Relation of Local Cell Voltage and Current Density Distribution during Fuel Starvation in PEMFC Stacks

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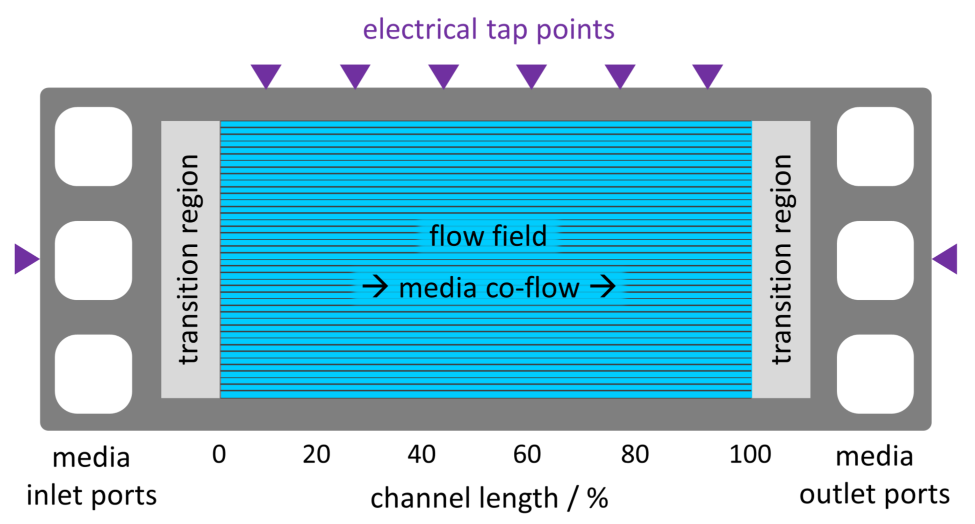
Objective

Carbon support of anode catalyst layer is known to corrode by oxidation under fuel starvation conditions. This degradation stressor is typically investigated only on laboratory scale in single cells.

This study investigates the transfer to multi-cell stacks of large active area including the interaction of adjacent cells via bipolar plates of finite conductivity.

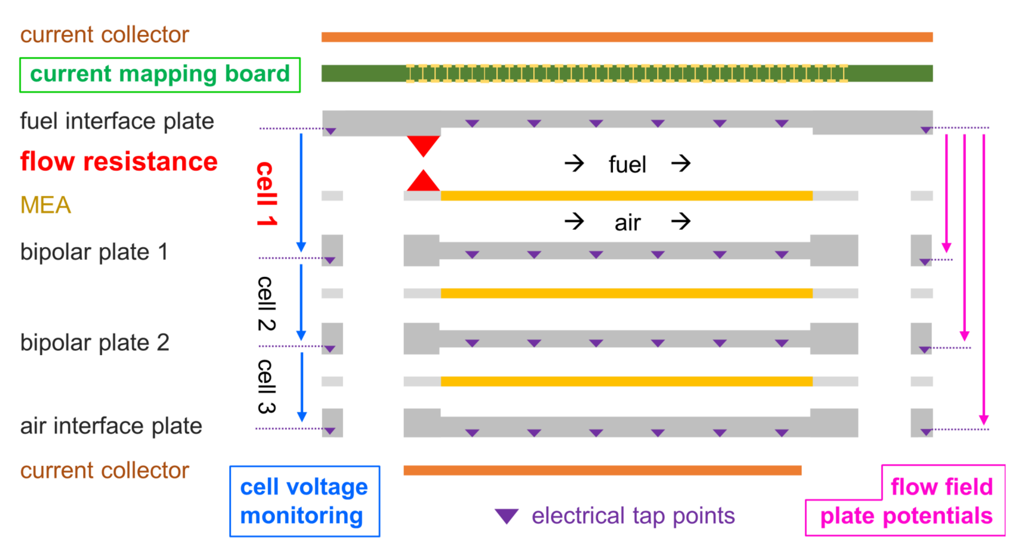
Bipolar Plate & MEA



State-of-the-art carbon composite flow field plates were used. Eight electrical tap points were installed at their outer edges. Air, fuel and coolant passed the straight-channel flow field in co-flow. Bipolar plates (BP) contained flow fields for all three media, interface plates (IP) lacked the outer reactant flow field.

Pure platinum catalyst was used both in cathode and anode. The anode catalyst layers contained a reversal tolerant catalyst to enable oxygen evolution reaction (OER) under fuel starvation.

Stack Assembly

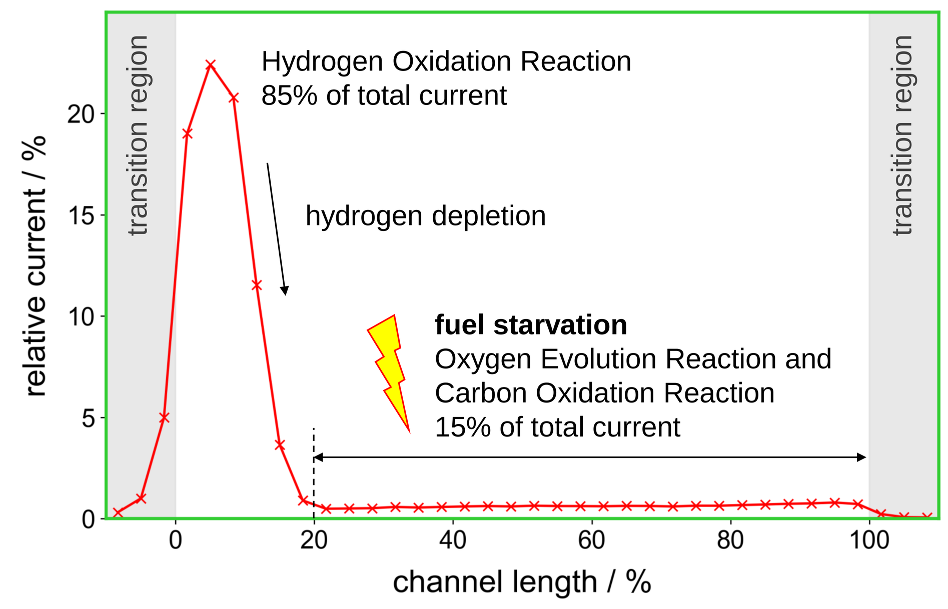


The fuel cell stack assembly consisted of three cells, including three membrane electrode assemblies (MEA), two IPs and two BPs. An artificial fuel starvation was introduced into cell #1 by physically increasing the flow resistance of the fuel media flow.

The current distribution of fuel-starved cell #1 was measured by a current mapping board, produced by company S++ Simulation Services.

The locally resolved electrical response of this stack was recorded by a potentiostat over all tap points. Cell voltage measurements describe the voltage difference at the same tap point of two adjacent flow field plates. By choosing an identical electrical reference point, absolute flow field plate potentials were measured.

Current Density Distribution



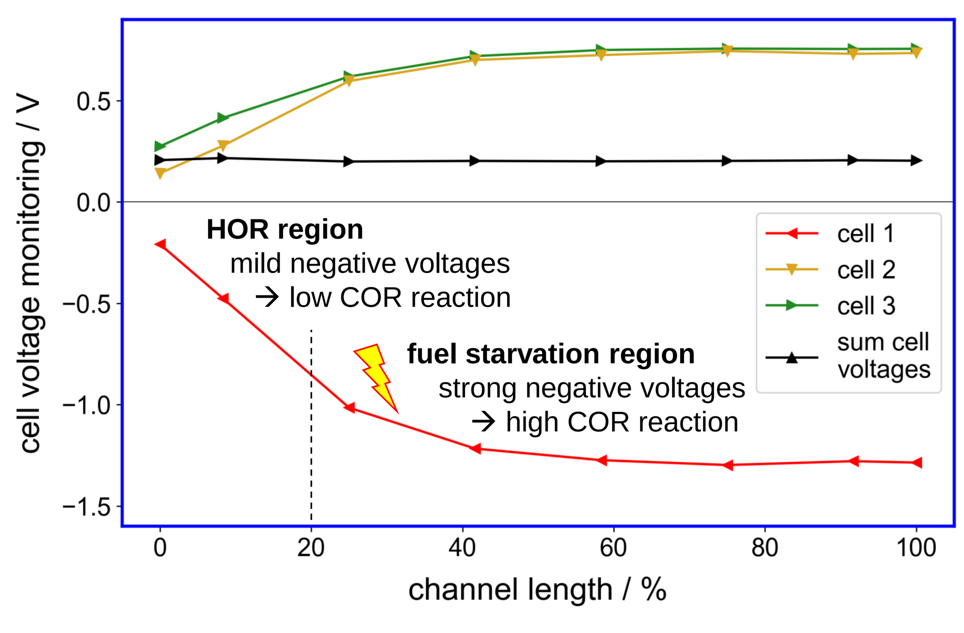
The local current distribution of cell #1 became distorted by the fuel starvation. Thus, two distinct regimes become visible.

A very high current density was observed at the media inlet. Reduction of reactant stoichiometry is known to cause a redistribution of current density towards the media inlet [1]. Therefore, 85% of the total current occurred in the first 20% of the active area. This current is accounted to the regular hydrogen oxidation reaction (HOR).

The latter 80% of the MEA, however, showed a much lower, almost flat current density, which accounts for 15% of the overall stack current. This current is assigned to the oxygen evolution reaction (OER) plus the harmful carbon oxidation reaction (COR).

A hydrogen stoichiometry of 0.85 was calculated for this fuel starved cell 1, based on these two current density regimes.

Cell Voltage Monitoring



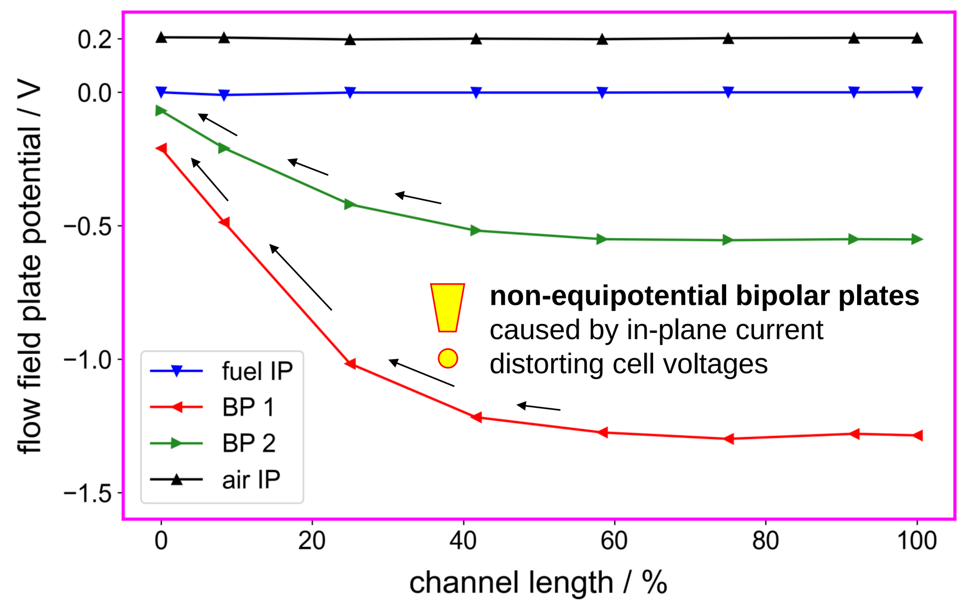
The cell voltage monitoring measurement during fuel starvation showed drastic variations of the cell voltages over the flow direction for all cells.

The voltage of the fuel starved cell #1 progressed from only slightly negative voltages at the media inlet to intense negative voltages at the media outlet. Strongly negative voltages under fuel starvation conditions are known to accelerate the COR reaction rate [2]. Therefore, an increasing degradation in flow direction is expected for this fuel starved cell #1.

The local voltages of both non-starved cells increase in flow direction. The sum of all three cell voltages therefore keeps identical at each measurement position.

This progression of the cells local voltage is directly related to the flow field plate potentials.

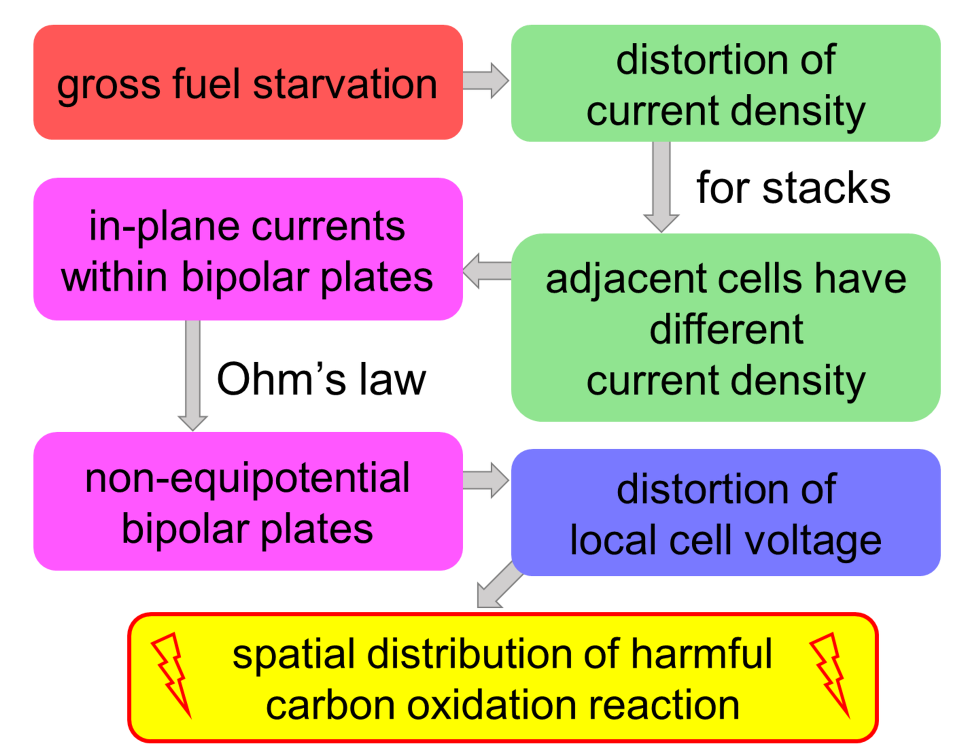
Flow Field Plate Potentials



Flow field plate potentials against the fuel interface plate potential were measured during the fuel starvation event.

Intense potential gradients were found within both bipolar plates. They are caused by currents within the BP plane, according to Ohm's law. These in-plane currents originate from differences in current density of adjacent cells [3].

Proposed Mechanism



Conclusions

- Local voltage of a fuel starved cell in a PEMFC stack does not need to be constant. Our results suggest an increased carbon oxidation towards the anode outlet.
- The current distribution of a fuel starved cell attained two distinct regimes, supposedly separating the HOR from the starvation region.
- Positioning of an electric tap point is relevant to detect such error states. Using multipoint CVM is highly recommended for stacks with carbon composite bipolar plates [4].

References

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