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

Dr. John Arnold, PI
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Project ID # ES265

Project Overview

Timeline:

Start Date: 12/01/2015
End Date: 09/30/2018
Percent Complete: 56%

Budget:

DOE Share	$1,742,560
Cost share	$ 513,640
FY 16	$1,742,560

Barriers to Electric Vehicles addressed in this project :

1. Cost, reducing Electrode Manufacturing Costs, Safety, Energy, …
2. Performance, possible advantages

Partners:

Argonne National Laboratory
Oak Ridge National Laboratory

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

Relevance

Lowering Cathode Manufacturing Costs 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):
  - 50% for the two single-sided layers in each cell
  - 25% for each double-sided layer in each cell

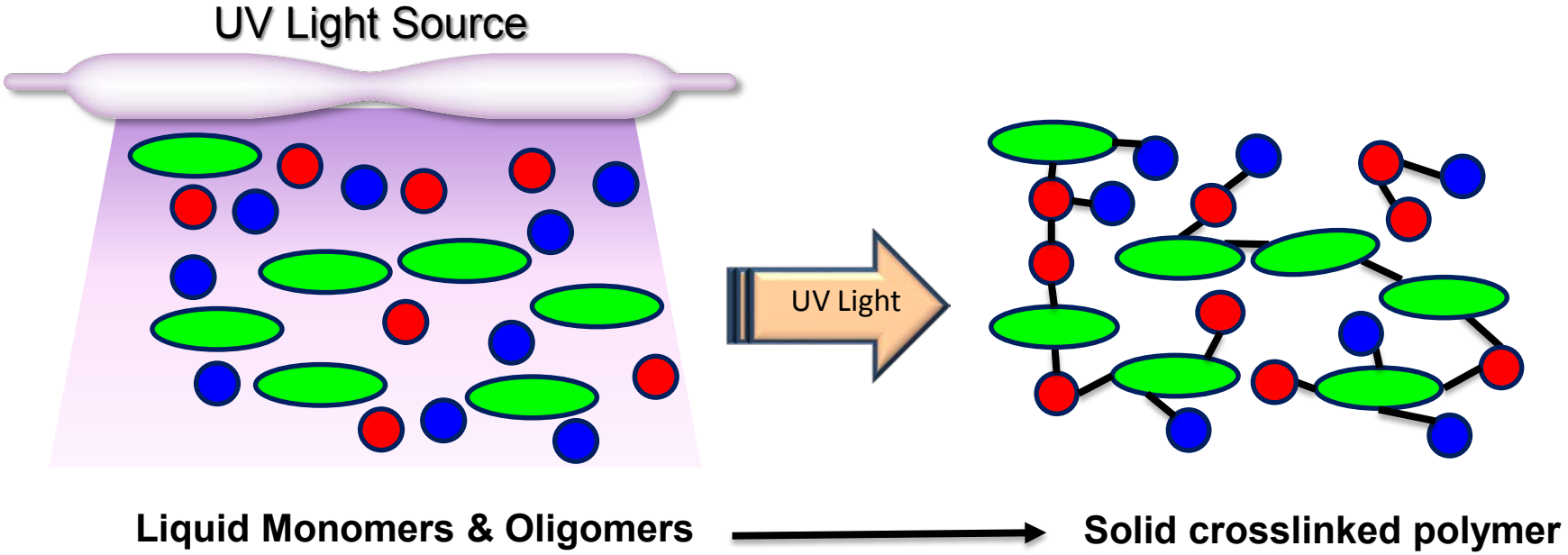
Proving It Can Work

- ✓ Reduce binder (90/5/5 and 90/7/3) in hybrid type batteries
- ✓ Achieve reactive impedance and long term cycling equal or better than PVDF
- ✓ Proved fast curing (100 m/min) with hybrid power cathodes
- Demonstrate faster coating technology
- Demonstrate layered coating and thicker curing capability for high energy electrodes

Approach & Milestones	Planned Completion	Status
Budget Period 1		
Project Management Plan	12/31/2015	Complete
Confirm binders and coating procedures and testing protocols	12/31/2015	Complete
UV curable Binder Formulation with improved AC Impedance	06/15/2016	Complete
Complete integration and installation of print coating equipment	07/24/2016	Complete
Complete Test to confirm lower AC Impedance and acceptable long term capacity (Go-No Go)	11/30/2016	Complete
Budget Period 2 …		

Approach & Milestones	Planned Completion	Status
Budget Period 2		
Demonstration of two-sided electrode coating	03/31/2017	Complete
Determine maximum speed and cathode thickness using a slot-die coater and 3 lamp UV curing process	06/30/2017	Progress
Determine maximum speed and cathode thickness using a letterpress and 3 lamp UV curing process	09/30/2017	Progress
Determine minimum inactive material (UV curable binder and carbon) loading with either a slot die or letterpress process complete	12/30/2017	Progress
Coating on coating cathode evaluation complete with slot die and letterpress processes	2/28/2018	Began
Long term cycling evaluation complete	5/31/2018	
Multilayer pouch cell performance evaluation complete	8/31/2018	

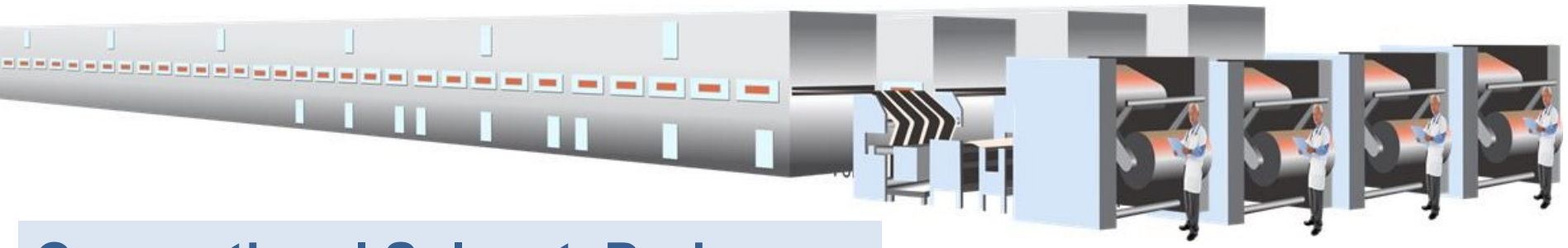
UV Curing Replaces Polymer Drying



UV Light instantly polymerizes photoreactive mixture into a solid plastic.

Coating is fully cured and ready to use or test immediately after light exposure.

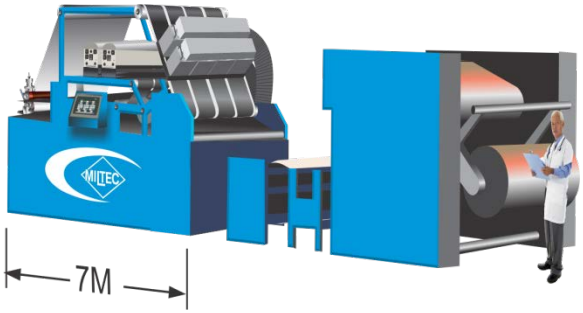
UV vs Conventional



Conventional Solvent Drying

- Instant UV curing reduces space, capital, and operating costs
- One two-side UV system @ 60 m/m has output of four conventional coating lines @ 30 m/m

UV Curing



Miltec's UV Electrode Coating Process is smaller, simpler, and can reduce manufacturing expenses by 80%

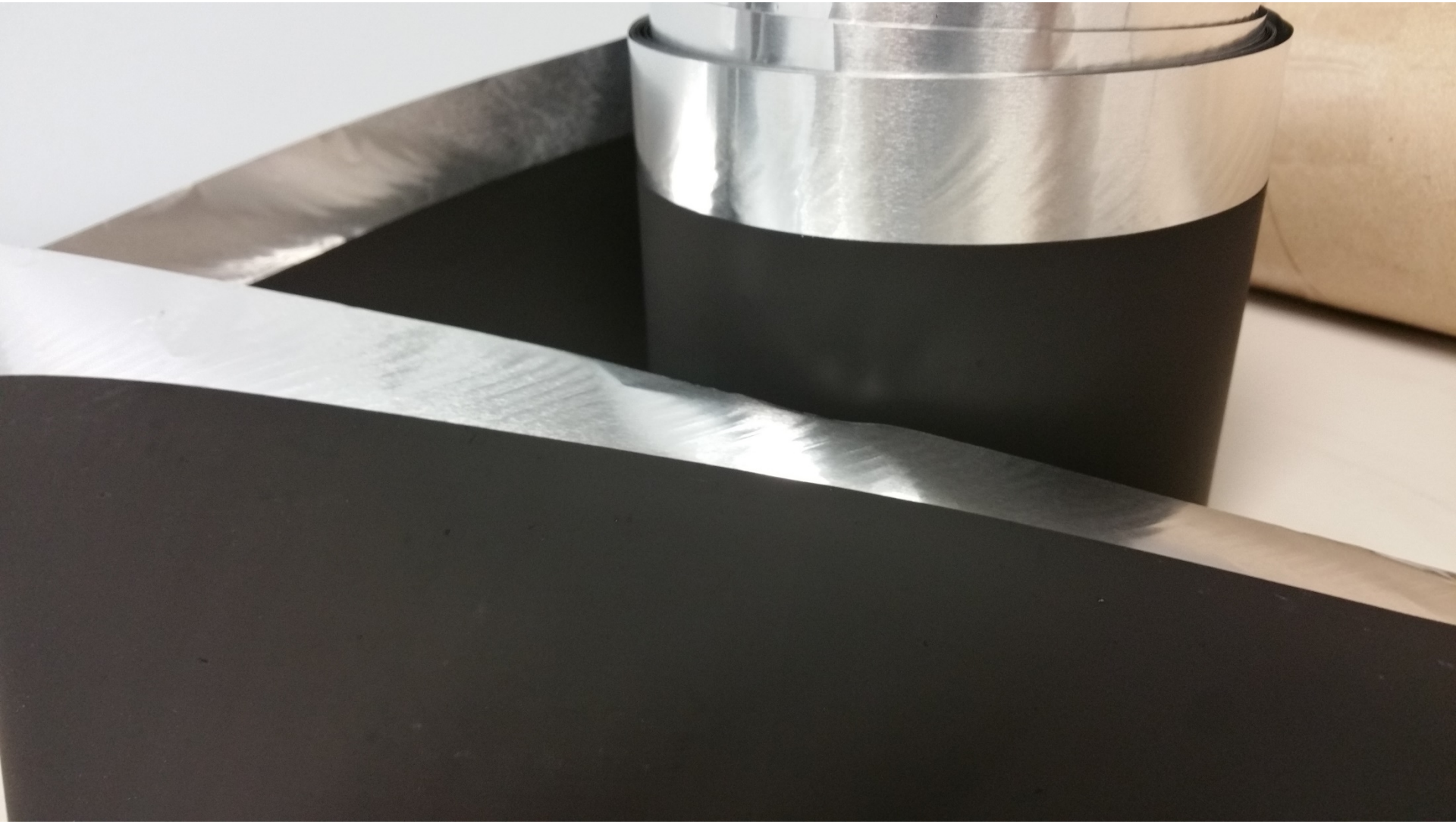
Approach & Strategy

UV cathode coatings have cured up to 100 m/min

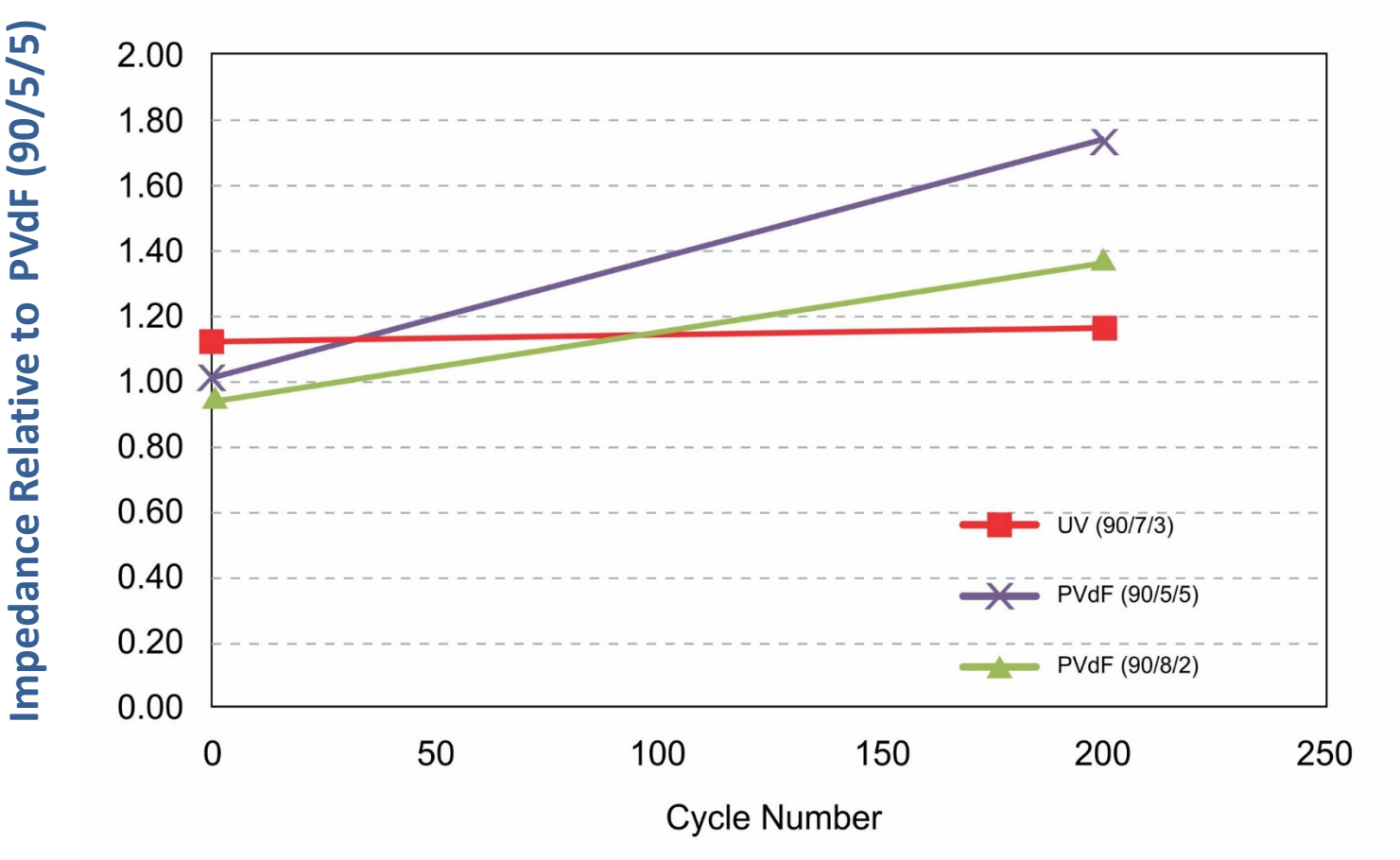
Now focus shifts to see if slot die or printing technologies can equal these speeds as well as the use of thicker layered coatings and superior double-sided coating processes

Accomplishments: Roll to Roll UV 90-7-3 NMC cathode

Accomplishments: 2-Side UV 90-7-3 NMC cathode



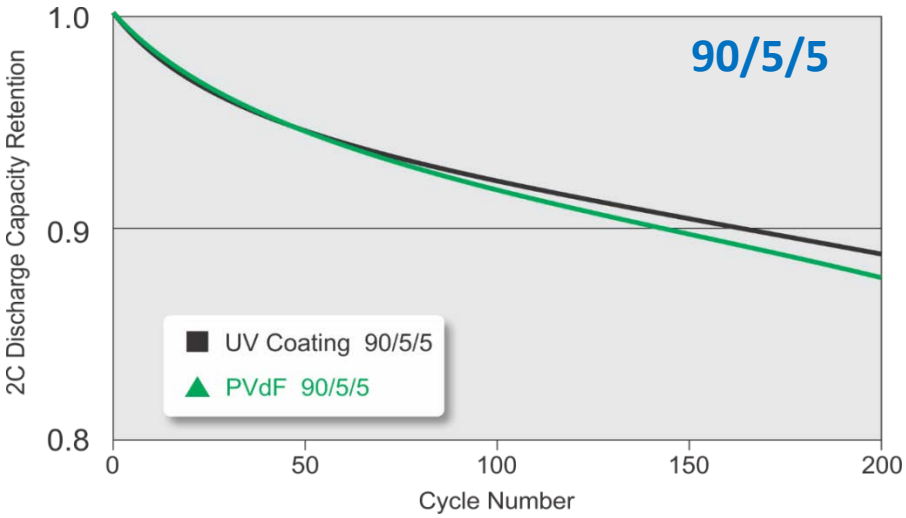
More stable low temperature impedance with UV NMC Cathode (90/7/3) than PVDF (90/5/5 and 90/8/2)

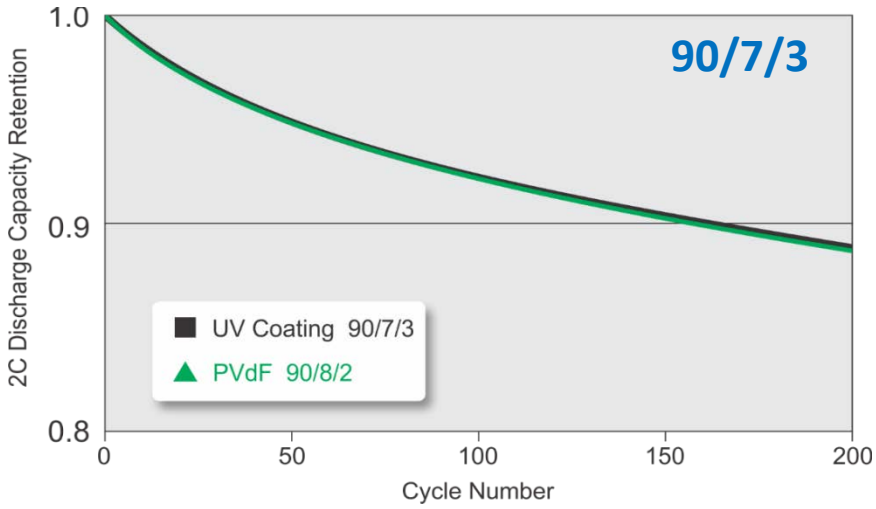


Pouch Cell AC Impedance @-10°C

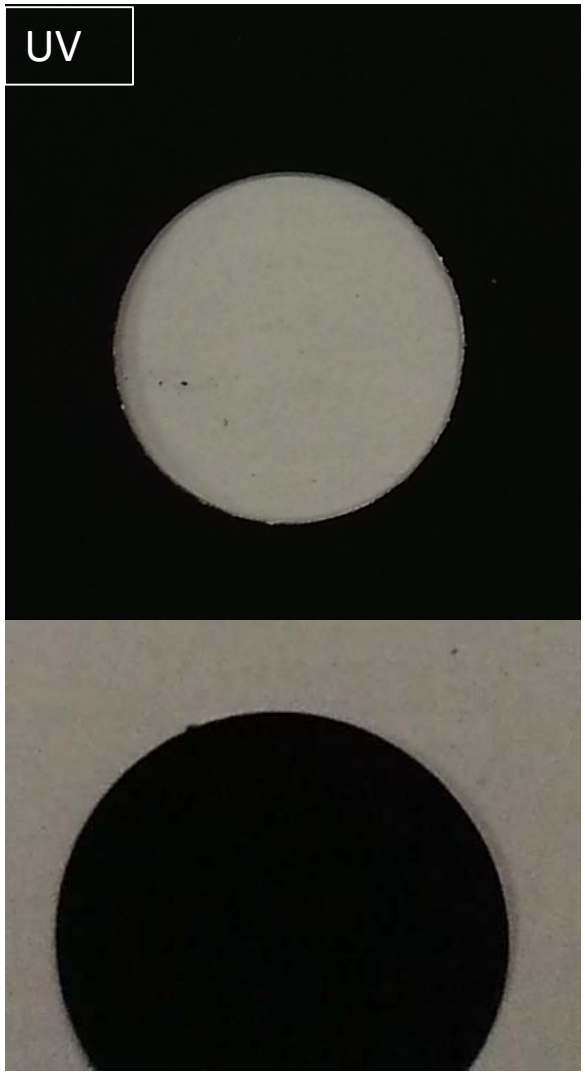
5.8 mg/cm2, 25 µm thick, NMC 111, carbon, UV binder

UV Cathodes Have Equivalent Accelerated 60°C Cycling Performance as PVDF Cathodes with Similar Loading in Single Layer Pouch Cells





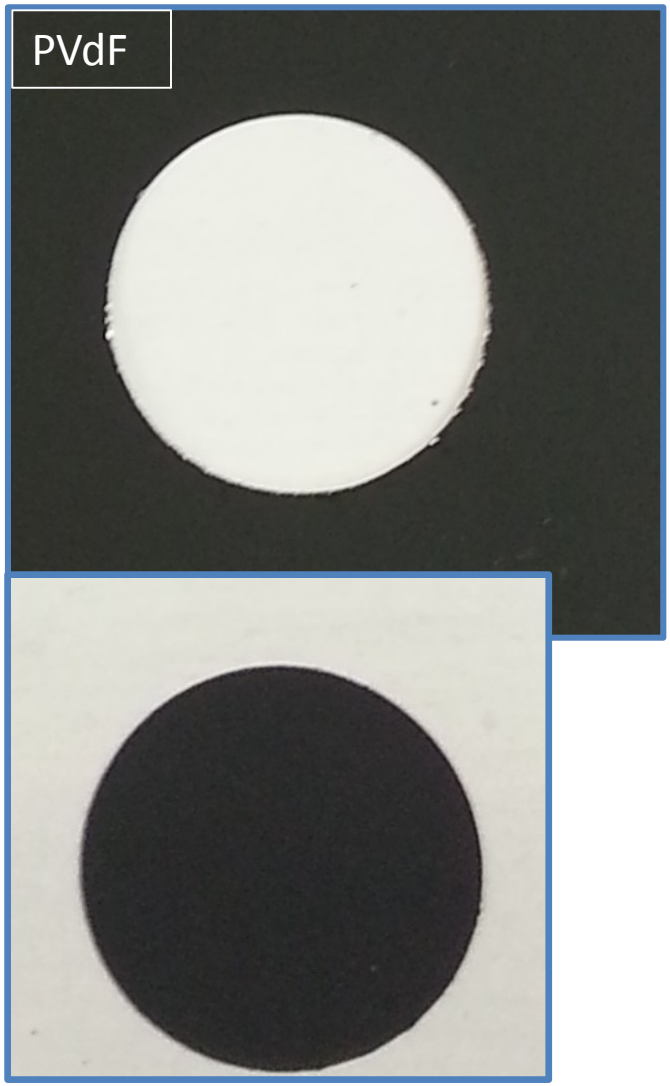
1% UV binder cathode shows comparable or better cut edges than cathodes made with 1% PVDF



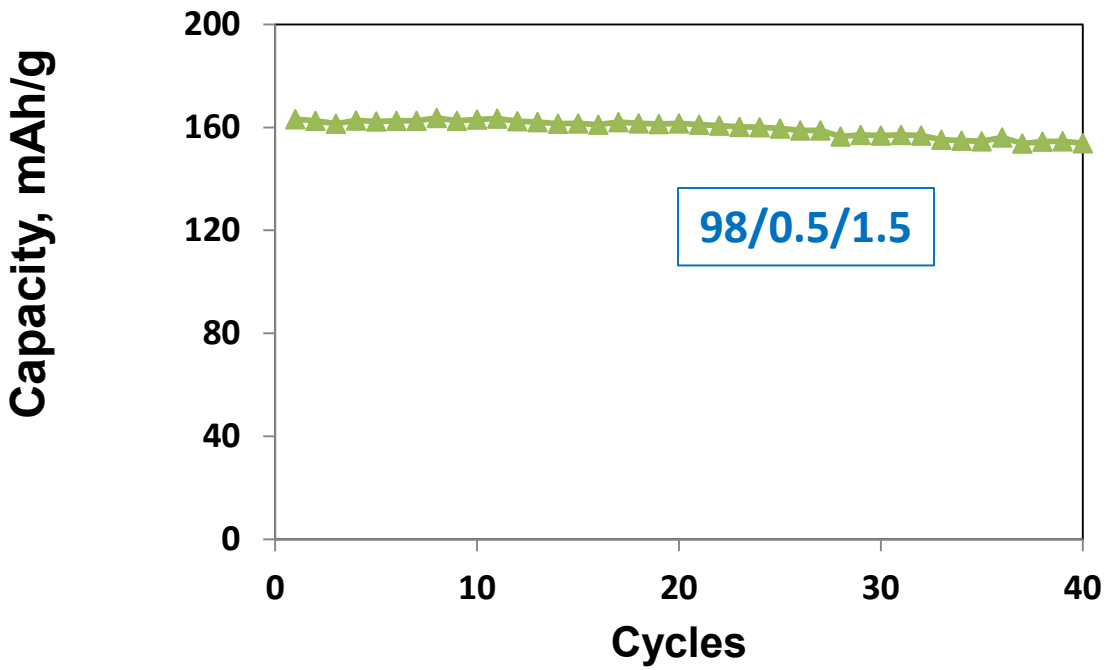
Cathode with 1% UV also has better:

1. Rub
2. Bend
3. Cohesion

Cleaner cuts, better rub, bend, cohesion, increase robustness and yield of cell manufacturing



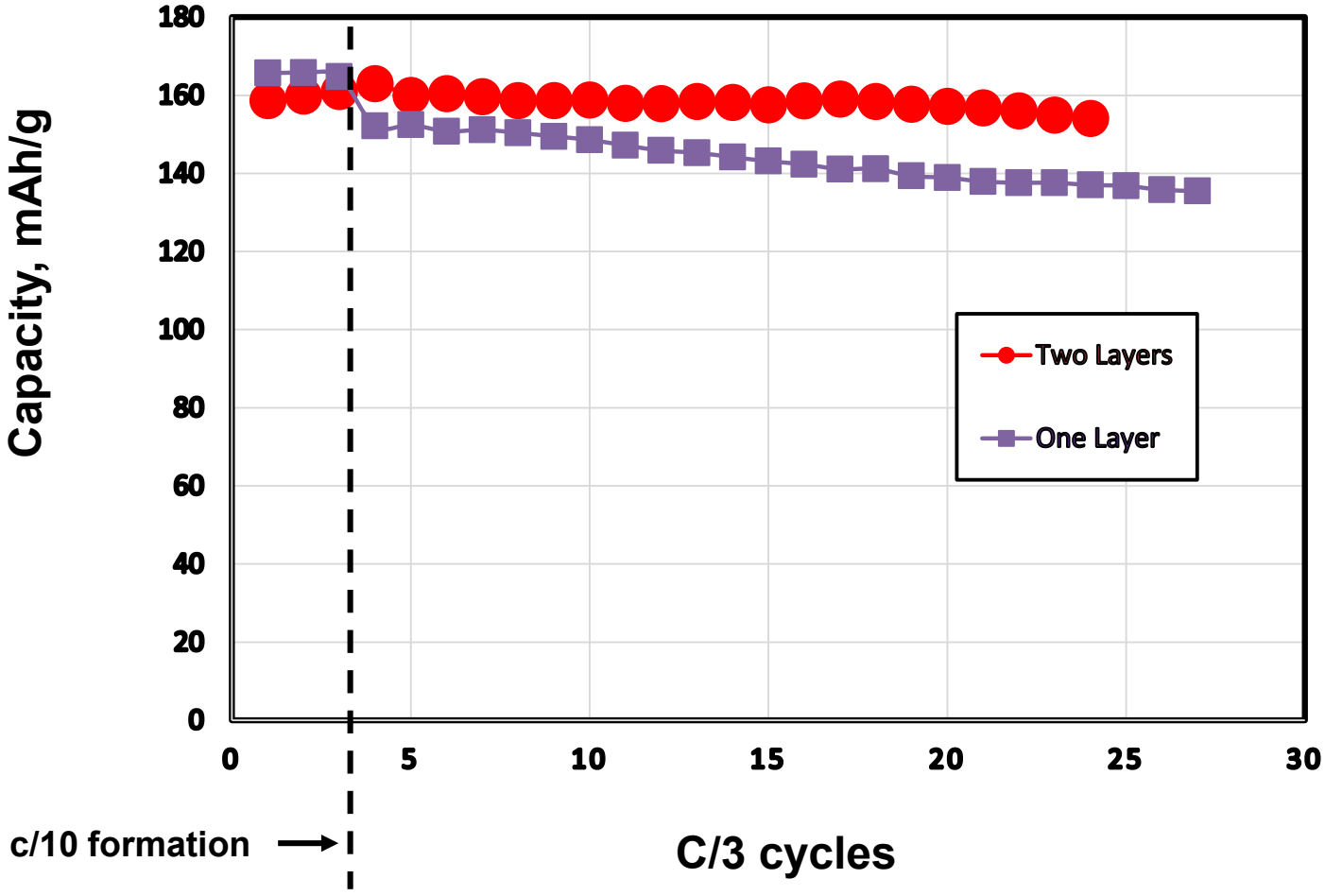
98% NMC, 0.5% Carbon, 1.5% UV binder showing good stability half-cell, next step pouch cell



C/3 cycling

Hybrid 5-6 mg/cm^2

A UV cathode coating (made by application, cure, application, cure) has the same or better cycle performance of a UV cathode made in a single application and cure process. [Preliminary Results]



Interfacial Layer between Two UV Coating – more myth not an issue.
Total coating thickness both samples ~22-24 µm, NMC 90-7-3 UV binder

Partners & Collaboration

Testing and analysis of UV cured cathodes in pouch cells and compare performance to PVDF baseline

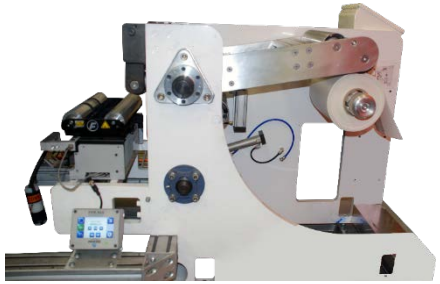
Dr. Khalil Amine, ANL

Coating and testing of multilayered UV cathode with goals of higher energy density and higher voltage cells

Dr. David Wood, ORNL

Remaining Challenges Future Work

- ✓ **Major challenges of capacity, impedance, and long term cycling have been overcome for cathodes**
- **Special and new compositions always take a few cycles to optimize**
- **Exploring LTO and MCMB anodes with waterbase UV**
- **Focus now shifts operation of high speed coating with slot die and printer technology to demonstrate high speed coating and curing; single and double sided**



- **Confirm ability to make thick EV high energy density cathode coatings with a multilayer UV process**

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

Summary

- **Estimated 80-90% manufacturing cost reduction; 24% cost reduction including materials for 2-side cathodes and 50% cost reduction for 1-side cathodes**
- **Capacity, impedance, cycling UV Process ≥ PVDF NMP Process (at 90/5/5 and 90/7/3 NMC compositions)**
- **98% NMC coatings possible**
- **Multilayer UV cathode process is possible for thicker cathodes**
- **Focusing on high speed coating and curing with slot die and printing technology and layered coatings**