Virtual Research Presentation Conference

Extremely High-Energy Density Batteries Using Fluoride-Ion Insertion

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Program: SURP
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Tutorial Introduction

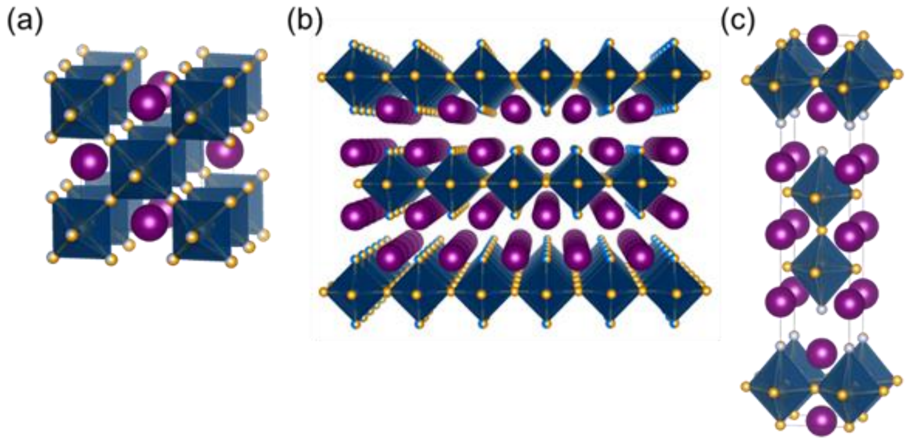
Abstract

A relatively new cell chemistry, the fluoride ion battery, presents a promising battery cell design that offers the potential to significantly exceed the energy density of state-of-practice Li-ion batteries.

The objective of the SURP effort was to demonstrate and develop a new, high energy density battery technology based on fluoride-ion insertion.

The SURP effort builds on prior foundational discovery at JPL and Caltech identifying for the first time a liquid fluoride-ion electrolyte. New electrode materials coupled with the new electrolyte were to be studied in this work.

We identified several classes of materials that could reversibly insert and de-insert fluoride ions, demonstrating functional cells working on this new principle. We have filed an NTR and a Caltech provisional patent based on this work. Carry on funding will be sought through NASA and DOE.



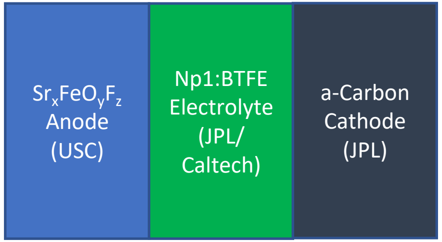
Strontium iron oxyfluorides are very promising fluoride insertion hosts for novel fluoride-ion batteries. a) $SrFeO_2F$, b) Sr_2FeO_3F , c) $Sr_3Fe_2O_5F_2$.

Problem Description

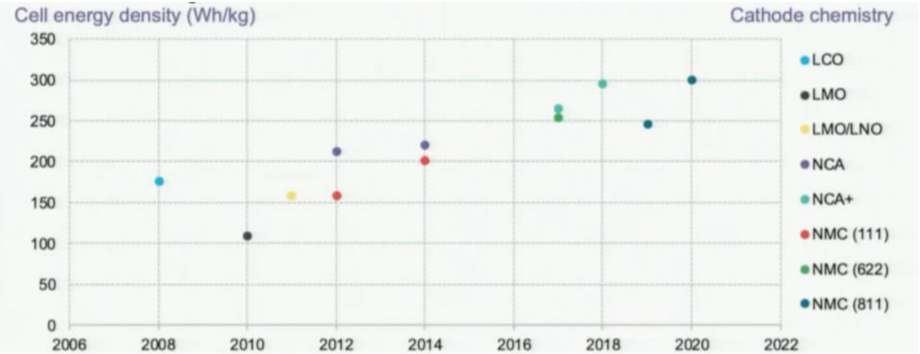
- Context: After several decades of intensive research and commercialization, the energy density of state-of-art Li-ion cell may be approaching an asymptotic limit. The novel fluoride-ion battery presents an entirely new battery cell design that offers the potential to significantly exceed the energy density of state-of-practice Li-ion batteries.

- SOA: Li-ion batteries ≈ 700 Wh/l; first generation FIB have the potential to exceed 900 Wh/l with significant improvements over time in analogy to Li-ion battery advancements

- Relevance: Development of this FIB technology will enable longer run times and greater capabilities for on-board instrumentation, which is key to the success of future missions. In addition, this technology has very significant infusion potential into many terrestrial applications (e.g., transportation, portable devices).



F-ion batteries may exceed state-of-art Li-ion batteries in both energy density and specific energy.

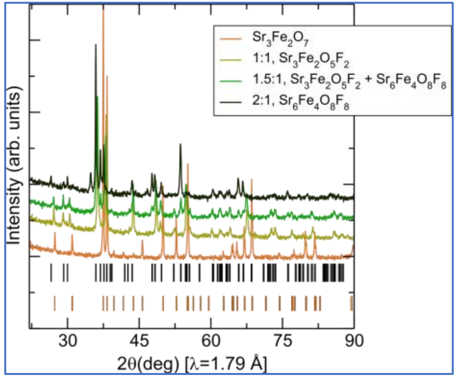


https://cleantechnica.com/files/2020/02/bloomberg-nef-battery-lithium-ion-cell-energy-density-chart-graph-BNEF.png

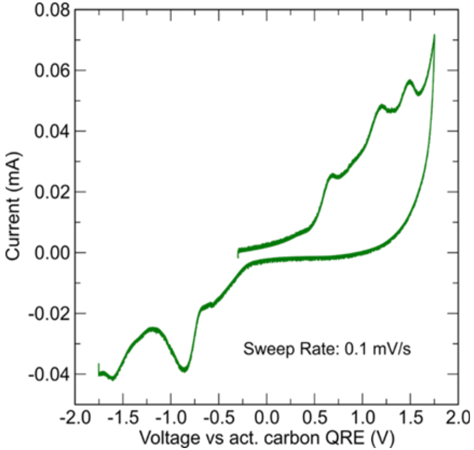
Li-ion battery energy density may be approaching the limits on energy density. Future leaps in performance may come with alternate cathode and anode materials.

Methodology

- Consider perovskite and Ruddlesden-Popper families of materials from the class of strontium iron oxyfluorides as intercalation hosts
  - Intrinsic fluoride ion channels and synthetic tenability
- Also consider BiF_3 as a classic conversion compound
  - Serves as a used to benchmark electrolyte stability over extended cycling
- Prepare Sr-Fe-O-F compounds by two different methods at USC:
  - Allows control the degree of fluorination for sample tuning
  - Sr_2FeO_3F prepared traditional solid-state ceramic methods, with SrF_2 as the F source
  - $Sr_3Fe_2O_5F_2$ prepared by synthesizing $Sr_3Fe_2O_7$ using solid-state ceramic methods and was post-synthetically fluorinated via PVDF decomposition at 300 °C
- Perform a suite of electrochemical and structural measurements on synthesized F-(de)intercalation compounds
  - XRD, CV, EIS, charge/discharge cycling
- Carry out conversion electrode studies of against high-surface area amorphous carbon counter electrodes at JPL
  - Includes ex-situ XRD of charged and discharged BiF_3 electrode to confirm electrochemical reaction mechanisms.



X-Ray diffractograms of various strontium iron oxyfluorides prepared in this study.

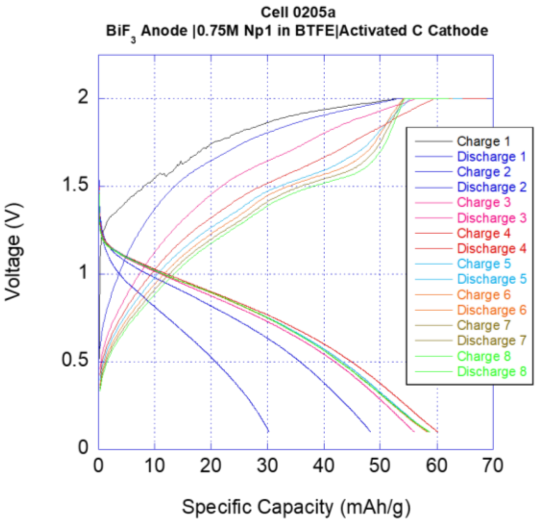


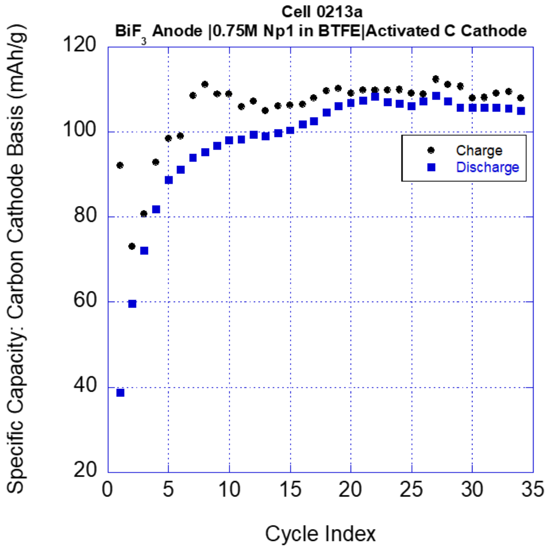
Cyclic voltammogram of Sr_2FeO_3F

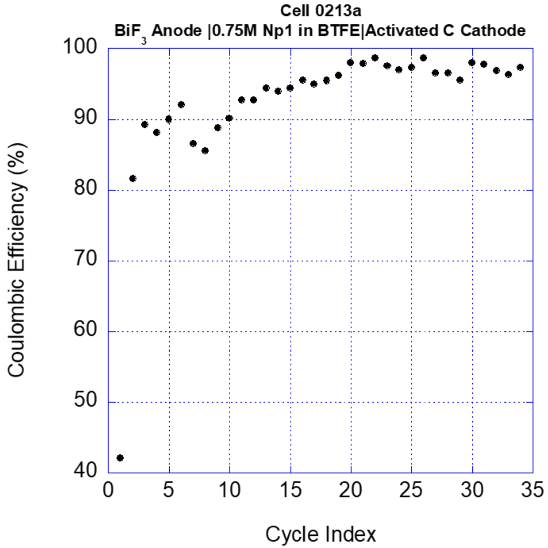
Results

Key Accomplishments

- Developed two synthetic techniques for preparing phase-pure novel F-ion hosts
- Demonstrated reversible intercalation of multiple fluoride ions per unit cell in novel oxyfluoride compounds
- Identified a high-performance counter electrode capable of relatively high Coulombic efficiency







Significance

- A viable F-ion cell has been demonstrated with Caltech/JPL's liquid electrolyte, USC intercalation electrode, and JPL's amorphous carbon electrode.
- The accomplishment sets the stage for further elaboration of the design with higher capacity and higher voltage electrodes

Next steps:

- Complete electrochemical characterization of strontium iron oxyfluorides in full cell configuration
- Carry out operando XRD to directly observe (de) intercalation process
- Publish finding and seek DOE/NASA carry out funding

Publications

1. “Fluoride Ion Capacitor”, William C. West, Stephen A. Munoz, New Technology Report #51526, (2020).
2. “Fluoride Ion Capacitor”, William C. West, Stephen A. Munoz, Provisional Patent Application, CIT File No. CIT-8454-P, (2020).