Spatially-Resolved Measuring Techniques for Detailed Investigation of Fuel Cell Operation

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Introduction

The detailed analysis of the processes taking place inside fuel cells is an important topic to understand the fuel cell behavior and its degradation phenomena and to optimize cells and their operation modes in highly efficient systems. DLR has developed spatially-resolved measuring techniques for both low temperature (PEFC, DMFC) and high temperature fuel cells (SOFC) which allow the determination of local effects and the identification of critical parameters for operation. By analyzing the local operating conditions inside the fuel cells in situ, degradation processes can be identified and strategies to minimize degradation effects can be derived. Furthermore, control strategies may be developed by means of implemented 'diagnostic cells' in stacks.

Locally Resolved Measuring Technique for PEFC Cells and Stacks

For reliable and safe operation of a fuel cell stack an intelligent diagnostic system is needed to detect indications for a potential malfunction in an early stage. A locally resolved diagnostic system with sensors in the stack can provide accurate information about the status of the cells, i. e. inhomogeneous current density distributions which might be used for a control strategy.

For the measurement of current density distributions in PEFC a technique based on a printed circuit board has been developed that is used as a bipolar plate and is favorable to be integrated in a stack arrangement (Fig. 1). This technique allows a flexible design of the number and size of the current collectors as well as the dimension of the plate.

Fig. 2 shows the application of the segmented bipolar plates (active area 25 cm² divided into 49 segments) in a 3-cell short-stack to determine the current density distribution. The most sensitive operating parameter was identified as the humidification of the reactant gases. Measurements with air and hydrogen in counter flow mode showed similar current density distributions for all 3 cells for a low humidification (40°C dew point, 70°C cell temperature). In case of using fully humidified air the current density distributions changed (Fig. 3). Although the single cell voltages were very similar, the current density distributions were different due to non-uniform gas supply in the manifold.

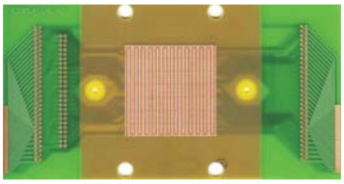

Fig. 1: Segmented bipolar plate for the determination of current density distribution with 49 segments and integrated single serpentine flow field channels

Fig. 2: Short-stack consisting of 3 cells with segmented bipolar plates

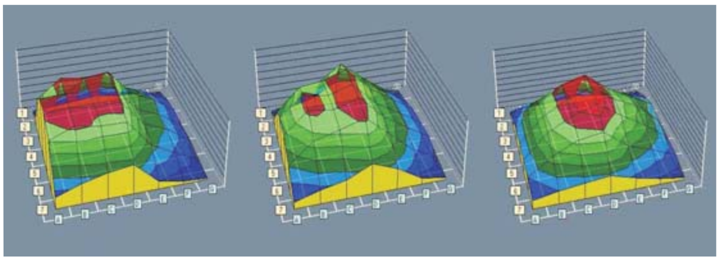

Fig. 3: Different current density distributions of the three cells in the stack for operating conditions involving highly humidified gases (75°C, 1.1 bar; Air: λ=3, 75°C dew point; H_2: λ=1.5, 70°C dew point)

The measurement results can be used to validate models and to implement intelligent diagnostic systems. Such a system with low cost sensors integrated in bipolar plates at relevant positions in the stack in combination with actuators can detect the best operating conditions and avoid potential limits.

Locally Resolved Measuring Technique for SOFC

For a detailed local electrochemical characterization of SOFC cells a measuring system has been developed and built up (Fig. 4) that allows the determination of local effects and the identification of critical parameters for operation by means of spatially-resolved i-V characteristics, impedance data and anode gas composition and temperature over 16 segments (active area: 4.6 cm² per segment).

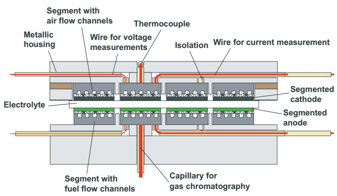

Fig.4: Schematic representation of segmented cell approach for SOFC with metallic housing which is segmented on both anode and cathode side.

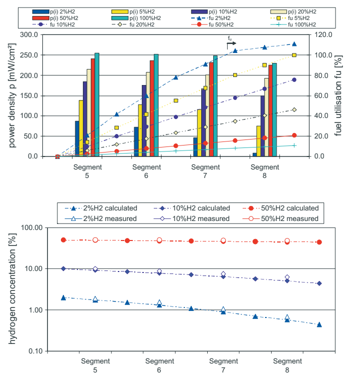

Fig 5 : a) Locally resolved power density distribution (filled bars) and fuel utilization (filled symbols) for different hydrogen concentrations of an electrolyte supported cell ESC 2 (InDEC)
b) Comparison of calculated (filled symbols) and measured hydrogen concentration (open symbols) by gas chromatography for a segment row in the ESC 2 cell.
Average cell voltage: 0.6 V, operating temperature: 800°C, fuel flow : 0.025 SLpM/cm² H_2 + N_2 + 3 % H_2O, oxide gas flow: 0.08 SLpM/cm² air, active area: 73.96 cm ², fuel is entering from the left side at segment 5.

Test runs were performed with an electrolyte supported cell ESC2 (InDEC, Netherlands) in counter flow mode for different hydrogen concentrations varying from 2 % to 100 % in order to identify concentration limitations and to optimize fuel utilization. The power density distribution remains homogeneous when the system is operated at low fuel utilization (f_u<25%), whereas with higher fuel utilizations significant gradients in the power density could be observed resulting from both the variation of current density and voltage along the flow channels. At low hydrogen inlet concentrations the voltage at the fuel outlet drops to values that might be harmful for the stability of the anode since reoxidation of nickel can occur. The local data showed differing behavior in the middle of the cell compared to the fuel outlet. Leakage at the sealing could be identified as a possible reason. Temperature measurements show that local temperatures differ significantly depending on the load applied to the cell. This emphasizes the importance of a thermal management that is adapted to the characteristics of operating conditions of the cells.

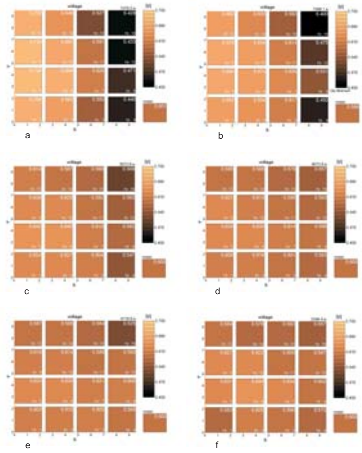

Fig.6: Voltage distribution in an electrolyte supported cell (InDEC) at different hydrogen concentrations. *Average cell voltage: 0.6 V, operating temperature: 800°C, anode gas flow: 0.025 SLpM/cm² H_2 + N_2 + 3 % H_2O cathode gas flow: 0.08 SLpM/cm² air, active area: 73.96 cm², counter flow a) 2 % H_2, b) 5 % H_2, c) 10 % H_2, d) 20% H_2, e) 50 % H_2 f) 100 H_2*