Seawater Battery for Long Duration Storage

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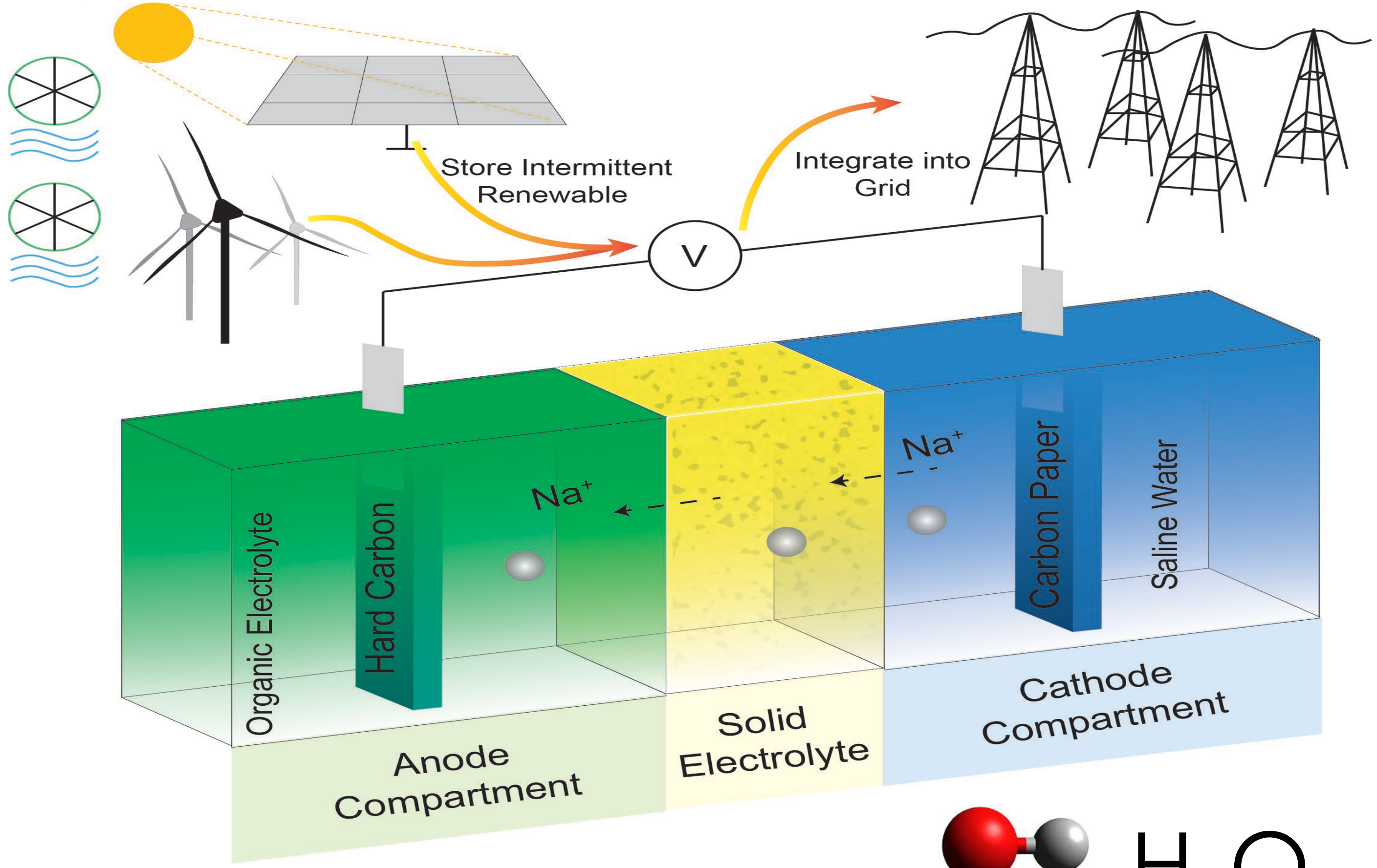
Seawater battery: Potential cost-effective storage solution to large-scale energy storage

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

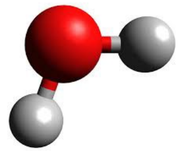


Charge reaction:

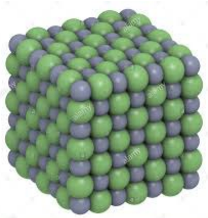
$NaCl(aq)+1/2H_2O(aq) \longrightarrow Na(s)+1/2O_2(g)+HCl(aq)$

Discharge reaction:

$Na(s) +1/2H_2O (aq) +1/2O_2 \longrightarrow NaOH(aq)$



H_2O



NaCl

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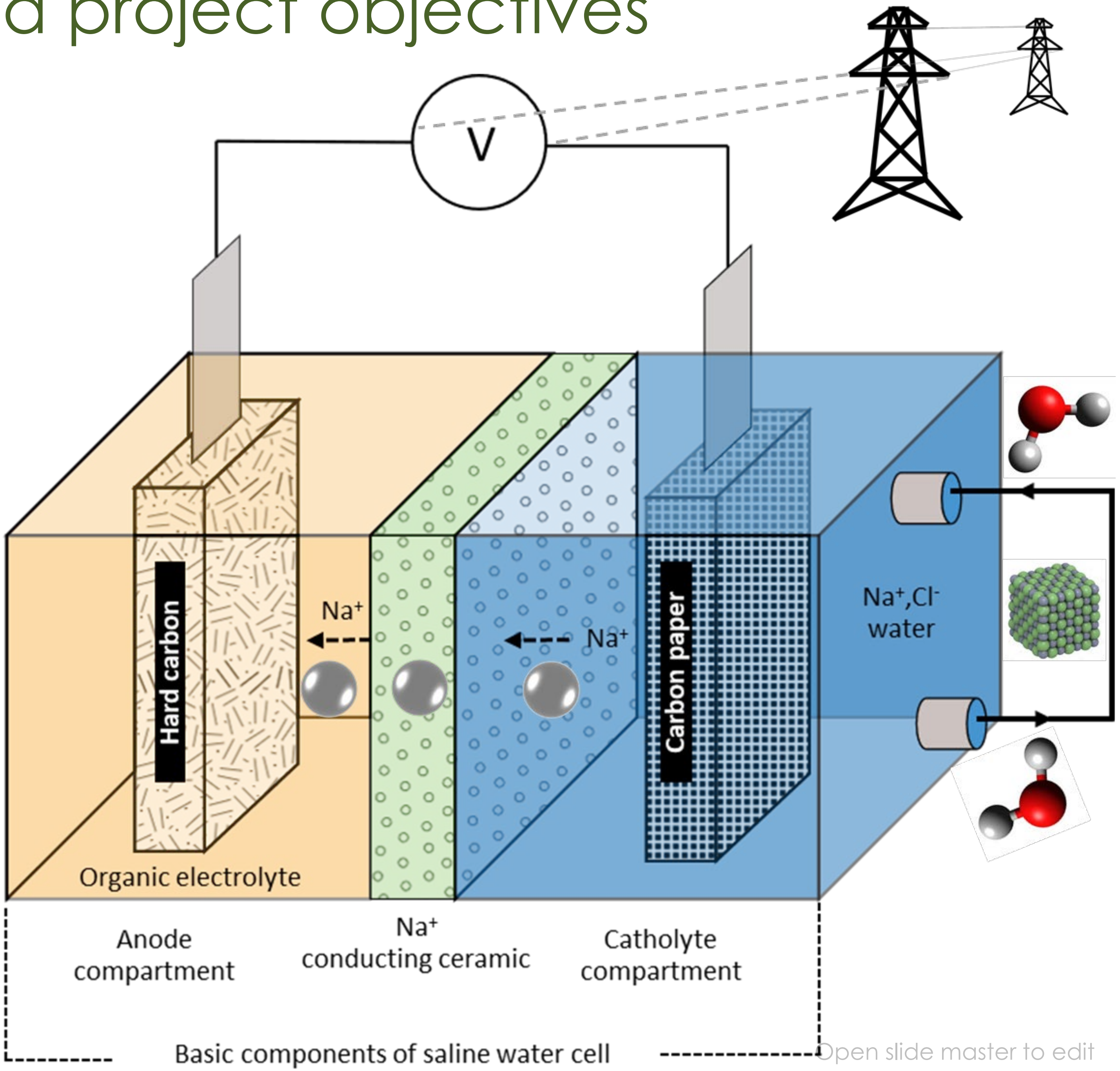
Technical challenges and project objectives

- 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



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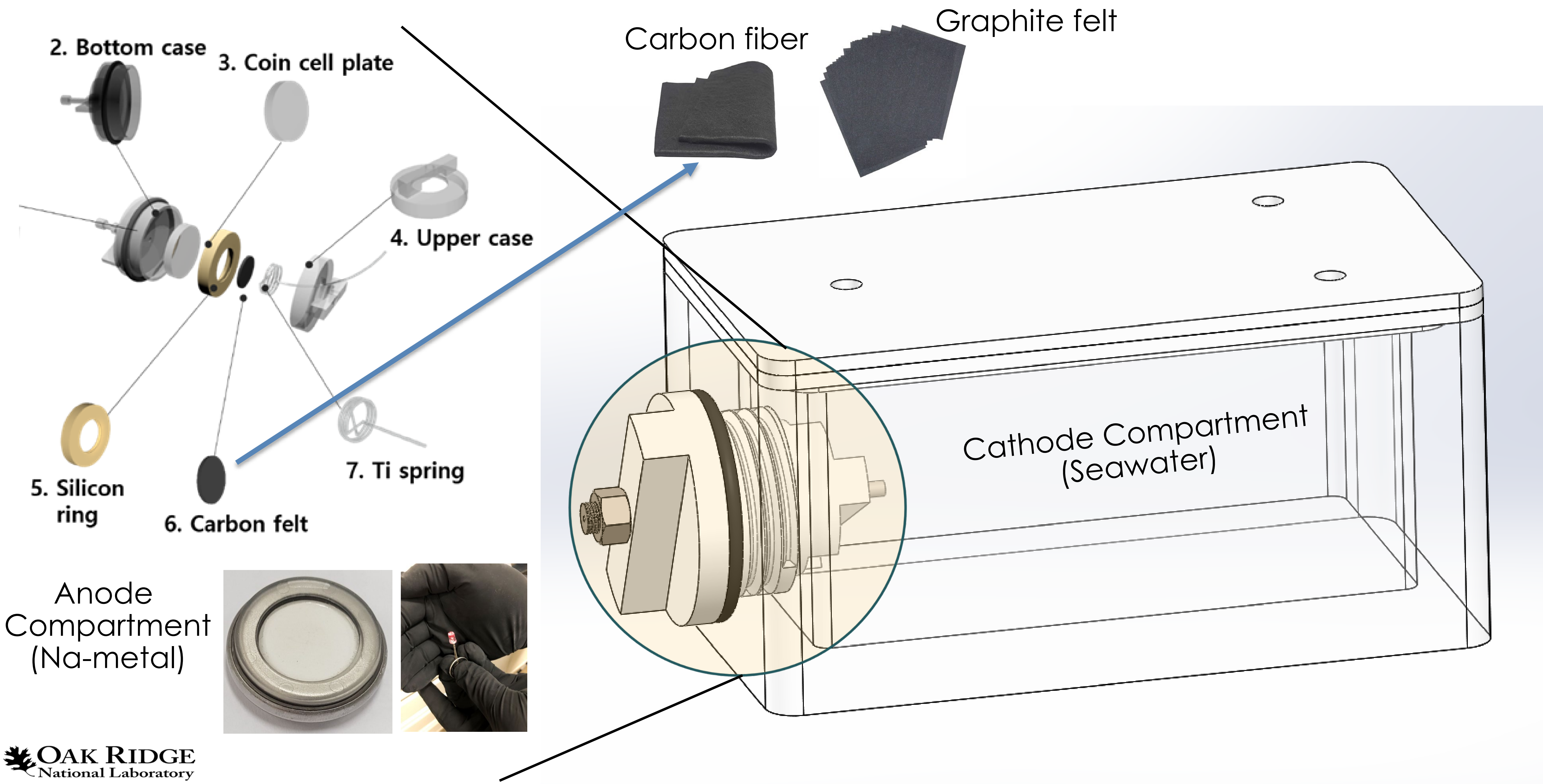
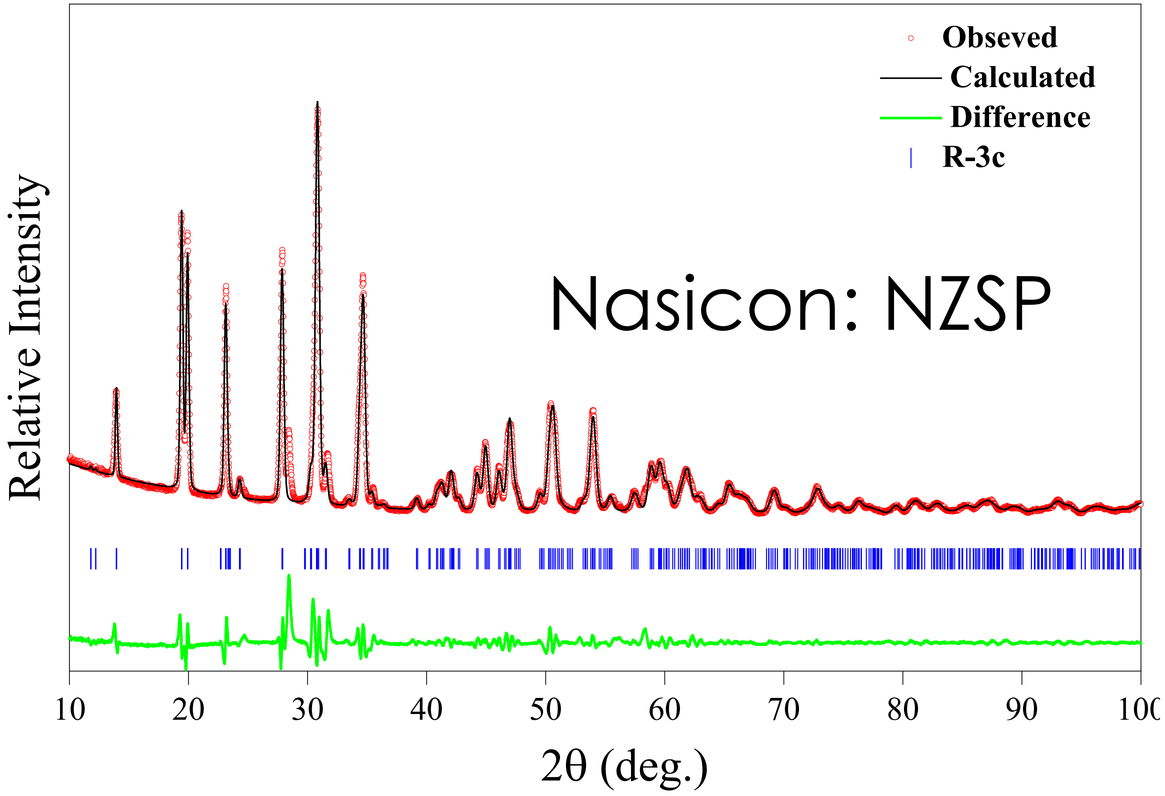
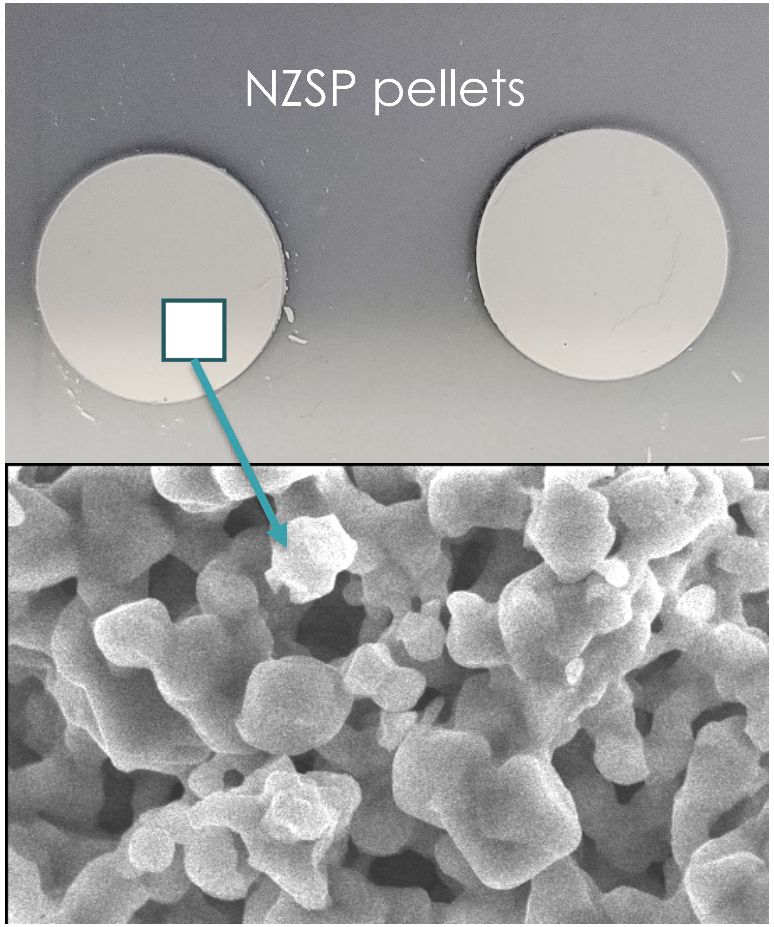
ORNL seawater battery cell design



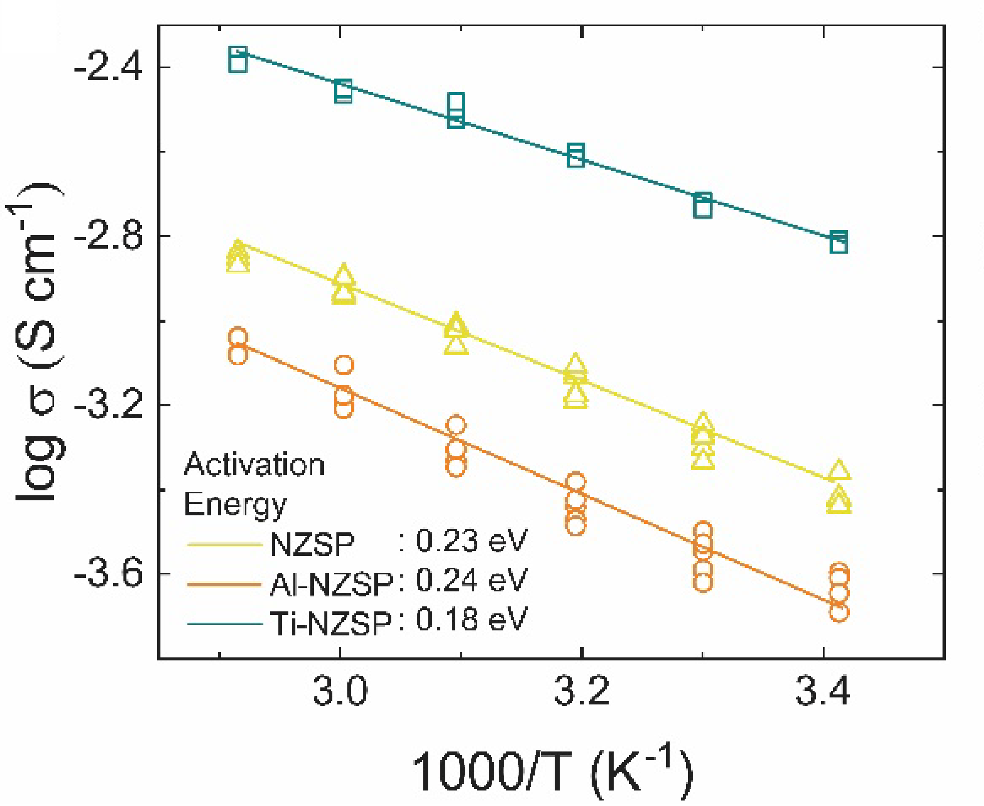
Nasicon solid electrolyte (membrane/separator)

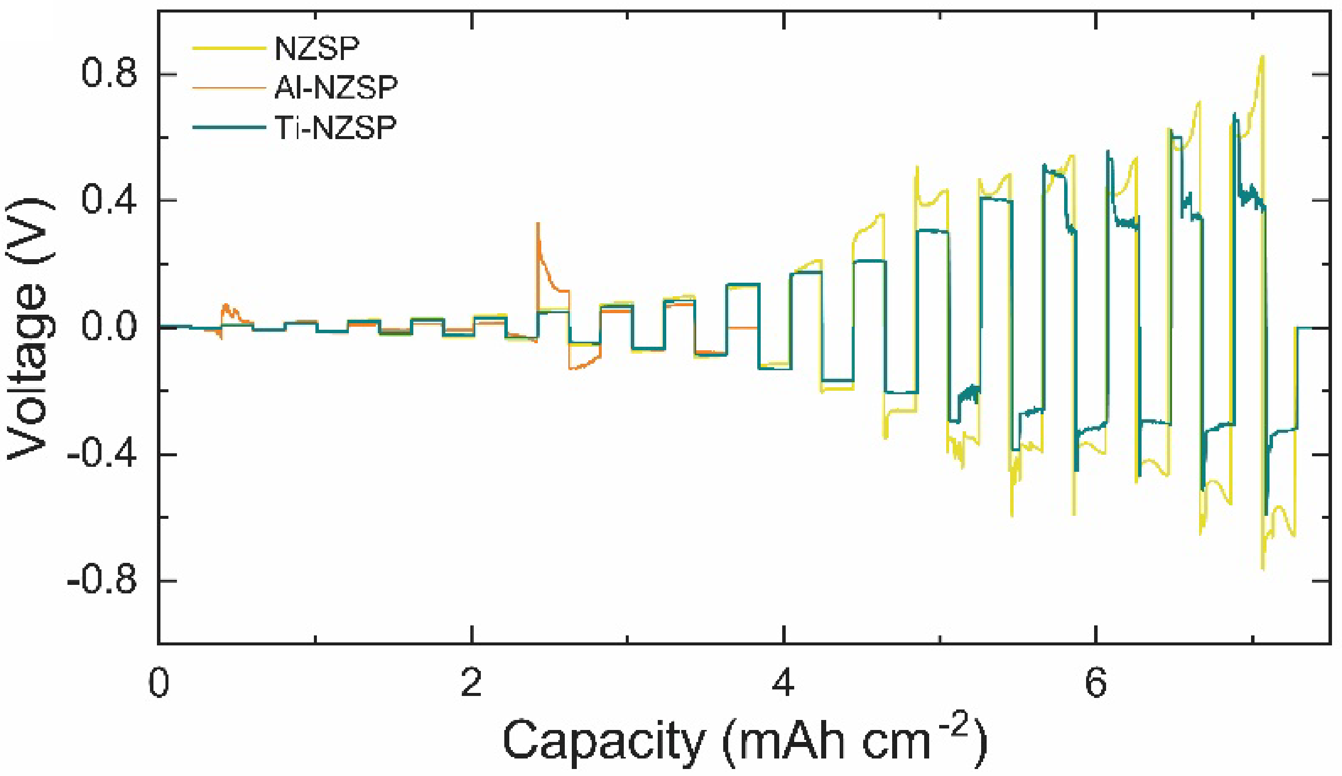




- Polyanionic NZSP synthesized by solid-state reaction
- NZSP has RT conductivity of 0.4 mS cm^{-1} comparable to commercial alternatives

Nasicon doping study (Pure NZSP, 2% Al, 2% Ti)



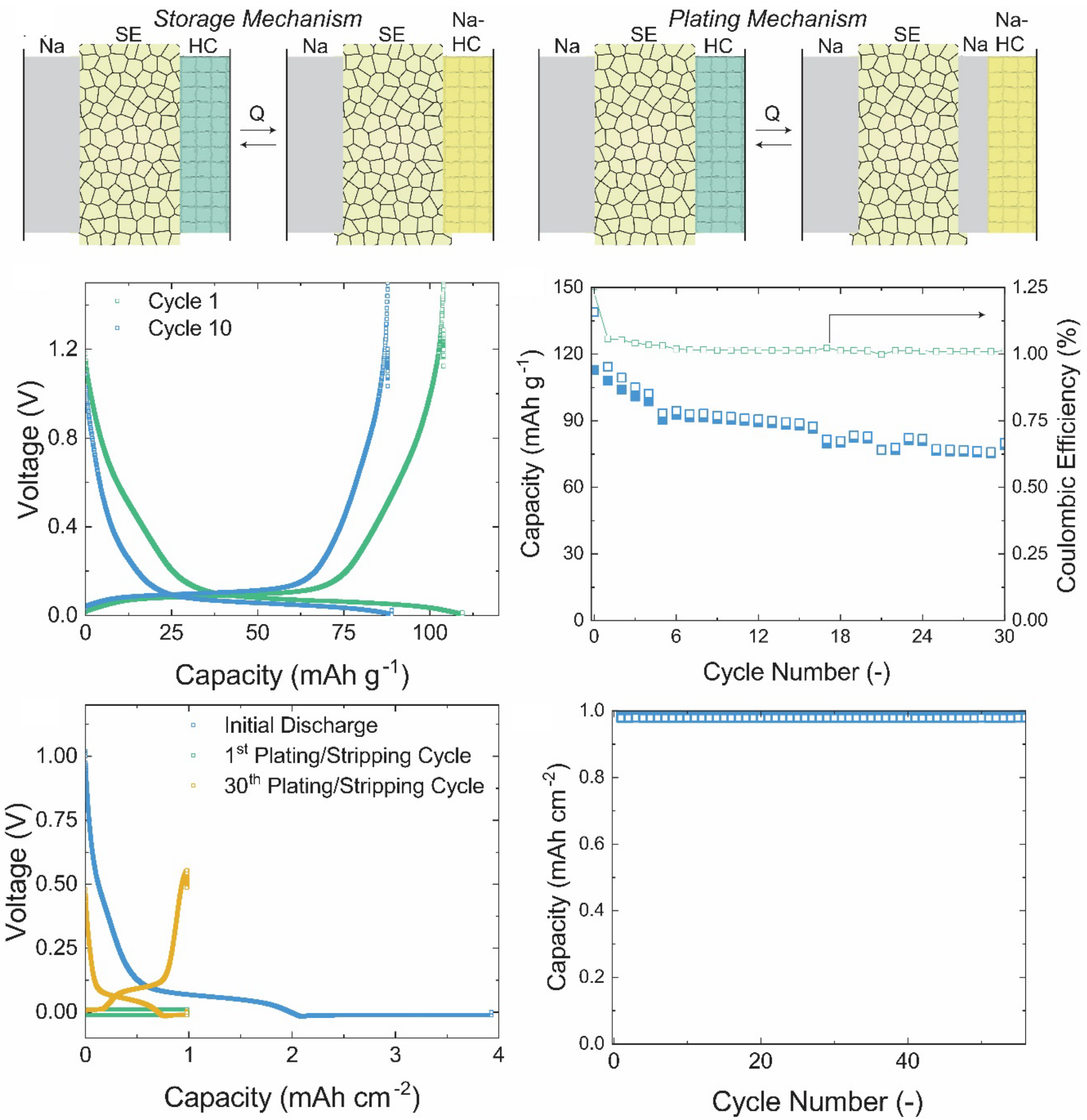


- Na | SE | Na Testing Protocol, ~800 µm pellet thickness, $NaPF_6$ in Diglyme | 2 drops
- Current densities up to 8 mA.cm^{-2} tested

- 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.



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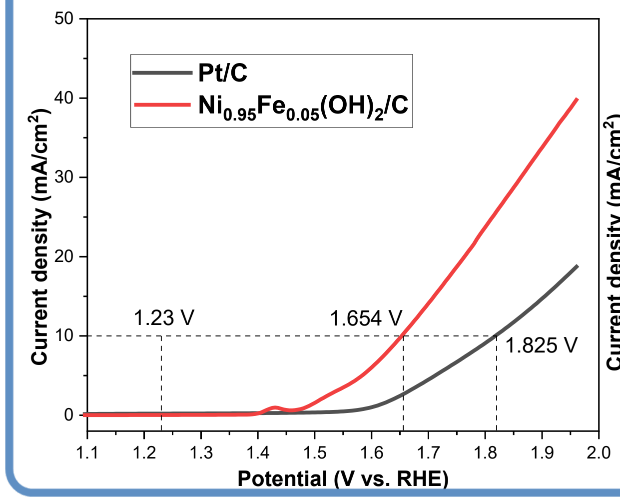
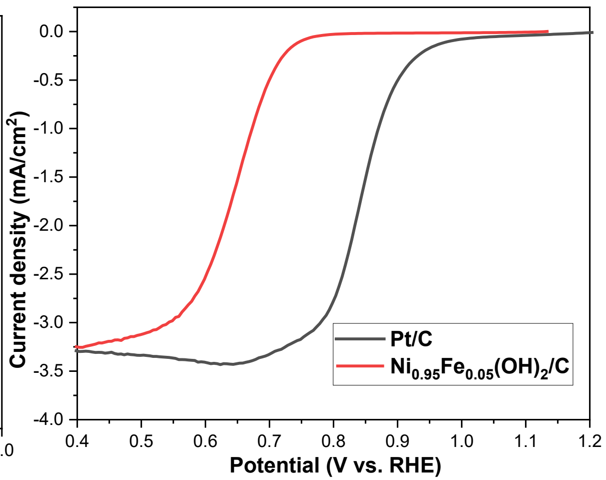
Development of catalyst $Ni_{1-x}Fe_x(OH)_2$ hydroxides

0.1 M KOH

OER, 5 mV/s

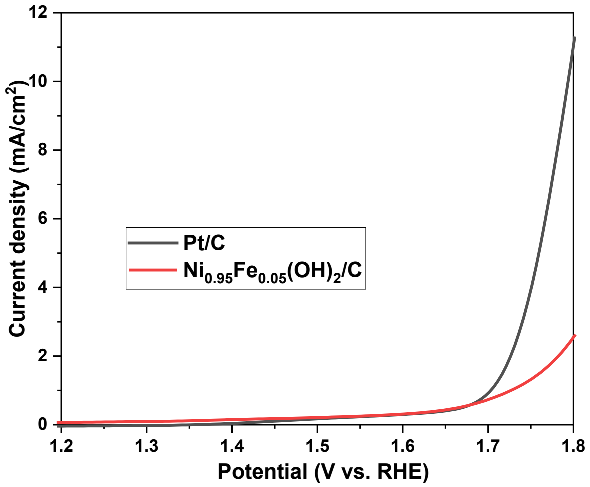


ORR, O_2 saturated
5 mV/s, 1600 rpm

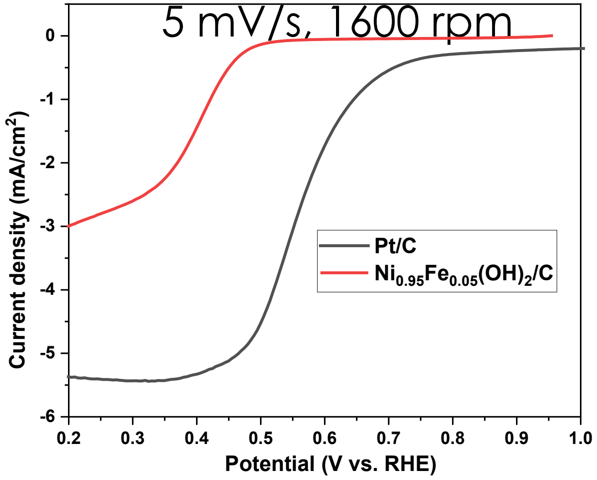


2.7wt% NaCl

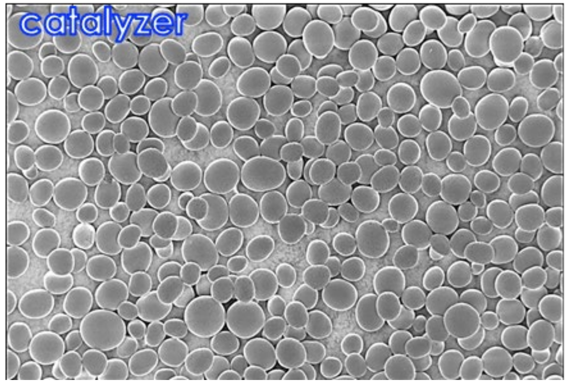
OER, 5 mV/s

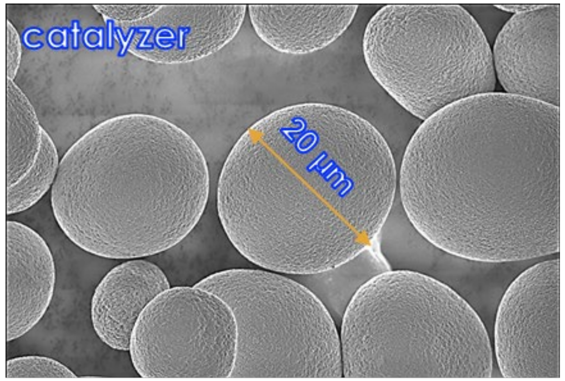


ORR, O_2
saturated
5 mV/s, 1600 rpm



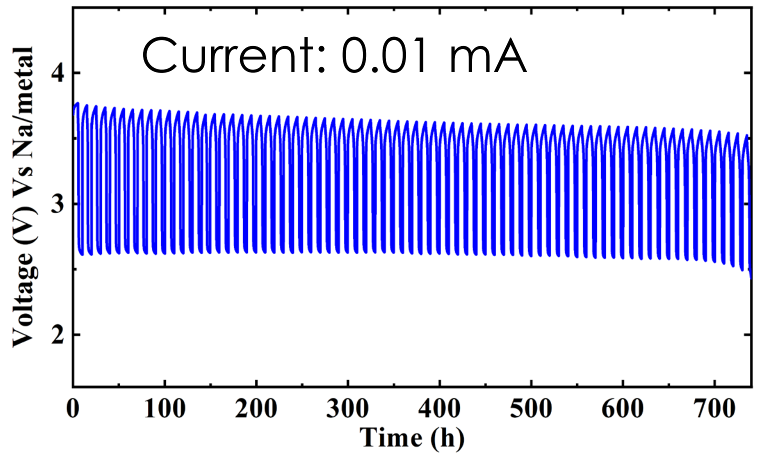
- Under alkaline conditions (0.1M KOH), $Ni_{0.95}Fe_{0.05}(OH)_2/C$ and Pt/C showed an overpotential value of 424 mV and 595 mV at 10 mA/cm^2, $E_{1/2}$ at 0.645 V and 0.852 V, respectively
- However, both catalysts showed slower kinetics in 2.7wt% NaCl electrolyte due to the neutral condition.

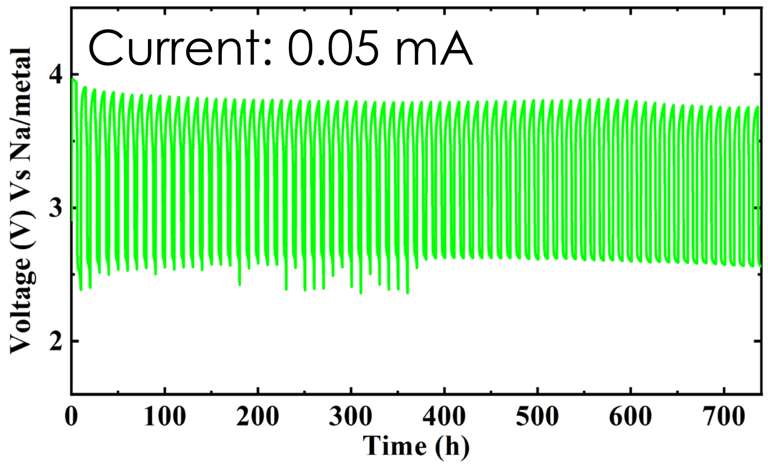


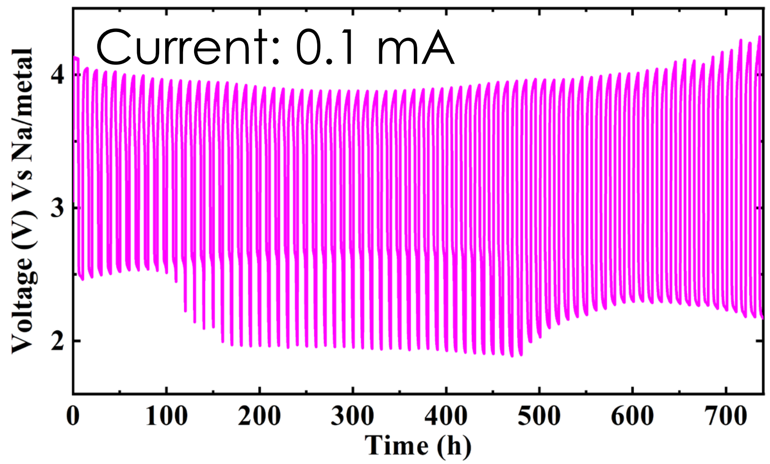


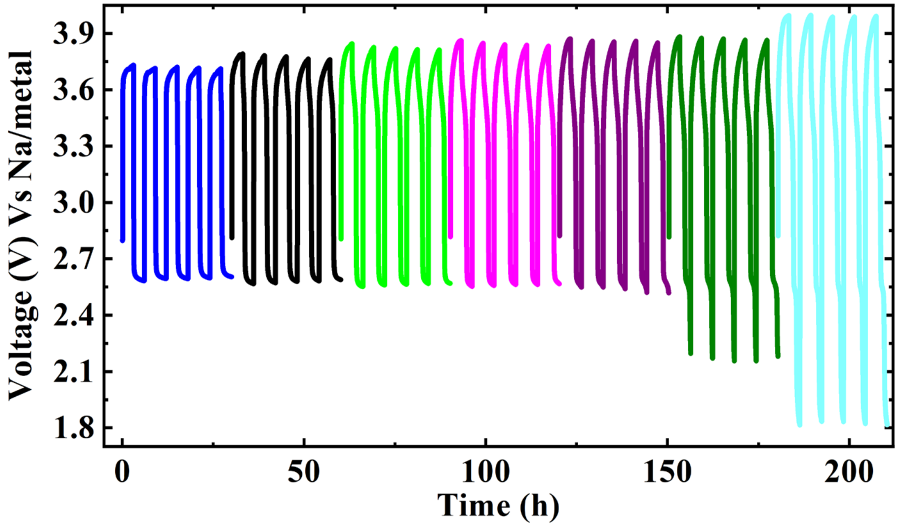
Cycling performance

Catalyst: $Ni_{0.95}Fe_{0.05}(OH)_2$ on activated carbon felt Half-cycle Duration : 5 hours









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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Thank you