Evaluation of an Optimised Half-Cell for Quality Control of GDEs

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Motivation & Approach

- Operating conditions: Proton exchange membrane (PEM) fuel cells operate at up to 4 bar(a) and 80-160 °C
- Gas diffusion electrodes (GDE) quality control (QC): Half-cell measurements evaluate anode or cathode individually[1-2]
  - No overlap from membrane or other cell components
- Requirement for routine QC: Standardised, commercially available half-cells (e.g., for manufacturer testing)
- Commercial half-cells do not exist for these pressure/temperature yet[2]

Objective

- Development of pressure-resistant, heat-resistant, standardised half-cell for reproducible GDE testing
- Based on the ElyFlow® cell (Gaskatel GmbH), project TheMes (ZIM KK5432602MP4)
- Hydrogen oxidation reaction (HOR) as model experiment for validation

Cell Development

Pressure-Resistant Reference Electrode

- Reversible hydrogen electrode (RHE) made of polypropylene (PP)
  - Chemical resistance
  - Reducing usage of PTFE in comparison to former reference electrodes by Gaskatel GmbH
- Screws directly into cell
  - To achieve gas-tightness
- Measurement possible at pressures of > 1 bar(rel)



Figure 1: Photo of newly developed pressure-resistant RHE reference electrode.

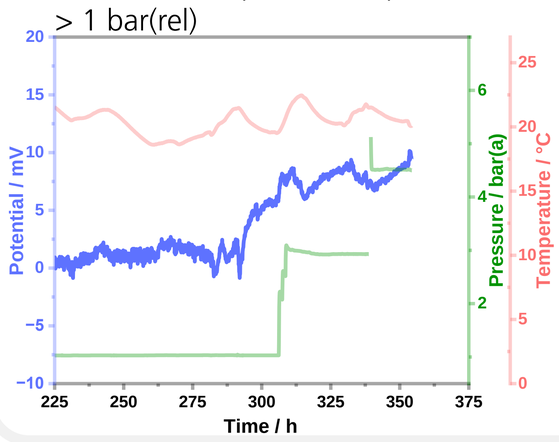


Figure 2: Measurements of reference electrode potential after 12.5 days at normal pressure, change to pressures 3 bar(a) and 4.5 bar(a).

- Measurement of potential in pH 2 over 12.5 days
  - Stable potential over time at about -1mV
  - Potential deviations of < 5mV
- Followed by variation of pressure
- Measurement possible up to 4.5 bar(a) over several hours
- After pressure change:
  - Potential needs time to stabilise
  - Potential deviations of < 3mV

Novel Titanium Flow Field Sealing

- With flow field more application-related
- More conductive material than standard silicon based sealing
  - Resulting in lower high frequency resistance (HFR)
- Reduction of sample size possible
- Less electrolyte leakage
- Problem:
  - Measurements under higher pressure
  - Gas tightness needs to be improved
    - Testing of other sealings planned

Technical Specifications

- Active area: 10 cm^2
- Electrolyte volume: 12 mL
- Material: PTFE and/or PEEK
- Maximum temperatures
  - With electrolyte flow: 90 °C
  - Without electrolyte flow: 150 °C
- Counter electrode material
  - Nickel (pH 10 – 16)
  - Mixed metal oxide (pH -2 – 10)

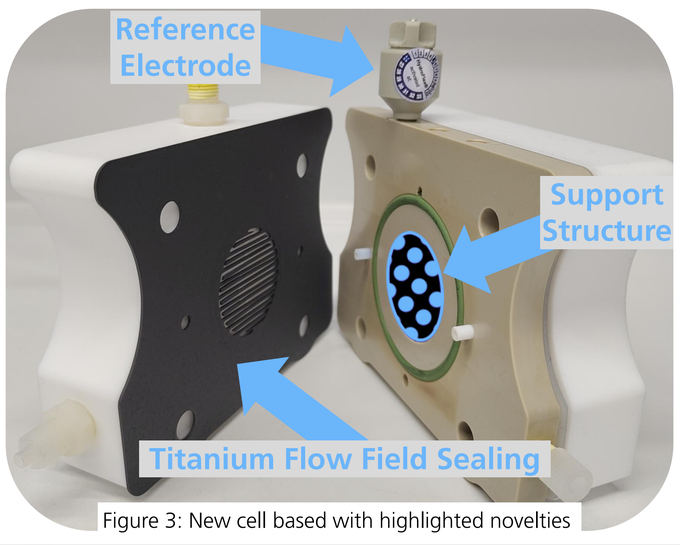


Figure 3: New cell based with highlighted novelties

Support Structure

- Necessary to prevent the sample from bending under pressure

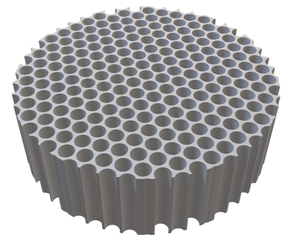


Figure 4: 3D image of model version of support structure.

Results

Variation of Pressure and Temperature

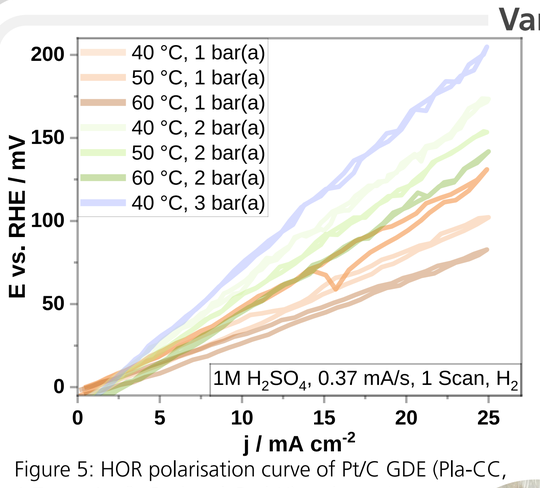


Figure 5: HOR polarisation curve of Pt/C GDE (Pla-CC, 1.7 mg_{Pt}/cm^2, Gaskatel GmbH) with varying temperatures and pressures.

- The higher the temperature, the flatter the slope
  - Higher proton transport and higher ion mobility result in lower HFR
- The higher the pressure, the steeper the slope
  - Expectation: increase due to higher partial pressure of H_2
- Explanation: Use of first version support structure, made of glass
  - Damage of membrane
  - Less contact to sample; gas bubbles enter support structure
    - Resulting in increased HFR

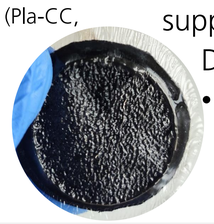


Figure 6: GDE with hot-pressed membrane after measurement (see above); membrane is roughened and partially perforated by glass support structure.

Variation of Electrolyte and GDE

- NT-GDE shows steeper slope
  - Higher catalyst loading, catalyst layer thickness results in higher HFR
    - NT-GDE: 0.2 mg_{Pt}/cm^2
    - Pla-CC: 1.7 mg_{Pt}/cm^2
- Use of 1 mol L^{-1} H_2SO_4 as electrolyte shows higher slope compared to use of 1 mol L^{-1} $HClO_4$
  - Proton conductivity of $HClO_4$ is lower
    - Resulting in increased cell resistance

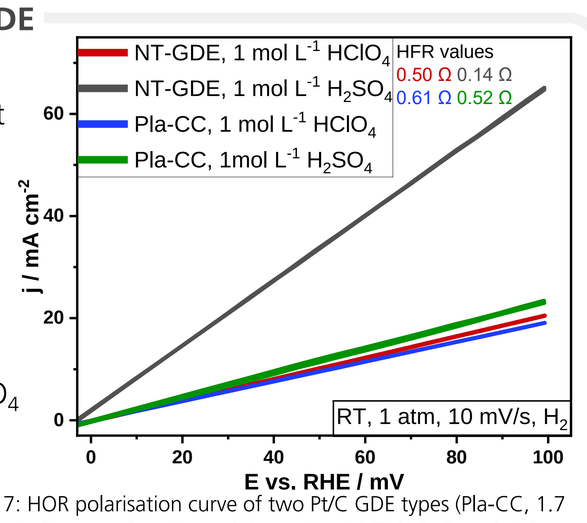


Figure 7: HOR polarisation curve of two Pt/C GDE types (Pla-CC, 1.7 mg_{Pt}/cm^2, Gaskatel GmbH and 0.2 mg_{Pt}/cm^2, NT-GDE, Fuel Cell Store) with different electrolytes (1 mol L^{-1} H_2SO_4 and1 mol L^{-1} $HClO_4$).

Variation of Sealings

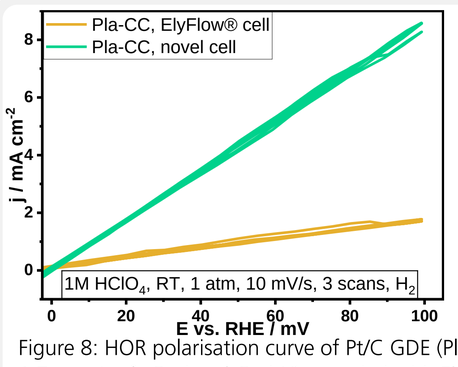


Figure 8: HOR polarisation curve of Pt/C GDE (Pla-CC, 1.7 mg_{Pt}/cm^2, Gaskatel GmbH) recorded with ElyFlow® and new cell.

- Same measurement conditions, but different cells and sealings
  - Higher slope when using new cell
- Novel cell includes novel Ti flow field sealing
  - Ti flow field sealing more conductive than silicone sealing
  - More conductive material leads to lower HFR: 13.76 Ω (silicone) → 2.54 Ω (Ti)

Summary & Outlook

- Successful initial measurements under elevated pressures using the optimised half-cell
- Pressure-resistant reference electrode enables measurement at pressures up to 4.5 bar(a)
- Improved support structure reduces sample deflection without damaging of the membrane
  - Further improvements with different designs and materials are planned
- Use of novel Ti flow field sealing results in electrolyte leakage and lower HFR
  - Improvement of an alternative is still required for higher pressures

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References:

[1] J. Fan, M. Chen, Z. Zhao, Z. Zhang, S. Ye, S. Xu, H. Wang, H. Li 2021, Nat Energy 6 475–486.

[2] S. Nösberger, A. Tirmidzi, R. Ohno, G. K. H. Wiberg, K. Kakinuma, M. Arenz, J. Power Sources 2026, 673, 239720

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