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H_2FC

Integrating European Infrastructure to support science and development of Hydrogen- and Fuel Cell Technologies towards European Strategy for Sustainable, Competitive and Secure Energy

Deliverable

D8.5 Test Facility for high Power Testing of Fuel Cells

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Contributing partners (short names)	**KIT, VTT**

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Document History

Issue Date	Version	Changes Made/Comments
27.11.2013	1.0	Josef Mertens (Jülich)
28.11.2013	2.0	Josef Mertens / Izaak Vinke (Jülich)
28.11.2013	2.1	André Weber (KIT)
29.11.2013	2.2	Josef Mertens

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Test Facility for High Power Testing of Fuel Cells

This is the end version of deliverable D8.5. The original completion date of this deliverable was the 31st October 2012.

The delay was caused by the commissioning of the laboratory of the newly formed institute IEK-9. Which unfortunately took over half a year. The permission to operate the test rigs was granted in August 2013 after the rigs were installed in the laboratory in December 2012. Test runs have been performed since them. The test rigs will be ready for TNA after January 2014 (delay of 14 month).

1 Introduction

The deliverable D8.5: - Availability of High-power Test Rig - is a part of the task JRA2.4. - Facility and measurement improvements for investigations of high temperature fuel cells components and systems.
Partners involved: Jülich, JRC, VTT, CEA, task leader: Jülich
Report: FZJ

One of the major problems in investigating the cell performance of electrodes of a technically useful size, (at Jülich for instance minimum electrode size of 16 cm²), is their high power output. In a typical specific power of 1.5 W/cm² at 600 °C and up to 2.5 W/cm² at the operating temperature of 800 °C very high currents flow (at 0.7 V up to 60A!). In this task we propose and adaptation of the cell housing and test rig setup to accommodate high currents without impacting on the gas flows. Previously, such results were obtained by extrapolation. It is expected to give the ability to characterize fuel cells at high current loads under technically relevant conditions and to allow the evaluation of the potential of high current tests for HALT testing (highly accelerated lifetime testing)

Status of Task JRA2.4.1 Test facility for high power testing of fuel cells

Report: J. Mertens, I. C. Vinke

FZJ contribution:

2 State of the art

To be able to predict the electrochemical behavior of the cell in a stack, single cell measurements are performed. The difference in electrochemically active area between stacks and single cell measurement set ups is often considerable. In stacks an electrochemical active area of up to 360 cm² can be found whereas the single cell experiments are frequently carried out on 1 cm² sized electrode surfaces. From experiments performed in the Forschungszentrum Jülich a decrease in the electrical power density of 30% is observed going from cells of 1 cm² to cells of 16 cm² sized cathodes produced from the same paste (Figure 1).

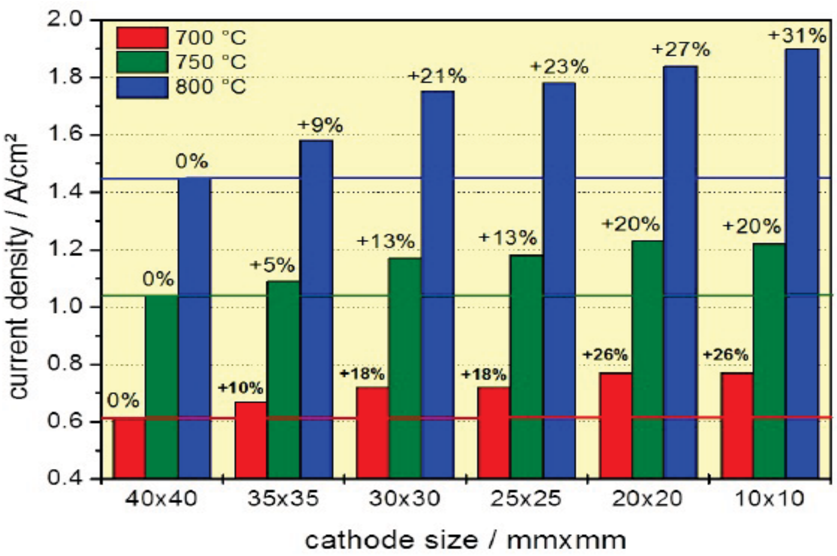

Figure 1 : Current density result depends on area of cathode

The reason for this decrease is probably caused by an increasing inhomogeneity of the contact between the cell and the current collectors. The larger cathodes also can give rise to a temperature gradient across the active area and a change in composition of the fuel and oxidant due to the electrochemical conversion. Further the resistance of the current collector (Pt or Au mesh) may play a role. These results suggest that when results from single cell measurements are to be comparable with stack results the data should be obtained on large cells. By increasing the maximum current at which a test stand can operate the need for extrapolation can be avoided and the electrochemical characteristics can be directly measured at high current densities. The adaptation of existing test stands to allow high current operation involves a larger number of modifications of these test stands.

3 Improvements

FZJ-Contribution:

At the Forschungszentrum Jülich an existing test rig was modified by upgrading the electrical load from 20 A to 40 A. One of the major problems associated with this upgrade is the Ohmic resistance in the current conducting circuit. At these high currents the voltage losses in this circuit exceed the maximum power output of the electronics. To lower the Ohmic resistance the wiring between the load and the furnace were adapted to the high current. The feed through into the furnace was changed from a simple wire to a massive steel rod of 6 mm. Inside the furnace the current is transported through 4 Platinum wires of 1 mm diameter. First measurements show that the test rig is capable of measuring up to the maximum current of 40 A.

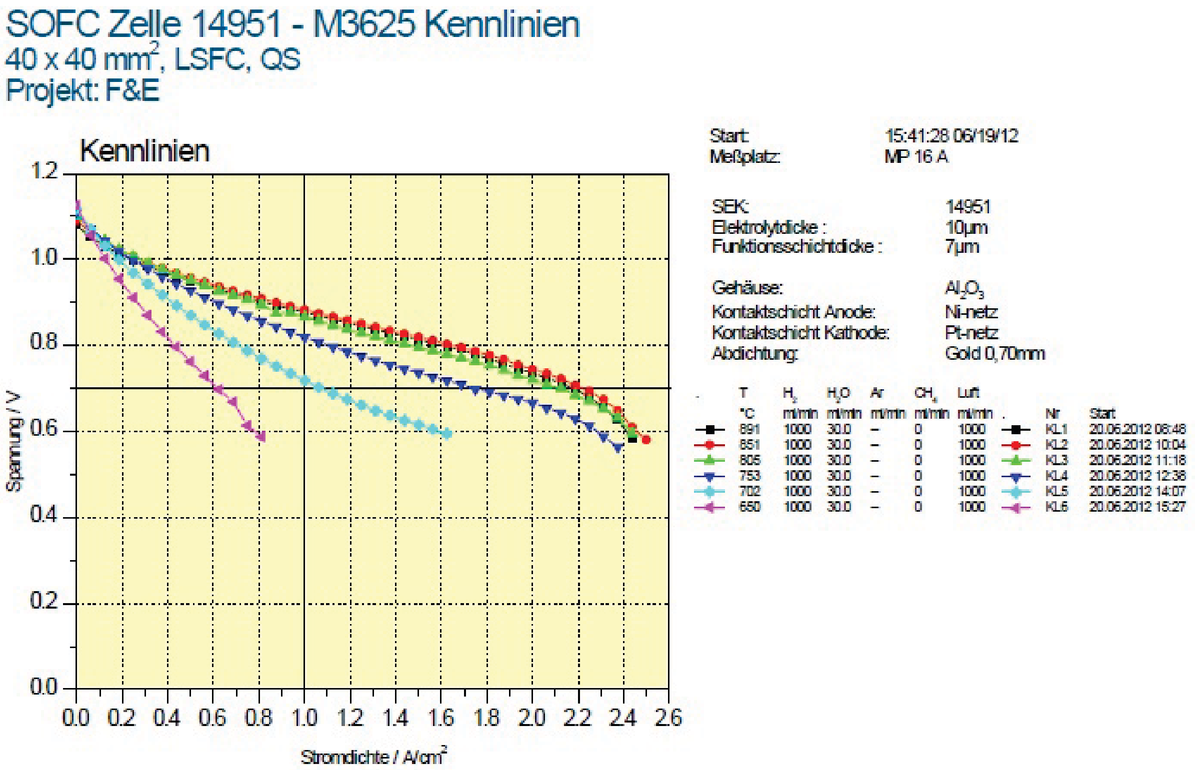

Figure 2: Current-voltage measurements on a standard Jülich anode substrate cell with LSFC cathode up to 40 A.

From the results of these first measurements a problem with the gas and air supply of the cell housing becomes obvious. To solve these problems new cell housing was designed and manufactured. The cell housing is constructed from Aluminum oxide. The sealing of the cell is a combination of a gold gasket and aluminum oxide felt. The current connectors are primarily constructed of nickel and gold meshes. The aluminum oxide flow fields in the cell housing can be exchanged for flow fields of other materials e.g. Crofer 22 APU. This new cell housing comprises CFD optimized manifolds. A fuel bypass present in the old housings was minimized as was the dead volume in the fuel compartment. Due to the shift of the activities from IEK-3 to IEK-9 and the accompanying problems with the infrastructure the test of this new housing is still pending. Independent of these problems with the infrastructure two test rigs capable of high currents were ordered and are awaiting installation on site.

Cell and stack testing facilities can be used for normal operation, life-time and degradation studies by changing operating conditions like current, temperature, fuel and air utilization rate, fuel composition, additional impurities etc. In addition stack testing facilities have been equipped with oxygen and humidity sensors to detect possible changes in leakages and utilization rates.

Figure 3: New test benches for single cells of 16 cm² at Forschungszentrum Jülich with cell current up to 40 A.

KIT-contribution:

At KIT a 16 cm² SOFC test bench was modified to allow an operation of the single cells at currents of up to 50 A (3.125 A/cm²).

The test bench is equipped with a furnace including a housing for different types of 16 cm² active area cells (50 x 50 mm² substrate size). Tests of electrolyte, anode and metal supported cells have been performed so far. The gas supply is realized via one MFC (3 slm) for the cathode and 7 MFC´s (10 … 1000 sccm) for the anode, enabling a wide variety of fuel compositions composed of H_2, CO, H_2O, CO_2, CH_4, N_2 and various hydrocarbons. The water vapor supply systems is capable of providing a "fuel" consisting of up to 100% H_2O. The electrical contacting of the cells is usually performed with gold meshes on the cathode side and nickel meshes on the anode side. The gas is distributed by Al_2O_3-flowfields on both sides. A 25 A load (Agilent) enabling a maximum current density of 1.56 A/cm² was installed.

To enable cell tests at higher current densities the Al_2O_3-flowfield on the anode was exchanged by metallic flowfields (either nickel or Crofer 22 APU) acting as a low resistance current collector. The former bilayer Ni-mesh acting as contact and current collector was exchanged by a single layer contact mesh to provide a good contact between anode and flowfield and to avoid any direct contact between the fine Ni-particles in the anode and the Crofer flowfield. The gold mesh on the cathode was reinforced by welding the formerly used fine gold mesh onto a coarse gold mesh and additional gold wires, resulting in a significant reduction of the in-plane resistance. The platinum wire (∅ 1 mm) inside the furnace was exchanged by 2 gold wires (∅ 1 mm each). The electronics in the test bench were modified to enable currents of up to 50 A. At the moment a number of tests is performed with different electronic loads and potentiostats:

- Agilent power supply / load, 50 A (3.125 A/cm²)
- Zahner IM6 + PP241, ± 40A (± 2.5 A/cm²) for SOFC and SOEC operation
- Zahner IM6 + EL1000, 200 A (current density of theoretically up to 12.5 A/cm²)

VTT-contribution:

For this task, VTT has improved two single cell test and four stack test.

- *2x Single cell test stations:*
- Fully automated, automatic shut-down and emergency procedures, 24/7 operation
- Fuel options: bottle gases (CO, CO_2, CH_4, H_2, etc.), natural gas, reformate (real and synthetic), impurities
- Oxidant: compressed air, synthetic air
- Open ceramic cell housing, excess fuel burns inside the furnace (Easy to install, No need for gaskets, No steel parts in cell housing, uneven temperature distribution, Gas analysis not possible, Polarization, impedance, long-term measurements)

- *4xStack test stations:*
- Designed and built in-house
- Up to 200 A stack currents
- Fully automated, 24/7 operation, programmable operation, automatic shut-down procedures
- Fuel options: bottle gases (CO, CO_2, CH_4, H_2, etc.), natural gas, synthetic and real reformates
- Oxidant: compressed air, synthetic air

4 First results

FZJ

First measurements at high current densities have been performed. The reported problems with diffusion limitation on the cathode have been reproduced and the increased flow of the oxidant mitigated the problem and current densities of close to 2 A/cm² could be reached. The projected target of 2.5 A/cm² could not be achieved yet because of some hardware problems in the power boosters.

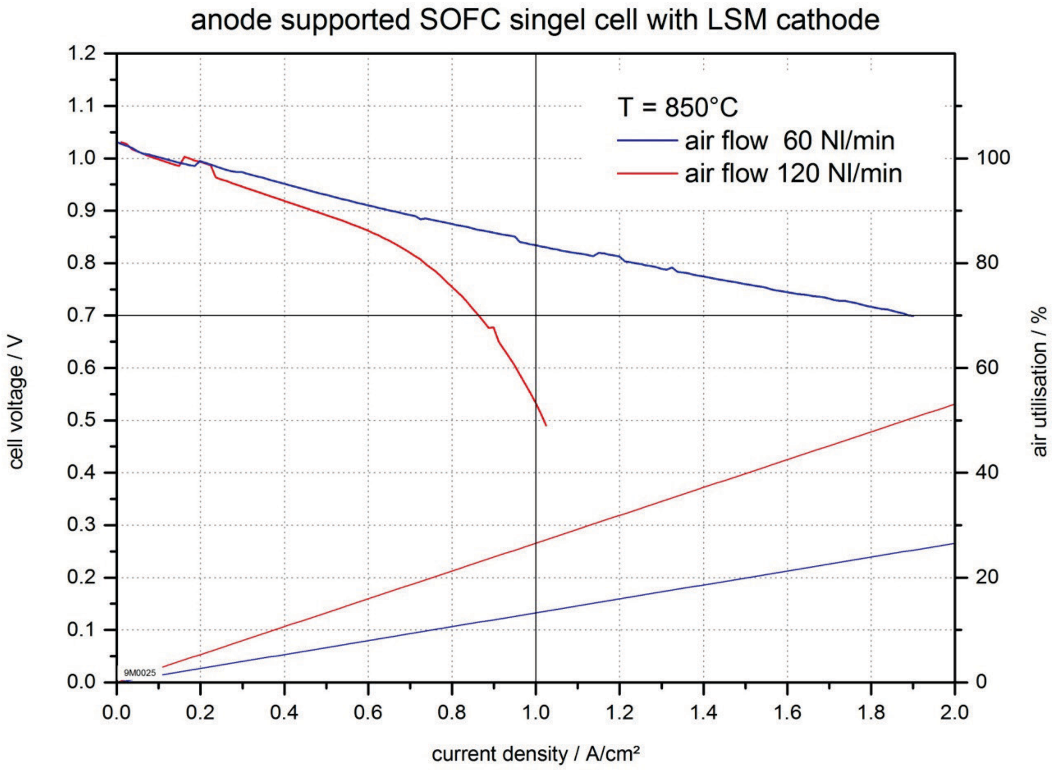

Figure 4: Current-voltage curves for a anode supported single cell with LSM cathode at different air supply rates.

KIT

The detailed results of the ongoing tests will be available in approximately 2 to 3 month. First results on single cell tests (CV-characteristics) at high current densities are provided in the following figures.

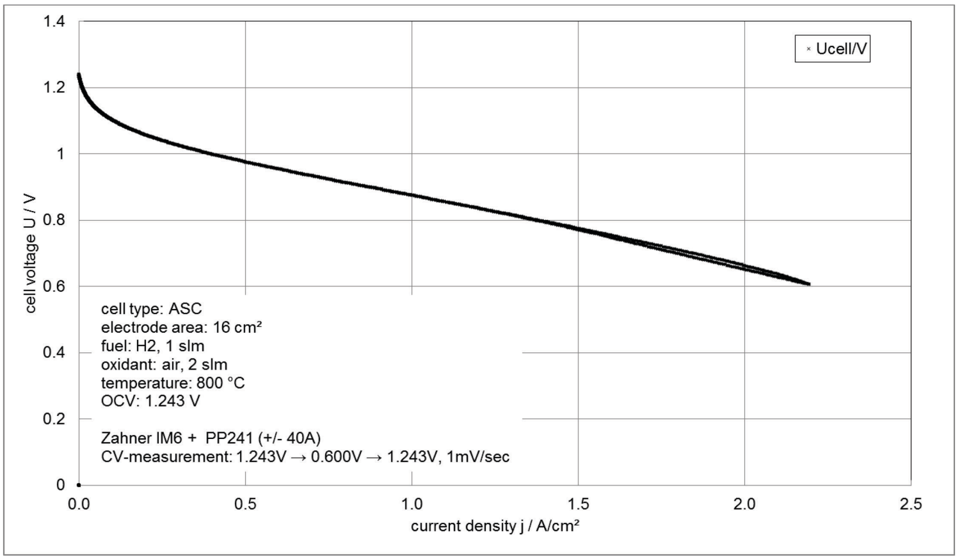

Figure 5: Current-voltage curve of an anode supported cell operated in the SOFC mode.

The anode supported cell tested so far could be operated to current densities of up to 2.2 A/cm² in the SOFC-mode (Figure 5). At this value the minimum cell voltage of 0.6 V was achieved. A further increase in current density to the target value of 2.5 A/cm² is no problem with respect to the test bench but will result in cell voltage values in the range of 0.4 to 0.6 V. As these potentials are fairly below the Ni/NiO potential an electrochemical reoxidation of the nickel in the AFL has to be expected. Further test were carried out to analyze the impact of the hydrogen flow rate (Figure 6). It is obvious that even at fuel utilization rates exceeding 80% an average current density above 1.25 A/cm² is possible. In case of low fuel flow rates (here 0.125 slm) the maximum current density is limited by the available fuel.

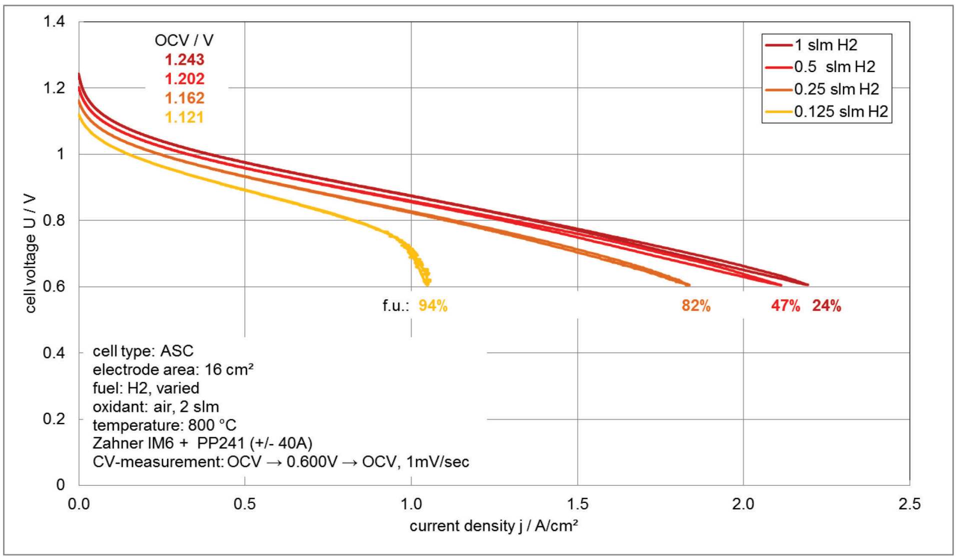

Figure 6: Current-voltage curves of an anode supported cell operated with different H2 flow-rates.The fuel utilization (f.u.) corresponds to the maximum current density of the related CV-characteristic.

Figure 7 shows a CV-characteristic measured in the SOFC and SOEC mode. The maximum current density in the SOFC mode is smaller because 50% of the hydrogen was exchanged by water vapor. In the electrolysis mode a current density of -2.2 A/cm² was achieved at the chosen maximum cell voltage (1.3 V).

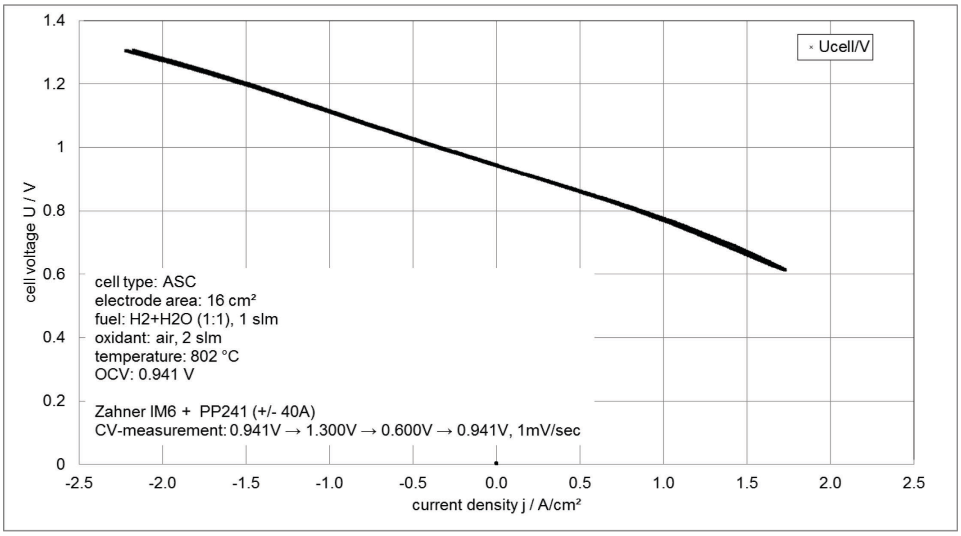

Figure 7: Current-voltage curve of an anode supported cell operated in the SOFC and SOEC mode.

5 Conclusion

FZJ

The previously reported problems due to changes in the organisational structure of the Forschungszentrum have led to a considerable delay in the commissioning of the new test rigs. The permission for operation of the laboratory was granted end of august. Since then the two new high current density rigs have been installed and are now in trial operation.

The test benches are expected to be available for TNA in the first quarter of 2014

KIT

A test bench was successfully modified to enable the operation of single cells at current densities fairly above 2 A/cm² in the SOFC and SOEC mode. First tests at high current densities have been performed. As the tests are still ongoing, no conclusions are so far possible.

VTT

Test benches are ready for operation.