Design of Cost-Effective, Mechanically Robust Membranes for Sodium Polysulfide Hybrid Redox Flow Battery

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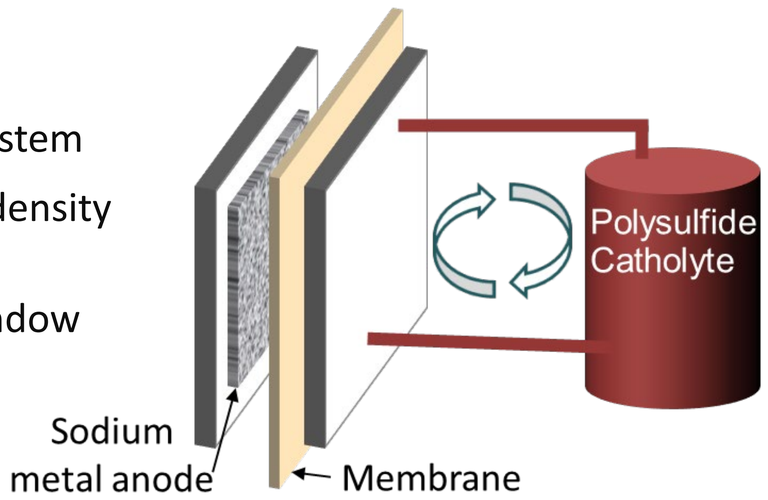
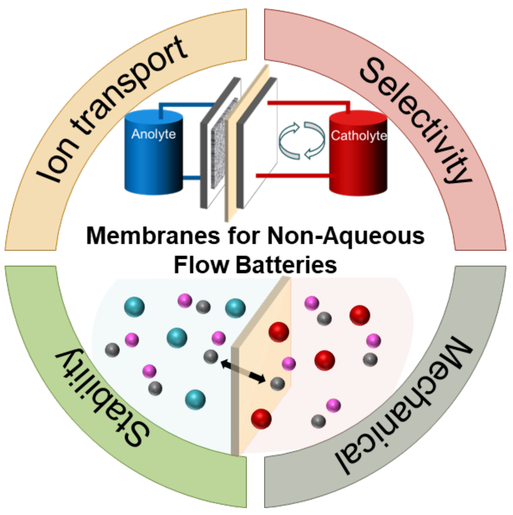
Introduction

Redox flow battery:
Na/Polysulfide Hybrid system

- High specific energy density
- Non-aqueous – high operating voltage window



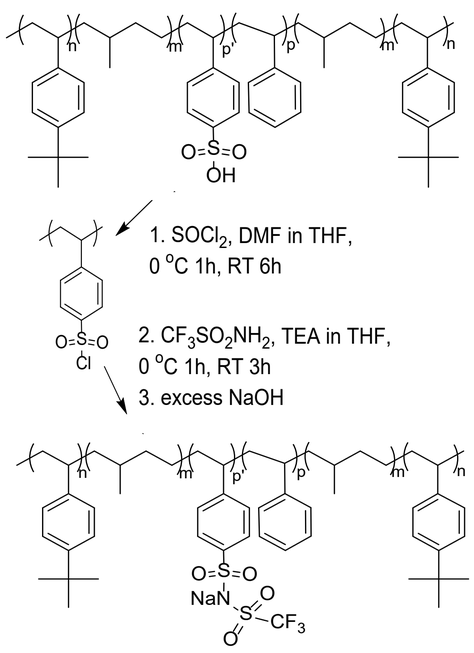
- Low-cost high-performance membranes are still a major bottleneck in increasing TRL of non-aqueous RFBs

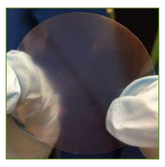


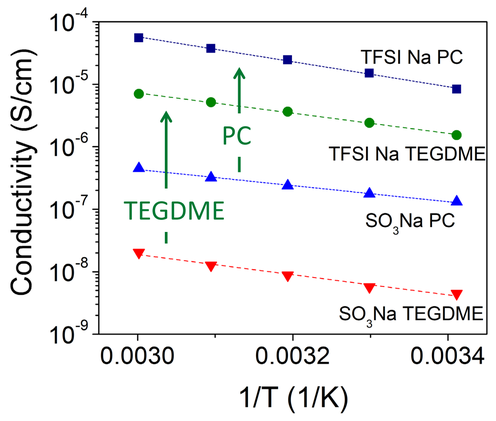
- ✓Thin (low resistance)
- ✓Low electrolyte uptake
- ✓Mechanically robust
- ✓High selectivity
- ✓High ionic conductivity
- ✓Excellent chemical and electrochemical stability

Our goal is to develop low-cost hydrocarbon-based membranes with improved selectivity, stability and Na^+ conductivity. Additionally, we aim to gain a greater understanding of the factors that influence crossover, uptake, and stability in non-aqueous systems.

Nexar Block Copolymer



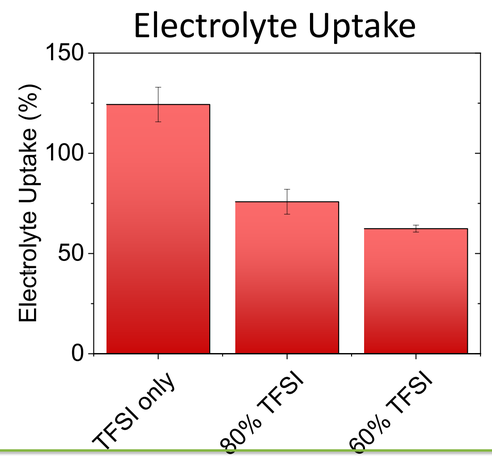


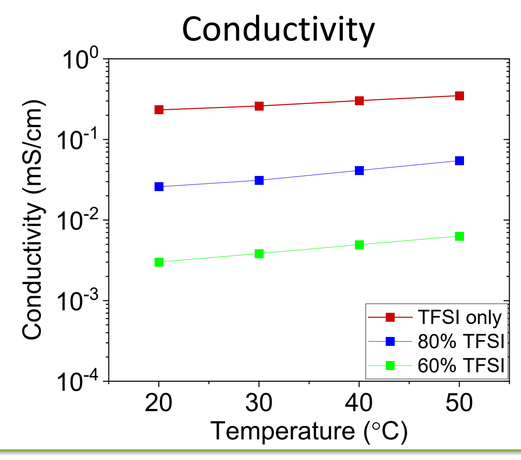


		Uptake (%)	λ
PC	TFSI Na	103	6.3
	SO_3 Na	116	6.0
TEGDME	TFSI Na	99	2.8
	SO_3 Na	77	1.8

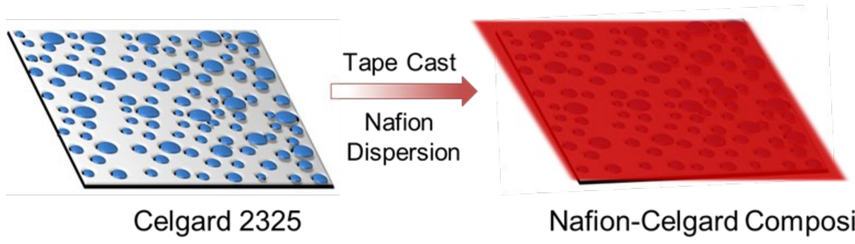
TFSI-Nexar / SO_3-Nexar Blends- annealed

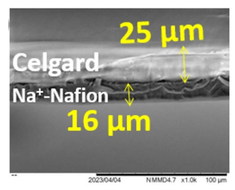
- Sulfonate form is too brittle
- Goal: 'sweet spot' of blend that maintains reasonable uptake with excellent mechanical properties
- Optimization in progress

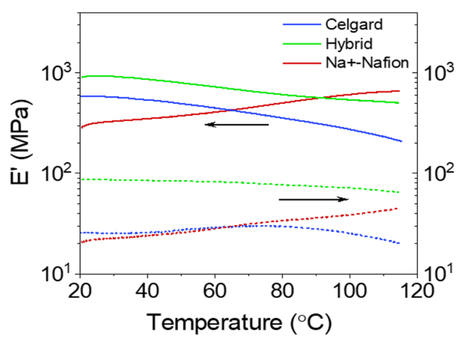


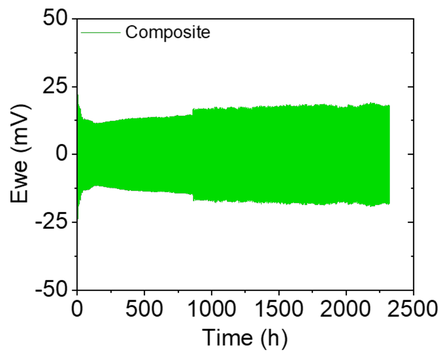


Composite Membrane



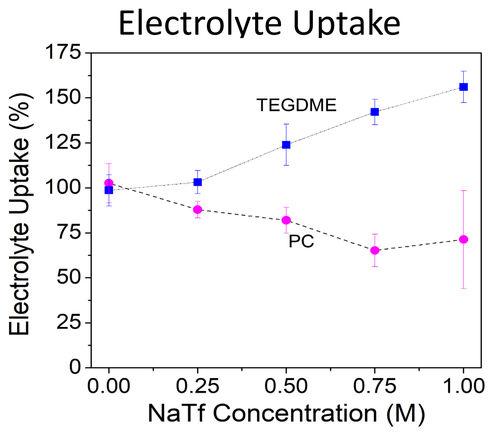


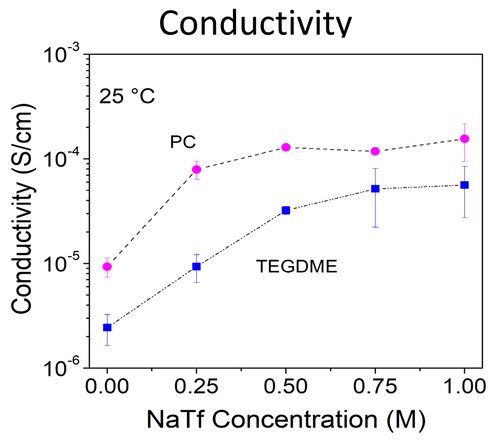




- Enhanced mechanical strength
- Alleviated Na dendritic growth

TFSI-Nexar with different electrolyte concentrations





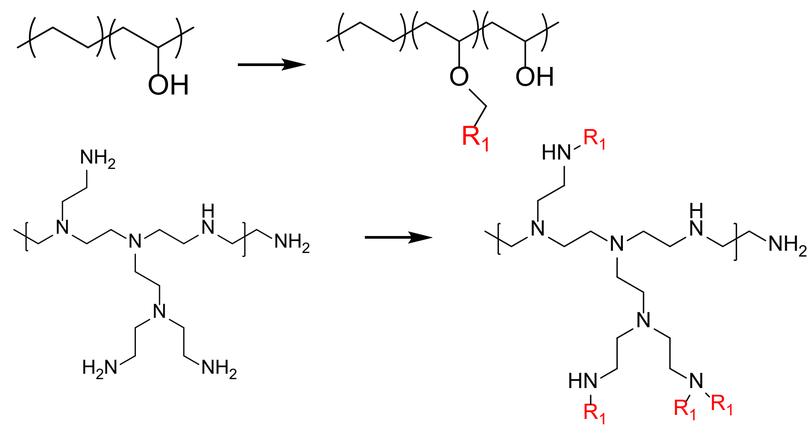
- TFSI anion significantly increases Na^+ conductivity compared to the sulfonate anion within the polymer
- Electrolyte uptake too high at relevant concentrations of salt in ether electrolyte

KRATON

Conclusions/On-going Work

- Membrane-electrode Assembly: composite/layered membranes increases polymer stability against Na metal and reduces polysulfide crossover
- TFSI moiety greatly enhances Na^+ conductivity

Ceramic coating/
Single-ion conducting layer
Catalytic active layer
Structural porous carbon current collector



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- Utilize commercially available, low-cost base polymers
- Leverage synthesis developed in FaCT EFRC to develop novel polymers
- Further develop composite/ layered membranes

Collaborators:

Prof. David Mitlin (UT Austin) and Prof. Nian Liu (GIT)

References

1. M. L. Lehmann, et al. "Membrane Design for Non-Aqueous Redox Flow Batteries: Current Status and Path Forward" Chem. 2022
2. M. L. Lehmann, et al. "Unraveling Ion Transport of Trifluoromethanesulfonimide Pentablock Copolymer Membranes in Non-Aqueous Electrolytes" Macromolecules. 2022
3. (Invited) Lehmann, Self, Saito, and Yang "Composite Membrane for Sodium Polysulfide Hybrid Redox Flow Batteries" Membranes, 2023
4. (Cover) Tyler, Lehmann, et al. "Nafion Inhibits Polysulfide Crossover in Hybrid Nonaqueous Redox Flow Batteries" Journal of Physical Chemistry C (2022)

Acknowledgements

This work is funded by Dr. Imre Gyuk, Office of Electricity Delivery and Reliability, Department of Energy.
Authors would like to acknowledge Jagjit Nanda (SLAC National Accelerator Laboratory) for the fruitful discussions.