Development of Ultraviolet Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of Lithium-Ion Battery Electrodes

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Project ID: bat265

Project Overview

Timeline:
Start Date: 12/01/2015
End Date: 01/31/2019
Percent Complete: 100%

Budget:
DOE Share $1,742,560
Cost share $ 513,640

Barriers to Electric Vehicles addressed in this project :

1. **Cost**, reducing Electrode Manufacturing Costs, no NMP (health and safety), reduced energy consumption, small footprint
2. **Life**, possible advantages, e.g., high temperature life and low temperature stability

Partners:
Oak Ridge National Laboratory
Argonne National Laboratory

Lowering Cathode Manufacturing Costs UV vs. NMP process

- ✓ Miltec cost model shows manufacturing savings in capital and operations of at least 80% and likely 95%.
- ✓ Total electrode savings *(including materials)*:
  - 25% for each double-sided layer in each pouch cell
  - 50% for end single-sided layers in each pouch cell
- ✓ NMP free UV Process

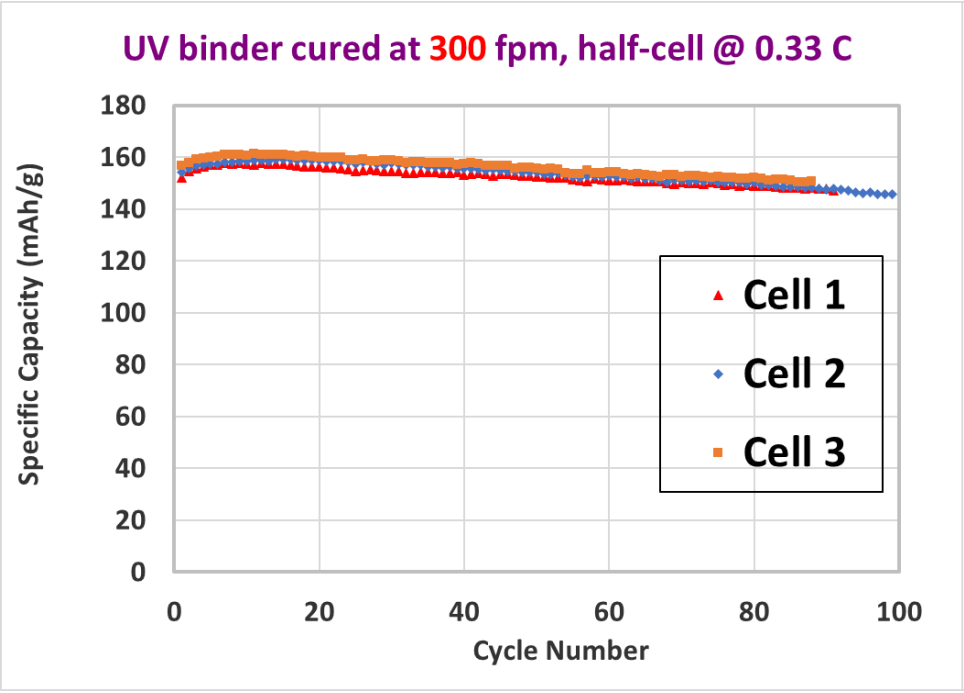
Proving It Can Work

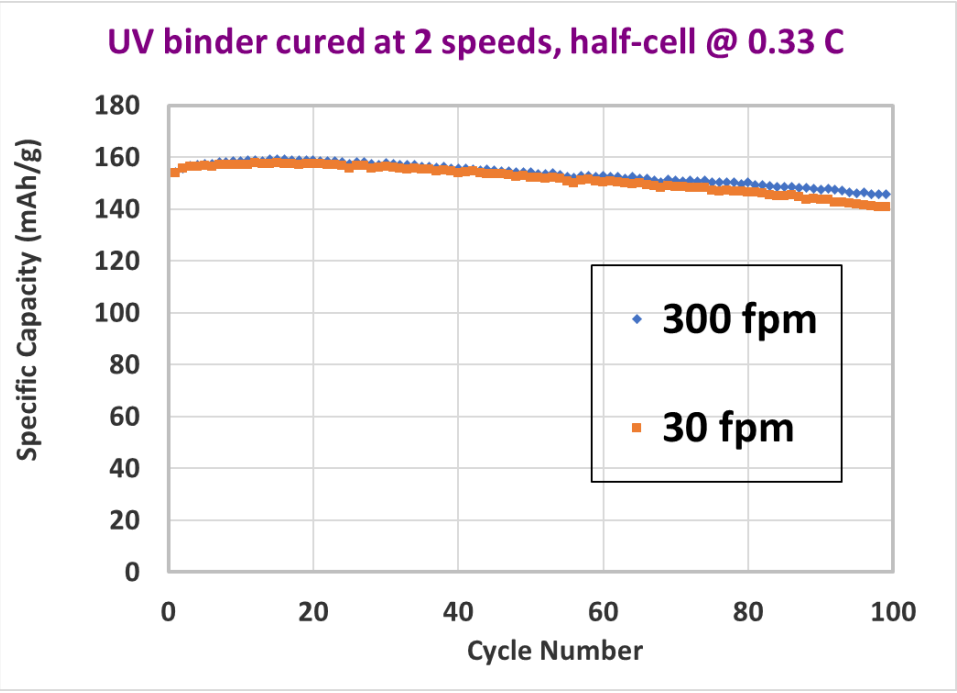
- ✓ Developed (94/3/3) Energy and (90/7/3) Hybrid NMC cathodes with impedance and cycling equal to PVDF
- ✓ Proved fast curing (300 fpm) with Power & Energy cathodes
- ✓ Demonstrated layered coating and thicker curing capability for thick, electrodes with higher energy density

Applied R&D Approach

1. **Cost models to prove value**
2. **Improve Binder Chemistry**
3. **Improve Coating Process & Web Equipment**
4. **Improve Curing Process**
5. **Test**
6. **Keep improving & Testing**

Latest UV Chemistry 300 fpm Very Consistent Electrodes, NMC 532 @ 9 mg/cm^2

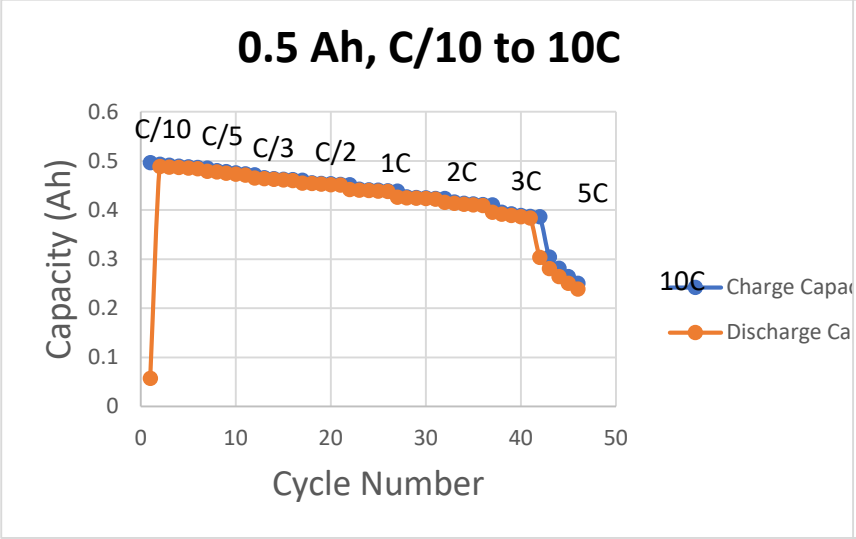


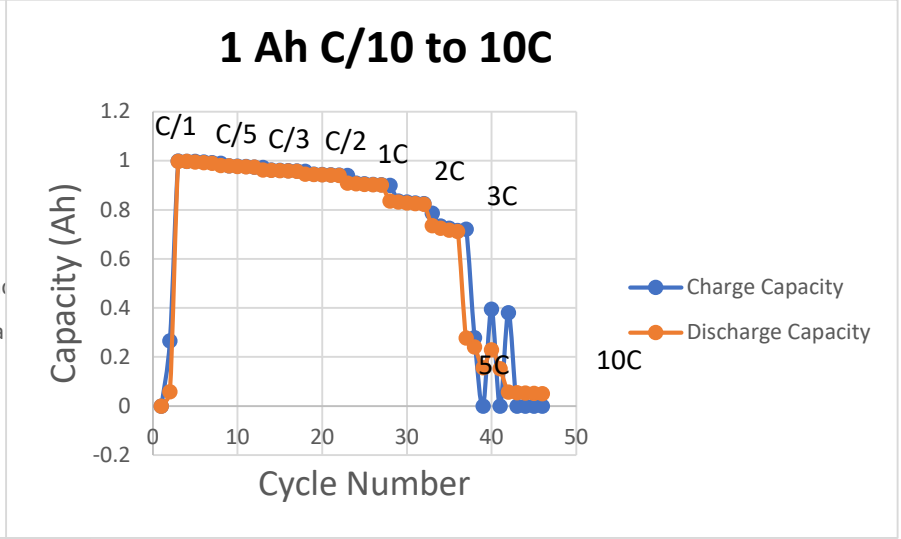


90-5-5 Believe 94-3-3 No Problem

First Pouch Cells Ever with Layered Cathodes with Good Rate Performance

UV NMC(532) 94-3-3 Cathodes pouch cells.
Coated at Miltec, then Assembled and Tested at ORNL with their PVDF Graphite Anodes





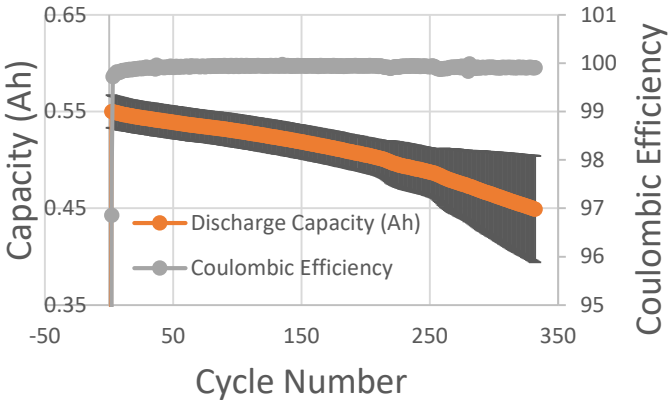
2-side total = 17.75 g/cm^2

2-side total = 29.2 g/cm^2

First Pouch Cells with Single and Double Layer UV Coatings

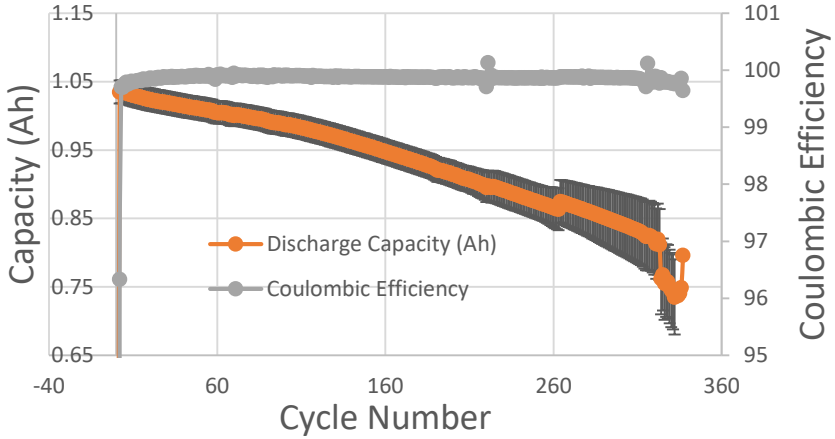
UV NMC(532) 94-3-3 Cathodes pouch cells.
Coated at Miltec, then Assembled and Tested at ORNL with their PVDF Graphite Anodes

0.5 Ah Single Layer Cathode



2-side total = 17.75 g/cm^2

1 Ah Double Layered Cathode



2-side total = 29.2 g/cm^2

New chemistry in Slide 5 will cycle even better

Now that we can layer electrodes…

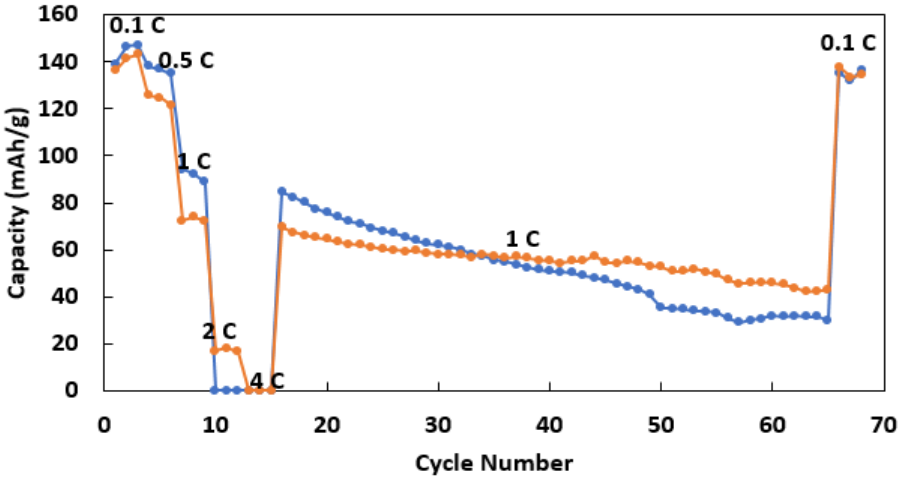
Question: 2 Layers, which on top Power or Energy?

Answer: **Power Layer underneath the Energy Layer**

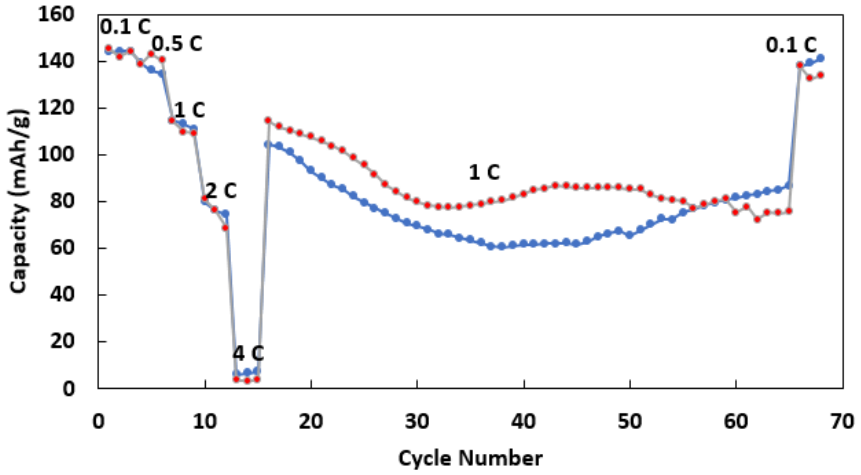
Energy Layer 94-3-3 10 mg/cm^2 NMC 111
Power Layer 82-12-6 6 mg/cm^2 NMC 111

Power under Energy = best ionic and electrical conductivity = best battery

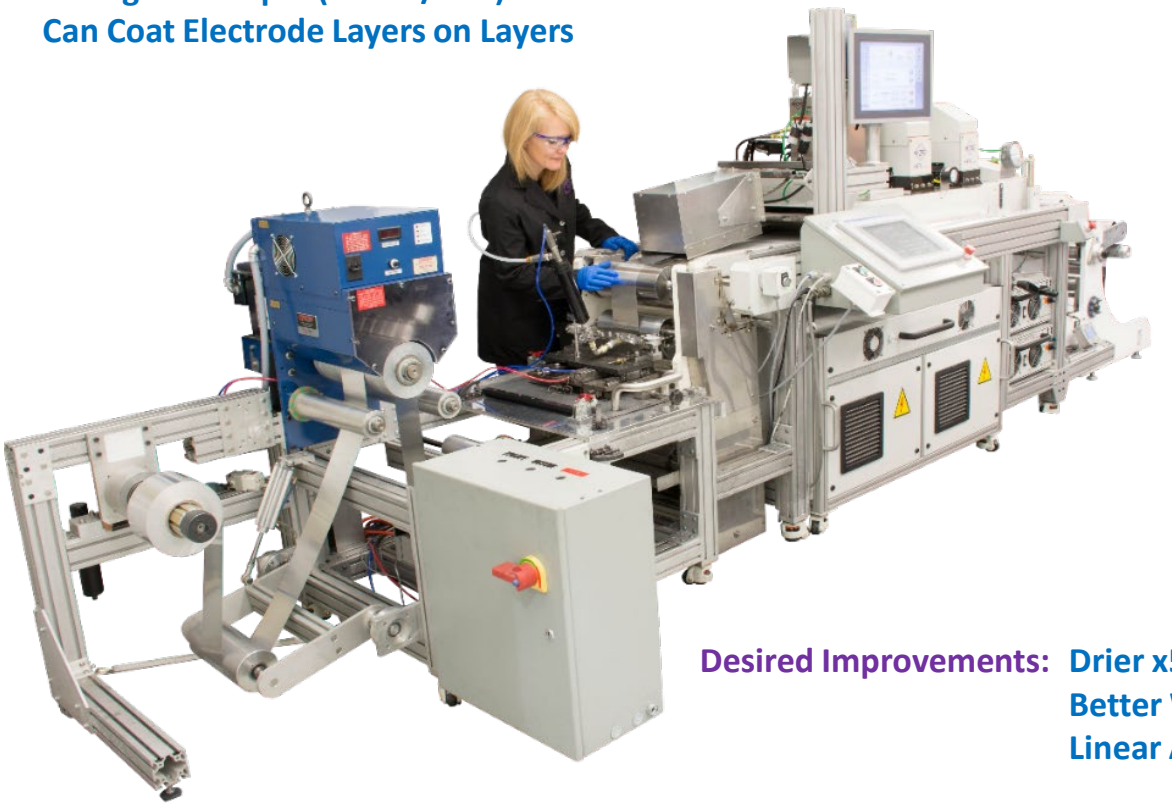
Bottom Energy Layer-Top Power Layer



Bottom Power Layer-Top Energy Layer



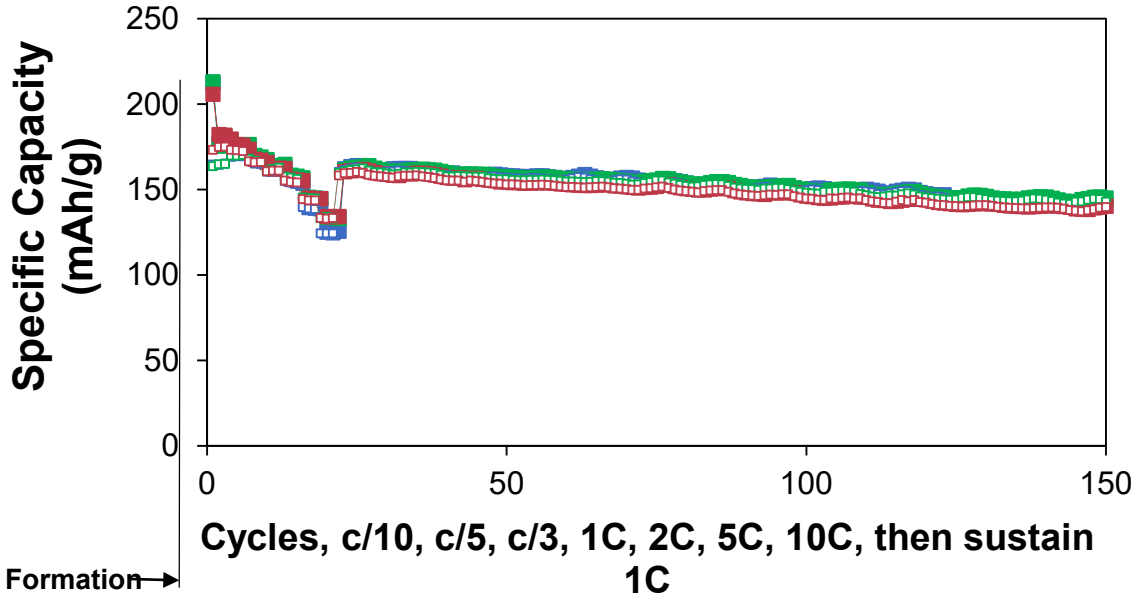
Accomplishment: Developed UV Equipment and Slot Die Process
Curing to 330 fpm (100 m/min)
Can Coat Electrode Layers on Layers



Desired Improvements: Drier x5 Length
Better Web Path and Lamp Placement
Linear Actuators on Slot Die

Accomplishment: Performance

UV Power Cathode shows 75% capacity retention at 10C Rate
UV Cathode also withstands High Temperatures (>120°C)



82-12-6

$NMC_{(111)}$-C-UV Binder

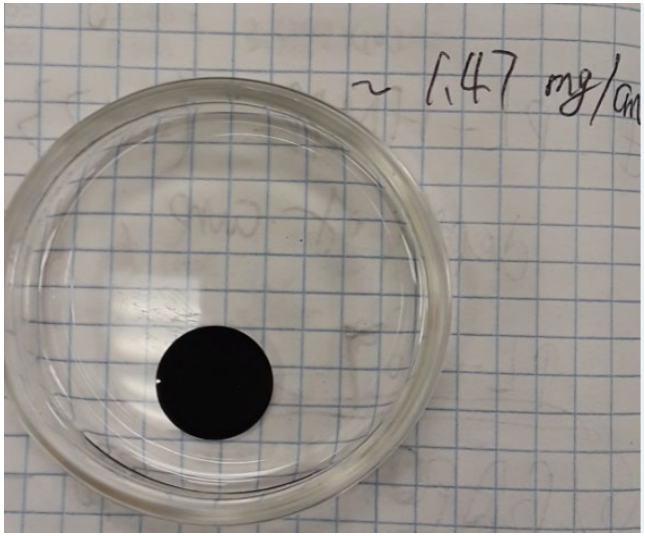
4 mg/cm^2

Prepared for a USA Battery Manufacturer

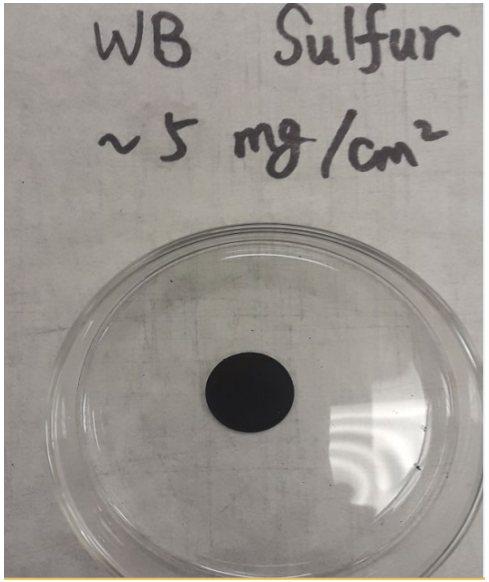
Slot die applied. Shows tight consistency for all 3 cells.

High loading Sulfur electrode made with new UV Coating

Electrode with Solvent-based UV binder
Electrolyte (EC:DMC) Test



Electrode with water-based UV binder
Electrolyte (EC:DMC) Test

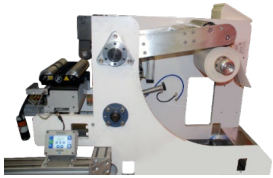


Sulfur-Carbon mixture 70-30 (Mixture provided by prospect)
Formulation of Sulfur-Carbon/UV binder: 95-5

Proposed Future Research

Future Plans

- **Working with Battery Manufacturers, OEMs and Integrators to customize chemistry and processes for their applications**
- **Collecting 1,000 cycle pouch cell data for power and energy batteries**
- **Battery Line install and to improve laboratory equipment**
- **Work with OEMs, Battery Manufacturers, and Research institutions to develop UV process for next generation higher energy density batteries**



Special Thanks

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