Sandia National Laboratories

AGING & DIAGNOSTICS DEVELOPMENT OF ALL-VANADIUM REDOX FLOW BATTERY

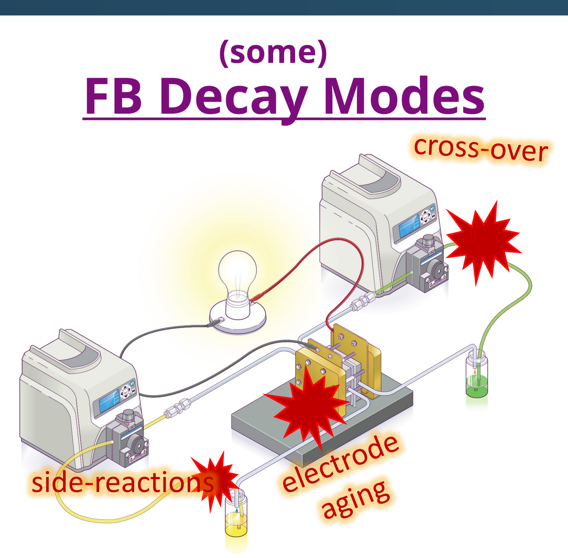
[1]Samantha P. Macchi, [1]Jesse Cordova, [2]Mike L. Perry, [1]Reed M. Wittman

[1]*Sandia National Laboratories*, [2]*Storion Energy*

PROJECT PROFILE
Topic: Safety & Reliability | Vertical: Safety & Reliability
Strategic Pathway: Optimize & Grow
Project start and finish: FY25-FY26

PROBLEM

- Diagnosing battery issues is non-trivial (Flow or otherwise)
- Flow batteries offer a pathway to grid resilience
- Adoption has been hindered by:
  - Lack of safety & reliability information
  - Scaling chemistries too quickly



- Detailed understanding of failure modes will support deployment of RFBs and strengthen grid energy storage capabilities

APPROACH

- In situ electrochemical diagnostics (e.g. polarization curves, EIS, current interrupt)
  - Changes are correlated to aging modes
- Easily scalable / integrated into deployment-level systems
- Simplistic enough for end-users / system owners
- Recovery method used to assess reversibility/origin of degradation

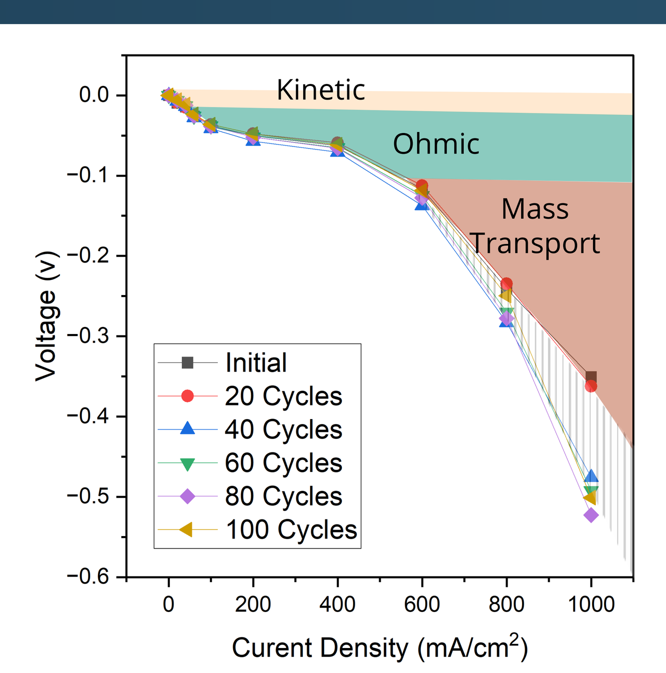
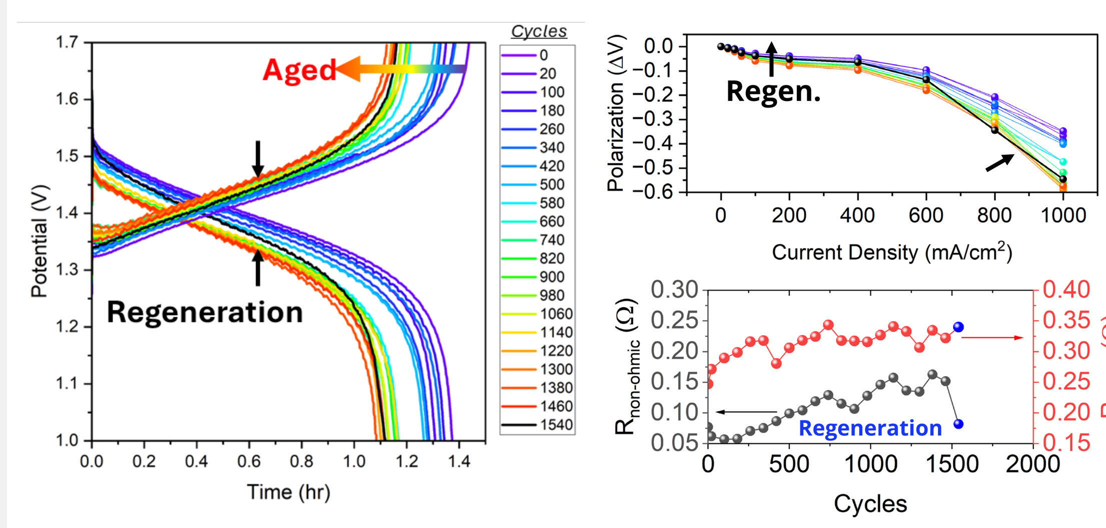


Fig. 1. Polarization curve showing regions of interest and impact from aging

Table 1. Diagnostic modes and decay mechanisms of all-Vanadium RFBs

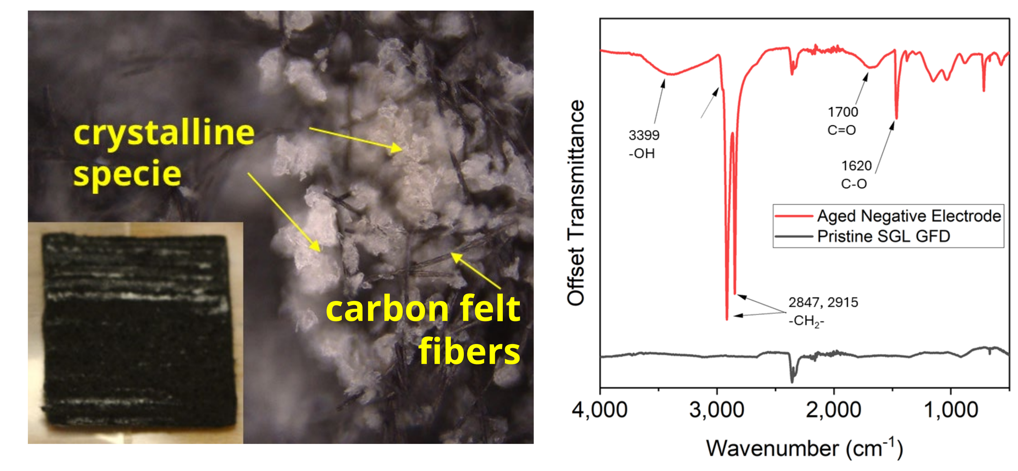
Performance Loss	Possible Decay Mechanisms			Targeted Diagnostic Technique
	Electrolyte	Electrode	Membrane	
Kinetic	• Contamination/ impurities	• Adsorption of contaminants • Degradation of reactive sites/area		• Polarization curves
Ohmic			• Contamination • Aging	• Polarization curves • Impedance (EIS)
Mass transport	• Change in concentration (crossover or O_2 contamination)	• Degradation of reactive sites/area • Pore blocking/ structure changes		• Polarization curves

RESULTS



- Aging results in loss in **Voltage** and **Capacity**
- Electrode degradation evidenced by loss in kinetic polarization and increased resistance ($R_{non\text{-}ohmic}$)
- Voltage loss is **reversible**

Fig. 2. (left) charge/discharge curves of VRFB, (right) diagnostic results



- Ex-situ evaluation of carbon felt electrodes revealed white crystalline deposits
- Identified to be **stearates** from mechanical/chemical aging of flexible tubing

Fig. 3. (left) Post-cycled electrode microscope image showing crystalline deposits, (right) FTIR spectra of pristine and aged electrode showing evolution of stearates upon aging

CONCLUSIONS & IMPACT

- Cell polarization can differentiate between **electrode health** (kinetic region) and **tank capacity** (mass transport region) and is **simplistic to implement at scale**
- Peristaltic pump tubing leads to stearate accumulation over long-term cycling in harsh acid environment – highlights importance in understanding **differences between R&D and industrial-scale battery testing**

FUTURE DIRECTIONS

- Investigation of electrolyte purity effects on long-term VRFB performance (**Collaboration with industry, to influence standards**)
- Scaling up to small stacks (**end-user proof-of-concept for diagnostics**)

Fig. 4. PinFlow 5-cell stack

References

[1] Perry, M. L., & Darling, R. M. (2024, August). Mitigation of Negative-Electrode Degradation in Vanadium Redox Flow Batteries. In Electrochemical Society Meeting Abstracts 245 (No. 3, pp. 566-566). The Electrochemical Society, Inc..

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