New High-Energy & Safe Battery Technology with Extreme Fast Charging Capability for Automotive Applications

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Microvast, Inc.

Annual Merit Review

DOE Vehicle Technologies Program

Washington, DC

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Project ID#: BAT395

Overview

Timeline

- Project Start Date: Jul 2018
- Project End Date: July 2020
- Percent Complete: 35%

Budget

- Total Project Funding
  - DOE Share: 50%, 1.5M USD
  - Contractor Share: 50%, 1.5M USD
- FY 2018
  - DOE: $786,053
  - Contractor: $829,200
- FY 2019
  - DOE: $713,947
  - Contractor: $670,800

Barriers Addressed

- Extreme fast charge (XFC) cell cycle life
- XFC cell energy density
- Cell abuse tolerance

Partners

- Argonne National Labs
  - Khalil Amine, Zonghai Chen, Tongchao Liu, Jihyeon Gim, Chi Cheung Su
- BMW
  - Peter Lamp, Odysseas Paschos, Forrest Gittleson
- Interactions/collaborations
  - Yang Ren, Lui Li (ANL APS)
  - Jianguo Wen, Duan Luo (ANL CNM)

Relevance

Goal: Research, fabricate and test cells up to 260-300 Wh/kg capable of 500 XFC cycles with < 20% energy density loss.

Overall Objectives:

- Design, build and test safe, high energy XFC cells using new cathode and electrolyte materials to improve safety and/or impedance rise in high energy XFC cells
- Demonstrate XFC cells using both pouch and prismatic large format automotive cells

FY 2018 Objectives:

- Go/No-go – Deliver 20 AH cells (Gen1, ~220 Wh/kg) that PASS 500 XFC cycles
- Build pouch and hard can large format cells using identical XFC electrodes
- Select high-Ni gradient cathode for use in next round of higher energy (Gen2) XFC cells

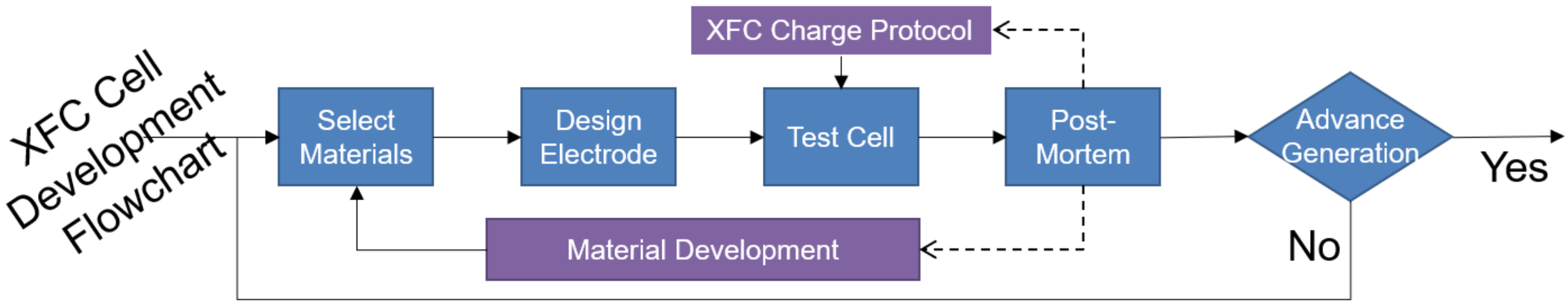
Impacts:

- Research that improves the understanding of cell failure during XFC cycling, and innovations that may solve the identified issues
- Developing technology that would enable EV cars to recharge at similar rates to gasoline vehicles, improving the convenience for consumers
- XFC capable cells may accelerate adoption of EVs for commercial fleet vehicles that could now run continuously

Milestones

Milestone	Target End Date	Description	Milestone Progress
Gen1 Build Complete	10/3/2018	At the start of project, a baseline cell will be designed by project partners.	Complete
Gen1 Analysis Complete	1/3/2019	The final analysis on Gen1 cell will be complete, and the technology gap will be known to aid additional cell development	Complete
Gen2 FCG-VS Selected	4/3/2019	The cathode material process for use in Gen2 cells is complete	Complete
Deliver 9 cells to DOE	7/3/2019	Upon completion of budget period one 9 cells (Gen1 or Gen2) will be delivered to the DOE for cycle testing	In Progress
Go/No Go Decision Point	Go/No Go	Gen-1 cells PASS 500 cycles 6C charge*/1C discharge cycle requirements (see FOA for * details)	Not-started
Ageing Study Complete	10/3/2019	The findings of spent cell diagnostics are done for Gen2 cell	Not-started
>10 kg Cathode Scale-up	1/3/2020	The newly designed cathode is scaled to at least 10kg	Not-started
Low impedance Additive	4/3/2020	The new additive designed to limit impedance rise in the cell is determined	Not-started
Gen3 Build Complete	7/3/2020	The final Gen3 pouch and can cells completed Gen3 TRL4 to TRL5	Not-started

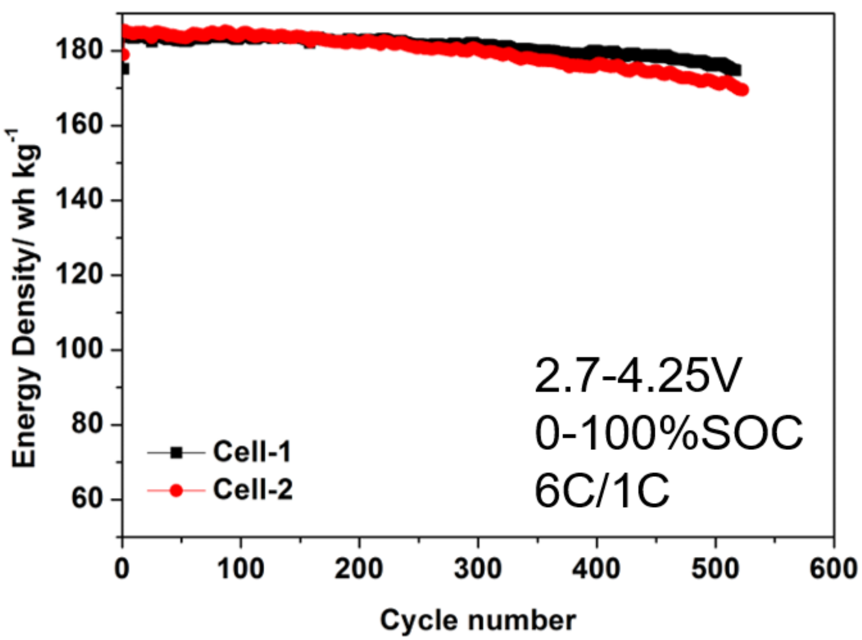
Technical Approach

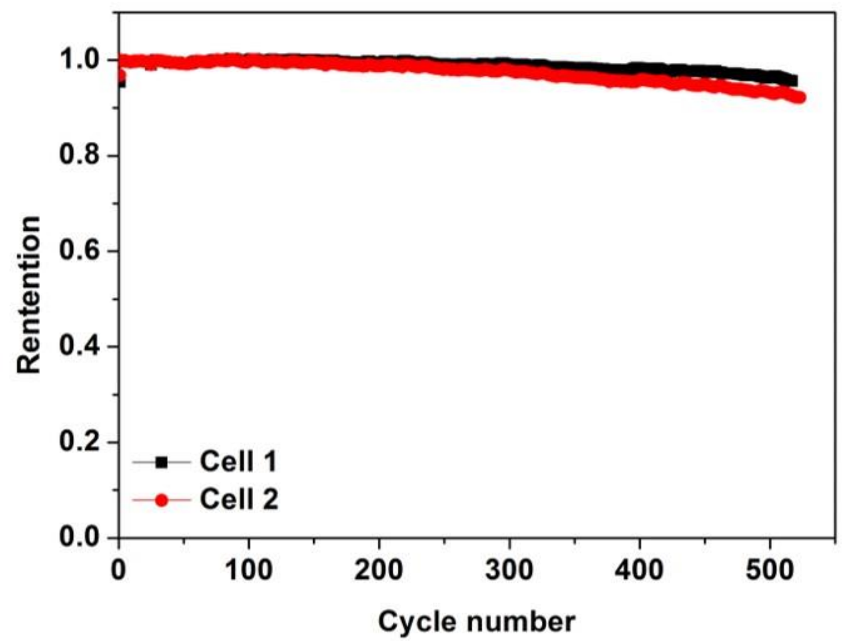


- Build 3 rounds of XFC cells; each round increasing in energy density
  - Use identical electrodes to compare pouch (stacked electrode) vs. hard can (jelly roll) cell design
  - Following XFC testing perform post-mortem to ID fail mechanism
- Develop materials for use in later generation cells
  - Low impedance electrolyte additive
  - High-Ni concentration gradient cathode

15AH XFC Cell

- 200 Wh/kg (0.33C) pouch cell only using materials from MV commercial fast charge product
- >90% capacity retention after 500 cycles of 10-minute fast charge, 1C discharge





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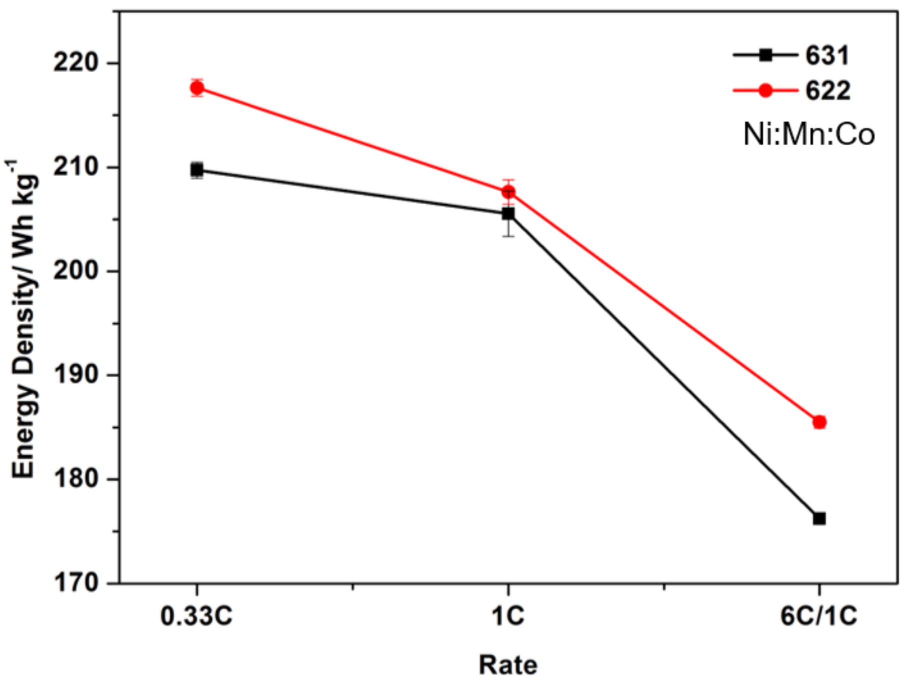
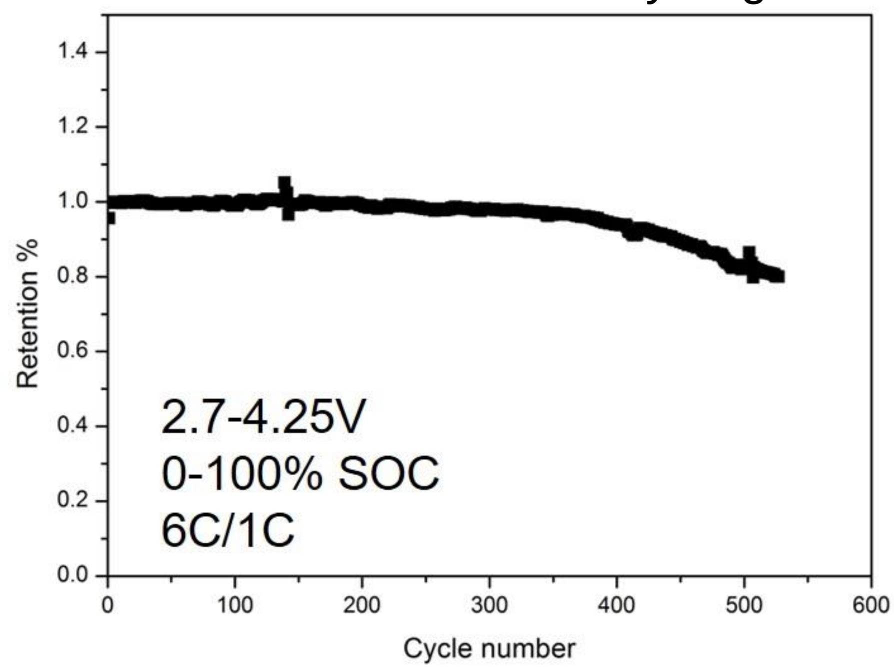
Pouch Gen1 XFC Cell

- 22AH, 220 Wh/kg cells are being prepared and tested under standard and XFC cycle conditions
- Exploring influence of cobalt on XFC cell performance
- Energy density retention near 80% after 500 cycles



631FCG XFC Cell Cycling



*6C represents < 10 minutes charge

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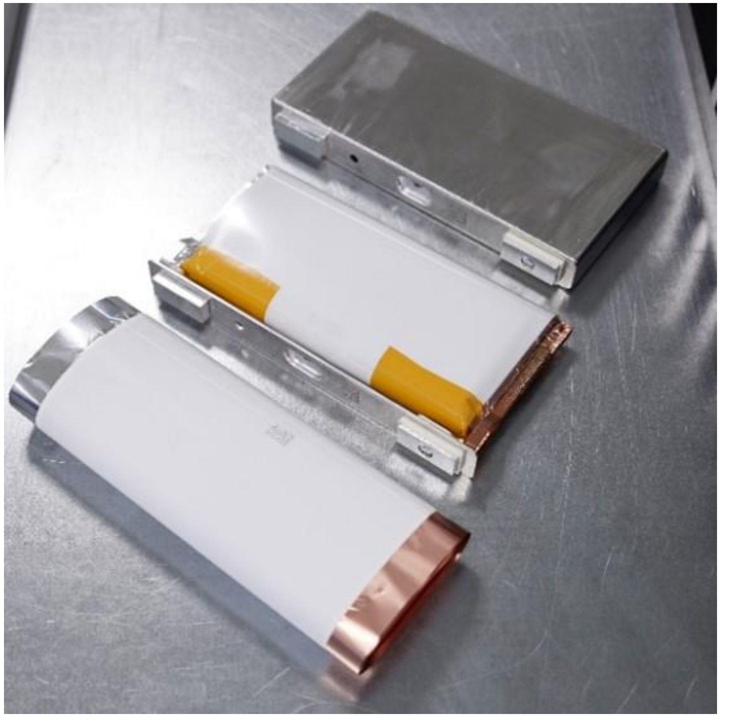
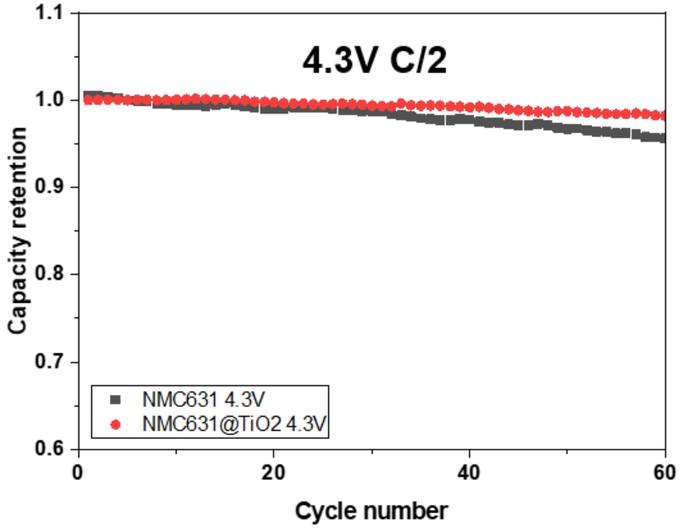
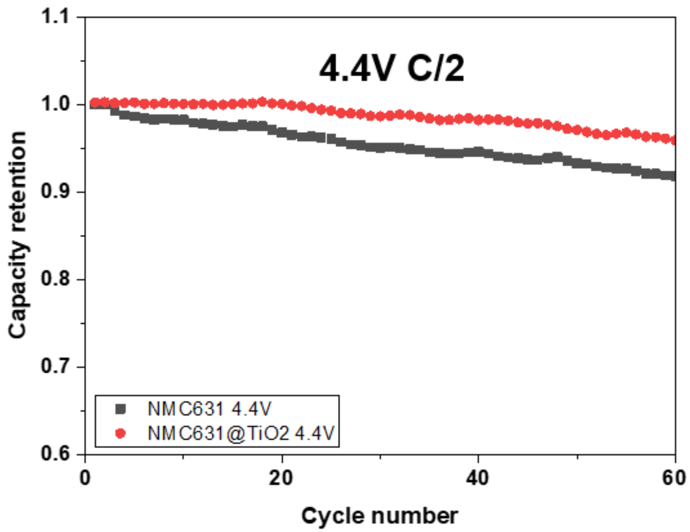
Prismatic Gen1 XFC Cell

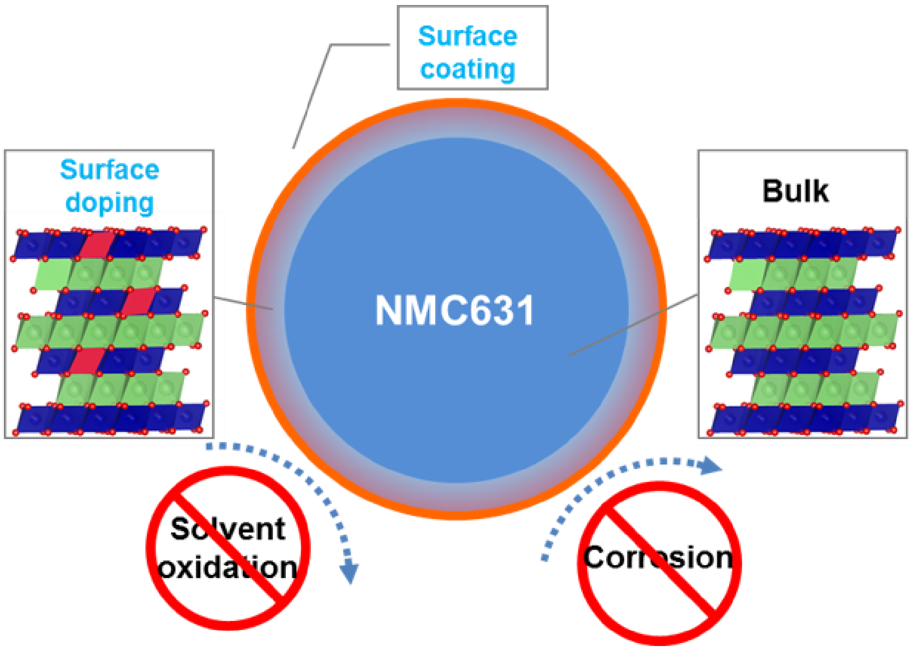
- Hard can cells successfully assembled using Microvast FCG cathode and graphite anode in PHEV1 format (24 Ah)
- Jelly-roll winding of electrodes necessitates well aligned coatings, good roll integrity
- Preliminary cell design: 180 Wh/kg
  - Further optimization in Gen2 and Gen3 to increase energy density >200 Wh/kg in hard can format
- Baseline performance and fast charge testing ongoing



Gen1 Cathode Surface Protection





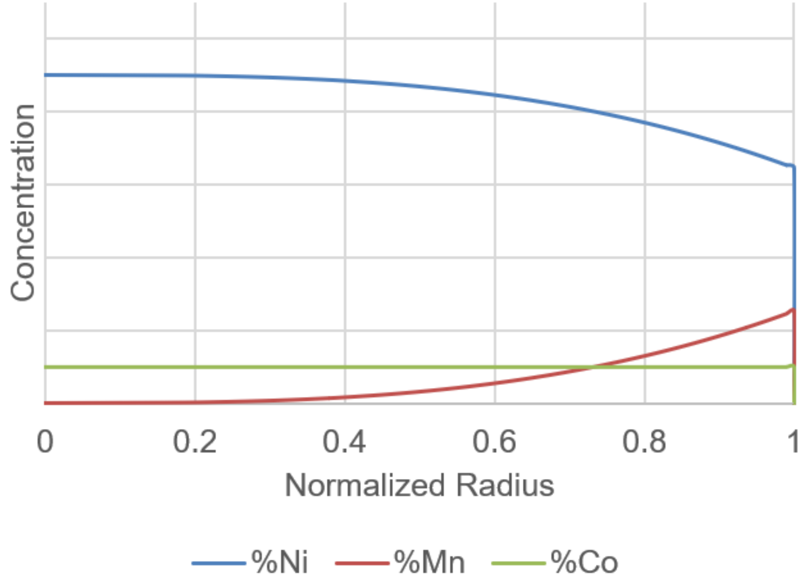


- Surface TiO_2-coating / Ti-doping
- Significantly improving stability at high potentials

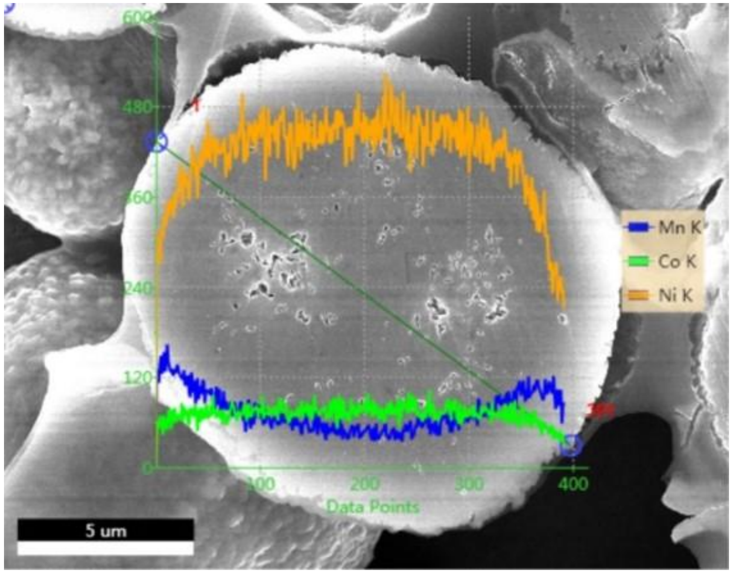
Gen2 Cathode Selected

- Full concentration gradient cathode material
- C/10 capacity (2.7-4.4V) is ~210 mAh/g

Concentration Gradient Design Profile



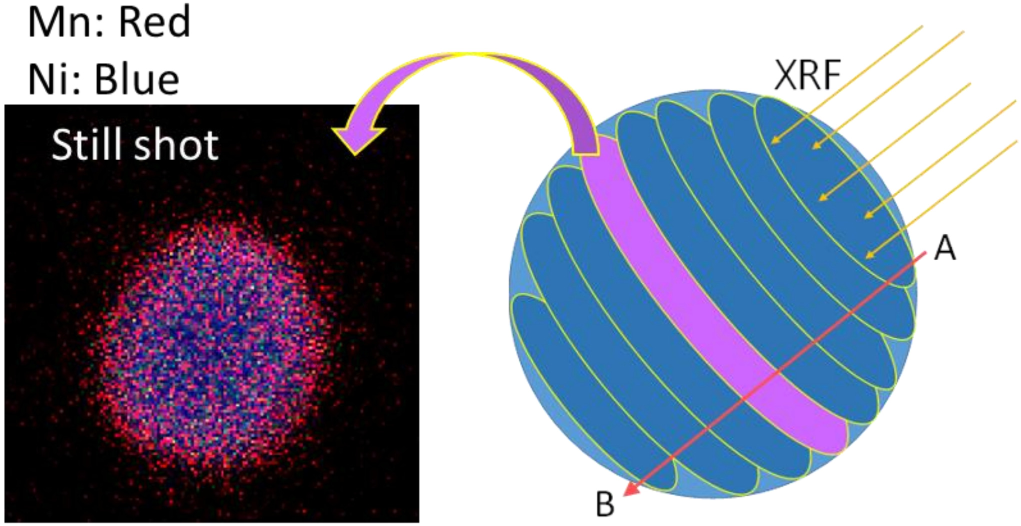
EDS Line Scan of Cross Sectioned Cathode Particle

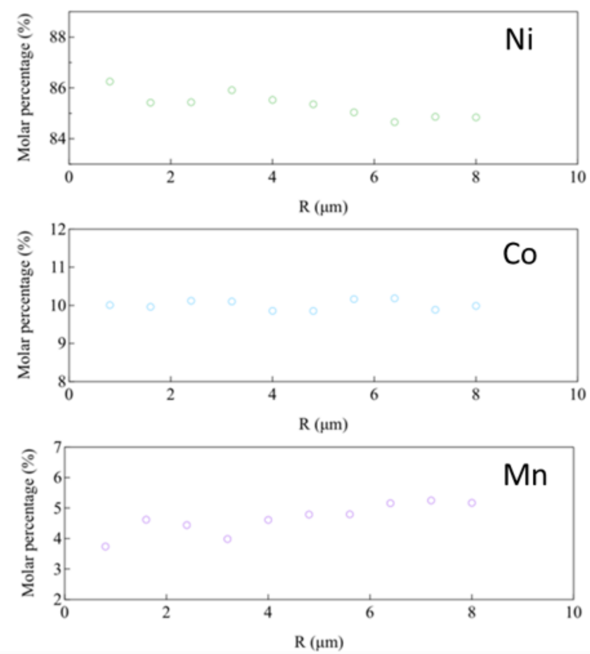


Shallow Gradient Control for High Energy

- High nickel concentration gradient cathodes require shallow gradients to keep average Ni content high
- Confirmed gradients still exist after calcination x-ray fluorescence element mapping
  - Advanced Photon Source (APS) Beamline 2 ID-E

Mn: Red
Ni: Blue





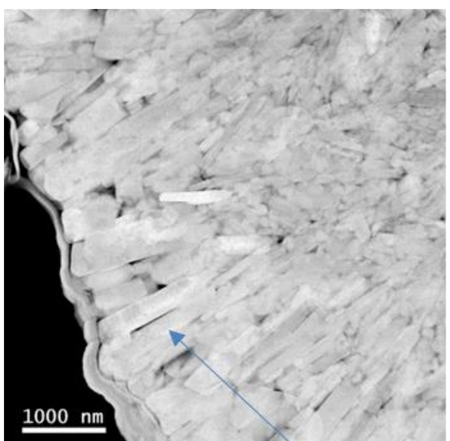
Ni ↓

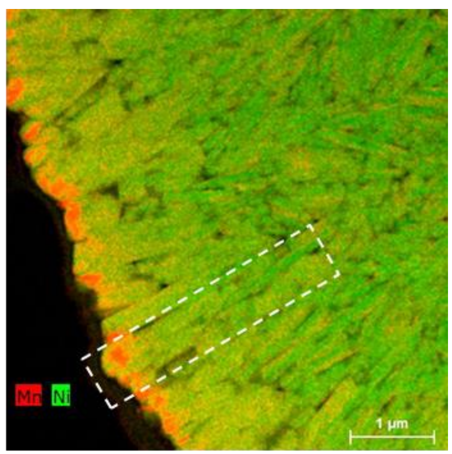
Mn ↑

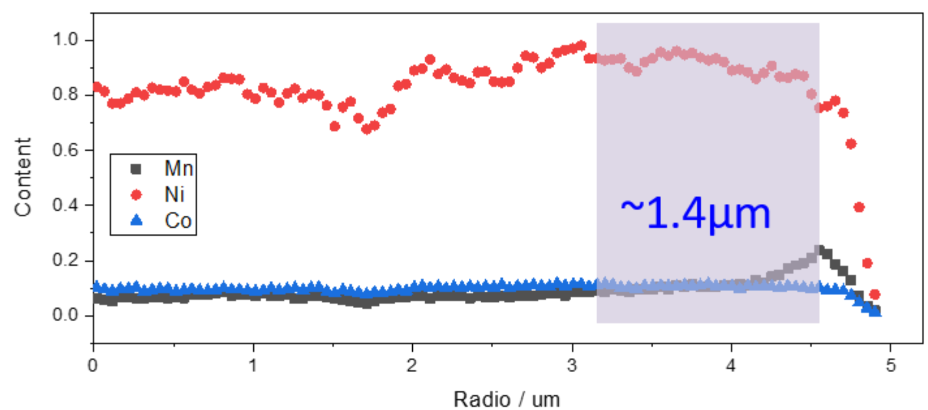
Technical Progress

Steep Surface Gradient Control for Higher Stability

- Known that higher Mn surfaces are more stable and have delayed phase changes to spinel and rocksalt during thermal decomposition
- Transmission electron microscopy (TEM) mapping confirms gradient can quickly change transition metal ratios near the secondary particle surface



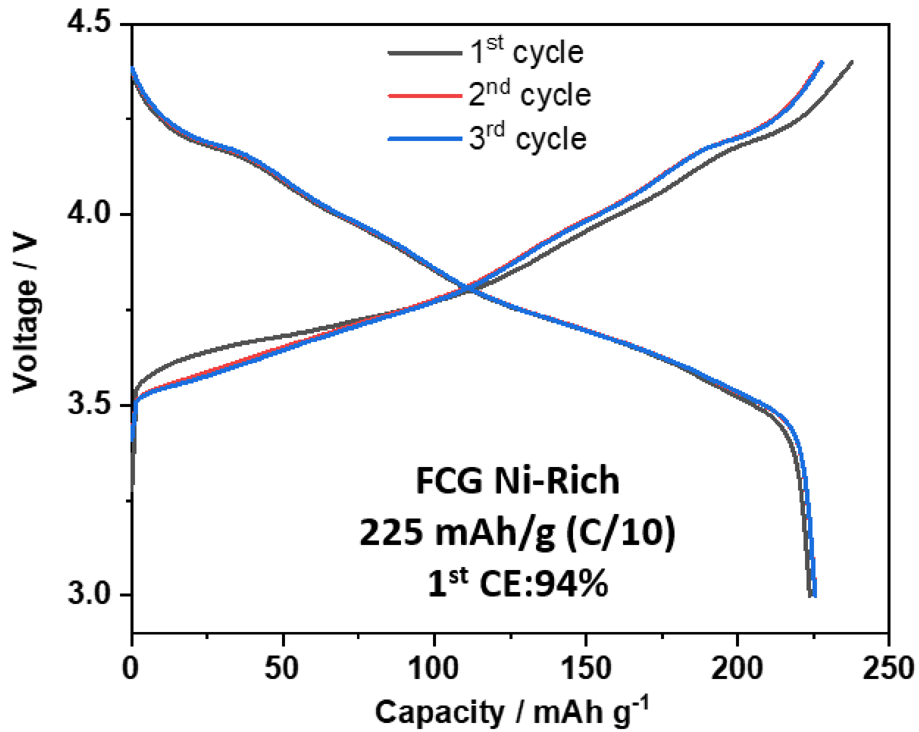


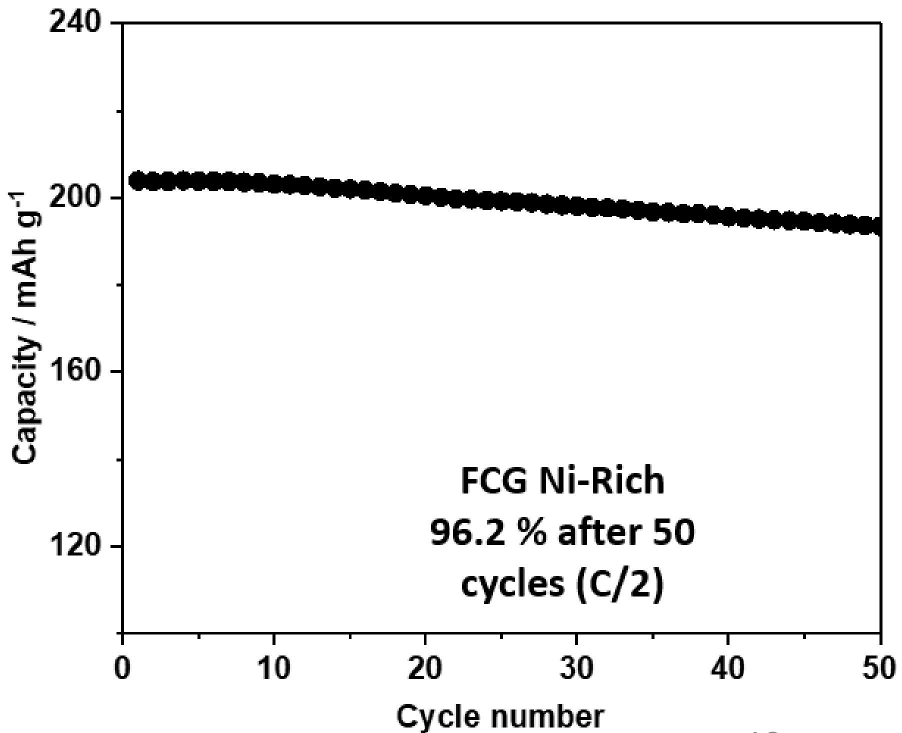


Rod structure

Steep Surface Gradient for High Performance

- Full concentration gradient cathode material (Ni≥85%)
- C/10 capacity (3.0-4.4V) is ~225 mAh/g





Responses to Previous Year Reviewer Comments

- This project is new, and was not reviewed last year.

Partnerships / Collaborations

Sub-contractor (National Laboratory)

New cathode and electrolyte additive development; advanced characterization of materials and post-mortem electrodes

Sub-contractor (Industrial)

Hard can (jelly roll) cell build; advanced fast charge protocols; input on commercial battery EV specs

Remaining Challenges and Barriers

- Integrating new cathode and additive materials designed by ANL into the higher energy density cell designs
- Optimizing electrodes to reach pouch and hard can cell target performance
- Setting reasonable safety limits for fast charging protocols
- Identifying lithium plating conditions in XFC cells so the correct material or engineering counter measures can be instituted

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

Future Work

- Gen1 XFC Cell Go/no-go
  - Will deliver XFC cells for testing at national laboratory
- Gen2 XFC Cell
  - Will build XFC electrodes and cells using selected cathode
  - Complete post-mortem studies after XFC cycling to assess SEI stability and cell failure mechanism
- Gen3 XFC Cell
  - Complete development of new electrolyte additive
  - Finish research and select Gen3 cathode tech
  - Build and test Gen3 XFC cells using advanced charge protocols to minimize dendrite formation risk

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

Summary

- 200 Wh/kg, 15AH cells undergo 500 XFC cycles with > 90% retention
- 220 Wh/kg, 20AH cells show sensitivity in capacity to cobalt content in the cathode
- 180 Wh/kg, 24AH prismatic hard can cells built and under test
- Systematically increasing the energy density of XFC cells thru new materials and revised electrode & cell designs

Technical Back-up Slides

XFC Cell Active Materials

Generation	Cathode	Anode	Energy Density (pouch cell) Wh/kg
Baseline	NCM – 532	Synthetic Graphite	200 Wh/kg
Gen1A	FCG (Ni:Mn:Co 60:30:10)	Synthetic Graphite	210 Wh/kg
Gen1B	FCG (Ni:Mn:Co 60:20:20)	Synthetic Graphite	218 Wh/kg

Anode: Synthetic Graphite and Synthetic Graphite/MCMB blends are being investigated and considered for later generations

Cathode: Adjustment to cell voltage range and concentration gradient Ni content are being considered for later generations

Reviewer ONLY Slides After This Point

Publications and Presentations

- Nothing to report to date

Critical Assumptions

- XFC cell energy density for project is determined at 0.33C/0.33C CCCV/CD
- To determine if XFC performance meets FOA objectives 6C/0.33C CCCV/CD is used to determine if the energy density is above 180 Wh/kg (beginning of cycling)
  - Cycling is done at 6C/1C as outlined in the FOA
- Cell energy density goals in project are defined for the pouch cell format. The hard can system also uses high capacity cells (>20AH); but the energy density will be different due to the different packaging method and can weight.