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Effect of humidity in air on performance and long-term durability of SOFCs

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Performance, durability, and costs are crucial aspects for the success of SOFC technology. Detailed study of the initial performance and degradation mechanisms under relevant operating conditions and at different levels – from materials to stacks and systems – is required to develop a competitive SOFC technology.

The application of SOFCs using ambient air is an attractive option as costs for cleaning/drying units and increase of the complexity of the system can be avoided. To accomplish such a solution it is necessary to study the effect of relevant ‘impurities’ in air on the performance (immediate) and durability (long-term) of SOFCs.

In this contribution, single, anode supported cells with LSM/YSZ cathodes, YSZ electrolytes, and Ni/YSZ anodes were studied over operating periods between 500 and 2500 hours with regard to the effect of humidity of air. The parameters current density and temperature were varied. The study comprised a detailed micro structural analysis of the tested and reference cells, as well. Air was humidified by leading it through a water flask at room temperature, giving a humidity of ~4%.

The humidification of air had an immediate effect on the cell voltage only, when current was applied. The cell voltage under current load dropped fast with a magnitude increasing with increasing the current density when air was humidified with the ~4%. Impedance spectra revealed that this drop, i.e. increase of resistance, was due to a simultaneous increase of both serial and polarization resistances.

The long-term effect was studied for a series of cells over usually 1500 hours at 850, 800, and 750 °C at different current densities and compared to tests in dried air. At the higher operating temperatures the cell voltage was hardly affected by introduction of ~4% humidification of air. At 750 °C, the cell voltage degradation rate was larger compared to the operation in dried air. The effect of humidification of air on the cell voltage degradation was reversible, i.e. the cell voltage recovered after the humidification was stopped.

Post-test micro structural analysis indicates a strong effect of humidity in air on the microstructure of the cathode/electrolyte interface. Cells tested under humidified conditions show for example the formation of ripple-like structures, randomly distributed along the cathode/electrolyte interface and furthermore a flattening of crater structures representing contact points between LSM cathode and YSZ electrolyte. Generally, the effects were the same as observed for cells tested in dried air under harsh operating conditions over 1500 h, i.e. high current density at 750 °C, only more pronounced when the air had been humidified.

The cathode/electrolyte interface thus seems to be a determining part of the cell for the durability in both dried and humid air under polarization and the operating conditions applied in this study. It was therefore attempted to improve this interface by depositing a

LSM/YSZ cathode with smaller and more evenly distributed particles at the interface. Indeed, a cell with an in this way improved LSM/YSZ-cathode / YSZ electrolyte interface proved to be significantly more durable in humid air at 750 °C, even over more than 2000 hours (by a factor of over 10 in regard to the cell voltage degradation rates, see Figure 1, where the cell voltage is shown for a standard and an optimized cell).

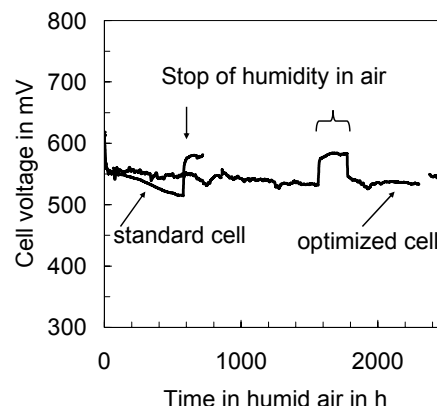


Fig. 1 Durability tests in humid air (~4%) on a standard and optimized (improved cathode/electrolyte interface) cell at 750 °C, 0.5 A/cm², synthesis gas fuel with 75% fuel utilization, 50% air utilization on the standard and 70% on the optimized cell. Both cells had been long-term tested before the period under humid air, the standard cell for 1800 hours and the optimized cell for 2300 hours. The time scale was normalized to zero at the start of humidification of the air.

Detailed electrochemical testing and micro structural analysis data will be presented and thermodynamic considerations about the formation of foreign phases under these conditions discussed.