Development of an Extreme Fast Charging Battery

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Project ID: BAT393

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Overview

Timeline

- Project start date: July 1st, 2018
- Project end date: June 30th, 2020
- Percent complete: 50%

Barriers

- Li plating during fast charge which drastically reduces cell life.
- Low energy density and high cost of fast-charge cells
- Need for strong cooling during fast charge

Budget

- Total project funding
  - DOE share: $1,000,000
  - Contractor share: $112,133
- Funding for FY 2018
  - $ 560,484
- Funding for FY 2019
  - $ 551,649

Partners

- Project lead
  - PSU
- Interactions/collaborations
  - ANL

Relevance / Objectives

Overall Objective

- Develop extreme fast charge (XFC) cells can meet the following target simultaneously:
  - Recharge to 80% state of charge (SOC) within 10 minutes
  - Cell-level specific energy ≥225 Wh/kg
  - Cost <$150/KWh
  - Cycle life >1000 cycles at 20% capacity fade

Objective in this period

- Develop Gen-1 XFC cells with an energy density >200 Wh/kg that can sustain >1000 cycles of 6C charge to 80% SOC at <20% capacity fade.

Impacts

- Governments and companies worldwide are pushing for deployment of 350kW fast charging stations. No battery electric vehicles (BEVs) as of today can accept 350 kW due to restrictions of battery technology. Meeting the technical target of this project will enable 350 kW charging of BEVs.

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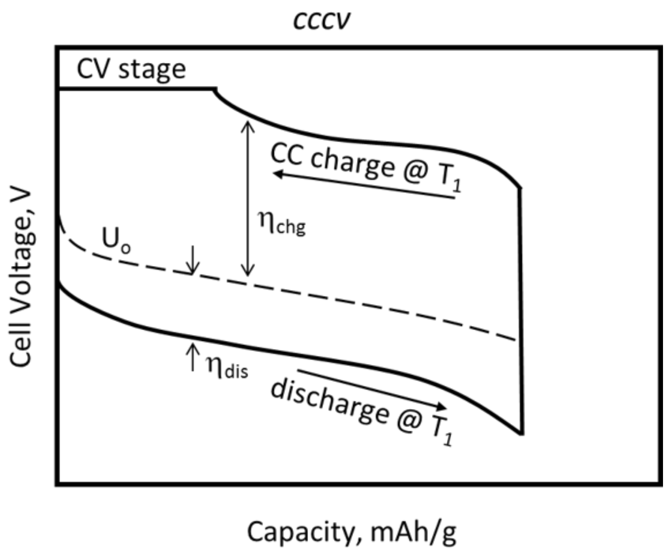
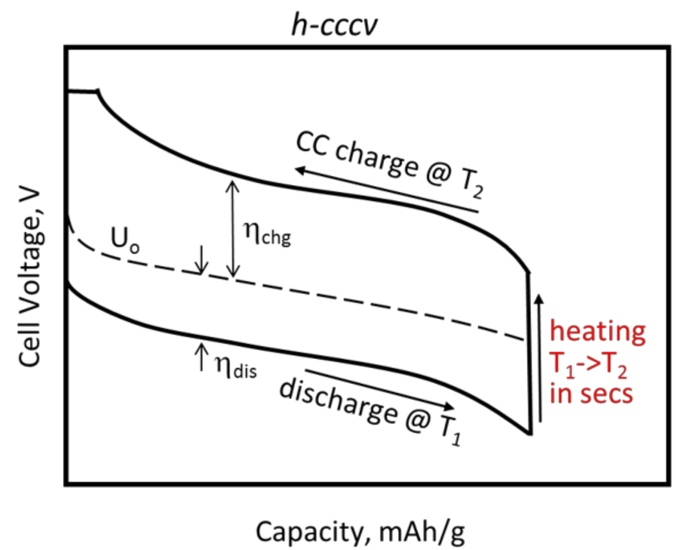
Milestones

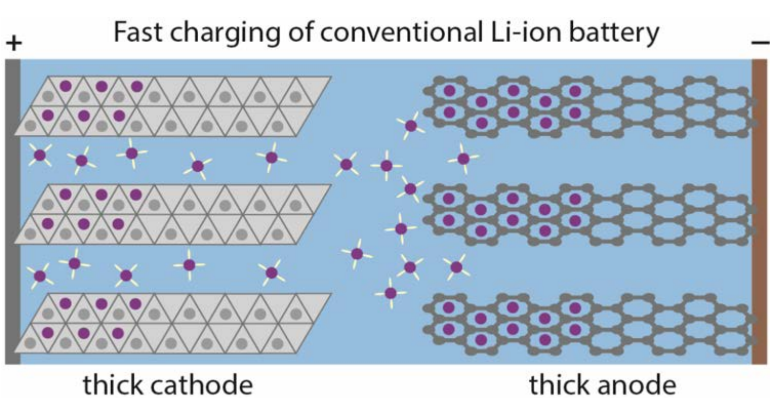
	Milestone	Status
Q1	Design of Gen-1 XFC cells; screening commercial graphite and NMC materials and conduct characterization test of selected materials.	Completed
Q2	Fabrication of Gen-1 XFC cells and conduct performance test.	Completed
Q3	Cycling testing of 6C fast charging of Gen-1 XFC cells	On track
Q4	Demonstrate that Gen-1 XFC cells having an anode areal capacity of 3 mAh/cm^2 can sustain >1000 cycles of 6C charge to 80% SOC with <20% capacity loss. (Go/No-Go). Delivery of 9 Gen-1 XFC cells in 5Ah format.	On track

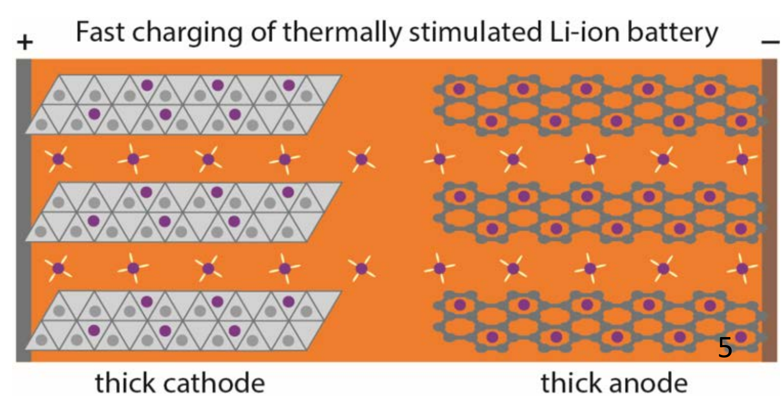
Approach

- We propose a new strategy to charge a Li-ion cell at a high temperature (40-60^{o}C) to eliminate lithium plating
- The cell stays at high temperature only during charge (~10-min per cycle)
- Heating time is <1-min (heating speed is >1^{o}C/sec)



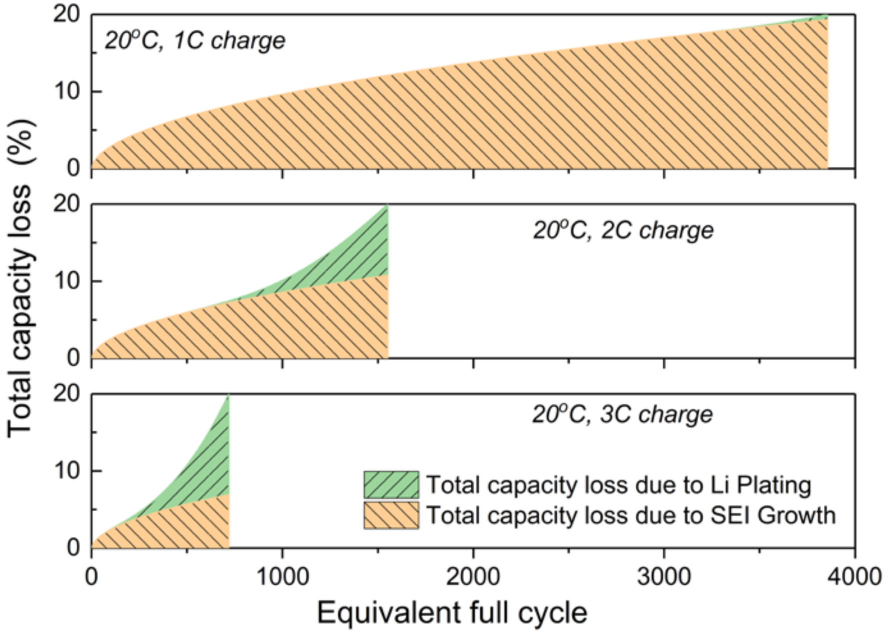


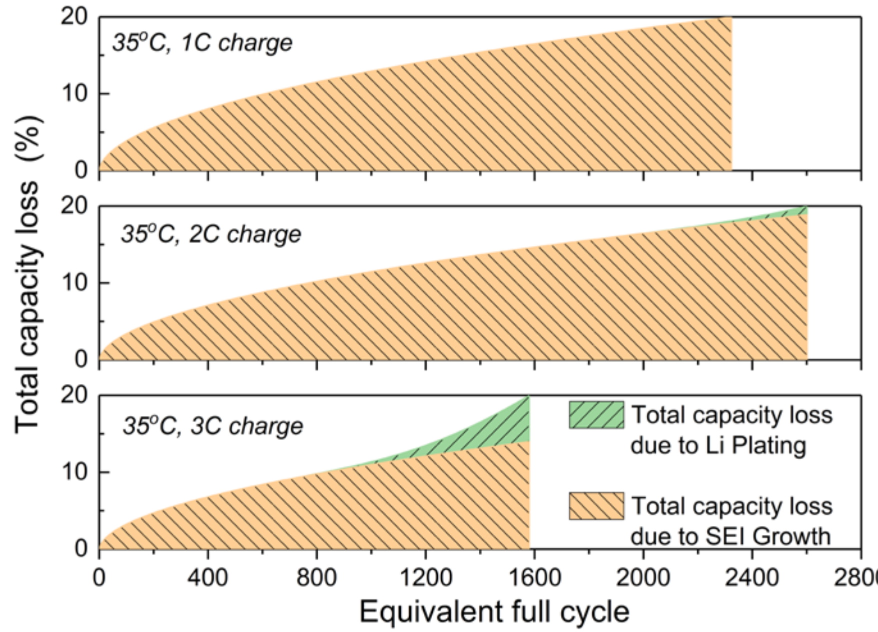




Technical Accomplishments and Progress

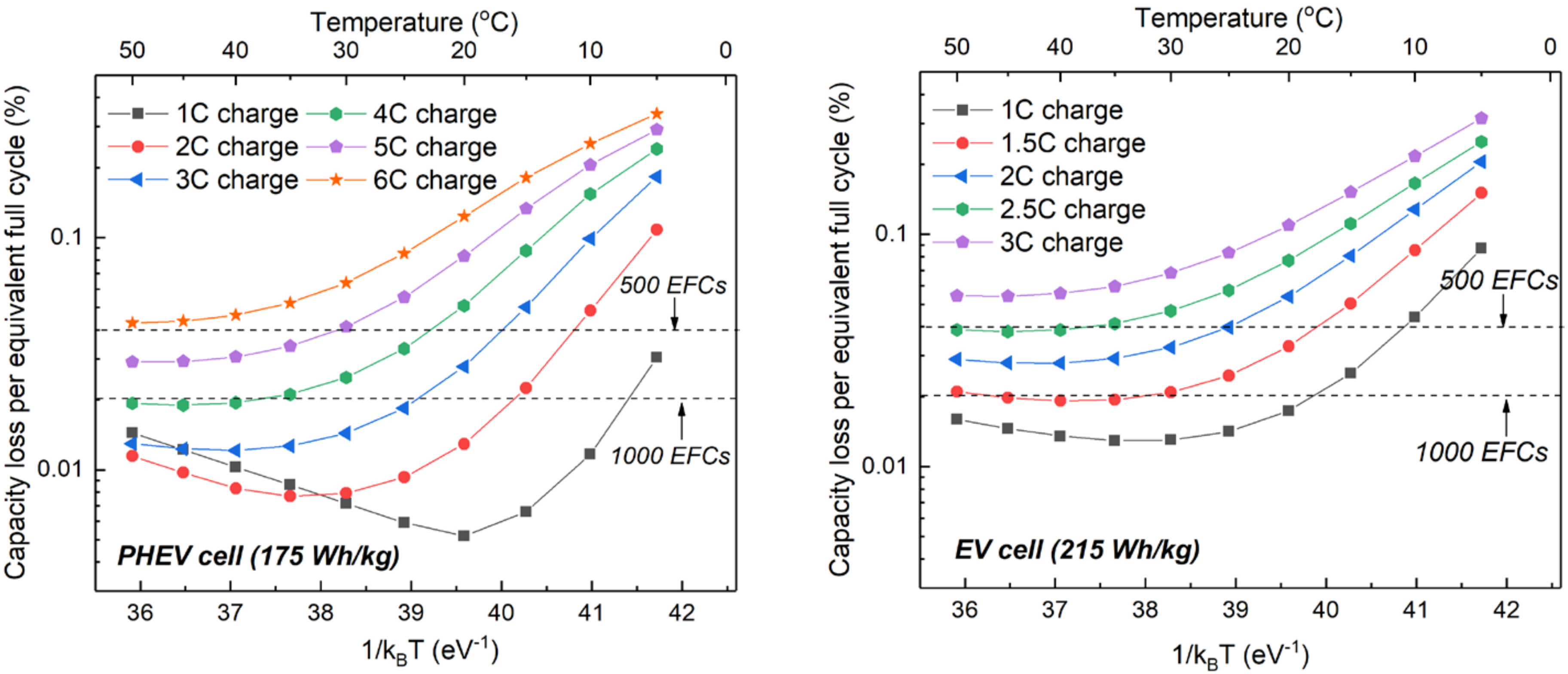
- ✓ We developed a numerical model that can predict capacity loss induced by lithium plating and SEI growth.
- ✓ Overall cycle life depends on the trade-off btw lithium plating and SEI growth.
- ✓ Onset of lithium plating leads to rapid capacity fade.
- ✓ Elevating operating temperature postpones the onset of lithium plating.





X.G. Yang and C.Y. Wang (2018).J. *Power Sources*, *402*, 489-498.

We propose, for the first time in the literature, that elevating charge temperature is an effective method to solve the trilemma of fast charging, energy density and cycle life



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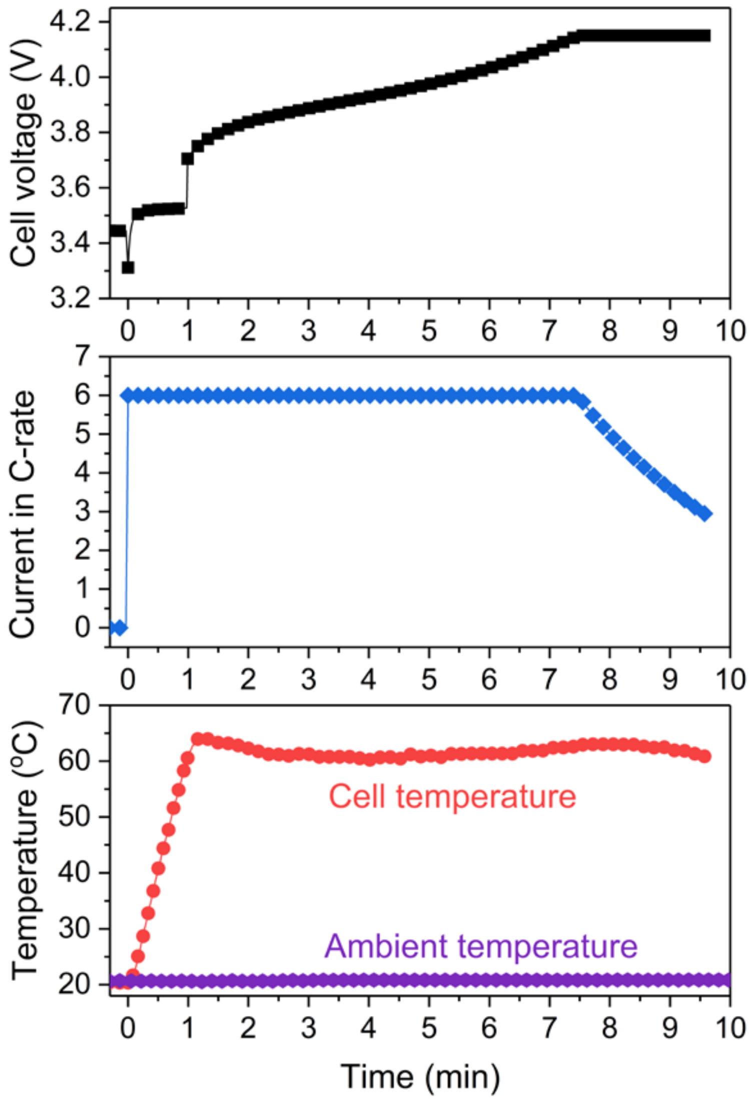
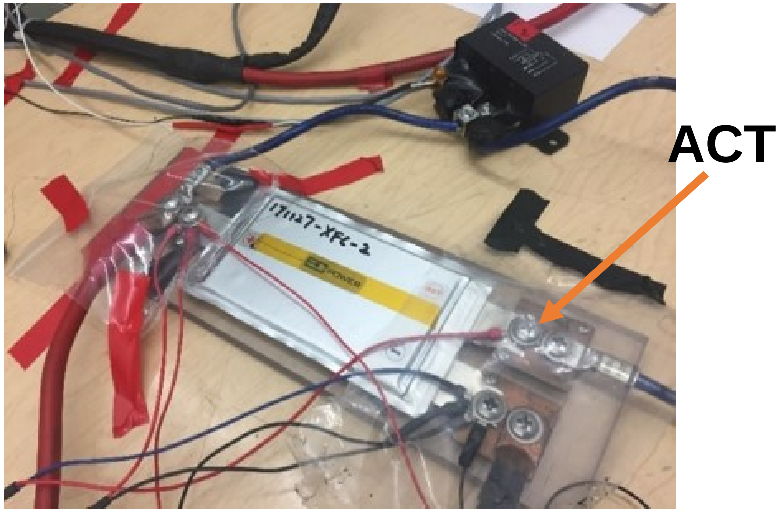
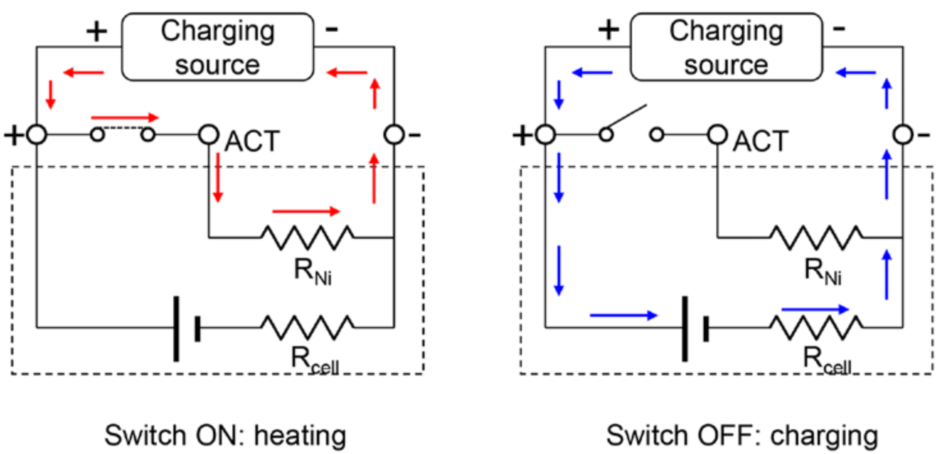
Technical Accomplishments and Progress

Rapid heating by using the self-heating battery structure enables 10-min (including heating time) recharge to 80% SOC.





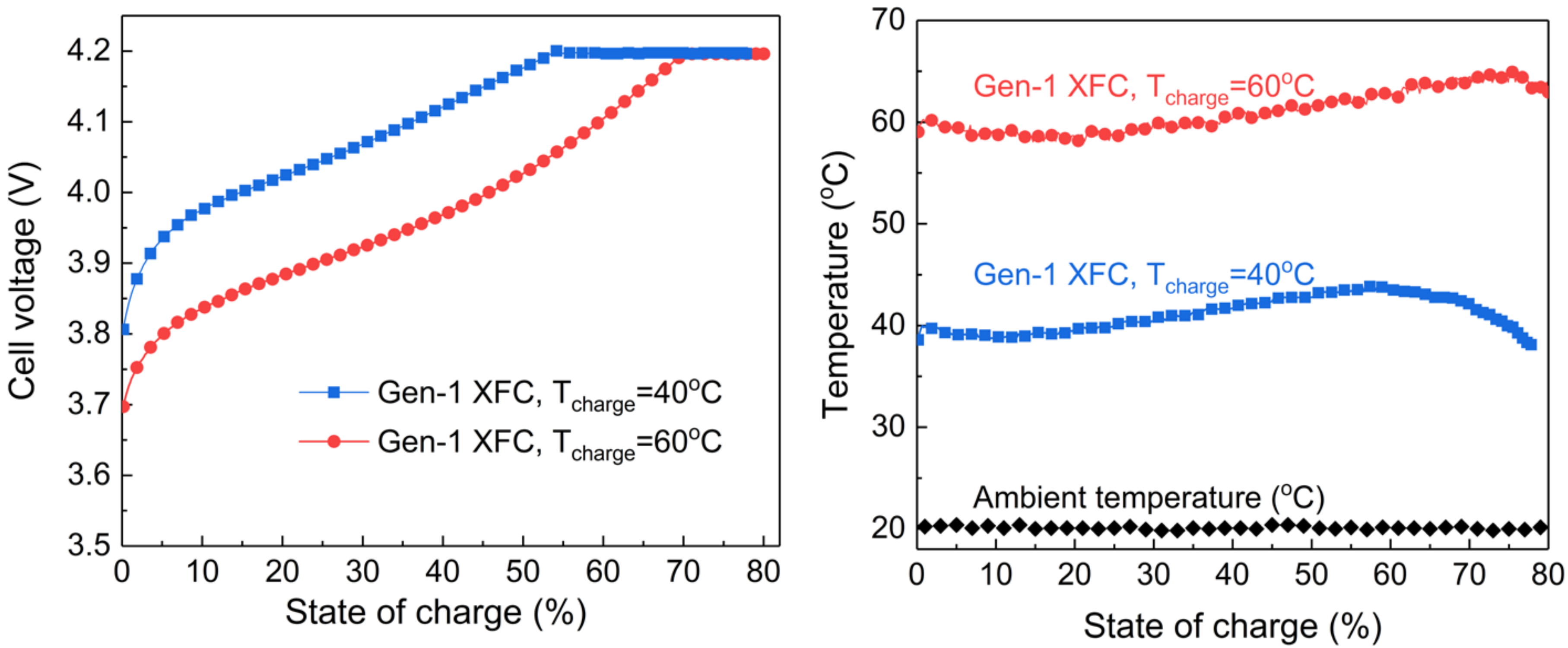
10.5-Ah Gen-1 XFC cell



Working principle

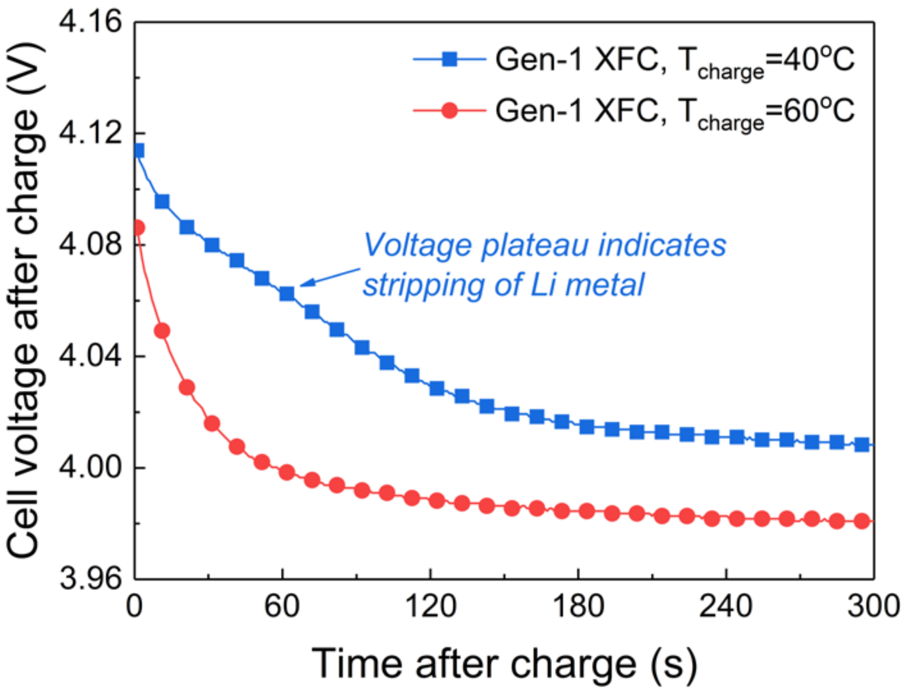
Technical Accomplishments and Progress

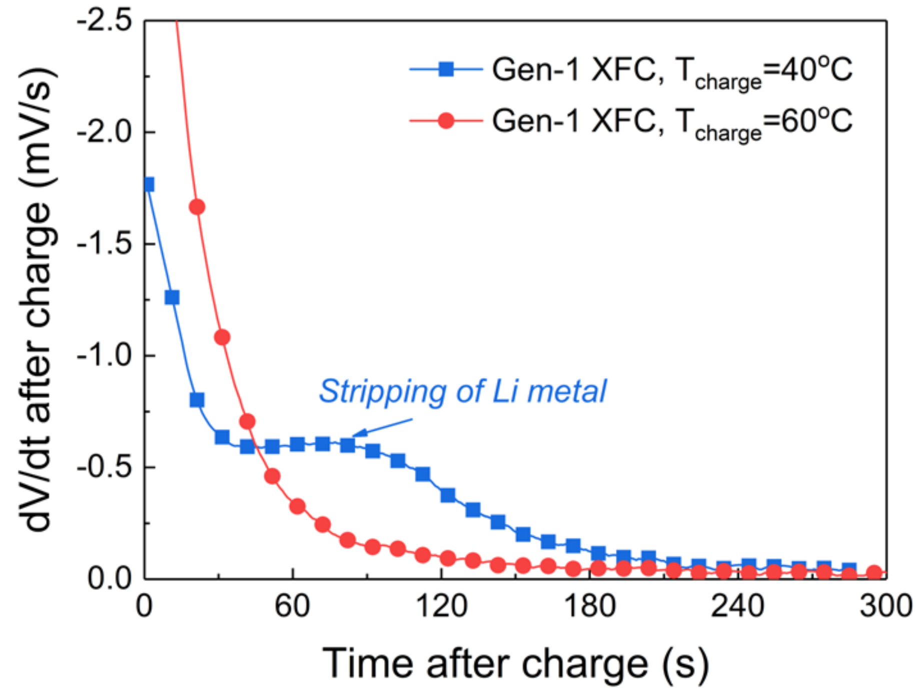
Charge at elevated temperature reduces the need for strong cooling



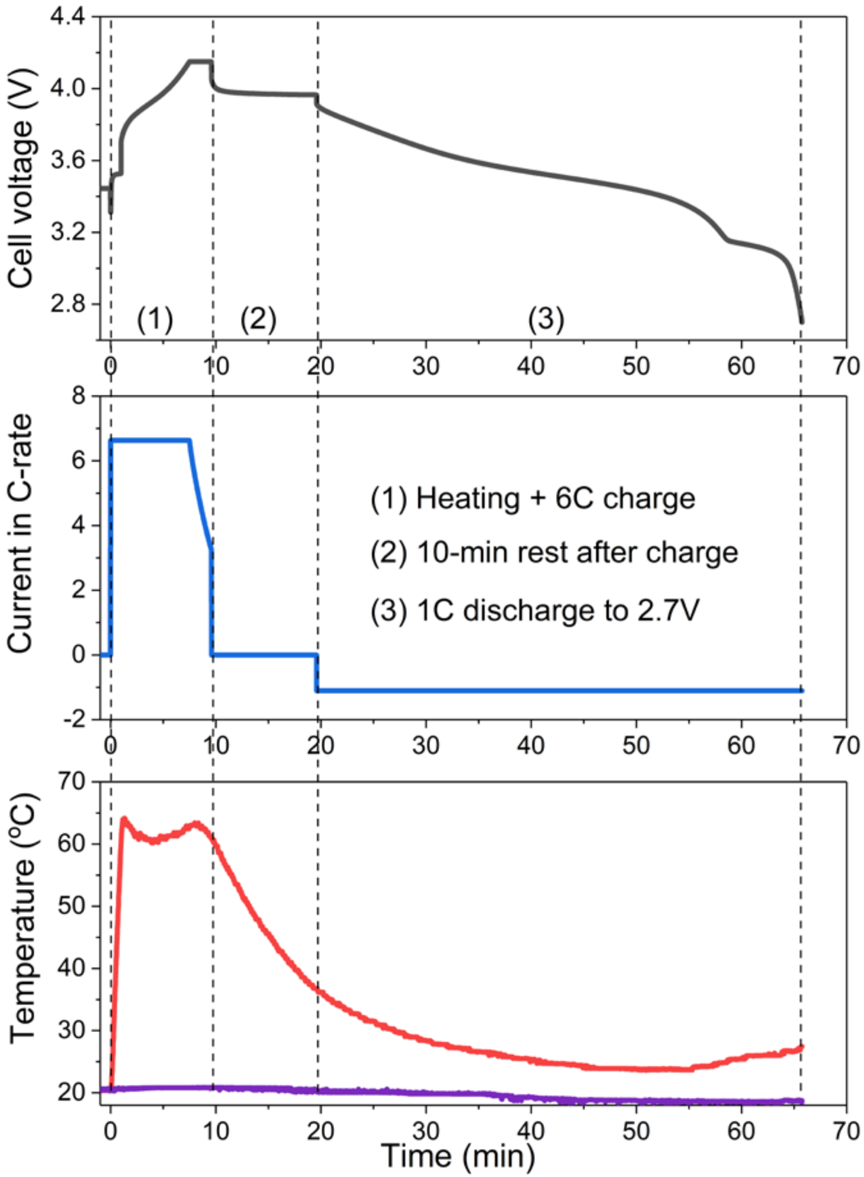
- ✓ Heat generation I^2*R is reduced due to the lower resistance at high T.
- ✓ Heat dissipation rate $h*(T_{cell}-T_{amb})$ is greatly enhanced by the larger temperature difference

Elevating charge temperature effectively eliminates lithium plating.

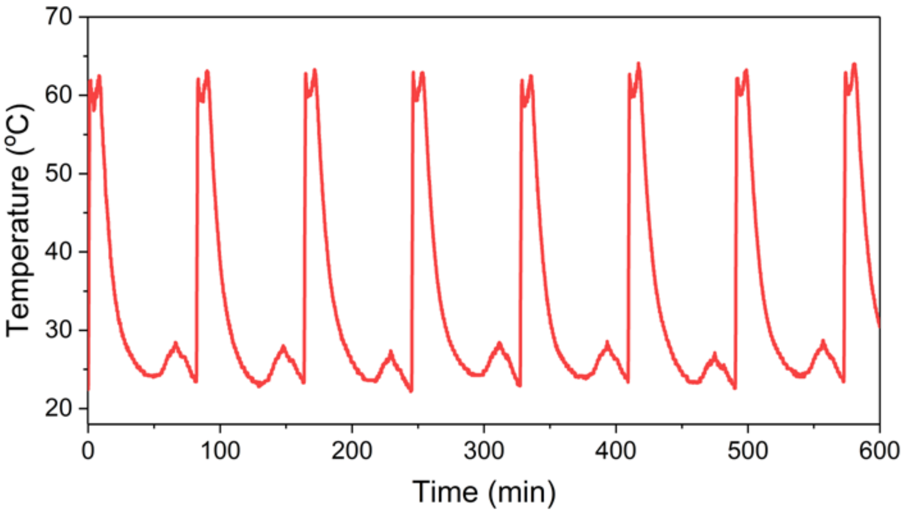




Technical Accomplishments and Progress



Cycling test protocol

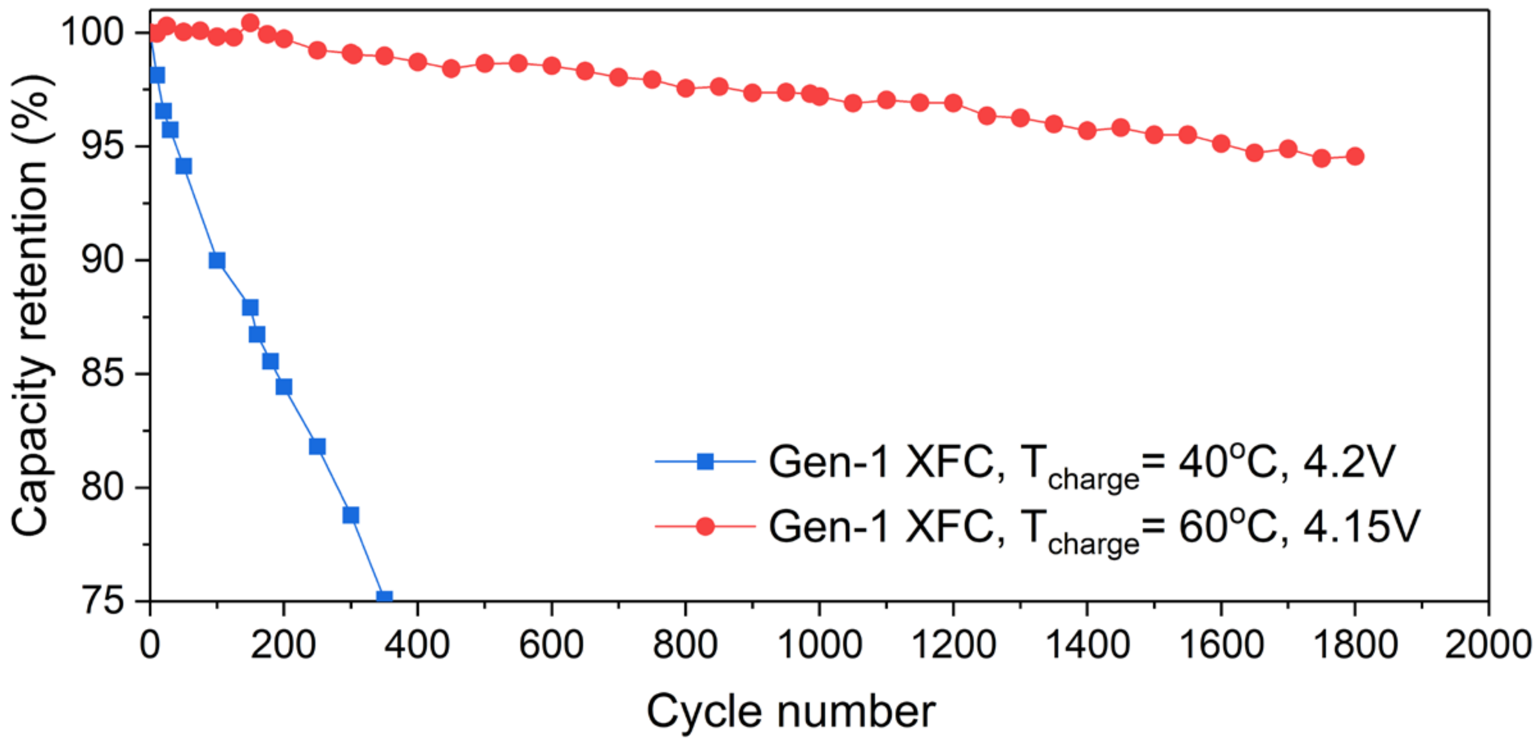


Temperature evolution over
8 XFC cycles

The cell is exposed to 60°C only ~10 minutes per cycle, which can effectively suppress SEI growth.

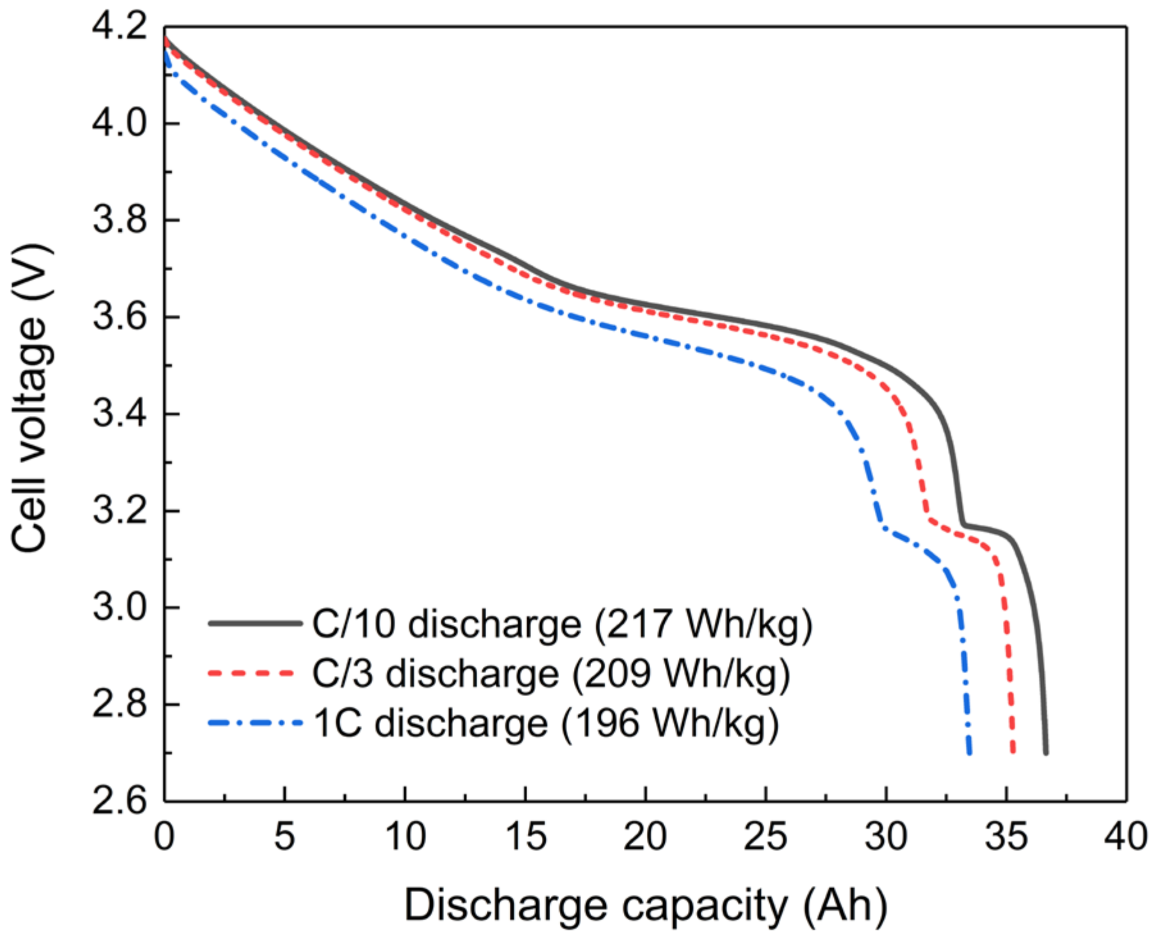
Technical Accomplishments and Progress

By elevating the charge temperature to 60ºC, the Gen-1 XFC cells retain 94% capacity after 1800 cycles of 6C charge to 80% SOC



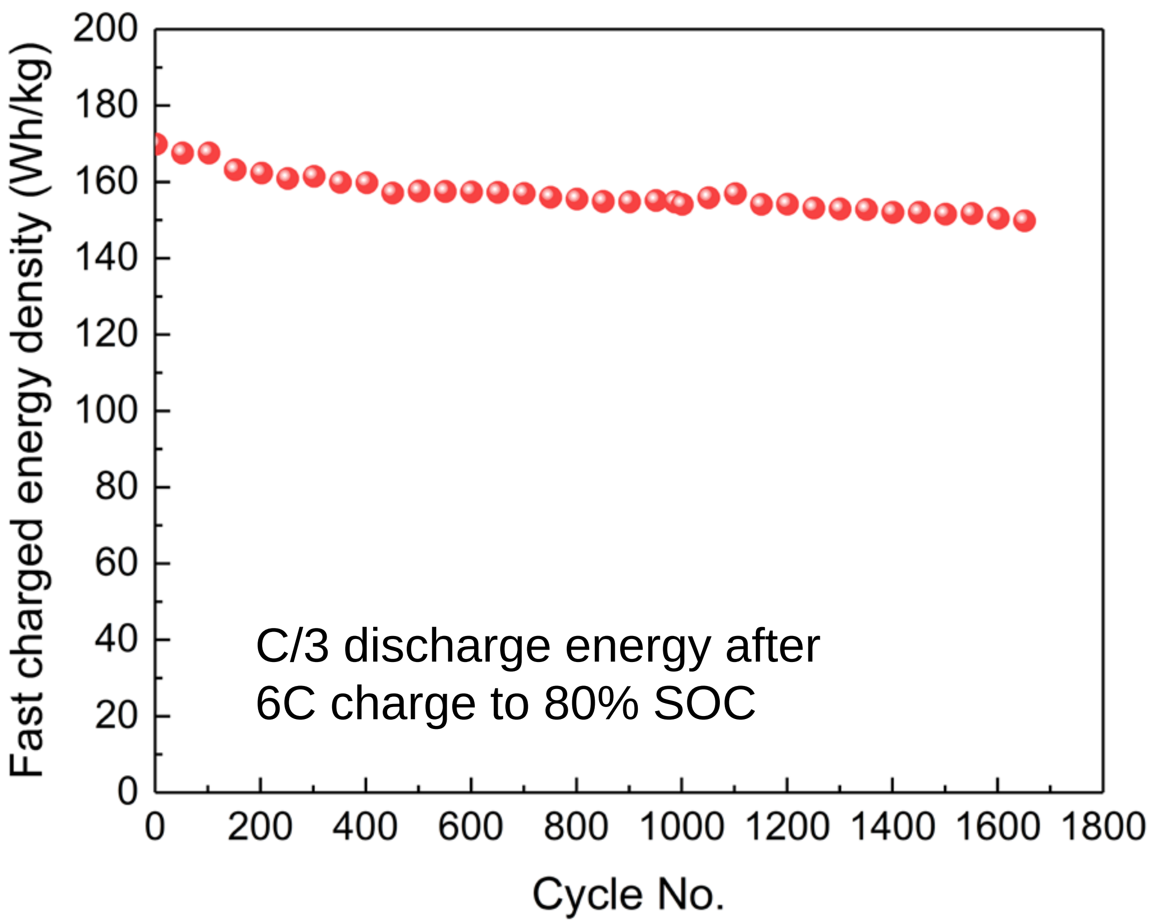
Technical Accomplishments and Progress

In 35-Ah configuration, Gen-1 XFC cell can deliver an energy density of 217 Wh/kg at C/10 discharge and 209 Wh/kg at C/3 discharge



Technical Accomplishments and Progress

In 35-Ah configuration, Gen-1 XFC cell gives a C/3 discharge energy of 170 Wh/kg after 6C charge to 80% SOC, which is close to the DOE target (180 Wh/kg)



Responses to Previous Year Comments

- This project is a new start.

Partners/Collaborators

- Collaboration with Dr. Donghai Wang at PSU for development of novel binders to enhance the electron and ion transport through thick electrodes.

- Collaboration with Dr. Zhengcheng Zhang at ANL for development of new electrolyte and additives to improve the electrolyte's thermal stability and increase tolerance to high temperatures.

Remaining Challenges and Barriers

Lithium plating

- Gen-2 XFC cells will have a thicker anode with a higher anode loading (~4.0 mAh/cm^2), which makes lithium plating more prone to occur. Charge temperature may be further elevated to >60^{o}C in order to eliminate lithium plating.

High temperature stability

- Gen-2 XFC cells will utilize NMC811 as cathode materials; its thermal stability at high temperatures could be an issue and will be investigated in detail.
- New electrolyte and additives will be evaluated to protect cathode materials as well as suppress anode SEI growth.

Proposed future research

- Fabricate Gen-2 XFC cells using graphite as anode materials and NMC811 as cathode materials. The cells will have an anode loading **>4mAh/cm^2** and achieve a cell-level energy density **>225 Wh/kg**.

- Optimize the charge temperature to make sure that lithium plating can be eliminated and SEI growth is not serious.

- Develop new electrolytes and additives that can improve the thermal stability of anode, cathode and electrolyte at high temperatures (>60^{o}C).

- Demonstrate that Gen-2 XFC cells will meet the DOE target: a C/3 discharge energy of >180 Wh/kg after 10-min fast charge.

Any proposed future work is subject to change based on funding levels

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Summary

- We presented a heated charge method and demonstrated that elevating the charge temperature to ~60^{o}C can effectively eliminate lithium plating during 6C extreme fast charge.
- Gen-1 XFC cells, having an anode loading of 3 mAh/cm^2, can deliver a C/3 discharge energy of 170 Wh/kg after 6C charge to 80% SOC.
- Gen-1 XFC cells sustained 1800 cycles of 6C charge to 80% SOC with only 6% capacity fade.