membrion

Flexible Ceramic Membranes for Redox Flow Batteries

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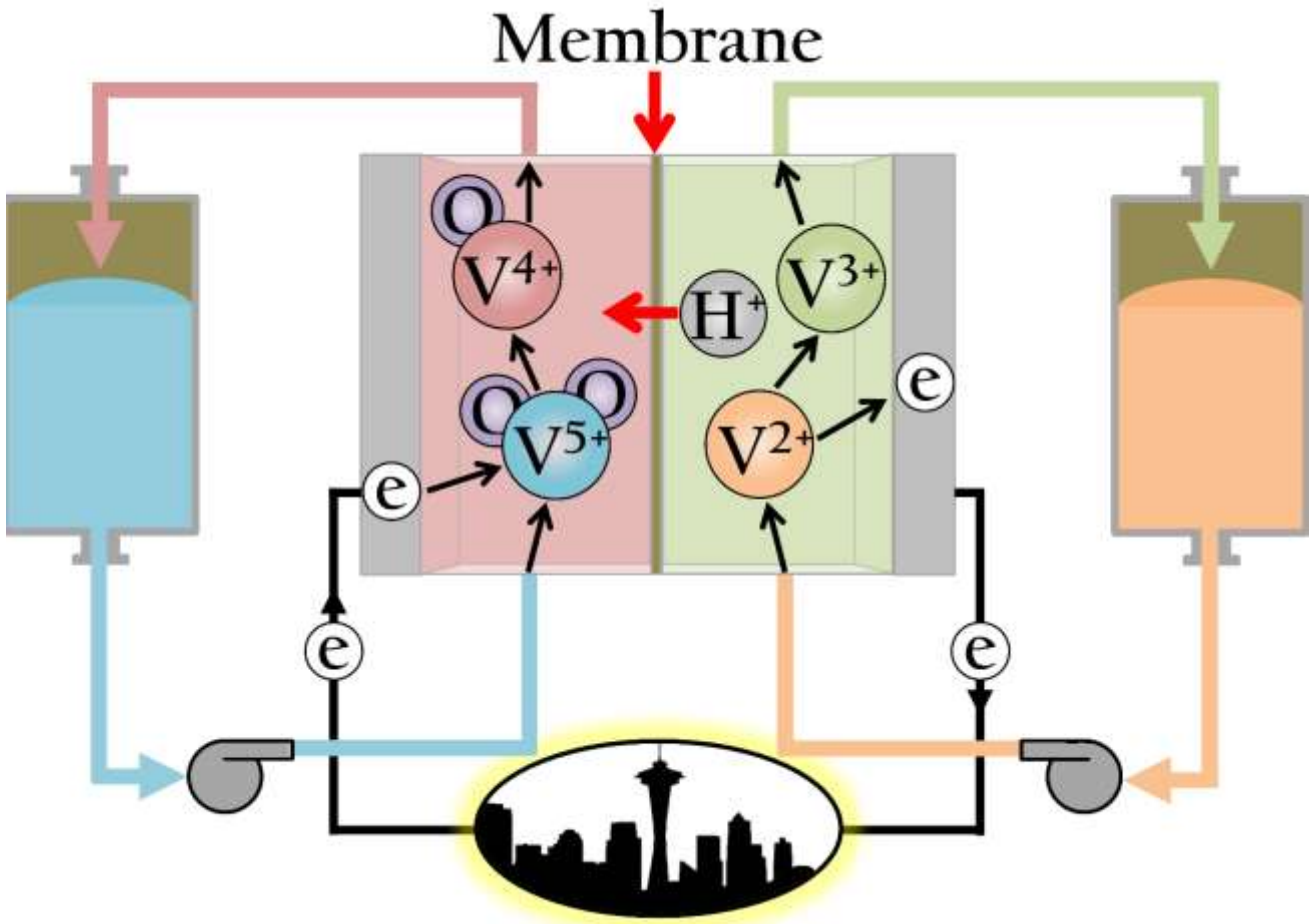
Flow battery operation and costs



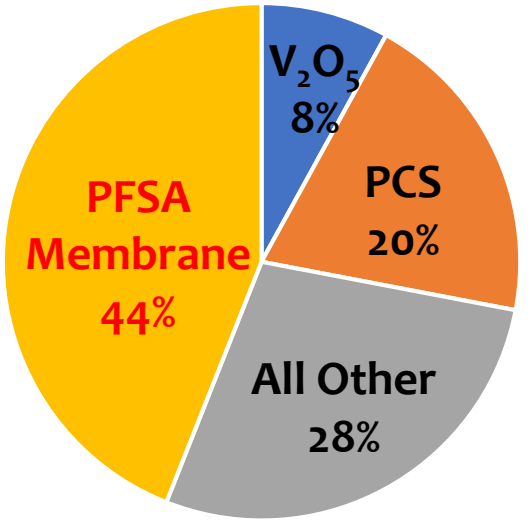
Cathode:

$$VO_2^+ + 2H^+ + e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} VO^{2+} + H_2O$$

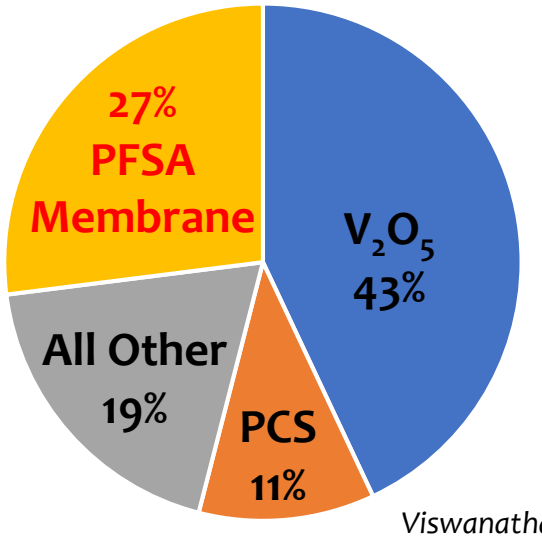
Anode:

$$V^{3+} + e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} V^{2+}$$

VRFB Capital Costs (2012)



0.25 MWh

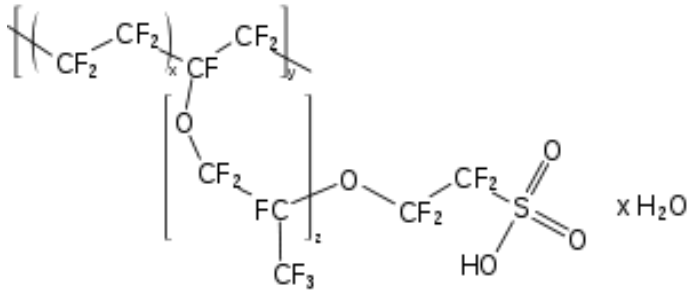


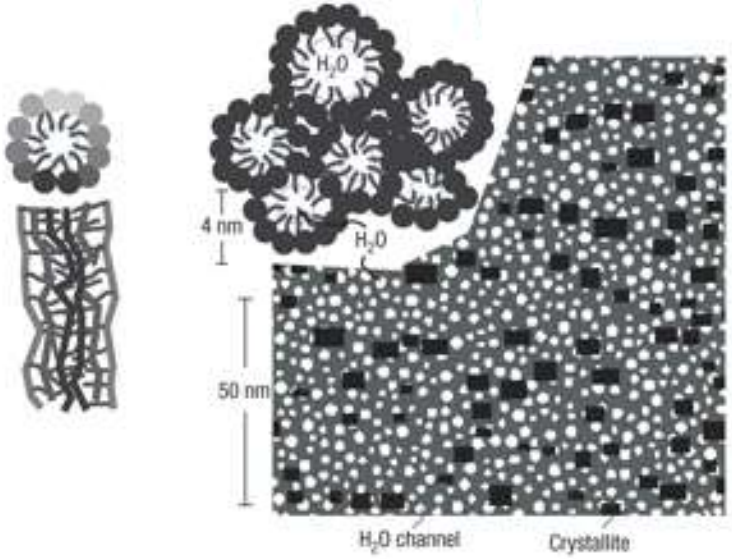
4 MWh

Viswanathan et al., 2012, sandia.gov

Current Membrane Options

PFSA Membranes

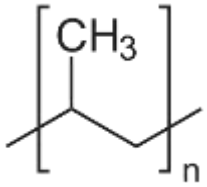


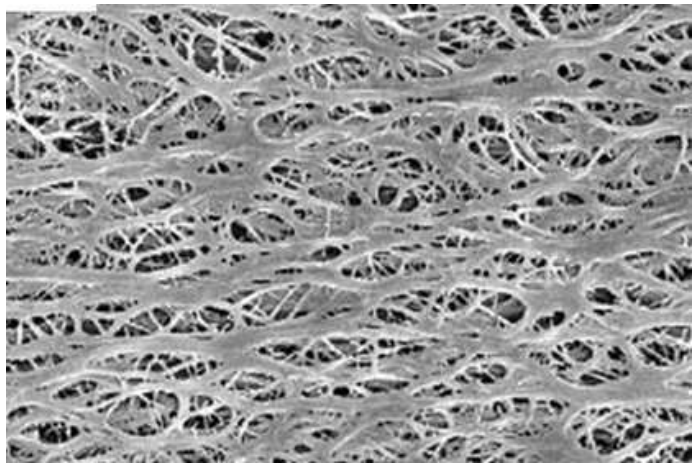


Selective Durable Expensive

Schmidt-Rohr, Nat. Mater., 2008, 7, 75

Li-ion Separators





Non-selective Semi-durable Cheap

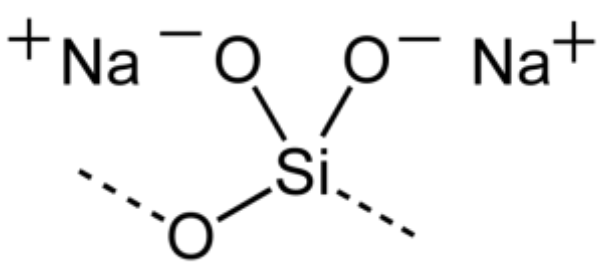
Lee, Energy Environ. Sci., 2014, 7, 3857

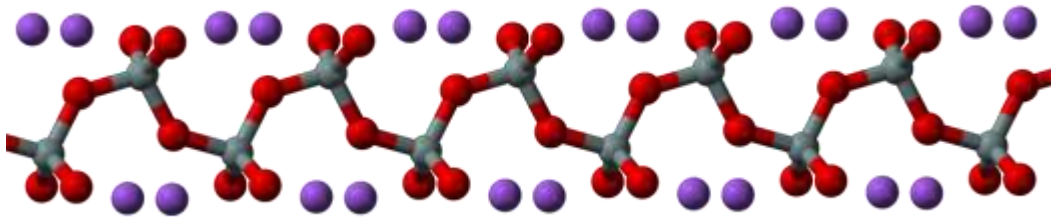
New Membranes

- ✓ H^+ Transport
- ✗ V ion Transport
- ✗ e^- Transport
- ✓ Chemical Stability
- ✓ Mechanical Durability

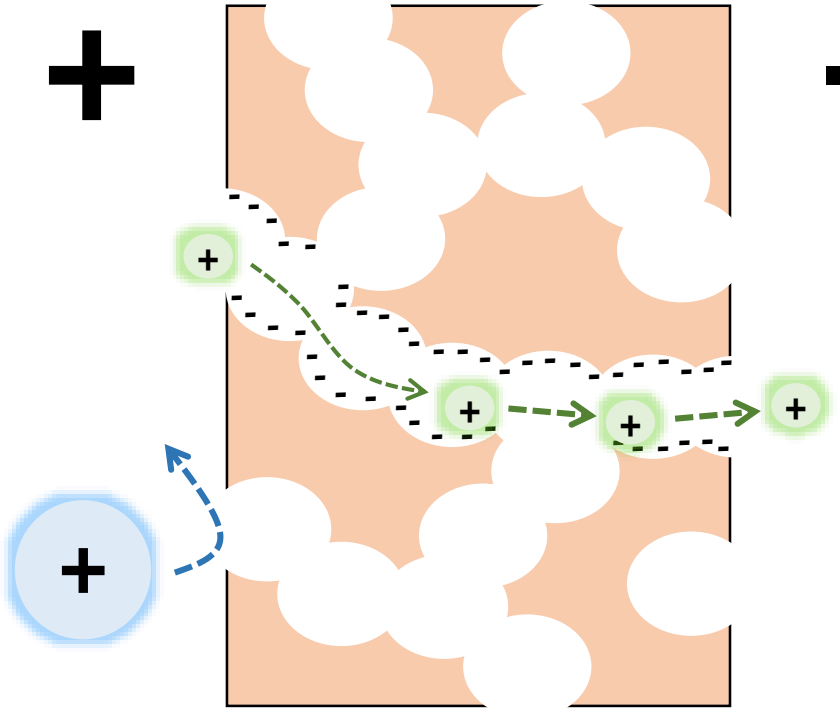
Nanoporous Ceramic Membranes

Silica Gel



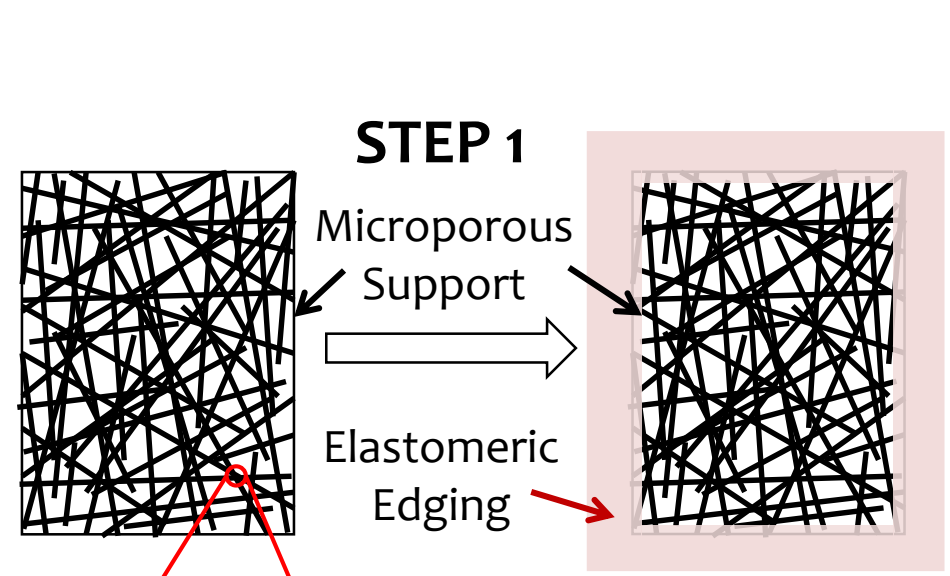


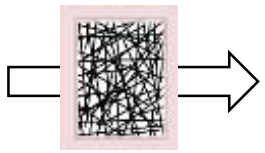
Ion Separation by Size, Charge & Functionality

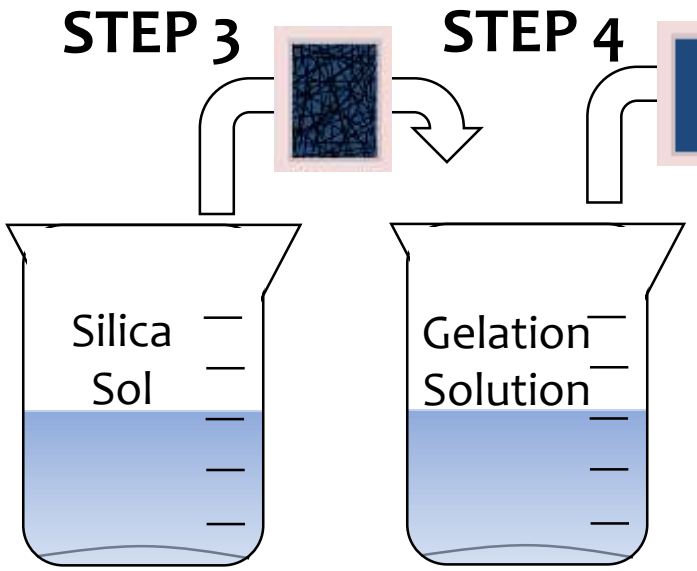


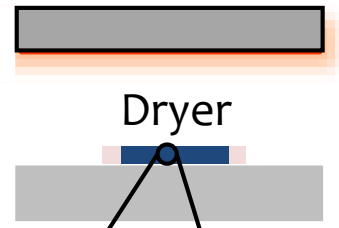
Selective	Durable	Inexpensive

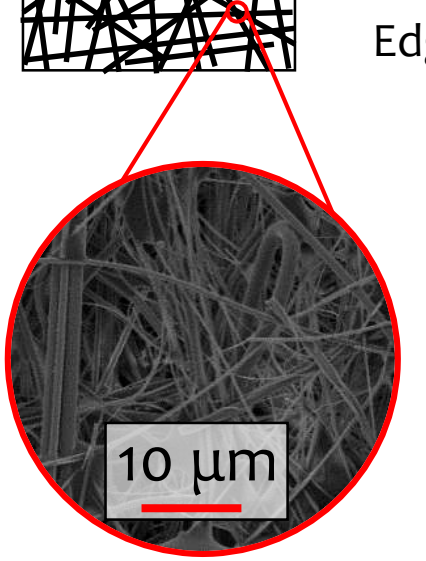
Self-assembly driven process



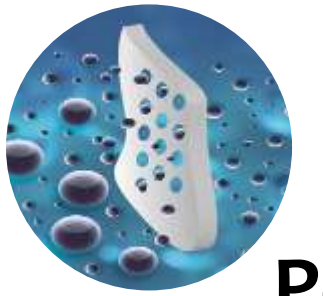




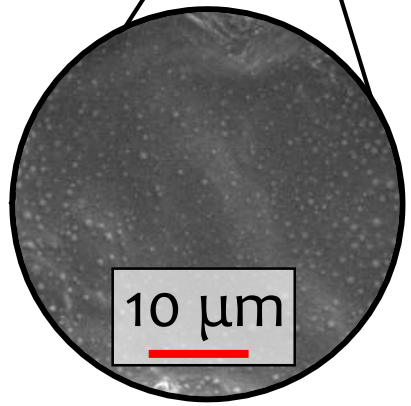




SUPPORT



Porosity
Pore Size
Polydispersity
Network Structure



MEMBRANE

Robust IP Portfolio

IP PCT filed Globally (2017 & 2019)

+ 7 international utility applications filed (2017)
+ 1 US utility application filed to-date (2019)

IP Protected

for both Manufacturing and Composition

Core patent approved by USPTO (Sep 2018)

Trade Secrets

& strategies for proprietary manufacturing

University of Washington License

exclusive, global, all fields of use

Concluding remarks

Summary:

- Developed a ceramic membrane that is highly tunable at the nanoscale
- Achieved performance parity to industry standard PFSA
- Process is scalable to relevant industry sizes
- 1/10th the production cost of PFSA
- Future work includes:
  - Decreasing thickness to ⬇ ASR
  - Increase quality control to ⬆ CE
  - Increase size to > 1000 cm^2

Beyond Flow Batteries:

Water Purification

Batteries

Fuel Cells

Pharma Purification