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2011 DOE Vehicle Technologies Annual Merit Review

Process for Low Cost Domestic Production of LIB Cathode Materials

Project ID # ES013

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BASF The Chemical Company

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

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

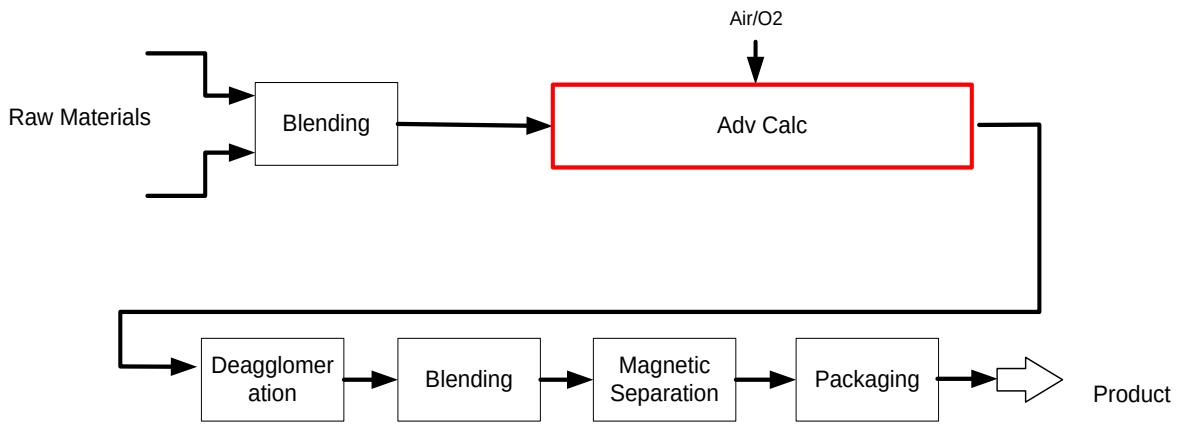
- Successfully produce two cathode materials, suitable for electric vehicle application, (HEV - PHEV - EV)
- Use BASF's existing assets and low cost production process.
- Validate that cost and quality targets are met via coin cells, pouch cells and 18650 cells.
- Incorporation into a battery pack for 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

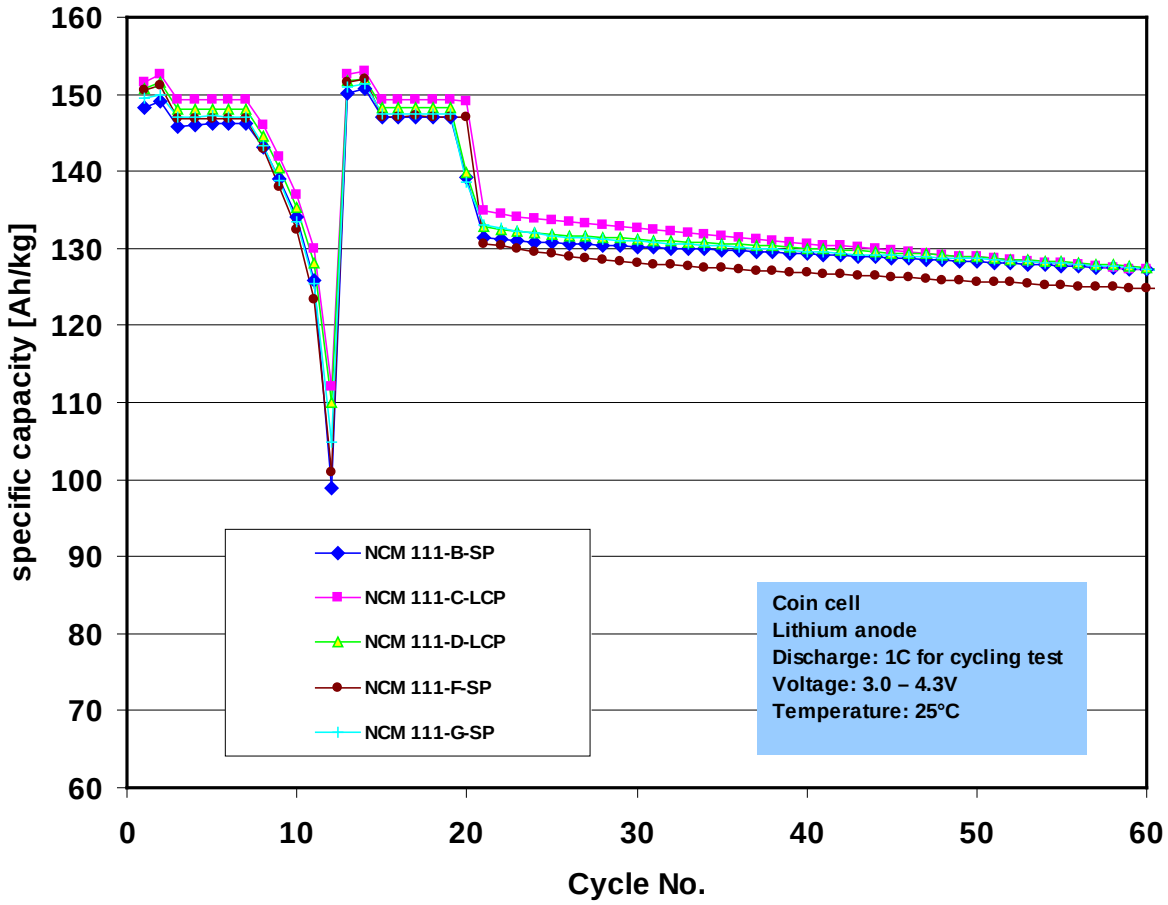
Material Cost Analysis for NCM based Materials

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

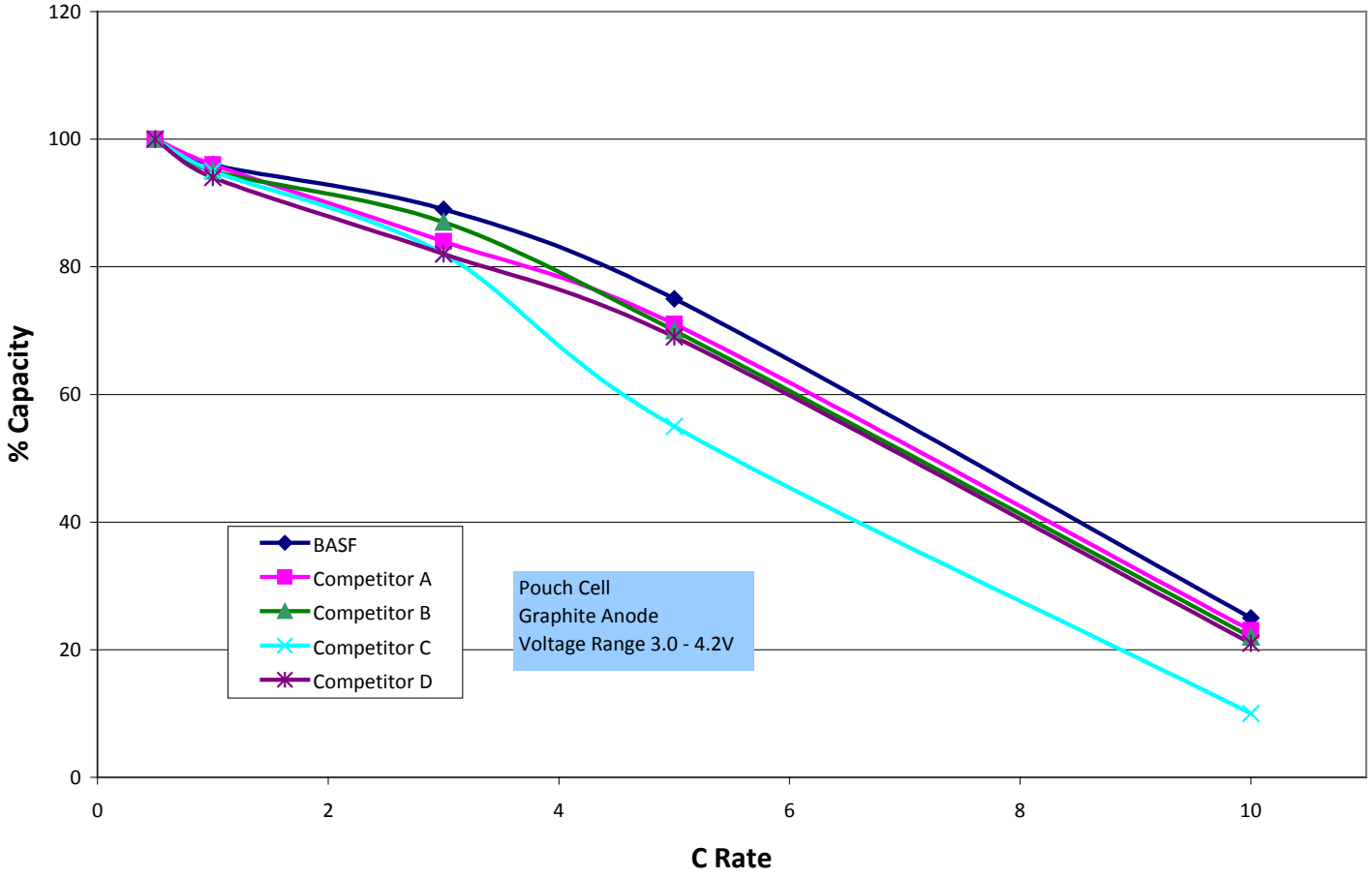


For NCM-111 BASF has demonstrated that the Low Cost Process (LCP) is capable of producing materials that are equal to the standard process (SP)

The LCP represents a 25% decrease in processing time compared to the SP

Technical Accomplishments & Progress

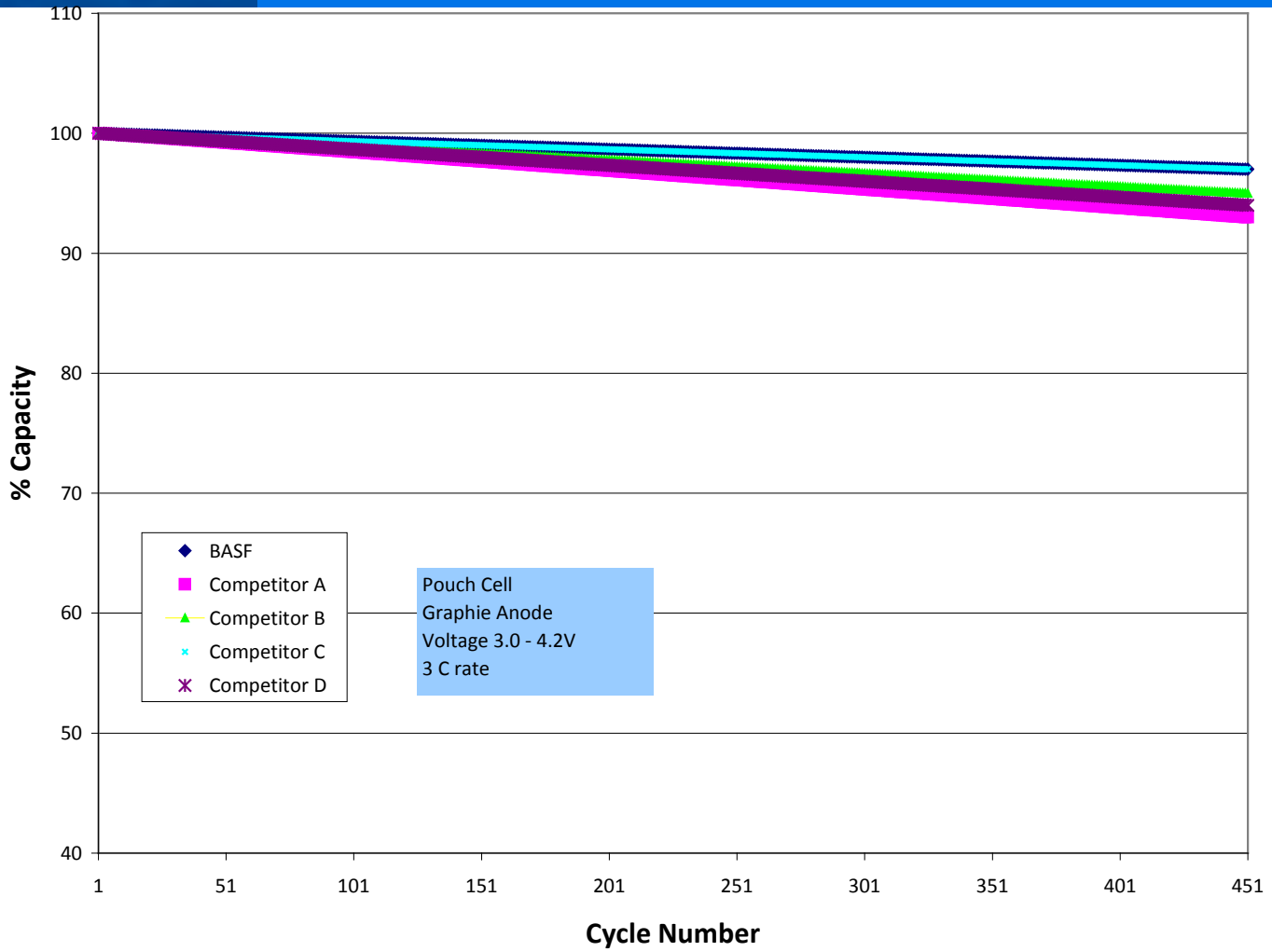
Rate Capability of BASF NCM 111 vs Competitors



The rate capability of BASF NCM 111 is equal or better then competitor materials.

Technical Accomplishments & Progress

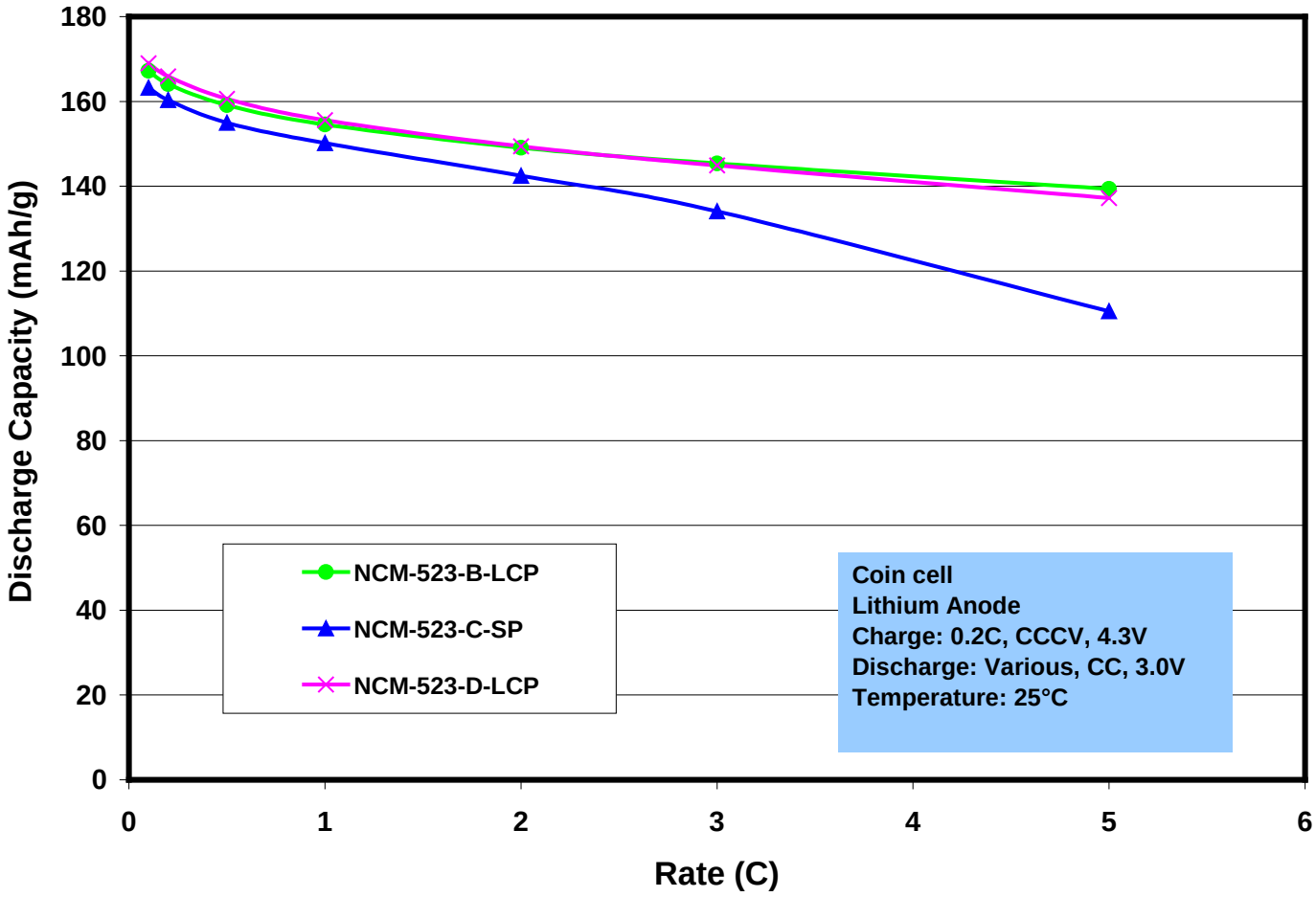
3C Cycling of BASF NCM 111 vs Competitors



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

Technical Accomplishments & Progress

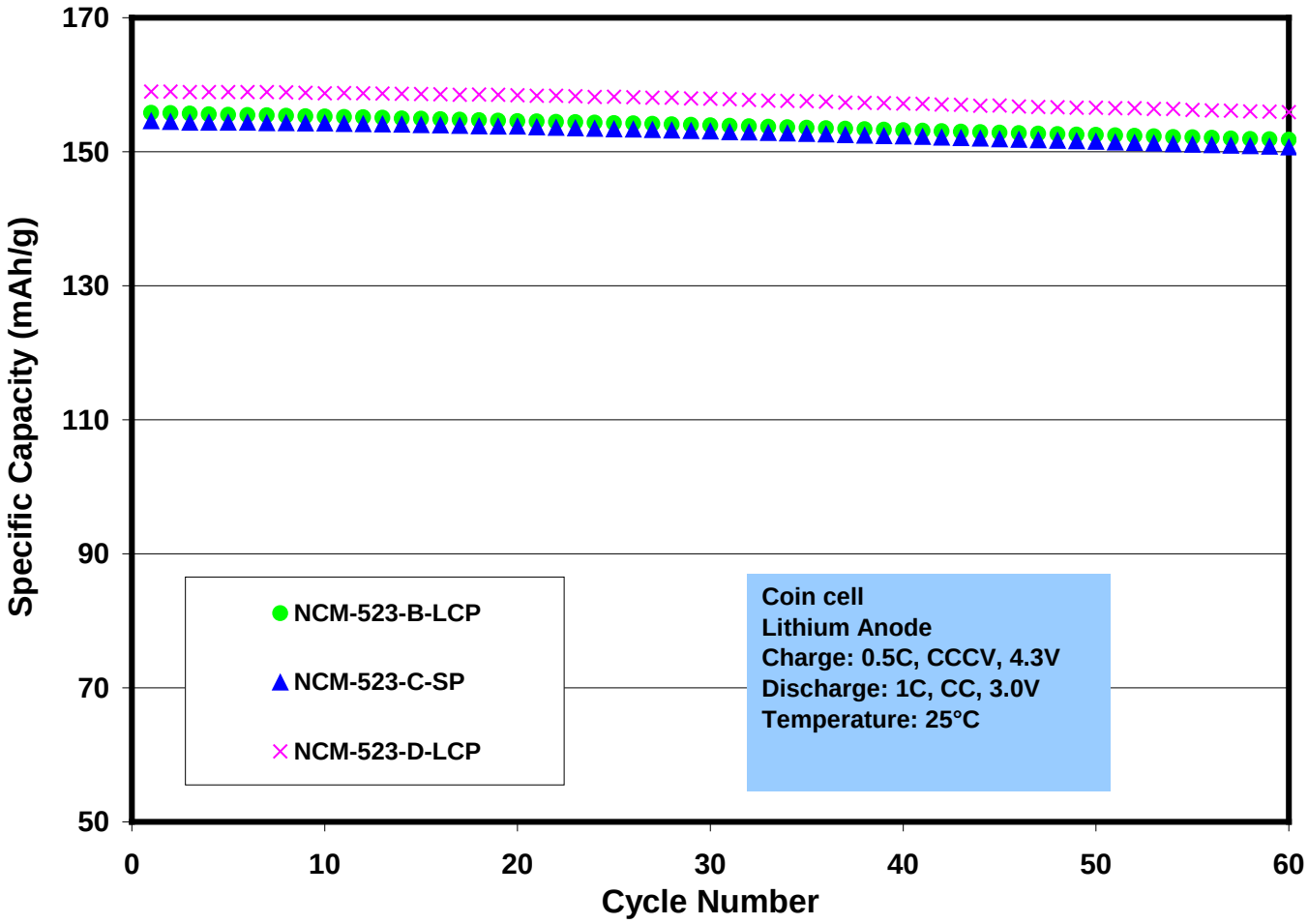
NCM 523 Rate capability of Standard Process vs Low Cost Process



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

Technical Accomplishments & Progress

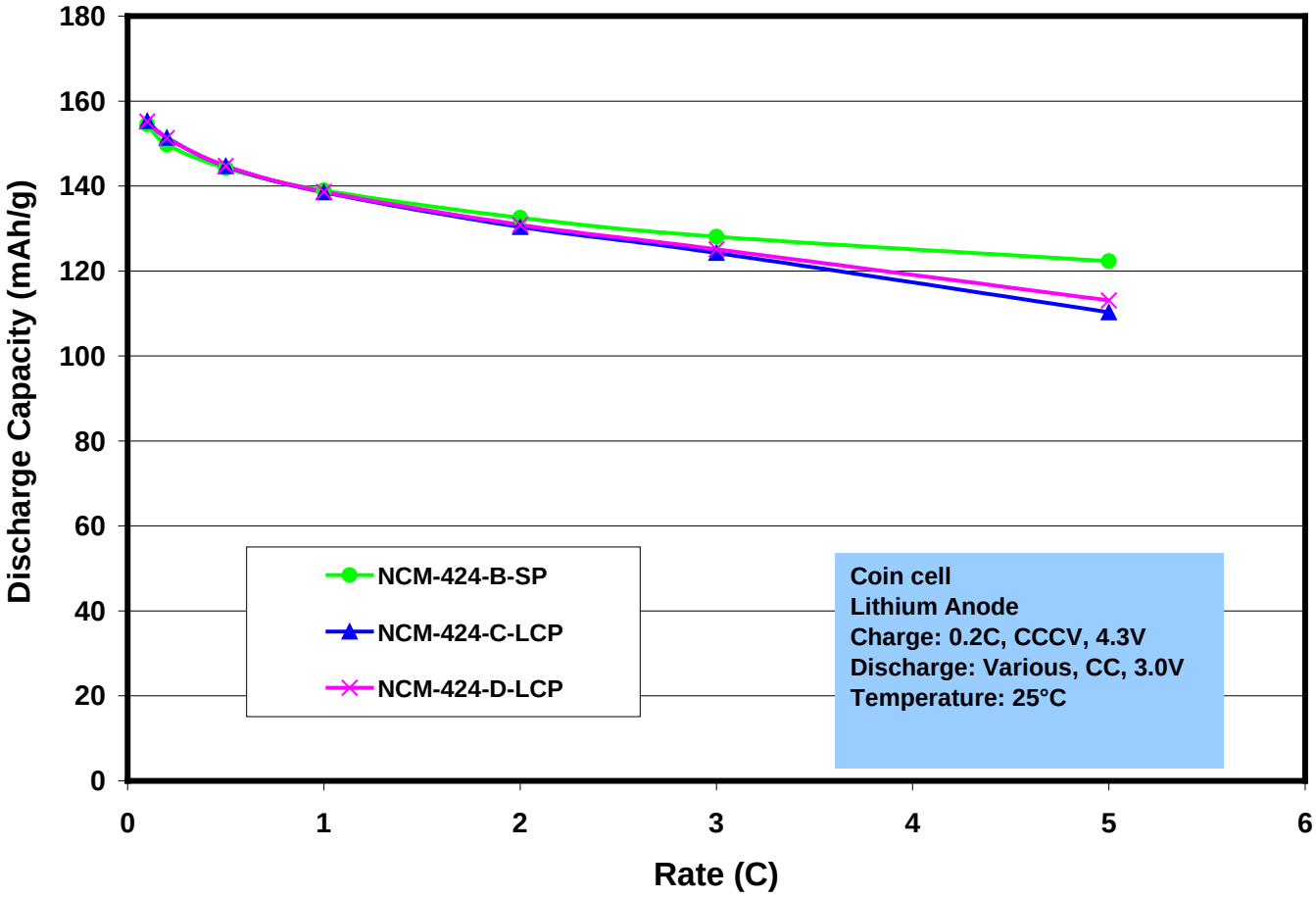
NCM 523 Capacity of Standard Process vs Low Cost Process



Equal capacity with Low Cost Process

Technical Accomplishments & Progress

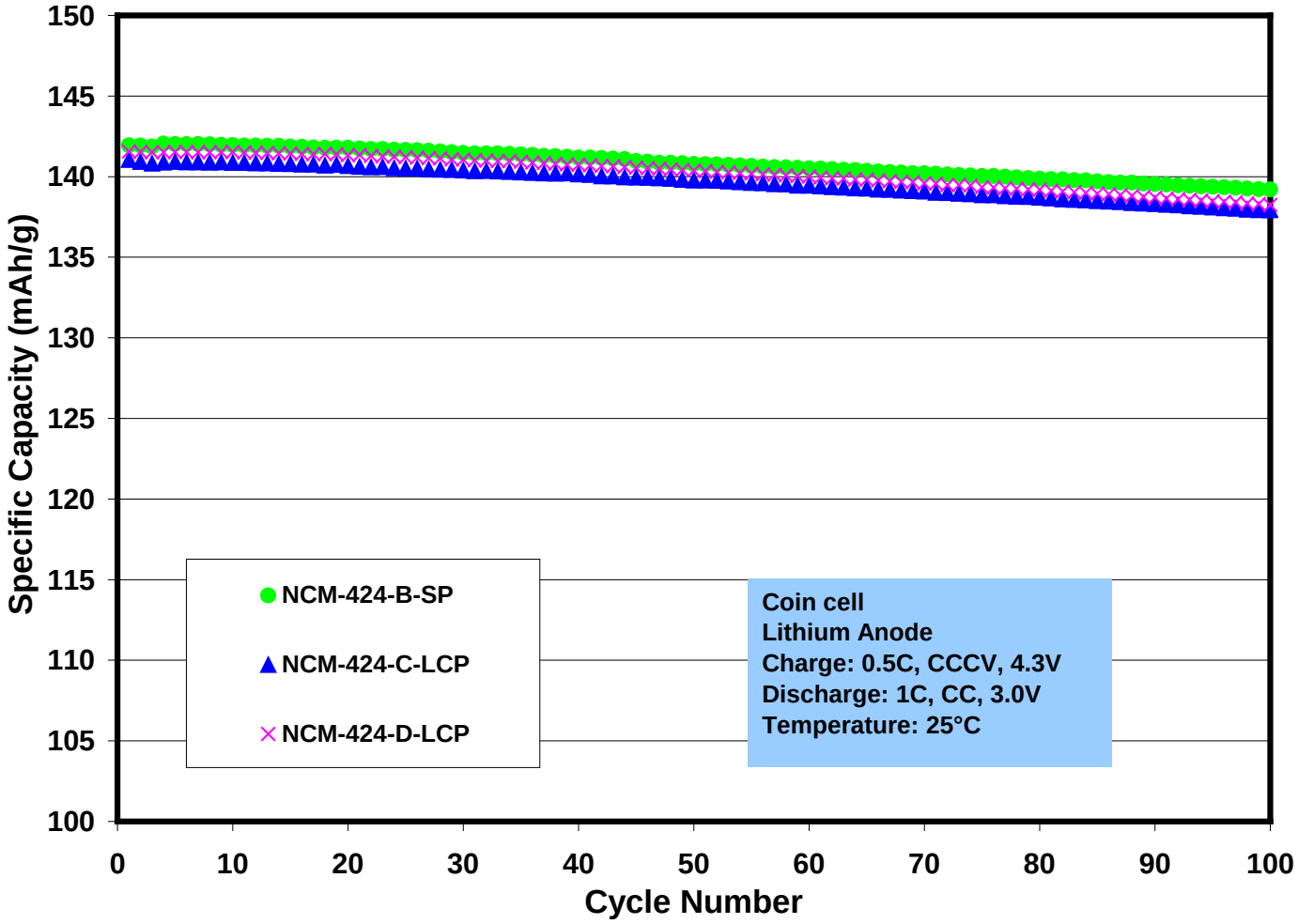
NCM 424 Rate Capability of Standard Process vs Low Cost Process



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

Technical Accomplishments & Progress

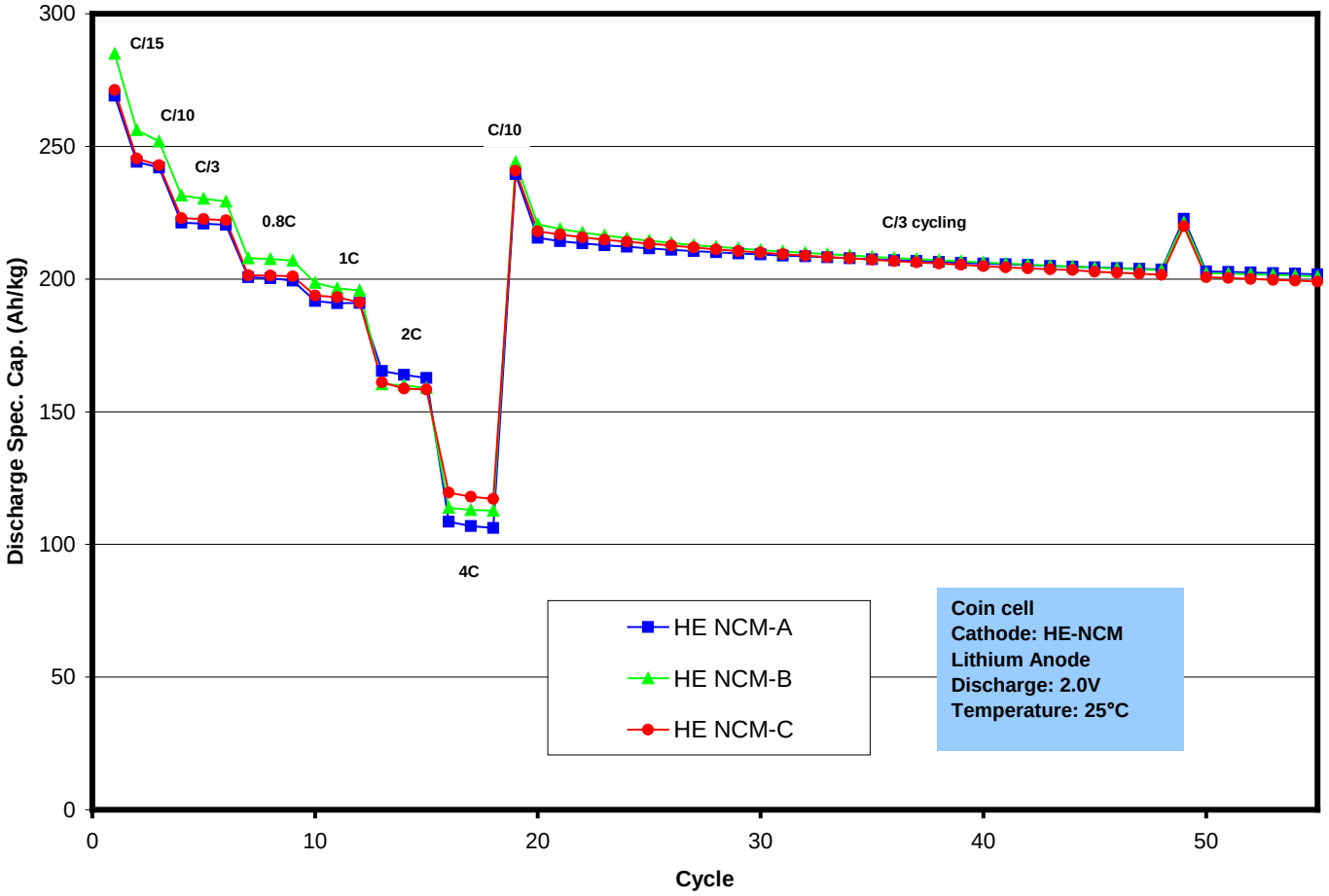
NCM 424 Capacity of Standard Process vs Low Cost Process



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

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

Milestone Timeline

Month / Year	Milestone or Go/No-Go Decision
✓Sept / 09 - Complete	Milestone: Establish lab synthesis process of NCM up to 5 kg level to determine baseline performance
✓June /10 - Complete ✓Oct / 10 - Complete ✓July / 10 - Complete ✓Dec / 10 - Complete ✓Dec / 10 – Complete	Milestone: Complete pilot plant synthesis of NCM up to 100 kg level. Go/No-Go: Confirm product quality meets or exceeds lab produced sample. Milestone: Establish lab synthesis procedure for advanced cathode material – Prepare 5kg sample and determine baseline performance Go/No-Go: Confirm acceptable product quality and cost are achieved prior to Pilot Phase Milestone: Begin Pilot Phase for Advanced Cathode Material
Mar /11 June / 11 Oct / 11	Milestone: Pilot production of 1MT of NCM in Pilot Plant Milestone: Pilot production of 100 kg of HE NCM Cathode Material in Pilot Plant Go/No Go: Confirm product quality of HE NCM Cathode Material
Feb / 12 June / 12	Milestone: Assembly and Testing of LIB prototype pack Project Completion

Collaboration

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

BASF ↑ ⟷ Farasis ↓

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

Summary

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

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