Flow Rate and Temperature Variations in a Segmented SOFC

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Motivation

Planar SOFC

High fuel utilization results in strong gas concentration gradients along the cell leading to

- decreasing local performance with distance from fuel inlet
- reduced electrical efficiency
- thermomechanical stresses
- degradation due to locally critical conditions

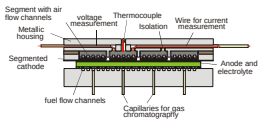
Aim:

- Understanding of spatial distribution of electrochemical and thermal cell behavior
- Identifying critical conditions
- Improving homogeneity

Local power density

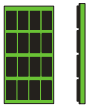
Experimental

Setup for segmented cell [1]



- 4 x 4 galvanically isolated segments
- Local and integral iV curves
- Local temperature
- Local fuel gas concentration

Segmented SOFC



- Anode supported cell
- Segmented cathode

Measurements

Flow rate variation

Nr.	H_2 [%]	N_2 [%]	H_2O [%]	Flow rate [l/min]
1	48.5	48.5	3	1.44
2	48.5	48.5	3	0.72
3	48.5	48.5	3	0.36
4	48.5	48.5	3	0.22

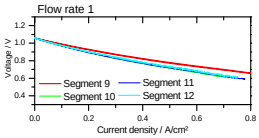
- Temperature: 800°C, 750°C, 700°C
- Current-voltage characteristics
- Anode gas composition @ OCV, @ 850mV, @ 700mV

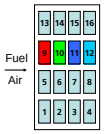
Results

Flow rate variations

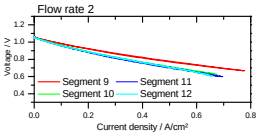
Local iV curves

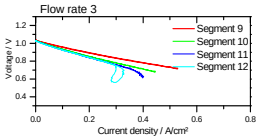
Local voltage is plotted versus local current density for one row of segments from the fuel inlet to the outlet

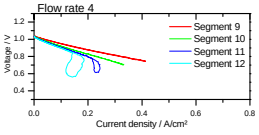




Numbering of segments







Flow rate 1 and 2:
- Little difference between the characteristic curves of the segments.

Flow rate 3 and 4:
- Characteristic curves of segments fan out at higher current densities
- Further distance from entrance leads to stronger drop in iV curve

Flow rate 3:
- i-V curve of last segment (segment 12) drops strongly at current density of 0.3 A/cm²
- Current density starts to decrease while voltage is decreasing due to depletion of fuel along the flow path
- Strong hysteresis between the curves for load increase and decrease at last segment
- Other segments do not show this hysteresis.

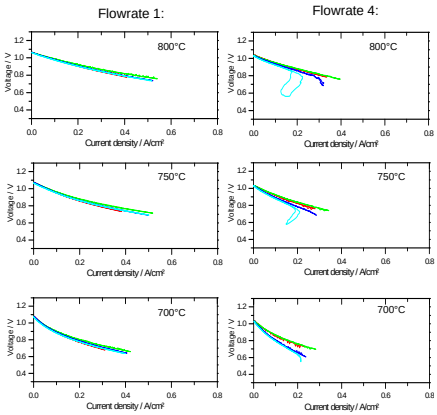
Flow rate 4:
- Hysteresis appears at the last two segments (segment 11 and 12)

Temperature variations

Local iV curves at different temperatures

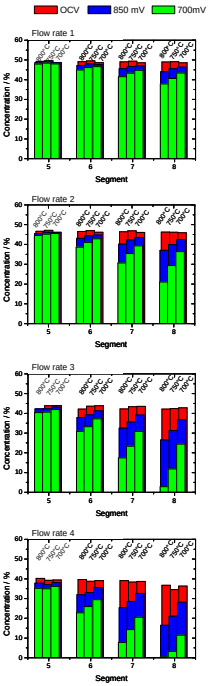
Local voltage is plotted versus local current density for one row of segments from fuel inlet to outlet for highest and lowest flow rates

- The lower the temperature the stronger is the slope of the curves.
- No turning of iV curves at flow rate 1
- Turning of iV curves for flow rate 4 at all temperatures:
  - Turning at same current density for all temperatures but at different voltages
  - The higher the temperature the more pronounced is the turning and hysteresis
- With lower temperature differences between segments decrease



Anode gas composition

Gas composition along the flow path from fuel entrance to exit



Gas composition along the cell for one row of segments measured with gas chromatograph.
- at OCV (red)
- at 850 mV total cell voltage (blue)
- at 700 mV total cell voltage (green)
- at 700°C, 750°C, 800°C
- 4 flow rates

- At OCV concentration of hydrogen remains constant along cell.
- Under load hydrogen concentration decreases along flow path.
- Smaller cell voltage
  → greater decrease of hydrogen content
- Decrease of hydrogen concentration smaller for higher flow rate, corresponding to lower fuel utilization
- At high temperatures hydrogen concentration along cell decreases faster, more fuel is consumed
- For low temperatures distribution is more homogeneous. Since power of cell decreases, less fuel is consumed at beginning of cell.
- At flow rate 3, 800°C and total cell voltage of 700 mV fuel is almost entirely consumed at last segment. Amount of hydrogen measured was below 3 %.
- For smallest flow rate, 800°C and total cell voltage of 700 mV hydrogen content is below 1 %.
  → Damage of cell is expected

References

1. Metzger, P., Friedrich, K.A., Schiller, G. and Willich, C. Spatially Resolved Measuring Technique for SOFC. in 2nd European Fuel Cell Technology and Application Conference. 2007. Rome, Italy.