Enabling Long Duration Metal Hybrid Redox Flow Batteries

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U.S. DEPARTMENT OF ENERGY

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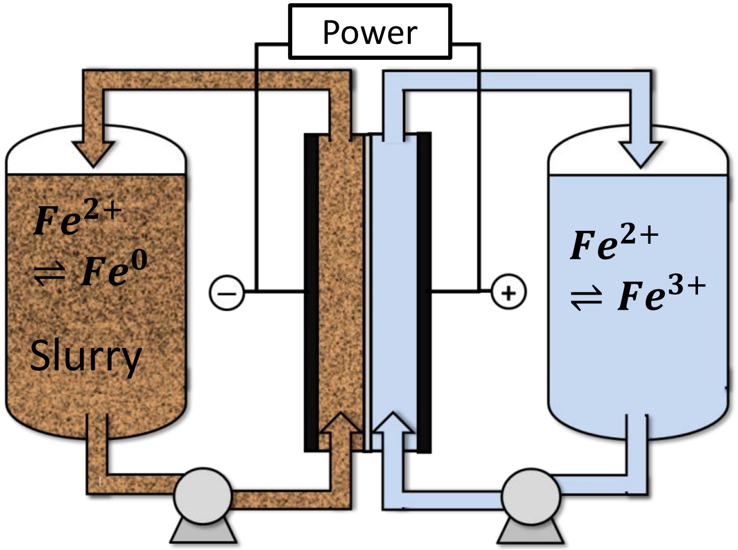
Approach:

- **Negative Couples Based on Iron and Zinc Plating/Stripping**
  - **low cost, US abundant materials**
- **Carbon Slurry Electrodes to De-couple Energy and Power**
  - **plated metal stored on dispersed carbon particles**
  - **energy stored scales with tank size, not cell area**



Previous Work on this Concept at CWRU (all Iron chemistry):

- **demonstrated slurry electrode with low cost carbons (<$1/kg)**
  - **continuous flow, low conversion per pass**
- **demonstrated charge acceptance up to 1 mol/liter**
  - **no change in slurry properties**
  - **acceptable viscosity and associated pumping losses**
- **50 - 60% voltaic efficiency at 100 – 150 mA/cm²**
  - **H_2 evolution also a challenge with Iron chemistry**

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Task 1: Fundamentals of Zinc Electrodeposition on Flowing Slurries

- **Suppression of Hydrogen Evolution**
  - **Characterize HER rates on charge and discharge**
  - **Develop additives and understand their mechanistic behavior for suppressing HER**
- **Understanding Deposit Morphology on Slurries**
  - **Does dendrite growth occur on slurries?**

Task 2: Particle Interactions and Dynamics in Flowing Slurries

- **How Does the Flow Field Affect the Dispersed Phase Structure?**
  - **Characterize slurry behavior at walls or flow stagnation points**
- **Influence of slurry physiochemical properties on electrical and physical percolation**
  - **Evaluate effect of surfactants on slurry conductivity, particle agglomeration**

Task 3: Demonstration of an Advanced Slurry Flow Battery

  - **Improved positive and negative electrode architecture**
  - **Prototype Fabrication and Testing**

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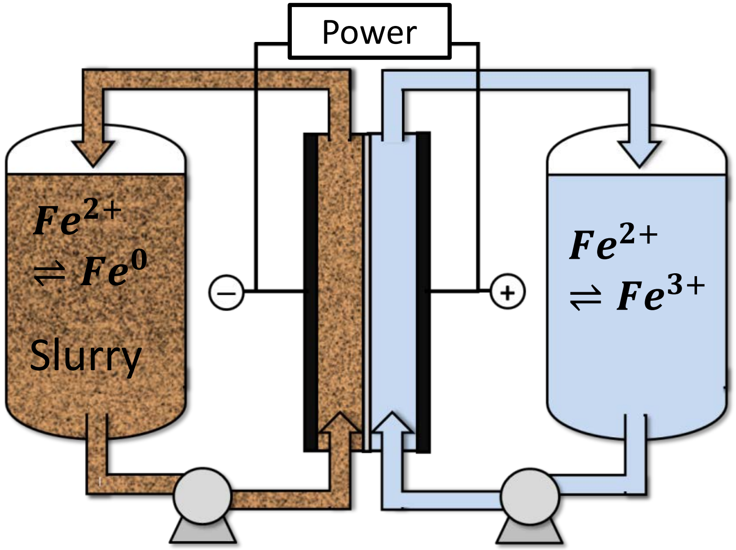

Year 1 Milestones:

- Complete electrochemical polarization curves and associated kinetic parameters measured over the range of conditions tested. (Task 1.1.1)
- Develop two additive containing chemistries with significant (>50%) decrease in self-discharge rates of flat Zn electrodes. (Task 1.1.2)
- Measure and compare the limiting current density for electrodeposition on a flat plate exposed to laminar flow for neat electrolyte and for an electrolyte containing carbon particles at loadings below the percolation limit (Task 1.2)
- Quantify the fractional currents on the slurry and on the current collector for slurries below the percolation limit as a function of particle loading and Reynolds number. (Task 1.2)
- Complete experimental measurements and FEM simulations of a particle free flow field in the battery geometry. (Task 2.1.1)
- Develop fluid formulation rules for reducing particle adhesion to stack and cell materials (Task 2.2.1)

Year 1 Deliverables:

- Submit two peer reviewed articles based on fundamental investigations initiated in year 1.
- Present findings at DOE-OE Energy Storage Peer Review

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Result – Reactivity Enhancement At the Percolation Threshold:

Experiment:

$Fe^{2+/3+}$ symmetric cell

fixed cell potential = 50 mV

Carbon loading and flow rate varied

Result:

- Intermediate loadings (≈6 %) maximize current at all flow rates (6 % carbon is the percolation threshold in this system – see inset figure)
- Strong effect of flow rate as well

Conclusion:

- Even modest carbon loadings can significantly enhance the effective electrode area
- Previous studies that used much higher loadings (>20%) were possibly not optimal for voltaic efficiency