# Iron Based Flow Batteries for Low Cost Grid Level Energy Storage

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## 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: | $Fe^{+2} \Leftrightarrow Fe^{+3}$ | +0.77V |
| Negative: | $Fe^{+2} \Leftrightarrow Fe^{0}$ | -0.44V |
| Cell: | $3Fe^{+2} \Leftrightarrow Fe^{0} + 2Fe^{+3}$ | 1.21V |

## 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 $[Fe^{+3}]$ >0.5M @ pH>2
- $H_2$ evolution suppression – effect of pH, anions evaluated

Year 2: IN PROGRESS

- Effect of Ligands on Fe plating efficiency, morphology
- Separator studies – $Fe^{+3}$, Ligand crossover

Year 3:

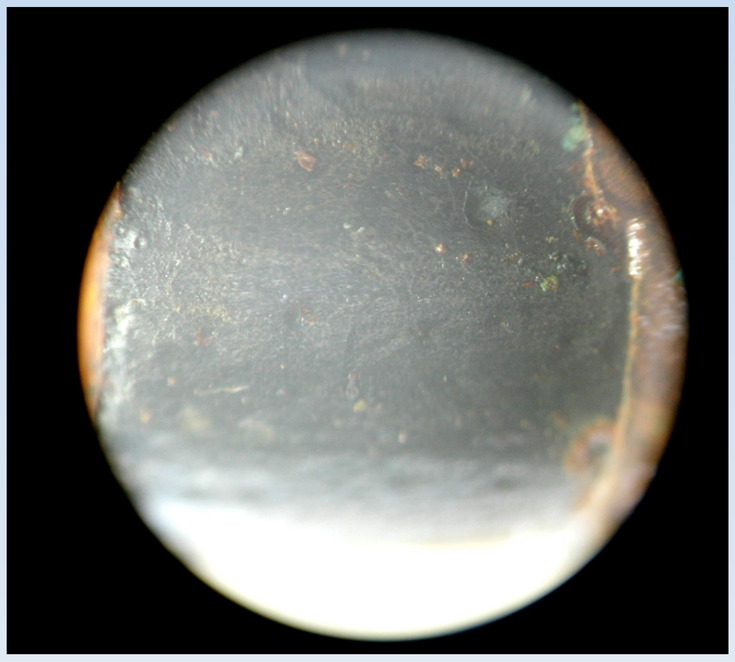
- Optimization of plating capacity, current density to maximize efficiency
- Scale up from 50 $cm^2$ to 250 $cm^2$

## Recent Results

**Demonstrated Adherent, Stress-Free, Dendrite-Free Plating**

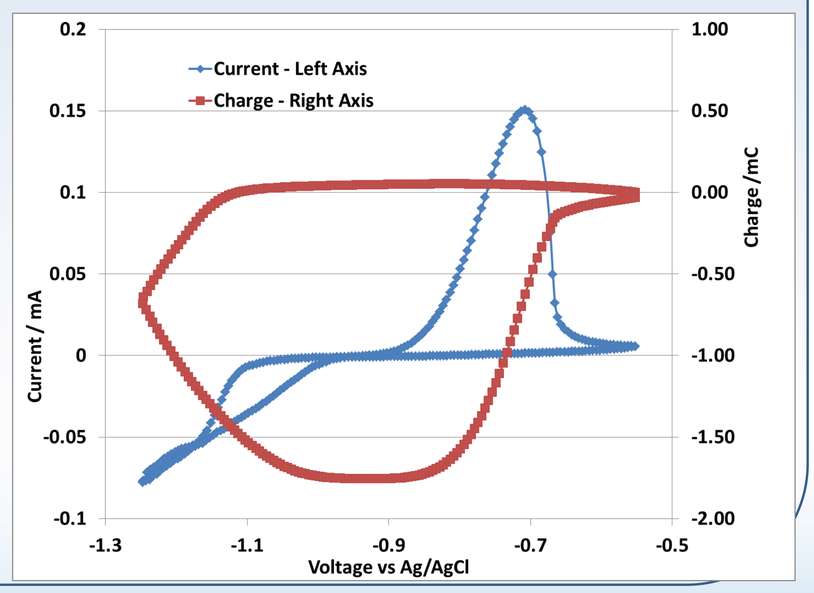
Deposit Thickness Shown is Equivalent to 75 $mAh/cm^2$

Deposits up to 150 $mAh/cm^2$ have been made



**Demonstrated Coulombic Efficiency >99% for Iron Plating**

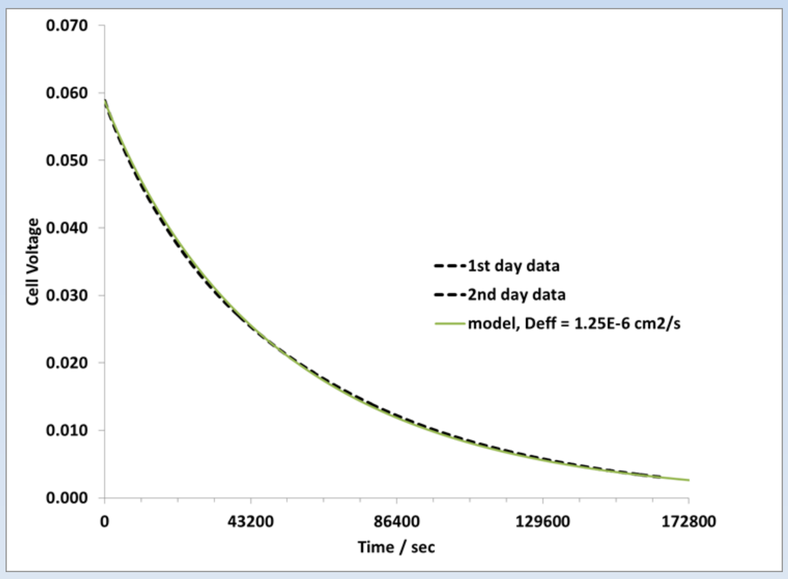
**T = 60C**




## Recent Results

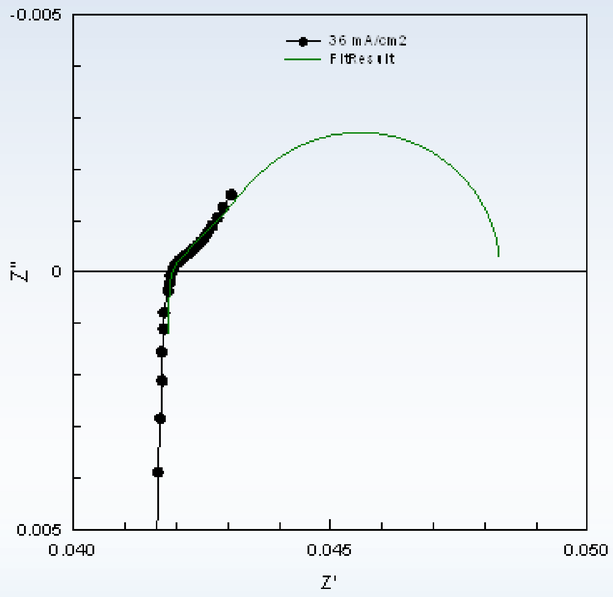
**Measurement and model of Fe+3 crossover**

- Room Temperature
- Daramic Separator
- Equivalent to 0.5% Capacity Loss in 24 hrs with Electrolyte Circulating




**Measurement and model of Fe(II)/Fe(III) Overpotentials**

- Negligible Kinetic Loss
- Ohmic and Mass Transfer Overpotentials
- Total Overpotential <20 mV @ 0.1 $A/cm^2$

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