Phenazine-Based Anolyte Materials in Aqueous Redox Flow Batteries

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Redox Flow Batteries (RFB)

➢ High safety
   ✷ Spatial separation of reactive materials
   ✷ Major constituent is water
   ✷ Easy thermal management.
   ✷ Battery health monitoring

➢ Easy recycling after service life
   ✷ Consumption vs. Investment

➢ Decoupling of Power and Capacity
   ✷ Tailor system to application

OE Priority
Megawatt Scale Grid Storage
Vanadium vs Organic

➢ Vanadium Redox Flow Battery (VRB)
  ◇ Current state-of-the-art, highly studied
  ◇ High material cost
  ◇ Precipitation (temperature window)

➢ Benefits of Organics vs Vanadium
  ◇ Potentially lower cost
  ◇ Tunability of material and supporting electrolyte
  ◇ Candidates with $2e^-$ redox events

New materials development to drive down cost and improve performance of flow battery systems.
Previously Reported Phenazine

- Straightforward synthesis
- High solubility (up to 1.8 M)
- Promising cell performance
  (ferrocyanide catholyte)

1.4 V Theoretical Potential

1.4 M DHPS $\rightarrow$ 2.8 M $e^-$

Capacity Fade: 0.0195% / cycle, 0.68% / day
ASO Research in FY 2020

➢ Objectives
  ✷ Demonstrate ASO chemistry on prototype scale stack
  ✷ Cost modeling of ASO system
  ✷ Develop molecular-level understanding of ASO candidates to drive performance improvement

**FY 2020 Milestone**
Evaluate improvements to novel aqueous soluble organic flow battery on a prototype scale stack capable of meeting $250/kWh cost target for a projected 1MW/4MWh system operating at a 50% increase in current density - 150mA/cm².
Material Scalability

- Straightforward synthesis
- Hundreds of grams (to kgs) needed for demonstration
- Initial scale-up performed at 2 kg. scale

Trevor Dzwiniel & Krzysztof Pupek
Materials Engineering Research Facility (MERF)
Argonne National Laboratory
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ASO Demonstration at 200 cm²

1M DHPS / 1M Ferrocyanide
- 15 Wh/L at 150 mA/cm² (EE = 72.6%)
  - Average: 177 mW/cm²
- 17.5 Wh/L at 100 mA/cm² (EE = 78.3%)
  - Average: 124 mW/cm²

Ed Thomsen
ASO Demonstration at 780 cm² – 3 Cell Stack

1M DHPS / 1M Ferrocyanide
- 18.1 Wh/L at 150 mA/cm² (EE = 77.9%)
  - Average: 190 mW/cm²

Ed Thomsen
Cost Modeling of DHPS System

Cost projection based on 200 cm² cell data

Chemicals → largest share of cost, assumed cost reduction to reagent costs at high volume
Phenazine Derivatives – Long Term Stability

➢ Improving Long-Term Cyclability
   ✦ Identifying long-term instability issues
   ✦ Molecular modification to address side-reactions

Nadeesha Nambukara Wellala, Ruozhu Feng
Matthew Bliss, Prof. Navnidhi Rajput (Stony Brook U.)
New Phenazine Derivatives

- **Highly stable derivatives**
  - Multi-month cycling of 1,4-DHP
    - 0.034% capacity loss/day (galvanostatic cycling)
  - Cell voltages ~300 mV less than DHPS
  - Solubilities of 0.5-0.6 M
    - Potential improvements with electrolyte formulation
Summary

- Material performance demonstration at 780 cm² prototype stack
- Cost modeling analysis → Within 250 $/kWh cost target
- Molecular-level understanding of cyclability → new approaches to functionalization

Future Direction

- Advance the new highly-stable derivatives and investigate novel stabilizing approaches with existing system

Support

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Thank You For Your Attention

Questions?

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