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Investigating mass transfer relationships in 3D printed electrodes for redox flow batteries

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Redox flow batteries (RFBs) are a promising technological platform for grid-level storage of intermittent renewable electricity and their independently scalable tank volume and reactor size facilitate their use for large-scale applications[1]. Porous electrodes govern the electrochemical performance and pumping requirements in RFBs, yet conventional porous electrodes have not been tailored to sustain the requirements of liquid-phase electrochemistry. In this work[2], we investigate mass transfer relationships in stereolithography 3D printed and carbonized model grid structures. We systematically studied the effect of the **printing direction, pillar geometry,** and **flow field type** on the cell performance, where the manufacturing procedure is shown in **Figure 1**. This study shows the potential of 3D printing to manufacture customized electrode scaffolds, which could enable multiscale structures with superior electrochemical performance and low pumping losses.

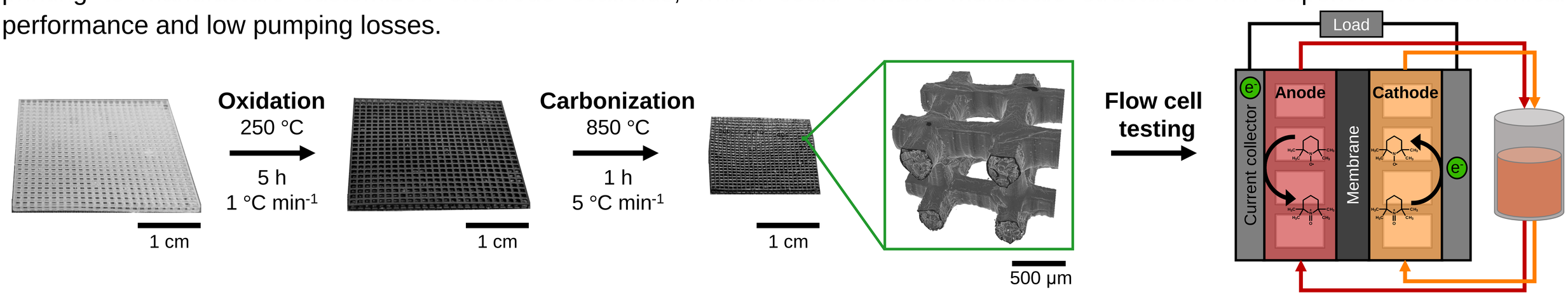

Figure 1: Representation of the process workflow to obtain a conductive electrode from a nonconductive 3D print to be tested in an organic flow cell (0.1 M TEMPO/TEMPO$^+$ in 1 M $TBAPF_6$/MeCN).

Printing line induced roughness

The printing direction (**Figure 2**) impacts the electrode performance through a **change in surface roughness**, affecting the shrinkage upon carbonization (**Figure 1**), internal surface area, and thus the pressure drop and charge and mass transfer resistances.

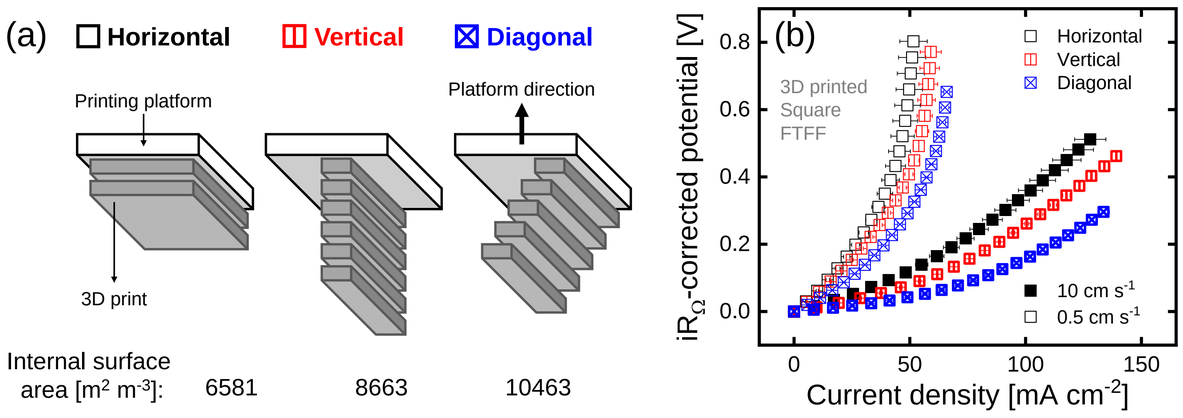

Figure 2: **(a)** The printing directions investigated (horizontal, vertical, and diagonal with respect to the printing platform), and **(b)** their resulting electrochemical performance.

Pillar geometry induces mixing

The helical pillar shape (**Figure 3**) shows an increased mass transfer coefficient and thus performance compared to the square pillar shape. The helical twist is expected to induce **local mixing of the electrolyte**, improving the active species transfer of the bulk to the electrode surface.

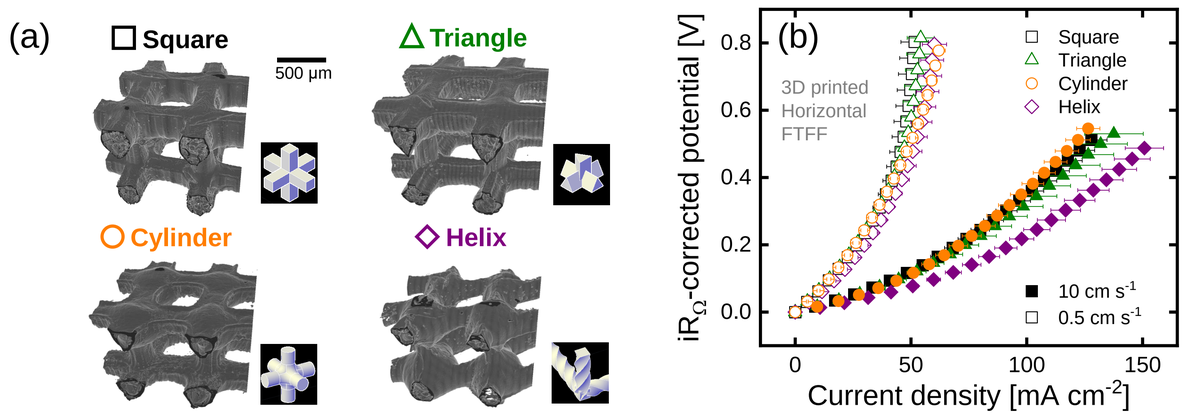

Figure 3: **(a)** The pillar shapes analyzed (square, triangular, cylindrical, and helical), and **(b)** their resulting electrochemical performance.

Electrode-flow field interactions

The interplay between the flow field type and electrode has proven to be crucial in the selection of electrodes for RFBs[3]. By combining interdigitated flow field designs (**Figure 4**) with the 3D printed electrodes, the **mass transfer coefficient** within the electrode can be improved compared to flow through designs.

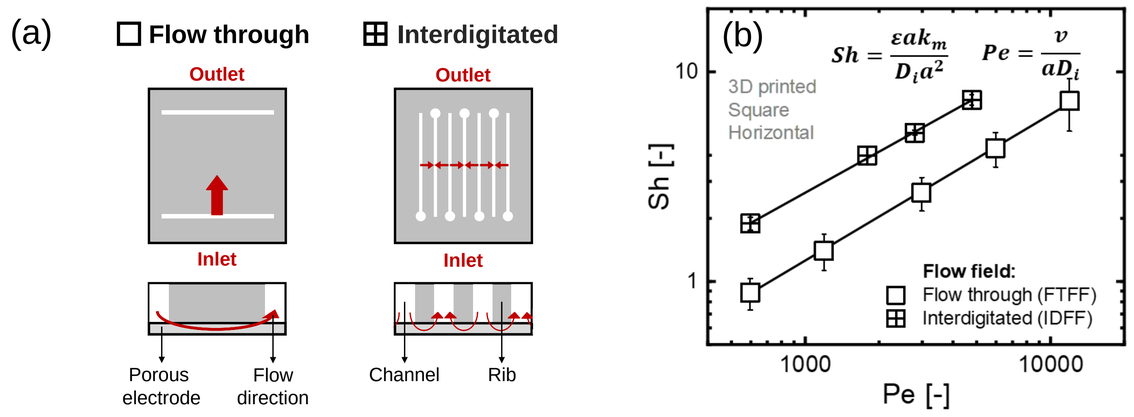

Figure 4: **(a)** The flow field geometries analyzed (flow through and interdigitated), and **(b)** their resulting dimensionless mass transfer correlations with the 3D printed electrodes.

Potential of 3D printed electrodes

3D printing emerges as a viable manufacturing method to **enhance mass transfer rates** and to **decrease the pumping demands** in RFBs compared to conventional electrodes (**Figure 5**). Future efforts should focus on producing finer features and increased surface area and conductivity.

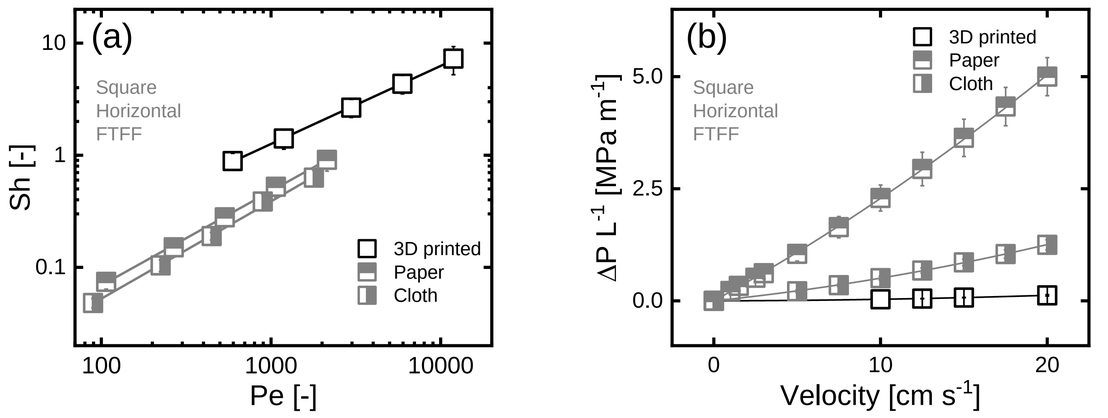

Figure 5: A comparison between 3D printed and conventional electrodes, for: **(a)** the dimensionless mass transfer correlations, and **(b)** the pressure drop through the electrodes.

Acknowledgements

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References

[1] van der Heijden et al., Encyclopedia of Energy Storage, 480-499 (2022)
[2] van der Heijden et al., ChemRxiv, 10.26434/chemrxiv-2023-kpd8x (2023)
[3] Muñoz-Perales et al., ChemRxiv, 10.26434/chemrxiv-2023-2zthc (2023)