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ELECTROCHEMICAL PERFORMANCES AND POST-OPERATIONAL CHARACTERIZATION OF A SEGMENTED SOFC OPERATED UNDER LOAD FOR 15K HOURS

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***Abstract* - In the frame of the ENDURANCE FCH-JU-FP7 project (2014-2017) a segmented cell (20 segments regularly distributed from fuel inlet to fuel outlet) was operated for 15k hours in co-flow at 750°C (average temperature) in hydrogen under load.**

Each segment was carefully monitored during operation by periodically acquiring the impedance spectra and constantly checking the voltage under current load.

After 15k hours of operation the test was stopped and the cell used for further investigations in order to compare the cell evolution with the segment degradation.

The overall observation in cross section of the cell has shown a good stability, however some differences were observed in the electrodes that might be related to the local operating conditions: temperature, H_2/H_2O ratio in the fuel stream.

The gathered results will contribute to increase the understanding the evolution of a SOFC in real operating conditions. Evidences of the effect of temperature, time and fuel pollutants were found.

***Index Terms* - Segmented cell, SOFC, Anode evolution, long lasting operation time.**

I. Introduction

To better understand the phenomena occurring in single repeating element of a stack (i.e., in large cells) under operation a special set up was designed able to host anode supported cells with on top a screen printed segmented cathode interfaced with a instrumented and segmented current collector (fig.1). The current collector acquires data from each segment separately (i.e. T, V, i) and allows impedance measurements. Such data directly correlate the electrochemical behavior to the local operating conditions, the degradation rate, and in case of local failure to find out the source of it. The latter results useful to identify the most meaningful zone for post-experiment characterization by microscopic and spectroscopic techniques. The whole data collection is then fundamental for modeling development and refinements.

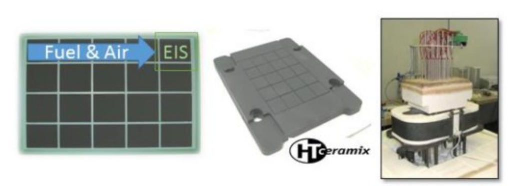

Fig. 1. Example of a segmented cell and setup.

II. Electrochemical measurements

The sample was operated nominally at 750°C under dry hydrogen/air co-flow according to the details reported in table I.

TABLE I
Operating conditions during the experiment

Type of cell	Segmented, 4 lines 5 columns, ASC, Ni/YSZ/LSCF,
Duration	15000 h
Fuel	60%/40% H_2/N_2
Fuel flow rate	480 Nml/min
Air flow rate	7600 Nml/min
Current load	0.5 A/cm^2

EIS curves were acquired from each segment under specific operating conditions all along the experiment duration: 1) at

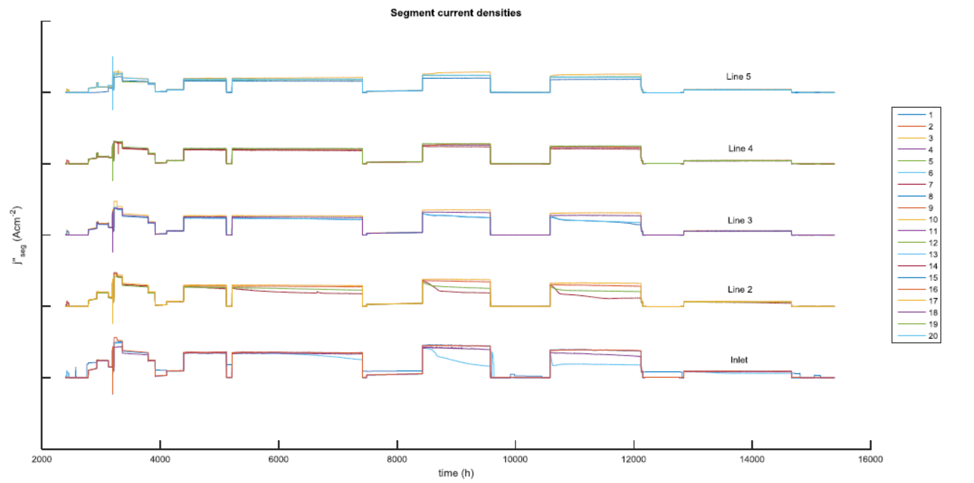

Fig. 2. Current densities distributed per segment and per line from inlet to outlet of fuel

various cell working point and fuel utilization under galvanostatic load (i.e. 0.2A, 0.3A, 0.4A, 0.5A, 0.6A, 0.8A, 0.9A) and normal operating conditions throughout the test (i.e. 1064h, 1544h, 2720h, 5024h, 7520h, 9750h, 12264h, 13060h, 13800h). The extrapolation of electrochemical data was interpreted according to the Gas Compositions (i.e. O_2 / H_2 ratio respectively: 21%/60%; 21%/36%; 21%/26%; 17%/60%) and to the Temperatures (i.e. in the range 675°C to 780°C) directly related to the segment taken into account. No i-V curves were measured but Current densities in function of time and according to the position in the cell as shown in figure 2.

III. Post Experiment Characterizations

A. Scanning Electron Microscopy, Microanalysis and image analysis

Segments from a central line and covering the whole inlet to outlet distance were mounted in epoxy-resin and polished to investigate their cross sections. The anode was analysed by EDSX and image analysis on SEM-BSE pictures using the equation from [1] to establish the Ni distribution in the anode. In figure 3 the resulting Ni relative amount distribution is shown. Raman spectroscopy, SIMS and XRD were used to characterize the cathode while synchrotron nano-tomography is actually under interpretation for a whole cell 3D reconstruction.

IV. Discussion and Conclusions

A cell in a commercial stack is confirmed to suffer temperature, current density and gases composition ranging around the average values officially declared from the inlet to the outlet. This generates a remarkable variability of working parameters causing a number of differing phenomena to appear all over the cell itself. Such position related working conditions affect the materials evolution resulting in local changes (e.g. microstructural, compositional) leading to the conclusion that the overall degradation rate usually declared is the average effect of various processes occurring in the cell and the stack. As an example the tendency of Ni to migrate from the active zone in the center of the fuel path to position closer to the outlet but farther from the electrolyte/anode interface was found and investigated. Further details on degradation were found by Raman spectroscopy, SIMS and XRD applied on cells considered critical due to their electrochemical behavior. The whole activity contributed to increase the awareness on cell materials evolution in operating stacks.

Acknowledgment

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References

[1] P. Piccardo, A. Morata, V. Bongiorno, J.P. Ouweltjes, Proc 12th European SOFC & SOE Forum, Luzern (CH) 5-8 July 2016, B1204 (2016)

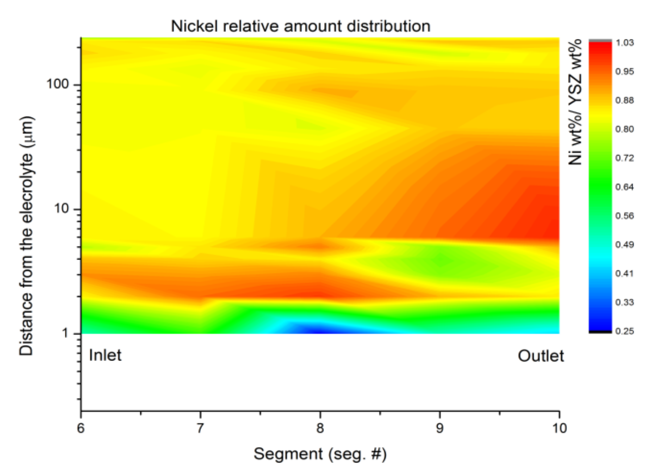

Fig. 3. Ni amount distribution in the anode according to the segment and the distance from the electrolyte