2021 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, 2021

Budget

- Total project funding
  - DOE share: $2,215,556
  - Contractor share: $310,694
- Funding received in FY 2020

  - $268,925
- Funding for FY 2021

  - 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/ Review Criterion

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 processing.
2. To scale up the flame spray 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

FY20/FY21 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.	Completed
Tech	Materials processing method using either a flow process or a stationary process will be selected.	Completed
Tech	Pilot production line construction and demonstrated production capacity.	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. Powder processing with in situ annealing

Work has been conducted by using the flame zone to process the powders materials, with the aim to the effect of flames on the powder properties. The in situ "annealing" process with flames was studied with direct flames and indirect flames, in which direct flames were in contact with the powders. We found that the powders thus processed with direct flames did not show a good capacity (Fig. 1(B)). This was attributed to the high temperature (~1500 C) flames burning the powders and making the powder surface deficient in lithium. When indirect flames were used, the powders showed much better capacity (see Fig. 1(A)).

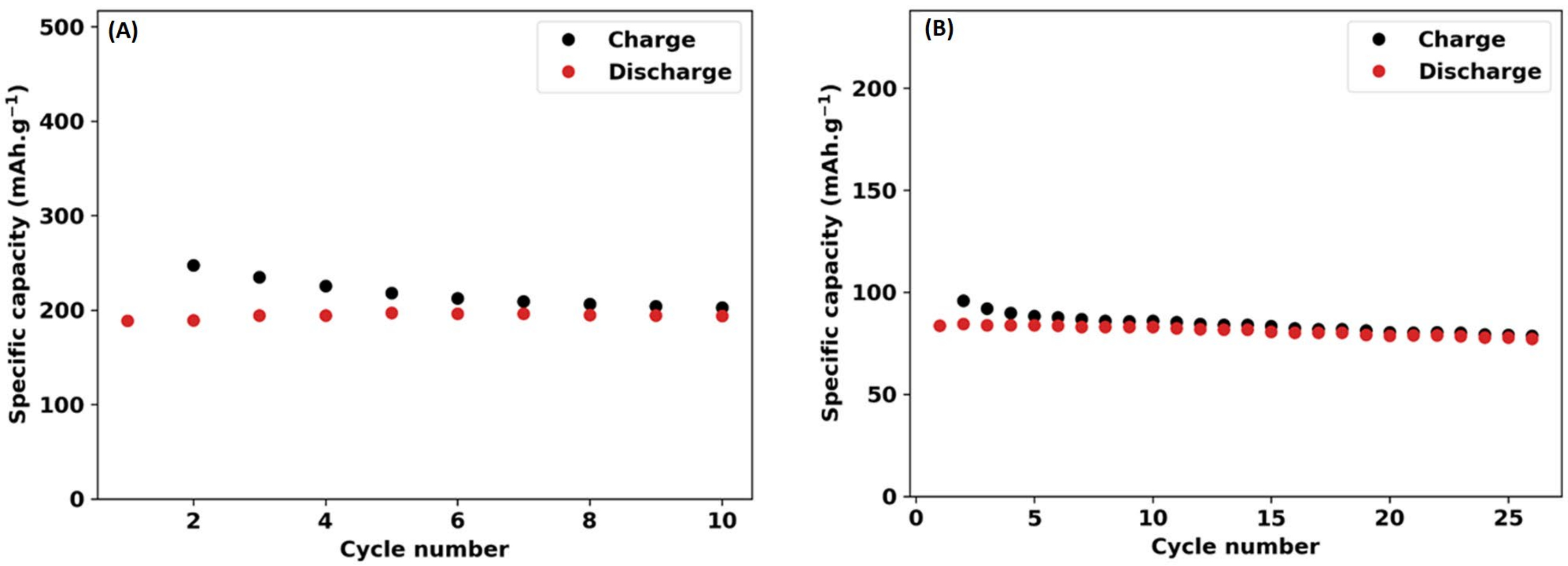

Fig. 1. Charge/discharge profiles showing much better capacity with non-direct heating (A) and direct flame heating (B).

Technical Accomplishments and Progress (2)

2. Powder processing with ex situ annealing

Annealing process is still a factor affecting the capacity of the powders, despite that the powders do not need long duration calcination. Annealing time is anywhere from 2 to 4 hours for our samples. A definite conclusion has not reached, although we believe 2 hours is enough. Further work is needed in this aspect. Fig. 2 shows new cycling data of an NCA powder which was annealed at 750 °C for 4 hours. It can be seen the retention is good (Fig. 2).

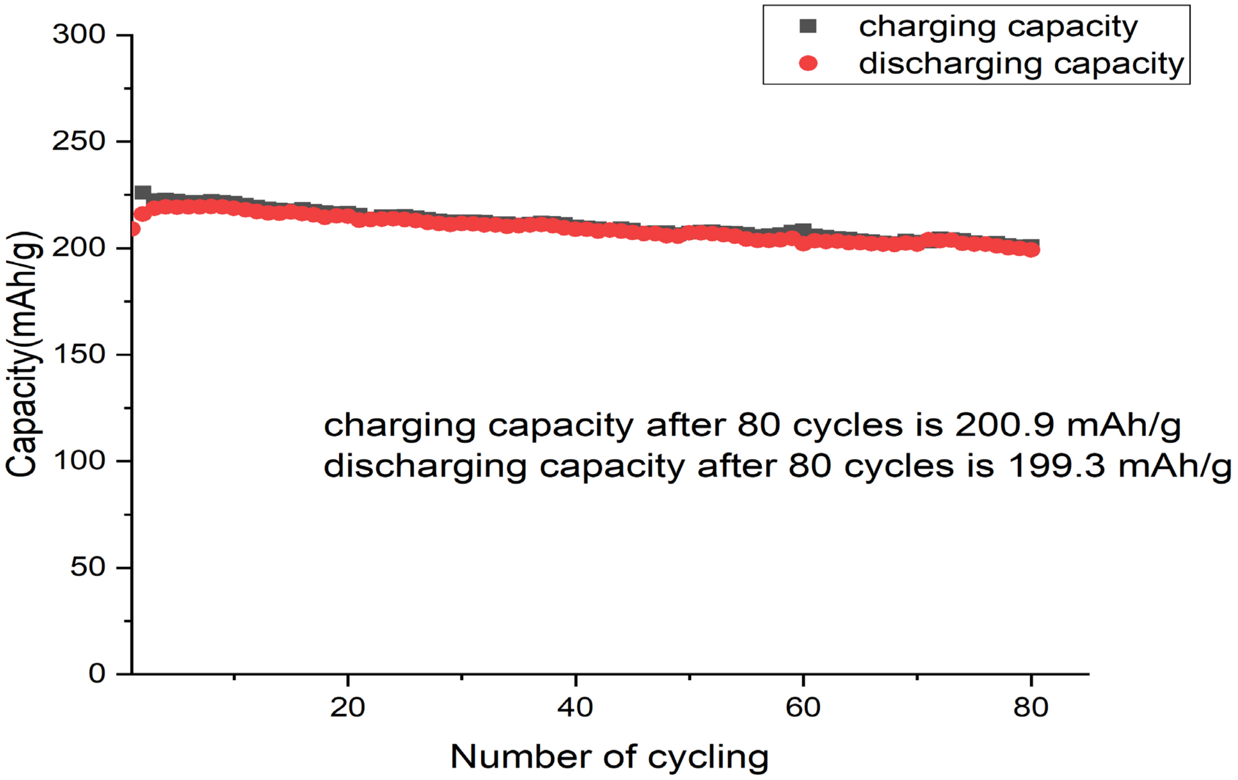

Fig. 2. Cycling performance of an NCA powder that was annealed 750 °C for 4 hours, showing good capacity as well as good retention for 80 cycles.

Technical Accomplishments and Progress (3)

3. Pilot production line construction

Scale-up of the manufacturing process has been made by construction of a pilot production line. The equipment of the entire process has been designed and fabricated. The production line is being installed and tested. It will be put into operation as soon as the test is completed. Fig. 3a shows a partial view of the set up and the control lines of the air and precursor feeding and Fig. 3b shows a photo of glycerol spray during a test in a precision machined air-atomizing nozzle utilizes steady streams of compressed air and precursor solution to create the micro-sized droplets required for the synthesis of consistent electrode materials.

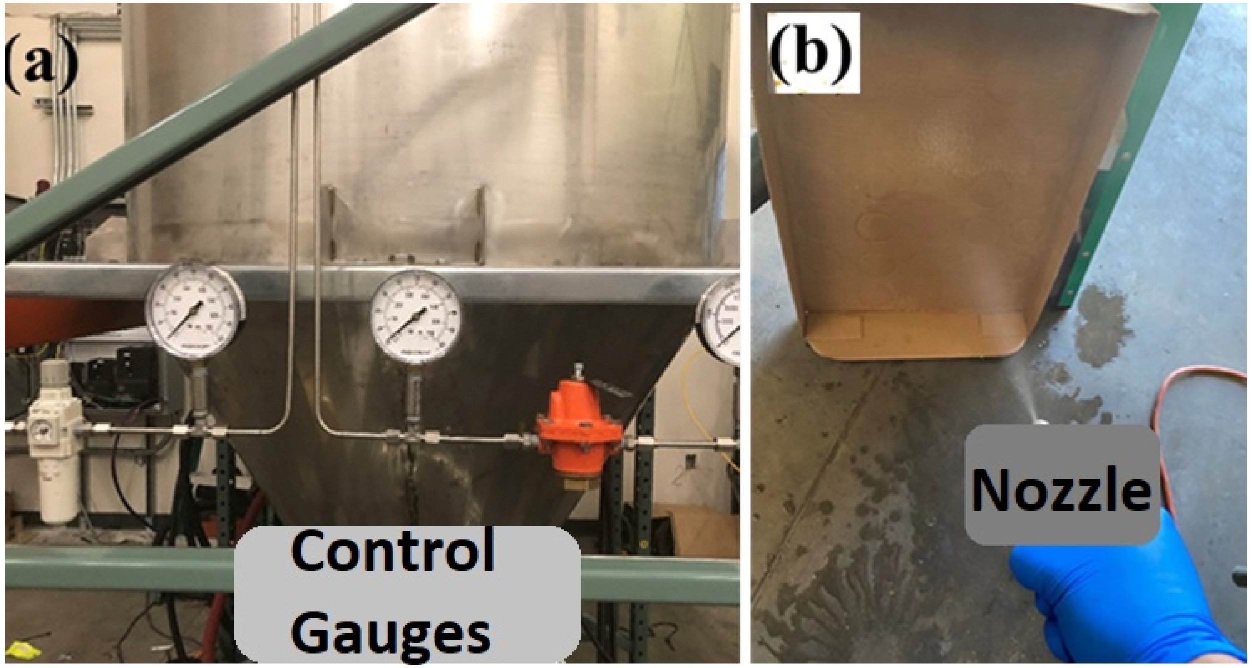

Fig. 3 Digital photos of (a) air/precursor feed line and control system, (b) test glycerol solution spray.

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 as a battery and materials production company is working on the pilot production line.

- Argonne will conduct tests on the powders on their thermal properties as well as other performances.

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 energy density.

- The pilot production line may need time to find the best conditions in making the cathode powders.

Proposed Future Research

- To design and fabricate battery cells to achieve the targeted energy density (FY20/21). This is for cell demonstration.
- To construct and operate the pilot scale production line and to demonstrate its production capacity (FY20/21).

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

Summary

In this performance period,

1. Materials processing in terms of in situ annealing and ex situ annealing was studied. It was found that flame for in situ annealing could be detrimental to the powder performances and ex situ annealing is still needed but the time period is much shorter (< 4 hours) after flame processing.

2. All equipment for the pilot production line has been fabricated. The production line is being tested. Its operation will soon start in producing battery powders.