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Variance of ECSA-scaling factors of flow battery cells with internal flow fields

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HYPOTHESIS

The electrochemically active surface area (ECSA) of a flow cell with an optimized flow field design will be higher than the ECSA of an identically constructed cell with unstructured electrodes and therefore compensate the loss of felt material and active area, caused by the flow channels.

BACKROUND

- A part of the physically measurable surface area of porous felt electrodes is not available for electrochemical reactions, due to:
  - Low wettability
  - Surface structure of the felt material
  - Obstruction of flow paths by contacting fibers
  - Non-uniform fluid distribution
- The electrochemically active surface area (ECSA) is an important parameter for the determination of concentration overpotentials and therefore for the design, calculation and layout of flow batteries
- Inadequate or incorrect evaluations of the ECSA will lead to large differences between model predictions and experimental data

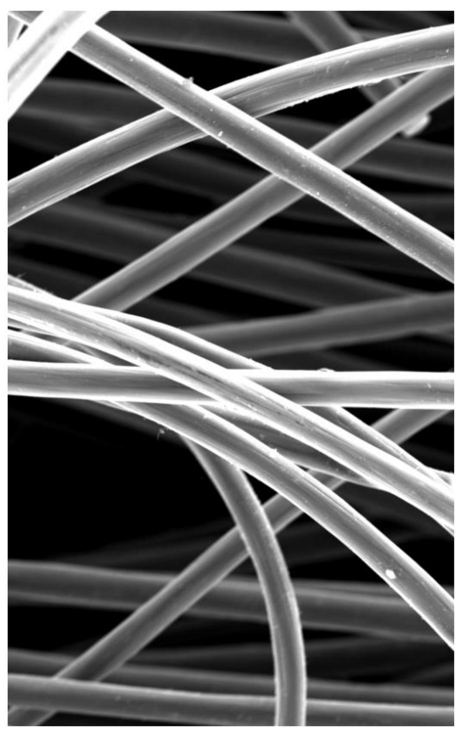

Figure 1. *Contacting fibers in a porous felt electrode*

- [1] introduced the ECSA-scaling factor S_{ECSA} to link the geometrical electrode area to the actual ECSA and detected an average value of S_{ECSA}= 2.38

APPROACH

- As the ECSA can be an operation related parameter, dependent on the volumetric flow, conventional ECSA testing methods, like cyclic voltammetry, are not suitable
  → Effects can only be ascertained during operation of the battery
- Using the advanced Nernst equation, the maximum volumetric flow rates of structured electrodes and varying values of S_{ECSA} can be correlated (shown in figure 2)

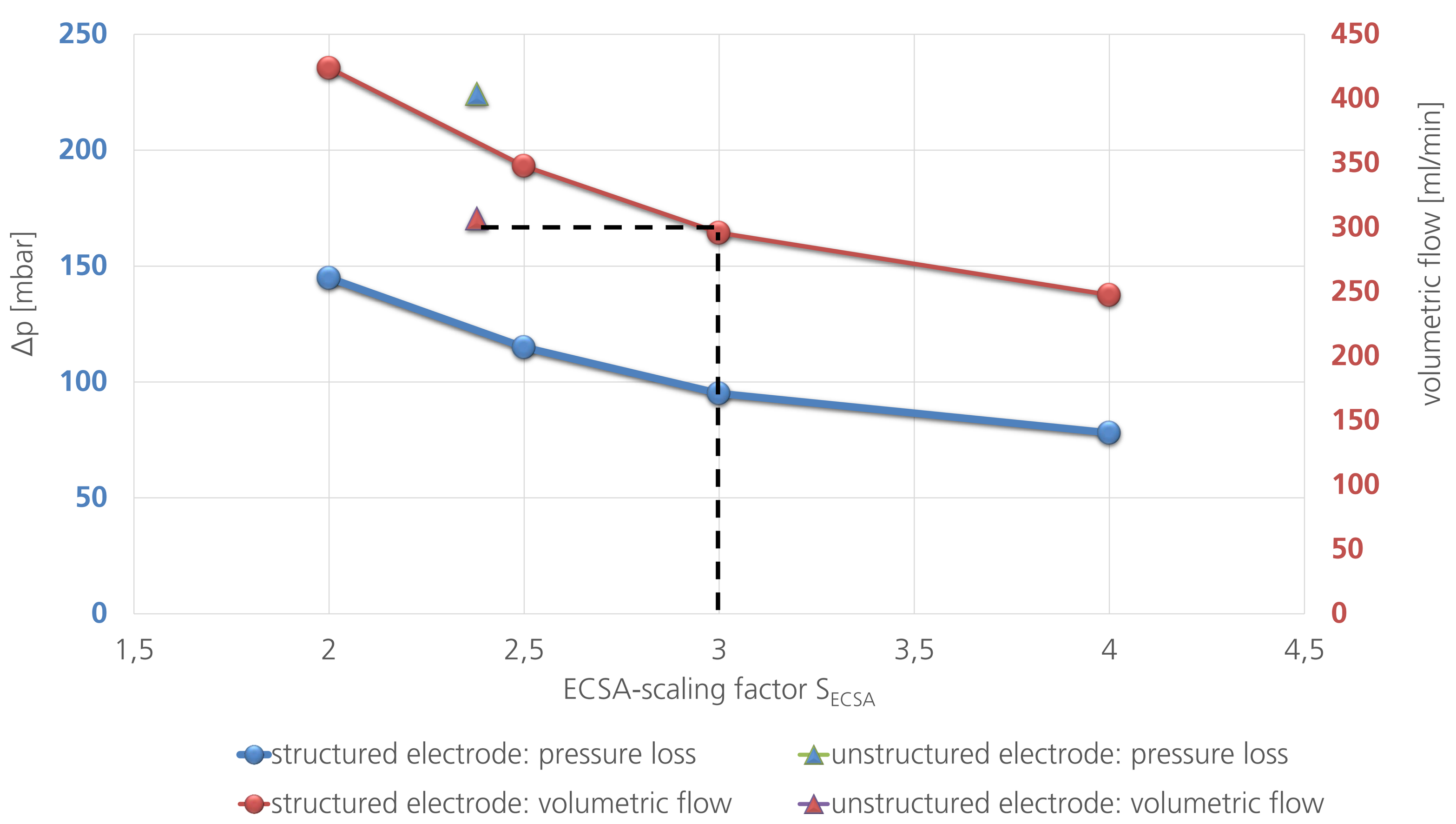

Figure 2. *Calculated maximum volumetric flow and pressure losses of a 160 cm² flow battery cell with unstructured and structured porous electrodes (interdigitated flow field) over the ECSA-scaling factor (unstructured electrode S_{ECSA}=2.38 [1]), $V^{2+/3+}$, 1.6 mol/L V, 2.6 mol/L H_2SO_4, SOC 80%, 30°C*

- With the assumptions of figure 2, structured electrodes exceeding S_{ECSA}=3 would result in:
  - Equal maximum flow rates as unstructured electrodes with S_{ECSA}=2.38
  - Pressure loss reduction of more than 60 %

MOTIVATION

- Internal flow fields in graphite felt electrodes can improve the convection and the accessibility for electrolytes and enhanced the cell performance [2,3]
- [2] found, that an optimized interdigitated flow field can even reduce the required volumetric flow over an unstructured porous electrode

→ A better exploitation of the physically measurable surface area and a more even fluid distribution can be assumed for structured electrodes

POSSIBLE BENEFITS

An increased ECSA of porous electrodes with optimized interdigitated flow fields would:

- Reduce the required volumetric flow rate
- Reduce pressure losses
- Allow for thinner electrodes

OUTLOOK

- Under identical conditions (cell designs, materials and process parameters) S_{ECSA} of structured and unstructured porous felt electrodes shall be determined by evaluating experimental data from performance tests
- Remaining specific parameters of porous felt electrodes have been determined
- 160 cm² test cells have been designed and assembled (shown in figure 3)

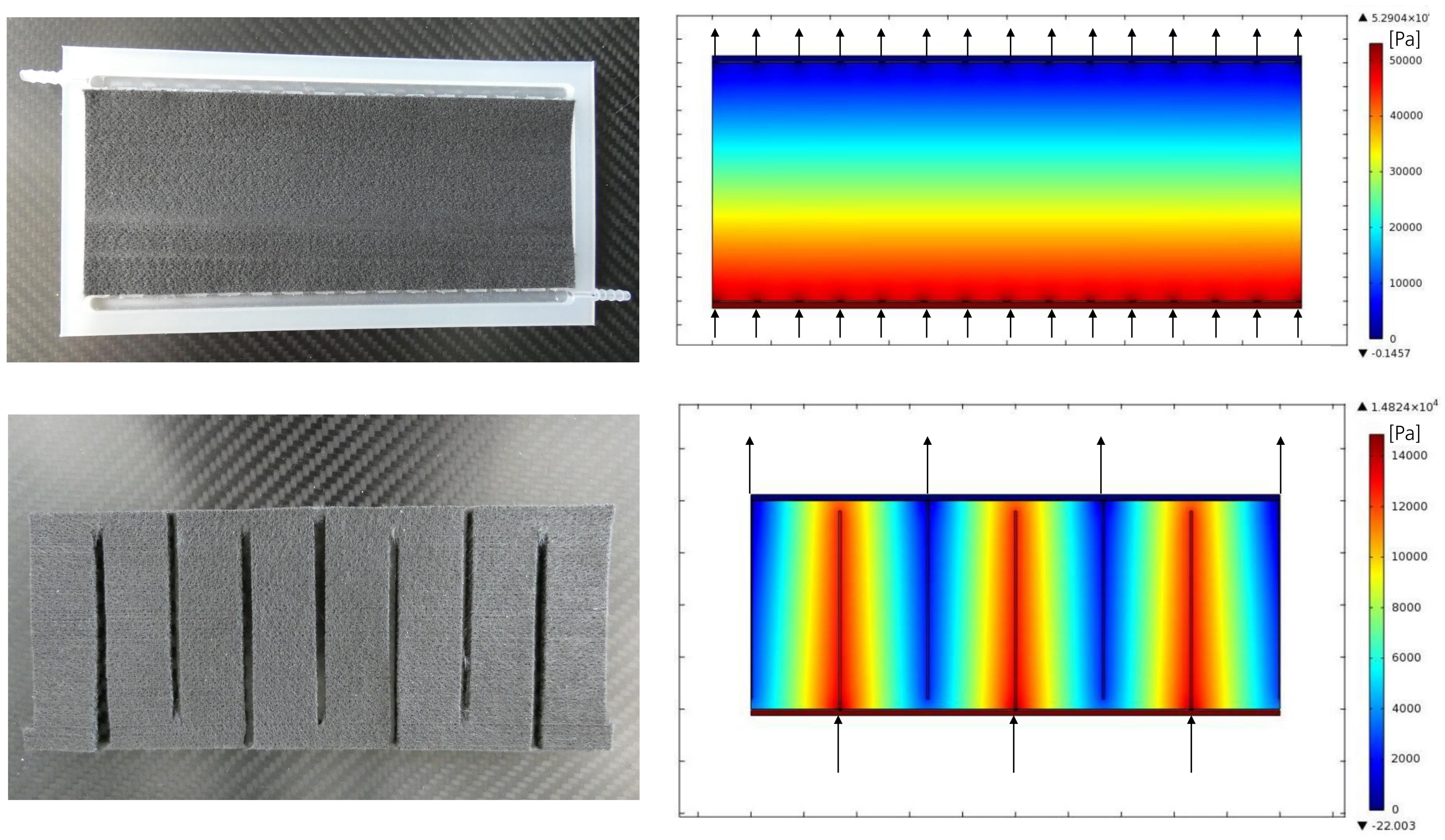

Figure 3. *Unstructured and structured porous felt electrodes with optimized interdigitated flow field and simulations of hydraulic pressure processes*

References
[1] König, S.: Model-based Design and Optimization of Vanadium Redox Flow Batteries. Dissertation, Karlsruhe Institute of Technology KIT, 2017.
[2] Bhattarai, A., et al.: Advanced porous electrodes with flow channels for vanadium redox flow battery. Journal of Power Sources, 2017.
[3] Mayrhuber, I., et al.: Laser-perforated carbon paper electrodes for improved mass-transport in high power density vanadium redox flow batteries. Journal of Power Sources, 2014.