Silicon Nanostructure-based Technology for Next Generation Energy Storage

Ionel C. Stefan, Principal Investigator
Yoni Cohen, Program Administrator
Amprius, Inc.

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ES126

Overview

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Timeline

- Start date: October 2011
- End date: September 2014
- Percent complete: 50%

Barriers

- Performance
  - Energy Density
  - Specific Energy
  - Power
- Life
  - Cycle life
  - Shelf life

Budget

- Total project funding:
  $8,215,068
  - DOE share: $4,998,336
  - Contractor share: $3,216,732
- FY12 received: $1,998,662.76
- FY13 projected: $1,469,323.09

Partners

- Yardney Technical Products – cell design and fabrication
- BASF – cathode development
- Nissan – cell design

Objective

Project Objective

- **Develop, optimize and validate silicon nanowire anodes as an anode platform for use in conjunction with commercial cathode materials in next generation high-energy lithium ion batteries for vehicle applications.**
- **Performance targets:**
  - >680 Wh/L energy density, >330 Wh/kg @ 300-1,000 cycles
  - Calendar life degradation indicative of 5-10 year life
  - Safe, durable cell construction

Year 2 Objectives

- **Cycle Life: 300-1000 cycles to 80% capacity retention at 950mAh/cc reversible capacity of the anode**
- **Energy density: NCM523 or LCO cathode and balance of cell components, >250Wh/kg**

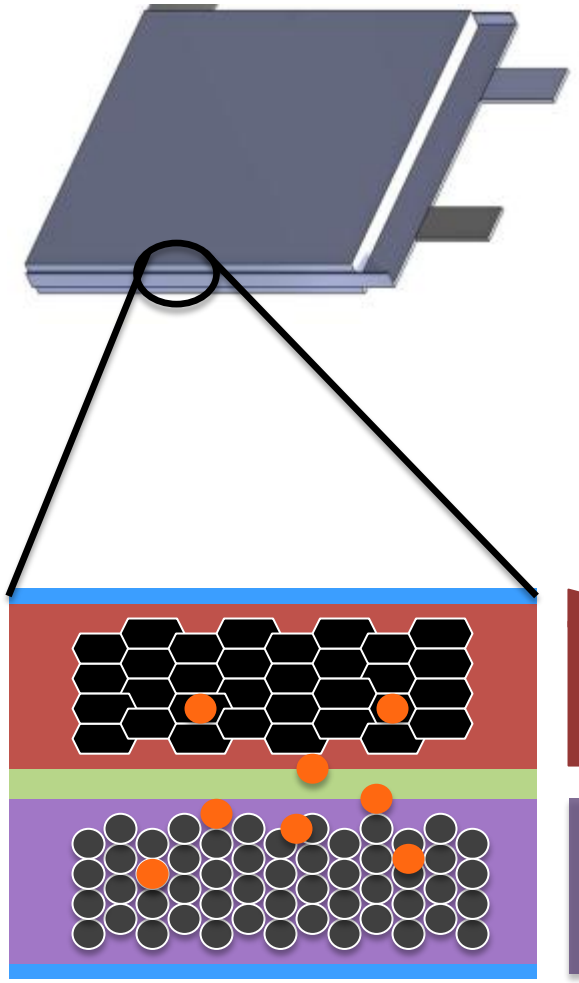
Relevance:

Milestones

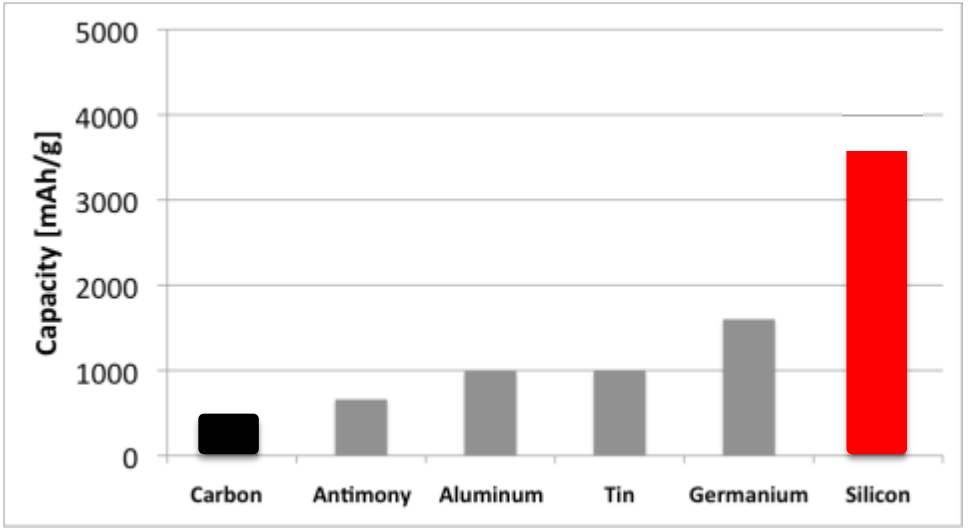
Month/Year	Milestone or Go/No-Go Decision
Feb-12	• Draft performance model and determine anode, cathode, and electrolyte performance specifications. • Test baseline component performance for anode and cathode.
May-12	• Complete baseline cathode formulation and qualifying tests.
Aug-12	• Anode material design complete. • Electrolyte specification complete. • Baseline cell design and materials validated.
Oct-12	• Baseline cells delivered.
Mar-13	• Complete design of 2Ah cell.
May-13	• Identified and documented the first order process conditions necessary to optimize the target anode structure
Oct-13	• Anode fabrication process selected and documented for high volumetric charge density (950 mAh/cc). • Interim cell performance target demonstrated with Si/LCO or Si/NCM523
Oct-13	• Interim silicon cells delivered.

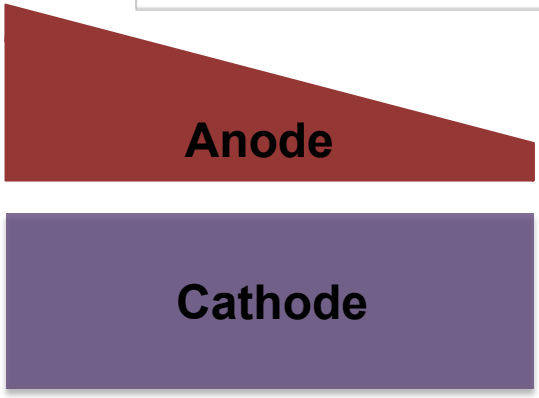
Approach:

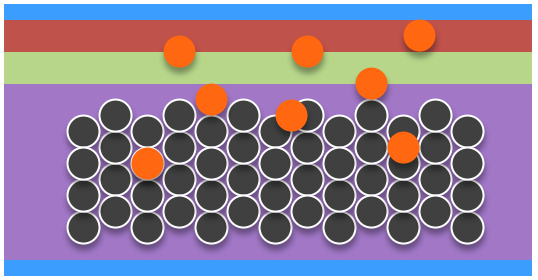
Background



Silicon offers 10x the performance of Carbon







Amprius greatly improves the performance of the battery cell by shrinking the size and weight of the anode using Si

Approach:

Amprius' Breakthrough

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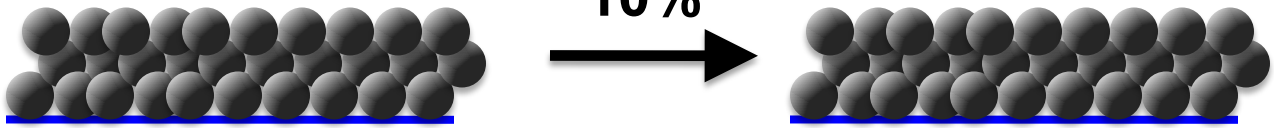
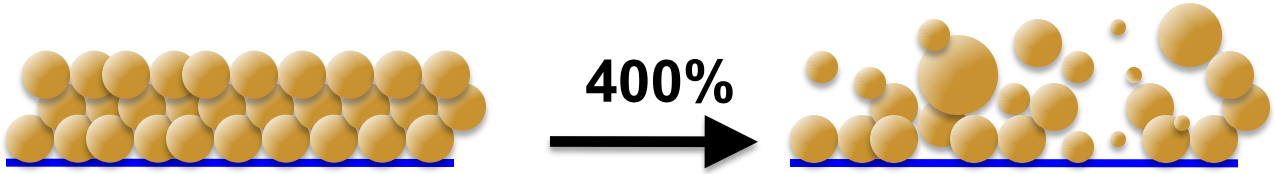
Carbon *(State of the Art)*

C_6Li_1



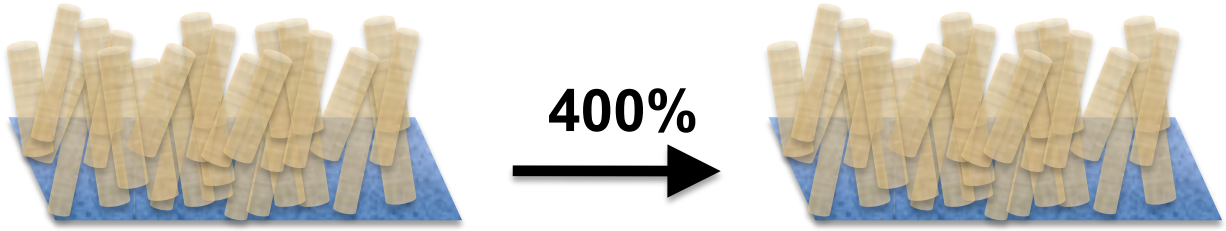
Silicon *(Conventional Approach: fails – poor cycle life)*

Si_5Li_{22}



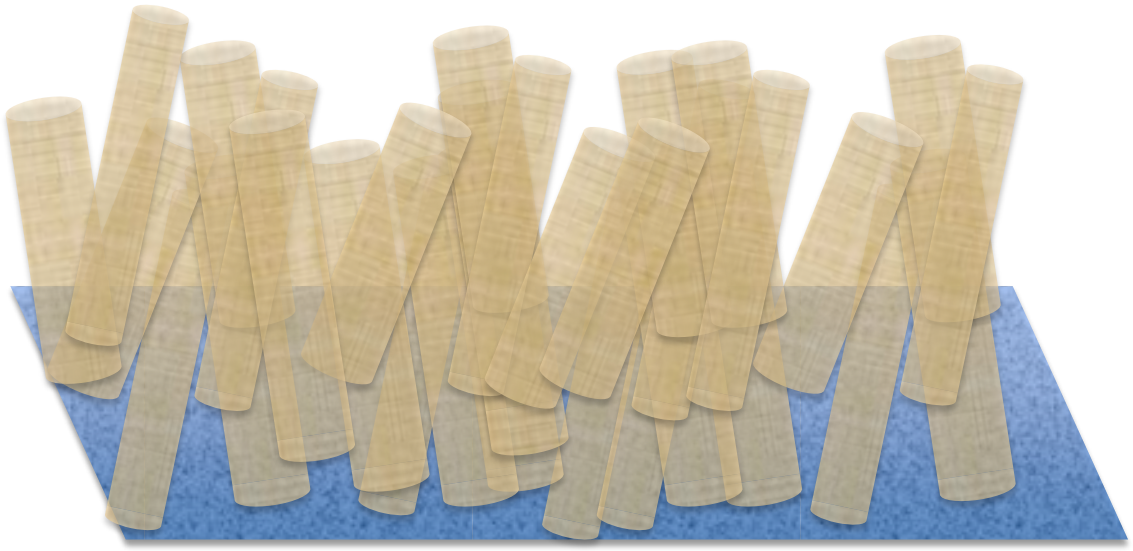
Amprius *(Silicon Nanowires: potential for 000s of cycles)*

Si_5Li_{22}



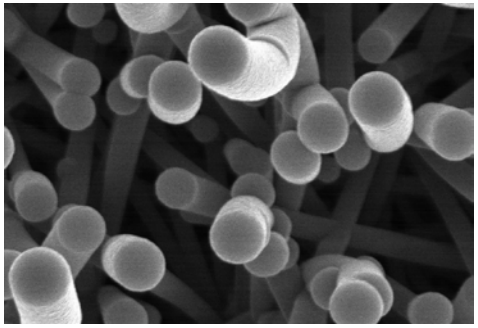
Approach:

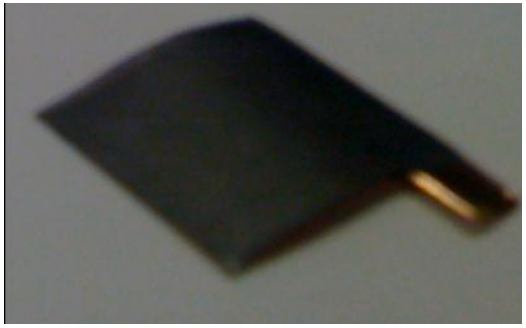
Silicon Nanowire Fabrication Process



Process:

- Foil Substrate
- Prepare Surface
- Deposit Silicon



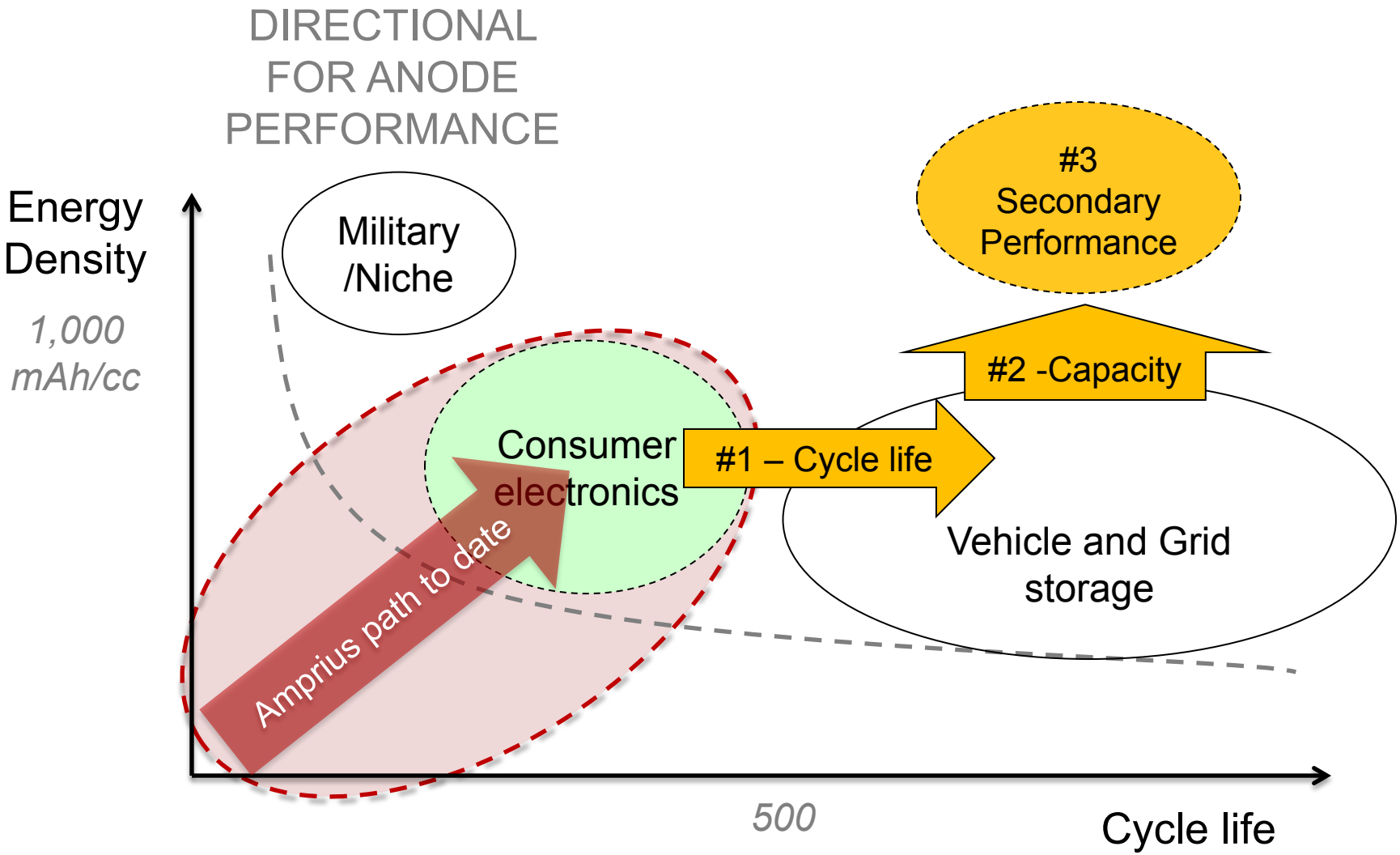


Result:

- Si material is maximized

Approach:

Anode Path for the Project



Technical Accomplishments:

Q1- Q5 Technical Accomplishments

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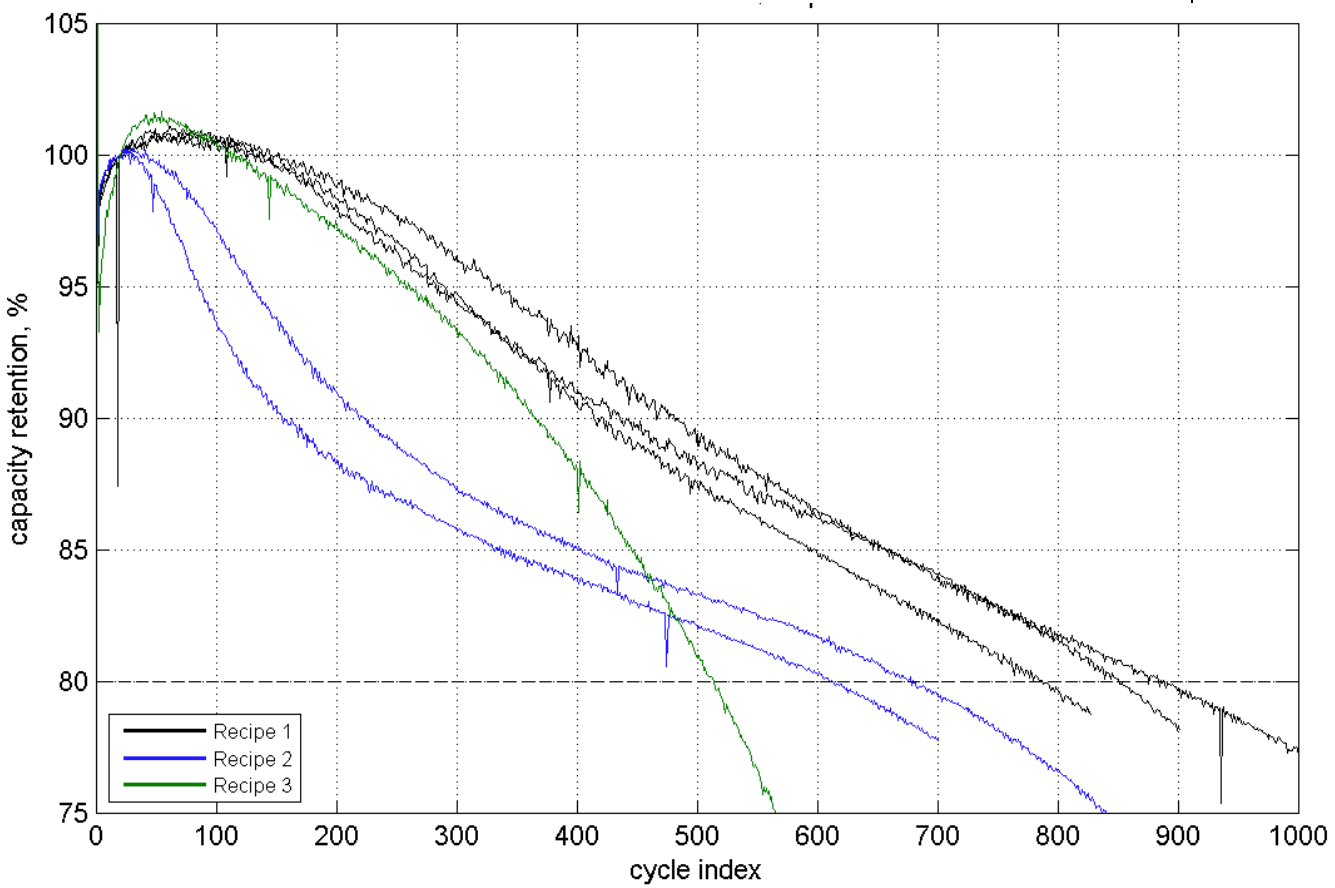
- Baselined initial Si nanowire anode performance in full cell with NCA and NCM cathodes
- Improved anode design to enable longer silicon cycle life
- Improved stability of the Solid Electrolyte Interface (SEI) that forms on the surface of the silicon electrode
- Identified additives that extend silicon cycle life
- Qualified NCM cathode materials to be integrated into the baseline cells
- Designed, built and delivered 18 baseline cells matching graphite anodes with NCM cathodes

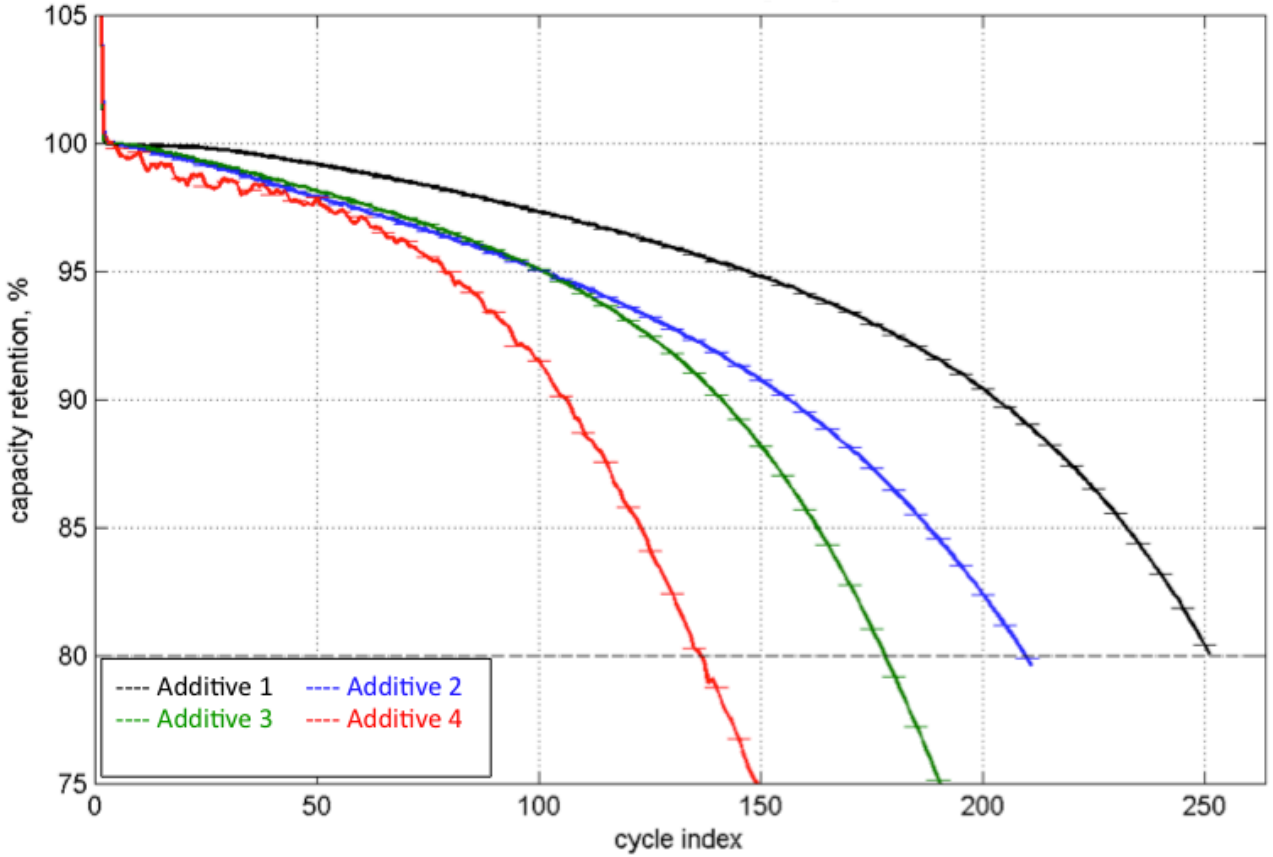
Technical Accomplishments:

Full cell cycle life performance



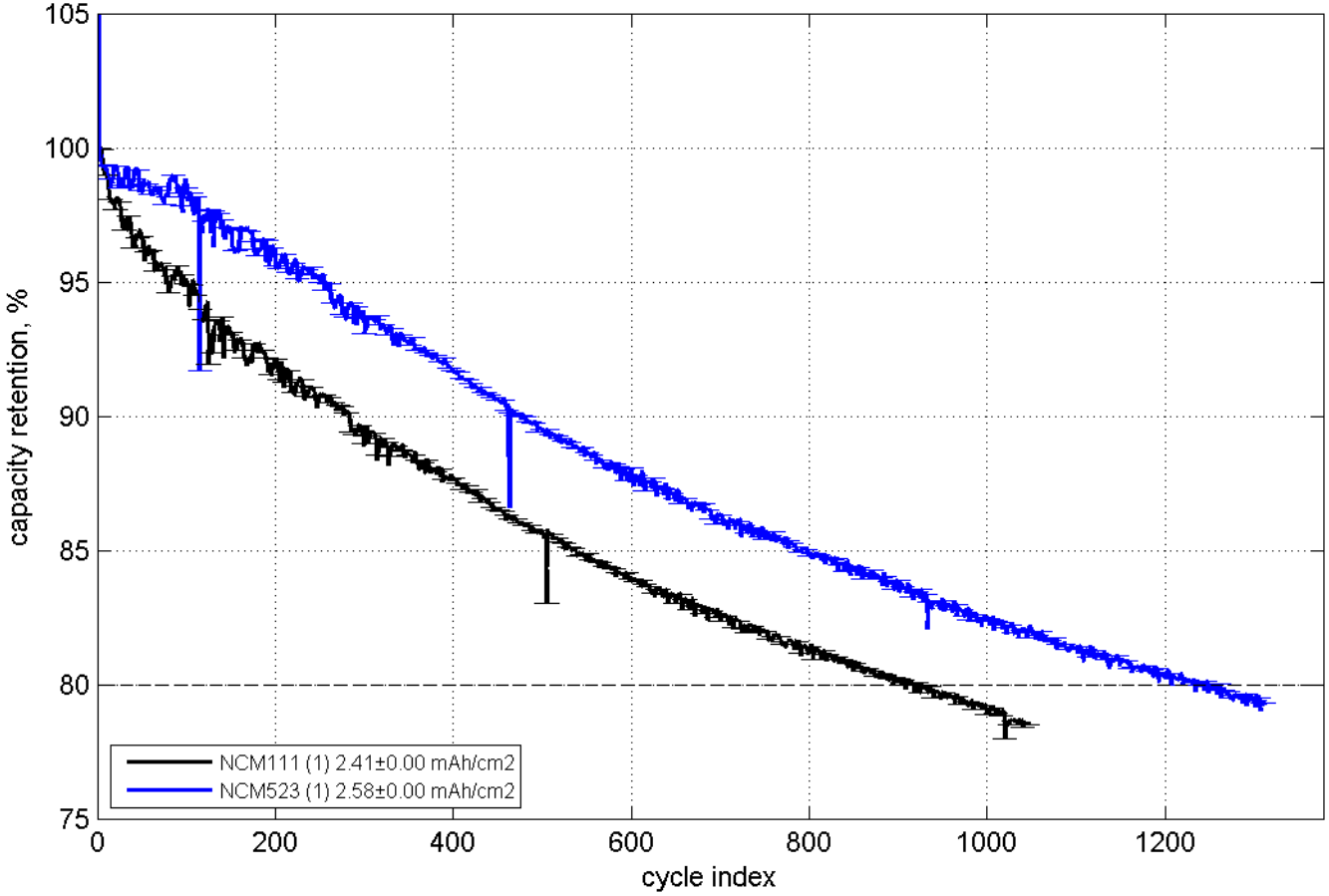
Amprius improved the cycle life of laboratory cells matching silicon anodes and NCA cathodes by improving the fabrication recipe

Electrolyte Formulation Development for Si Anode



Various electrolyte formulations and additives strongly affect the cycle life in full cells

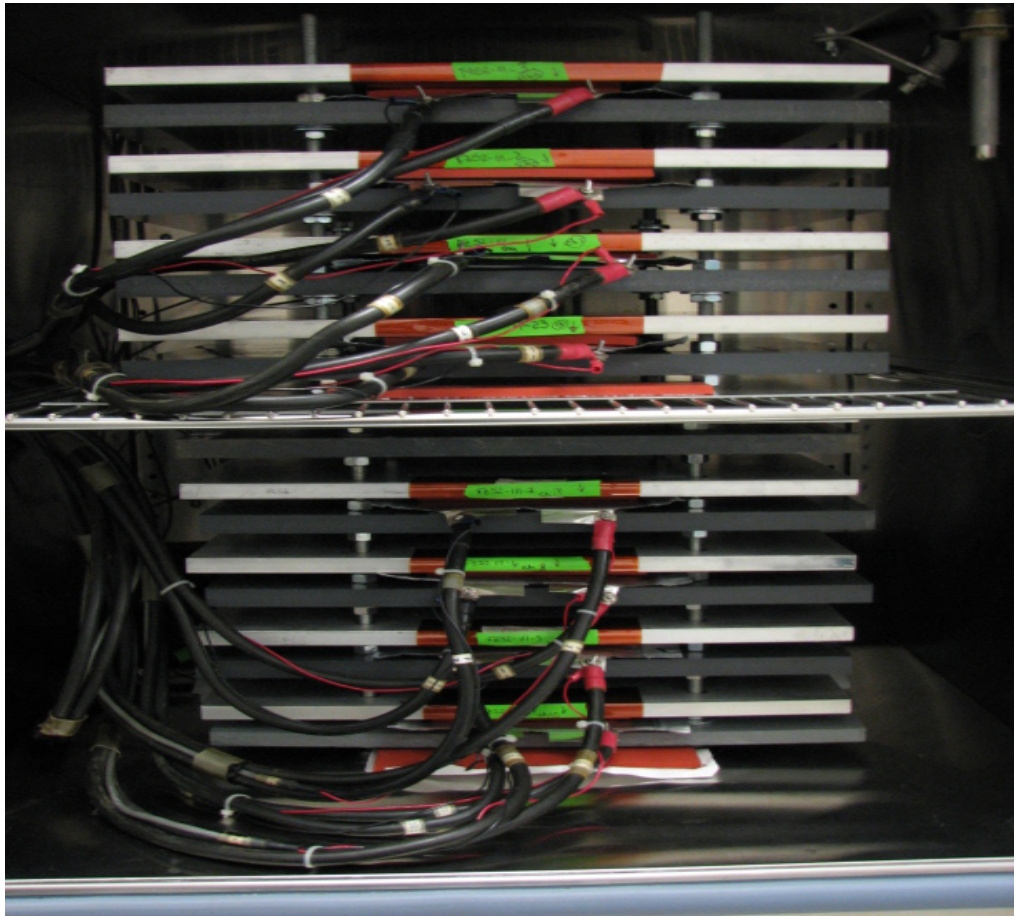
Baseline Cathode Formulation and Performance



Coating formulation was developed

Capacity, coulombic efficiency, cycle and rate performance are adequate

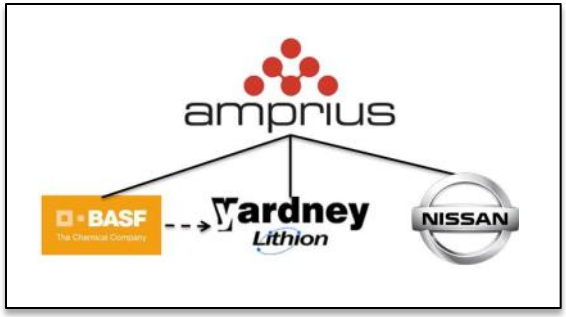
Baseline Cell Design



18 baseline cells delivered to testing laboratory

Collaborations:

Team Overview



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Optimize anode nanostructure.	Optimize Cathode	Optimize system	Balance of cell components	Scale up anode manufacturing	Cell Manufacturing
amprius	Yardney Lithion BASF The Chemical Company amprius	amprius	Yardney Lithion amprius	amprius	Yardney Lithion amprius

Future Work:

Activities for Next 12 Months

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Anode material efforts

- Optimize size, structure, surface and composition of the silicon nanowires to increase cycle life and volumetric charge capacity
- Improve anode uniformity and production yield

Electrochemistry

- New electrolyte formulations for silicon SEI and high voltage cathode
- Formation and cycling protocol
- Anode/Cathode matching

Cathode development

- Coating formulation development and validation for high loading and high energy density cathodes
- Electrolyte compatibility validation

Cell design and testing

- Iterate cell design for best energy density and safety performance

Summary

Meeting the energy density performance and cycle life targets for silicon anode cells will double the driving range of EVs and/or cut the pack size and weight in half

- **This will help to reduce the US dependence on foreign oil and reduce greenhouse emissions**

Amprius has assembled a cross-functional team of experts in battery materials and cell design – Amprius, Yardney, BASF, Nissan

Si nanowire structure enables 800+ cycles in full cells at 80% depth of discharge

Balance of cell components performance is closely developed in parallel with the anode material