Application of segmented cell to detect stability & deterioration of PEM fuel cells

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Research Topics

**Topic (1)**
Design and performance investigation of PEFC and DMFC
-- Advanced manufacturing methods (Dry Spraying for low cost and mass production)
-- Identification of degradation mechanism and of strategies to prevent degradation
-- In-situ and ex-situ studies of fuel cells by means of innovative measurement technology (e.g. spatially resolved measuring technique-Segmented Cell)
-- Modeling of electrochemistry and transport processes in fuel cells

**Topic (2)**
PEFC system
-- Development of PEFC stacks for operation temperature -30°C to 130°C
-- Integration of fuel cell systems for special application (e.g. for low pressure condition)

**Topic (3)**
SOFC stack
-- Development of planar SOFC stacks with metal supported cells (MSC)
Application of segmented cell to diagnose PEM fuel cell

- Water management in PEM fuel cell system
- Error detection of MEA
- Relaxation Investigation of fuel cell system
- Reversibility Investigation of fuel cell system
Segmented current density measuring board

Segmented measuring board with 49 segments for fuel cell

On-line visualization of current distribution measurements
Segmented cell bipolar plate made by non-conducting material except the surface. Currents go on discrete one direction pathways. The current measured by integrating calibrated resistors and the voltage drop.
Segmented current density measuring board

Segmented plate for commercial stack
108 segments, 225 cm² active area
Segment area 2 cm²
Segmented flow field of current density measuring board

Gas Inlet: Segment G1

Gas Outlet: Segment A7

Current density distribution measurements
Demonstration of Segmented Cell

Dynamic change of current density distribution in segmented cell

Resolution: 20 steps / 1 step – 10.0 % of average current density (447mA/cm²)
Water management in PEM fuel cell system
Instability of PEM fuel cell at drying out

Overview of operation parameters (pressure, humidification temperature, flow) for current peaks up
Investigation of Water Management in PEM Fuel Cells

Bode curves: Comparison membrane resistance between peak and baseline

- $R_m=8.3\,\text{m Ohm}, \, I=12.8\,\text{A}$
- $R_m=4.2\,\text{m Ohm}, \, I=20.2\,\text{A}$
Stability Optimization

Stability optimization by adjusting feed stream humidification: Increase of anode humidification at Tcell = 80\(^\circ\)C
Stability optimization by adjusting feed stream humidification:
Increase of anode humidification at Tcell = 120°C
Overview of operation parameters (pressure, humidification temperature, flow) for current peaks down

Instability of PEM fuel cell at flooding
Error detection of MEA
Malfunction behavior

Plots of global current density distribution and cell voltage versus time
Malfunction behavior

Current density plots of segments E1, G6, F1, D1, G5 and G4.
Mapping of current density distributions during evolution of leakage

Absolute values of current density plotted (E1, G6, F1, D1, G5 and G4)
Evolution of pressure, current and temperature of the segmented cell

**Effect for formation of membrane leakage**

Two days before the membrane leakage started
Relaxation Investigation of fuel cell system
Constant current output while decreasing cathode humidification at 600 mV

T cell = T humid Anode = 85°C; T humid Cathode = 68-40°C, F air = 900 ml/min; F H₂ = 300 ml/min.

Effect of humidification on the performance of cell
An internal change of inhomogeneous current distribution occurred while global cell current did not change.
Reversibility Investigation of fuel cell system
Reversibility of current density distributions after a cyclic process
Mapping of current density distribution changes during a cyclic process

Mapping of current density distributions of the starting, during and after going back to the starting operating conditions.
Conclusions:

Detect and assess phenomena which may occur in PEM fuel cell systems:
instable operations, degradation & deterioration, flooding & drying, relaxation processes (i.e. retardation of equivalent system output to change of system input), etc.

Identify methods and system signals to diagnose and to avoid malfunctions with a minimum amount of sensors.

Contribute to the development of a closed-loop control for fuel cell systems to enhance their lifetime and efficiency.
Thanks for your attention!