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2020 DOE Vehicle Technologies Office Annual Merit Review

An Integrated Flame Spray Process for Low Cost Production of Battery Materials

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Project ID#: bat269

Overview

Timeline

- Start: January 1, 2016
- End: September 30, 2020

Budget

- Total project funding
  - DOE share: $2,215,556
  - Contractor share: $310,694
- Funding received in FY 2019
  - $13,875.93
- Funding for FY 2020
  - N/A

Barriers addressed

- Low cost battery target of $125/kWh
- Energy density target of $250 Wh/kg
- Cost-effective battery materials manufacturing process

Partners

- Project lead
  - University of Missouri
- Industrial Partners
  - EaglePicher Technologies
  - Storagenergy Technologies

Relevance

Overall objective

The overall objective of this project is to develop an advanced manufacturing technology for battery materials production at low cost and in a green chemical process using glycerol as solvent to replace water.

Specific objectives

- To reduce material cost by at least 25% to $34/kg or less as compared to a baseline $45/kg;
- To achieve a lab scale production rate of 3 kg/day and a pilot scale production rate of 4 metric tons per year of cathode powders.
- To demonstrate battery cells with 250 Wh/kg energy density.

Objectives for the Review Period

1. To optimize powder morphology and size
2. To achieve a material with high specific capacity
3. To scale up the flame process at a pilot scale

Resources

At University of Missouri

- Custom-designed and fabricated flame spray reactor for the work.
- Full dedicated lab (~1500 ft^2) with walk-in hood for the experimental setup of the flame spray work.
- A battery lab (~900 ft^2) equipped with Unilab Mbraun glovebox and Innovation Technology glovebox, Arbin battery cycler, and coin cell fabrication equipment.
- Wet chemistry lab with fume hood for any chemistry work and battery materials handling.
- Several potentiostats/galvanostats for electrochemical property measurements.
- On campus facilities include SEM, TEM, XRD, ICP-MS, and other equipment.

At EaglePicher Technologies

- Complete battery fabrication facilities
- Dry rooms
- Complete battery testing equipment
- Battery R&D facilities

At Storagenergy Technologies

- Battery fabrication facilities
- Dry rooms
- Battery R&D and testing facilities

Milestones

FY18/FY19 Milestones and Work Status

Milestone	Descriptions	Status
Go/No Go*	Demonstrate a production capacity of 3 kg/day with the high throughput spray technology.	Completed
Tech	Select an in situ or semi-in situ coating process.	Completed
Tech	Demonstrate control of active material powder sizes to around 10 microns on average.	Completed

FY19/FY20 Milestones and Work Status

Milestone	Descriptions	Status
Tech	Cell design including matching anode and suitable electrolytes	On-going
Tech	Demonstrate five (5) cells of 250Wh/kg energy density	On-going
Tech	Cost reduction of at least 25% to $34/kg or less for active material NMC demonstrated.	On-going
Tech	Materials processing method using either a flow process or a stationary process will be selected.	To start
Tech	Pilot production line construction and material production.	On-going

Approach

The **overall approach** is to develop a new flame spray process to make active cathode powders with new chemistry. Glycerol, as a cheap industrial byproduct, is used as solvent to replace water and as a fuel to process transition metal oxide powders to reduce energy consumption. The process also uses natural gas through combustion to provide energy to anneal the powders during the synthesis to lower material cost.

Approaches to technical barriers:

- ❑ High capacity powders have been made with NCA chemistry (Completed).
- ❑ Process economic analysis of the flame process for achieving low cost target (Completed).
- ❑ Cell fabrication and density target (On-going).
- ❑ Scale-up process (On-going).

Technical Accomplishments and Progress (1)

1. High capacity NCA powders

To achieve high capacity, $Li(Ni_{0.8}Co_{0.15}Al_{0.05})O_2$ (NCA) chemistry was used and NCA powders were made in the spray reactor with flame or flame spray process (FSP) and without flame or spray drying (SD). The powder morphology shows denser powders when flame is used in the process (Fig. 1 left column). Its capacity is also better.

The X-ray diffraction of the powders shows the powders are identified with NCA for both materials, after heat treatment at 750 °C for 7 hours (Fig. 2).

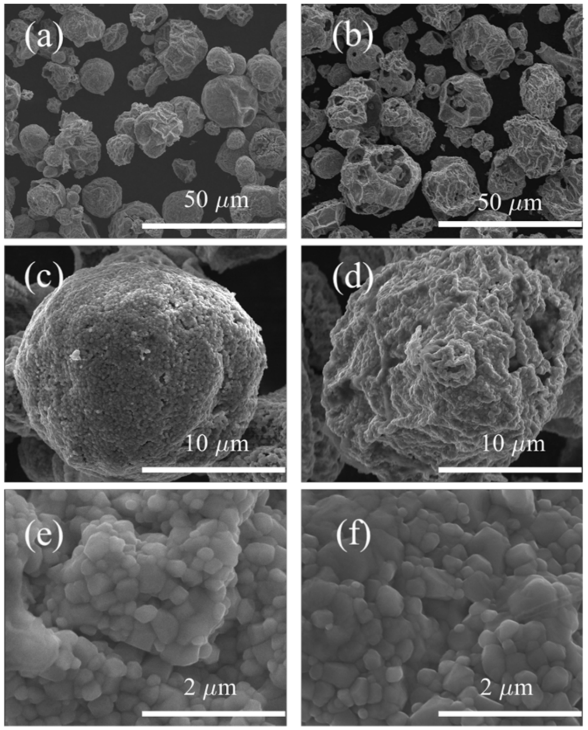

Fig. 1. SEM images of NCA powders made with flame (left column, (a), (b), (c) and without flame (right column), showing denser spherical morphology with flame.

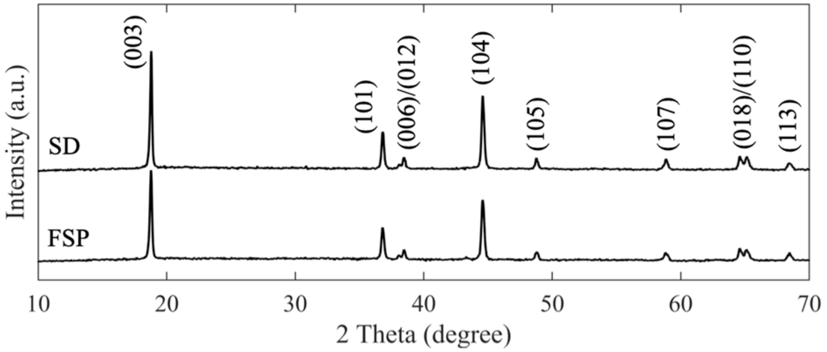

Fig. 2. XRD patterns of NCA powders made from FSP and SD processes.

Technical Accomplishments and Progress (1) cont'd

The NCA powders were was tested in half coin cells. Fig. 3(a) shows the initial charge and discharge curves. The initial discharge capacity and the coulombic efficiency of the powder from the FSP process are 200.2 mAh/g and 83.4% and are 185.1 mAh/g and 82.7% for the powder from SD process. Rate performances (Fig. 3(b)) shows powder made with flame performs much better, whereas retention rates are also better as shown in Fig. 3(c) for 1C and Fig. 3(d) for 5C.

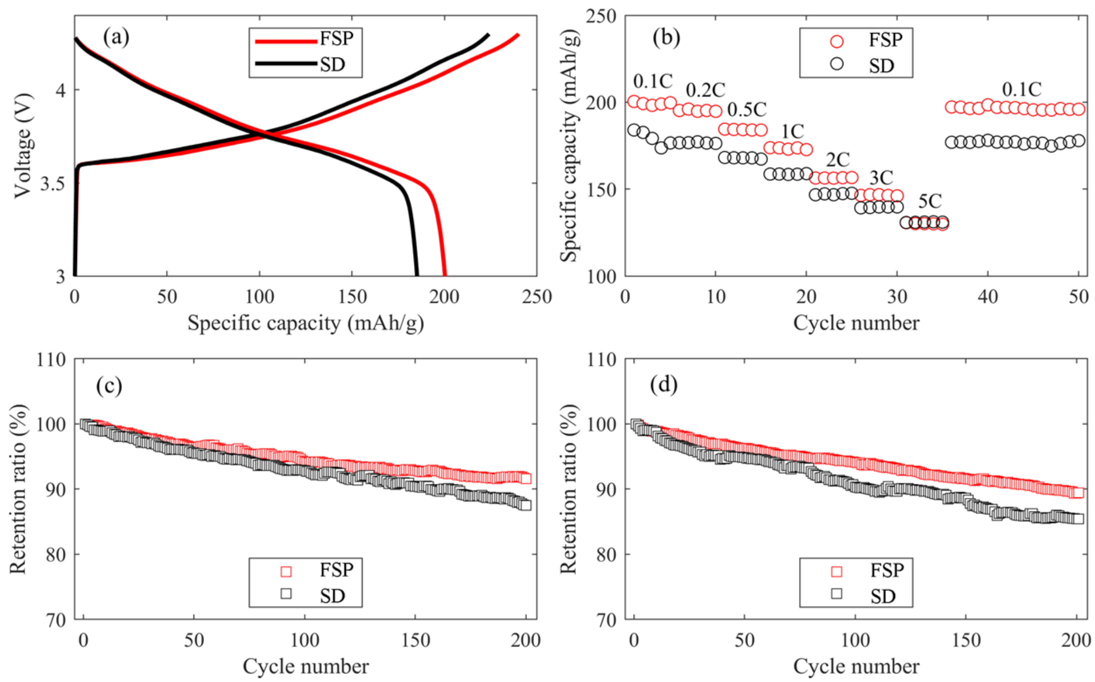

Fig. 3 (a) Initial charge and discharge curves at 0.1C of the powders; (b) rate performance; (c) cyclic performance at 1C; (d) cyclic performance at 5C.

1 C (=180 mA/g)
4.3 – 3.0 V

Technical Accomplishments and Progress (2)

2. Process Economic Analysis

To achieve cost target, the flame spray process was analyzed on its economical benefit in cost reduction. Four compositions (NMC333, NMC 622, NMC532, NMC811) of the NMC were analyzed. The techno-economic analysis was based on a two-step economic analysis model, and minimum cathode material selling price (MCSP) is used as the major economic indicator. The cost of cells are also evaluated based on these compositions.

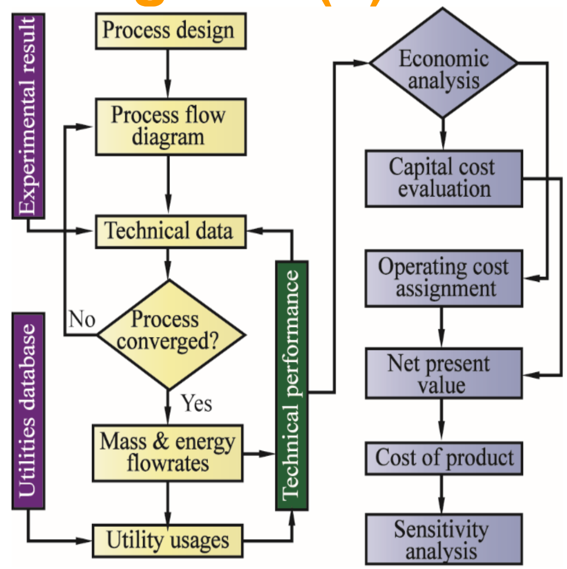

Fig. 4 Two-step techno-economic analysis model.

Results show that the FSP process can produce NMC 333 powders at $19.1/kg, but when the sintering process is integrated it is lower at $15.6/kg, representing a 32.2% cost savings as compared to the referenced co-precipitated carbonate pathway. When NMC811 is evaluated, it has the lowest MCSP as well as the lowest cost of battery cells (Fig. 5), which is at $111.5 /kWh, lower than the DOE target.

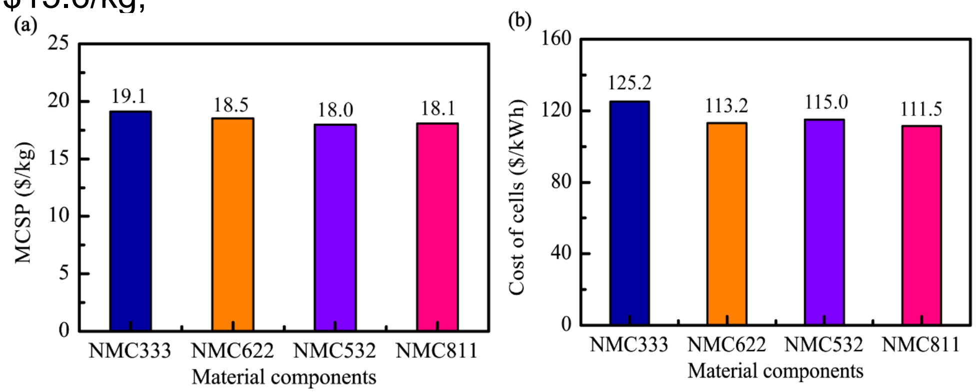

Fig. 5 Effect of different cathode powder compositions on (a) MCSP and (b) cost of cells.

Responses to Reviewers' Comments

The project was not reviewed last year.

Collaboration with Other Institutions

- EaglePicher Technologies (EPT) is a collaborator in the project. EPT as a battery manufacturer and developer has vast capabilities in battery research. The role of EPT in this project is to design and make battery cells to achieve the targeted energy density.

- Storagenergy Technologies is a new industrial partner, which is focusing on scale-up of the flame process.

- Collaborations with Argonne has been forged for benchmark of our powder materials. ANL has conducted some initial work on our materials.

Remaining Challenges and Barriers

- To achieve the energy density target (250 Wh/kg), the NCA chemistry was used. The NCA powders were made and test results showed that they have a desired performance. Expected challenges could arise in cell design and fabrications using the NCA powders, but we expect to overcome them.

- Other Ni-rich chemistries (e.g., NMC811) will be explored in the flame spray process to ensure achievement of the target.

Proposed Future Research

- To design and fabricate battery cells to achieve the targeted energy density (FY19/20). This is for cell demonstration.

- To design and integrate other processes (e.g., inline heat treatment; coating) (FY19/20). This is for more cost reduction and battery performance improvement.

- To scale up the flame spray process (FY19/20). This is to demonstrate the feasibility of the production process.

Any proposed future work is subject to change based on funding levels.

Summary

In this performance period,

1. High capacity NCA powder has been made and tested, which showed promising specific capacity (>200 mAh/g) and retention rate.

2. Economical analysis of the flame spray process shows that the flame process is a lower cost process as compared to the co-precipitation process. NCA or NMC811 could meet the targeted performances.

3. Scale-up process is being constructed.