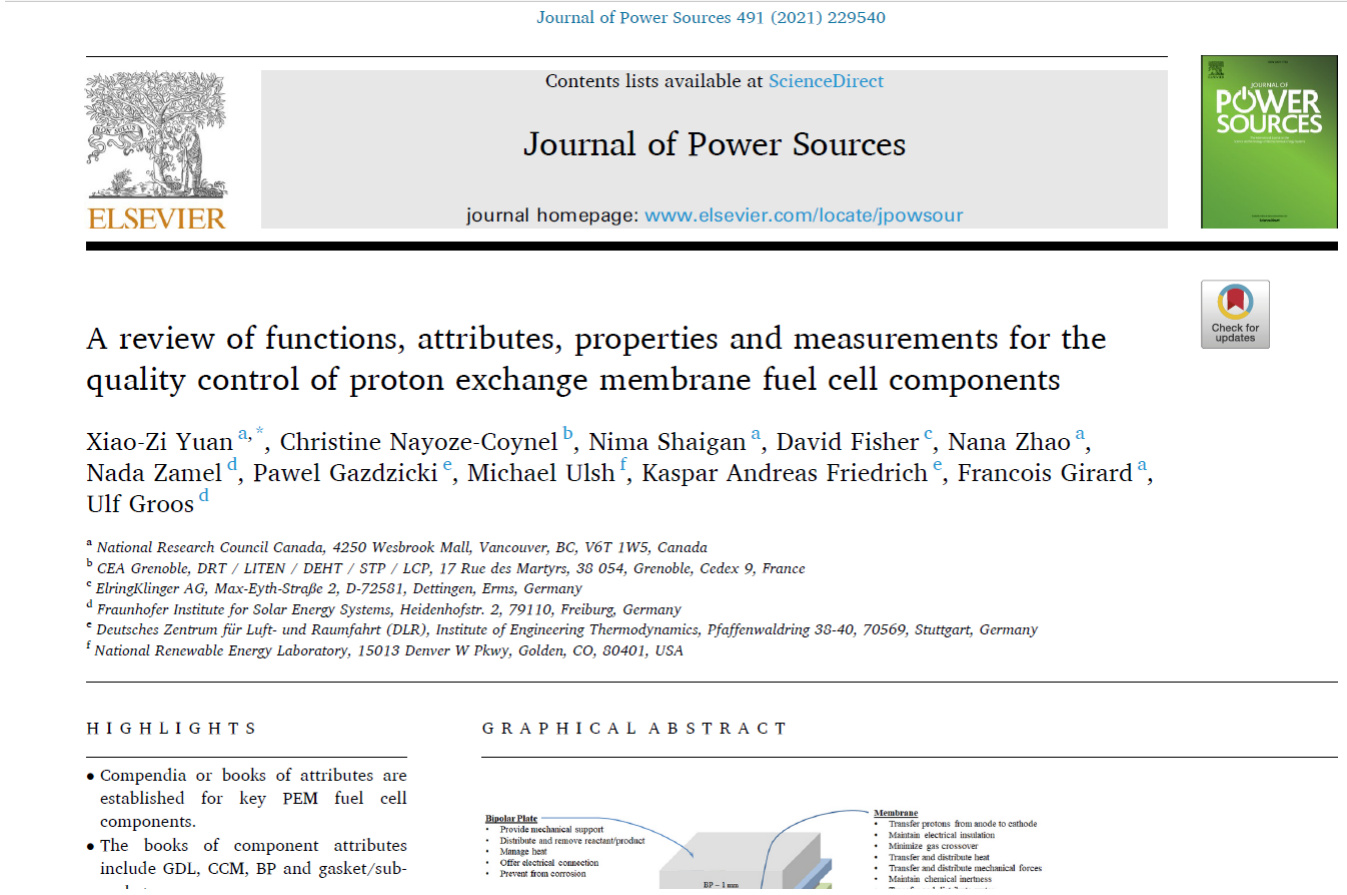
The pledge to reach zero-net greenhouse gas emissions by 2050 and the increased use of renewables in our electricity mix have been the main drivers for research and development (R&D) around hydrogen as an energy carrier. Abundantly available, hydrogen is also considered to be one of the best energy storage solutions. An end-use technology of hydrogen, R&D on polymer electrolyte membrane (PEM) fuel cells has also gained traction in the last thirty years. PEM fuel cells convert the stored chemical energy of hydrogen and oxygen (from air) to useable electrical energy. These cells are a great solution for mobile applications due to their scalability, efficiency, easy start-up and zero emissions at use. Although promising, groundbreaking scientific work is still required to optimize and bring PEM fuel cells to market. Marketability is best achieved through fundamental and systematic analysis combined with open collaboration between industry and research facilities.

In 2007, the Canadian/German initiative by the Germany Federal Ministry on Education and Research (BMBF) on Energy Collaboration paved the way for a strong and ongoing collaboration on PEM fuel cells between Canadian and German universities/institutes. In parallel the Fraunhofer Society created an important impetus for the collaboration by investing in a program to enable several guest professors' stays at the Fraunhofer Institute for Solar Energy Systems ISE and scientific exchange between the two countries.

Since 2007, both partners have worked tirelessly towards the optimization of the so-called membrane electrode assembly (MEA), which is where the electrochemical reactions occur. Its optimization will not only lead to improved performance and increased durability, but will also lower the overall costs of PEM fuel cells, making them competitive. To date, we have collaborated through three BMBF-funded projects (PEM-CaD, GECKO and DEKADE) from the German side that were complemented by CaRPE-FC on the Canadian side. The main aims of the projects were the development of novel characterization methods, understanding the underlying mechanisms behind performance loss, degradation of the MEA and the production of the next generation MEA.

Kooperation International

ITB infoservice Special Edition No. 16-06/2021. Germany & Canada. Celebrating 50 Years of Scientific and Technological Cooperation. Published by the BMBF



Journal of Power Sources 491 (2021) 229540

Contents lists available at ScienceDirect

Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

Check for updates

A review of functions, attributes, properties and measurements for the quality control of proton exchange membrane fuel cell components

Xiao-Zi Yuan [a,*], Christine Nayoze-Coynel [b], Nima Shaigan [a], David Fisher [c], Nana Zhao [a], Nada Zamel [d], Pawel Gazdzicki [e], Michael Ulsh [f], Kaspar Andreas Friedrich [e], Francois Girard [a], Ulf Groos [d]

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[b] CEA Grenoble, DRT / LITEN / DEHT / STP / LCP, 17 Rue des Martyrs, 38 054, Grenoble, Cedex 9, France
[c] ElringKlinger AG, Max-Eyth-Straße 2, D-72581, Dettingen, Erms, Germany
[d] Fraunhofer Institute for Solar Energy Systems, Heidenhofstr. 2, 79110, Freiburg, Germany
[e] Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institute of Engineering Thermodynamics, Pfaffenwaldring 38-40, 70569, Stuttgart, Germany
[f] National Renewable Energy Laboratory, 15013 Denver W Pkwy, Golden, CO, 80401, USA

HIGHLIGHTS

- Compendia or books of attributes are established for key PEM fuel cell components.
- The books of component attributes include GDL, CCM, BP and gasket/sub-

GRAPHICAL ABSTRACT

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Lessons Learned

how to build a cooperative R&D space

- The biggest driver towards the success we have had over the years is due to **Personnel Exchange**
- A true collaborative environment would only be possible through
  - Open exchange of ideas
  - Complimentary work rather than competitive work
  - 50/50 involvement in proposal writing/acquiring of funding
  - Passion for the topic at hand

Thank You for Very Much for Your Attention!

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