Bridging the gap between fundamental and applied fuel cell electrocatalysis

High-throughput catalyst screening of gas diffusion electrodes (GDE)

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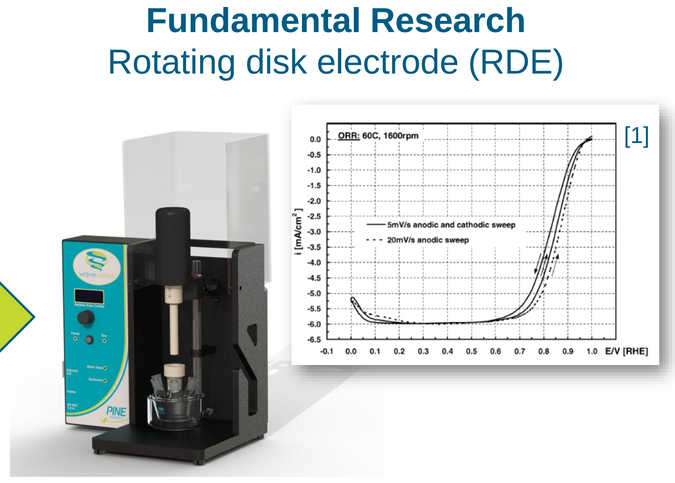
Motivation

Applied Research
Membrane electrode assembly (MEA)

- \+ High current densities (1 A/cm² and higher)
- \+ Activity measured in relevant potential range for fuel cells (e.g. oxygen reduction reaction: $E_{Cathode}$ = 0.6 – 0.8 V vs. RHE)
- \+ Catalyst layer on gas diffusion layer
- – Time consuming, high cost, exact half-cell considerations difficult

Fundamental Research
Rotating disk electrode (RDE)



https://www.pineresearch.com/shop/rotators/standard/wavevortex/

- \+ Low current densities (mA range, due to diffusion limitation)
- – ORR activity measured @ 0.9 V vs. RHE
- – Non-realistic catalyst structures
- \+ Low costs, fast screening & good evaluation and comparability

GDE set-up combines advantages of RDE with realistic conditions of MEA.

Methods

- Novel set-up for GDE testing designed (Fig 1, B): GDE or half-MEA (= GDE + membrane) as working electrode (S_{geo} = 2 cm²)
- Optimized gas distribution and electric contact through graphite flow field (Fig. 1, A) [2]
- Integrated reference electrode (RE) compartment

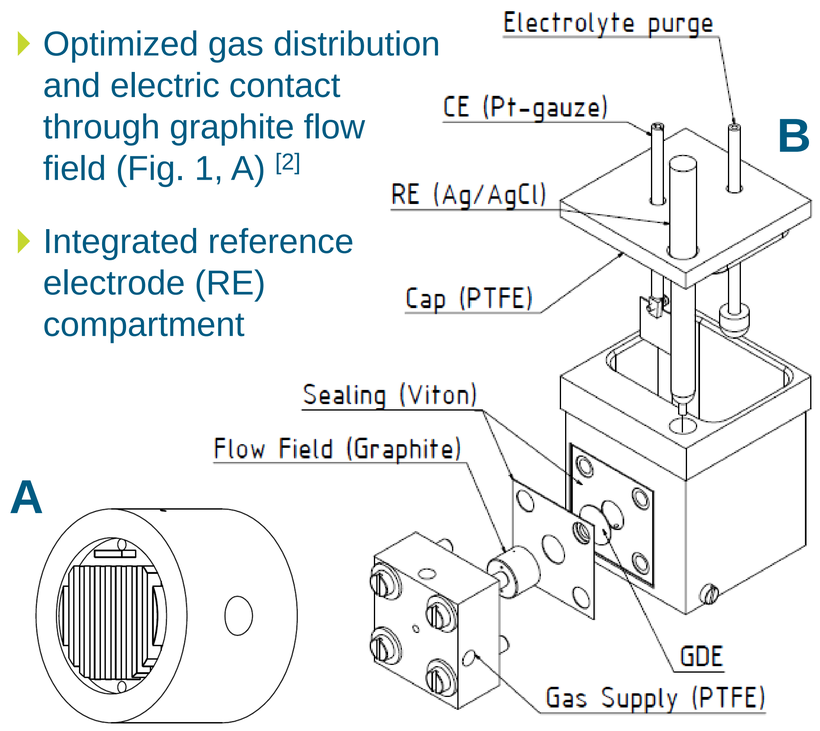


Fig. 1: Scheme of GDE set-up (B) and flow field (A).

First results for oxygen reduction reaction (ORR)

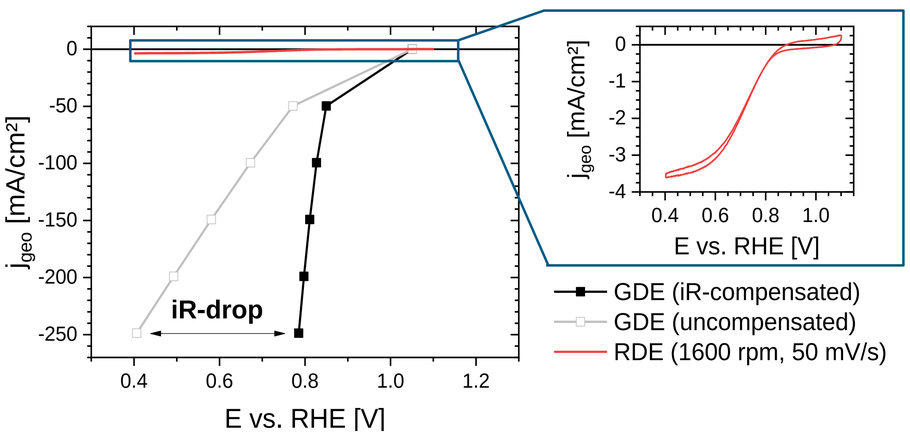


Fig. 2: ORR on GDE with 0.3 mg/cm² Pt/C (40 wt.-%) on Sigracet 29 BC MPL/GDL(black) and RDE with same catalyst loading (red).

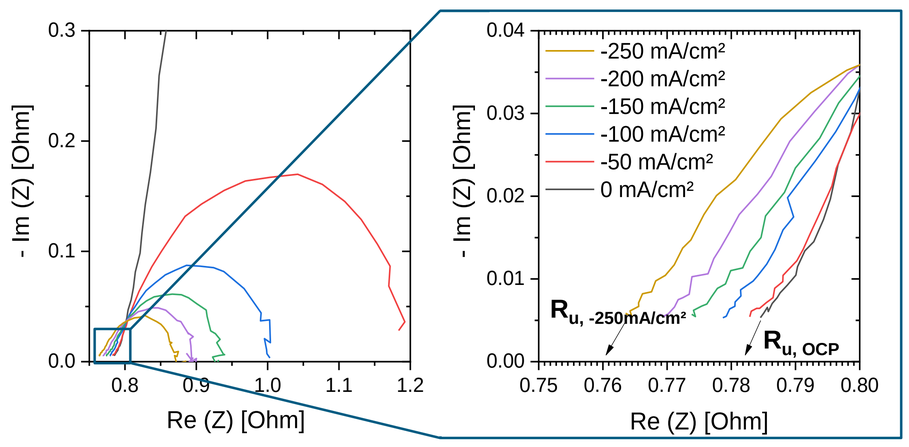


Fig. 3: Impedance measurements (1 kHz – 0.5 Hz) to determine uncompensated resistance (R_u) at different current densities.

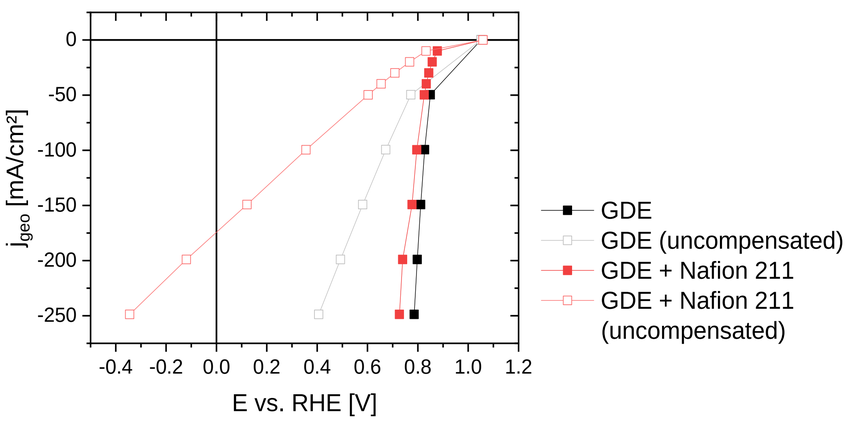


Fig. 4: ORR on GDE with 0.3 mg/cm² Pt/C (40 wt.-%) with (red) and without (black) hotpressed Nafion® 211.

- With the newly designed **GDE set-up** it is possible to achieve orders of magnitude higher current densities compared to RDE (s. Fig. 2).
- **No diffusion limitation** is detected up to 250 mA/cm².
- Catalyst **activity** can be investigated **in relevant potential and current range**.
- Due to high current densities **iR-compensation** is crucial. Therefore exact **determination of uncompensated resistance (R_u)** is essential.
- R_u is decreasing with rising current density (s. Fig. 3). To avoid overcompensation it has to be determined at each current step via impedance measurements.
- By adding a **membrane to the GDE** the effect of membrane composition and structure on catalytic activity can be investigated.
- By hotpressing Nafion® 211 membrane (1 kN, 160°C, 5 min) on GDE R_u increases significantly but **comparable activities** for ORR **in investigated range** are obtained (s. Fig.4).

Outlook

- Data obtained from GDE set-up at high current densities will be systematically compared to MEA data.
- GDE system will be transferred to Scanning Flow Cell [3] (s. Fig. 5) to enable rapid screening of catalyst layers or Half-MEAs. By using this flow cell it is also possible to couple with analytic techniques (e.g. ICP-MS to evaluate catalyst dissolution).
- The GDE system can not only be used for ORR but can also be transferred to other electrochemical three-phase reactions (e.g. CO_2 reduction).

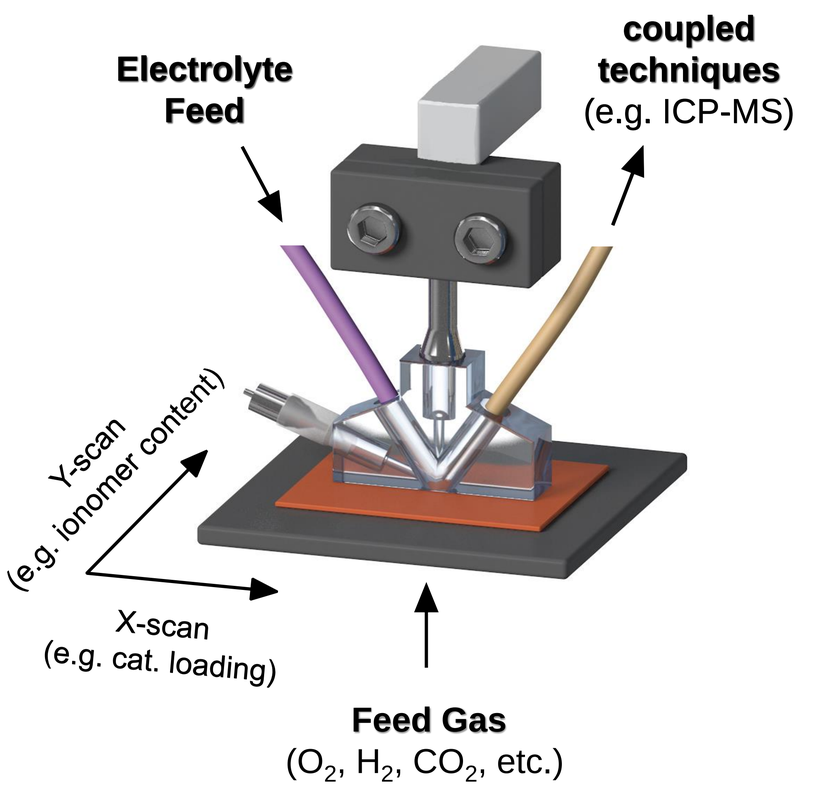


Fig. 5: Scheme of a Scanning Flow Cell (SFC).

[1] Gasteiger, H.A., Appl. Catal. B 2005, 56, 9–35, [2] Pinaud, B.A., J. Electrochem. Soc. 2017, 164(4), F321-F327, [3] Klemm, S., Electrochem. Comm. 2011, 13(12), 1533-1535

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