Institute of
Technical Thermodynamics

Degradation of Solid Oxide Cells During Electrolysis and Co-Electrolysis Operation

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Motivation

High temperature steam and co-electrolysis have a high potential for the efficient production of hydrogen or syngas. For a further development of this promising technology, development work on materials and cells as well as extensive operational experience is still needed.

A main objective is to develop highly efficient and long-term stable cells and stacks using novel electrode materials and to improve the degradation behavior by elucidating the relevant degradation mechanisms. In this respect, a series of long-term measurements > 1000 h was performed in both operating modes to be evaluated.

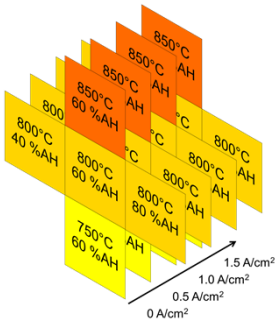


Fig.1: Operating parameters that are investigated during long-term degradation experiments

Measuring setup

The measurements were conducted using a newly developed cell holder which allows the measurement of ASCs as well as ESCs of any thickness using solely gold as sealing material. The test bench is able to measure up to 4 cells simultaneously. While gas supply and furnace temperature are identical for all cells, the current loading can be varied individually for each cell. ASC cells from CeramTec (Marktredwitz, Germany) were used for the long-term measurements.

Degradation experiments

Correlation between degradation and operating conditions such as current density, temperature and humidity has been investigated through long-term measurements and monitoring of impedance spectra.

Steam electrolysis operation

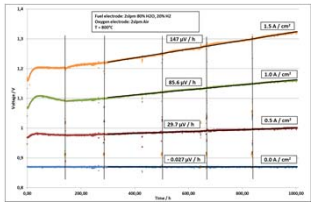


Fig.2: Test run at 800 °C and 80% H_2O/20% H_2 in dependence of current density

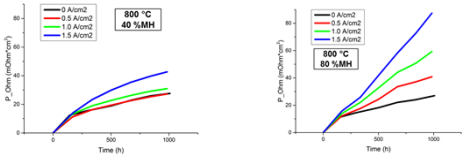


Fig.3: Ohmic resistance at 800 °C and different steam contents (left: 40%, right: 80%) as a function of current density

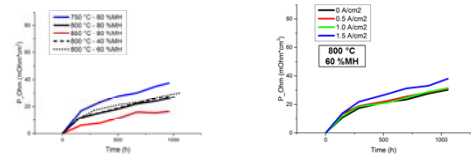


Fig.4: Ohmic resistance at OCV as a function of temperature and steam content (left) and as a function of current density at 800°C, 60% MH

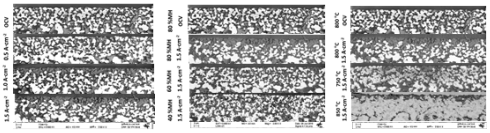
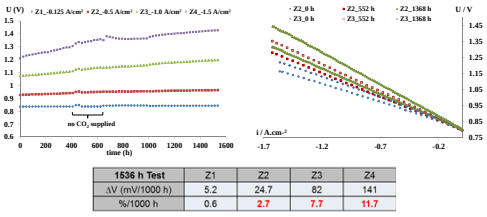


Fig.5: SEM images of fuel electrode/electrolyte interface after operation at different operating conditions: dependence of current density (left), steam content (middle) and temperature (right)

Summary Steam Electrolysis

- Ohmic degradation dominates overall degradation
- Ohmic degradation increases with current density, highest impact at high humidity (80%)
- Ni depletion at fuel electrode/electrolyte interface with increasing current density above temperature (>800°C) and humidity (>60% MH) threshold
- Ni agglomeration at high operating temperature
- Deterioation of electrolyte structure at high current density
- Degradation of air electrode, independent of current density, change of phase composition (XRD, BSE-SEM)

Co-electrolysis operation



1636 h Test	Z1	Z2	Z3	Z4
ΔV (mV/1000 h)	5.2	24.7	82	141
%/1000 h	0.6	2.7	7.7	11.7

Fig.6: Long-term test run over 1500 h at 800 °C: (left) life cycle at 4 current densities (-0.125,-0.5,-1.0,1.5 Acm^{-2}), (right) IV curves after 0 h, 552 h and 1368 h (fuel: 57% H_2O, 36% CO_2, 7% H_2)

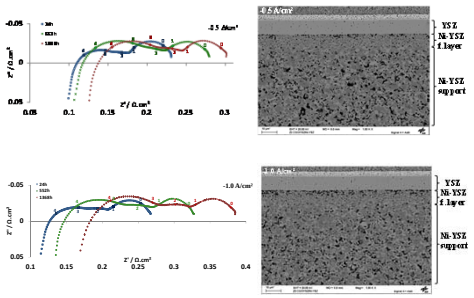


Fig.7: Impedance spectra at -0.5 and -1.0 Acm^{-2} after 24 h, 552 h and 1368 h (left) and SEM images at -0.5 and -1.0 Acm^{-2} (right)

Summary Co-Electrolysis

- Overall performance degradation originates in an increase of both ohmic and polarization resistances
- Increase of polarization resistance (R_{pol}) mainly due to the increased contribution of the electrochemical process at 100 Hz on EIS
- Overall degradation increases with current density
- Ni depletion at fuel electrode/electrolyte interface with increasing current density

Acknowledgment

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