13th Annual International Conference

Small Fuel Cells® 2011

Portable & Micro Fuel Cells & Hybrid Devices for Commercial & Military Applications

June 9-10, 2011
Boston, MA USA

In its 13th year, Small Fuel Cells - "Fuel Cells & Hybrid Devices for Commercial & Military Applications" - is the primary source of information for end-users, developers and manufacturers of portable fuel cell powered devices. With an impressive lineup of speakers from around the world, and industry leaders exhibiting the latest technologies, this year's conference is not to be missed. Program topics include:

- Commercial success of small fuel cells: PEM, SOFC, alkaline, direct borohydride & DMFC
- Advances in fuel development
- Portable fuel cells for military & commercial applications
- Micro fuel cells for mobile electronics
- Hybrid portable power systems
- System integration & balance of plant engineering
- Materials challenges and use of materials-by-design approach
- Role of nanotechnology & nanomaterials
- End-user and OEM perspective on manufacturing & applications
- Safety, durability & reliability

This two-day meeting program will feature:

- Four half-day Technical Sessions of the Main Conference Program
- Exhibits and workshops in exhibit area
- Networking opportunities

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CONFERENCE FACULTY:

Marc St. Arnaud,
SIM Composites, Inc., Canada

Jeff Bentley,
CellTech Power LLC

Martin Blechert,
Technische Universität Berlin, Germany

Prasad Enjeti,
Texas A&M University

Paolo Fracas,
GENPORT srl & Politecnico de Milano, Italy

Christopher Hebling,
Fraunhofer ISE, Germany

Shanna Knights,
Ballard Power Systems, Canada

Ulrike Krewer,
Max Planck Institute for Dynamics of Complex Technical Systems, Germany

Sascha Kühn,
eZelleron GmbH, Germany

Andrei Leonida,
Axiome Advisors

Fong Yau (Sam) Li,
National University of Singapore, Singapore

Delia Muñoz Alé,
Hynergreen Technologies S.A., an Abengoa Company, Spain

Paul F. Mutolo,
Cornell University

David Nicholas,
Adaptive Materials, Inc.

Paul Osenar,
Protonex Technology Corporation

Ken Pearson,
Jadoo Power, Inc.

Michael Stelter,
Fraunhofer IKTS, Germany

Andrew P. Wallace,
SiGNa Chemistry

Seong Ihl Woo,
Korea Advanced Institute of Science &Technology (KAIST), Korea

Wei Zhu,
Bing Energy, Inc. & FAMU-FSU College of Engineering

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Portable & Micro Fuel Cells for Commercial & Military Applications

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Conference Agenda

Thursday, June 9, 2011

8:00 *Registration, Exhibit Viewing/Poster Setup, Coffee and Pastries*

8:50 **Organizer's Welcome and Opening Remarks**

ADVANCES IN MATERIALS RESEARCH AND COMPONENTS DEVELOPMENT

9:00 **Advanced *In-Situ* Characterization Techniques for the Optimization of PEM Fuel Cell Systems**

Christopher Hebling, PhD, Head of Dept - Energy Technology, Fraunhofer ISE, Germany*

Due to the separation of the energy converter and the energy storage in PEM fuel cell systems, inhomogeneous in-plane conditions occur since fuel cells always need inlet and outlet ports for educts and products, respectively. The arising gradients in humidity, reactant concentrations, pressure, saturation and temperature can lead to flooding in some regions which can cause high performance losses and accelerated local degradation. To specify the state-of-health of fuel cells and to discriminate the dominant loss mechanisms, electrochemical impedance spectroscopy is a powerful characterization tool. This work presents the analysis of inhomogeneities by conducting impedance spectroscopy on a segmented 7x7 test cell with a novel synchronized 50-channel characterization system. Results from different stacks including a 28-cell Mark 1020ACS from Ballard are discussed with respect of the impedance behaviour of each single cell measured simultaneously by a multi-EIS-high-power system. Obtained data is used to develop an improved in-system diagnostic method. In order to reduce the complexity of the diagnostic tool, two discrete frequencies were chosen instead of performing a complete spectrum. Data of these two-frequency impedance measurements are discussed and compared to cell and stack voltage measurements. An impedance based control strategy that improves stability and efficiency of fuel cell operation compared to traditional designs is proposed. **In collaboration with: R.Alink, D.Gerteisen, S.Keller, T.Kurz, C.Sadeler*

9:30 **Durability Approach for Air Cooled Stack Integration in a Materials Handling Application**

Shanna Knights, Research Manager, Ballard Power Systems, Canada

Ballard's 1kW FCgen®-1020ACS Air Cooled Stack, originally designed for telecommunications back-up power, is being integrated into a longer life dynamic materials handling application for small fork lift trucks through a collaboration with Plug Power. The U.S. Department of Energy funded the research activities to understand and mitigate failure mechanisms associated with the expected duty cycle, including operation under sub-zero conditions. The dominant failure mechanisms were delineated over time, including Pt dissolution, changes in Pt particle size, cathode corrosion, and membrane degradation. Testing at the stack level provided validation of small scale research diagnostic stress tests and models, enabling durability predictions of various operating strategies and design changes. Freeze related failure mechanisms and start-up under sub-zero conditions were evaluated and mitigation activities determined. The overall approach resulted in an extension of stack durability and increased functionality via integration with system design.

10:00 **Ultra-Low Platinum Loading High-Performance PEMFCs Using Buckypaper-Supported Electrodes**

Wei Zhu, PhD, Director of R&D Department, Bing Energy, Inc.; and Research Scientist, ECE Dept, FAMU-FSU College of Engineering

The microstructure of the catalyst layer in proton exchange membrane fuel cells (PEMFCs) greatly influences catalyst (Pt) utilization and cell performance. We demonstrated a functionally graded catalyst layer based on a double-layered carbon nanotube/nanofiber film- (buckypaper) supported Pt composite catalyst to approach an idealized microstructure. The gradient distribution of Pt, electrolyte and porosity along the thickness effectively depresses the transport resistance of proton and gas. A rated power of 0.88 W/cm^2 at 0.65 V was achieved at 80°C with a low Pt loading of 0.11 mg/cm^2 resulting in a relatively high Pt utilization of 0.18 gPt/kW. The accelerated degradation test of catalyst support showed a good durability of buckypaper support because of the high graphitization degree of carbon nanofibers.

10:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

11:00 **Ultra Low Loading CCM Performance in Low or Dry Humidity Conditions PEM**

Marc St. Arnaud, President and CEO, SIM Composites, Inc., Canada

It is now well known, catalyst-coated membranes (CCM) exhibit significantly higher electrochemical performance and power density than those prepared with conventional hot-pressed MEAs under identical conditions of Pt electrolcatalyst loadings. Also, great electrochemical performance in low or no humidity in inlet gas has significant benefits, specially in small portable fuel cells or Small PEM stacks. SiM Composites proprietary technologies bring together nanocomposite techniques to enhanced low loading CCM by improving the catalyst layer accessibility and membrane interface. The presentation will include and discuss on fuel cell performance and low humidity operation with ultra low catalyst loading CCM.

11:30 **Fuel Cell With *In-Situ* Electrode Activity Management**

Andrei Leonida, President, Axiome Advisors

The effect of catalyst poisons in a PEM fuel cell is reversed by the application of an electrical potential of appropriate polarity. Materials that would normally lose their catalytic activity continue to provide stable performance when polarized. A unique, patented fuel cell design that allows the operation under biased conditions was developed and tested. Very stable performance has been documented.

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ALKALINE

12:00 **Toward an Alkaline MEA for Fuel Cells: Electrolyte, Ionomer, and Electrocatalyst**

Paul F. Mutolo, PhD, Associate Director, Cornell Fuel Cell Institute; Senior Research Associate, Energy Materials Center at Cornell, Cornell University*

Abstract not available at time of printing. Please visit www.KnowledgeFoundation.com for the latest Program updates. **In collaboration with: G.Coates, H.D.Abruña, F.J.DiSalvo*

12:30 *Luncheon Sponsored by The Knowledge Foundation Membership Program*

SYSTEM INTEGRATION

2:00 **A Modular Hybrid Fuel Cell System with Energy Storage**

Prasad Enjeti, PhD, Professor, Power Electronic & Clean Power Research Laboratory; and

Fuel Cell Power Systems Laboratory, Texas A&M University

A modular fuel cell system has many advantages:
(a) is capable of supplying partial load under fault conditions;
(b) is capable of supplying sudden demands in energy.
A design example is presented for a 150-W, three-section fuel cell stack and dc-dc converter topology. We will present experimental results obtained on a 150-W, proton exchange membrane (PEM) fuel cell stack.

SOFC

2:30 **Highly Efficient Planar Micro-SOFC**

Michael Stelter, PhD, Head of Department - Processes and Components, Fraunhofer IKTS, Germany

A detailed development update is given on the mass-producible eneramic® Micro-SOFC system that is being developed at Fraunhofer IKTS. Due to a strictly simplified system and well balanced internal heat and fluid streams a very high net system efficiency of well over 21% has been achieved with off-the-shelf sensors and actuators and operating on commercial fuel. The multilayer approach for the stack and further system components will be shown to be a very cost effective way to manufacture small scale, compact SOFCs. Recent system test results and data will be presented.

3:00 **Direct JP-8 Fuel Cell for Portable Power**

Jeff Bentley, CEO, CellTech Power LLC

CellTech has developed the Liquid Tin Anode SOFC (LTA-SOFC) for direct conversion of fuel to power. The LTA-SOFC is not harmed by sulfur or carbon so it is an ideal power source for operation on military logistics fuel as well as other commonly available hydrocarbon fuels. This talk will review the operating principles of LTA-SOFC and discuss cell, stack and system level progress in portable power.

3:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

4:00 **Fuel Cells Enabling Applications**

David Nicholas, Vice President, Adaptive Materials, Inc.

AMI offers high energy density SOFC power sources for military applications in portable power and unmanned vehicles, and will soon offer commercial variants of these products for industrial and leisure markets. We will present recent successes and demonstrations of our power systems in unmanned vehicles with extended duration as well as portable power systems being field tested by the US military.

4:30 **Thin Film Technology for Portable Gas Batteries**

Sascha Kühn, PhD, CEO and CTO, eZelleron GmbH, Germany

Microtubular Solid Oxide Fuel Cells are operational within seconds and allow a higher power density per volume than the larger version. Hence they are a potential technology for automotive, auxiliary and small scale portable power supply devices. The electrolyte layer is the heart of eZelleron's microtubes and because it is free of pores and still submicrogranular structured the cells show extremely high power densities of more than 1.5 W/cm≤ at 800˚C. Issues of such thin layer SOFC and the way to solve them are presented.

5:00 **Selected Oral Poster Highlights I**

5:30 *Concluding Discussion, End of Day One*

Friday, June 10, 2011

8:00 *Exhibit/Poster Viewing, Coffee and Pastries*

APPLICATION AND COMMERCIALIZATION

9:00 **Commercialization of Portable Hydrogen**

Andrew P. Wallace, Director of the Alternative Energy Research Center, SiGNa Chemistry

SiGNa Chemistry has developed a range of commercial sodium silicide based hydrogen systems for applications requiring 1 to 300 Watts. This work will summarize the lessons learned from manufacturing the first 1,000 cartridges for a particular application.

9:30 **Fuel Cells and Power Management for Military Applications**

Paul Osenar, PhD, President & CEO, Protonex Technology Corporation

Protonex continues to focus on the commercialization of fuel

cell systems and power management equipment for high value portable military applications. Within the military, there is a long standing need for advancements in portable and remote power. Simply providing better energy density over traditional batteries has proven not enough to propel rapid deployment. Rather the integration of high-density storage with intelligent power management is resulting in very positive signs to sustained procurement of portable field battery chargers and associated equipment. Our SPM (Soldier Power Manager) devices, M300 battery charger (Reformed Methanol, PEM Fuel Cell) and upcoming developments will be discussed.

10:00 **Advanced Approaches to Manufacturing of Fuel Cell Stacks for Portable Applications**

Ken Pearson, Chief Operations Officer, Jadoo Power, Inc.

Jadoo Power is a US-based fuel cell developer/manufacturer that supplies patented fuel cell products to commercial and military customers. The company has developed an integrated fuel cell power system and four generations of products, initially targeting portable applications that require long runtime and reliable off-grid power solutions. To lower the cost of fuel cells, production improvements and innovation must be achieved. Advancements must be made in the multiple disciplines of the fuel cell system manufacturing, which include metal components, seals, composite polymeric materials, integrated electronics and automated assembly. Jadoo Power will present approaches in advanced manufacturing methods of fuel cell stacks for portable applications

10:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

11:00 **Hybrid Power Source Integrating Solar, PEM and Sodioboro Technologies**

Paolo Fracas, CEO, GENPORT srl, spin-off of Politecnico de Milano, Italy

Advanced lightweight generators, integrating the long running time of PEMFC, the quick response of batteries, the intermittent availability of solar energy and the high energy density of solid hydrogen, will ensure to extend the power need of electronic-based equipment in many off-grid contests. The hybrid concept extended to chemical storages as well as PV generation opens the door to a great amount of improvements in term of system reliability, long term energy retention and cost effectiveness. Technical challenges concerning this complex system will be illustrated with a specific focus on different hydrogen on demand strategies based on Sodioboro and metal hydrides storages providing experimental and simulation results.

11:30 **Development of $NaBH_4$-Hydrogen Generator for Deep Water Fuel Cell Applications**

Martin Blechert, Portable Power Supply Group, Dept High Density Interconnect & Wafer Level Packaging, Technische Universität Berlin, Germany*

A consortium of companies and academia is developing a small fuel cell system for under water and deep-sea applications. The fuel cell features a direct H_2O_2 supply at the cathode and hydrogen which is produced on demand in a $NaBH_4$ hydrogen reactor. An open concept was implemented to avoid bulky pressure vessels. Therefore reliable performance of all components at a pressure of up to 700 bars had to be demonstrated. The paper describes the design of the hydrogen reactor including thermal management and catalyst stability. A hydrogen rate control system was developed which includes a micro pump, and a bellow system as hydrogen buffer and rate monitor. Long term tests including the reactor and the PEM fuel cell will be presented. **In collaboration with: R.Hahn, K.Höppner, S.Wagner, W.Fröhlingsdorf, J.Mainert, T.Hahn*

12:00 **Fuel Cell Based Portable Generators: Design and System Integration**

Delia Muñoz Alé, Industrial Engineer, Systems Engineering Dept, Hynergreen Technologies S.A., an Abengoa Company, Spain

System requirements that must meet fuel cell based portable generators are not only related to the basic performance in terms of power, weight and autonomy, but also to external restrictions and regulations to comply for most commercial and military applications. The issues in the design and system integration to achieve these goals include every component of the generator and can be grouped in three distinctive areas. Some elements as the fuel cell or the output voltage regulator act as heat sources. Strategies for maintaining a proper temperature at every location are simulated. Another important issue to consider is the electromagnetic compatibility (EMC). In most simple systems where a standard low frequency controller is used, EMC compliance is not hard to reach, but when power conversion for a regulated output or PWM control of valves and fans is used, EMC problems could arise mostly because of radiated interference. EMC can be achieved by suppressing the parasitic antennae created by long wires and by reducing the bandwidth and amplitude of signals that control valves and fans. A third matter is the enhancement of the systems power efficiency. This efficiency relates the output power and the internally consumed power to make the whole system work. This efficiency is increased by the use of optimal valve and fan control algorithms as well as the use of low-power electronic circuits. Unfortunately, the use of these techniques may lead to an increase in electromagnetic emissions and, thus, a compromise between those must be reached. **In collaboration with: A.Pérez Vega-Leal, Universidad de Sevilla; V.Mesa Velez-Bracho, G.Adame García, Hynergreen*

12:30 *Lunch on Your Own*

2:00 **Highly Active Carbon-Based ORR Catalysts for PEMFC**

Seong Ihl Woo, PhD, Professor, Dept of Chemical & Biomolecular Engineering; Dept of Chemistry & EEWS; Director, Center for Ultramicrochemical Process Systems, Korea Advanced Institute of Science and Technology (KAIST), Korea*

As an alternative of Pt/C catalysts for oxygen reduction

reaction in PEMFC, nitrogen doped carbons having various morphologies and characteristics were prepared. N-doped-CNTs grafted on Fe/C catalyst was synthesized via pyrolysis of dicyandiamide onto Fe_2O_3/C. Pyrolysis of DCDA at higher temperatures increased the amount of N-doping and it had positive effects on electrochemical properties toward ORRs. Two-dimensional carbon structure, graphene, was modified by N-doping via Hummers method. Around 42% of the catalyst showed the pyridinic-N site which was the most active N-doped structure towards ORRs. For an environmental friendly synthesis method, amino acids were used to prepare N-doped carbon. It also revealed that not only N-doped carbon but N, S-dual doped carbon could also be synthesized. **In collaboration with: C.H.Choi, S.H.Park, K.R.Lee*

2:30 **Model-Based Analysis of Portable DMFC System Configurations**

Ulrike Krewer, PhD, Prof, Max Planck Institute for Dynamics of Complex Technical Systems, Germany

Model-based system analysis and design allows detecting limitations of DMFC system designs at early project stages. This presentation gives a fundamental insight into selected active DMFC system configurations. It elucidates their theoretical capabilities and limitations with a focus on environmental reliability and fuel efficiency. Details on the feasibility envelope for water-autonomous operation and the effect of system design on efficiency are given.

ALTERNATIVE CATALYSTS

3:00 **Carbon Nanotube Supported MnO_2 Catalysts for Oxygen Reduction Reaction and Their Applications in Small Fuel Cells**

Fong Yau (Sam) Li, PhD, Professor of Chemistry, Deputy Director, NUS Environmental Research Institute, National University of Singapore, Singapore

Manganese dioxide materials were tested as alternative cathode catalysts for oxygen reduction reaction (ORR) in air-cathode microbial fuel cells (MFCs). Prepared by solution-based methods, the MnO_2 nanoparticles were comprehensively characterized and incorporated into electrodes together with carbon nanotubes (CNTs). The electro-catalytic activities in neutral electrolyte were investigated by cyclic voltammetry (CV). Beta-MnO_2 appeared to have the highest catalytic activity due to its structure and better interaction with carbon nanotubes.

3:30 **Selected Oral Poster Highlights II**

4:00 **Concluding Discussion:**

Portable Fuel Cells Marketplace Outlook: *From 2000 to 2020 - Lessons learned. What's next?*

4:30 *End of Conference*

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Discount Accommodations and Travel: A block of rooms has been allocated at a special reduced rate. Please make your reservations by May 9, 2010. When making reservations, please refer to the The Knowledge Foundation. Contact The Knowledge Foundation if you require assistance.

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