Stack Testing of Solid Oxide Cells

When developing the solid oxide fuel cell (SOFC) and electrolysis (SOEC) technology, it is important to understand the performance and degradation behaviour of stacks, cells and components.

FCH Test Center offers stack testing of solid oxide cells (SOC) following a wide range of protocols. When detailed electrochemical testing is combined with analysis and microscopy it can show:

- The general performance and durability of the cells and stacks under various operating conditions.
- Single cell behaviour in stack environment, including distribution of internal losses in the cells.

When combined with single cell testing:

- Differentiation between single cell and stack performance can be made (e.g. between losses from the cells and stack components).
- Degradation Mechanisms down to component level can be identified.

Monitored parameters	
Temperatures	Inlet and outlet
Gas flows	Mass-flow controllers for each gas
Partial pressures	pO_2 (inlet), pO_2 (outlet)
Stack and individual cell voltage, current	
Operating parameters	
Temperature	650 - 1000 °C
Gas options	H_2, O_2, CO, CO_2, CH_4, N_2 Ar, H_2S, H_2O & other upon request
Loads (SOFC)	Up to 7.2 kW (130 V, 400 A)
Power (SOEC)	Up to -52 kW (130 V, -400 A)
Impedance	At OCV or under current on stack & individual cell
Gas cleaning	Removal of impurities from inlet gas (optional)
Influence of impurities	Sensitivity towards sulphur and other

Table 1: List of key parameters that are monitored during a stack test at FCH Test Center as well as a specification of the operating parameters.

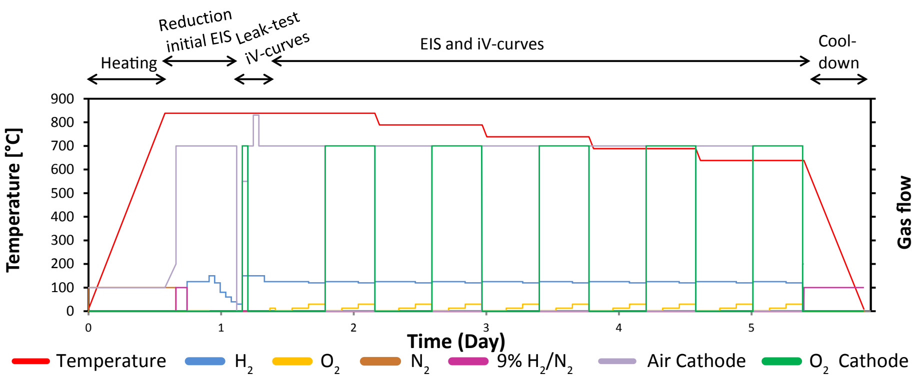

Figure 1: Test profile 'fingerprint', SOFC stack or single cell testing with characterization by iV and EIS.

Performance and Durability Test

Initial characterization of the stack can be done by performing a "finger print", see Figure 1, the results of which can be compared with single cell tests as well as benchmarked against other stack results.

Long-term degradation studies can be performed and designed in several different ways, for example extended periods at constant conditions, thermal or load cycling.

Electrochemical Impedance Spectroscopy

Detailed electrochemical impedance spectroscopy (EIS) is a valuable tool for both performance and durability characterization, see Figure 2. It can be used to show how the resistances of the stacks and cells are distributed over the various parts e.g. anode, cathode and electrolyte and contribute to these resistances, e.g. contacting issues, porosity, thickness of layers etc. EIS results on individual cells in the stack can be compared with reference single cells data. This analysis can explain reasons for differences between cell and stack performance, such as uneven gas distribution leading to higher resistance and faster degradation of certain cells or groups of cells within the stack, or uneven contacting which may cause higher ohmic resistance etc.

High quality measurements

DTU has developed a method of obtaining EIS on up to 16 individual cells in a stack simultaneously, so the EIS results from each cell are comparable and not affected by degradation caused by the duration of testing each cell in sequence [1]. Further, DTU has developed a method of obtaining high quality spectra without noise to a resolution down to two milliohm.

All tests can be combined with microstructural analysis and advanced inspection with e.g. failure analysis or comparison between different cells in a stack.

References

[1] R.R Mosbæk, J. Hjelm, R. Barfod, P.V. Hendriksen, "Fuel Flow distribution in SOFC stacks revealed by impedance spectroscopy", 11th European SOFC & SOE Forum A902 p 14-22 (2014)

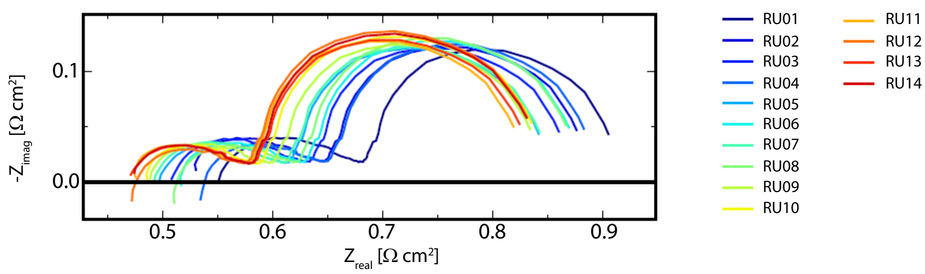

Figure 2: Simultaneous electrochemical impedance spectroscopy (EIS) on a 14 cell stack (repeating units). It shows relatively identical EIS shapes, but displacement of results (series resistance) is due to thermal gradient across the stack. Recorded at 700 °C, fuel: 20 % H_2O and 80 %H_2, oxidant: Air [1].

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The FCH Test Center is part of the Department of Energy Conversion and Storage at the Technical University of Denmark (DTU). The department has 220 employees, more than half of whom are working on fuel cells and electrolysis.

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