

Fuel Cell System HotModule: Highest Efficiency and Cleanliness at Sustainable Base Load Supply

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Fuel Cell System HotModule: Highest Efficiency and Cleanliness at Sustainable Base Load Supply

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Introducing the Company

MTU Onsite Energy, formerly known as CFC Solutions, is a Tognum Group Company with its place of business in Ottobrunn near Munich, Germany. MTU is a supplier of tailor made systems of highest efficiency and cleanliness for cogeneration and trigeneration based on carbonate fuel cell technology.

Applications and Clients

Within the existing market of cogeneration and trigeneration MTU focuses its marketing and sales efforts on industrial and commercial customers. Targeted clients are data centers, the telecom industry, hospitals, the food industry, waste water treatment operators, energy service companies and industrial key accounts.

Introducing the Product Portfolio

HotModule is the registered trademark of MTU's fuel cell systems. Based on three standardized building blocks, the stack module, the media supply, the inverter & control unit, MTU offers their customers tailor made solutions by complementing the HotModule with heat utilization and specific gas clean up systems as required.

OUR PRODUCT PORTFOLIO




- 250 kW_{el} – 2000 kW_{el}
- Hybrid HotModule – Gas engine
- Hybrid HotModule – ORC
- HotModule Maritime Application

Figure 1

The product range comprises currently single stack HotModules with an electrical output of approximately 250 and 350 kW followed by a 500 kW single stack HotModule in the near term. Based on multi stack HotModules MTU will cover a power range of up to 2 Megawatt.

Ongoing development

To fulfill the requirements of an emerging fuel cell market, today's gap of the total cost of ownership for an installation over a given time period in comparison to conventional CHP systems, has to be reduced. Besides working on cost reductions related to the process design, the focus is a development program, reducing cost, increasing lifetime and increasing the power density of the fuel cell stacks.

Cost reduction efforts

A great effort has been started in research for alternative powder materials for the electrodes. As a result, we were recently able to substitute the comparatively expensive Anode powder material based on a nickel alloy by a cheaper commercial Nickel material. Simultaneously with the anode cost reduction program a redesign of the anode was carried out, which resulted in an efficiency increased as described below.

In a second step recently investigations were carried out successfully to replace both the anode- and the cathode base material by a 30% cheaper version of Nickel material. Again these substitution efforts are accompanied by a redesign of both electrodes resulting in a further increase of the power output of the electrodes.

Concerning the metal components a complete redesign of the anodic current collector also resulted in considerable material cost savings of approximately 50%.

Efforts to increase lifetime

From mechanistic investigations it is well known that kinetic polarization of both electrodes decreases with increasing temperature. On the other hand corrosion effects tremendously increase with increasing temperature. To address these two contradictory aspects we take great effort to homogenize the temperature distribution of a full scale cell (increase of the minimum cell temperature to decrease kinetic polarization and reduction of local temperature peaks to decelerate corrosion effects).

In order to describe the actions concerning heat management, first the state of the art cell conditions are introduced. Within the cell the electrochemical reaction is producing electrical current and heat on the one hand. On the other hand due to the system conditions including the internal reforming reaction, the cell is cooled. The amount of cooling and the temperature distribution over a full scale cell now depends on maximum current density, amount of oxygen and fuel available at different cell regions and on the catalyst distribution within the cell. The present design reveals a delta in temperature of roughly 100°C over the cell area with a maximum cell temperature of roughly 650°C. Simulations revealed that with an optimized catalyst distribution a decrease in temperature delta to approximately 50°C accompanied by a slightly increase of the medium cell temperature by roughly 5°C is possible. This would directly result in an increased cell voltage and cell power. First measurements with full scale electrodes generally confirm these theoretical findings.

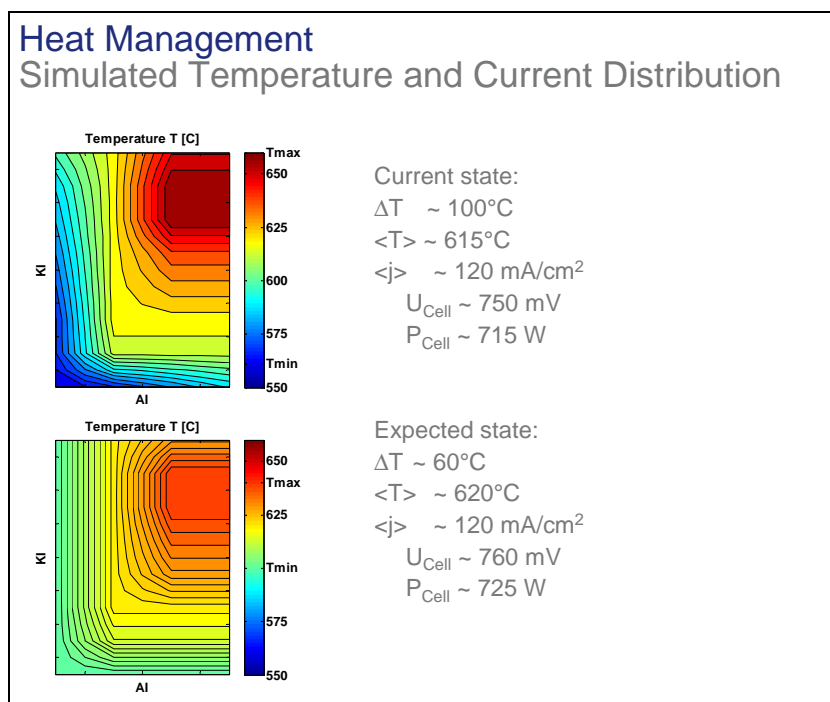


Figure 2

Efforts to increase power density

Major goal in MCFC research and development is to improve the power density and thus the efficiency of the stack. Appropriate electrode design is highly suitable to positively influence both the anode and the cathode reaction kinetics. An elemental base for specific optimization of the electrode design is a detailed knowledge of the reaction mechanism and of the factors of influence affecting the electrode reactions.

In order to find out about details of the overall electrode reaction mechanisms in house developed half cell test benches both for anode and for cathode examinations are used. These half cell test benches allow the cost and time efficient examination of a large range of different electrodes. In addition the application of a broad variety of testing parameters like gas composition, current density, temperature and humidification is possible. Sample size of electrodes applied in half cell test benches is in the range of 10 cm^2 . Besides that 250 cm^2 single cell test assemblies are used as well as laboratory scale small MCFC stacks for fundamental investigations in a real fuel cell surrounding. Impedance spectroscopy is applied as main diagnostic tool for mechanistic studies.

Considering the cathode reaction the first aim was to clarify the reaction mechanism by investigating the influence of varying oxygen and carbon dioxide partial pressure, temperature and humidification effects. In order to improve the cathode, the dependency of the cathode reaction on different morphologic electrode properties was investigated.

Trying to increase the efficiency of single electrodes and electrode-matrix-electrode assemblies a variety of measures was investigated like catalytic activation of the electrodes, optimization of the electrode morphology (i.e. the pore size and pore size distribution), optimization of fuel and oxidant composition etc. Based on the results from kinetic half cell

studies several generations of high performance MCFC cathodes which are subject to further improvements have been generated. Besides this a new generation of advanced anodes applying active pore design and taking into consideration the interaction between anode and cathode pore structure with respect to capillary forces and electrolyte distribution has been designed.

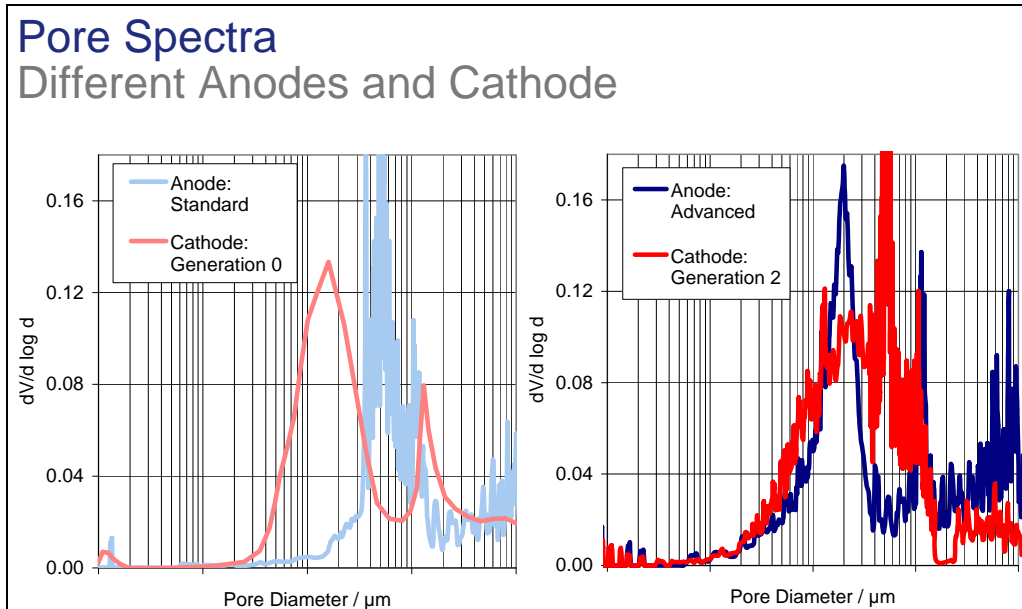


Figure 3

The figure on the left side demonstrates that in case of a standard anode, the pores within the structure of the electrochemical active layer were clearly larger than the ones in the electroactive layer of our generation 0 cathode. In the figure on the right side it becomes clear that in our advanced anode and our generation 2 cathode both active layers have similar pore diameters.

A surprisingly good accordance was found between half cell measurements, findings from lab scale MCFC single cells and lab scale stacks and even observations in full area technology stacks (20 cells with a cell area of approximately 0,8m²). This demonstrates the importance of fundamental kinetic investigations to proceed in electrode design and MCFC power density.

Finally the application of advanced anodes and cathodes compared with formerly used "standard" electrodes in a full scale MCFC-test was demonstrated. By substituting the standard cathode and anode by the respective advanced electrodes an increase in cell voltage of up to 60 mV has been proven. The results shown in the following figure demonstrate the potential of electrode design.

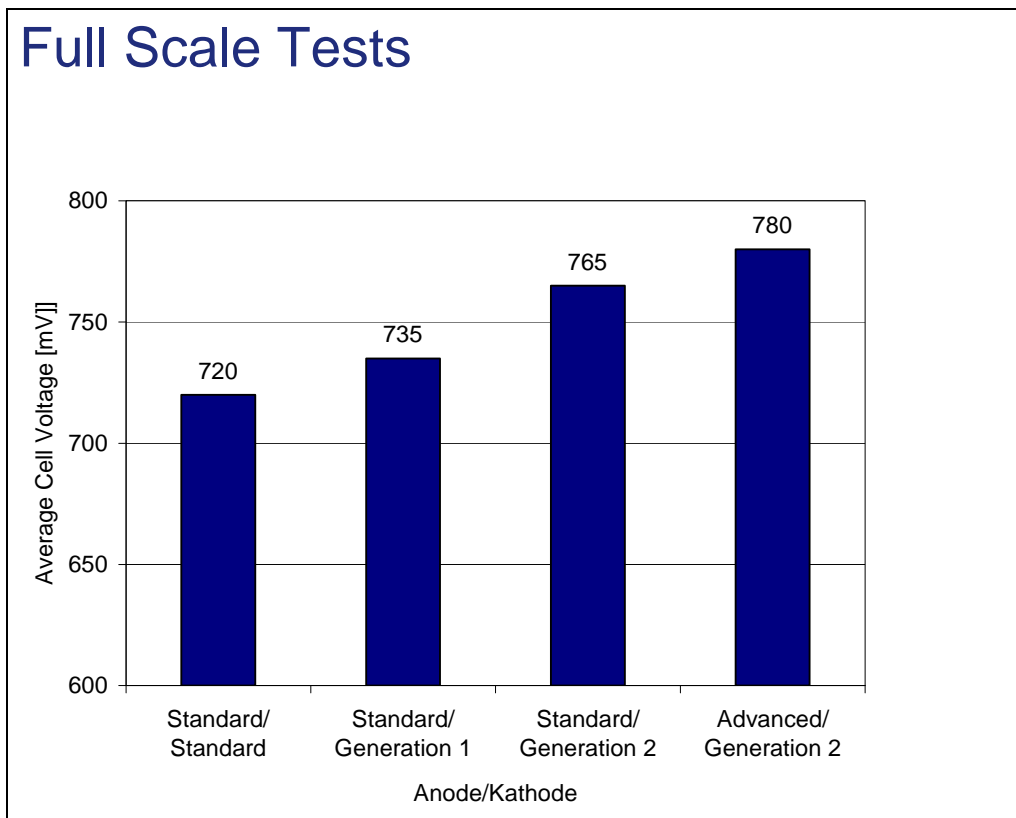


Figure 4

The above figure demonstrates results obtained in full area technology stacks (1000 h runtime, 120 mA/cm², 70% fuel utilization, medium cell temperature 620°C, system gases). The performance increase is clearly visible. For solely substituting the cathode a voltage increase of 45 mV could be realized. For substituting both the anode and the cathode by the newly developed versions a voltage increase of 60 mV was realized.

Future prospects

Above described activities together with others cover the whole range of cell-, stack- and system development as well as the monitoring of all operational data, the supply chain process and the manufacturing process.

MTU Onsite Energy GmbH performs these ongoing development activities with the aim of cost reduction, efficiency increase and increase in lifetime.

The up so far achieved results are very promising and will be continued in order to pave the way for the commercialization of the molten carbonate HotModule fuel cell system.