Electrochemical Materials Group
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Unlocking Efficient, Sustainable, and Low-Cost Redox Flow Batteries Using Solid-State Ceramic Proton Conductors

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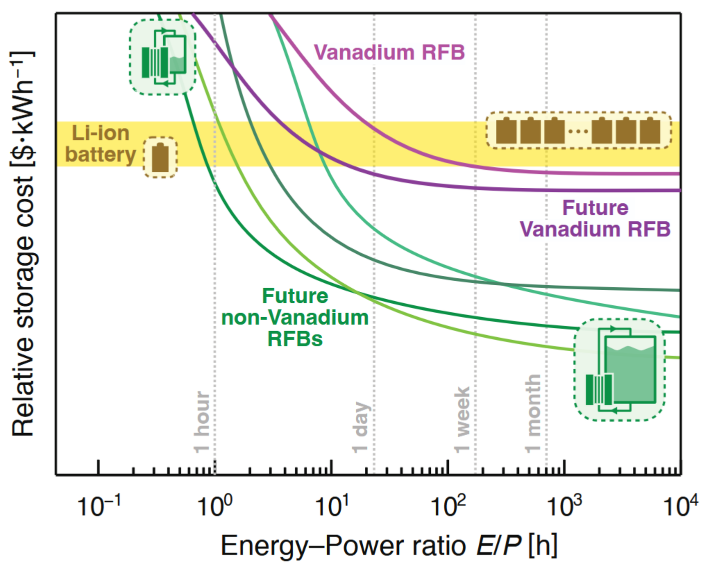
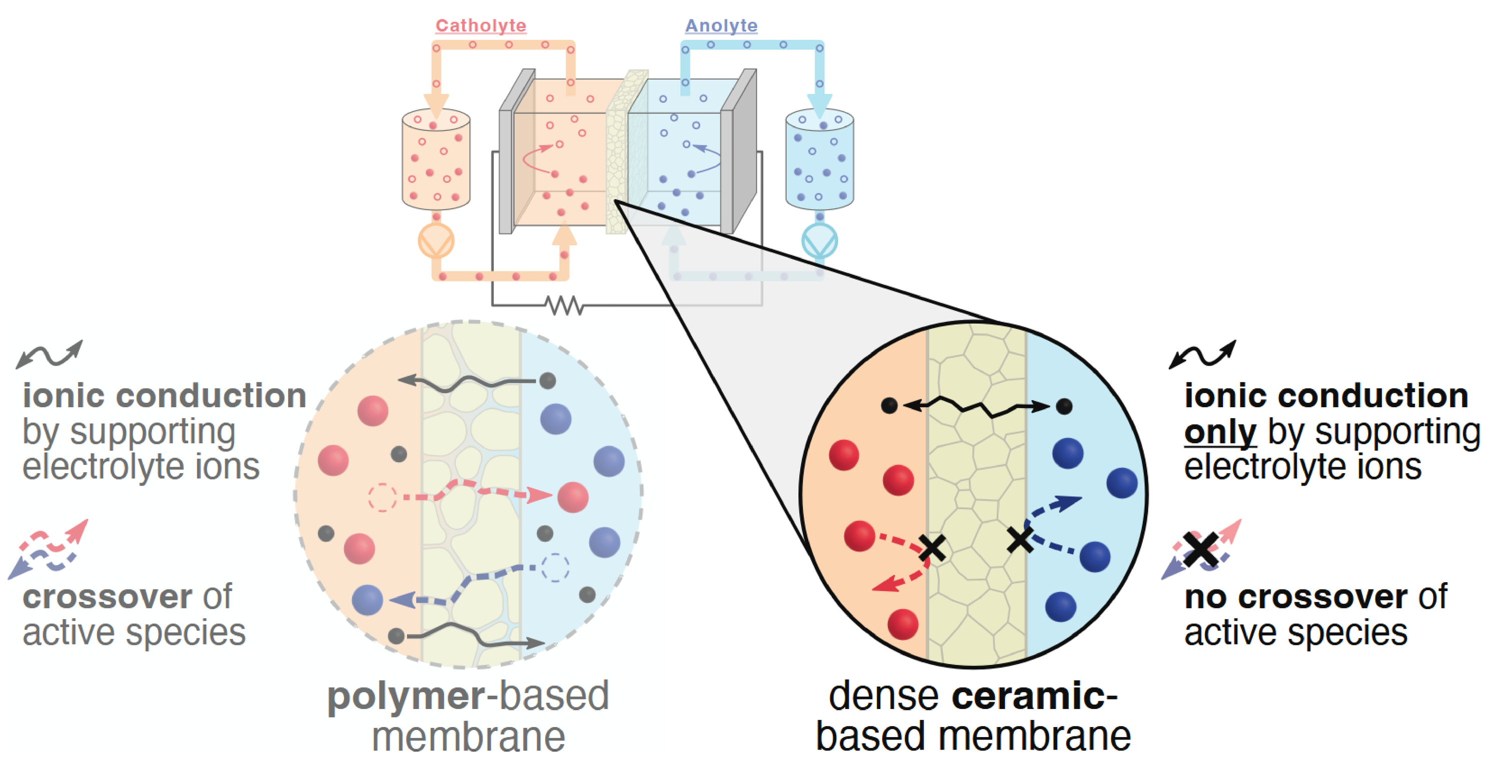
Introduction

Redox flow batteries (RFBs) already represent a promising option for long duration energy storage, but their development is constrained by crossover of active species through polymeric ion-exchange membranes. Vanadium (II/III vs. IV/V) is currently the dominant RFB chemistry due to its resilience to crossover, but the high cost and constrained supply chain limit the long-term viability and scalability of this system. Implementing a highly selective proton-conducting ceramic membrane to suppress crossover could enable access to inexpensive and sustainable redox molecules, including those sourced from industrial byproducts [1].

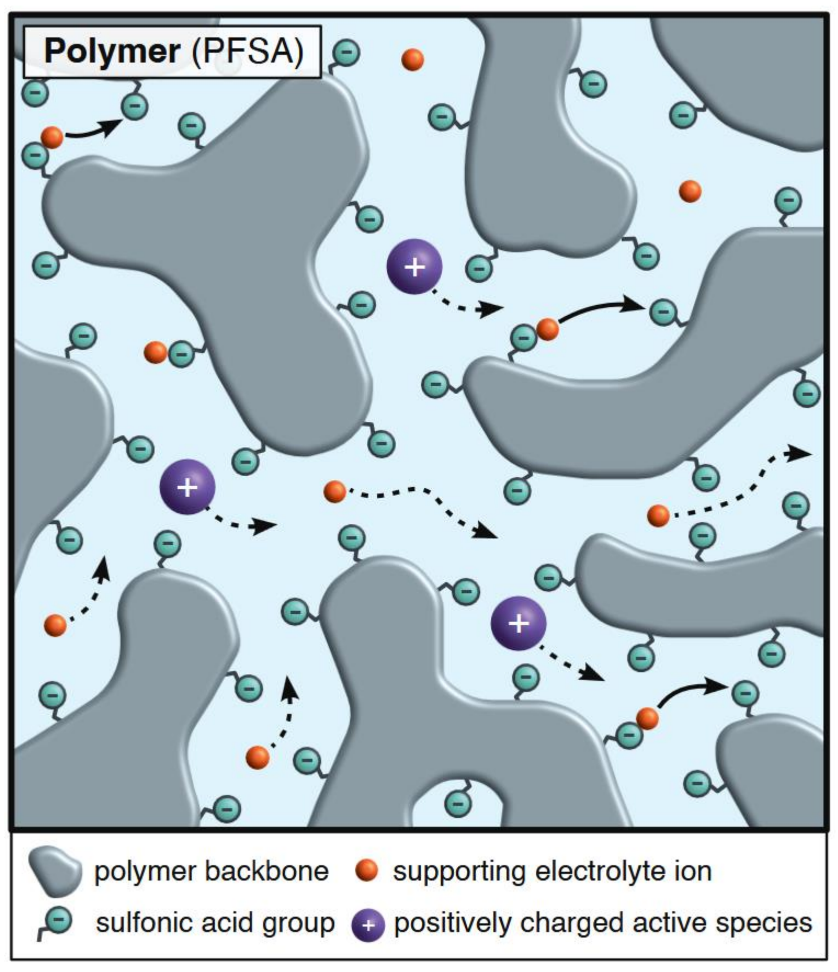


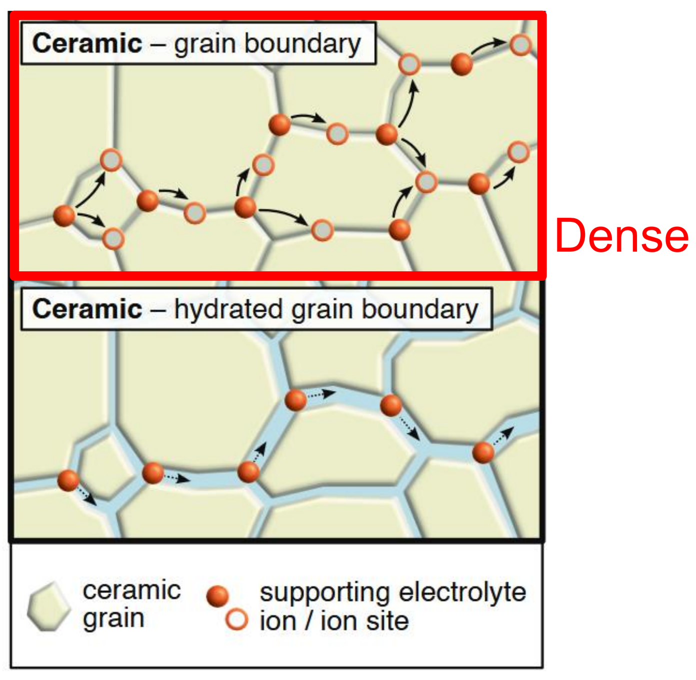
Ceramic vs. polymeric membrane



Cerium oxide as a room-temperature proton conductor

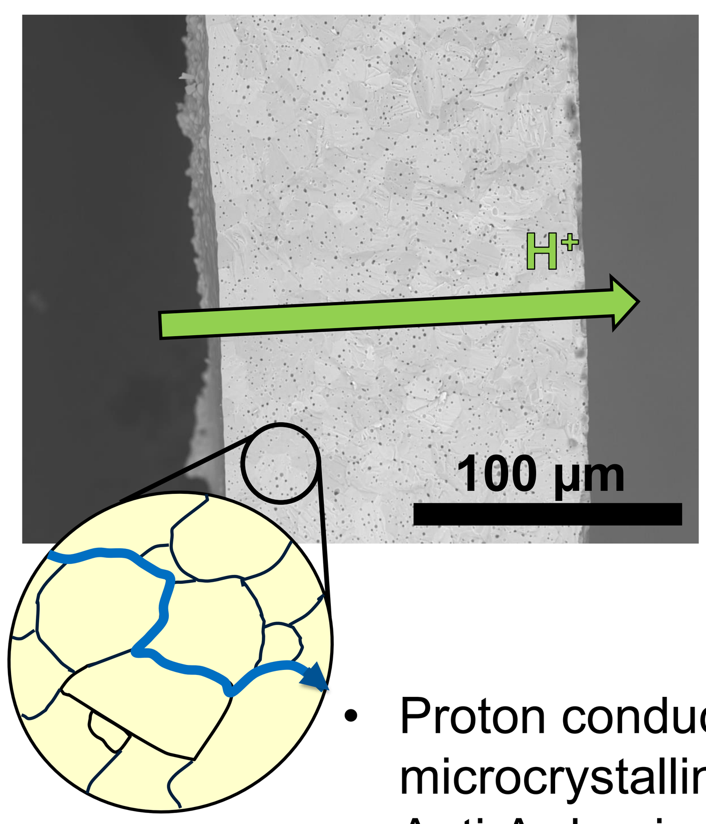
Proton conduction in polymer vs. ceria

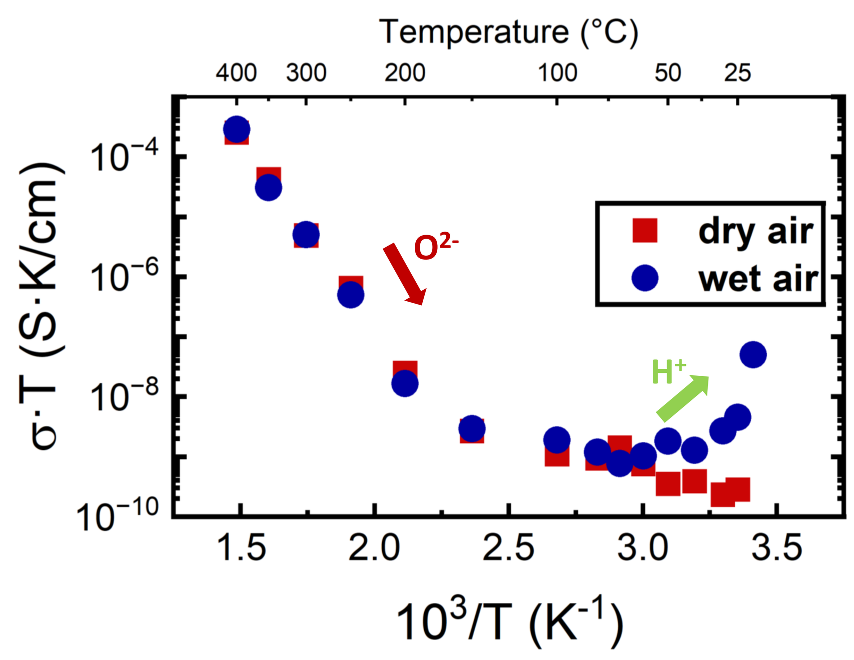




- H^+ conduction in PFSA through hydrated channels – vulnerable to crossover
- Ceria conducts via grain boundaries – highly selective, no possibility for crossover

Tape-cast ceramic membranes

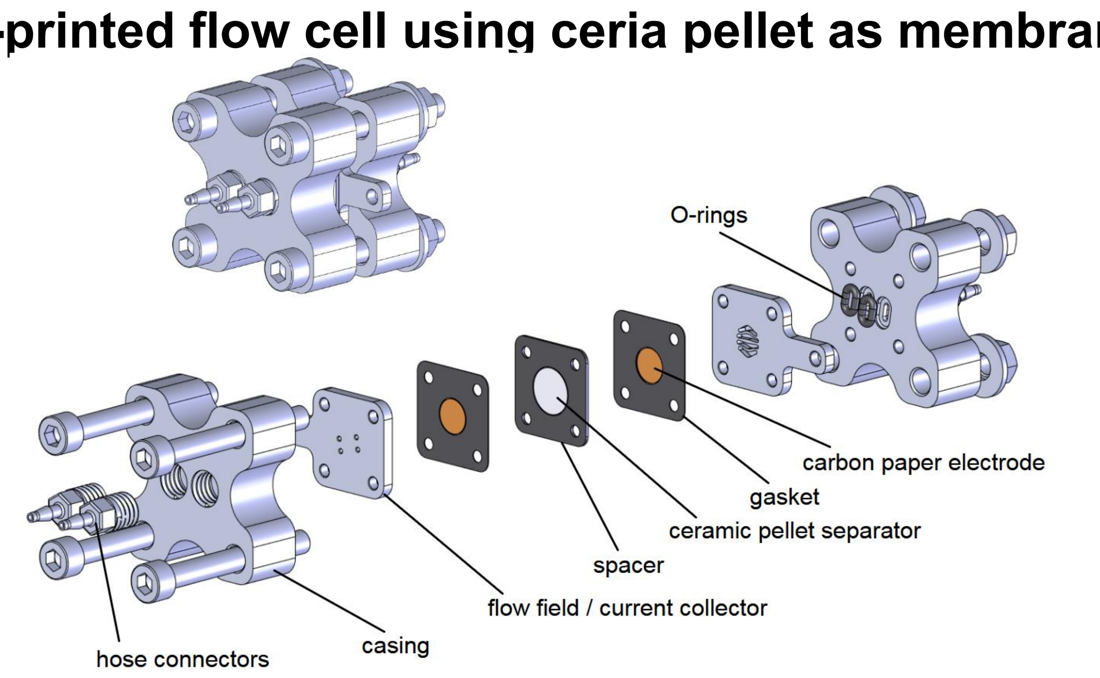


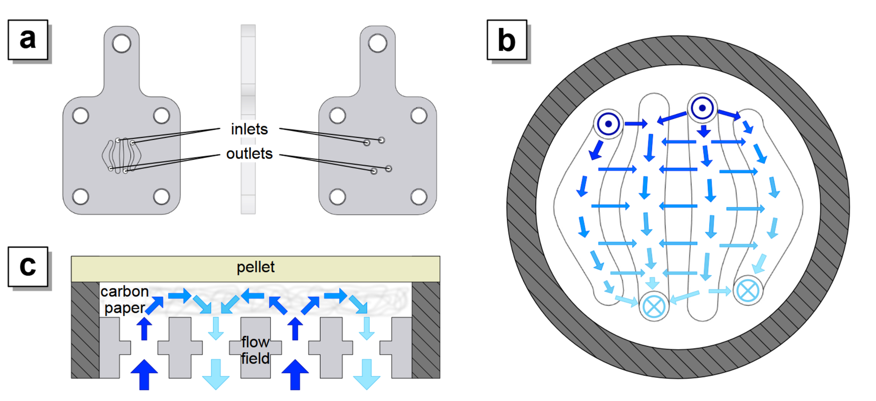


- Proton conduction demonstrated in dense (~96%) microcrystalline tape-cast ceria membranes [2]
- Anti-Arrhenius behaviour at low temperatures only in wet atmosphere → evidence of proton conduction

Incorporation into flow cell

→ 3D-printed flow cell using ceria pellet as membrane





Successfully used in conductivity studies with aqueous electrolyte

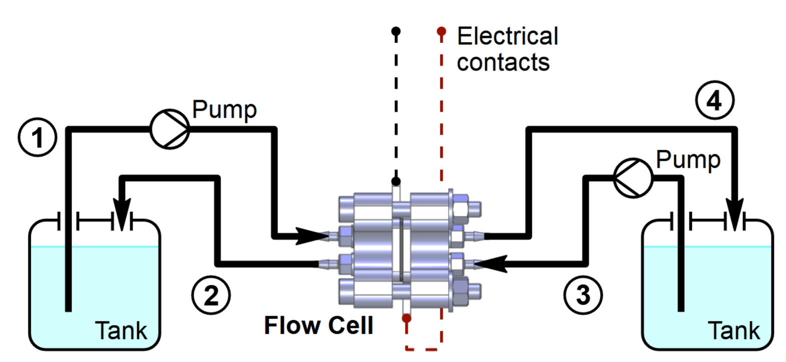
Outlook

Summary and challenges

- Polymer membranes have high conductivity, low selectivity
- Ceramic membranes have higher selectivity, lower conductivity
- Proton conductivity of ceria can be optimised

Next steps

- Grain boundary engineering using doping (Mg^{2+}, Gd^{3+}): influence on proton conductivity and hydration kinetics
- Grain size study: impact of nanocrystalline vs. microcrystalline structure on proton conduction
- Proof-of-concept cycling with redox active species



Selective ceramic separator can unlock sustainable flow battery chemistries if conductivity is optimised

[1] S. Ronchetti, E. Avellone et al., in preparation 2026
[2] S. Ronchetti, N. Isaev et al., in preparation 2026
European Patent Application No. 26 156 617.8 Redox flow battery, method of fabricating the redox flow battery, and use of the redox flow battery