OAK RIDGE National Laboratory

Presentation #600

Enabling integration of renewable energy sources with long duration electrochemical energy storage

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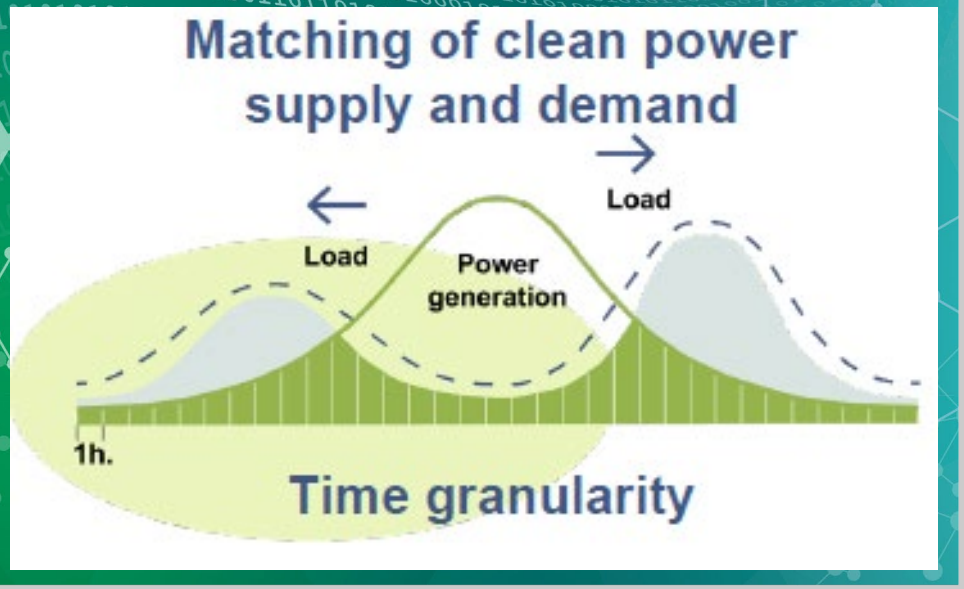
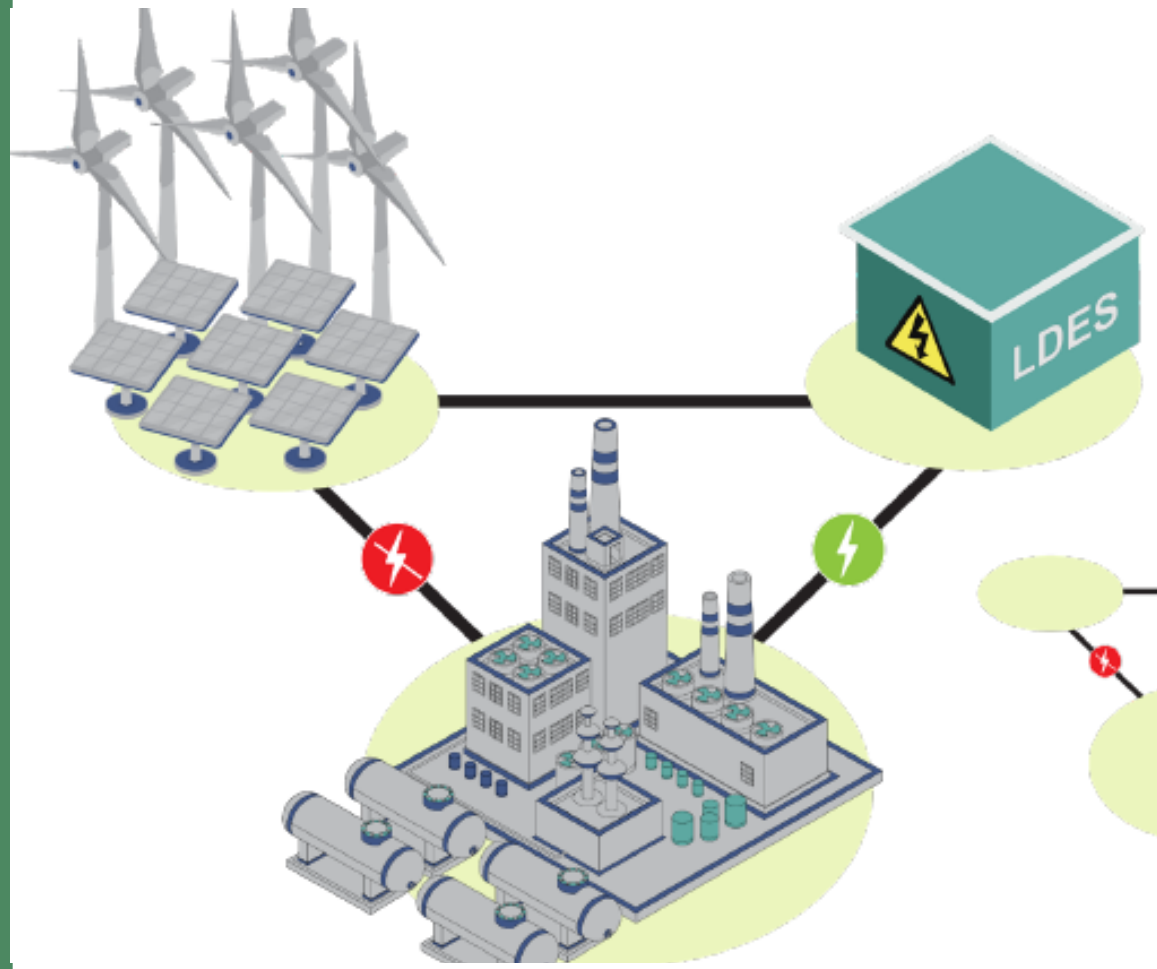


ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

This work supported by the US Department of Energy's Office of Electricity, Energy Storage Program, managed by Dr. Imre Gyuk.

Need new approaches to balance supply and demand of electricity at an unprecedented scale and cost



Clean flexibility additionality

Investments into new flexible or dispatchable capacity to enable the use of clean power at all times, also when the sun is not shining, and the wind is not blowing.

Geographical granularity

Limits for the location of the power supply, flexibility, and demand to ensure local decarbonization impact.

LDES Council

A path towards full grid decarbonization with 24/7 clean Power Purchase Agreements

McKinsey & Company

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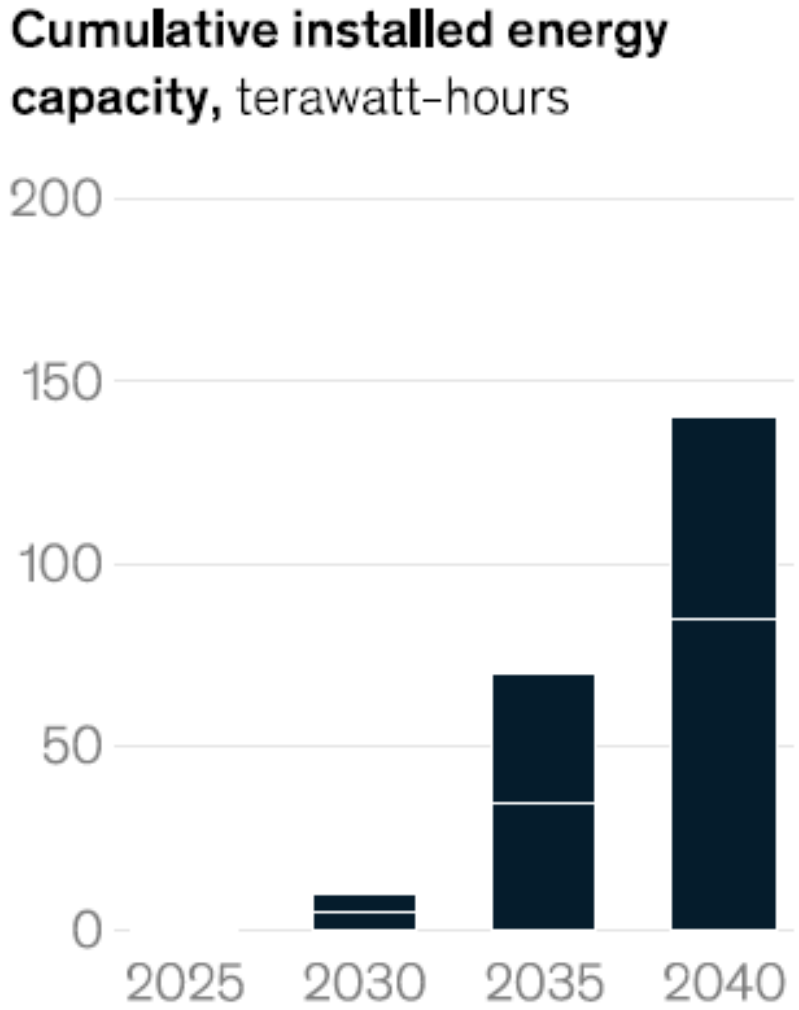
Critical National need to integrate long duration energy storage with renewable power generation



Globally will approach >100TW-h of capacity of renewables

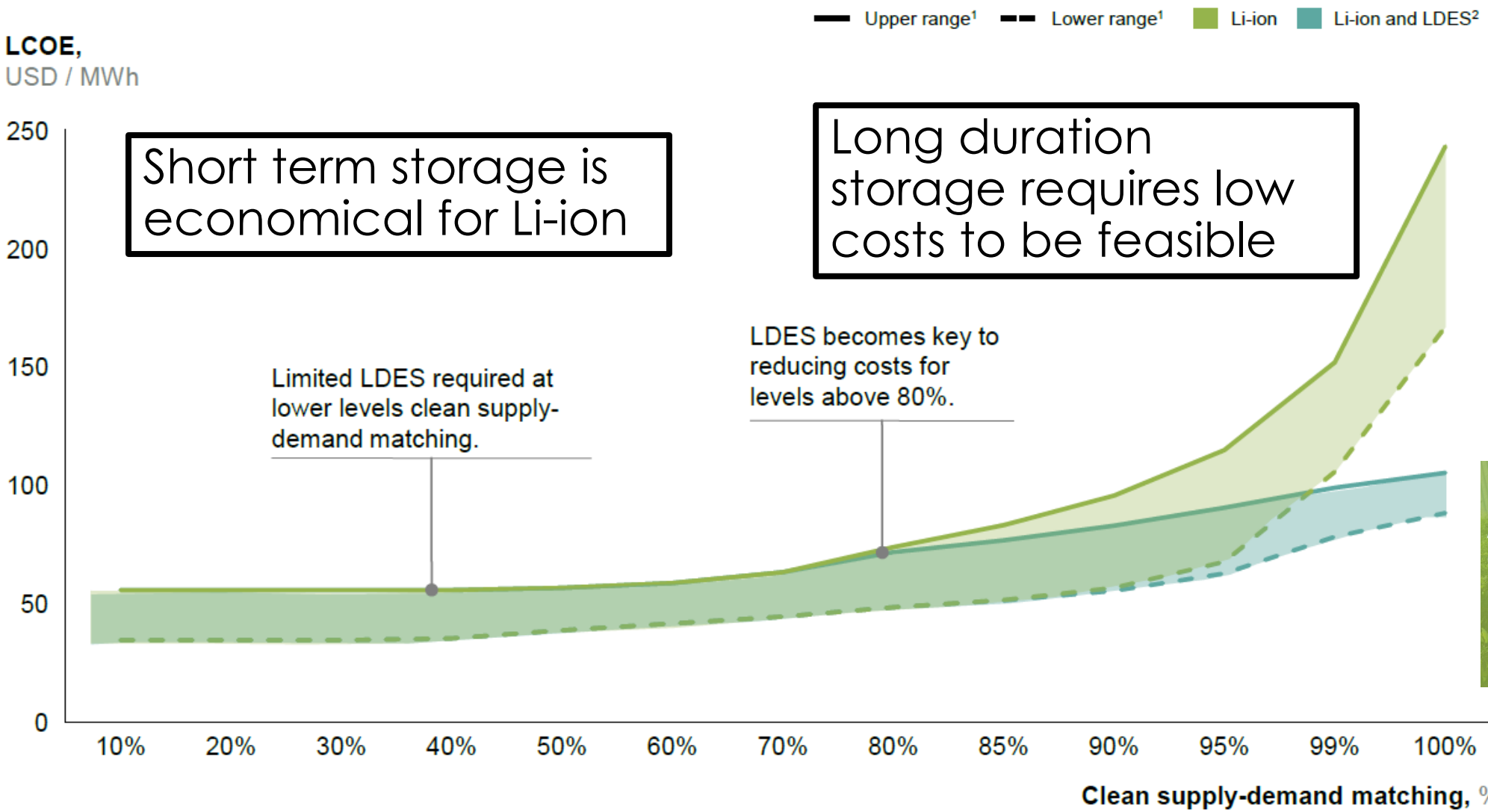
Require 1.5-2.5 TW of storage

McKinsey Sustainability

Net-zero power: Long-duration energy storage for a renewable grid

November 22, 2021 | Report

Scale, cost requirements, and volumes will require technologies beyond Li-ion or VRFB



LDES Council
A path towards full grid decarbonization with 24/7 clean Power Purchase Agreements
McKinsey & Company

National Laboratory
Open slide master to edit

5 Top Flow Battery Startups Impacting the Energy Industry

Extensive investments in traditional flow batteries

Mai 2019

This Heat Map illustrates the geographical distribution of 5 out of 124 flow battery startups disrupting the energy industry.

Current LDES technologies around vanadium won't cut it

- Largest VRFB has 60 MWh of capacity and lasts 4 hours
- Assuming we could use vanadium it would take 130 years to mine enough at current rates

HEPCO Minami-Hayakita Substation

The work in this program is focused on core enabling technologies for the future

Redox active molecules

- Low costs
- Earth abundant

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Membranes

- Key is cost and lifetime
- Manufacturing will be an issue particularly domestically

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Membranes

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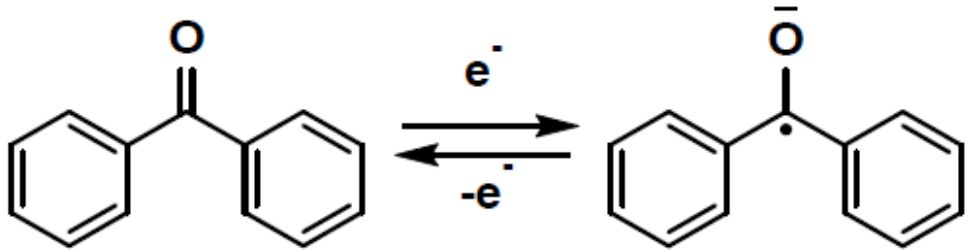
- Manufacturing will be an issue particularly domestically

Lifetime and durability

- How to accelerate failure
- Indicators of degradation

Low Cost Redox Molecules – Presentation 602



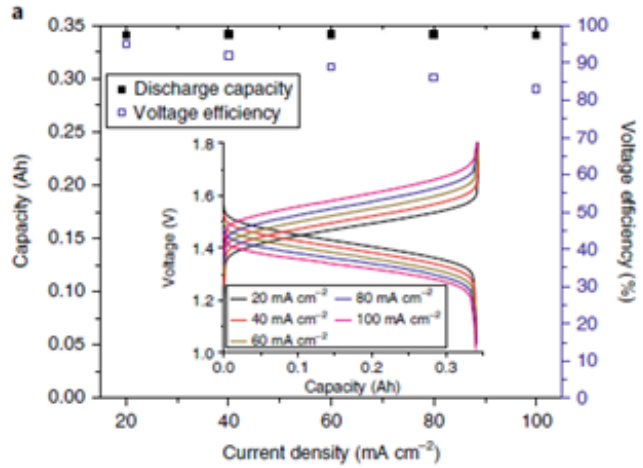
Highly soluble in MeCN (~ 4M in MeCN)

Reversible redox couple at -2.16 V vs. Ag/Ag^+ in MeCN

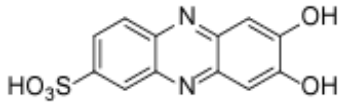
Conjugated pi system allows for delocalization of spin and charge density in the radical anion

- Work explores mechanism and transport of redox active molecules
- 4M vs 1.8M for VRFB
- Larger voltage window than VRFB

Looking at additives to enable long cycle life – Talk 603

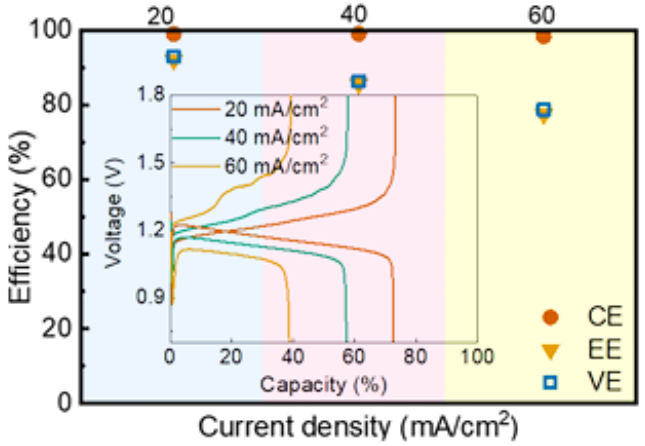


DHPS 75 Ah/L

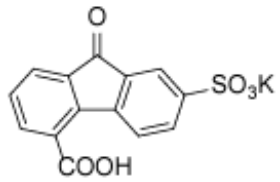


Nat. Energy **2018**, *3* (6), 508-514.

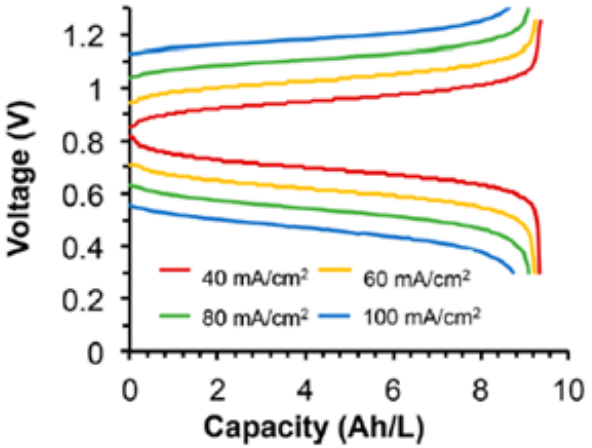
Alkaline system



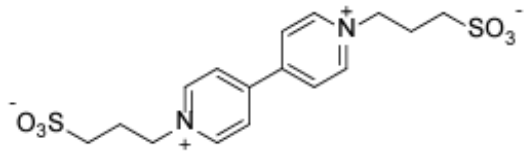
4C7SFL 73 Ah/L



Alkaline system



$(SPr)_2V$ 13.4 Ah/L



ACS Energy Lett. **2018**, *3*, 663–668.

pH neutral system

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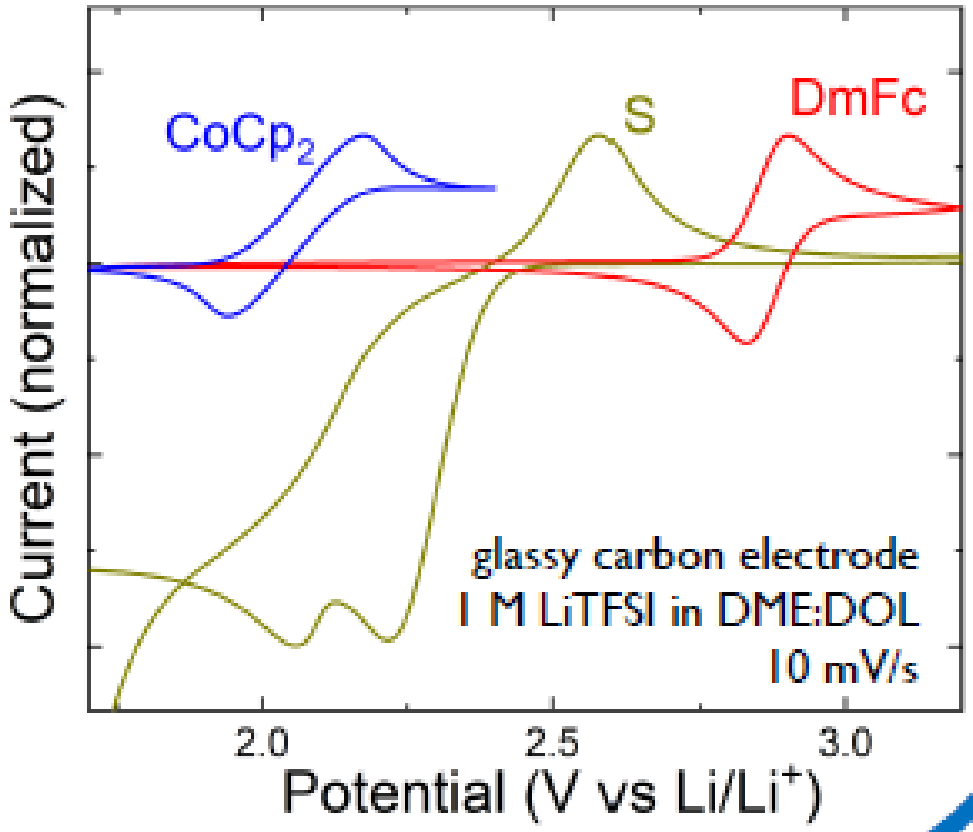
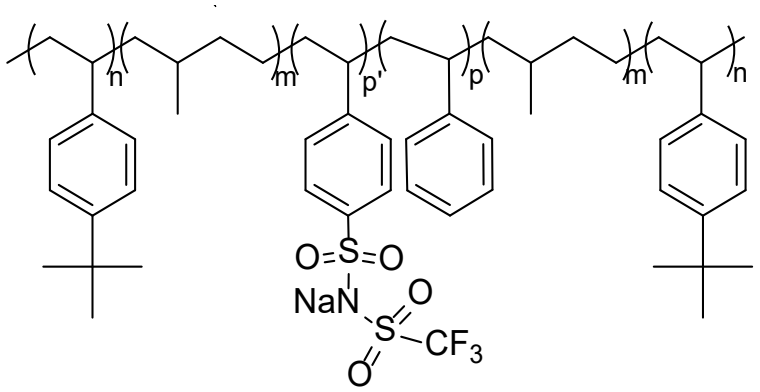
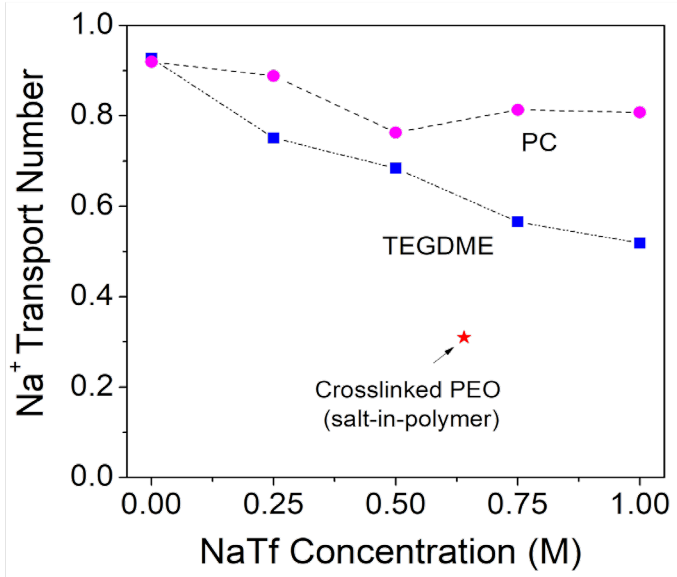
Low cost sulfur cathodes – Poster Meyerson

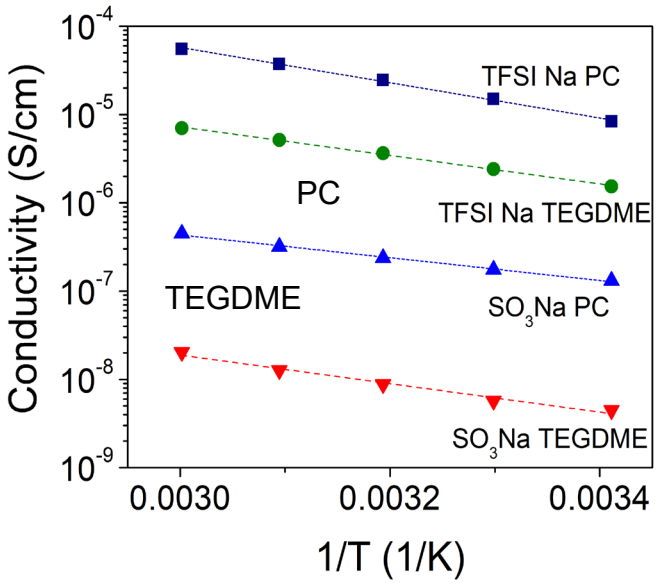
- Redox mediators used to enable electrochemistry of sulfur
- Very low cost electrode



New membranes are critical to enabling long cycling and high power densities of sulfide batteries – Talk 604





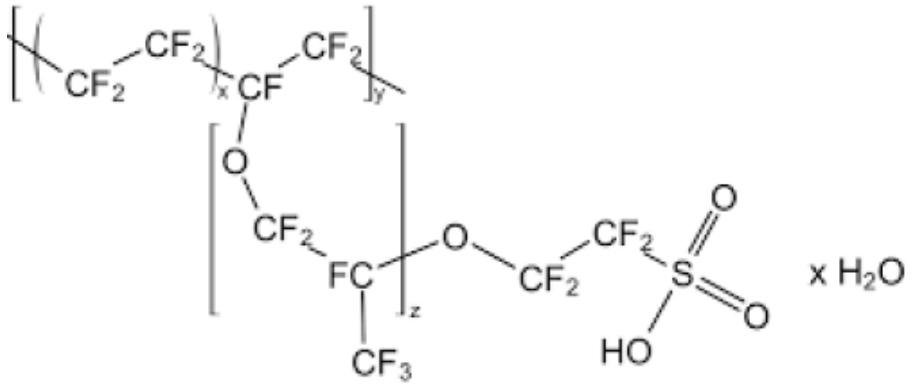


Traditional

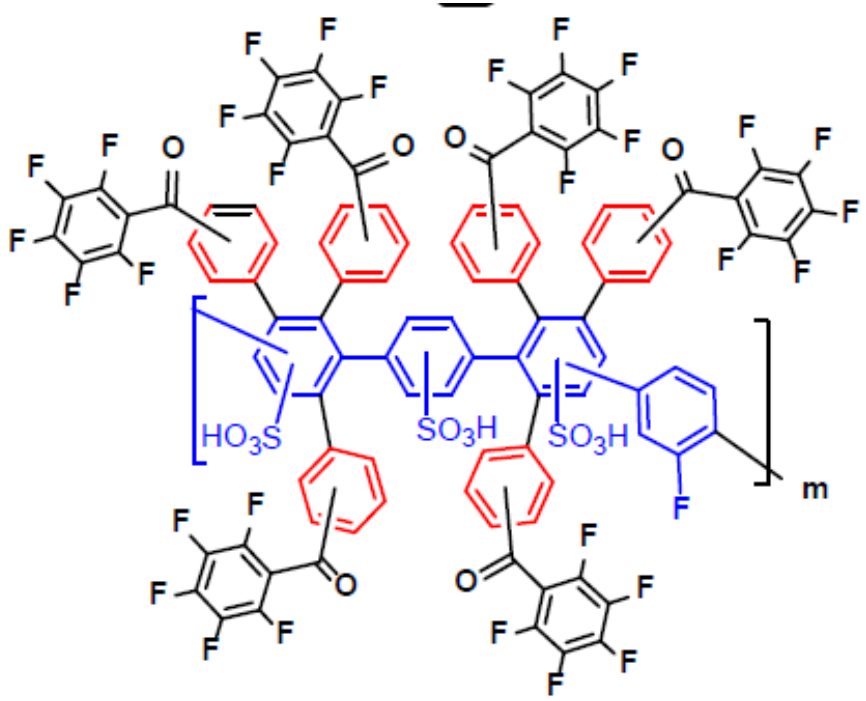
New membranes

Work compliments talk 404 – focused on low cost sulfides

Alternatives to Nafion membranes – Talk 601



Hydrocarbon alternative



ASR in Ω cm^2 in 1M MCl

Membrane	H$^+$	Li$^+$	Na$^+$	K$^+$
Nafion 212	0.2	0.8	0.9	2.7
Sandia^d 40	0.18	1.5	0.89	0.58

- **SNL membrane 4.5x less resistive to K+ than Nafion!**

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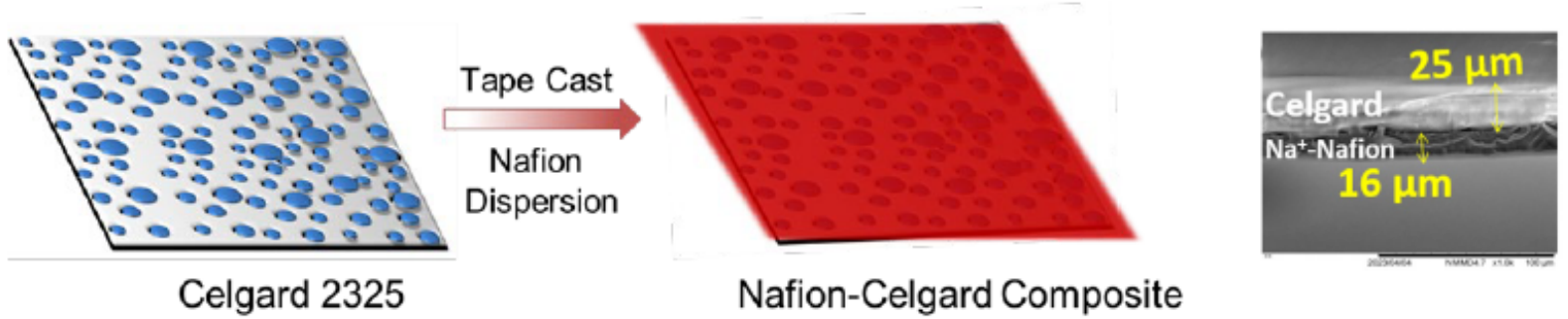
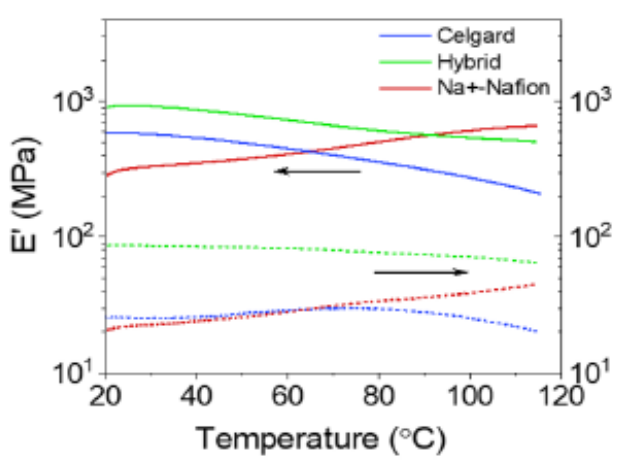
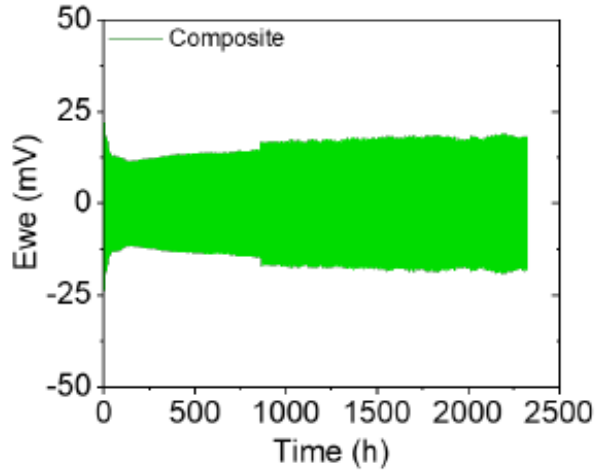
Low cost membranes to enable sodium metal – Poster Lehmann





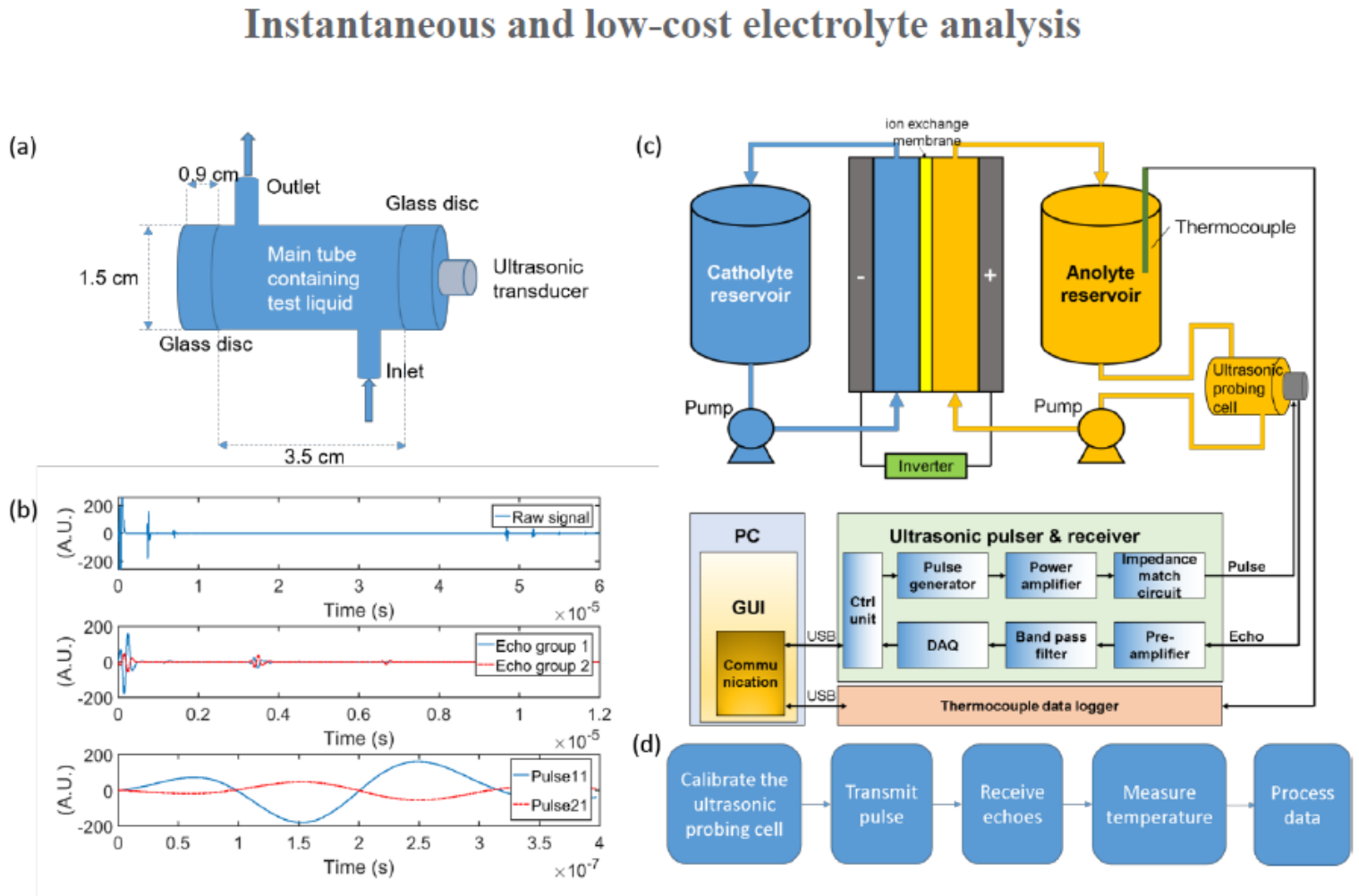


- Enhanced mechanical strength
- Alleviated Na dendritic growth

Development of hybrid structures enables cycling of sodium metal

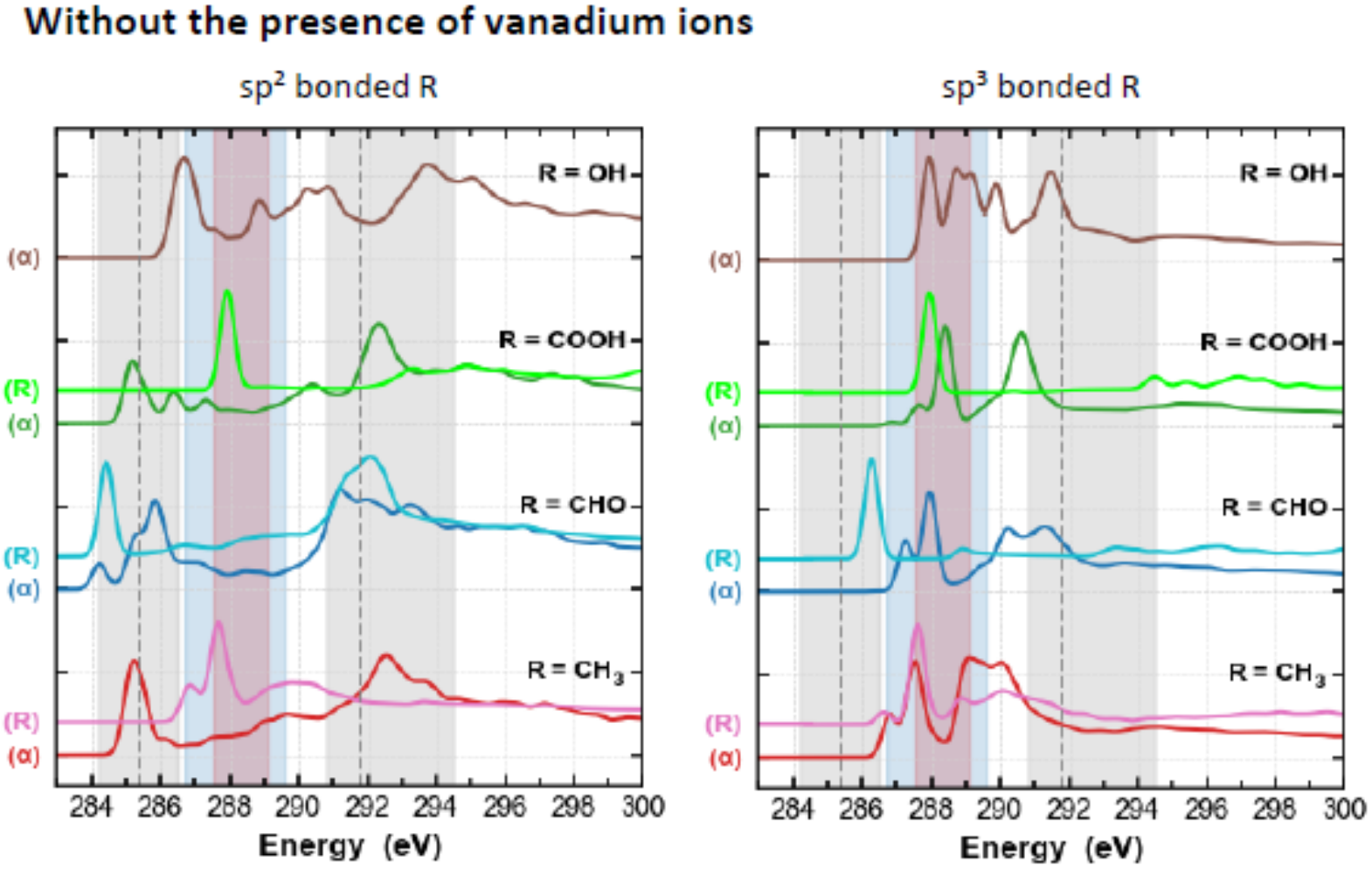
Key high energy density anode and cheap source material

Enabling long duration cycling through advanced analytics – Talk 605



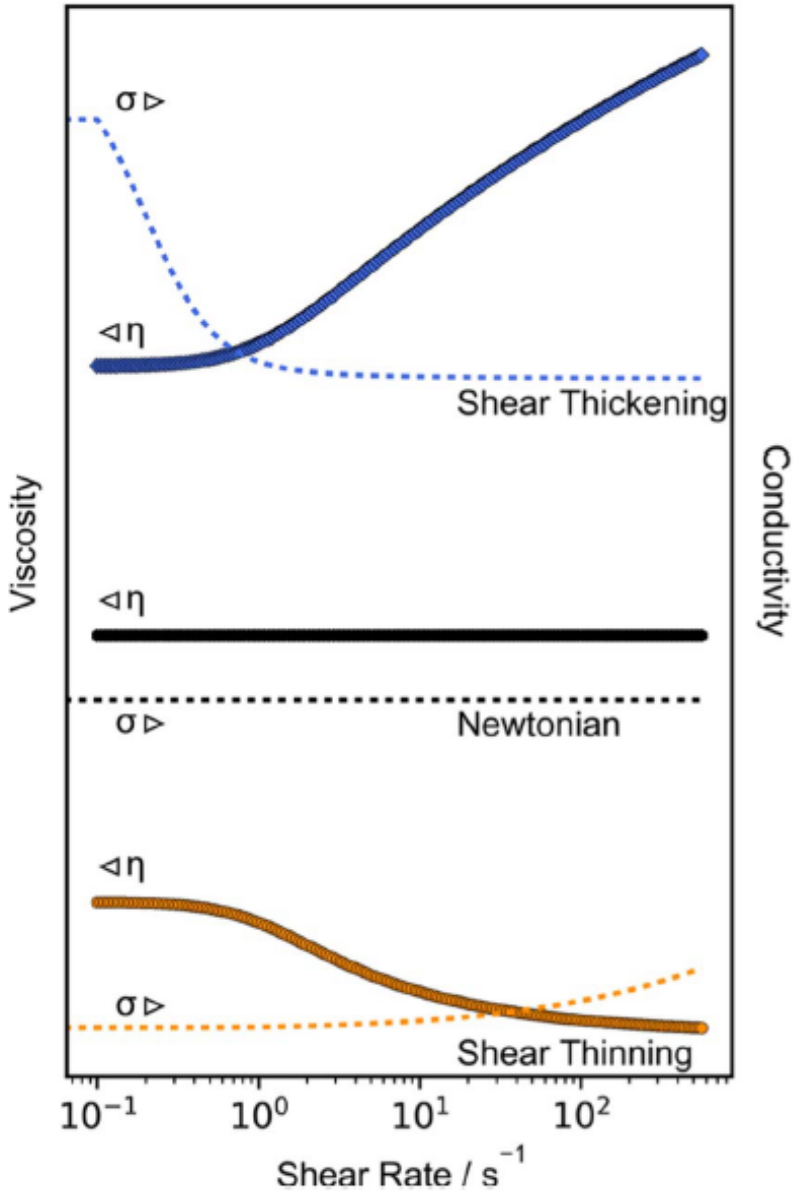
Approach to predictively estimate end of life and when to add new reagents

X-ray analysis to probe electrode degradation – Poster Sun



Evaluate electrode failure mechanisms through surface degradation

Ionic conductivity under flow becomes challenge with solubilized species



Shear thickening electrolyte

Normal electrolyte

VRFB freeze around 10°C which affects perforamance

Shear thinning electrolyte

Addition of rheological additives (α) enables better performance at higher flow rates – Poster Lee

Low flowrate → **High flowrate**

Capacity