Quantifying Ion Crossover for Proton-Exchange Membranes for RHFBs *via* ICP-MS

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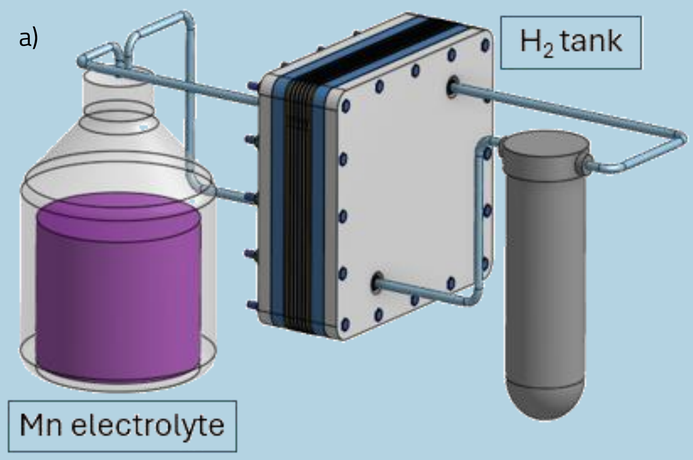
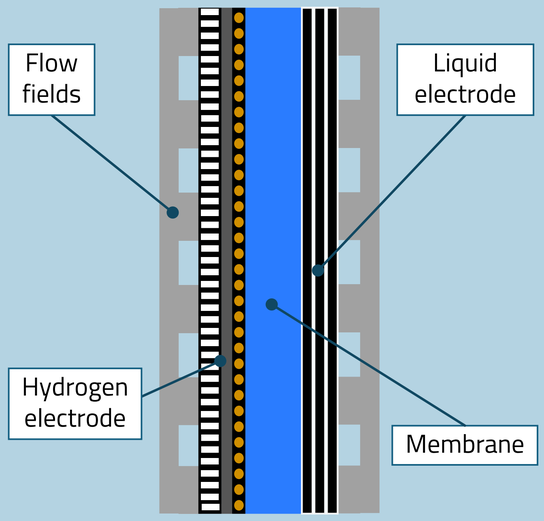
First-of-its-kind Regenerative Hydrogen Manganese Flow Battery

Regenerative hydrogen flow batteries (RHFBs) are a promising option for easily scalable, cost-effective long duration energy storage, as they combine the key benefits of flow battery and fuel cell technologies. A hybrid flow battery consisting of a hydrogen gas anolyte and a manganese-based liquid catholyte (Mn^{2+}/Mn^{3+}) offers a standard redox potential of 1.51 V, as well as high overall power densities due to the fast hydrogen redox kinetics.





a) Schematic for a H_2-Mn RFB

b) Break down of stack components in a H_2-Mn RFB

Cathode: $Mn^{2+} \rightleftarrows Mn^{3+} + e^- \quad E^\Theta = 1.51\,V$

Anode: $2H^+ + 2e^- \rightleftarrows H_2 \quad E^\Theta = 0\,V$

Focus Area

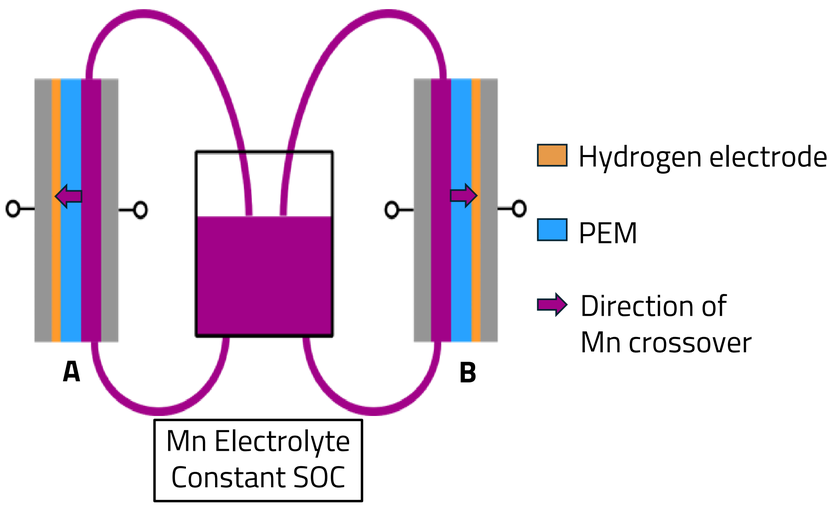
- Characterisation of transport of active species across proton-exchange membranes (PEMs) is imperative for RFBs, as it may result in capacity fade.[1]
- For mitigation, a deeper understanding of the ion crossover phenomenon in Mn-H_2 RFBs is required.

Objective

- Develop a reliable, reproducible method to quantify ion crossover for RHFBs *via* ICP-MS.
- Observe the changes in the rate of Mn crossover as the membrane composition and operating parameters are varied. Compare with full-liquid RFBs.

Methodology

The experiments were conducted in a two-cell configuration, in which cell "A" continuously charges, as cell "B" continuously discharges, which allows for the modes of operation to be analysed separately.



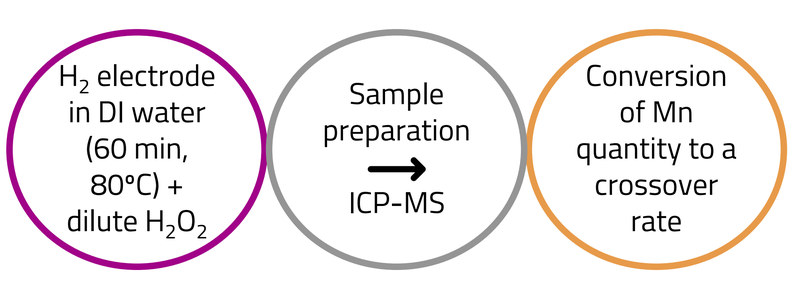
The variables:

Operating conditions (current density, temperature)

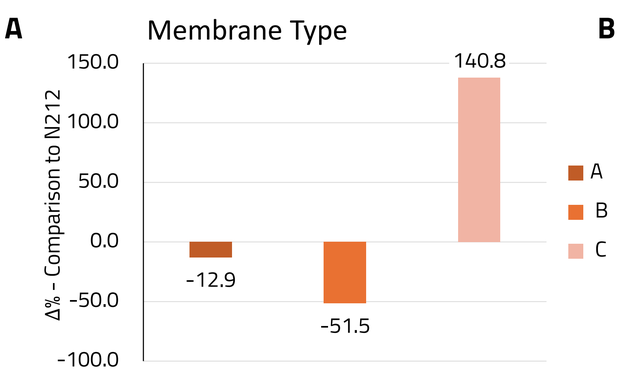
Modes of operation (charging, discharging)

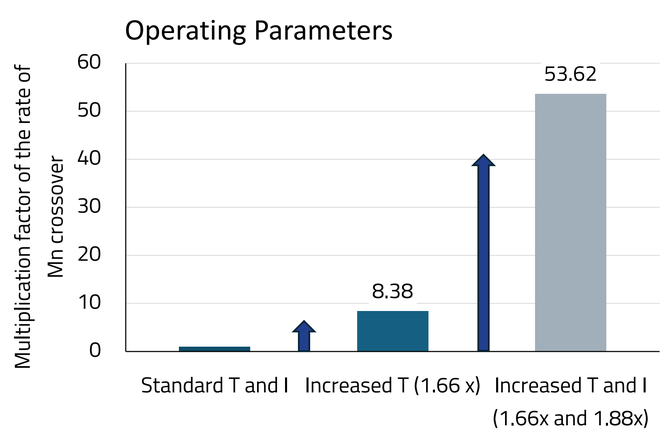
Types of PEMs (chemical composition)

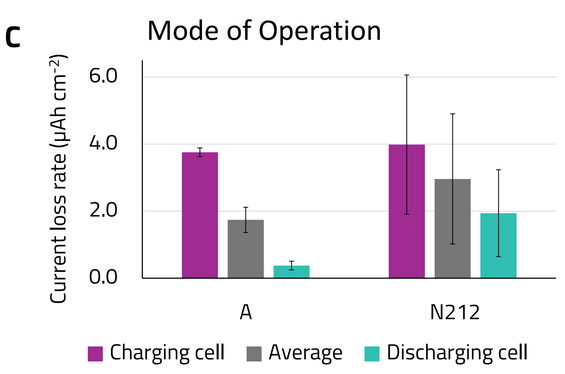
Ion Quantification Process



Results



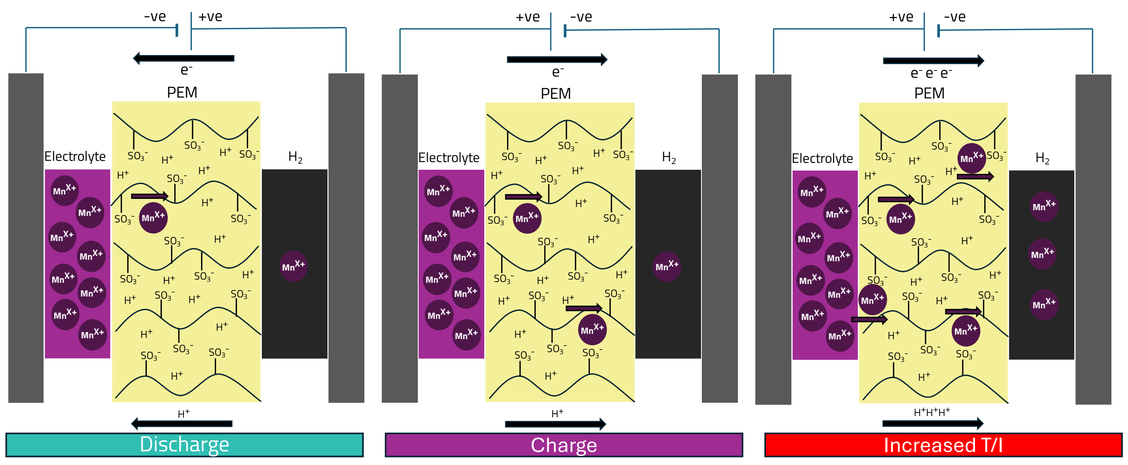




a. Mn crossover rate comparison for membranes A, B and C. Nafion™ 212 used as a baseline.

b. Mn crossover trends for variable operating parameters (current and temperature).

c. Current loss rate comparison for Nafion™ 212 and membrane A. Separation of operational modes.



Schematic for Mn crossover during variable operating conditions.

Conclusion

- During standard operation, the transport of active species across a membrane occurs at a slower rate for a hybrid Mn-H_2 RFB, in comparison with a full-liquid RFB.[2]

Next steps: Identify materials/design changes which minimise ion crossover for RHFB systems.

Acknowledgements

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Contact Information

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(1) Ertan Agar, K.W. Knehr, D. Chen, M.A. Hickner, E.C. Kumbur, Species transport mechanisms governing capacity loss in vanadium flow batteries: Comparing Nafion® and sulfonated Radel membranes, Electrochimica Acta, Volume 98, 2013, Pages 66-74, ISSN 0013-4686.
(2) Kara E. Rodby, Thomas J. Carney, Yasser Ashraf Gandomi, John L. Barton, Robert M. Darling, Fikile R. Brushett, Assessing the levelized cost of vanadium redox flow batteries with capacity fade and rebalancing, Journal of Power Sources, Volume 460, 2020, 27958, ISSN 0378-7753