Silicon Nanostructure-based Technology for Next Generation Energy Storage

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This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Timeline

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

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

Barriers

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

Partners

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

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
<table>
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<tr>
<th>Month/Year</th>
<th>Milestone or Go/No-Go Decision</th>
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| 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 |
Amprius greatly improves the performance of the battery cell by shrinking the size and weight of the anode using Si.
Amprius’ Breakthrough

**Carbon (State of the Art)**

\[ \text{C}_6\text{Li}_1 \]

→ 10%

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

\[ \text{Si}_5\text{Li}_{22} \]

→ 400%

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

\[ \text{Si}_5\text{Li}_{22} \]

→ 400%
Approach:

Silicon Nanowire Fabrication Process

Process:
- Foil Substrate
- Prepare Surface
- Deposit Silicon

Result:
- Si material is maximized
Approach:

Anode Path for the Project

Energy Density

1,000 mAh/cc

DIRECTIONAL FOR ANODE PERFORMANCE

Military / Niche

Consumer electronics

#1 – Cycle life

500

Amprius path to date

#2 - Capacity

#3 Secondary Performance

Vehicle and Grid storage

Proprietary/Business-Sensitive
Technical Accomplishments:

Q1, Q2 Technical Accomplishments

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
Technical Accomplishments:

**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

First iteration of the vehicle format cell design was finalized

Cell model and components performance specifications were finalized

Collaborations:

- Amprius
- Yardney Lithion
- BASF

Develop Cathode

Team Overview
Activities for Next 12 Months

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

Future Work:
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