U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

AMMTO & IEDO JOINT PEER REVIEW

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Dry Laser Powder-Bed Fusion for Structured Cathode Manufacturing | AMMTO

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WBS 2.1.0.614 | 10/1/22 to 9/30/25

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Project Overview

- **Primary innovation**
  - This project is a RD&D of innovative manufacturing for energy storage systems, a focus area of AMMTO in Energy Technology Manufacturing and Workforce.
- **Main barriers or challenges being addressed**
  - Energy efficient, environmental benign, low-cost and high-performance electrode manufacturing
- **Impact space**

Energy, Emissions, & Environment: Reduce 90% energy consumption in cathode processing; Avoid the use of poisonous NMP solvent.	**Cost & Competitiveness:** Avoid huge capital investment on solvent recycling; Cut electrode manufacturing cost by over 50%; Potentially reduce battery cost to < $75 per kWh.
Technical & Scientific: Understand laser/battery-material interactions; Adjust microstructures to improve battery performance.	**Other Impacts:** Reduce material waste; Be applicable to other materials and battery systems.

- **Collaborations/Community contributions**
  - Industrial partner with background of battery material synthesis
  - Local industrial subcontractor with powder coating background
  - Training summer student from NNSA-MSIIP program

Project Outline

Innovation: Dry laser powder-bed fusion for structured cathode manufacturing
Project Lead: LLNL
Project Partners: Ampcera

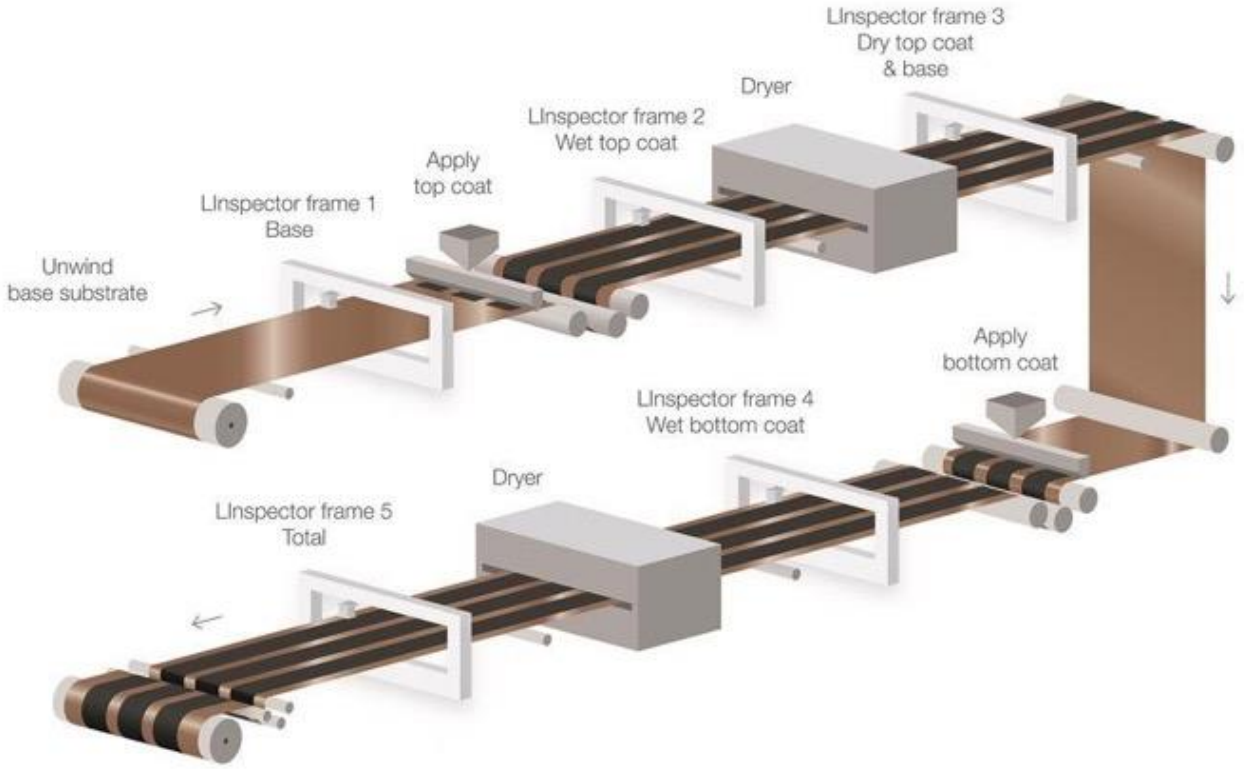
Timeline: 10/1/22 to 9/30/25, 17% completion
Budget:

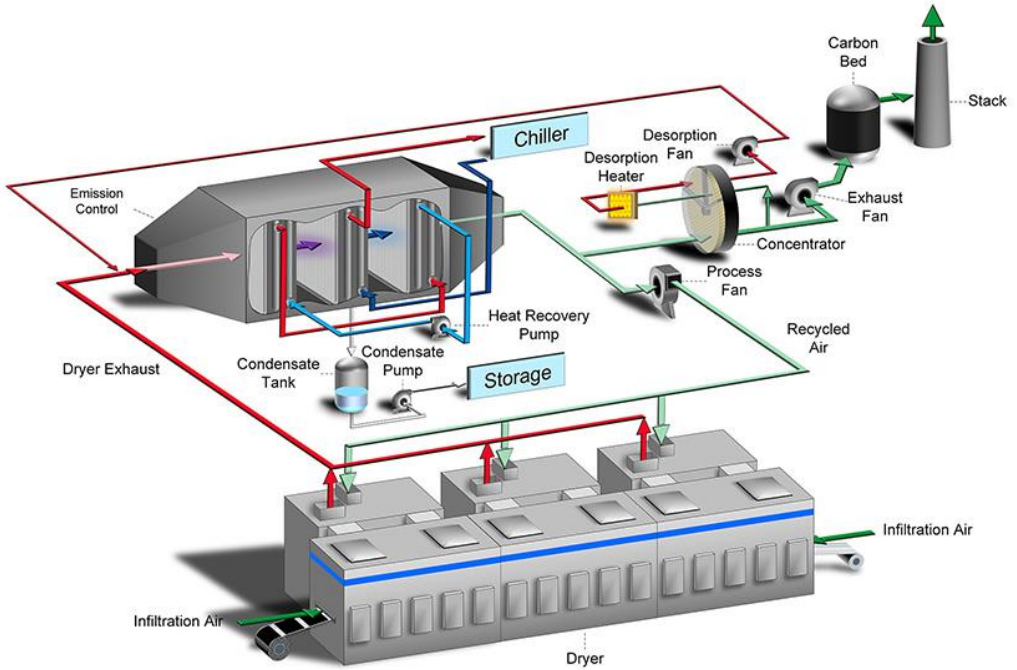
	FY23 Costs	FY24 Costs	FY25 Costs	Total Planned Funding
DOE Funded	$500,000	$500,000	$500,000	$1,500,000
Project Cost Share	$125,000	$125,000	$125,000	$375,000

End Project Goal: In a 2 Ah pouch cell with a structured L-PBF cathode, demonstrate a usable areal capacity of 3 mAh/cm2 at 2C, with > 80% capacity retention after 250 cycles.

Wet processing drives manufacturing cost high

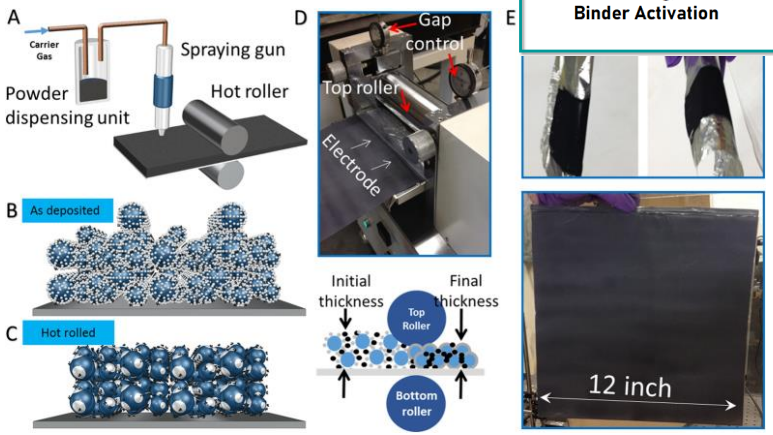
- **Current battery manufacturing: Slurry processing**
  - uses toxic solvent, not environmentally friendly and not cost effective.



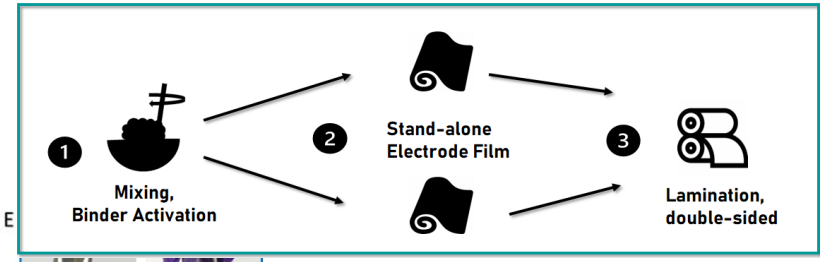


Dry processing will reduce manufacturing cost

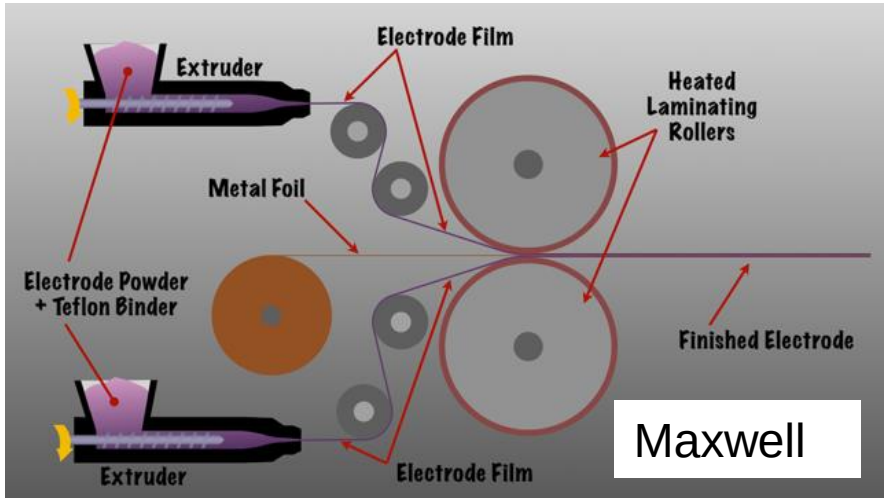
- **A better alternative processing: Dry processing**
  - Cost reduction, environment benign, and potentially better performance
- **Challenges in dry processing**
  - Thickness, porosity, structural control
  - Material waste reduction



(WPI, AM Batteries)

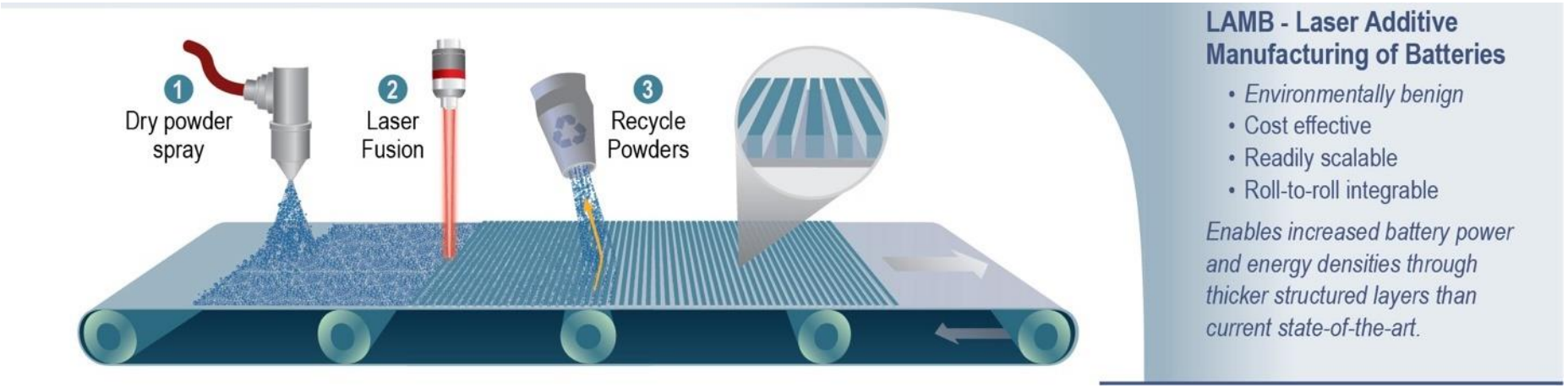


LiCAP

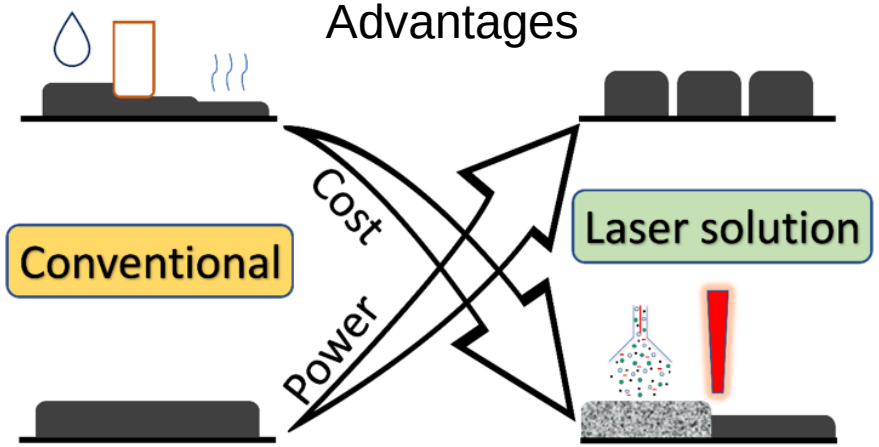


Selective Laser melting combines dry processing with structured electrode design

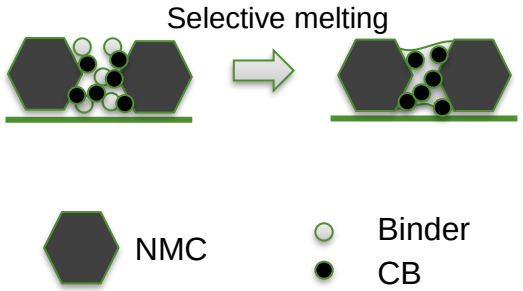
Our technology



Advantages



Working principle



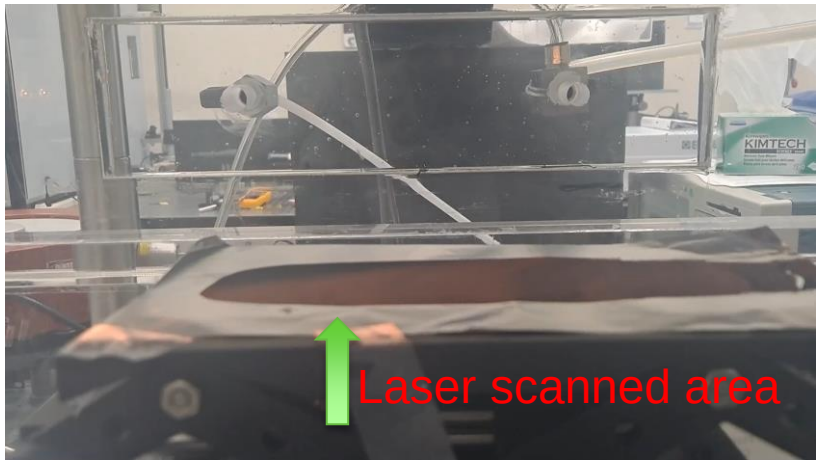
Objectives

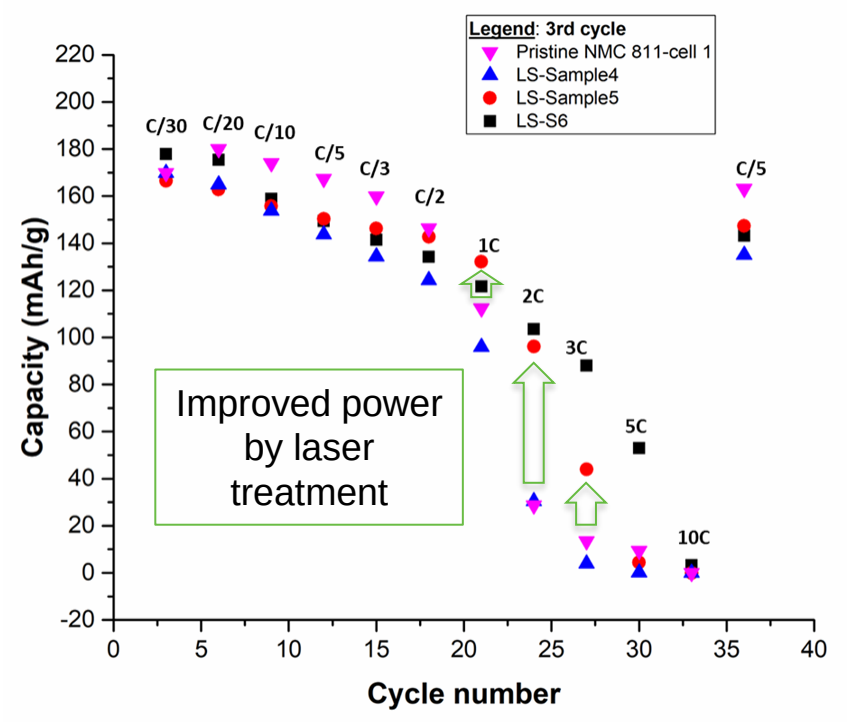
- **Objective I: Demonstrate L-PBF compatibility for LIB cathode processing. (Y1)**
  - Goal: The first goal of the project will be to make a uniform cathode coating on Al foil by laser powder bed fusion and show comparable battery performance to a baseline using the slurry-based tape-cast cathode films.
  - Outcome: As a Go/No-Go decision point, by the end of Y1 we will demonstrate that the L-PBF manufactured cathode films show performance that matches or exceeds lab tape-cast cathode films, *e.g.*, achieving an areal capacity of 2 mAh/cm^2 with 80% capacity retention after 100 cycles at a C-rate of C/3 using high capacity NMC811.

- **Objective II: Demonstrate high-power density at a C-rate of 2C. (Y2)**
  - Goal: After successful demonstration of 2D film manufacturing, we will proceed to construct 3D structured cathodes by L-PBF for improved rate performance (2C, 4C, 6C), which will place stricter requirements on the resolution and mechanical robustness of the cathode structure to achieve high resolution structuring.
  - Outcome: As a Go/No-Go decision point by the end of Y2, we will demonstrate a usable areal capacity of 3 mAh/cm^2 at 2C, with > 80% capacity retention after 200 cycles.

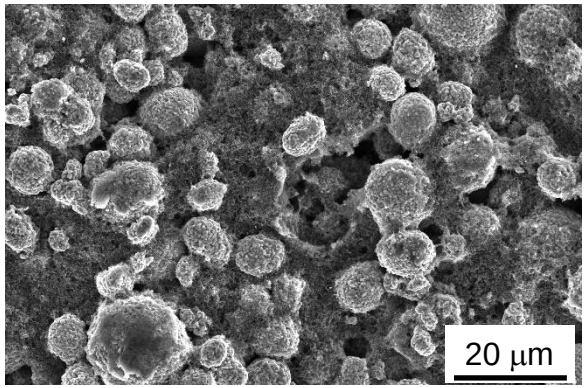
- **Objective III: Demonstrate scale-up capabilities in 2-Ah sized pouch cells. (Y3)**
  - Goal: After successful manufacturing of a 3D structured cathode, we will focus on demonstrating the scalability of the technique towards commercial readiness.
  - Outcome: By the end of the project, we will demonstrate a usable areal capacity of 3 mAh/cm^2 at 2C, with > 80% capacity retention after 250 cycles in a 2 Ah pouch cell.

Laser treatment itself could potentially increase rate performance

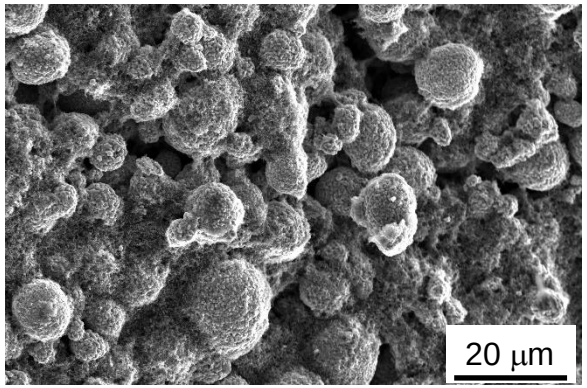




Pristine NMC film



Laser treated NMC film

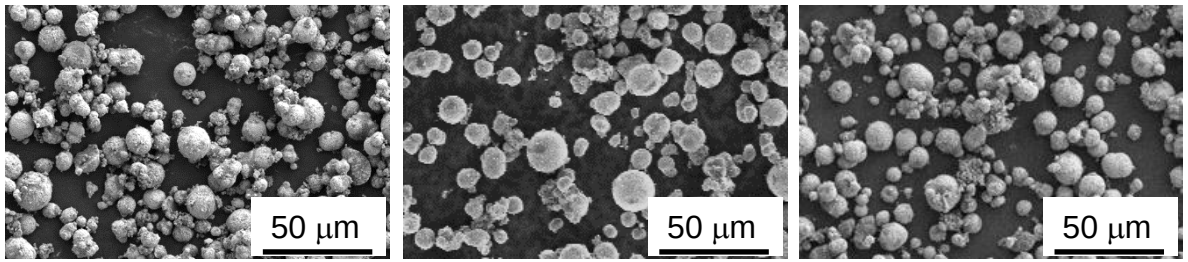


Proper laser power must be chosen to promote the beneficial effects in rate performance improvement, while avoid the adverse effects due to material degradation.

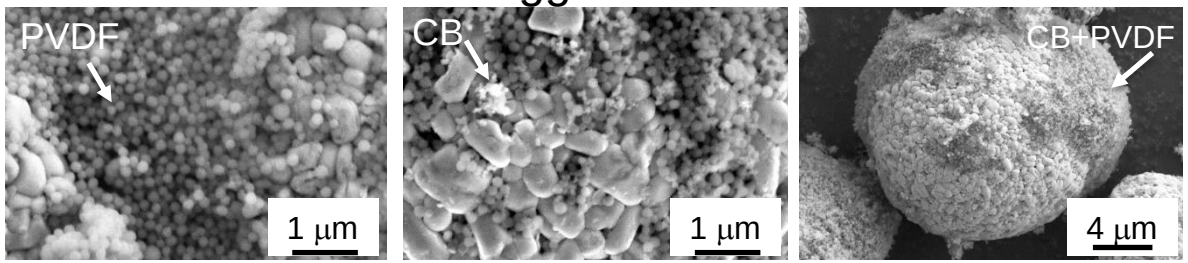
Two-step roller milling forms good mixture of NMC/PVDF/CB powders

- **Homogeneous powder mixing with Less agglomerates was achieved by two-step mixing.**

NMC+PVDF +Carbon black Longer mixing time

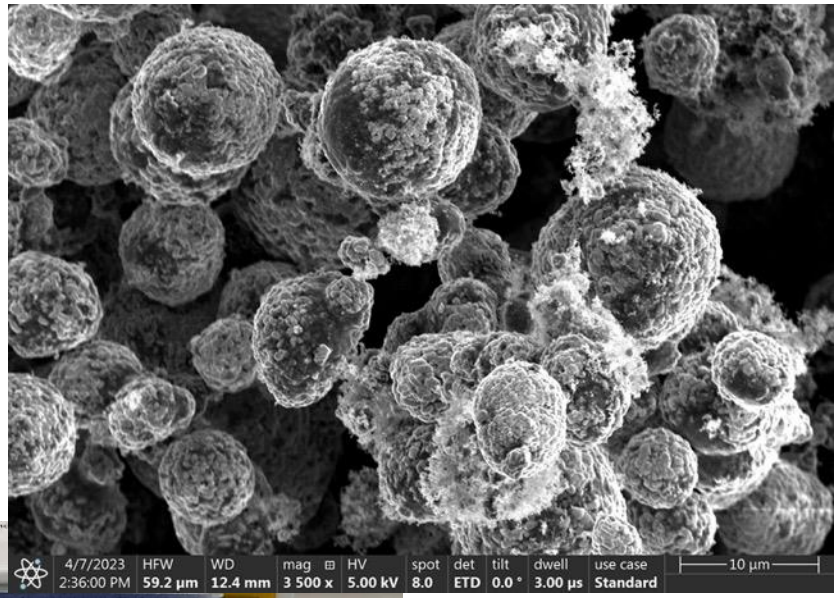


Less agglomerates



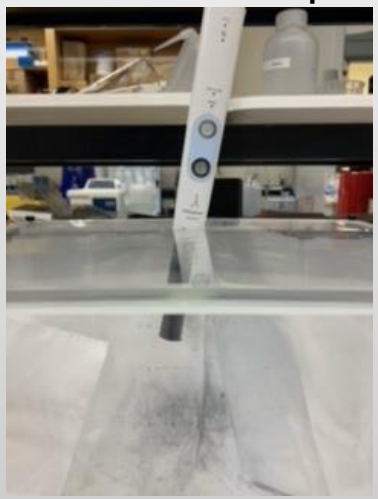
PVDF/CB attached on NMC powder surface

PVDF melt at 200ºC



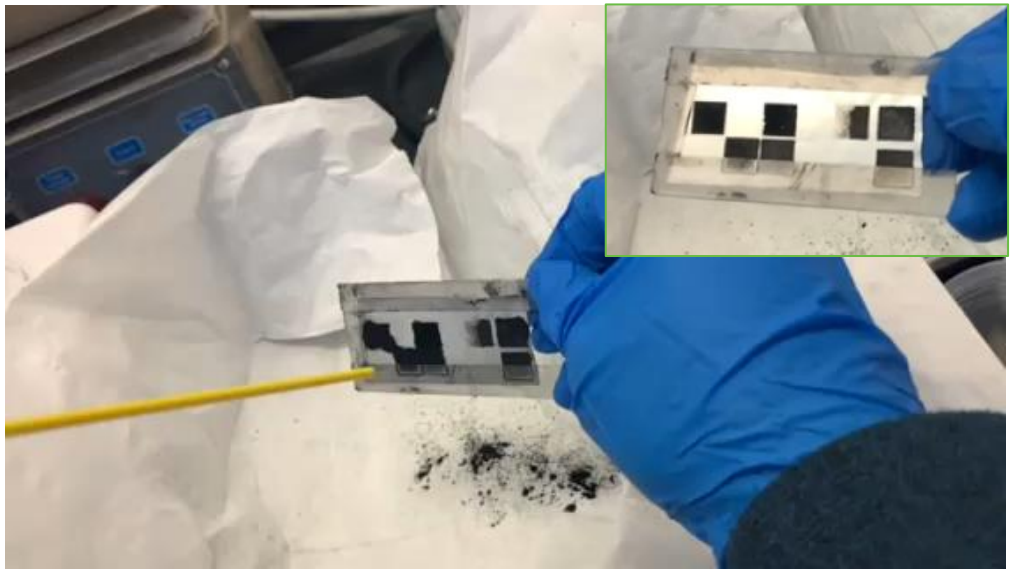
NMC power mixtures successfully attached to Al foil by laser sintering

Sonic powder coating

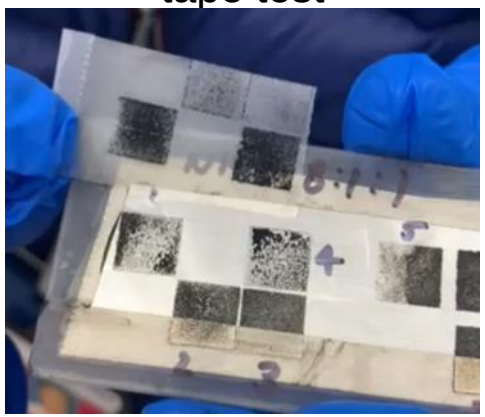


80NMC:10nano-PVDF:10CB

Adhesion test: air blow



tape test



Future Work, Technology Transfer, & Impact

Future Work:

- Optimize powder coating and laser sintering parameters; perform battery assembly and testing.

Technology Transfer:

- Work with industrial partners (*e.g.*,Ampcera) to integrate the laser processing into roll-to-roll manufacturing to further demonstrate the scalability and low-cost.
- We have not set up relationships with other AMMTO performers yet but are interested in expand the technology to other materials and applications.

Impact:

- With the success of the project, we will reduce the manufacturing cost while improve the power density of lithium-ion batteries.

Questions?

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