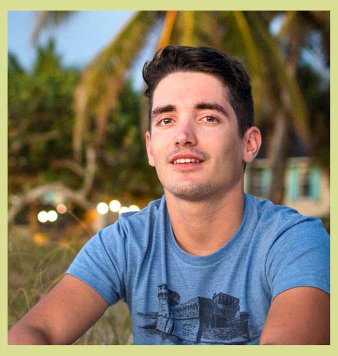
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Towards an Elevated Temperature and Pressure 3-Electrode Hydrodynamic Channel Flow Cell

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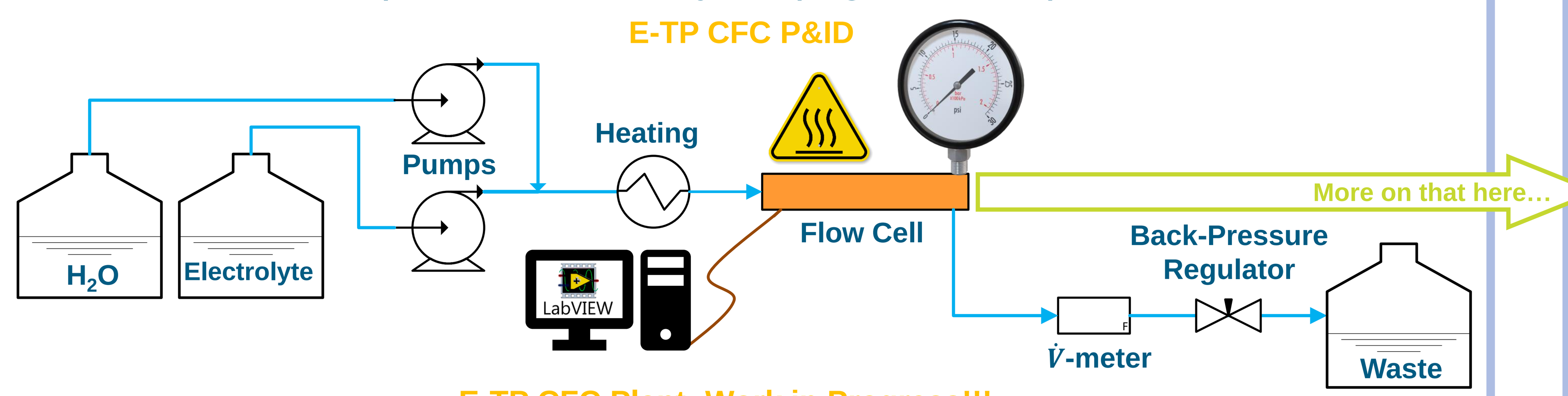
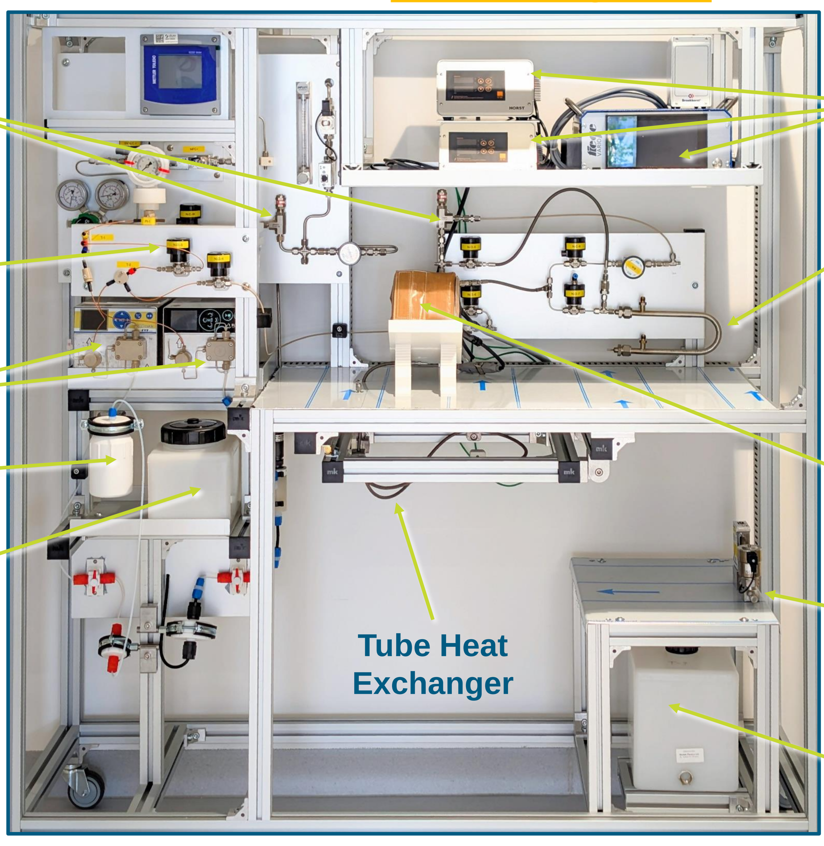
Motivation & Overall Goal

- Fundamental electrocatalyst characterization at **Elevated $T\&P$**
- Desired conditions: $P \geq 10\ bar$ → increased gas solubility (reactant or product); $T = 150\ °C$ → kinetic & selectivity effects
- Flexible electrolyte composition and real-time pH tuning
- Possibility of future T-dependend catalyst dissolution & stability studies with coupled online analysis (e.g. ICP-MS)

E-TP CFC P&ID



E-TP CFC Plant: Work in Progress!!!



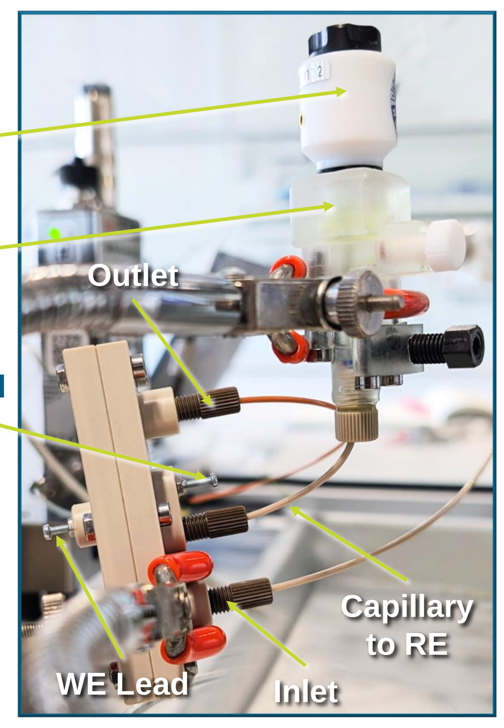
The Elevated T&P Channel Flow Cell (E-TP CFC)

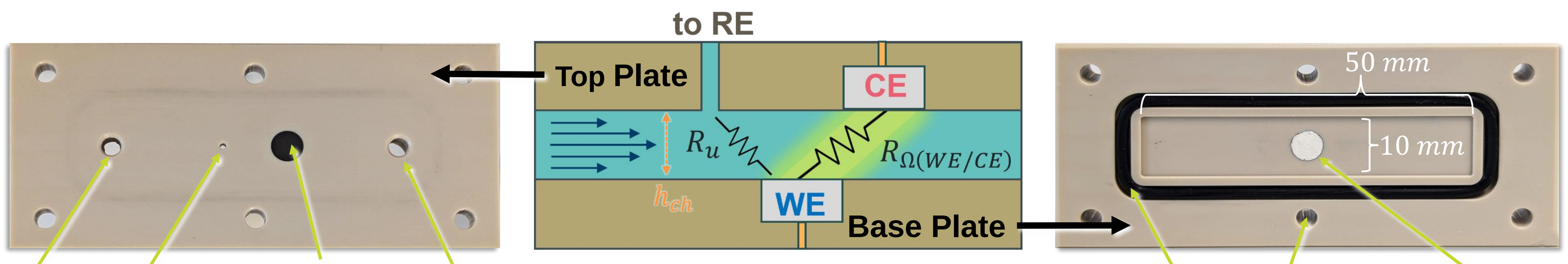
- CNC-machined polyether-ether ketone (PEEK)
- Chemically & mechanically stable
- Internal (pseudo)reference electrode
- Interchangeable electrode discs
- Glue & sealant free

The „Dummy" Channel Flow Cell

- Room temperature; $P \propto \dot{V}$
- Completely metal-free structure
- Same internal geometry as the E-TP CFC
- Uses a commercial reference electrode (RHE)
- Validation of the fluid-dynamics assumptions
- Probing of the electrodes configuration' electrochemical features (distance, position, etc)
- Simpler troubleshooting & system development (bubbles management, electrical contact, leak-tightness, etc)

Assembled DCFC





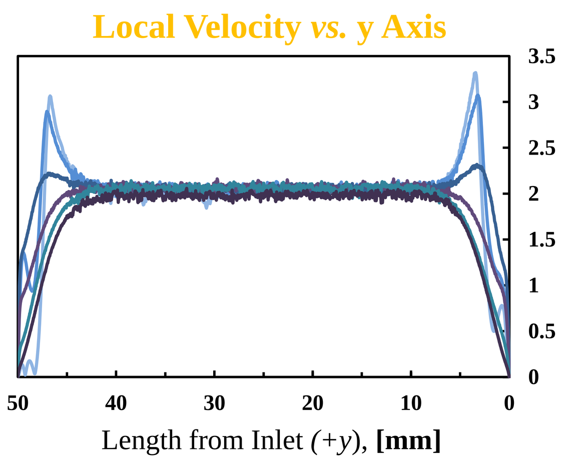
DCFC's 3-Electrode Confugruation Schematics

The Physical Electrochemistry of Channel Flow Cells

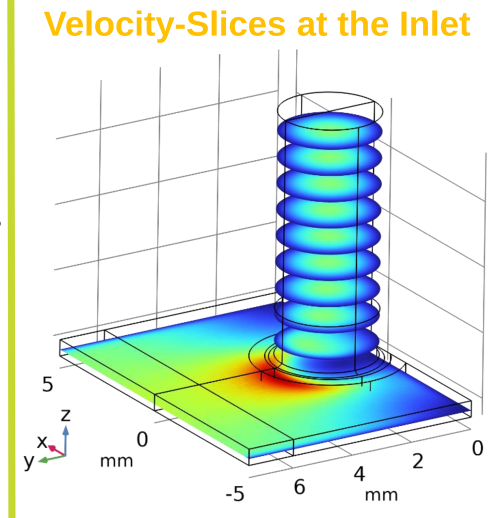
- Hydrodynamic systems (alternative to rotating disc electrodes)[1]
- The flowrate $\dot{V}$ directly controls the mass transport and current I_{LIM}
- Submillimetric channel height h_{ch} → possible ohmic effects[4]
- In laminar regimes:

$$|I_{LIM}|^{[2]} = n_{e^-} \cdot F \cdot k_{cell} \cdot C_{bulk} \left(\frac{A^{geo}_{WE} \cdot D}{h_{ch}} \right)^{2/3} \cdot \sqrt[3]{\dot{V}} \qquad \begin{cases} k_{cell} = 1.467 \\ D^{[3]} = 3.47 \cdot 10^{-6}\ cm^2 s^{-1} \\ h_{ch} = 0.055\ cm \\ A^{geo}_{WE} = 0.196\ cm^2 \\ C_{bulk} = 10^{-5}\ mol\ cm^{-3} \end{cases}$$

Finite-Element Simulations

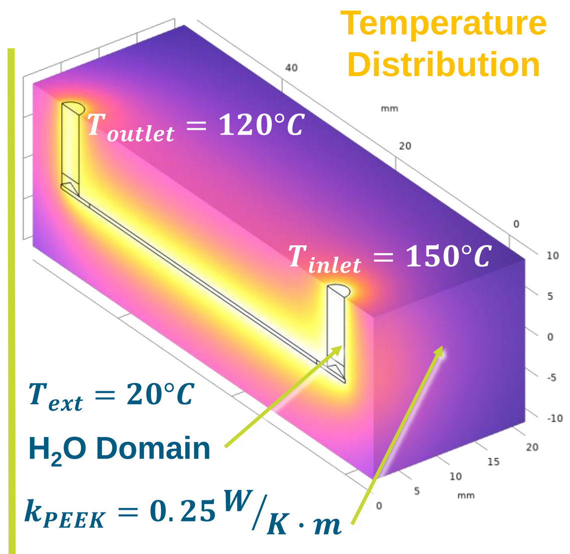


- Velocity is constant for $10 < y < 40\ mm$ → steady conditions over the electrodes

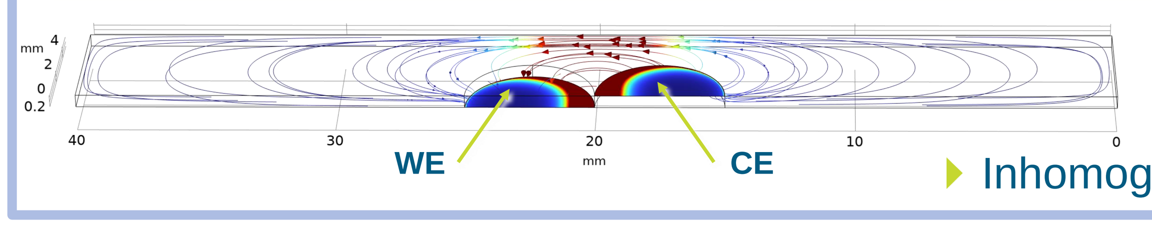


- Fast decay of the inlet flow disturbances

Temperature Distribution



- Large heat losses, highly dependent on $\dot{V}$: active heating is needed



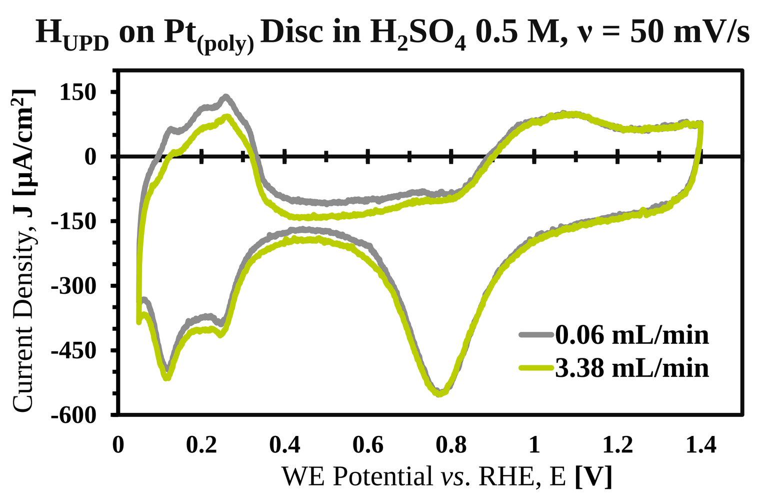
Primary Current Distribution Over Circular Electrodes

- Inhomogeneous current densities

Dummy Flow Cell Benchmarking at Room Temperature

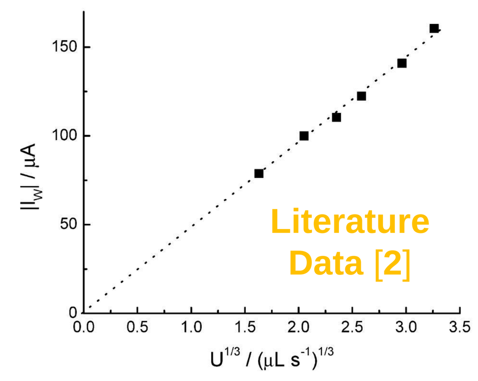
Hydrogen Underpotential Deposition

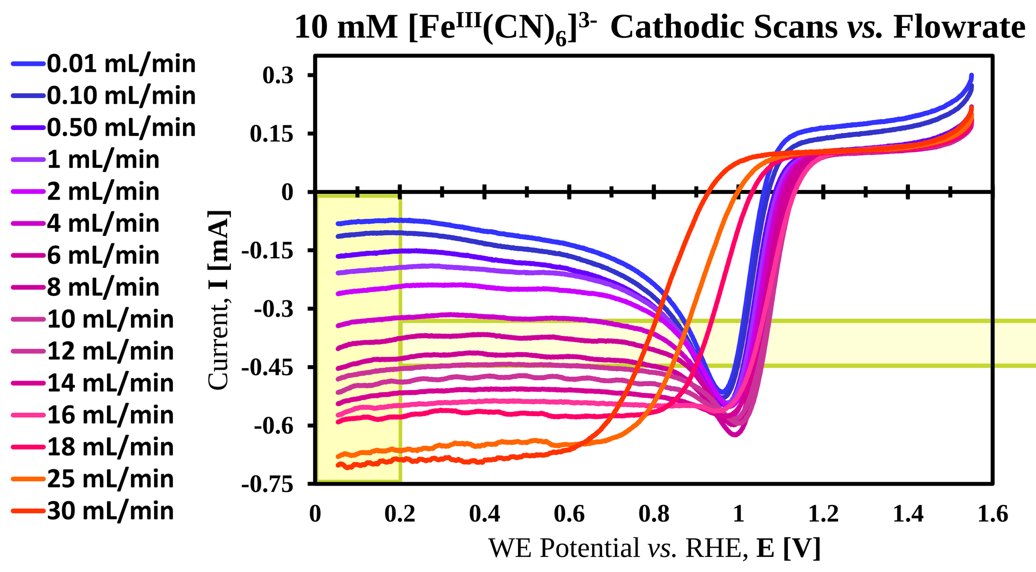
- Correct potential sensing, little resistance
- Potential values are independent on $\dot{V}$
- Traces of $O_{2(liq)}$ → negative current shift

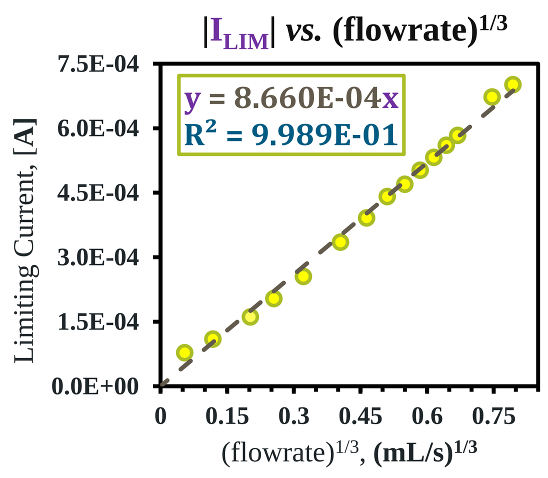


Limiting Current Analysis

- $[Fe^{III}(CN)_6]^{3-} + 1e^- \rightarrow [Fe^{II}(CN)_6]^{4-}$; $K_3Fe(CN)_6\ 10\ mM\ +\ KNO_3\ 0.2\ M$
- $0.05\ \rightarrow 1.6\ V$, $v = 250\ mV/s$ CVs
- Pt & GC discs both work as WE (CE = GC)
- $|I_{LIM}|_{Calc} = 7.54 \cdot 10^{-4} \cdot \sqrt[3]{\dot{V}}$ → $\Delta_{Exp/Calc} = +12.9\ \%$
- No disturbances, laminar flow ($0.04 < Re < 114$)







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[1] Fuhrmann, J., Zhao, H., Holzbecher, E., Langmach, H., Chojak, M., Halseid, R., Jusys, Z., Behm, J. *Phys. Chem. Chem. Phys.* (**2008**), 10, 3784-3795

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[3] $D_{[Fe(CN)_6]^{3-/4-}}$ from Diakowski, P.M., Kraatz, H-B. *Chem. Commun.*, (**2011**), 47, 1431–1433, SI.

[4] Coles, B.A., Compton, R.G., Larsen, J.P., Spackman, R.A. *Electroanalysis* (**1996**), 8, No. 10

Conclusions & Future Perspectives

- The DCFC demonstrated the effectiveness of the geometry and design
- Completing the commissioning and optimization of the E-TP CFC plant
- Multiphysics modelling of P, T & $\dot{V}$ effects and comparison with experiments
- Benchmark tests at the E-TP conditions, then "real" catalyst studies

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