



Advanced Membranes for Flow Batteries

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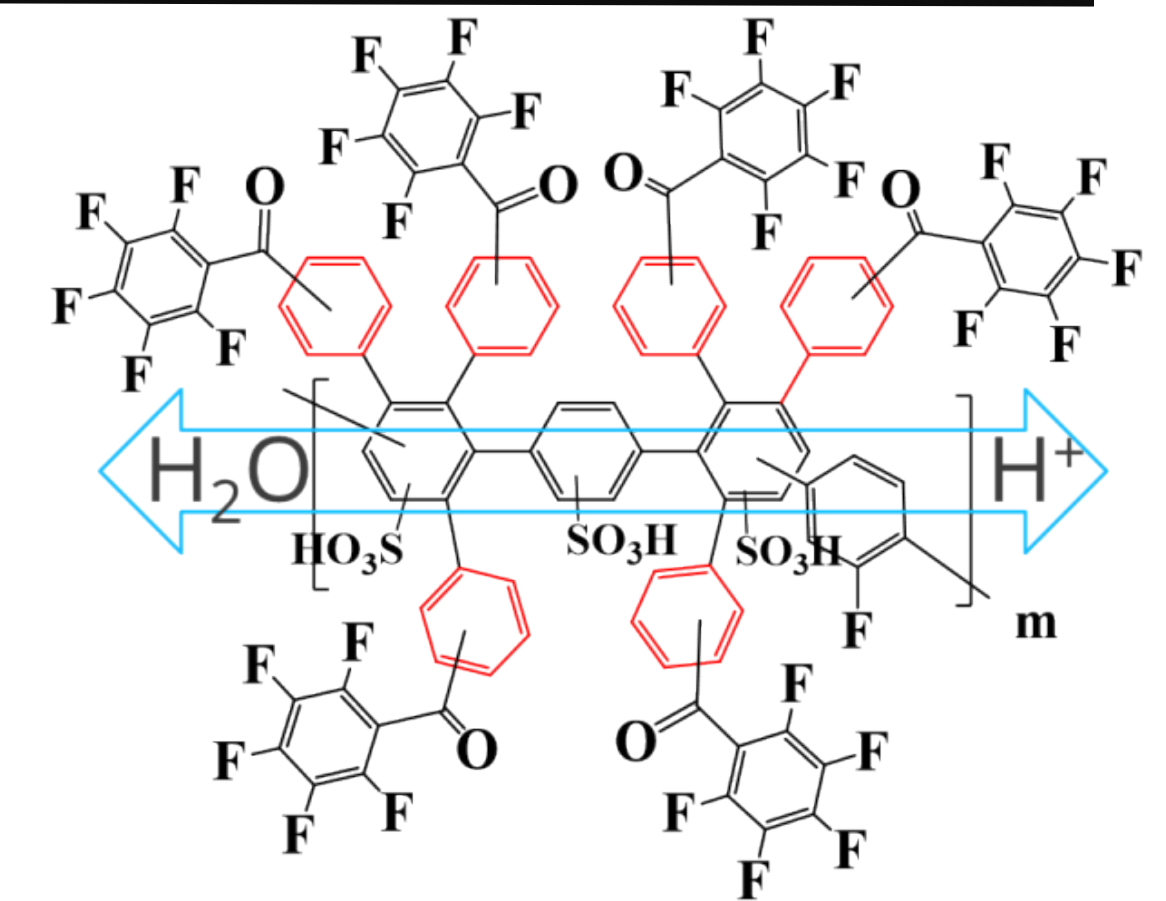
Objective:

The program's main goal is to develop membrane separators that helps US flow battery technologies/companies meet cost, performance and durability metrics, with the end goal of materials commercialization. We develop membranes as a resource and benefit for US companies to become successful in the flow battery space.

Key Properties:

- **Cost:** Developing hydrocarbon based membranes. Targeting cost of < \$20/m²
- **Performance:** Flow batteries are influenced by membrane properties. Developing membranes with low cell resistance (< 0.8 ohmcm²) and high coulombic efficiency (> 98%)
- **Durability:** Membranes need to have lifetimes of at least 20 years in flow battery deployment.

Materials Innovation: Sandia has developed and patented (US20220059861) a unique membrane design with narrow hydrophilic domains near the polymer backbone. This allows the passage of smaller charge balancing species while blocking larger electroactive materials from permeation through the membrane.



Focus: This year we collaborated with the Professor Michael Marshak, the inventor of metal chelate complexes as neoglyte near neutral pH. It has been found that the chelates enhances redox kinetics, improves solubility and improves metal stability against water assisted oxidation. Moreover, this chemistry is based on Cr and Fe, both abundant and low cost metals.

Results:

Ionic Resistance

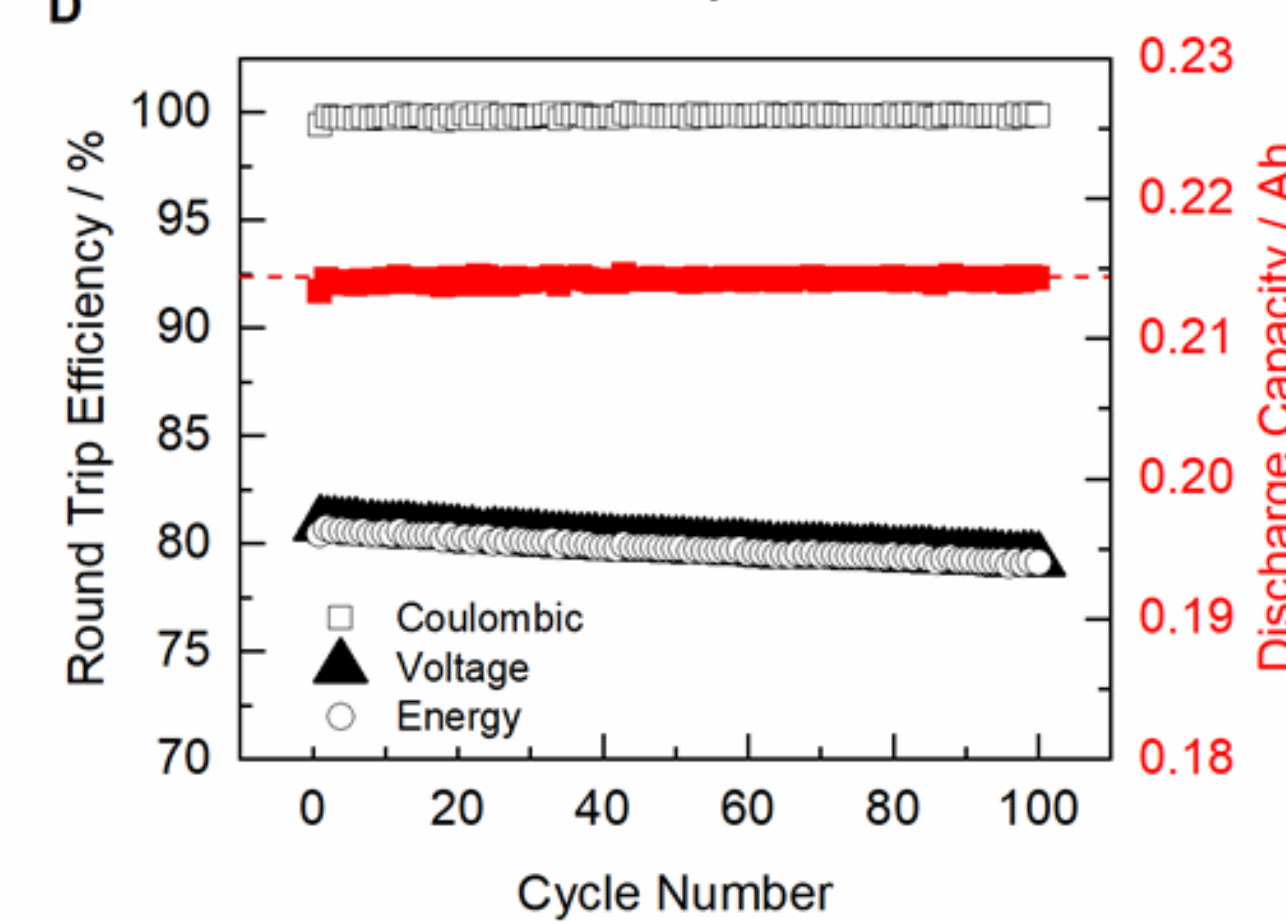
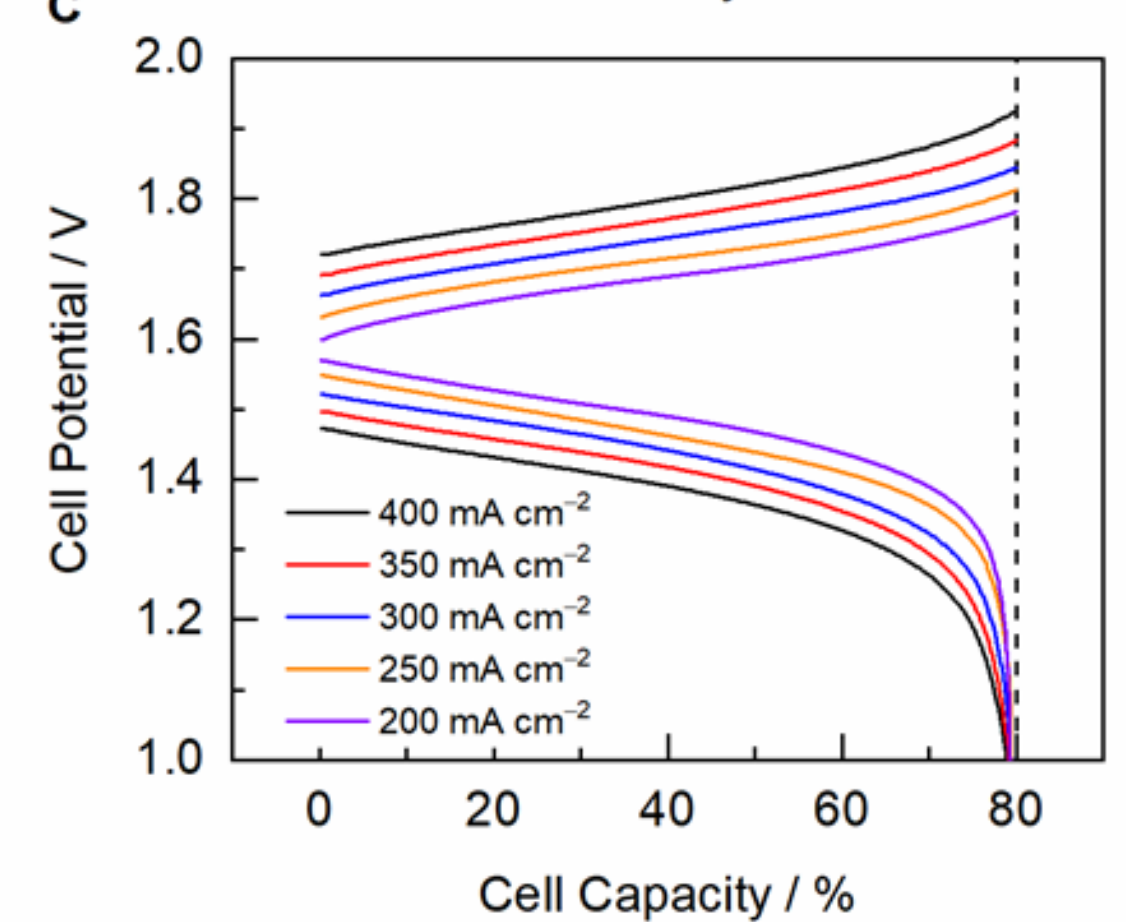
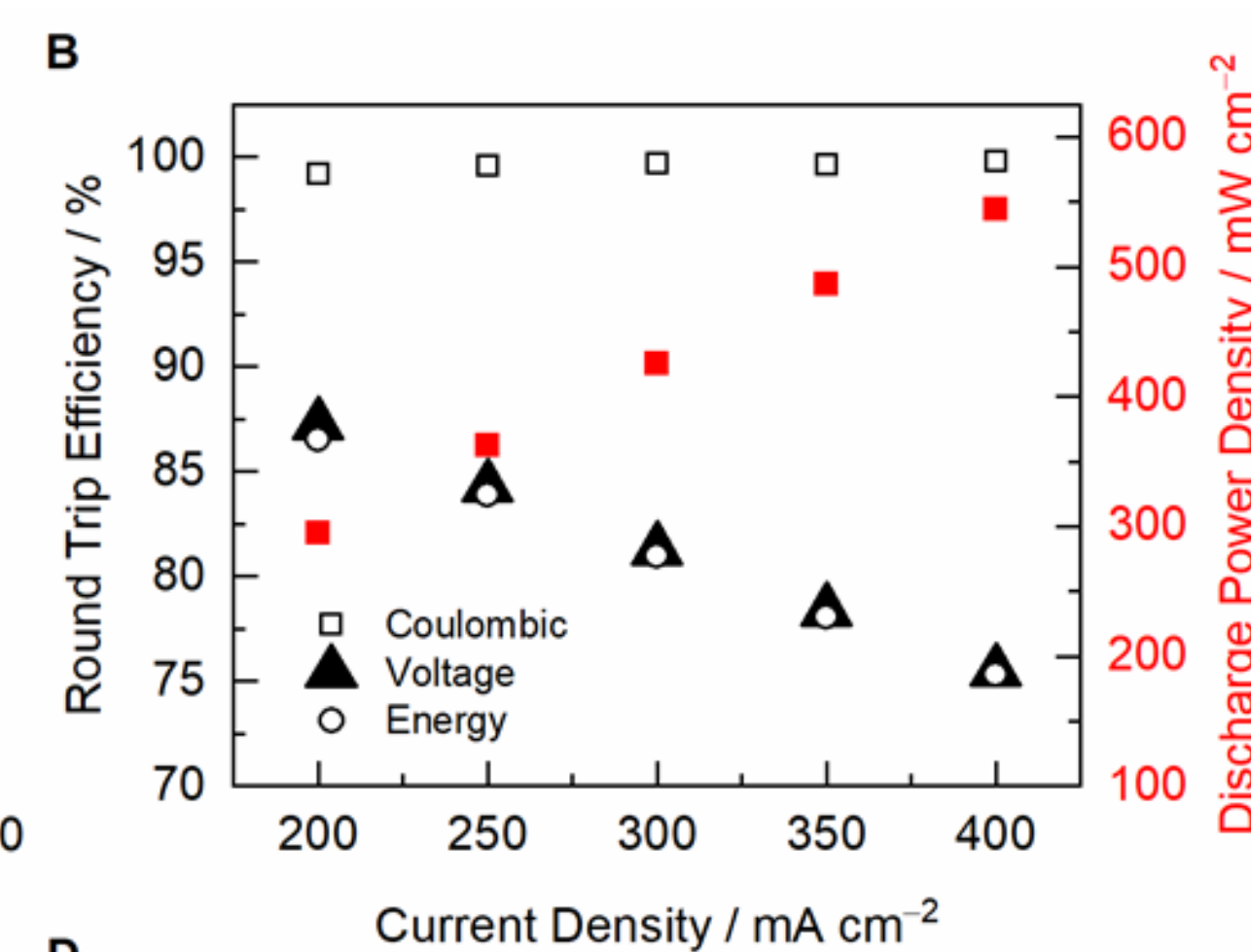
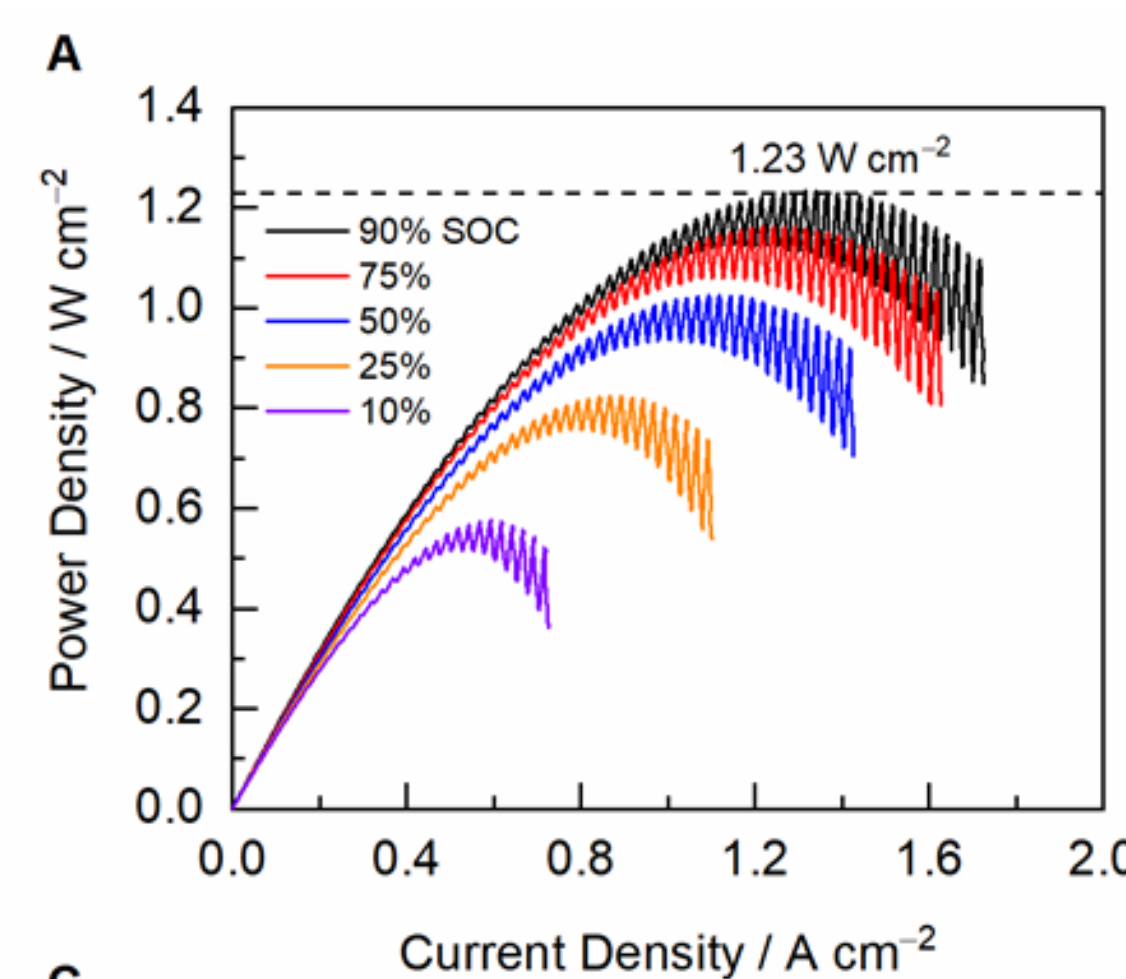
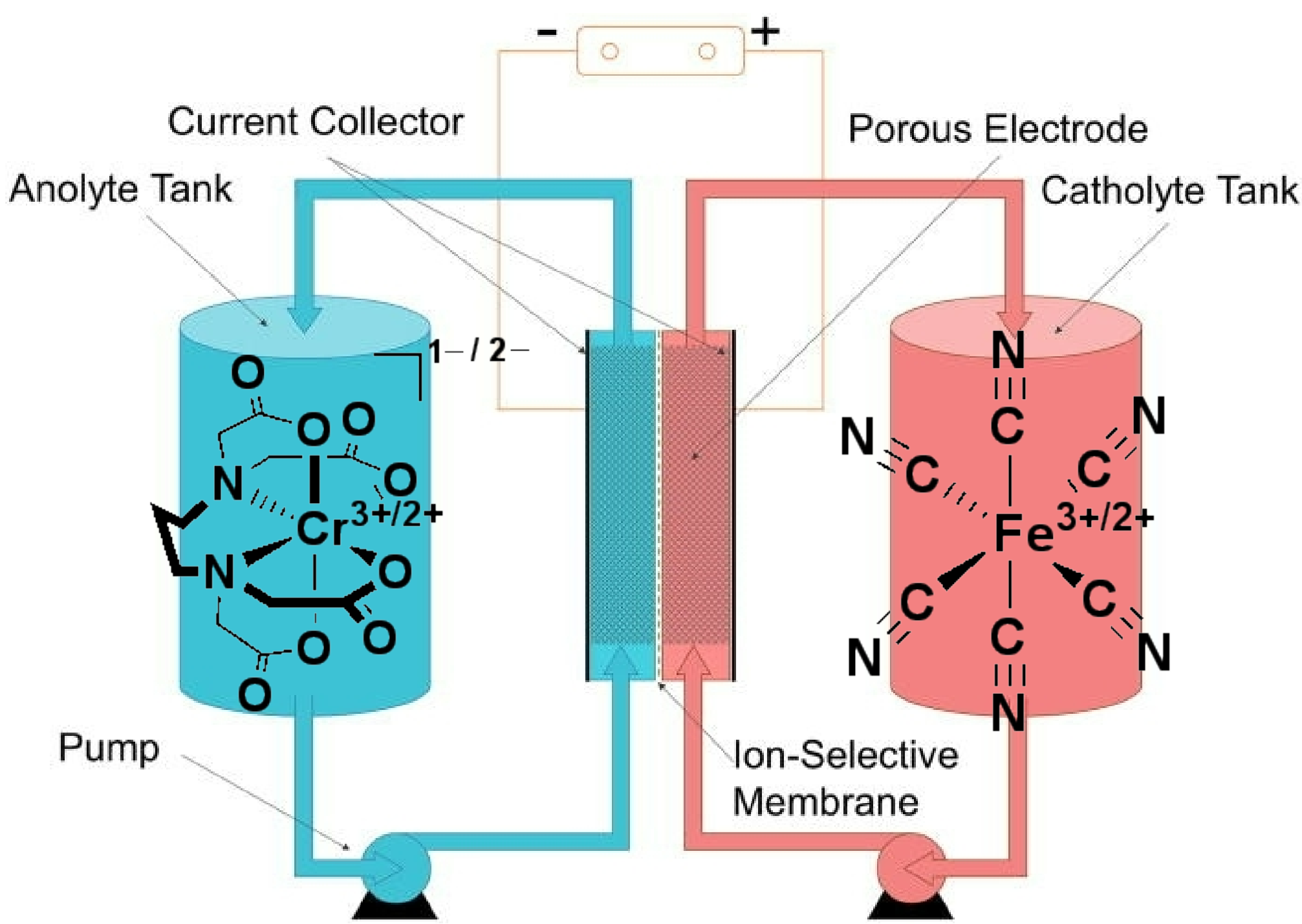
Potassium is common cation used in neutral and high pH flow batteries. Sandia material shows 3x lower resistance over Nafion 212

Ion resistance (Ohm cm ²)	H ⁺	Li ⁺	Na ⁺	K ⁺
Nafion212	0.2	0.8	0.9	2.7
Sandia	0.18	1.50	0.89	0.56

Ferricyanide Permeability

Ferricyanide commonly used polysolyte in neutral and high pH flow batteries,

Membrane	Fe(CN) ₆ ³⁻ permeability / cm s ⁻¹ (test time / days)
NR212*	< 4 × 10 ⁻¹³ (5)
Sandia	< 2 × 10 ⁻¹³ (5)



- SNL membrane over 3x lower resistance for K⁺ transport = max power 1 W <
- No observable losses due to crossover
- No membrane degradation



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Conclusions/Future:

- These membranes promise a significant improvement over other membranes based on high conductivity and ionic selectivity. Last year we demonstrated superior VRFB performance over Nafion212 (J. Power Sources, 520, 2022, 230805-230816), This year we display membrane versatility in a pH neutral system with high power density 1Wcm⁻² < and no apparent crossover.
1. Sandia membrane has shown excellent flow battery performance in both high acidic and near neutral pH.
 2. Publication: J. Power Sources: 520, 2022, 230805-230816; 2 Patents published: 17/391,508 & 17/569,777
 3. Current membrane not stable at high pH (e.g. 4 M KOH) developing base stable analog.