Process for Low Cost Domestic Production of LIB Cathode Materials

Project ID # ES013

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BASF Catalysts, LLC

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Overview

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Timeline

- Project Start – February 2009
- Project End – June 2012
- 30% Complete

Budget

- $5.0 Million Award
  - 50% DOE ($2.5M)
  - 50% BASF ($2.5M)
- FY09 Funding Received = $ 472K
- FY10 Funding Expected = $ 890K

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

Objective

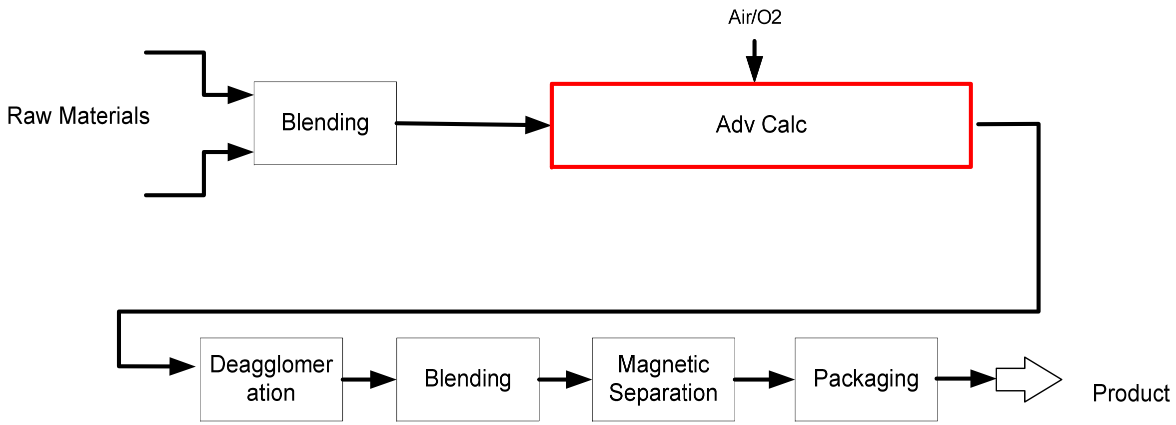
Successfully produce two cathode materials, suitable for electric vehicle application, (HEV,PHEV,EV), using BASF's existing assets and low cost production process. Validate that cost and quality targets are met via coin cells, pouch cells and 18650 cells, with final incorporation into a battery pack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

BASF has a low cost production process for Li ion battery cathode materials. In this project, the cathode materials developed in the laboratory will be scaled-up in a pilot plant and finally 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 and commercial partners such as automotive OEMs and Tier I suppliers to validate BASF's cathode materials and finally test a Li ion battery pack containing BASF's cathode materials. BASF will use its production and R&D facilities in the US for this project. When successful, this project will strengthen BASF's position as a US based LIB cathode material supplier for the global market and provide an assurance of quality and supply to US consumers.

Approach

- Selection of preferred starting materials
- Combined with intimate and uniform blending
- Reduction of calcination time by utilization of advanced processing
- Finish processing as needed



Technical Accomplishments & Progress

NCM-111 1st Discharge vs. Process

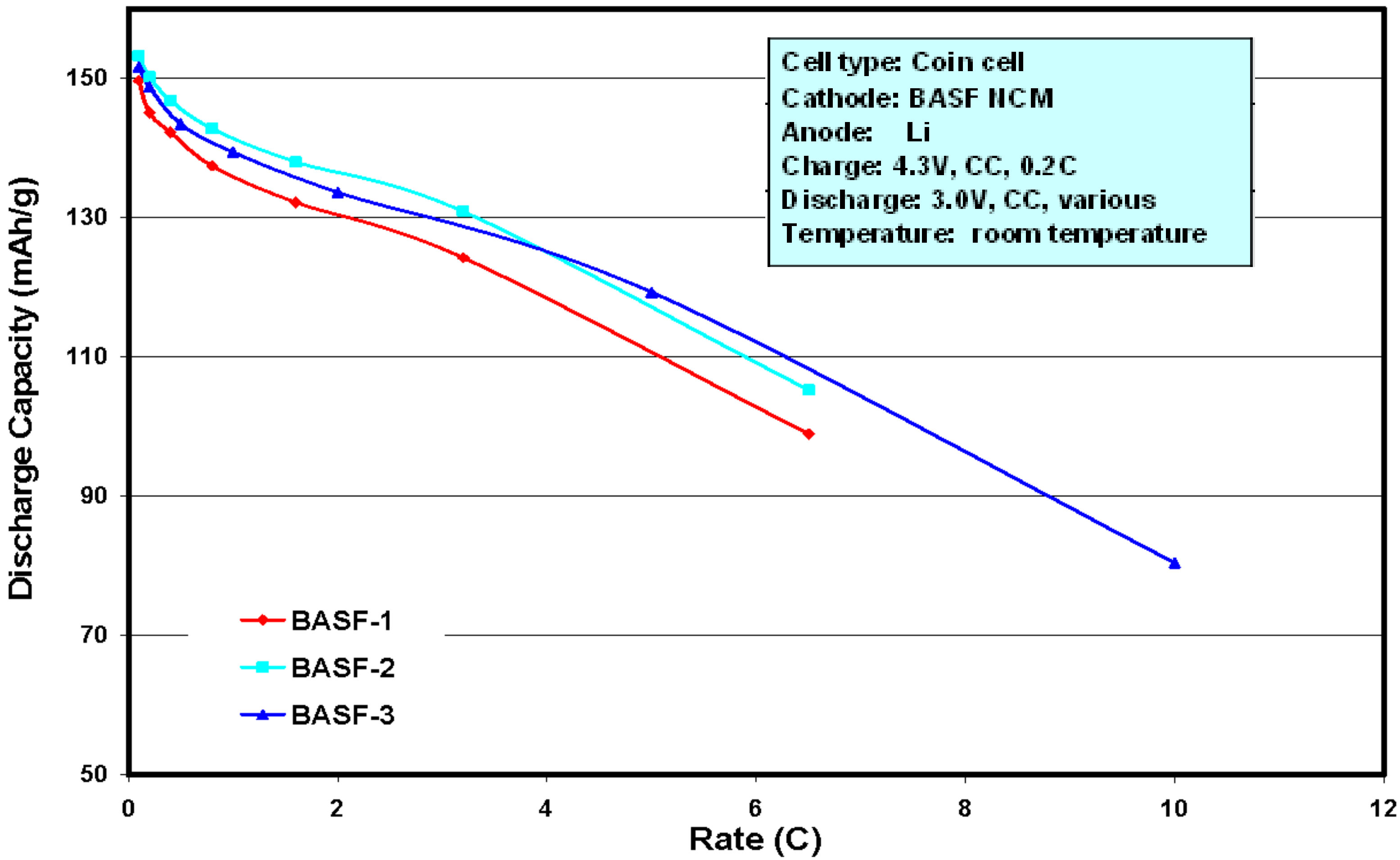
	1st Charge mAh/g	Variation (+/-)	1st Discharge mAh/g	Variation (+/-)	Coulombic Efficiency
BASF-1	167.11	0.56/0.65	148.49	0.77/0.64	88.9%
BASF-2	169.70	1.40/0.60	150.16	1.40/0.60	88.5%
BASF-3	196.94	1.10/0.60	151.32	0.60/0.90	89.0%

Current Process changes have resulted in reduced processing time and increased potential production capacity while maintaining product performance.

BASF-1 is a standard laboratory synthesis, BASF-2 represents process improvements in the lab and BASF-3 is a Pilot Sample incorporating some of the lab process improvements.

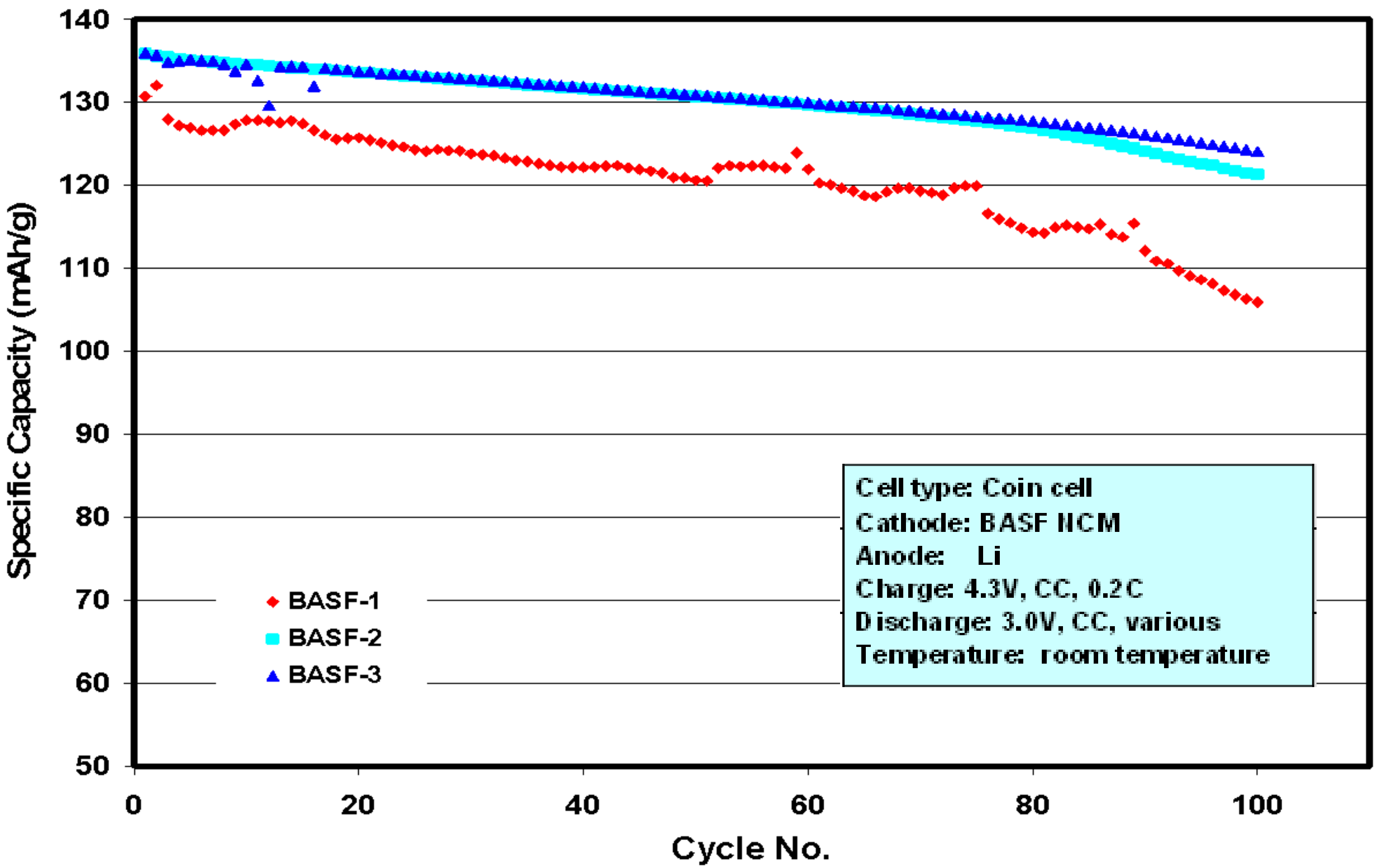
Technical Accomplishments & Progress

NCM-111 Rate Capability vs. Process



Technical Accomplishments & Progress

NCM-111 Capacity vs. Process



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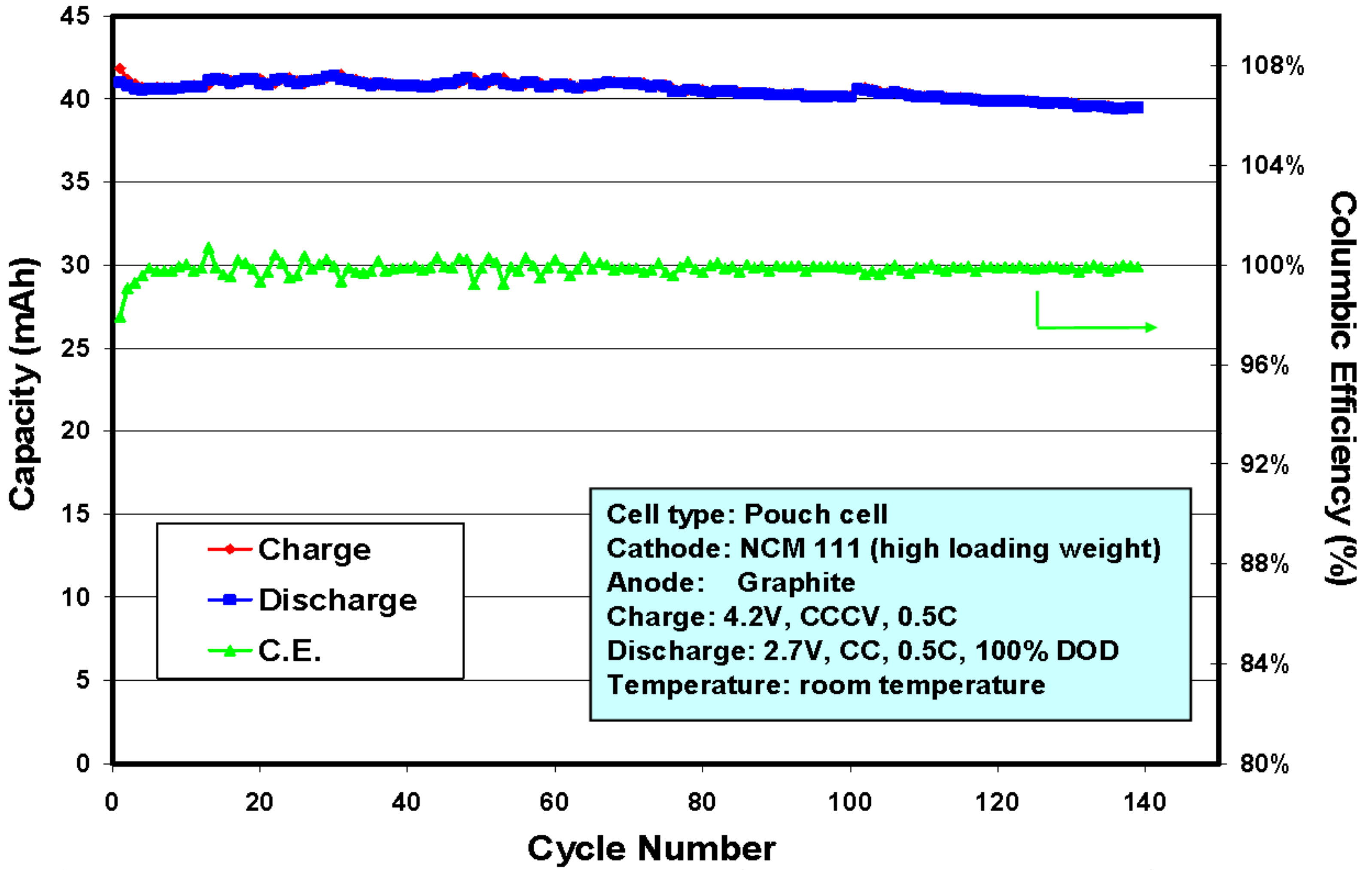
Technical Accomplishments & Progress
NCM-111 Pouch Cell Data



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Technical Accomplishments & Progress

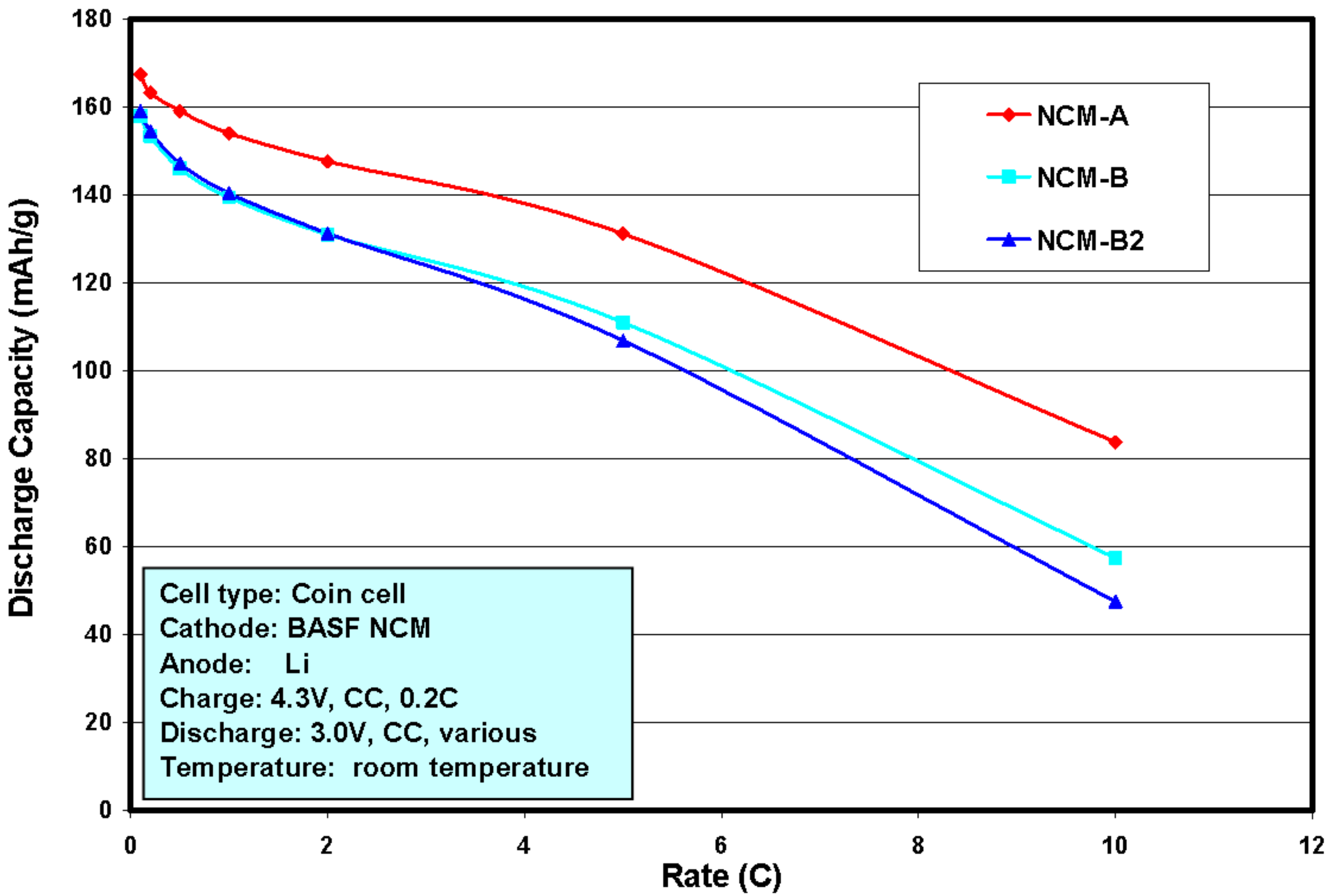
Next Materials for Evaluation - NCM-A and NCM-B

Sample ID	Charge	Discharge	Columbic Efficiency
	mAh/g	mAh/g	
NCM-A	186.85	164.53	88.1%
NCM-B	180.30	155.15	86.1%
NCM-B2	176.09	156.07	88.6%

NCM-A has better initial discharge capacity and slightly better columbic efficiency but presents some processing difficulties in scale-up from the lab to pilot plant

Technical Accomplishments & Progress

NCM-A and NCM-B – Rate Comparison



Technical Accomplishments & Progress

NCM-A - Effect of Li/Metal ratio

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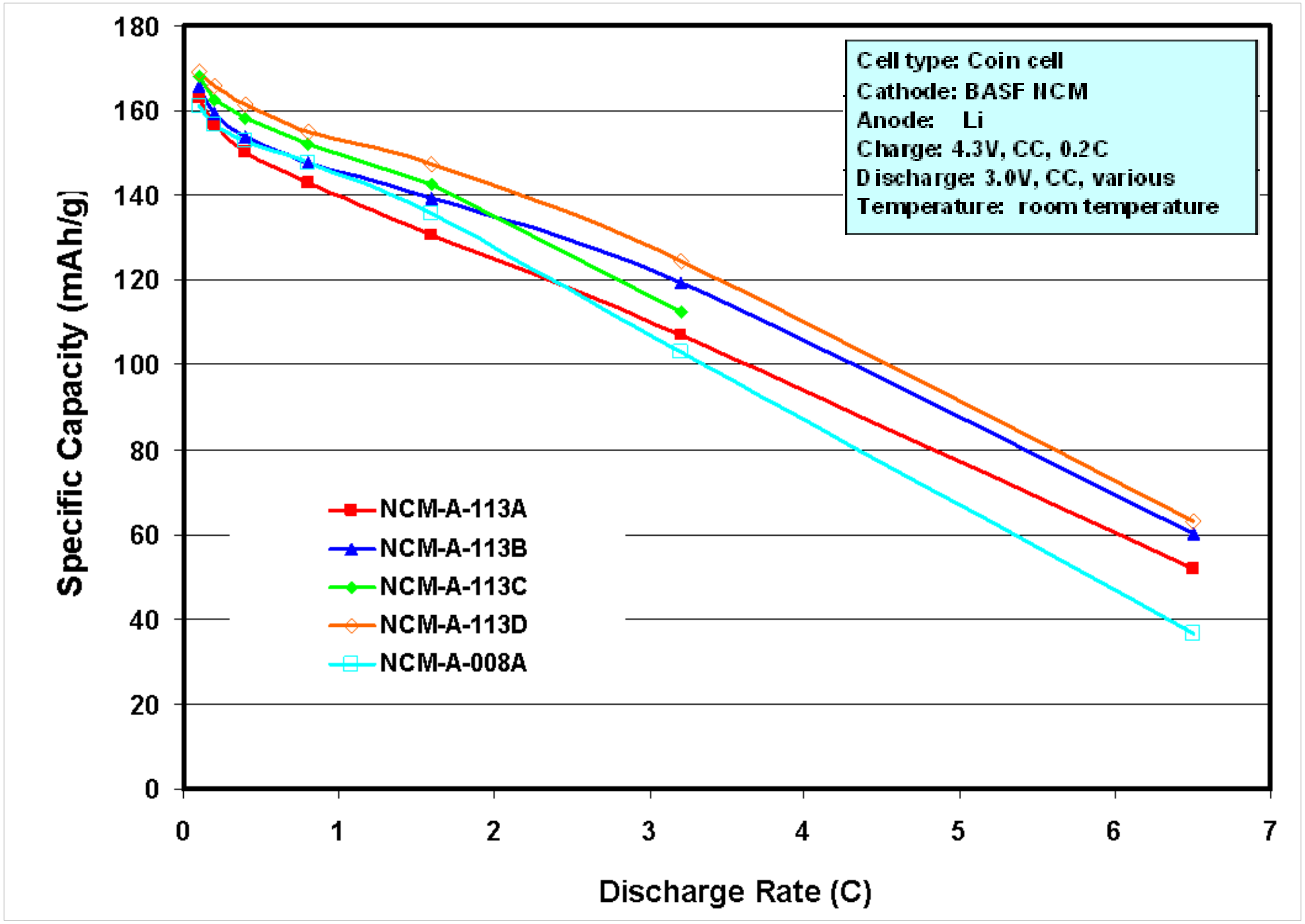
Sample ID	1st Charge	1st Discharge	Columbic Efficiency
	mAh/g	mAh/g	
NCM-A-113A	190.52	161.36	84.7%
NCM-A-113B	191.13	163.41	85.5%
NCM-A-113C	191.01	166.36	87.1%
NCM-A-113D	187.50	167.31	89.2%
NCM-A-008A	188.12	161.47	85.8%

Ideal Area (NCM-A-113C, NCM-A-113D)

Optimization of Lithium Stiochiometry helps reduce raw material costs and improves post processing efficiency.

Technical Accomplishments & Progress

NCM-A - Effect of Li/Metal ratio



Increased Li/metal ratio yields better rate capability…To a break point at 113D

Milestone Timeline

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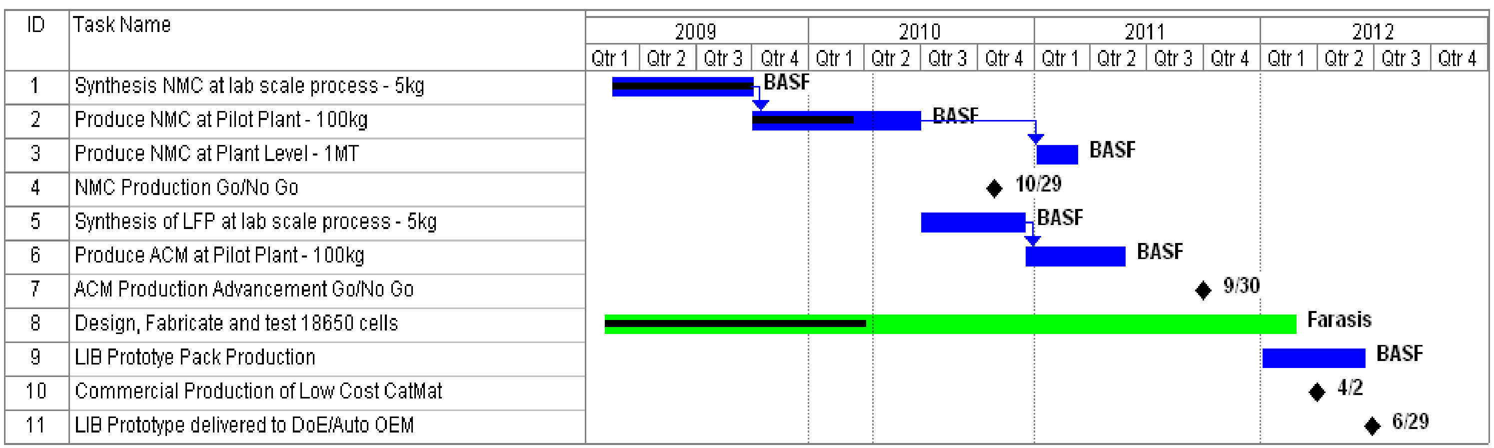
Month/Year	Milestone or Go/No-Go Decision
Sept - 09	Milestone: Establish lab synthesis process of NCM up to 5 kg level to determine baseline performance
June - 10 Oct - 10	Milestone: Complete pilot plant synthesis of NCM up to 100 kg level, Go/No-Go: Confirm product quality meets or exceeds lab produced sample.
July - 10 Dec - 10 Dec - 10	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



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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 ↓

2010 Project Objectives

- Complete Pilot Production Trials for NCM 111, NCM-A and NCM-B
  - Validation of BASF Process
  - Cost analysis for Production
  - Customer evaluation and validation
- NCM production at Plant level
  - Starting Q1 2011
- Initiate advanced cathode material lab phase in Q3-Q4 2010
  - Pilot Trials for advanced cathode material to begin in Q1 2011

Summary

Today the competitive landscape for Cathode Materials is dominated by Asian companies where the primary applications are consumer electronics and power tools.

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.

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Acknowledgment

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