Research group Membrane Materials and Processes

Optimizing the 3D microstructure of redox flow battery electrodes

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Need for large-scale energy storage

Integrating renewable energy technologies in to the grid is necessary to enable a sustainable energy economy. However, their intrinsic intermittency (Figure 1) motivates the development of low-cost, large-scale energy storage systems, in the pursuit of filling the gap between renewable energy generation and consumers demands.

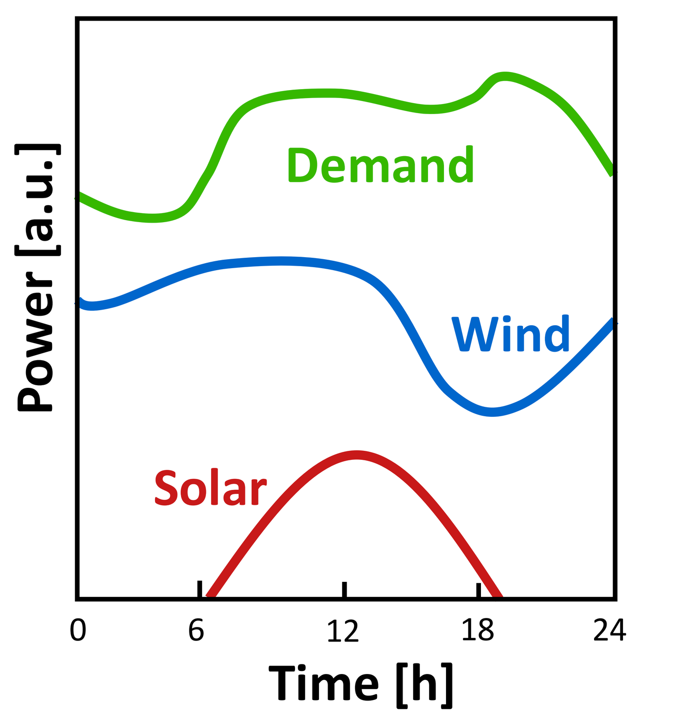

Figure 1: Mismatch between renewable energy generation and demand in Germany (02/2018).[1]

Redox flow batteries

Redox flow batteries (RFBs) (Figure 2) are rechargeable electrochemical reactors that are promising for grid storage due to the possibility to decouple energy (i.e. tank volume) and power (i.e. reactor size), facilitating their large-scale deployment[2].

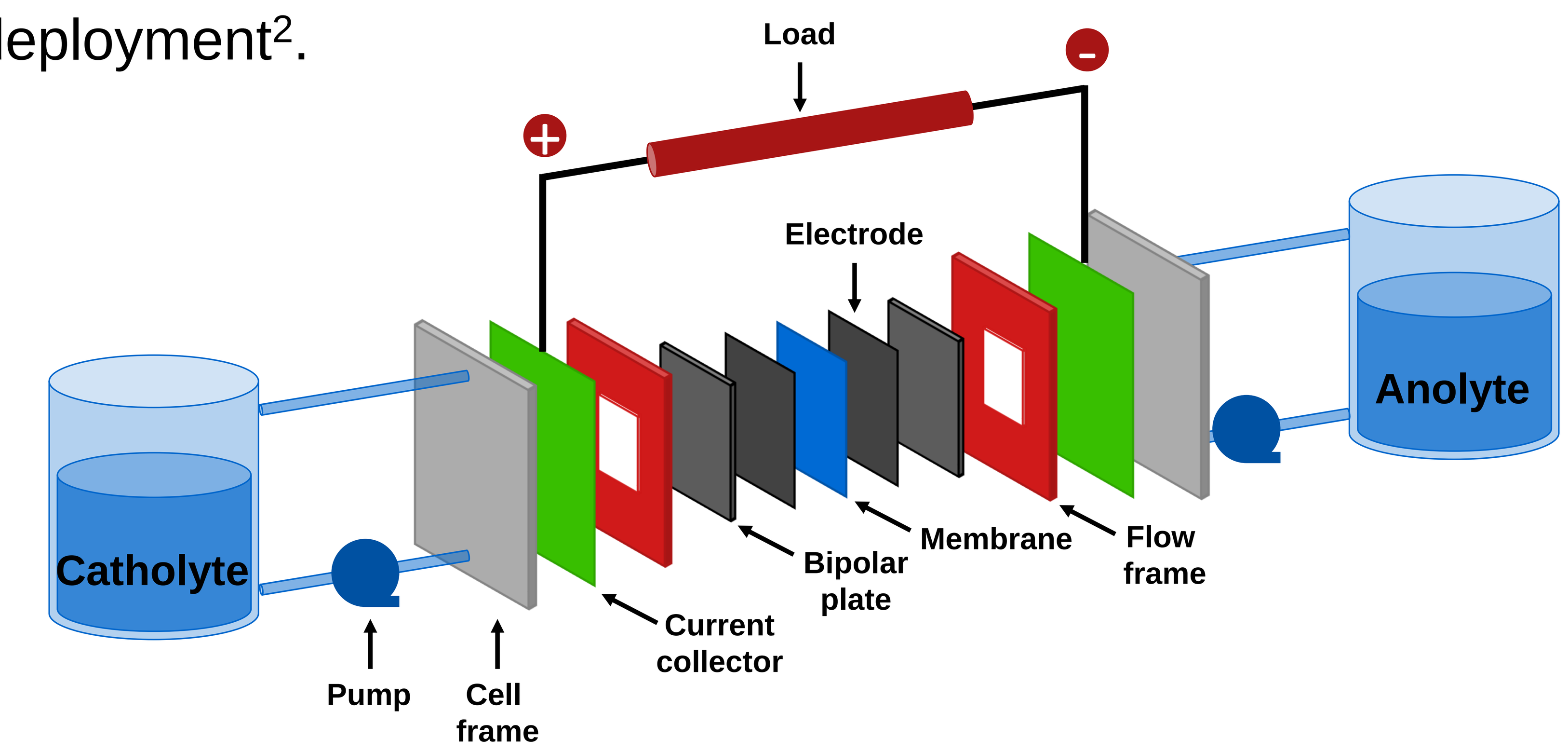

Figure 2: Schematic diagram of a redox flow battery.

Electrodes influence RFB performance

Porous electrodes need to fulfil several performance-relevant functions, such as providing surface area for electrochemical reactions, distributing liquid electrolytes, conducting electrons, and cushioning mechanical stresses, which impact the overall efficiency (Figure 3).

Key properties:

- Surface area ↑
- Pressure drop ↓
- Mass transport ↑
- Mechanical properties ↑
- Electrochemical activity ↑
- (Electro)chemical stability ↑

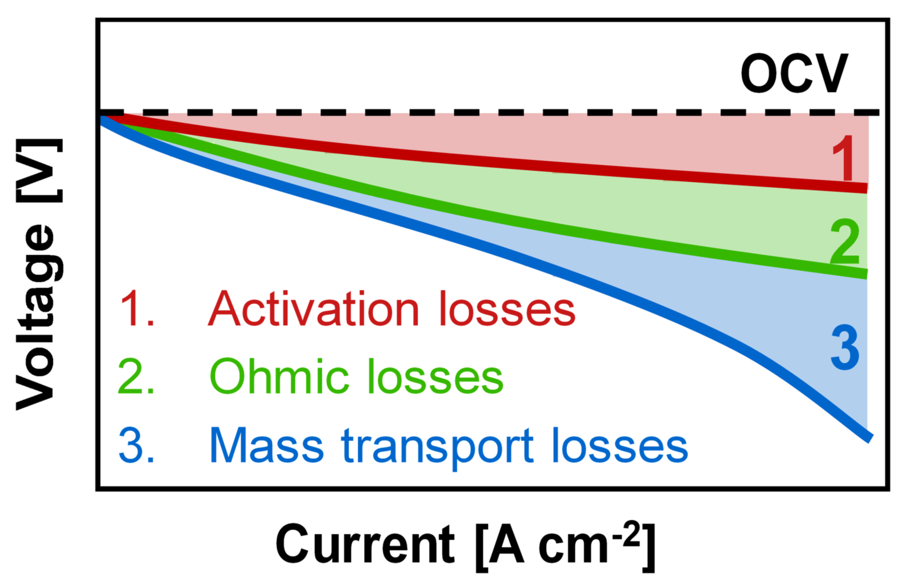

Figure 3: Discharge polarization curve.

Project goal

In this project, the electrode 3D microstructure will be optimized employing a combination of computer aided-design, fabrication, and operando characterization (Figure 4).

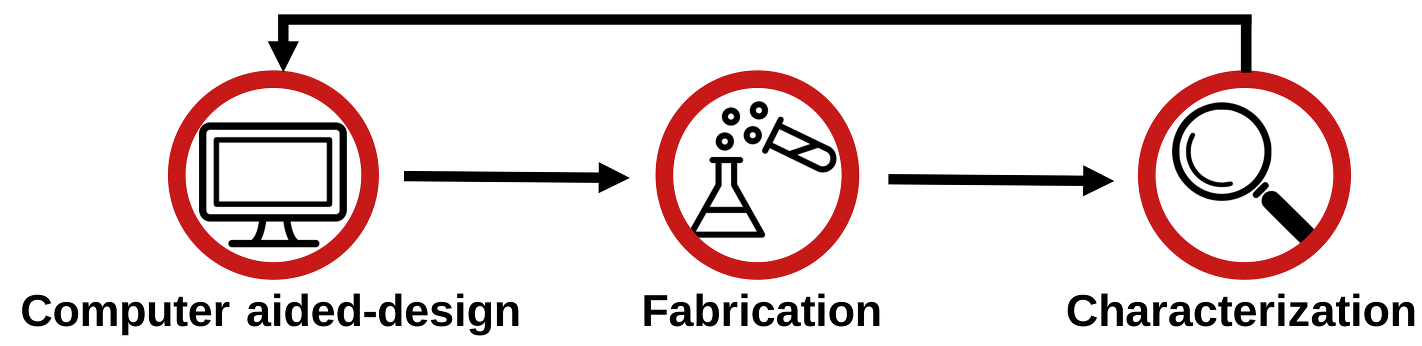

Figure 4: Schematic representation of the *computer-to-battery* approach.

Computer aided-design

Multiphysics simulations are used to understand the influence of the electrode microstructure with increasing level of detail (Figure 5). These learnings are leveraged for the bottom-up design of optimal electrodes with improved RFB performance.

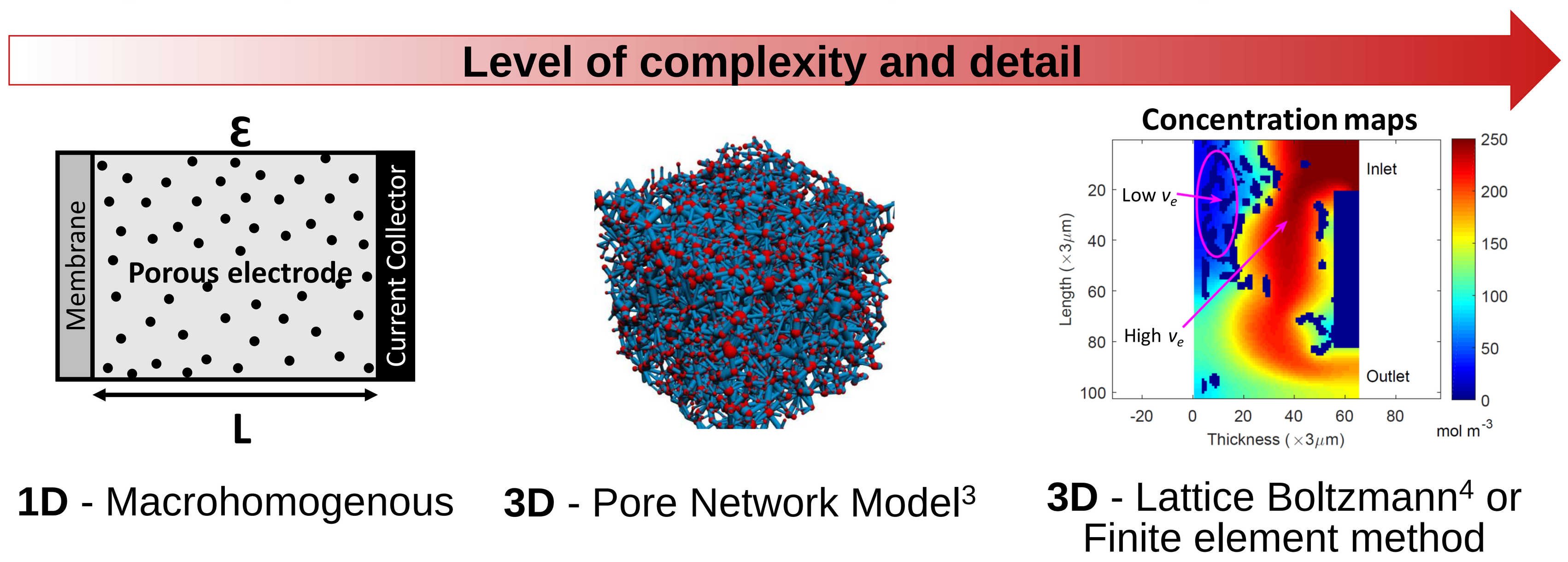

Figure 5: Overview of various multiphysics simulations with increasing complexity.

Operando Characterization

By characterizing the electrodes in a flow cell platform, the key properties and the main losses of the electrodes are obtained (Figure 6), which can be used as input for the multiphysics simulations to increase their performance.

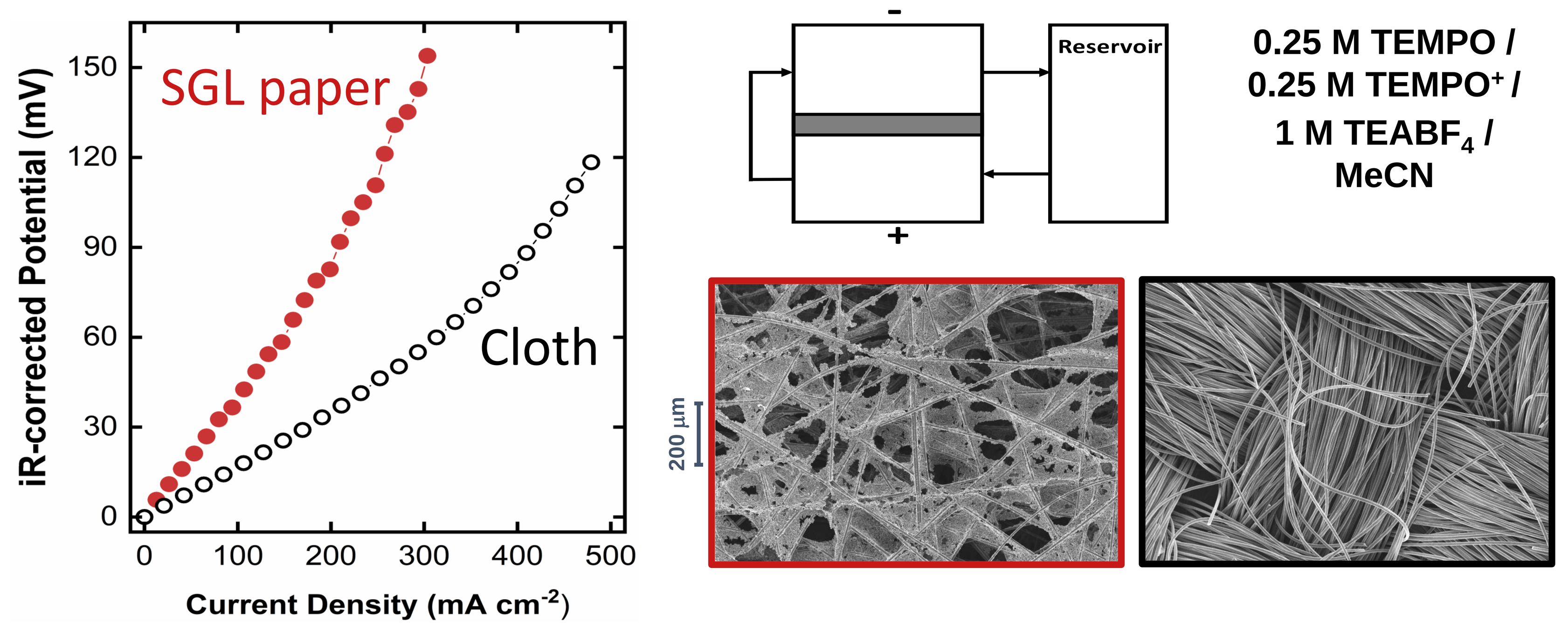

Figure 6: iR_{Ω}-corrected cell potential at 1.5 cm s^{-1} electrolyte velocity for the SGL carbon paper and carbon cloth electrode, shown in the corresponding SEM images. A single electrolyte cell with an organic electrolyte was used.

References

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