Steam electrolysis in reversibly operated SOFC: Long-term cell testing beyond 1000 h

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The operation time of solid oxide cells in a practical application as energy converter is envisaged to reach at least 20 to 50 000 h. Such lifetime was demonstrated for the fuel-cell (SOFC) mode but not yet for the steam-electrolysis or SOEC mode (SOEC = solid oxide electrolysis cell). In the last years, high electrical-to-chemical energy conversion efficiencies for hydrogen production were achieved with different planar solid oxide cell types and structures [1] – [6]. It was shown that degradation is rather generally accelerated in the SOEC mode, though quantitative comparisons are complicated by the different experimental conditions, such as often chosen higher current density magnitudes in the SOEC mode. Higher SOEC current densities are facilitated by the lower thermal load to the cell (SOEC operation is commonly endothermal or thermalneutral whereas SOFC operation is exothermal). SOEC degradation may also be affected by complications arising from a noisy steam supply.

The different SOFC and SOEC degradation behaviour implies a need for specific cell testing in the SOEC mode. It also implies testing times significantly longer than 1000 h for those cells which yield reasonably low degradation in shorter tests, first, in order to evaluate the risk of sudden cell failure and, second, to obtain a more wide extrapolation base for the often non-linear degradation. The use of cells which successfully passed several thousands of hours of testing will then reduce the risk of a (much more costly) failure in the cell stack environment. So far, the majority of the reported tests does not exceed 1000 h.

In a recently reported 9000 h test, done under a high current density magnitude of 1 Acm^{-2}, an average cell-voltage degradation of 3.8 % / 1000 h (40 mV / 1000 h) was obtained [3]. This degradation value includes number of experimental incidents, notably perturbations in the steam supply. In wide operation periods which were free of incidents degradation was less than half of this value (< 2 % /1000 h). Such degradation extrapolates to a practical SOEC operation of up to 20 000 h [3], achieved with a cell merely developed as SOFC. Cutting that voltage degradation by a further factor of 2 would thus provide sufficient lifetime for practical application, including reversible (SOFC-SOEC) operation. It is therefore of importance to investigate to which degree this aim can be reached already by modification of the experimental conditions, such as a (moderate) reduction of the current density or an optimisation of the cell temperature.

In this contribution, several long-term cell tests in the SOEC mode will be presented, all exceeding 1000 h operation. Anode as well as electrolyte supported (SOFC) cells were analysed. In-situ impedance spectroscopy was applied without interrupting the nominal DC current flow. One aim of these tests is to achieve a more reliable and essentially incident-free operation, which also facilitates the interpretation of the post-test analysis [4]. Other aims are to obtain cell-degradation values as function of the operation parameters current density, cell temperature, steam-conversion rate, and quality of the steam supply. The focus of the parameter settings is the range not deviating too far from the one used in long-term SOFC testing.

References:

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