Overview

Timeline
• Project start date: Oct. 1, 2011
• Project end date: Oct. 4, 2014
• Percent complete: ~2%

Barriers
• Barriers addressed
  – Increase energy density of lithium ion battery
  – Reduce the cost
  – Maintain good cycle life

Budget
• Total project funding
  – DOE share: $4,986,984
  – Dow Kokam share: $2,431,606
• Funding received in FY11: $1,957,460
• Funding for FY12: $997,560

Partners
• Dow Kokam – Project Lead
• Wildcat Discovery Technology – Cathode Materials
• Oak Ridge National Lab – Testing Services
• Dow Chemical – Anode Materials
Project Objectives

- To research, develop, and demonstrate Li-ion battery cells that are capable of achieving an energy density of >500 Wh/l and a power density of >500 W/l while maintaining comparable performance standards in terms of cycle life (300-1000 cycles at 80% depth of discharge), calendar life (5-10 years), and durable cell construction and design capable of being affordably mass produced.
Project Scope

• **Phase 1:** Mobilize Resources, Implement Project Management Plan, Institute Project Controls

• **Phase 2:** Establish Model & Performance Baseline NMC/Graphite Cell, Establish Baseline Capacity For Cells, Install Equipment

• **Phase 3:** Optimize High Voltage Cell Design And Finalize Materials Development, Scale Up High Voltage Cathode Material, Produce High Energy Interim Cells, Estimate Costs

• **Phase 4:** Develop And Optimize High Capacity Materials And Cell Designs, Produce High Energy Interim Cells, Estimate Costs

• **Phase 5:** Produce And Deliver Large Format Baseline And High Energy Cells

• **Phase 6:** Verify Achievement Of Cost Goals And Develop Commercialization Plan
Approach

- **Phase 1**: Project Management
  - Start: 10/3/11
  - End: 10/4/14

- **Phase 2**: Establish Baseline
  - Start: 10/3/11
  - Milestone: 5/1/12

- **Phase 3**: Optimize High Voltage System
  - Start: 10/3/11
  - Milestone: 3/26/13
  - Milestone: Deliver High Voltage Interim Cells to DOE

- **Phase 4**: Scale Up High Voltage Cathode
  - Milestone: 1/8/13
  - Milestone: 1/6/14

- **Phase 5**: Development of High Capacity Materials
  - Milestone: 11/29/12

- **Phase 6**: Optimize of High Capacity System
  - Milestone: 11/29/12

- **Phase 7**: Produce Large Format Cells
  - Milestone: 4/8/14

- **Phase 8**: Commercialization Plan
  - Milestone: 2/7/12

- **Deliver High Capacity Interim Cells to DOE**
- **Deliver Baseline & High Energy Cells to DOE**

- **8 Ah Cells**
- **40 Ah Cells**
## Baseline Data

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Capacity (Ah)</td>
<td>40</td>
</tr>
<tr>
<td>Nominal Voltage (V)</td>
<td>3.7</td>
</tr>
<tr>
<td>Maximum Discharge Current (Amp)</td>
<td>320 Continuous</td>
</tr>
<tr>
<td></td>
<td>480 Pulsed &lt; 10 sec</td>
</tr>
<tr>
<td>Operating Temperature Range (C)</td>
<td>-20 to 60</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>1030</td>
</tr>
<tr>
<td>Cell Dimensions (mm)</td>
<td>222.0 X 214.0 X 10.7</td>
</tr>
<tr>
<td>Energy Density (Wh/L)</td>
<td>290</td>
</tr>
</tbody>
</table>
Cell performance modeling will be employed to verify cell design parameters.
High Voltage Cathode Materials

Wildcat Discovery is to provide cathode materials based on lithium cobalt phosphate olivine structure.
High Capacity Cathode Materials

Lithium Manganese Silicate (Li$_2$MnSiO$_4$) offers the potential for specific capacities as high as 330mAh/g at >4.0V in theory.
High Capacity Anode Materials

- Two silicon-base anode material have been selected, both have specific capacity above 800 mAh/g
- Physical and electrochemical characterization is underway
- Alternative lithiation process may be required to improve the first-cycle efficiency
Process Flow for Cell Development

A. Material Testing
- pH testing, Tap density testing, particle size, Moisture, BET etc

B. Half Cell Assembly
- Slurry Mixing, Coating, Drying, electrode slitting, pressing, vacuum drying, stacking, tab welding, pouch forming, sealing, electrolyte filling

C. Half Cell Testing
- Aging, Formation, capacity, cycle life, c-rate, AC impedance

D. Full Cell Assembly
- Slurry Mixing, Coating, Drying, electrode slitting, pressing, vacuum drying, stacking, tab welding, pouch forming, sealing, electrolyte filling

E. Full Cell Formation & Testing
- Aging, Formation, capacity, cycle life, c-rate, AC impedance, c-rate, peak power, thermal tests

F. Success Criteria & Failure Mode Analysis
- N/P Ratio, Pressing Ratio, loading weight, coating volume density

G. Final System Design
- Self-Discharge, Columbic Efficiency, thermal stability, overcharge, over discharge

H. Final Cell System validation
- Optimization of Electrolyte, Electrode designs, separator etc.

Design Optimization

Go

No Go
Low Volume Slot Die Coating System

- A slot-die coating system with a scaled-down coating head and a precision low-volume slurry delivery system has been developed for R&D activities.
- The engineered die is mounted on a commercial-scale coating line to produce high quality coatings with as little as 150 ml of slurry, rather than in liters.
- Electrodes produced will be highly representative of those made under mass-production environment.

Slot die coating head

Slurry delivery system
## Performance Targets

<table>
<thead>
<tr>
<th></th>
<th>Voltage (V)</th>
<th>Specific Capacity (mAh/g)</th>
<th>Energy Density (Wh/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal Voltage</td>
<td>Cathode</td>
<td>Anode</td>
</tr>
<tr>
<td>Baseline NMC/Graphite</td>
<td>3.7</td>
<td>138</td>
<td>252</td>
</tr>
<tr>
<td>HV System/Graphite</td>
<td>4.8</td>
<td>150</td>
<td>252</td>
</tr>
<tr>
<td>HV System/Si-C</td>
<td>4.8</td>
<td>150</td>
<td>750</td>
</tr>
<tr>
<td>HC System/Graphite</td>
<td>3.7</td>
<td>300</td>
<td>252</td>
</tr>
<tr>
<td>HC System/Si-C</td>
<td>3.7</td>
<td>300</td>
<td>600</td>
</tr>
</tbody>
</table>

- Calculations are based on
  - Material properties
  - Internal Dow Kokam models
Status of Work

- **Completed:**
  - Initial screening of high capacity anode materials
  - Preliminary cell performance model developed
  - Establishment of test procedures
  - Development of high throughput synthesis and screening methodology for high capacity cathode targets
  - Validation of a low-volume slurry mixing & delivery system to simulate mass-produced electrodes

- **In progress**
  - Design of low volume slot die complete – awaiting delivery
  - Initial scanning of alternative high capacity cathode material concept approach
  - Evaluation of high voltage cathode materials for cell design
  - Evaluation of high capacity anode materials for cell design
  - Production of baseline cells
Summary

- Dow Kokam is working to increase the energy density of its large format lithium ion cells to 500 Wh/L, by incorporating phosphate-based high voltage materials, high capacity silicon-based anodes, and high capacity cathodes.
- Wildcat Discovery is a partner to supply the next-generation cathode materials and electrolytes.
- A low-volume slot die coating system has been developed, allowing us to simulate mass-production environment in an R&D laboratory with high degree of confidence.
- A cell performance model is developed that can predict cell performance data reliably.