Silicon Nanostructure-based Technology for Next Generation Energy Storage

Ionel C. Stefan, Principal Investigator
Tianyue Yu, Program Administrator
Amprius, Inc.

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ES126

Overview

Timeline

- Start date: December 2011
- End date: January 2015
- Percent complete: 15%

Barriers

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

Budget

- Total project funding:
  $8,197,288
  - DOE share: $4,998,336
  - Contractor share: $3,198,952
- Funding received in FY11: $0
- Funding for FY12: $2.158,701

Partners

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

Objective

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Project Objective

- **Develop, optimize and validate silicon nanowire anode as an anode platform for use in conjunction with emerging cathode materials in next generation high-energy lithium ion batteries for vehicle applications, that will deliver the following performance:**
  - >900 Wh/L energy density, >400 Wh/kg @1,000 cycles
  - Calendar life degradation indicative of 5-10 year life
  - Safe, durable cell construction

Year 1 Objectives

- **Cycle Life: 1000 cycles to 80% capacity retention at 1000mAh/g reversible capacity of the anode**
- **Energy density: Baseline cathode and balance of cell components**

Relevance:

Milestones

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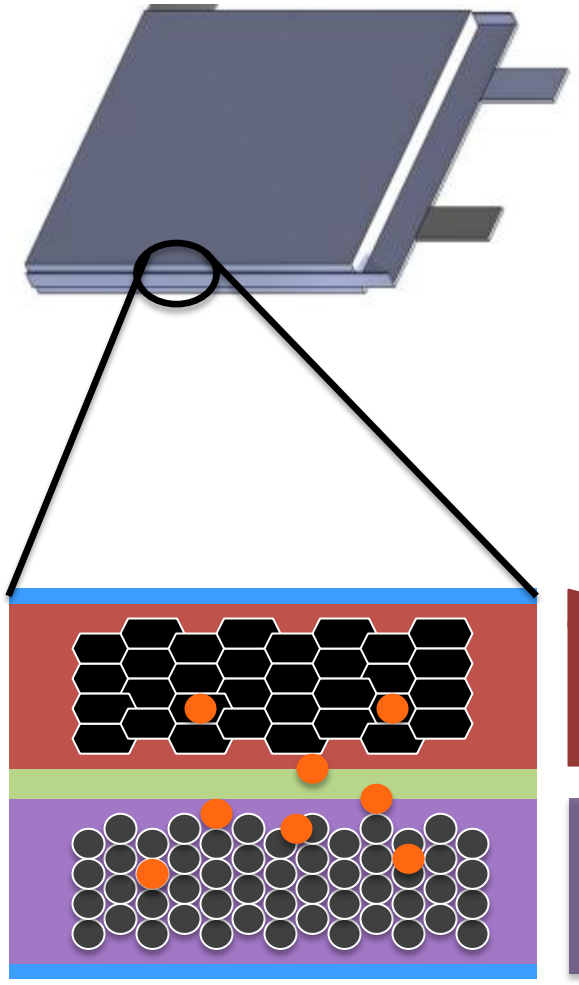
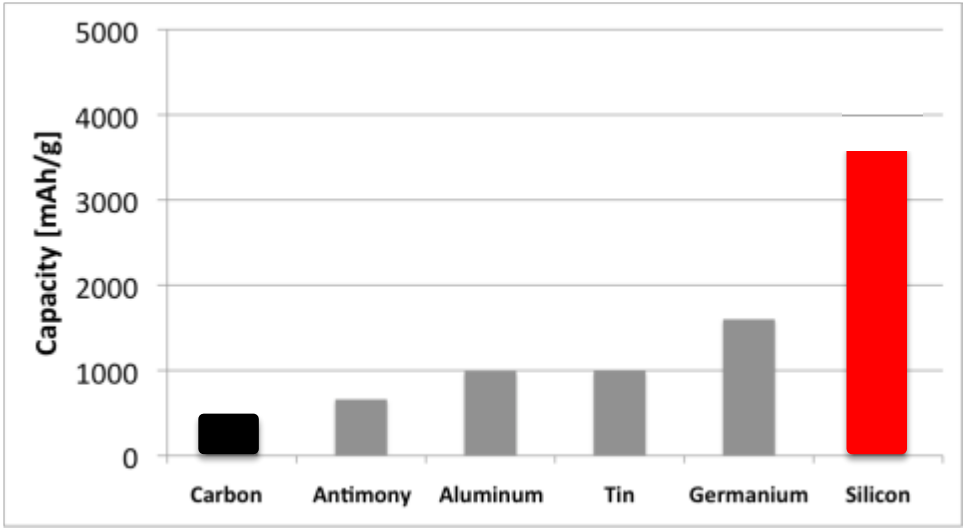
Month/Year	Milestone or Go/No-Go Decision
Feb-12	• Milestone: Complete vehicle cell form factor design, performance model, anode, cathode, electrolyte performance specifications. • Milestone: Test baseline component performance for anode and cathode.
May-12	• Milestone: Complete baseline cathode formulation and qualifying tests. • Milestone: Baseline vehicle form factor tests started.
Aug-12	• Milestone: Anode Material design (1,000 cycle, 1,000 mAh/cc) complete. • Milestone: Electrolyte specification (1,000 cycle, 1,000 mAh/cc) complete. • Milestone: Baseline cell design and materials validated.
Oct-12	• Milestone: Baseline cells delivered
Dec-12	• Milestone: Anode material downselect (1,000 cycle, 1,000 mAh/cc).
Feb-13	• Milestone: Anode material design (1,000 cycle, 1,500 mAh/cc) complete
May-13	• Go/No-Go Decision: Option 1 and Option 2 cathodes validated. Select cathode for FY3 deliverable
Oct-13	• Milestone: Interim silicon cells delivered

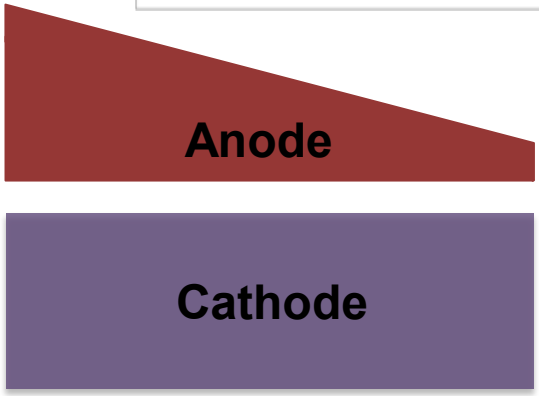
Approach:

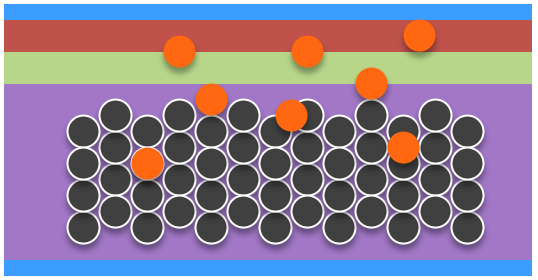
Background



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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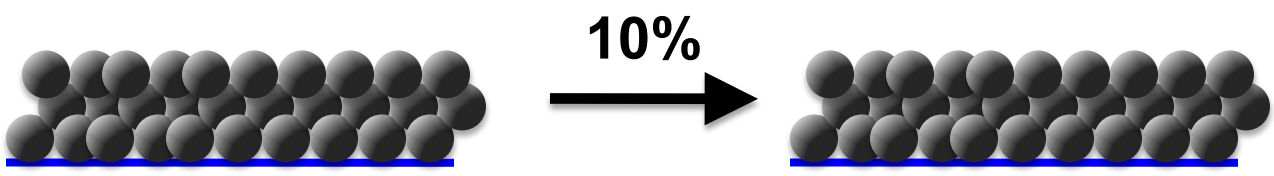
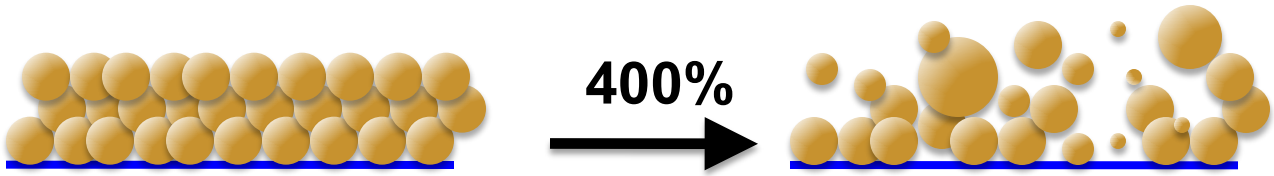
Carbon *(State of the Art)*

C_6Li_1



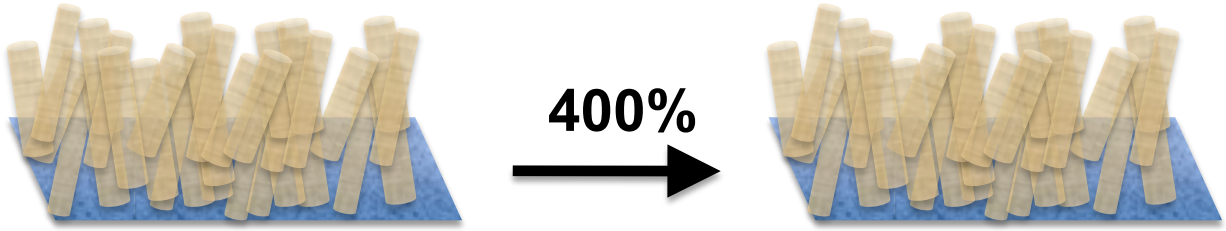
Silicon *(Conventional Approach: fails – poor cycle life)*

Si_5Li_{22}



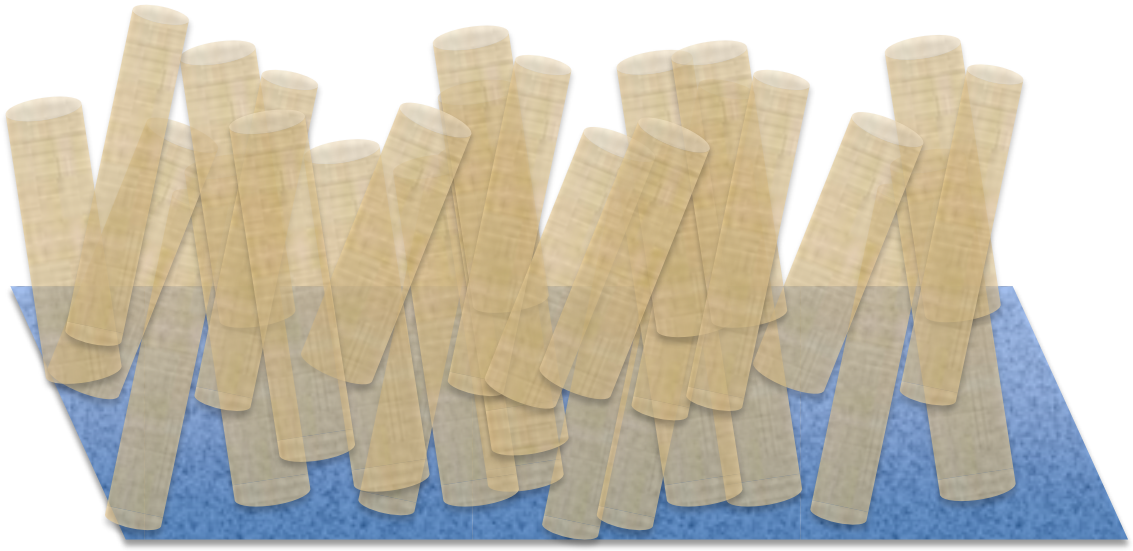
Amprius *(Silicon Nanowires: potential for 000s of cycles)*

Si_5Li_{22}



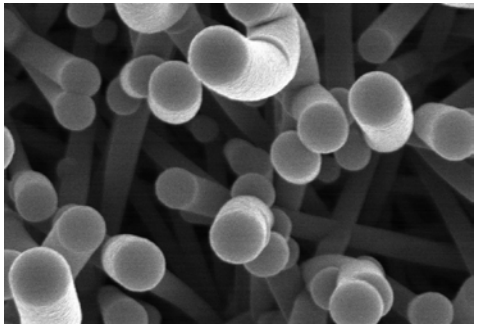
Approach:

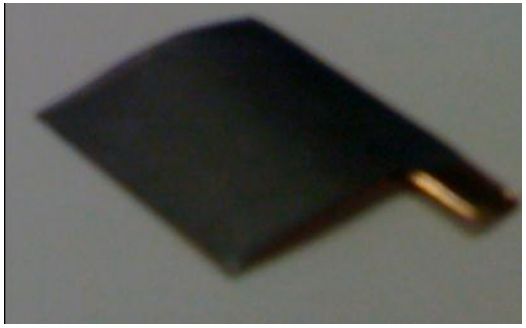
Silicon Nanowire Fabrication Process



Process:

- Foil Substrate
- Prepare Surface
- Deposit Silicon



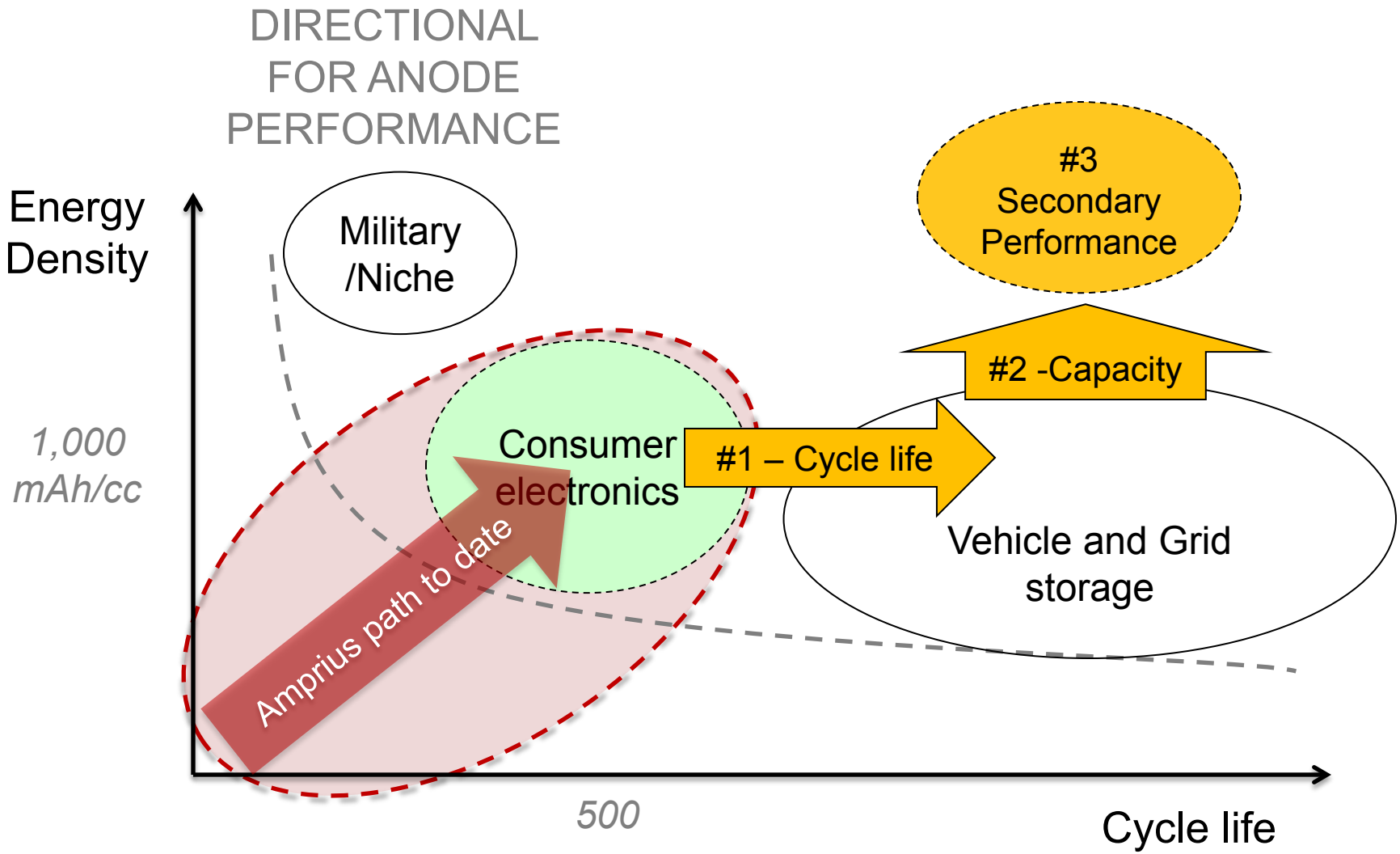


Result:

- Si material is maximized

Approach:

Anode Path for the Project



Q1, Q2 Technical Accomplishments

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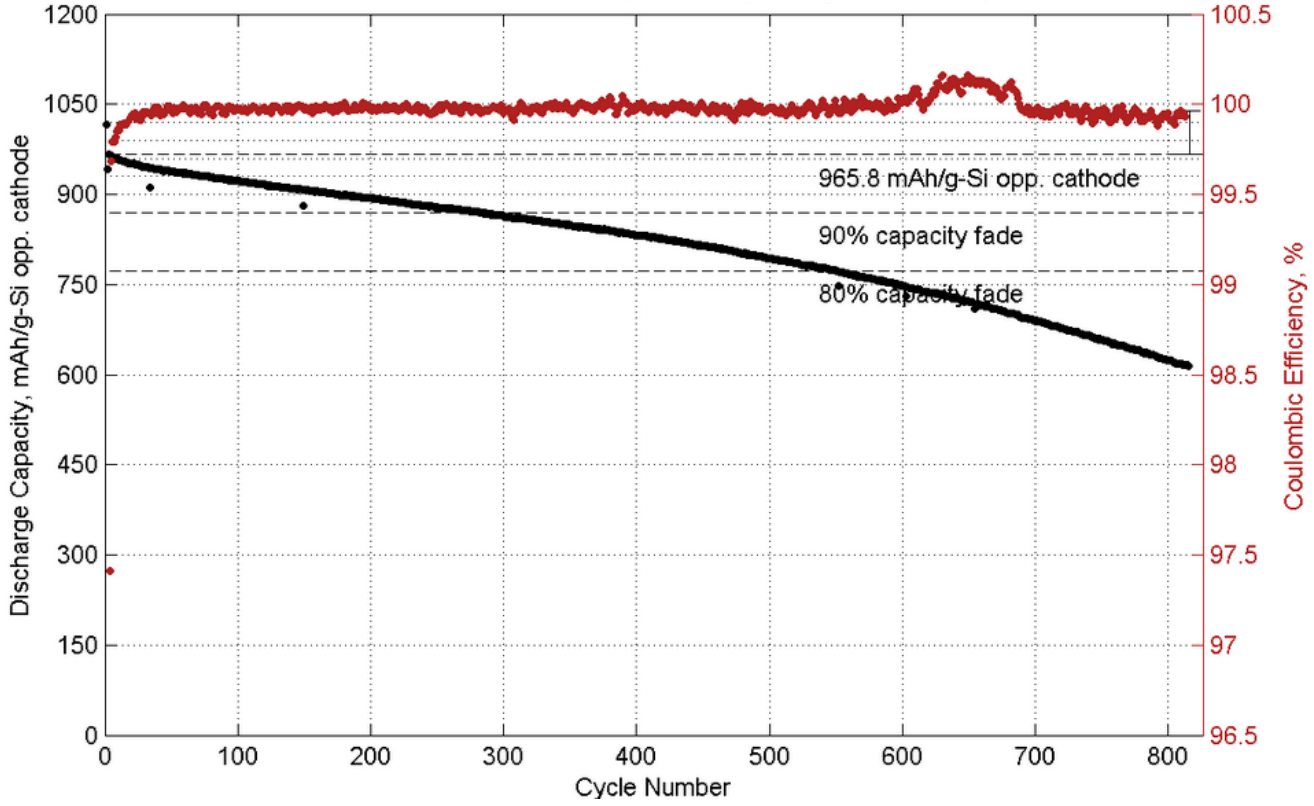
- Current status of Si nanowire anode performance was baselined in full cell
- Baseline cathode formulation was developed
- Baseline cathode passed validation tests
- Electrolyte development started in half cells with Si nanowire electrode
- First iteration of the vehicle format cell design was finalized
- Cell model and components performance specifications were finalized

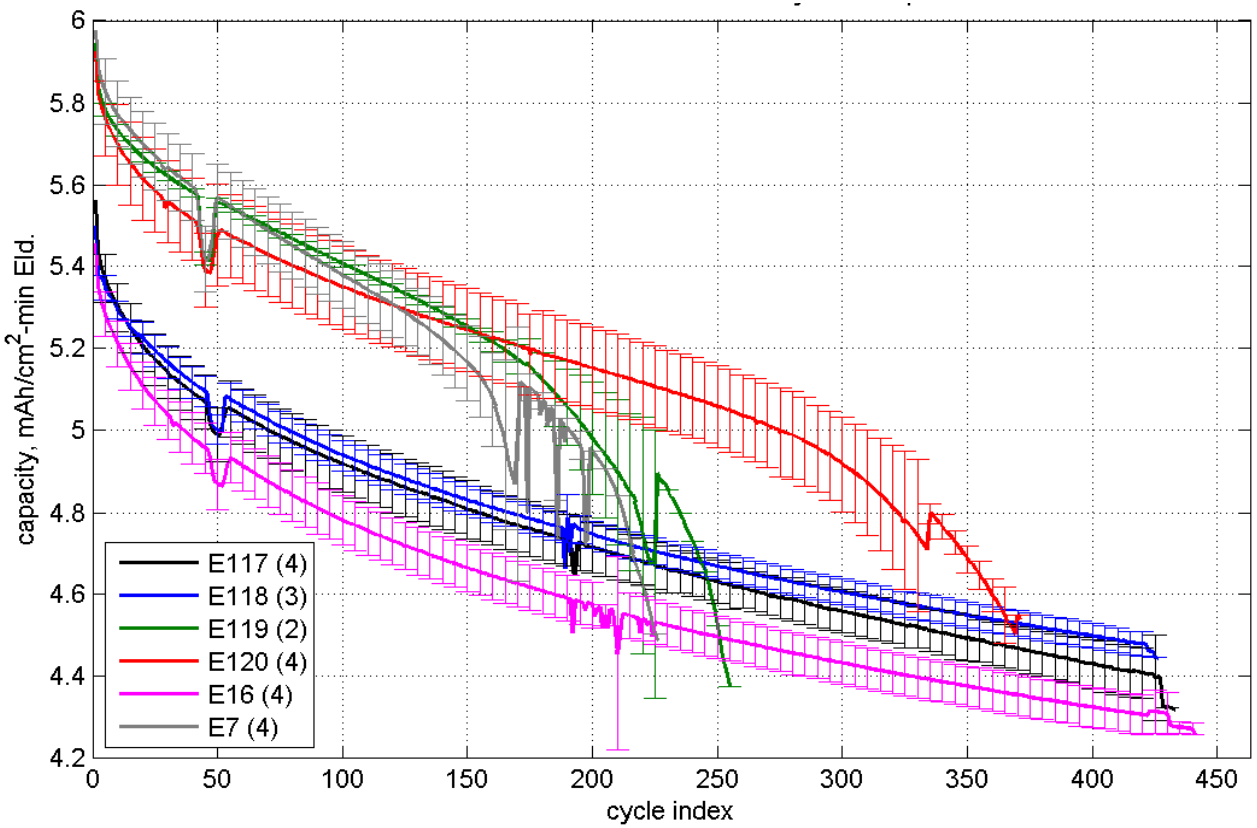
Technical Accomplishments:

Full cell performance of Si to 550+ cycles @ 3x graphite capacity



Both Si anode structure and coulombic efficiency are stable to 500+ cycles

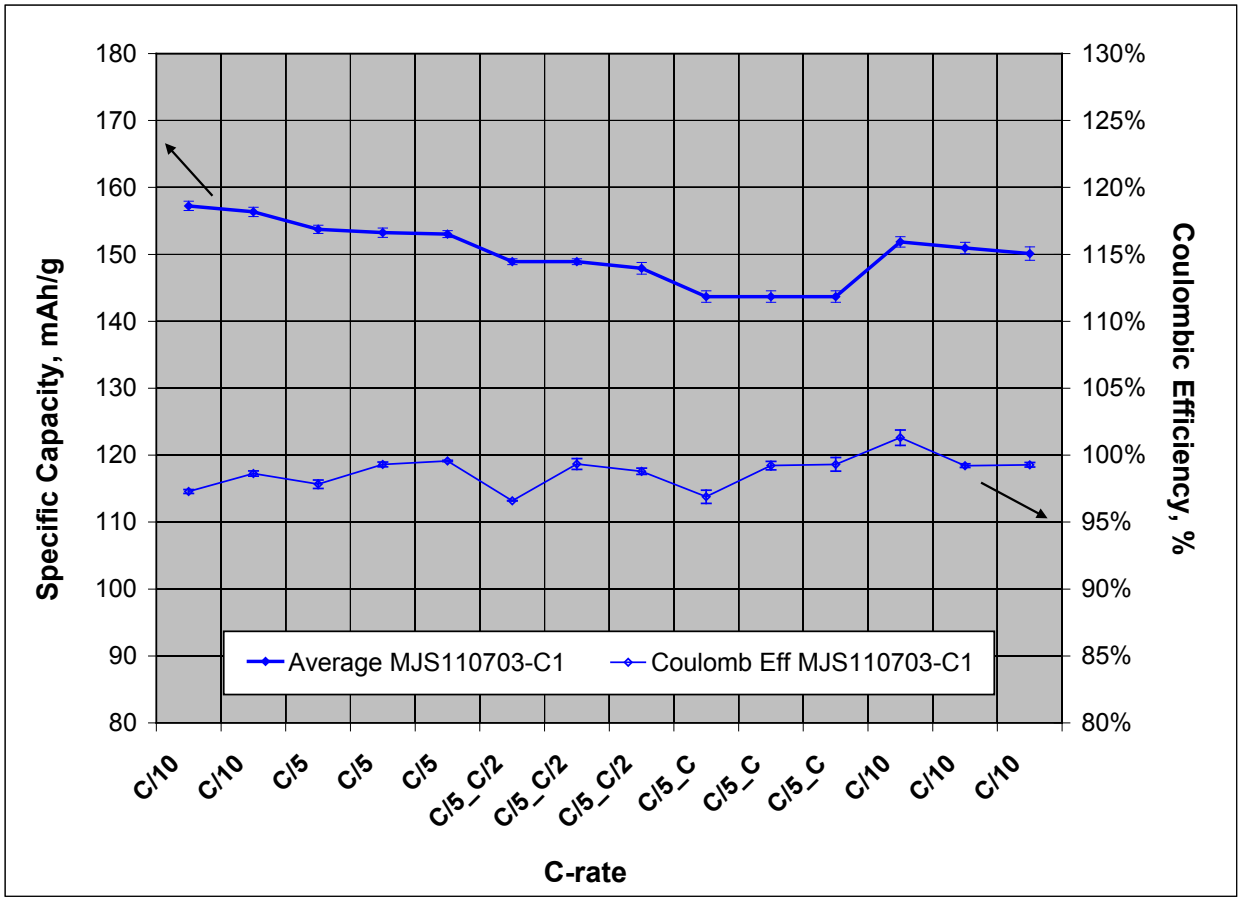
Electrolyte Formulation Development for Si Anode



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

Technical Accomplishments:

Baseline Cathode Formulation and Performance



Coating formulation was developed

Capacity, coulombic efficiency and rate performance are adequate

Technical Accomplishments:

Cell Design – Vehicle Form Factor

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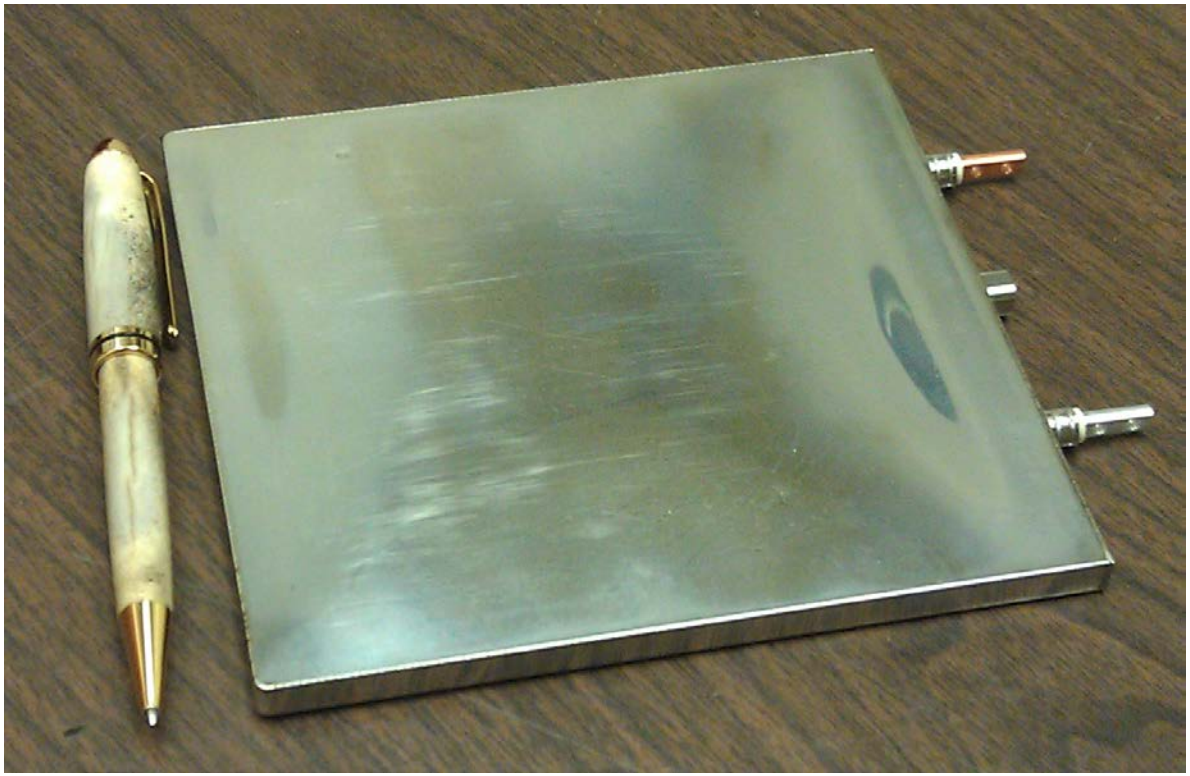
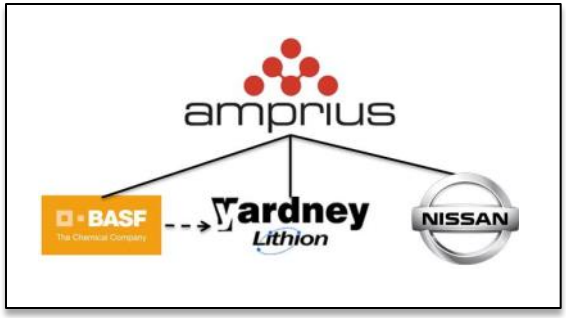


First iteration of the vehicle format cell design was finalized

Cell model and components performance specifications were finalized

Collaborations:

Team Overview



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Optimize anode nanostructure.	Optimize Cathode	Optimize system	Balance of cell components	Scale up anode manufacturing	Cell Manufacturing
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Develop Cathode

BASF The Chemical Company

Future Work:

Activities for Next 12 Months

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Anode material efforts:

- Size, structure, surface and composition of the silicon nanowires to increase cycle life, and then capacity

Electrochemistry

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

Cathode development

- Coating formulation development and validation
- 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 reduce the pack size and weight to 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

Initial starting materials allow 500+ cycles of full cells with silicon anodes at 1000mAh/g

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