Advanced Cathode Material Development for PHEV Lithium Ion Batteries

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Project ID # ES006

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

Overview

- Timeline
  - *start: 4/06/2009*
  - *finish: 9/1/2010*
  - *67% complete*
- Budget
  - *Total project funding*
  - *USABC share: $1,137,726*
  - *Contractor share: $1,137,726*
  - *Funding received in FY09: $185,264*
  - *Funding for FY10 : $902,521*
- Barriers
  - *Cost, Capacity, Rate and Thermal Control.*
- Targets
  - *Increase capacity 5-10%*
  - *Reduce Cost >10%*
  - *Maintain thermal stability and cycle life*
- Partners
  - *Major automakers*
  - *Major cell makers*

Project Objectives

To design an advanced cathode materials with the following performance improvement compared to MNC 111 for PHEV applications:

- *5 ~ 10% higher capacity improvement (mAh/g)*
- *~ 15% lower raw material cost*
- *Comparable or higher thermal stability*
- *Comparable or higher cycle life*

- **Achieving these objectives will result in a new commercial cathode material with cost and performance advantages for automotive applications**

Milestones

- √ Optimization of benchmark cell design
- √ Collection of benchmark cell data
- √ Identification of advanced cathode material meeting targets
- √ Development of large scale production process for advanced cathode material
- Optimization of cell design with advanced cathodes
- √ Build and evaluate 18650 Size cells with advanced cathode materials
- Assemble complete data package on advanced cells

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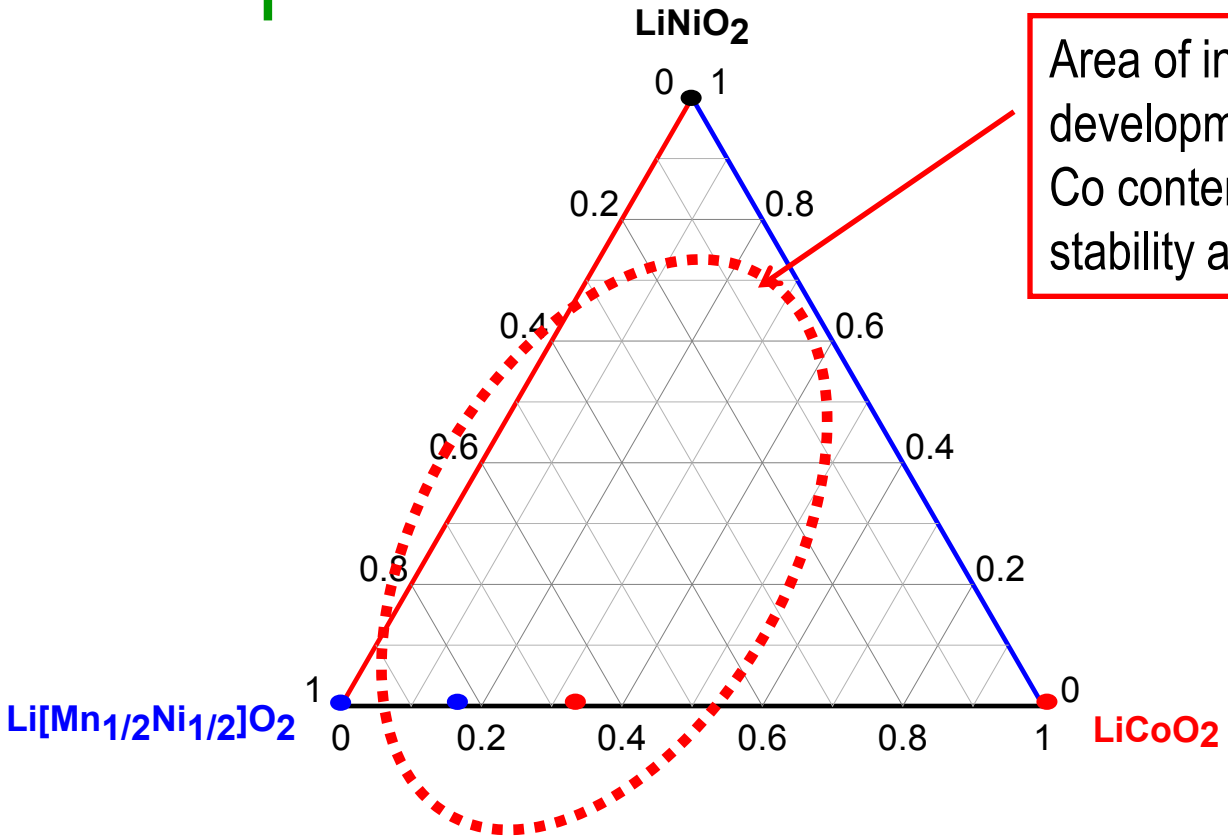
Approach to Cathode Development

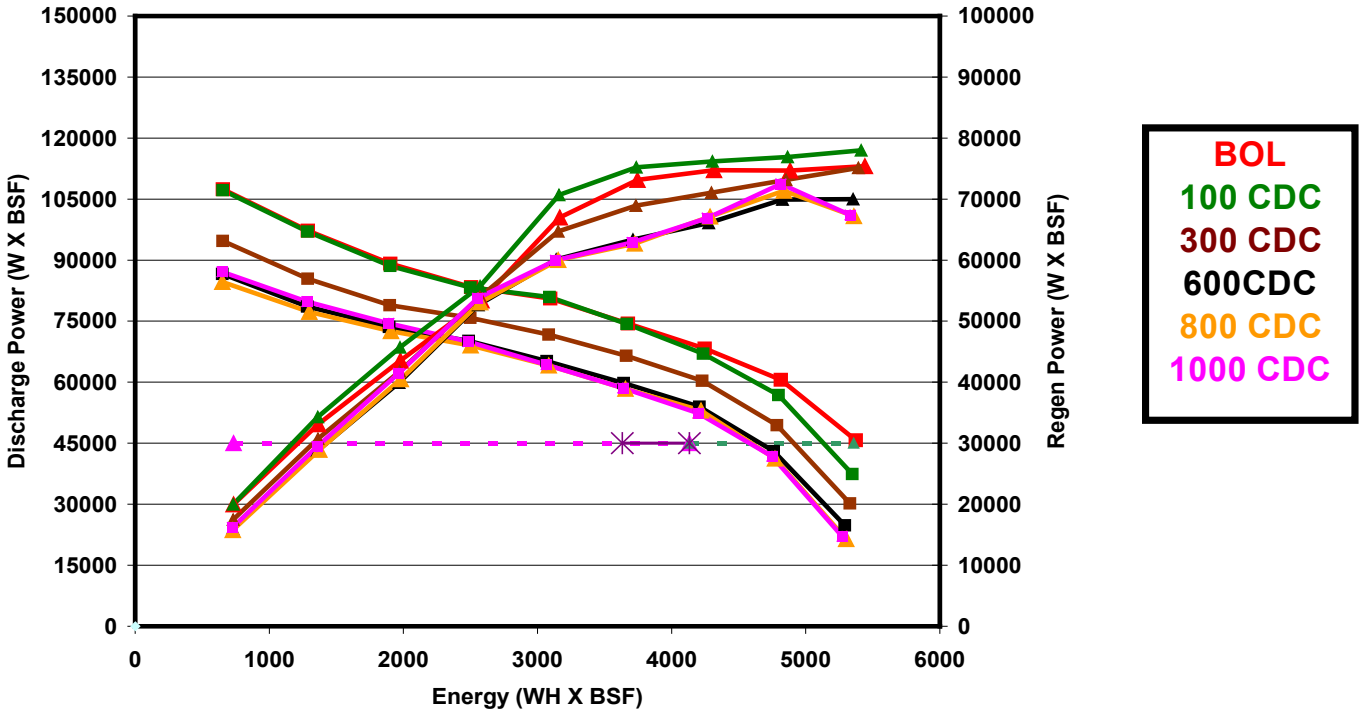


Area of interest for new cathode development because of the low Co content – cost, thermal stability and energy density

- **Prepared over 50 samples and using statistics modeling tool to identify the most promising two MNC compositions**

Accomplishments
Benchmark Cell Optimization and Performance

- **Cell design optimized**
- **Electrolyte system optimized**



- Benchmark 18650 Cell Design Successfully Optimized
- After 1,000 CD Cycles, > 11% Energy Available

Accomplishments
Progress / Gap Analysis

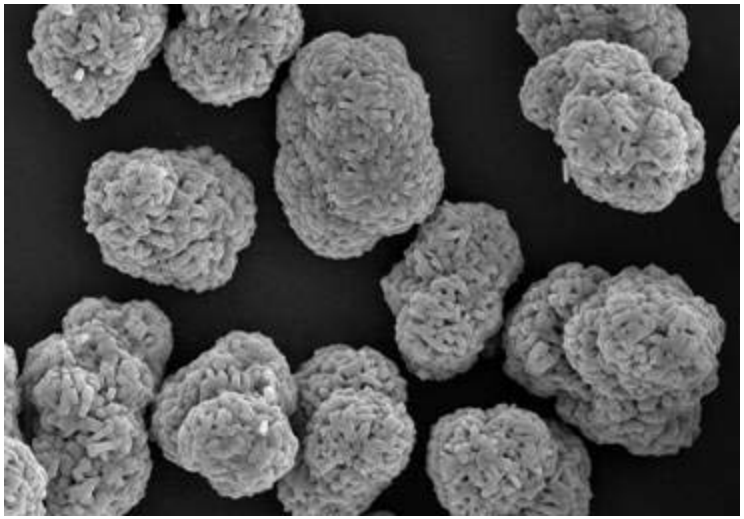
Requirement	BC618 Benchmark	Target	Adv. MNC 1	Adv. MNC 2
Capacity C/10 (mAh/g)	156	>165	168	168
Capacity C/2 (mAh/g)	145	> 155	157	158
Thermal Stability DSC (ºC)	315	≥ 315	321	315
Cycle Life (CD Cycling)	> 2000	≥ 2000	TBD	TBD
Cost (relative)	100%	≤ 85%	81%	72%

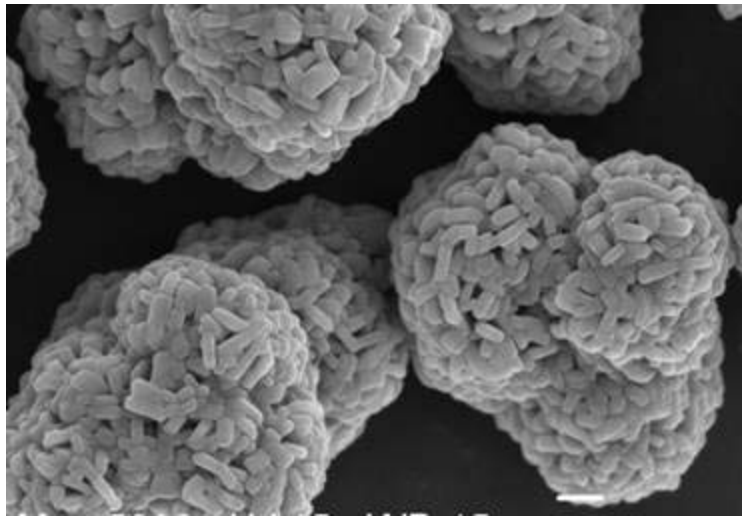
- Both Advanced MNC Candidates Meet Primary Objectives
- Large Scale Performance Validation Underway

Accomplishments
Large Scale Manufacturing

- **Large Scale Process Conditions Developed**
  - ***Both Advanced MNC Compositions Optimized in Large Scale Reactor***
  - ***Multiple Variables Evaluated and Optimized***

- **Produced > 25 kg of each Composition**





Proposed Future Work

- Optimize Electrode Coatings of Candidate Materials
- Build 18650 Size Cells with Advanced Cathode Materials
- Generate Initial Performance Data
- Downselect to One Advanced Cathode Composition Based on Data Generation and Perspective Customer feedback
- Complete Full Cell Performance Data Package

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Summary

- Improved the CD cycle life time of the benchmark cell with MNC 111 from 300 cycles to over 2000 cycles.
- Identified 2 final MNC candidates that meet project objectives.
  - *5-10% Increased Capacity*
  - *10% Reduced Cost*
- Established large scale production process for advanced MNC materials
- Produced > 25 kg of each advanced MNC material to support remaining phase of project

All Project Goals Met or Exceeded to Date

Advanced Negative Electrode Materials for PHEV Lithium Ion Batteries

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Overview

- Timeline
  - *start: 06/23/2009*
  - *finish: 06/22/2012*
  - *33% complete*
- Budget
  - *Total project funding*
  - *DOE share: $1,348,093*
  - *Contractor share: $1,348,093*
  - *Funding received in FY09: $266,214*
  - *Funding for FY10 : $720,000*
- Barriers
  - *E. Weight, volume and thermal control.*
- Targets
  - *increase cell energy density by 20%, significantly reducing system volume*
- Partners
  - *Major automakers*
  - *Major cell makers*
  - *Universities*
  - *National labs*

Objectives

- Develop practical negative electrode materials for PHEV Li-ion batteries with the following properties:
  - *> 2X specific energy as graphite (> 650 mAh/g)*
  - *> 2X volumetric capacity as graphite (> 1500 mAh/cc)*
  - *< 20% fade / 300 cycles*
  - *abuse tolerance better or equivalent to graphite*
  - *rate performance better or equivalent to graphite*

- Achieving these objectives is projected to result in cells with a 20% reduction in volume compared to those using conventional graphite anode materials.

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Milestones

FY09: Alloy and Cell Optimization

Specific Capacity	> 650 mAh/g (exeeds 2X graphite)
Volumetric Capacity	> 1500 mAh/cc (exeeds 2X graphite)
Cycle Life	< 20% fade / 300 cycles
Thermal Stability	exceeds graphite
Rate Performance	2C/0.2C > 90%
Manufacturing Viability	exceeds kg scale
Electrolyte Development	develop rapid screening method

FY10/11: Optimization for PHEV Applications

Optimize Abuse Tolerance

Optimize PHEV Cycling Protocol Performance

Optimize High/Low Temperature Cycling Performance

Approach

- low RM cost Si-based alloys
- low cost / high volume manufacturing
- active/inactive, nanocrystalline/amorphous alloy microstructure (good cycle life)
- low surface area (good thermal stability)
- 18650 cells used as primary test vehicle
- achieve performance targets by:
  - *alloy materials optimization*
  - *coating formulation optimization*
  - *electrolyte optimization*
  - *cell design optimization*

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Technical Accomplishments and Progress

	Project Start	End of FY09
Alloy Material	L-19725	L-19725 L-20772
Manufacturing Method	meltspinning	new low cost / high volume method
Cycle Life	40% fade / 250 cycles	<20% fade / 300 cycles
Electrolyte Development	no rapid test method	successful rapid test method

- Significant progress has been made in materials, manufacturing, cell design and electrolyte development

Accomplishments
Large Scale Manufacturing

- All project manufacturing goals exceeded
- L-17925 Alloy
  - *meltspinning method*
  - *target volumes exceeded*
- L-20772 Alloy
  - *proprietary manufacturing method*
    - *low cost / high volume / quicker to scale*
  - *target volumes exceeded*
  - *plan to increase scale this year*

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Accomplishments / Gap Analysis
All Year 1 Targets Exceeded

Properties Requirements	Conventional	Target	L-19725	L-20772
Composition	*Graphite*		*Si-Al-TM-RE-Sn*	*Si Based*
Surface Area (m^2/g)	*1*		*1*	*4.5*
True Density (g/cc)	*2.26*		*4.2*	*4.0*
Specific Capacity (mAh/g)	*320*	*> 650*	*800*	*860*
Volumetric Capacity (mAh/cc)	*660*	*> 1500*	*1580*	*1604*
Thermal Stability	*ref*	*≥ ref*	*> ref*	*TBD*
Cycle Life (% fade at 300 cycles)	*ref*	*≤ 20%*	*19%*	*27%*
Rate Performance (2C/0.2C)	*>93%*	*>90%*	*>93%*	*>93%*
Manufacturing Viability	*ref*	*Large Scale*	*Confirmed*	*Confirmed*

- L-19725 meets/exceeds all targets
- L-20772 alloy meets exceeds capacity targets

Proposed Future Work

- All Phase 2 targets met
- Excellent position to start Phase 3: Optimization PHEV Performance Characteristics
  - *coating formulation optimization*
  - *electrolyte formulation optimization*
  - *cell design optimization for PHEV*
    - *power, cycle life, high/low temperature performance*
  - *abuse tolerance optimization*

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Summary

- Significant progress made during FY09. Many large technical barriers overcome.
- High performance alloy materials, manufacturing methods, coating formulations, electrolyte formulations developed
- > 2X volumetric and gravimetric capacity of graphite achieved while maintaining good cycle life
- Low cost raw materials made using volume production methods developed
- Anticipate 15-20% increase in cell level volumetric capacity (verified internally)

All project goals exceeded for FY09

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