ABSTRACTS

SESSION B: STATIONARY POWER GENERATION AND CHP

1.) ROBANODE: Understanding and minimizing anode degradation in hydrogen and natural gas fuelled SOFCs

Dr. Dimitrios K. Niakolas

The development of Solid Oxide Fuel Cells (SOFCs) as viable energy conversion systems is still prevented by cost, which is several times higher than required for economic feasibility and by insufficient durability, especially concerning that of the Ni based cermet anode electrode. The successful implementation of solid oxide fuel cells largely depends on their performance degradation rate and consequently the lifetime of the SOFC. Thorough understanding of the degradation mechanisms will allow targeted design and development of optimization strategies to avoid degradation of the state-of-the-art SOFC materials.–Furthermore, it will allow development of new SOFC materials for efficient and long lasting operation. The loss of performance of Ni based anodes can be mainly attributed to four factors:

- Agglomeration of the Ni particles of the cermet anode due either to thermal or overpotential sintering
- Carbon deposition originating under conditions of internal steam reforming of hydrocarbons and biofuels
- Sulfur contamination due to the sulfur containing compounds in the hydrocarbon and biofuel feed stocks
- Redox instability of the cermet anode

The ROBANODE project proposes an integrated strategy for understanding the mechanism of processes, which cause anode degradation in hydrogen and natural gas fuelled SOFCs, by combining robust theoretical modelling with experiments over an extended range of operating conditions and using a large number of modified Ni-based catalysts (state-of-the-art cermet anodes). In particular, the ROBANODE project addresses the following scientific and technological issues:

- Development of detailed models for the operational performance of Ni-based cermet (YSZ or CGO electrolyte) SOFC anodes and for prediction of the degradation due to thermal and electrochemical sintering as well as to carbon deposition and sulfur poisoning.
- Investigation of the mechanism of degradation due to redox cycling and to thermal and electrochemical sintering of Ni-based (state-of-the-art) SOFC anodes under various operating conditions as well as identification of the key factors controlling the extent of sintering.
- Investigation of the mechanism of degradation of Ni-based (state-of-the-art) SOFC anodes due to carbon deposition or sulfur poisoning, for natural gas as fuel under internal reforming or direct oxidation conditions.
- Identification of degradation mechanisms common in SOFC and in catalytic reactors (reforming, oxidation, dehydrosulfurization reactions) aiming to a holistic, optimized strategy for improvement of the durability of Ni-based anodes.

2.) DEMMEA Project: Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High Temperature PEMFCs and Optimization of the Individual Components (245156 FCH-JU-2008-1)

Presentation by Dr. St. Neophytides

The state of the art High Temperature PEM fuel cell technology is based on H_3PO_4 imbibed polymer electrolytes. The most challenging areas towards the optimization of this technology are:
(i) the development of stable long lasting polymer structures with high ionic conductivity, and
(ii) the design and development of catalytic layers with novel structures and architectures aiming to more active and stable electrochemical interfaces with minimal Pt corrosion.

In this respect, the objective of the project is to understand the functional operation and degradation mechanisms of High Temperature H_3PO_4 imbibed PEM and its electrochemical interface. The degradation mechanisms will be thoroughly studied and focused on low loading Pt or nanostructured alloyed Pt electrocatalysts and catalytic layers, which will be supported on finely dispersed or structurally organized modified carbon supports (nanotubes, pyrolytic carbon). A stable electrocatalytic layer with full metal electrocatalyst utilization at the electrode/electrolyte interface can thus be achieved. The High Temperature PEM Membrane Electrode Assembly (MEA) will be based on:

a) PBI and variants as control group, and
b) the advanced state of the art MEAs based on aromatic polyethers bearing pyridine units.

These MEAs have been developed, optimized and tested at temperatures up to 200°C, where they exhibit stable and efficient operation. In the project they will be studied and tested in single fuel cells with regards to their operating conditions and long term stability aiming to the development of a series of diagnostic tests that will lead in the design and development of an accelerated test and prediction tool for the MEA’s performance. If we can really understand the fundamentals of the failure mechanisms, then we can use that information to guide the development of new materials or we can develop system approaches to mitigate these failures.

3.) ASSENT: Anode Sub-System Development & Optimisation for SOFC systems

Jari Kiviaho, VTT

Project Acronym: ASSENT
Grant agreement no.: 244821
Period: 1.1.2010 – 31.12.2012

Partners: 1) VTT Technical Research Centre of Finland (Coordinator), 2) HTCeramix SA, 3) EBZ Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH, 4) Wärtsilä Finland Oy, 5) Hexis AG and 6) Forschungzentrum Jülich GmbH

The high temperature fuel cell technologies have potential for high electrical efficiency, 45-60%, and total efficiency up to 95%. SOFC has the added benefit of offering commercial applications from 1 kW residential to several MW stationary units with high fuel flexibility. Whilst much effort is devoted to cell and stack issues, less attention has been paid to the components and sub-systems required for an operational system. Components and sub-systems such as fuel processing, heat and thermal management, fuel and water recycling and power electronics are as crucial to the successful commercialisation of fuel cell systems as the cell and stack.

ASSENT project is focused on the development of fuel and water management for SOFC systems. The fuel management, and especially recirculation, is a key question in achieving high electric efficiency and operation without external water supply. The recirculation increases the fuel utilization rate and can provide the water needed in the reforming of fuels. However, with current SOFC systems the anode exhaust gas circulation has been problematic from controllability and reliability points of view, and hence there is a need to develop the better solution of the anode subsystem. ASSENT project will evaluate different concepts for fuel and water management, e.g. blower-based approach, ejector-based approach, and water circulation by condensing from the anode off-gas/exhaust gas and evaporating back to the fuel loop. The aspects taken into account in the conceptual analysis are effects on electric efficiency and process simplicity implying easiness of controllability, and requirements on diagnostics accuracy into failure mode prevention. In the detailed evaluation, the suitable approaches are analysed more thoroughly in terms of component availability and reliability, achievable diagnostics accuracy, controllability, effects on reformer, mechanical integration feasibility to whole system, cost effects etc.

The objective of ASSENT project is to find better anode subsystem concepts that are validated for small-scale and large-scale SOFC systems to be implementable into a real system to fulfil performance, lifetime and cost targets for stationary applications. To find optimal anode subsystems to be validated, conceptual analysis and evaluation of the feasibility of the different recycle solutions for the anode subsystem will be carried out. In addition, sensing techniques are tested, evaluated, and also developed, where available techniques are not sufficient. Optimum components should be suitable for mass production.

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4.) OPERATING EXPERIENCE ON MCFC FULL SIZE POWER PLANTS: THE KEY TO DEVELOP NEW OPPORTUNITIES IN MCFC

Pietro Bedont (AFCo -Ansaldo Fuel Cells S.p.A., C.so Perrone 25, Genova, Italy)

According to the objective of the Session 5 of the meeting, state of progress and new opportunities for MCFC technology in Ansaldo Fuel Cells are presented.

The presentation summarizes the Ansaldo Fuel Cells technology based on proprietary MCFC stack design coming from over 25 years experience in the Molten Carbonate Fuel Cells R&D, starting with prototypes and small units and introducing in the recent years new configurations and manufacturing of industrial relevant sizes stacks.

At the same time solutions for the balance of plant systems have been developed and tested on a number of demonstration plants operated in Italy and other countries.

By means of these field tests Ansaldo Fuel Cells have accrued operational experience mainly aimed to application of the MCFC in the range of hundreds of kW to MW class to be applied in for distributed generation, CHP solution and commercial applications.

In addition, in Bosco Marengo (not far from Genoa' headquarters a Test Site for field test of full size stacks and equipments has been set up. Two full size plants (TECNODEMO and GP) are in place and operating, where the new technological solutions are tested in terms of performance, endurance and training of qualified personnel.

In particular by means of the long lasting operation carried out at the TECNODEMO Plant the goal of 90% availability of the plant was successfully achieved. The significant field experience gained was used to drive the plants improvements that are included in the AFCo's standard system configuration.

More recently a very interesting opportunity was envisaged for the MCFC technology: *"active"* CO_2 separation.

Reducing CO_2 emissions is becoming a worldwide must and a key contribution to this path is expected from CO_2 reduction in power generation. A number of studies are ongoing and the published results agree that the solution usually considered to capture CO_2 would determine high energy losses resulting in increased fuel consumption, lower efficiency and higher cost of produced electricity. In addition in the case of post combustion systems the environmental impact is emerging as a significant item to be investigated, mainly due to emissions of chemicals used for the separation.

Molten Carbonate Fuel Cells (MCFC) technology has an intrinsic capability to strongly concentrate CO_2 producing at the same

time additional electrical energy rather than consuming it.

The CO_2 coming from the flue gas is fed to cathode and via the MCFC electrochemical reactions is transferred to the anode stream, where it is easier to separate due to lower flow rate, higher concentration, mix with chemical specie containing only CO_2/H_2/steam.

MCFC works as an "active" CO_2 concentrator, repowering the power plant where it is applied.

Of course this new application requires specific development and new projects for qualifying and demonstrate the MCFC-CCS (Carbon Capture and Storage) capability that have been defined.

AFCo facilities will be used to supply experimental data from lab scale to full size MCFC stack and systems tested under CCS-like operating conditions with the goal to demonstrate the full chain flue gas-MCFC- CO_2 "active" separation, while for larger demonstration projects funding need to be made available through specific programs at regional, national and European level.

5.) THE HYDROGEN DEMONSTRATION SOCIETY AT LOLLAND ISLAND, DENMARK

Laila Grahl-Madsen, IRD Fuel Cells A/S

Denmark presently has the world largest electricity production from Combined Heat & Power (CHP) plants[1]. The Danish electricity production has moved during the last 30-years from a few central CHPs to a large number of decentralised CHPs and wind mills. This development is expected to continue towards even smaller CHPs such as µCHPs for single family houses. The main benefits of µCHPs are believed to be:

- Suitable for regulation (fast response)
- Less power grid loss (≈6%)
- Less need in grid investments for heat distribution
- A reduction in the need for new investments in central power plants (will be replaced by virtual power plants)
- A CO_2 reduction of up to 5 tons per year per 'single family house' is estimated when 'green' fuel from renewables are use e.g. hydrogen from Wind

IRD participates in a Danish fuel cell based µCHP project that was initiated in 2006 and estimated to continue until the end of 2012. All Danish fuel cell stakeholders for stationary applications participate in the project. One hundred µCHPs based on PEM or SOFC will in total be tried out. The SOFC and half of the PEM units are to be fuelled with NG, while the remaining 40 units are fed with pure hydrogen. IRD has constructed three versions of a hydrogen fuelled µCHP based on PEM FC (Fig. 1). Five β-units have already been field tested for one year (2008-9) in ordinary single family houses in a village at Lolland Island. The first of remaining 35 γ-units are presently being installed for the final field tested. The presentation will comprise the experience gained and the 'Danish' long-term hydrogen vision to facilitate the implementation of additional renewables without sacrificing the energy security.

	2006/7: α-µCHP	**2008/9: β-µCHP**	**2009/10: γ-µCHP**
All units: Nominal power: 1.5 kW_{AC}			
Efficiency (LHV): Electrical (H_2□P_{DC}): Electrical (H_2□P_{AC}): Combined efficiency:	 49% 43% 75%	 52% 47% 94%	 47% 44% 94%
Ready-mode Power:	105 W_{AC}	40 W_{AC}	15 W_{AC}

Fig. 1 The three IRD hydrogen fuelled µCHP units aimed for pure hydrogen operation.

[1] COGEN Europe, Overview of CHP in Europe (2005)