Spatially Resolved Measuring Technique for SOFC

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Introduction

Although tremendous progress in the last years has resulted in high power densities and the ability to use hydrocarbons as a fuel, solid oxide fuel cells still remain less developed than other fuel cell types. The difference in maturity is mainly related to the need to investigate and understand SOFC processes under technically relevant operating conditions, namely high fuel utilization and the associated inhomogeneous current density and temperature distributions. To optimize cells for operation in highly efficient systems a new measurement system is needed that allows the determination of local effects and the identification of critical operating parameters.

Experimental Details

The present measuring system at DLR (Fig. 1) allows the characterization of SOFCs at 16 distinct measuring points along the flow path of the gases in the cell allowing to determine concentration gradients of reactants and products. With the measuring system that has been built up, current, voltage, temperature and impedance data as well as their distribution can be measured. Additionally 16 capillaries are integrated to take gas samples of the anode gas atmosphere to be analyzed by gas chromatography. The metallic housing is subdivided into 16 galvanically isolated segments on both sides resulting in an active area of 73.96 cm².

Results and Discussion

The influence of the variation of the hydrogen content on the performance of the cell can be seen in Fig. 2 in which measurements with an electrolyte-supported cell (ESC2 from InDEC, Netherlands) are shown. The content of hydrogen in the fuel gas supplied to an ESC2 cell was varied between 2 and 100 % (the supplementary gas was N_2). The power density distribution remains homogeneous when the system is operated at low fuel utilization ($f_u < 25$ %). With higher fuel utilization, significant gradients in the power density could be observed resulting from both the variation of current density and voltage along the flow channels.

To verify the calculated values of fuel utilization they were compared with values that were measured with the gas chromatograph at 2 %, 10 % and 50 % hydrogen content. The comparison revealed good agreement between the measured and the calculated values (Fig. 3).

A further example covers the operation of an anode-supported cell (ASC2 from InDEC, Netherlands) with a reformate composition as the fuel gas (Fig. 4) and the electrochemical reaction of the fuel gas components along the flow path. The influence of the area-specific load on the power density and the fuel utilization at operation of a segmented ASC2 cell (counter flow) along a row of segments (segment 9 - 12) with fuel entrance at segment 9 is shown in Fig. 5; the fuel gas composition was 54.9 % N_2, 16.7 % H_2, 16.5 % CO, 6.6 % CH_4, 2.2 % CO_2, and 3.2 % H_2O, the air flow rate was 0.02 slpm/cm².

The results in Fig. 5 reveal an excellent conversion of CO- and CH_4-containing fuel gas with 78.1 % at 400 mA/cm² and with 83.9 % at 435 mA/cm² at the fuel exit. It seems that the increasing conversion rate at the segments 9 - 11 causes performance reduction at segment 12 that could result in critical conditions and hence enhanced corrosion at the fuel exit. The comparison of product and educt concentrations measured by gas chromatography along the flow path at different loads (0, 100, 435 mA/cm²) is depicted in Figs. 6 - 8.

Conclusions

Different cell concepts were investigated successfully with the segmented cell method and strong variations of power density, fuel utilization and temperature were observed along the fuel path. The homogeneity of power density and of voltage along the flow path mainly depends on fuel utilization. At low hydrogen contents, anode re-oxidation conditions may be established which could be dangerous for long-term operation of the cells. The exemplary results show the importance and the usefulness of spatially resolved measurement of SOFC. In particular the operation of SOFC with hydrocarbon-derived fuel at high fuel utilization requires the application of this methodology to optimize performance and minimize degradation effects.
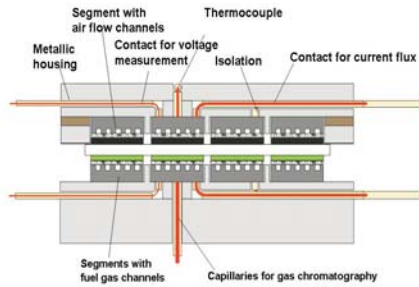

Fig. 1: Schematic representation of the segmented cell approach of DLR for SOFC with both cathode and anode segmentation.
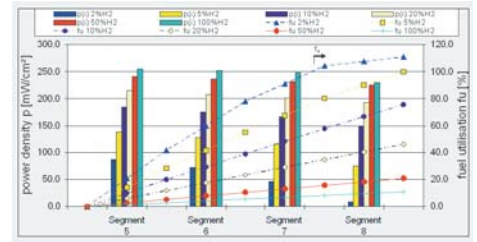

Fig. 2: Locally resolved power density distribution (filled bars) and fuel utilization (filled symbols) for different hydrogen concentrations of the electrolyte supported cell ESC2 (InDEC). Segment 5: fuel inlet, segment 8: air inlet.
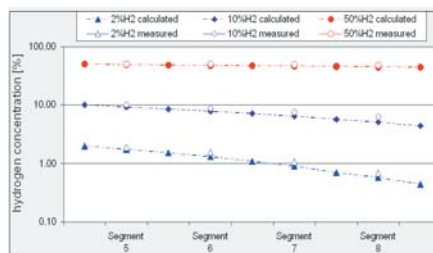

Fig. 3: Comparison of calculated (filled symbols) and measured hydrogen concentration (open symbols) by gas chromatography for a segment row in the ESC2 cell at an average voltage of 0.6 V.
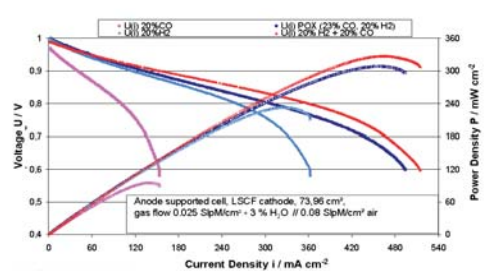

Fig. 4: V-i and p-i characteristics of an anode-supported cell (ASC2) operated with gasoline reformate.
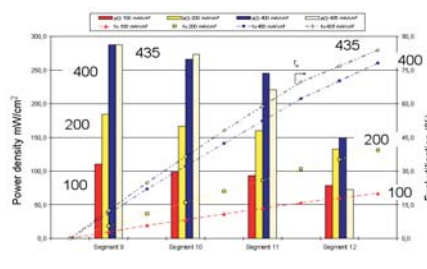

Fig. 5: Comparison of power density and fuel utilization along the flow path during variation of the area-specific load of a ASC2 cell (active area: 73.96 cm²); counter flow mode, fuel gas entrance at segment 9, fuel gas exit at segment 12.
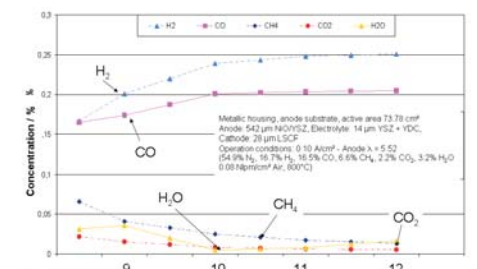

Fig 6: Comparison of product and educt concentrations along the flow path of an anode supported cell (ASC2) at 0 mA/cm².
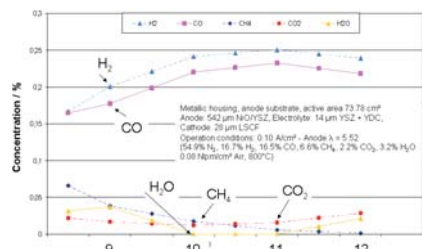

Fig. 7: Comparison of product and educt concentrations along the flow path of an anode supported cell (ASC2) at 100 mA/cm².
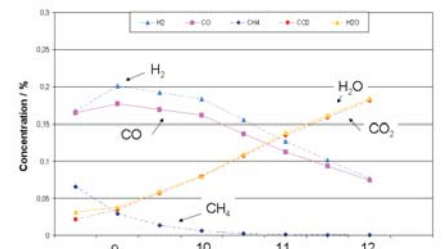

Fig. 8: Comparison of product and educt concentrations along the flow path of an anode supported cell (ASC2) at 435 mA/cm².