Process for Low Cost Domestic Production of LIB Cathode Materials

Project ID # ES013

Anthony Thurston
BASF Catalysts, LLC
May 10, 2011
Overview

Timeline

• Project Start – February 2009
• Project End – June 2012
• 70% Complete

Budget

• $5.0 Million Award
  • 50% DOE ($2.5M)
  • 50% BASF ($2.5M)
• FY09/10 Funding Received = $ 1.4M
• FY11 Funding Expected = $ 825K

Barriers

• Reduce the production cost of Cathode Material
• Meet PHEV battery requirements for a 40 mile all-electric range
• Enable cost competitive market entry into electric vehicles by 2014.

Partners

• Farasis Energy Inc, Hayward CA
  • Production of 18650 Cells
  • Cell design/modification guidance
• Request for Assembly of Prototype Module submitted to 4 companies
Objective

- Successfully produce two cathode materials, suitable for electric vehicle application, (HEV - PHEV - EV)
- Use BASF’s existing assets and low cost production process.
- Validate that cost and quality targets are met via coin cells, pouch cells and 18650 cells.
- Incorporation into a battery pack for complete testing and extensive material characterization.
- Work closely with a Tier I auto supplier and/or auto OEM to insure that the products meet required specifications and expectations.
Approach

- Utilize BASF’s low cost production process for Li ion battery cathode materials.

- Cathode materials developed in the laboratory will be scaled-up in a pilot plant and ultimately produced in a production plant at a few ton levels.

- BASF will work with a sub-contractor, Farasis Energy, Inc. (Hayward, California) to make and test 18650 cells.

- Commercial partners such as automotive OEMs and Tier I suppliers will be used to validate BASF’s cathode materials.

- Final testing of a Li ion battery prototype pack containing BASF’s cathode materials will be evaluated.

- BASF will use its R&D and Battery Materials Pilot Plant facility in the United States for this project.
Approach

- Selection of preferred starting materials to ensure consistent quality
- Combined with intimate and uniform blending
- Reduction of calcination time by utilization of advanced calcination
- Finish processing as needed
### Approach

**Material Cost Analysis for NCM based Materials**

<table>
<thead>
<tr>
<th></th>
<th>NCM 111</th>
<th>NCM 523</th>
<th>NCM 424</th>
<th>NCM 622</th>
<th>NCM 226</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Ni</td>
<td>21.3%</td>
<td>32.0%</td>
<td>25.7%</td>
<td>38.3%</td>
<td>12.97%</td>
</tr>
<tr>
<td>% Co</td>
<td>21.4%</td>
<td>12.9%</td>
<td>12.9%</td>
<td>12.8%</td>
<td>13.02%</td>
</tr>
<tr>
<td>% Mn</td>
<td>19.9%</td>
<td>18.0%</td>
<td>24.1%</td>
<td>11.9%</td>
<td>36.42%</td>
</tr>
<tr>
<td>Ahr/kg</td>
<td>135.0</td>
<td>155.0</td>
<td>145.0</td>
<td>165.0</td>
<td>200.0</td>
</tr>
<tr>
<td>Raw Material Cost</td>
<td>0%</td>
<td>-5%</td>
<td>-13%</td>
<td>3%</td>
<td>-30%</td>
</tr>
</tbody>
</table>

Cost based on 02/11 Metals Market Price

Based on the raw material cost alone it is clear that a transition from high nickel and cobalt containing cathode materials represents a potential savings of 30%. When this savings is coupled with the increase in capacity the savings are increased to approximately 50%.
Technical Accomplishments & Progress
NCM 111 Low Cost Process Evaluation

For NCM-111 BASF has demonstrated that the Low Cost Process (LCP) is capable of producing materials that are equal to the standard process (SP)

The LCP represents a 25% decrease in processing time compared to the SP
The rate capability of BASF NCM 111 is equal or better than competitor materials.
Technical Accomplishments & Progress

3C Cycling of BASF NCM 111 vs Competitors

The capacity retention of BASF NCM 111 is equal or better than the competitor materials.

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Technical Accomplishments & Progress
NCM 523 Rate capability of Standard Process vs Low Cost Process

Low cost process produces consistent and reproducible quality material with improved rate capability

Legend:
- NCM-523-B-LCP
- NCM-523-C-SP
- NCM-523-D-LCP

Coin cell
Lithium Anode
Charge: 0.2C, CCCV, 4.3V
Discharge: Various, CC, 3.0V
Temperature: 25°C
Technical Accomplishments & Progress
NCM 523 Capacity of Standard Process vs Low Cost Process

Equal capacity with Low Cost Process

Specific Capacity (mAh/g)

Cycle Number

NCM-523-B-LCP
NCM-523-C-SP
NCM-523-D-LCP

Coin cell
Lithium Anode
Charge: 0.5C, CCCV, 4.3V
Discharge: 1C, CC, 3.0V
Temperature: 25°C
Technical Accomplishments & Progress
NCM 424 Rate Capability of Standard Process vs Low Cost Process

Although the high rate capability of the Standard Process material is slightly better, additional work is focused on resolving this.
Technical Accomplishments & Progress

NCM 424 Capacity of Standard Process vs Low Cost Process

The capacity of the standard process material is slightly better than the low cost process; however, adjustments are in development to resolve this difference.

- **Coin cell**
- **Lithium Anode**
- **Charge:** 0.5C, CCCV, 4.3V
- **Discharge:** 1C, CC, 3.0V
- **Temperature:** 25°C

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Technical Accomplishments & Progress
Development of HE NCM – Low Cobalt, Low Nickel Cathode Material

HE NCM shows excellent capacity and represents a potential cost savings due to the reduced nickel and cobalt composition.

Coin cell
Cathode: HE-NCM
Lithium Anode
Discharge: 2.0V
Temperature: 25°C
### Milestone Timeline

<table>
<thead>
<tr>
<th>Month / Year</th>
<th>Milestone or Go/No-Go Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Sept / 09 - Complete</td>
<td>Milestone: Establish lab synthesis process of NCM up to 5 kg level to determine baseline performance</td>
</tr>
<tr>
<td>✓ June /10 - Complete</td>
<td>Milestone: Complete pilot plant synthesis of NCM up to 100 kg level.</td>
</tr>
<tr>
<td>✓ Oct / 10 - Complete</td>
<td>Go/No-Go: Confirm product quality meets or exceeds lab produced sample.</td>
</tr>
<tr>
<td>✓ July / 10 - Complete</td>
<td>Milestone: Establish lab synthesis procedure for advanced cathode material – Prepare 5kg sample and determine baseline performance</td>
</tr>
<tr>
<td>✓ Dec / 10 - Complete</td>
<td>Go/No-Go: Confirm acceptable product quality and cost are achieved prior to Pilot Phase</td>
</tr>
<tr>
<td>✓ Dec / 10 – Complete</td>
<td>Milestone: Begin Pilot Phase for Advanced Cathode Material</td>
</tr>
<tr>
<td>Mar /11</td>
<td>Milestone: Pilot production of 1MT of NCM in Pilot Plant</td>
</tr>
<tr>
<td>June / 11</td>
<td>Milestone: Pilot production of 100 kg of HE NCM Cathode Material in Pilot Plant</td>
</tr>
<tr>
<td>Oct / 11</td>
<td>Go/No Go: Confirm product quality of HE NCM Cathode Material</td>
</tr>
<tr>
<td>Feb / 12</td>
<td>Milestone: Assembly and Testing of LIB prototype pack</td>
</tr>
<tr>
<td>June / 12</td>
<td>Project Completion</td>
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</table>
Farasis Energy Inc
23575 Cabot Blvd.
Suite 205-206
Hayward, CA 94545

Assembly and testing of 18650 cells and packs from BASF produced NCM cathode materials

Provide guidance for design modifications in order to meet customer requirements
2011 Project Objectives

- Reduction of processing time by 25%
- Increase in production capacity by 25%
- Increase Energy Density of cathode material (Ahr/kg) by 25%
- Complete Pilot Production Trials for NCM 424, 523 and High Energy
  - Validation of BASF Process
  - Cost analysis for Production
  - Customer evaluation and validation
- Pilot Plant Production of NCM materials at +100 kg level
  - Q1-Q2 2011
To date BASF has been able to successfully scale up the development of NCM based cathode materials in its R&D center in Beachwood Ohio. Samples have been provided to customers and are in qualification testing. To date BASF’s cathode materials have received a very good response from its customers.

The development of a low cost Cathode Material process for lithium ion batteries for application in all electric vehicles (HEV, PHEV, EV) is BASF’s objective. To do this, BASF will leverage it’s license from Argonne National Labs, existing US assets, technological expertise and years of production experience to make this a reality.
Acknowledgment: "This material is based upon work supported by the Department of Energy [National Energy Technology Lab under Award Number DE-EE0000563."

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