

Annex 22
Collaborative Research on
Polymer Electrolyte Fuel Cells

Spring 2011 Workshop
Graz University of Technology, Austria
July 4-5, 2011

Welcome!

International Energy Agency (IEA) Implementing Agreement on Advanced Fuel Cells (AFC)

- **Established in 1990 as part of an international energy technology collaboration, duration of each implementing agreement is 3-5 years**
- **Current implementing agreement: Duration Jan. 2009 – Jan. 2014**
- **Signatories:** Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, Netherlands, Norway, Sweden, Switzerland, Turkey, United States
 - The program continues to actively encourage new participants
- **Aim of IEA–AFC**
 - Advance the state of understanding in the field of advanced fuel cells through
 - Coordinated program of research, technology development, and systems analysis on MCFC, SOFC, and PEFC systems
 - information exchange through Task meetings, workshops, and reports
 - Task-sharing with participating countries providing an agreed level of effort over the period of the Task

International Energy Agency (IEA) Implementing Agreement on Advanced Fuel Cell (AFC)

Current Annexes or Tasks

- Annex 22 Polymer Electrolyte Fuel Cells
- Annex 23 Molten Carbonate Fuel Cells
- Annex 24 Solid Oxide Fuel Cells
- Annex 25 Fuel Cells for Stationary Applications
- Annex 26 Fuel Cells for Transportation
- Annex 27 Portable Fuel Cells

Task/Annex 22: Collaborative Research on Polymer Electrolyte Fuel Cells

- **Objective:** To contribute to the identification and development of techniques to reduce the cost and improve the performance and durability of PEFCs and PEFC systems
- **Predecessor tasks:** VIII, XI, XI Phase II, and XVI
- **Operating Agent:**
U. S. Department of Energy
Argonne National Laboratory

Participants in Annex 22

- **Austria** 😊
- ***Belgium**
- **Canada** 😊
- **Denmark**
- **Finland**
- **France**
- **Germany** 😊
- **Italy**
- **Japan**
- **Korea** 😊
- **Mexico**
- ***Netherlands**
- ***Norway**
- **Sweden** 😊
- **Turkey**
- **United States** 😊

Red – countries that attended the “Fall” 2010 workshop (Web Teleconference)

😊 – countries participating in this workshop

Task Structure for Annex 22:

Subtask 1 Topics

- ***Subtask 1: Stack Materials***
 - Membrane materials (new functional groups, cheaper membranes, composite membranes, high-temperature membranes, low-humidity proton conductors)
 - Electrode catalysts (lower Pt loadings, CO tolerance, lower-cost higher-performance structures, non-Pt materials)
 - Bipolar plates (new materials, improved manufacturability, lower costs)
 - Cells and stack assemblies (higher power density, low degradation, light-weight, lower cost, continuous fabrication techniques, >100°C operating temp.)

Task Structure for Annex 22: Subtask 2 Topics

- ***Subtask 2: System, Component, and Balance-of-Plant Issues***
 - End-user aspects (contaminants, humidification and thermal management, operating environments and duty cycles, rapid-start, durability, freeze-thaw cycling, and characterization of materials and components)
 - System-level issues (systems analysis, stack/system hardware designs, fuel processing, and prototypes)

Task Structure for Annex 22: Subtask 3 Topics

- ***Subtask 3: Direct Fuel Polymer Electrolyte Fuel Cells***
 - Cell materials (anode and cathode catalysts, reduced precious metal loadings, MEA designs and processes for reduced fuel crossover, fuel impermeable membranes, anion-conducting membranes)
 - Operating conditions (pressure, temperature, vapor versus liquid feed, fuel concentration, etc.)
 - Stack and system designs and analyses (modeling, high-temperature operation, high power densities, high efficiencies, performance over duty cycles, etc.)

Recent Progress, Annex 22

- The fourth workshop of Annex 22 Working Group was held on January 26-27, 2011 in the form of a Web teleconference.
- 12 participants from 8 countries

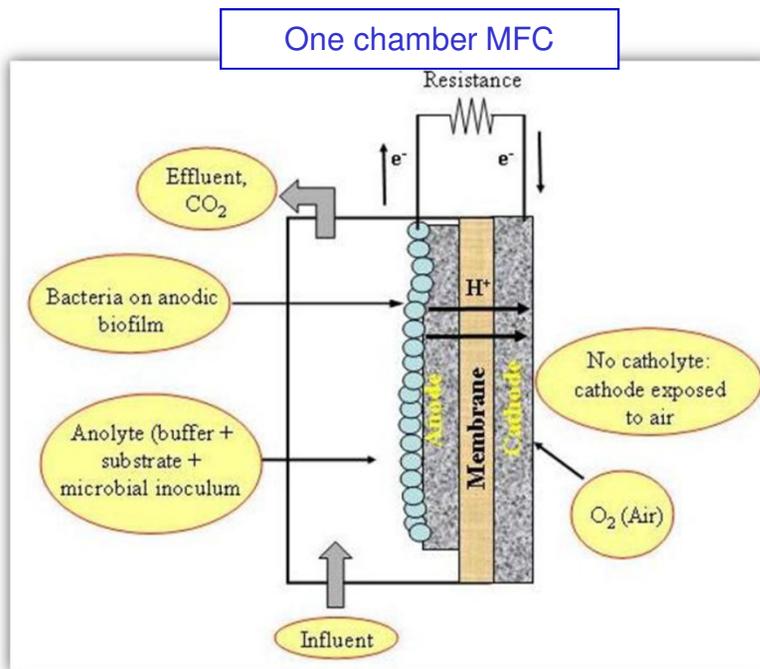
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- **The following slides are a summary of the Annex's technical highlights presented to the IEA-AFC Executive Committee at the semi-annual meeting, Rome, Italy, May 19-20, 2011**

Recent Technical Highlights

Subtask 1: New Stack Materials

Belgium, VITO --- Development of low cost microbial fuel cells (MFCs) for energy recovery from industrial wastewaters

- Novel ion permeable membrane: Zirfon[®] (85 wt% ZrO₂ and 15 wt% polysulfone)
 - High ion conduction and comparable oxygen mass transfer coefficient vs. Nafion[®]
 - Stable in MFCs condition
- Non-platinized graphite and activated charcoal in sandwich design for oxygen reduction



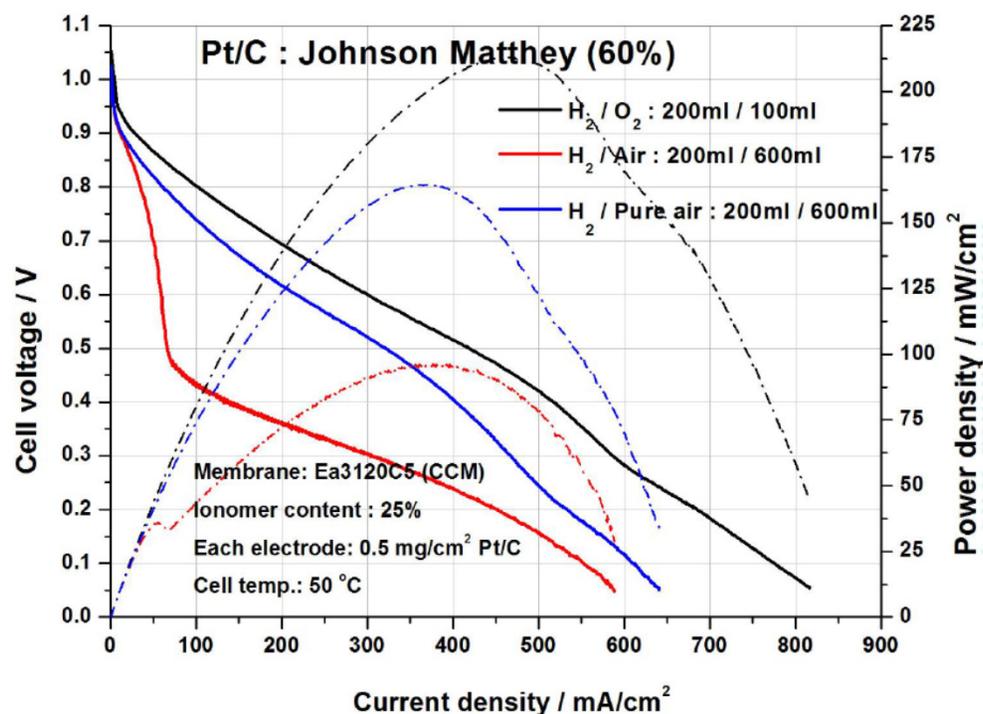
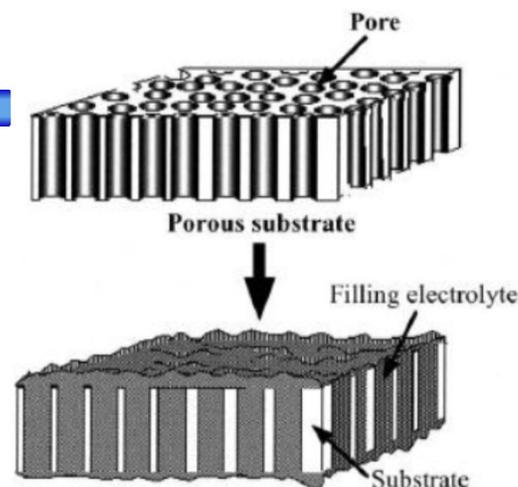
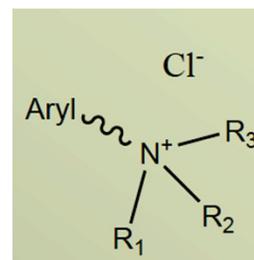
Clear water produced from dairy product wastewater that was fed to a MFC for 14 days
--- Yolanda Alvarez-Gallego, VITO, Belgium

Recent Technical Highlights

Subtask 1: Stack Materials

Korea, KIER --- Novel anion-conducting pore-filling membrane for a solid alkaline fuel cell

- Developed anion-conducting pore-filling membrane using amide-based crosslinker to crosslink quaternary-aminated hydrocarbon electrolyte into porous substrate (e.g., high density polyethylene)
 - Thermally stable up to 150°C
 - Exhibited a wide range of hydroxide ion conductivity (0.01 to 0.45 S/cm), depending on the composition of the membrane
 - Most of the membranes showed a hydroxide ion conductivity higher than the commercial products from Tokuyama



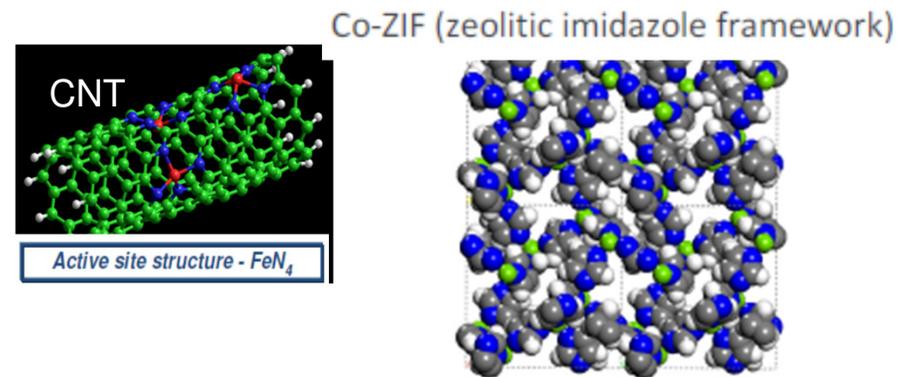
--- Young-Woo Choi, KIER, Korea

Recent Technical Highlights

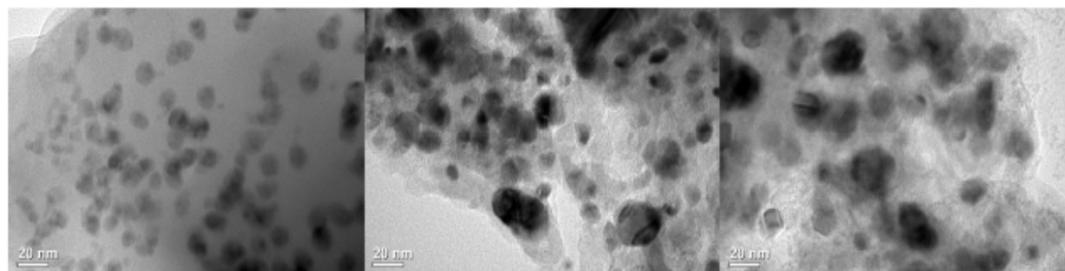
Subtask 1: New Stack Materials

United States, Argonne --- Non-PGM electrocatalyst development

- Iron and nitrogen-decorated aligned carbon nanotubes as integrated cathode electrocatalyst
- Metal organic frameworks as precursors for non-PGM catalyst preparation
- Porous organic polymers as precursors for non-PGM catalyst



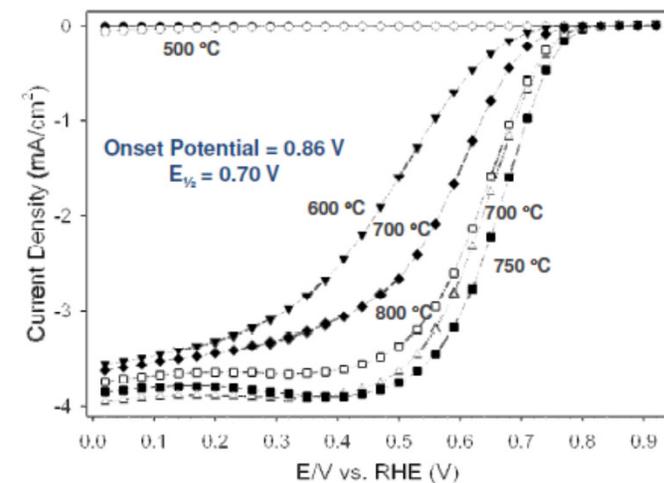
TEM images of thermally activated materials at different temperatures



(a) 500 °C

(b) 750 °C

(c) 900 °C



--- Di-Jia Liu, Argonne, USA

ORR activity of Co-ZIF as a function of heat treatment temperature

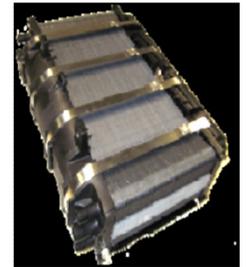
Recent Technical Highlights

Subtask 2: System and Balance-of-Plant



Canada, Ballard Power Systems ---

- Leader in PEMFC across multiple markets
 - Design and manufacture PEMFC products for a range of applications including backup power, distributed generation, material handling, and public transit
 - Products: fuel cell stacks, modules, and fully integrated system solutions
- Recent technical research activities address durability, performance, and cost of PEMFCs via both cathode and anode optimization to achieve increased commercialization
 - Understanding the effect of operating condition on durability
 - Developing microstructural catalyst and 1D macro MEA model to support mitigation of performance degradation
 - Understanding the effects of materials performance and design on system performance and durability, facilitating the lowest life-cycle cost designs



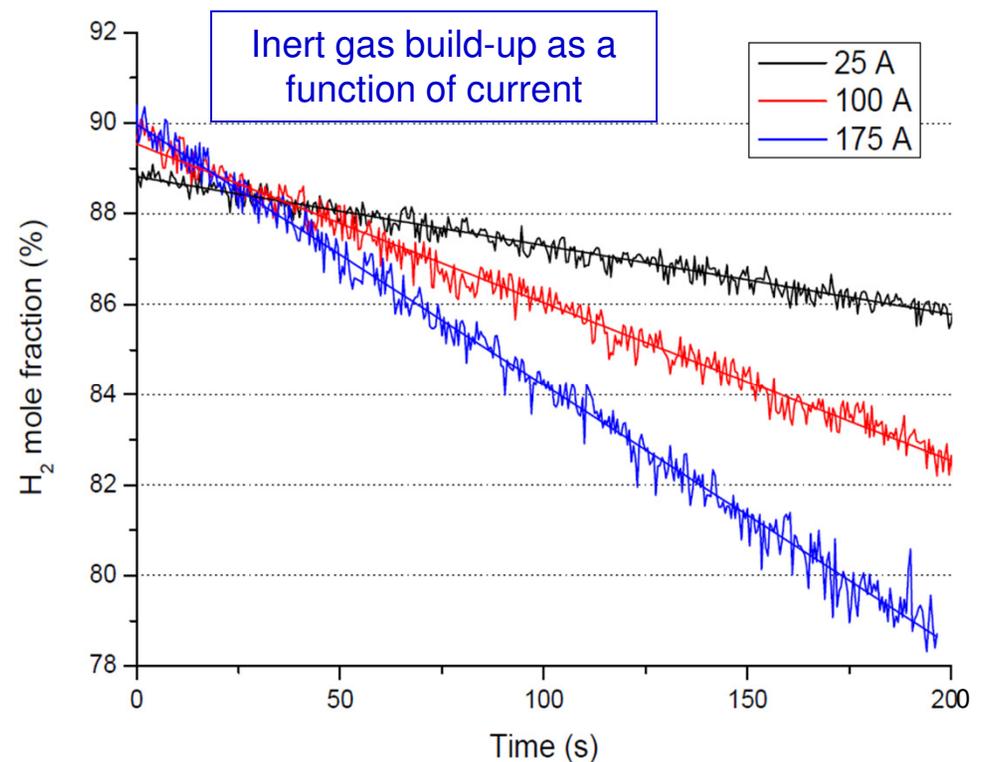
--- Shanna Knights, Ballard Power Systems, Canada

Recent Technical Highlights

Subtask 2: System and Balance-of-Plant

Finland, VTT --- Studies of inert gas enrichment in PEMFC system

- Developed hybrid forklift power source consisting of two 8-kW PEMFC systems, lead-acid battery packs, and ultracapacitor modules (peak power of $\sim 50 \text{ kW}_e$)
- Currently investigating the accumulation of water and inert gas (N_2) that causes mass transfer problem on the anode side of PEMFC, particularly with recirculation of hydrogen
- Re-assembled and tested an 8-kW PEMFC system with the use of a hydrogen sensor
 - Monitoring H_2 concentration change due to N_2 build-up
 - Investigating effect of N_2 build up on fuel cell performance and fuel utilization
 - The H_2 sensor used has limited measurable concentration range and is only applicable to dry gas



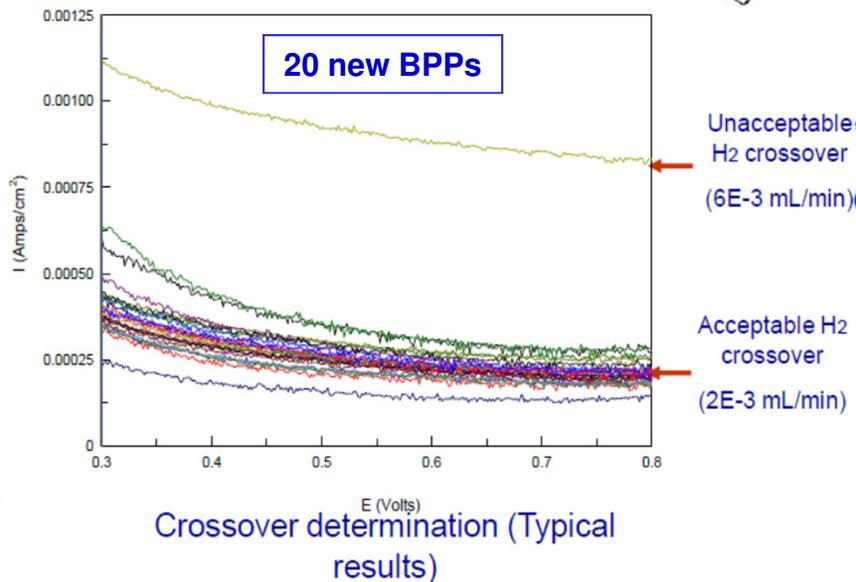
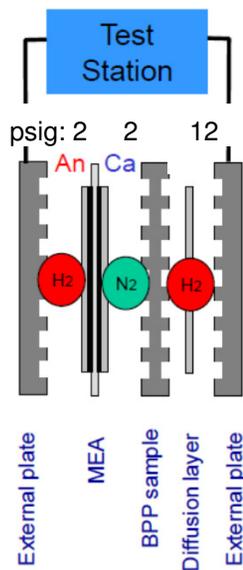
--- Jari Ihonen, VTT, Finland

Recent Technical Highlights

Subtask 2: System and Balance-of-Plant

Mexico, IIE --- Hydrogen crossover through BPPs and MEAs for quality control

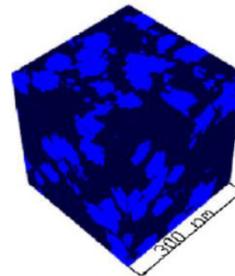
- Proposed a testing protocol as a quality control measure for bipolar plates (BPPs) and MEAs, via determining hydrogen crossover through BPPs and MEAs prior to fuel cell assembly



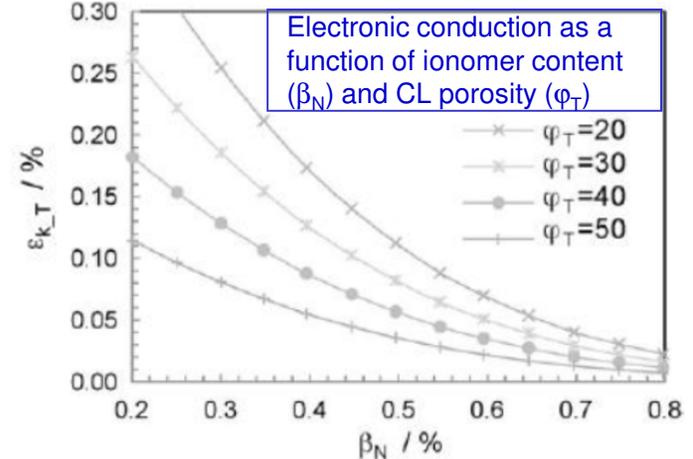
--- Tatiana Romero, IIE, Mexico

Mexico, IIE --- Evaluated effective transport coefficients in cathode layer (CL) via modeling

- Finite Control Volume method was used to construct cathode layer based on the typical parameters used in MEA manufacturing
- Effective conduction parameters were predicted



– Need experimental validation



--- Ulises Cano-Castillo, IIE, Mexico

Recent Technical Highlights

Subtask 2: System and Balance-of-Plant

United States, Argonne --- Role of Pt-based electrocatalyst degradation

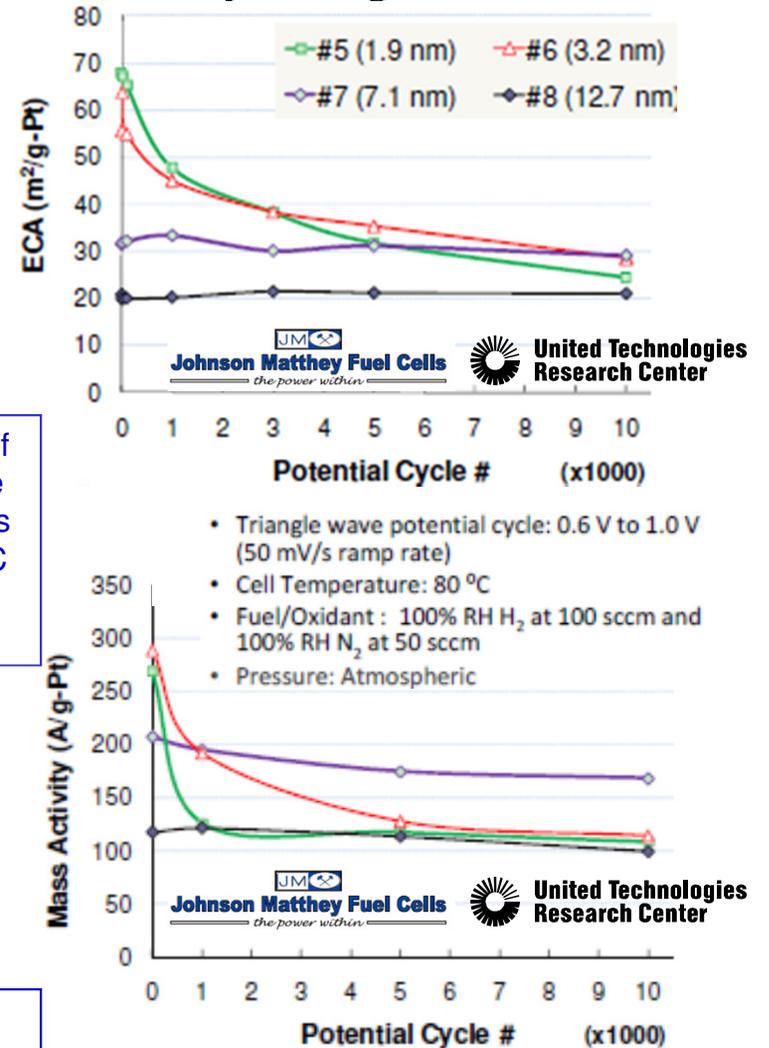
- Identify the degradation modes and factors contributing to PEMFC degradation by determining the effect of catalyst type, particle size, impurity, catalyst support, and cell operating parameters with the following methods or techniques
 - Systematic cell degradation tests
 - In situ and ex situ structural characterization of the catalyst using various X-ray techniques
 - Fundamental out-of-cell studies of aqueous cell dissolution/corrosion
 - Modeling of electrocatalyst degradation and effects on cell performance



Degradation of active surface area and mass activity of Pt/C with varied particle size



--- Xiaoping Wang, Argonne, USA



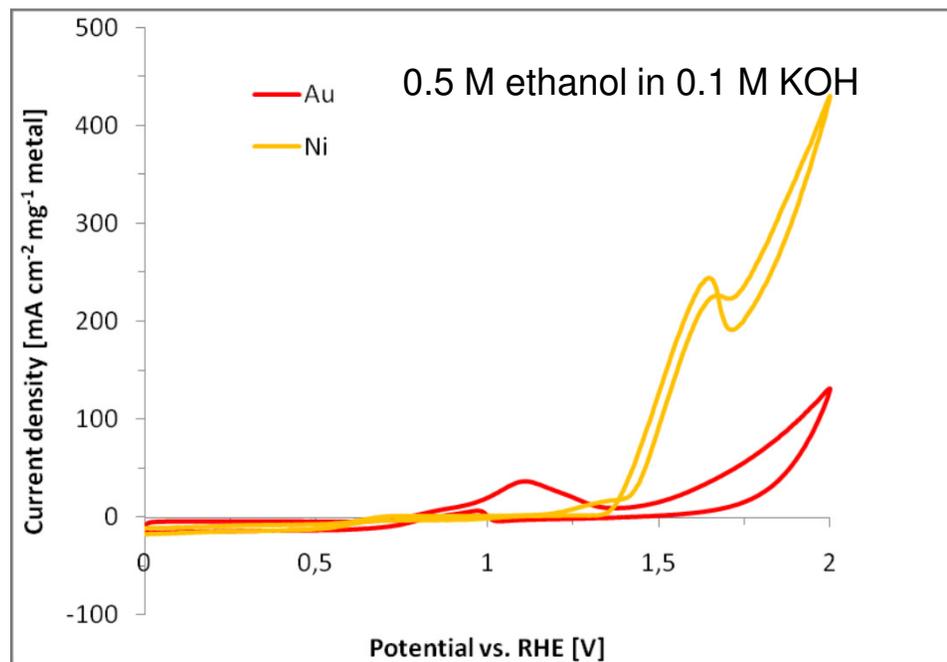
Recent Technical Highlights

Subtask 3: Direct Fuel Polymer Electrolyte Fuel Cells

Austria, Graz University of Technology ---- Developing non-Pt ethanol oxidation electrocatalysts for alkaline DEFCs

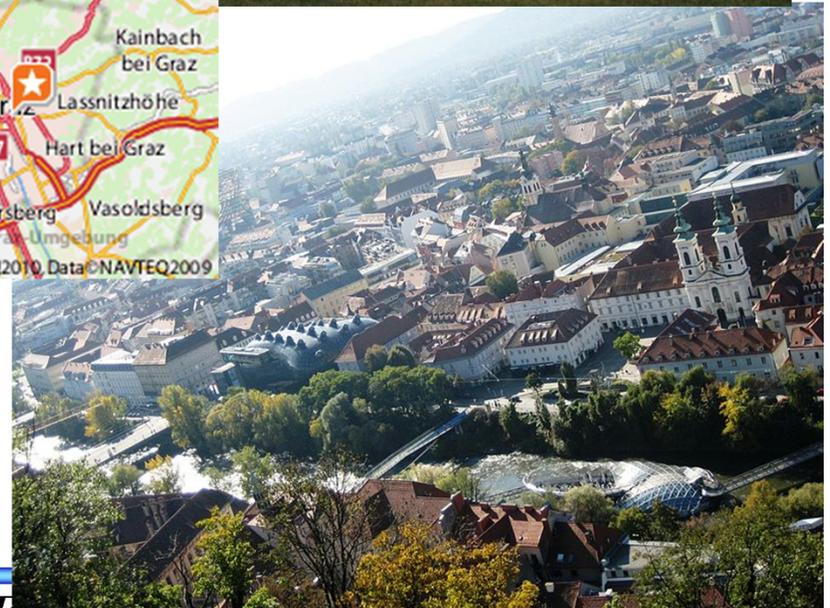
- Prepared and investigated various families of materials including metal (Au, Co, Ag, and Ni) or alloy (Ni-Co) supported on carbon, carbon nanofibers, and metal carbide (WC), and mixed oxides (La_2NiO_4)
- Catalysts tested using thin-film RDE with Nafion as binder in basic aqueous electrolyte
 - Au catalysts showed a lower onset oxidation potential than Ni-based catalyst
 - Ni catalysts showed a much higher oxidation current than Au catalysts
 - No activity shown by Ag and Co catalysts

---- Astrid Stadlhofer, Graz University of Technology, Austria



Conclusion

- Technical progress has been made in all three annex sub-topic areas
- Presentations from “Fall 2010” Workshop and recent workshop reports are being posted on the Annex 22 portion of the IEA-AFC website
- Next workshop (Spring 2011) will be hosted by Graz University of Technology, Austria on July 4-5, 2011



Invitation to the 5th International Conference on Polymer Batteries and Fuel Cells, July 31-August 5, 2011



5th INTERNATIONAL CONFERENCE ON POLYMER BATTERIES AND FUEL CELLS
July 31 - August 5, 2011
Advanced Photon Source, Argonne National Laboratory
Argonne, Illinois USA

About the Conference

It is a great pleasure for the organizing committee of the 5th International Conference on Polymer Batteries and Fuel Cells (PBFC-5) to invite all who are interested in materials for and systems based on lithium polymer, lithium-ion, metal-air, and flow batteries, and proton-exchange membrane and alkaline-exchange membrane fuel cells to attend PBFC-5. [Read more.](#)

Dates to Remember

March 15 - Registration Opens

May 31 - Poster abstracts due

June 7 - Early registration and payment due

June 15 - Abstracts due

June 30 - Final registration and payment due

July 31 - Conference opens

REGISTER
PBFC-5

Announcements

April 25 - **Registration now open.** Click the red button above to register!

April 6 - Call for [abstracts](#) now available

Feb 23 - Site launched. Visit often as we update conference information.

<http://www.cse.anl.gov/pbfc-5/>

U. S. Department of Energy / Argonne National Laboratory

Agenda

- **IEA Annex 22 introduction**
- **Member countries' presentations**
 - **Austria**
 - **Canada**
 - **Germany**
 - **Korea**
 - **Sweden**
 - **United States**
- **Discussion to determine the location and dates for next workshops (Fall 2011 and Spring 2012)**