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CFD study on the influence of water transpiration on flow and mass transfer in channels with bipolar membranes

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Introduction

The future energetic supply based on the massive use of renewable sources poses issues linked to fluctuations of power produced and consumed, thus requiring the use of energy storage systems. The "Blue Acid/Base Battery" has been recently proposed as an environment-friendly, cost-competitive, grid-scale battery storage system (van Egmond *et al.* (2017)) and is currently studied in the *BAoBaB* project. This technology stores the excess of electric power in the form of acid and base solutions (pH gradient), obtained from their corresponding salt, which are then recombined when electricity is needed. The electromotive force per membrane for 1M acid and base (0.83V) is an order of magnitude larger than that due to salinity gradients only, thus significantly boosting the power density. The process is based on the coupling of electrodialysis and reverse electrodialysis with bipolar membranes (BPMs), which promote catalytically water splitting. As well as membranes, fluid dynamics and mass transfer may crucially affect the energy conversion efficiencies. In this work, we developed a computational fluid dynamics (CFD) model aimed at assessing the influence of water transpiration through BPMs on flow and mass transfer.

CFD model

Continuity and Navier-Stokes equations and a convective-diffusive transport equation (passive scalar) were solved by the finite volume method using the *Ansys-CFX* code. Void (spacer-less, 2-D) and spacer-filled (3-D) channels were simulated (see Fig.1).

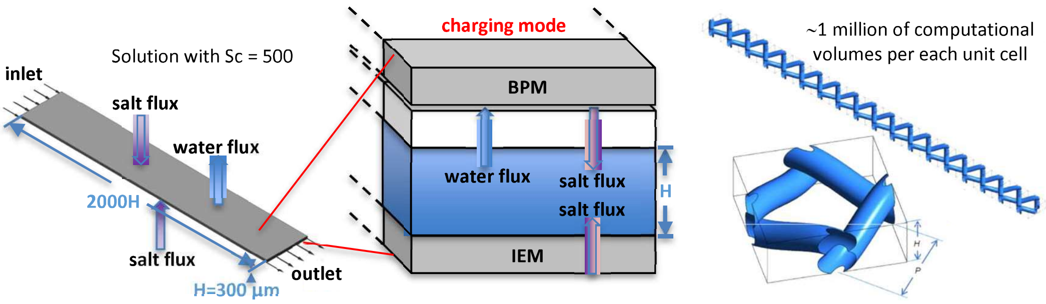

Figure 1. Void channel with enlarged view (left); example of woven net spacer-filled channel (right).

Results and Discussion

In the void channel under charging mode (outward water flux), the effect of water transpiration on mass transfer is detrimental and is larger as the current density (i)

increases (Fig.2 left top). The opposite effect of i for the discharging mode (inward water flux) and a mass transfer enhancement, albeit less pronounced, on the wall without water flux were observed. Pressure drop decreases with i and with the distance from inlet in charging mode (Fig.2 left bottom) and increases in discharging mode, but only of few percent. In spacer-filled channels (see example in Fig.2 right) the trends are qualitatively similar, but with even lower effects. Moreover, there is no practical influence on Sh at the wall without water flux and a negligible effect on pressure drop.

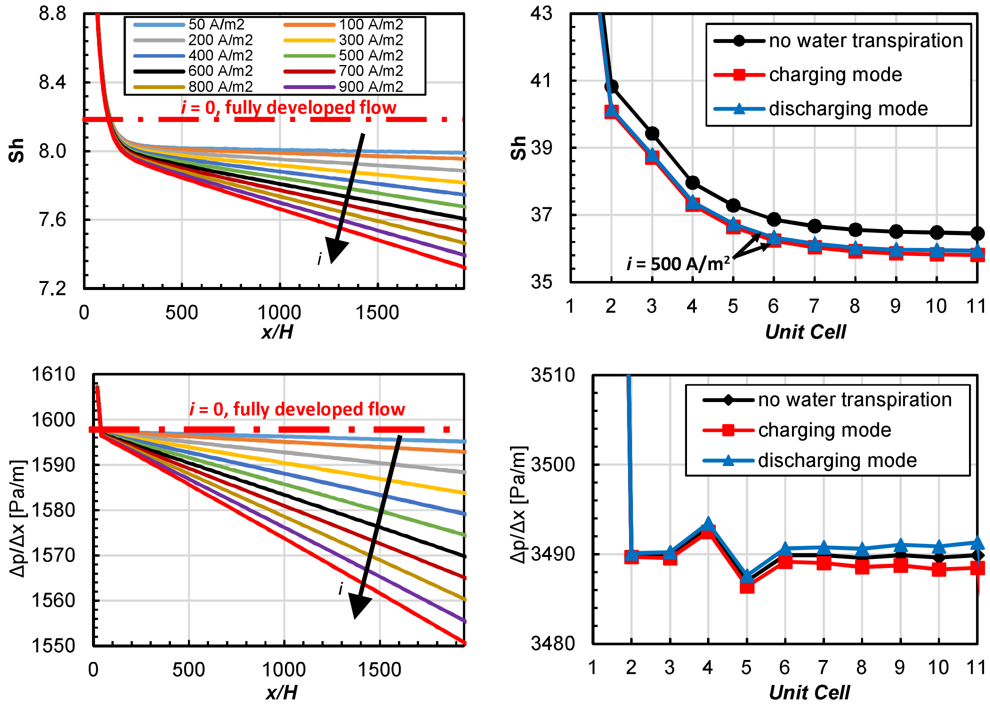

Figure 2. Sherwood number at the wall with water flux (top row) and pressure drop (bottom row) in the void channel (left) and in the woven spacer-filled channel with P/H=3 (right). Re = 8.

Conclusions

In channels of practical interest, i.e. provided with spacers, the water flux through the BPM causes only a slight disturbance of flow and concentration fields, with effects being moderate on mass transport and even negligible on pressure drop. A more generalized study extended to electromembrane processes in non-ideal conditions (e.g. in presence of electroosmotic transport) is currently performed.

Acknowledgements

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References

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