Iron Based Flow Batteries for Low Cost Grid Level Energy Storage

J.S. Wainright, R. F. Savinell, P.I.s
Dept. of Chemical Engineering, Case Western Reserve University

**Purpose**
Develop efficient, cost-effective grid level storage capability based on iron.

**Goals of this Effort:**
- Minimize Cost/Watt by increasing current density - Hardware Cost >> Electrolyte Cost
- Minimize Cost/Whr by increasing plating capacity
- Maximize Efficiency by minimizing current lost to hydrogen evolution

**Electrochemistry of the all-Iron system:**
Positive: \( \text{Fe}^{2+} \rightleftharpoons \text{Fe}^{3+} \ +0.77\text{V} \)
Negative: \( \text{Fe}^{2+} \rightleftharpoons \text{Fe}^{0} \ -0.44\text{V} \)
Cell: \( 3\text{Fe}^{2+} \rightleftharpoons \text{Fe}^{0} + 2\text{Fe}^{3+} \ 1.21\text{V} \)

**Impact on Iron Based Batteries on the DOE OE Energy Storage Mission**
Widespread grid level storage will require:
- Low Cost
  - All-Fe battery uses one low cost active element and inexpensive separators
- Environmental Acceptability
  - Mild pH, non-toxic electrolyte
- Geographic Flexibility
  - Iron is readily available from domestic sources

**Research Plan**
Year 1: COMPLETE
- Ligand Screening – demonstrated \([\text{Fe}^{3+}] >0.5\text{M} @ \text{pH}>2\)
- \( \text{H}_2 \) evolution suppression – effect of pH, anions evaluated

Year 2: IN PROGRESS
- Effect of Ligands on Fe plating efficiency, morphology
- Separator studies – \( \text{Fe}^{3+} \), Ligand crossover

Year 3:
- Optimization of plating capacity, current density to maximize efficiency
- Scale up from 50 cm\(^2\) to 250 cm\(^2\)

**Recent Results**
- Demonstrated Adherent, Stress-Free, Dendrite-Free Plating
  - Deposit Thickness: Shown is Equivalent to 75 mAh/cm\(^2\)
  - Deposits up to 150 mAh/cm\(^2\) have been made
- Demonstrate Coulombic Efficiency >99% for Iron Plating
  - \( T = 60\text{C} \)
- Measurement and model of \( \text{Fe}^{3+} \) crossover
  - Room Temperature
  - Daramic Separator
  - Equivalent to 0.5% Capacity Loss in 24 hrs with Electrolyte Circulating

- Measurement and model of \( \text{Fe}^{(II)}/\text{Fe}^{(III)} \) Overpotentials
  - Negligible Kinetic Loss
  - Ohmic and Mass Transfer Overpotentials
  - Total Overpotential <20 mV @ 0.1 A/cm\(^2\)