Durability of Nickel/Zirconia Anodes in SOFCs at High Fuel Utilizations

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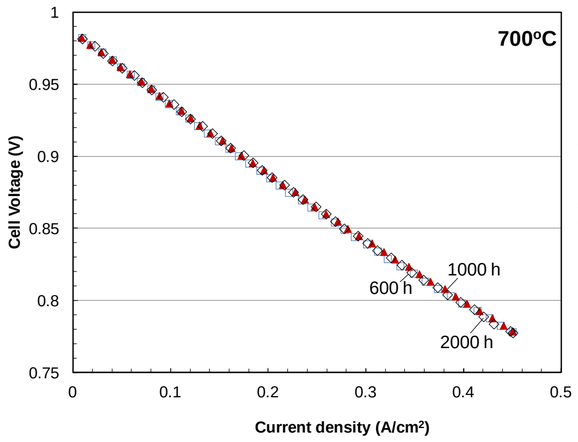
Purpose and Approach

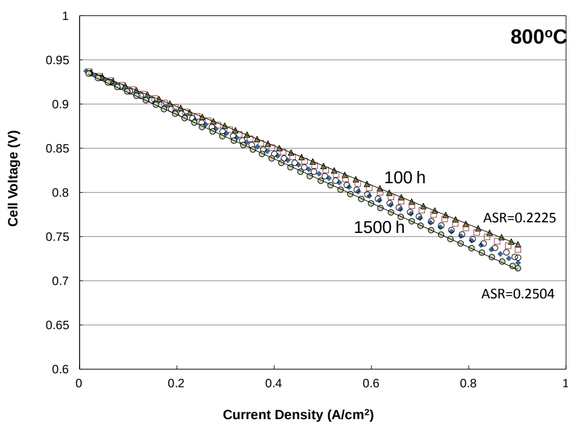
- The objective of this study was to evaluate whether high fuel utilization would lead to accelerated performance losses for nickel/yttria-stabilized zirconia (YSZ) anode-supported SOFCs.
- Dc and ac electrochemical characterization was performed during long term tests at 700, 800, and 900°C using button cells with a YSZ electrolyte and $(La_{0.8}Sr_{0.2})_{0.95}MnO_3$ (LSM) – YSZ composite cathodes. Ni mesh was used as the anode current collector, and Ag or Au meshes were used as the cathode current collectors. Cells were sealed to alumina test fixtures with a barium aluminosilicate glass, G-18.
- Simulated reformate, H_2-CO-CO_2-H_2O≈29-26-19-26%, with variable humidity corresponding to various (45-80%) fuel gas utilizations was fed to the anode. The cathode was supplied with oxygen.
- Multiple button cells were tested simultaneously at each temperature for 1,000-2,300 hours at a constant current corresponding to an initial voltage of 0.8 or 0.7 V, while monitoring the cell voltage. Each condition was duplicated at least once to confirm reproducibility. At least one control cell operating on reformate without increased humidity level was present in each furnace.

Eight button cells installed per box furnace, with individual gas flow controls

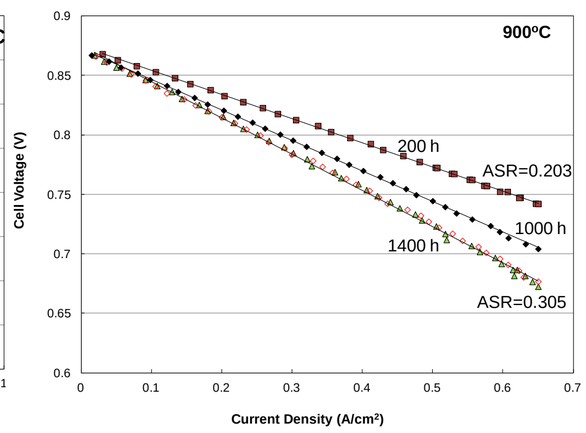
Results



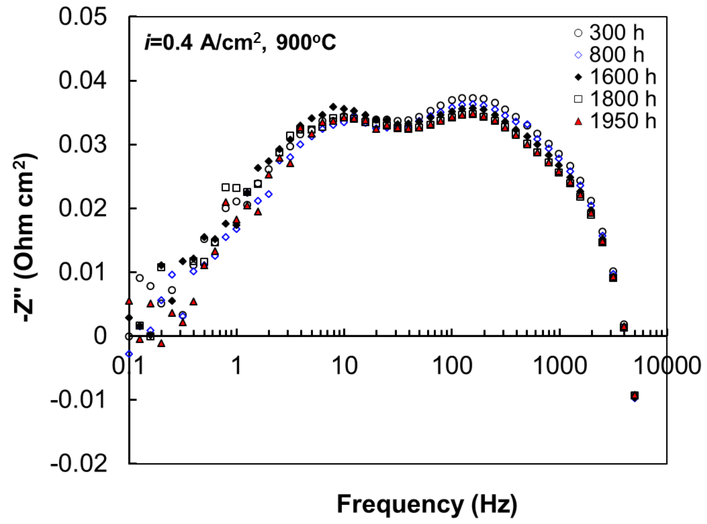
No accelerated losses in SOFC performance were observed at 700°C. Degradation rate of <1%/1000 hours measured at high humidity (up to 70%simulated fuel utilization) was comparable to that on control cells (below 5% fuel utilization).



A higher degradation rate was observed at 800°C and the area specific resistance increased ~ 12 % over 1,500 hour tests for both control cells and those tested at higher humidity (40-60% fuel utilization). This degradation mostly came from Ag migration from the cathode current collector.

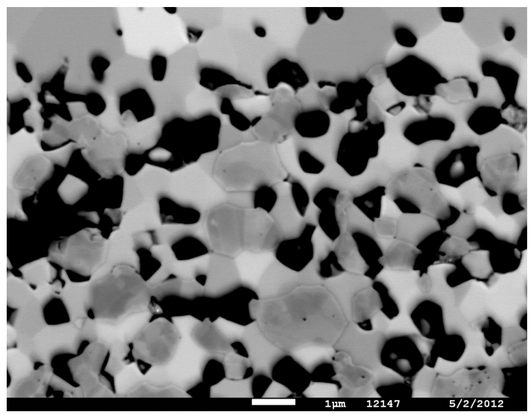


At 900°C the area specific resistance increased 5-30% over 1,000-2,300 hour tests for both control cells and those tested at higher humidity. An increase in both electrodic and ohmic losses was observed. This degradation came from glass seal aging and failure.

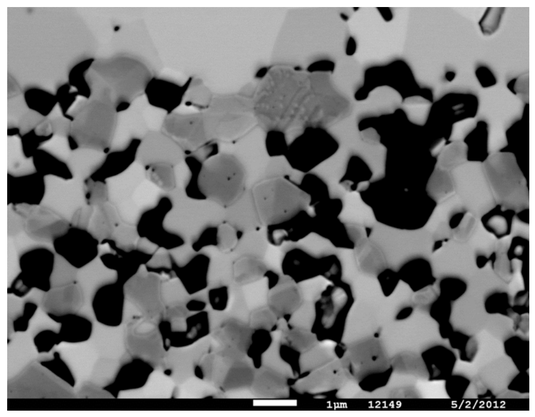


At 900°C, when no glass seal aging occurred, no change in electrodic resistance was observed during cell operation in reformate with humidity level corresponding to 60% fuel utilization.

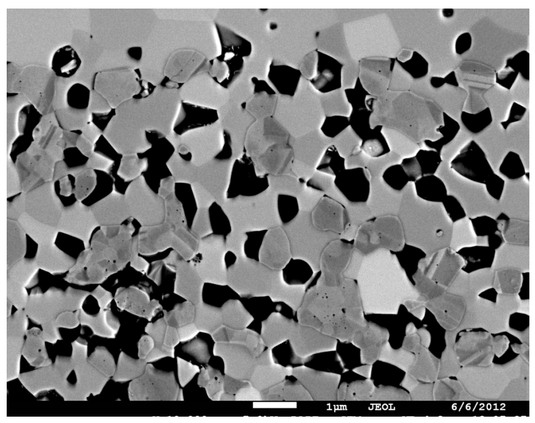
Bode plot of impedance spectra obtained at 900°C



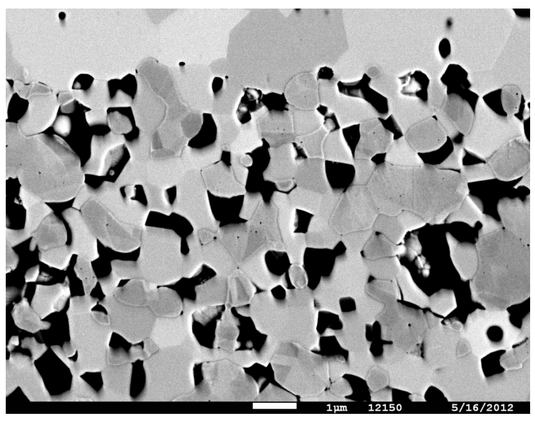
Ni/YSZ anode after 2200 hour test at 700°C in reformate at low fuel utilization



Ni/YSZ anode after 2000 hour test at 700°C in reformate at 70% simulated fuel utilization



Ni/YSZ anode after 2500 hour test at 900°C in reformate at low fuel utilization



Ni/YSZ anode after 2300 hour test at 900°C in reformate at 60% simulated fuel utilization

Summary

No accelerated performance degradation was observed during tests at 700°C with a steam content corresponding to 60-70% fuel utilization. No evidence of microstructural changes was found in post-test analyses using scanning ele*ctron microscopy and image analysis.*

At higher temperatures, 800 and 900°C, increases in the electrodic and ohmic resistances were observed, but none of them were related to the electrochemical anode degradation. Barium aluminosilicate glass seals, however, were found to add to the overall apparent SOFC degradation at high humidity levels at high temperatures. When Ag cathode current collector was used at 800°C, extensive Ag deposits were clearly distinguished at the YSZ electrolyte –LSM/YSZ cathode interface. Spiky appearance of those deposits suggested a vapor transport mechanism.

No apparent Ni particle growth was observed after 2,300 hour tests at 900°C with a steam content up to 50% in the fuel gas. While a modest nickel grain growth could not be completely ruled out, the image analysis performed on the anodes tested at 900°C at low (control) and 60% fuel utilization gave similar, within standard deviation, values of the average intersected area of the Ni grain, 0.89±0.13 μm^2 and 0.90± 0.09 μm^2.

Future work will include modification of contact and sealing procedures to allow for testing at higher simulated fuel utilizations at 800 and 900°C. Coupon tests will also be performed.

Acknowledgements

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