Seawater Battery for Long Duration Storage

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Seawater battery: Potential cost-effective storage solution to large-scale energy storage

- No critical materials
- Eco-Friendly
- Abundant Raw Materials
- No flammable
- Long-duration energy storage
- Grid and off-grid applications

Charge reaction:

$$\text{NaCl(aq)} + \frac{1}{2}\text{H}_2\text{O(aq)} \rightarrow \text{Na(s)} + \frac{1}{2}\text{O}_2(g) + \text{HCl(aq)}$$

Discharge reaction:

$$\text{Na(s)} + \frac{1}{2}\text{H}_2\text{O (aq)} + \frac{1}{2}\text{O}_2 \rightarrow \text{NaOH(aq)}$$
Technical challenges and project objectives

• Cell design
• Membrane/Separator
• Catalyst design
• Na-Anode
• Non-aqueous electrolyte

• In FY23, we will leverage the knowledge gained from LDRD (FY22) project to make progress on several of these challenges and to develop a demonstration seawater battery

• Next, we will describe some technical achievements funded by Laboratory Directed R&D at ORNL
ORNL seawater battery cell design

2. Bottom case

3. Coin cell plate

4. Upper case

5. Silicon ring

6. Carbon felt

7. Ti spring

Anode Compartment (Na-metal)

Carbon fiber

Graphite felt

Cathode Compartment (Seawater)
Nasicon solid electrolyte (membrane/separator)

- Polyanionic NZSP synthesized by solid-state reaction
- NZSP has RT conductivity of 0.4 mS cm\(^{-1}\) comparable to commercial alternatives
Nasicon doping study (Pure NZSP, 2% Al, 2% Ti)

- Na | SE | Na Testing Protocol, ~800 µm pellet thickness, NaPF₆ in Diglyme | 2 drops
- Current densities up to 8 mA.cm⁻² tested

- Al NZSP fails the fastest @~0.3 mA cm⁻²
- NZSP fails @~5 mA cm⁻²
- Ti-NZSP fails @~7.5 mA cm⁻²
Sodium storage mechanism in hard carbon

- Schematic illustration of the storage mechanism and the plating mechanism within the Na | SE | HC cells.

- Galvanostatic charge/discharge curves and cycling of the Na | SE | HC cell at 70 °C between 0.005 – 1.5 V at 0.1 C (1C = 250 mAh. g⁻¹).

- Galvanostatic charge/discharge curves and cycling performance of the Na | SE | HC cell with plating/stripping current of 1 mAh cm⁻² and -1V to 1V cutoff voltages.
Development of catalyst Ni$_{1-x}$Fe$_x$(OH)$_2$ hydroxides

Under alkaline conditions (0.1M KOH), Ni$_{0.95}$Fe$_{0.05}$(OH)$_2$/C and Pt/C showed an overpotential value of 424 mV and 595 mV at 10 mA/cm$^2$, $E_{1/2}$ at 0.645 V and 0.852 V, respectively.

However, both catalysts showed slower kinetics in 2.7wt% NaCl electrolyte due to the neutral condition.
Cycling performance

Catalyst: Ni_{0.95}Fe_{0.05}(OH)_2 on activated carbon felt

Half-cycle Duration: 5 hours

Current: 0.01 mA

Current: 0.05 mA

Current: 0.1 mA

Rate capability
Half-cycle Duration: 3 hours
Current: 0.01, 0.02, 0.04, 0.06, 0.08, 0.1 and 0.25 mA
Summary

We will continue the following R&D:

• Design of seawater battery prototype cells
• Demonstrate baseline cells for 5- and 10- hour charge cycles with higher coulombic efficiencies
• Optimize anode organic electrolyte to achieve efficient reversible Na storage
• Carry out x-ray/neutrons, SEM, µCT as well as XPS studies
• Develop a modeling framework for thermodynamic and techno-economic analysis of the seawater battery technology
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