Sandia National Laboratories

UNDERSTANDING AND OPTIMIZING DISSOLUTION SUPPRESSING ELECTROLYTES OF A SODIUM VANADATE CATHODE IN RECHARGEABLE ZINC-ION BATTERIES

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PROJECT PROFILE

Topic: Zinc Batteries | Vertical: Materials & Systems Innovation

Strategic Pathway: **Grow**

Project start and finish: FY26-FY28, Storage Innovations 2030

PROBLEM

Lithium-ion batteries dominate the current market for grid scale battery energy storage systems but are a source of continuing concern due to flammability. While rechargeable aqueous zinc-ion batteries (AZIBs) are desirable as safe alternatives, selection of the positive electrode (cathode) material is critical. Although vanadium oxides are appealing as high capacity AZIB cathodes, a limitation is their propensity for vanadium dissolution in aqueous electrolytes, manifesting as capacity fade over extended cycling.

APPROACH

Identify cost-effective and scalable materials and systems innovations toward high capacity long-life AZIB with vanadium oxide-based cathodes.

Select sodium vanadium oxide (NVO) cathode with synthetic versatility (Fig 1).

Determine impact of NVO synthesis condition on capacity and cycle life.

Study dual ion zinc-sodium electrolytes for dissolution suppression.

Quantify NVO cathode dissolution as a function of electrolyte (Fig 2).

Understand cell level behavior via extended cycling studies (Fig 3-4).

Achieve spatio-temporal resolution of (dis)charge in operating cells (Fig 5).

RESULTS

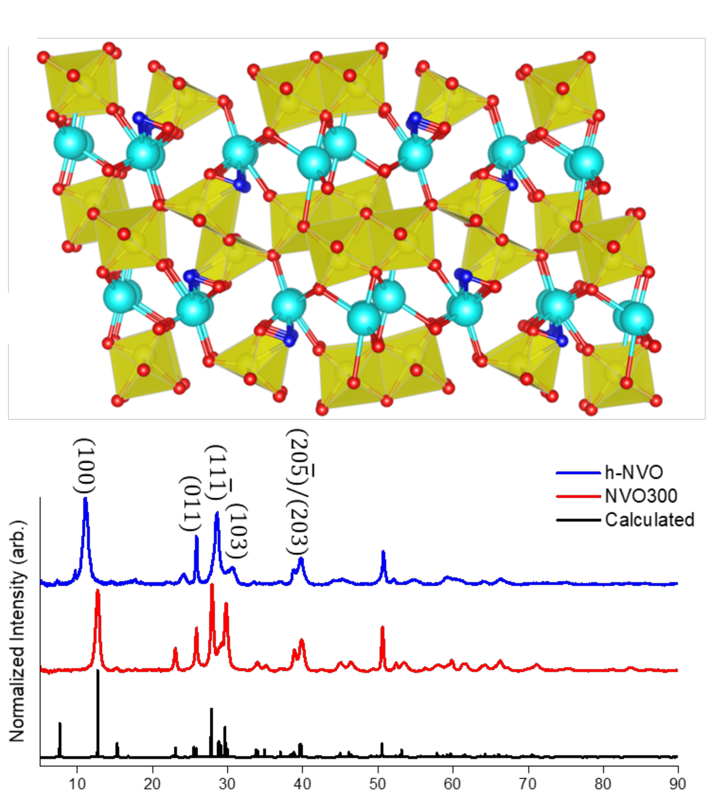

Fig 1: NaV_3O_8 (NVO) has Na^+ and H_2O in the interlayers which stabilize the vanadate backbone. NVO is prepared hydrothermally and can be used directly (h-NVO) or annealed to increase its crystallinity (i.e. NVO-300).

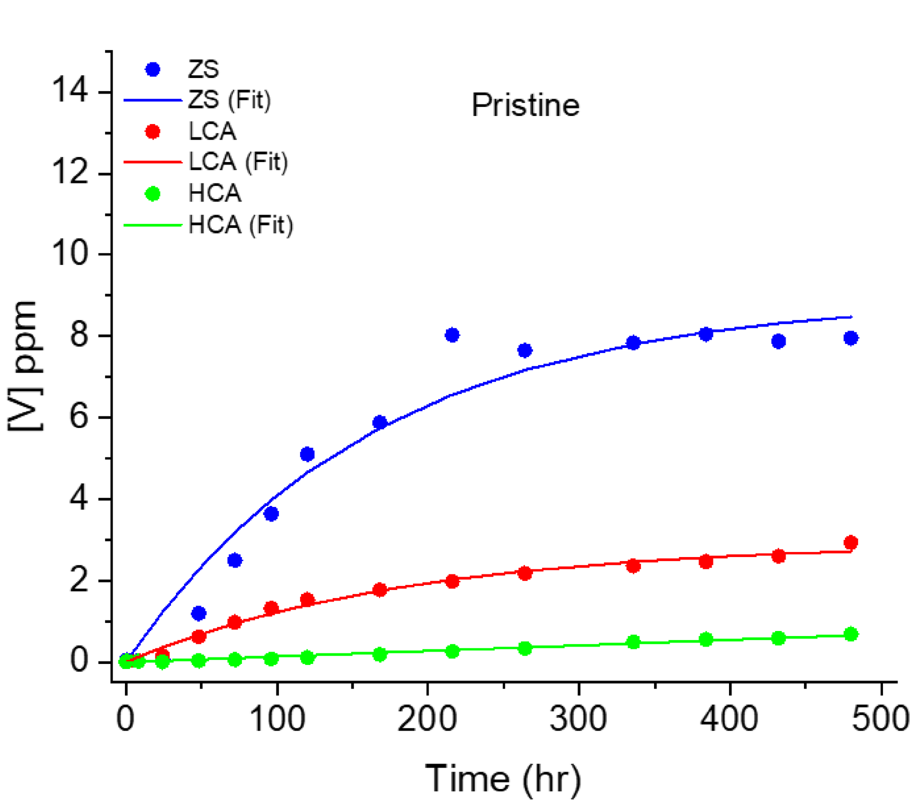

Fig 2: NVO cathode dissolution is suppressed with dual ion Zn-Na electrolytes. ZS = 1 M $ZnSO_4$, LCA = 0.5 M $ZnSO_4$ + 0.75 M Na_2SO_4, HCA = 0.5 M $ZnSO_4$ + 1.75 M Na_2SO_4

RESULTS

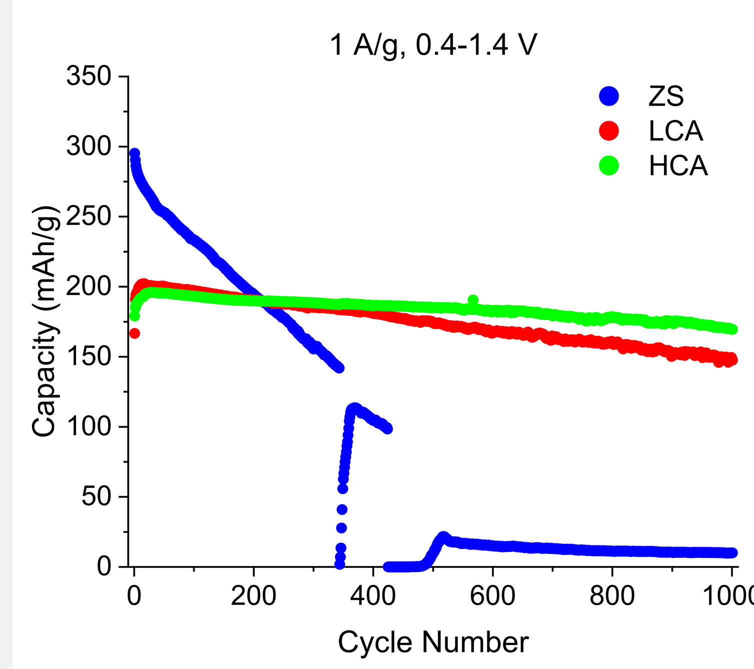

Fig 3: Dual ion electrolytes with higher and lower Na_2SO_4 additive concentrations (LCA, HCA) outperform $ZnSO_4$ electrolyte.

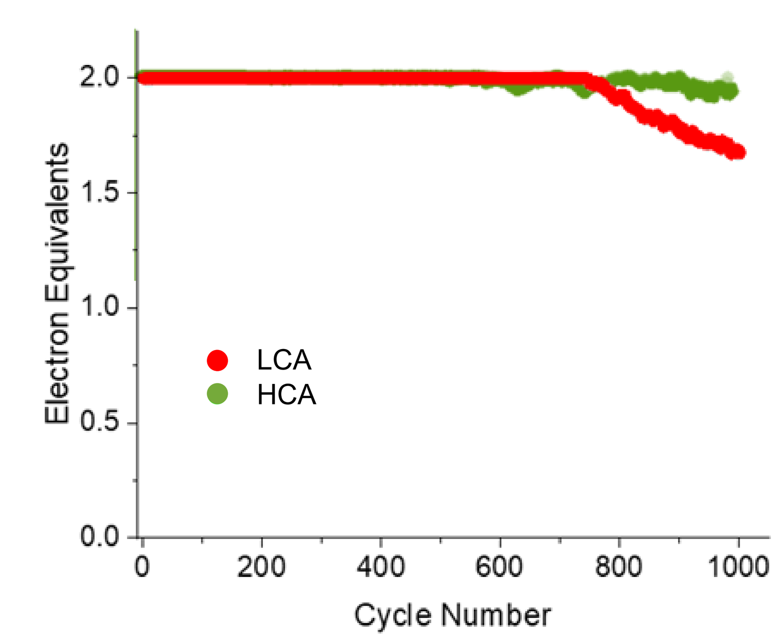

Fig 4: Higher Na_2SO_4 additive concentration (HCA) dual ion electrolyte is beneficial for both Coulombically (above) and voltage (left) controlled cycling.

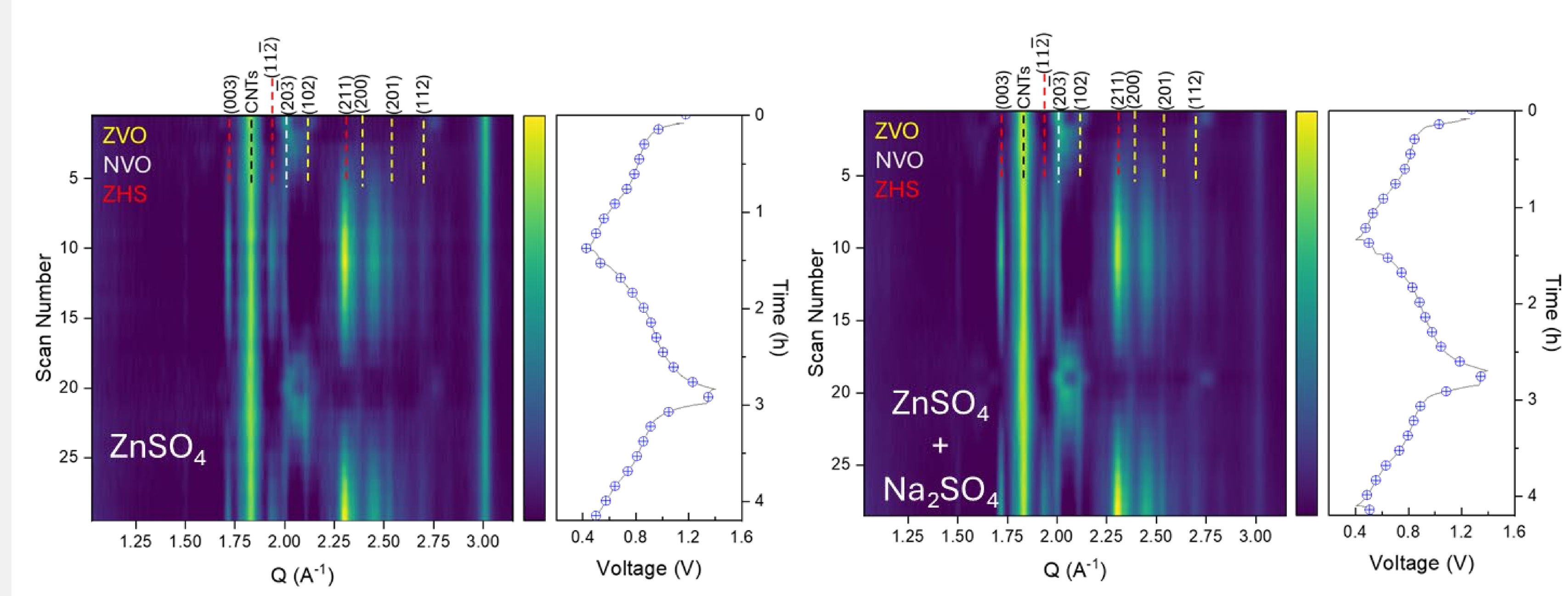

Fig 5: Operando energy dispersive X-ray diffraction (EDXRD) shows consistent NVO structural evolutions of during electrochemical cycling for single ion (Zn) and dual ion (Na-Zn) electrolytes. (left) ZS electrolyte, (right) LCA electrolyte.

CONCLUSIONS & IMPACT

- AZIB cells with low temperature h-NVO cathodes and cost-effective high concentration dual ion zinc-sodium ion electrolytes (HCA) achieved improved capacity retention (87%) with decreased vanadium dissolution.
- Vital electrochemical NVO phase transitions that support the Zn^{2+}/H^+ co-insertion mechanism were not hindered upon introduction of Na_2SO_4.
- AZIB with NVO cathodes and mildly acidic dual ion zinc-sodium ion electrolytes show promise for future safe long-life grid scale storage.

FUTURE DIRECTIONS

- Understand influence of pressure on the NVO AZIB cell system.
- Investigate pH evolution upon electrochemical (dis)charge cycling.
- Study zinc anode structural changes upon cell (dis)charge related to dual-ion electrolyte and NVO cathode properties.

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