2015 DOE Vehicle Technologies Program Review Presentation

Miltec UV International, LLC

Utilization of UV or EB Curing Technology to Significantly Reduce Costs and VOCs in the Manufacture of Lithium-ion Battery Electrodes

A revolutionary high speed approach to manufacturing cost reduction

June 9th, 2015

Principal Investigator:
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Presented by:
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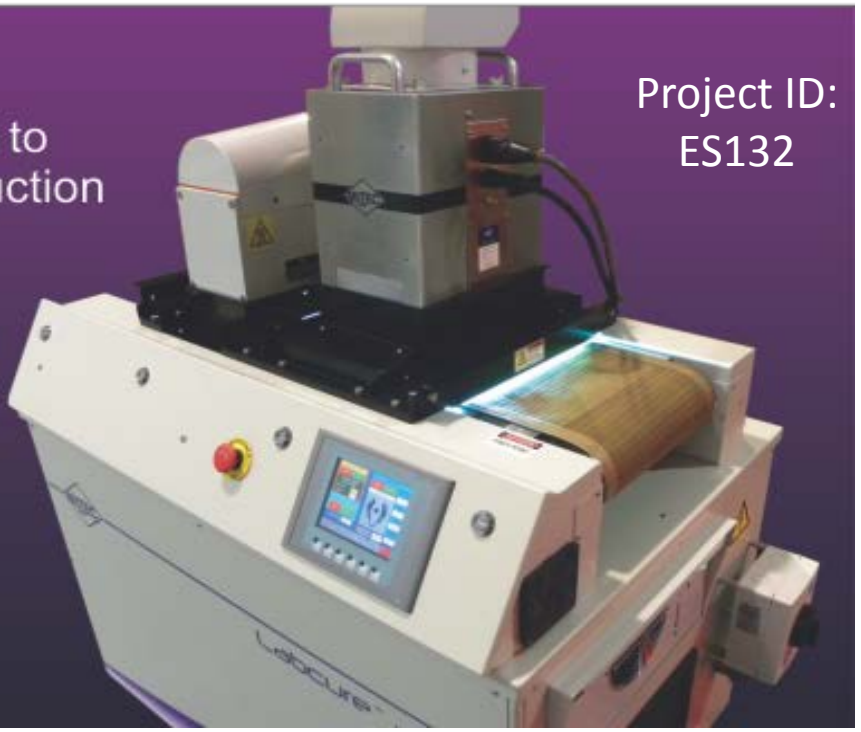
Project Director



Project ID:
ES132

Overview

Project Timeline:

- Start Date:10/01/2011
- End Date: 11/30/2015
- Percent Complete: 90%

Project Goal:

Demonstrate utilization of UV curable binder to produce LIB with performance equal to or greater than PVDF baseline and reduce electrode manufacturing cost by 50%.

Project Budget	
DOE Share:	$4,572,709
Miltec Share:	$1,143,299
Total Project Funding:	$5,716,008
FY11 Funding	$1,392,260
FY12 Funding:	$2,658,811
FY13 Funding:	521,638

Partners:

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

UV Battery Electrode Process

- **Start with liquid UV curable mixture (oligomers, monomers, photoiniators)**
- **Add carbon for conductivity and active material that produces an electrode potential**

- **Apply liquid coating**

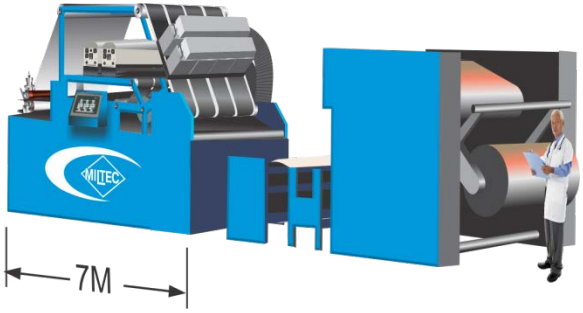
- **UV cure liquid slurry to solid electrode**

UV vs Conventional

Conventional Solvent Drying

UV Curing

- **Instant UV curing reduces space, capital, and operating costs**
- **One single side UV system @ 46 m/m (150 fpm) has output of 4 conventional systems @ 11 m/m (37 fpm) or 2 conventional systems at 22 m/m (74 fpm)**



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

Major Milestones

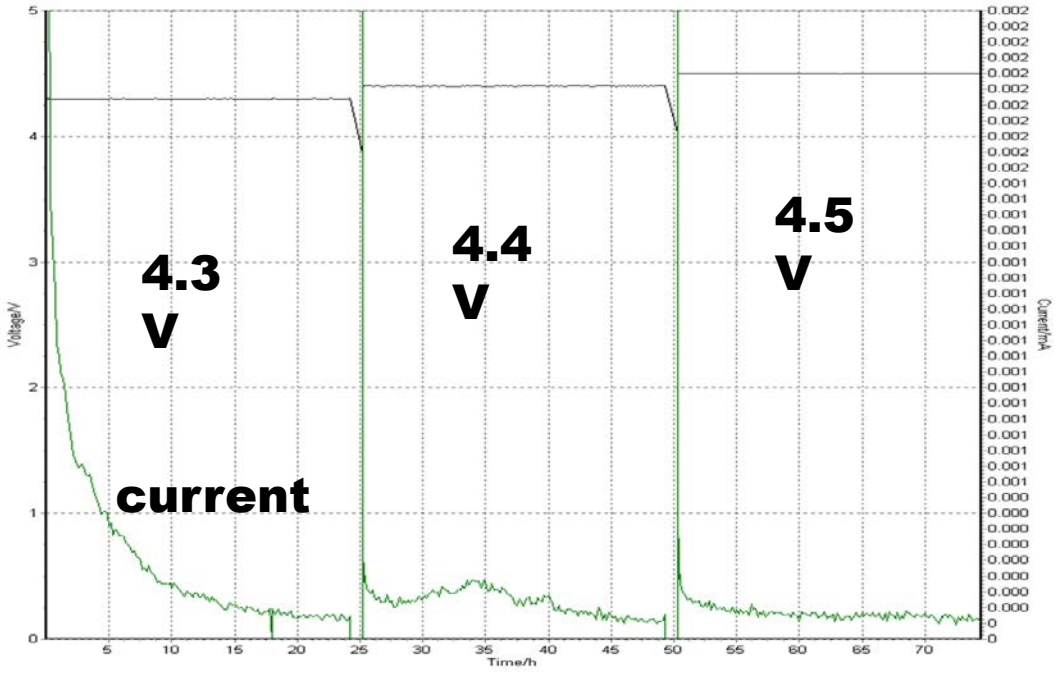
Milestone	Date	Status
Deliver Baseline Cells to INL	Mar 2012	Complete
Finalize UV Binder for Interim Cell Anodes	July 2013	Delayed
Deliver Interim Cells to INL	Jan 2014	Complete
Go-No-Go Decision	Nov 2013	Complete
Deliver Final Cells to INL	Oct 2015	Pending
Deliver Cost Savings Model	Oct 2015	Pending

Electrochemical Testing
Recent Results

Typical Coating, Curing, and Testing Conditions

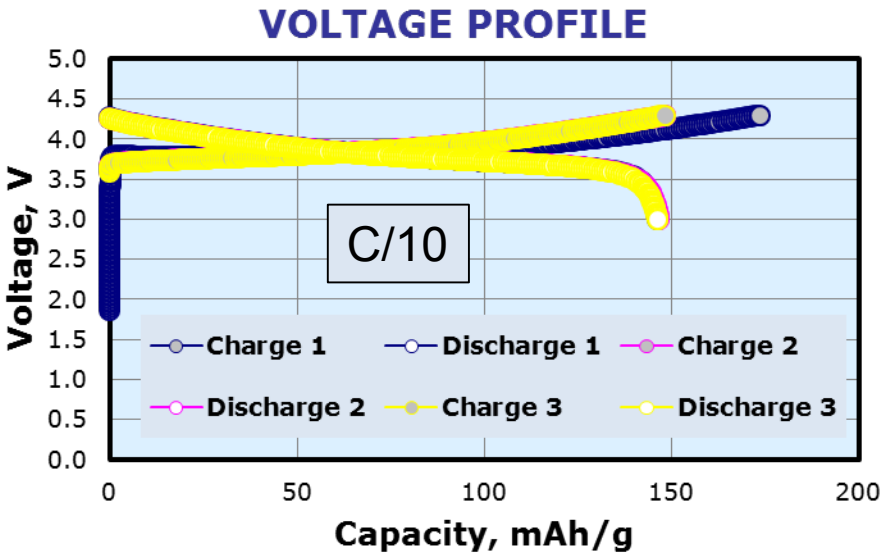
- 20-75 micron coating before curing and calendering, single layer
- 50 –325 fpm (15- 100 Meter/Min); 1, 2, or 3 UV lamps
- 90% NMC, 3-5% UV curable binder, 5-7% Carbon
- Nominal 1200-2000 lb/in^2 calendering
  - Nominal 5.5 – 15 mg/cm2 loading
  - Porosity calculated, nominal 30-42%
- Coin cell, half and full; pouch cell , full

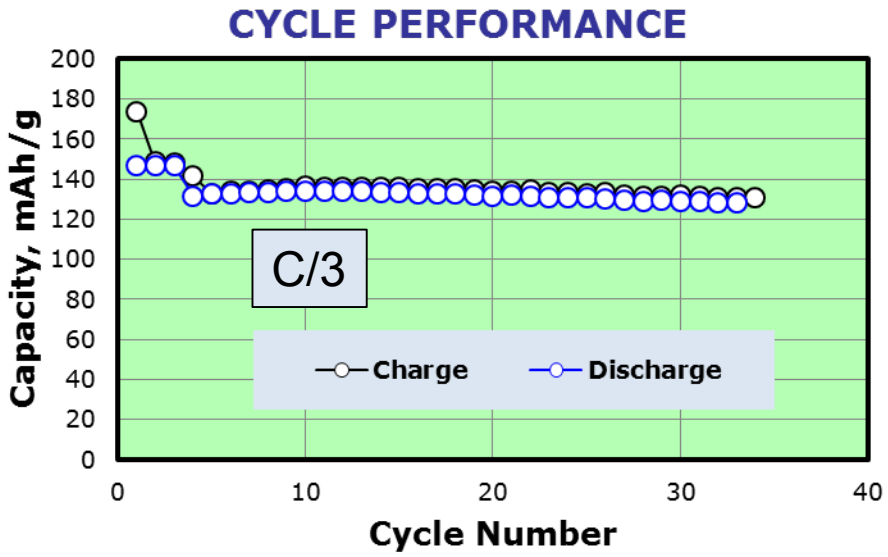
UV binder withstands voltages beyond carbonate electrolyte



Argonne Data

NMC (111) half cell with UV Binder: Miltec 497





Sample: 87% NMC, 5% carbon, 8% UV binder

Current developments: “FAST” and “SLOW” formulas

Comparison of “FAST” and “SLOW” formulas:

FAST:

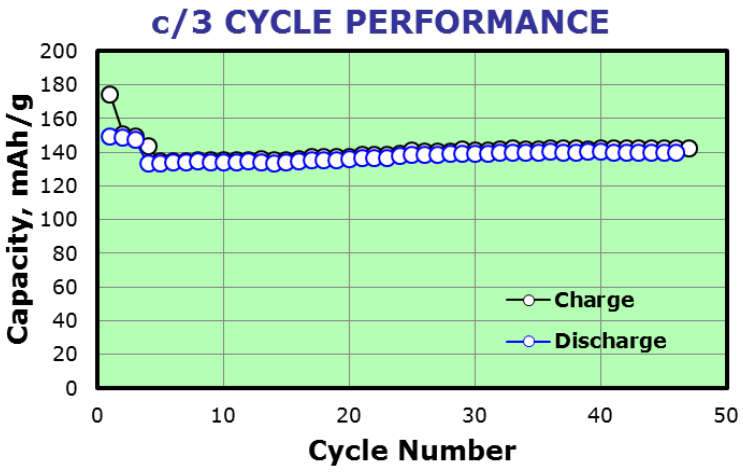
- ✓ Cure with excellent touch and rub adhesion after cure up to 328 fpm
- ✓ Can be cured with only 3% UV binder
- — lower initial capacity and capacity retention (after 50 cycles)

“SLOW”:

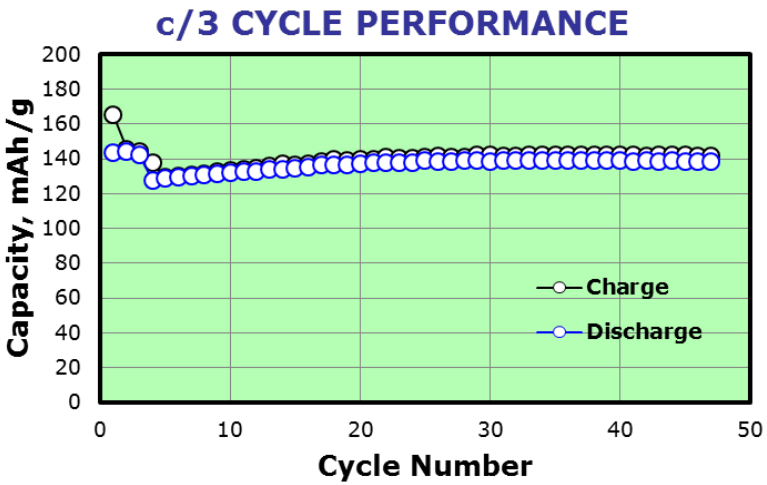
- ✓ Excellent rub, bend and touch adhesion; excellent in electrolyte.
- ✓ Excellent initial capacity and retention (after 50 cycles)
- — Slow cure (up to 50 fpm)

Further reduction of binder with what we call our “SLOW” UV formula

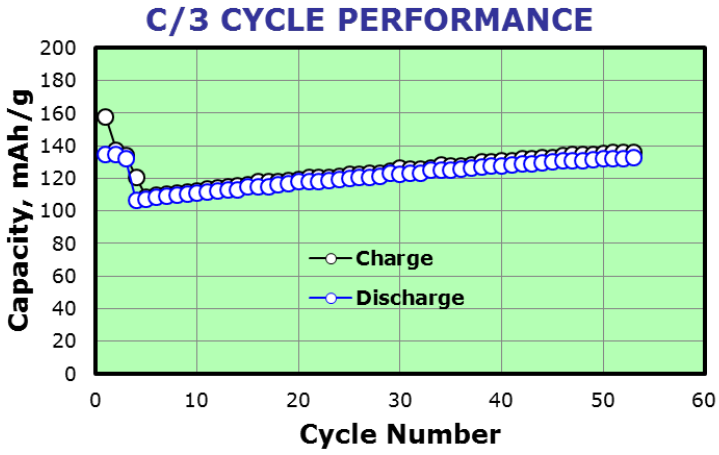
Miltec 732: “Slow” 90-5-5



Miltec 742: “Slow” 90-6-4

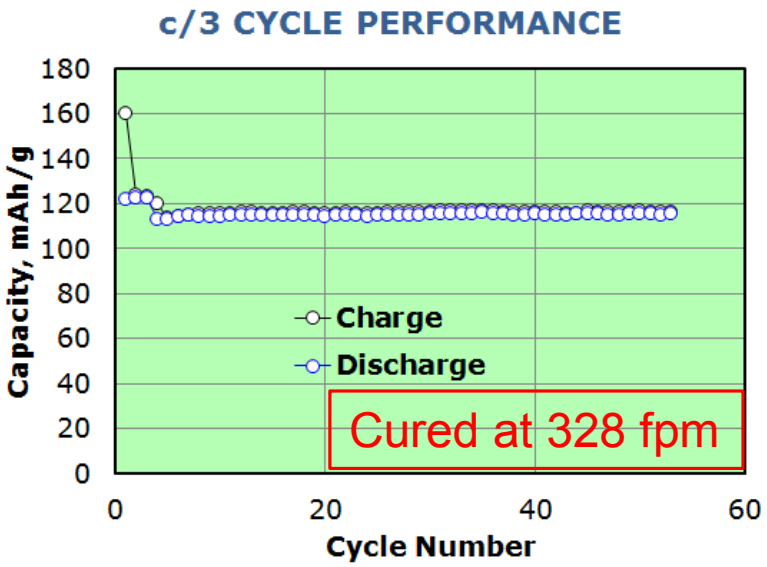


Miltec 743: “Slow” 90-7-3

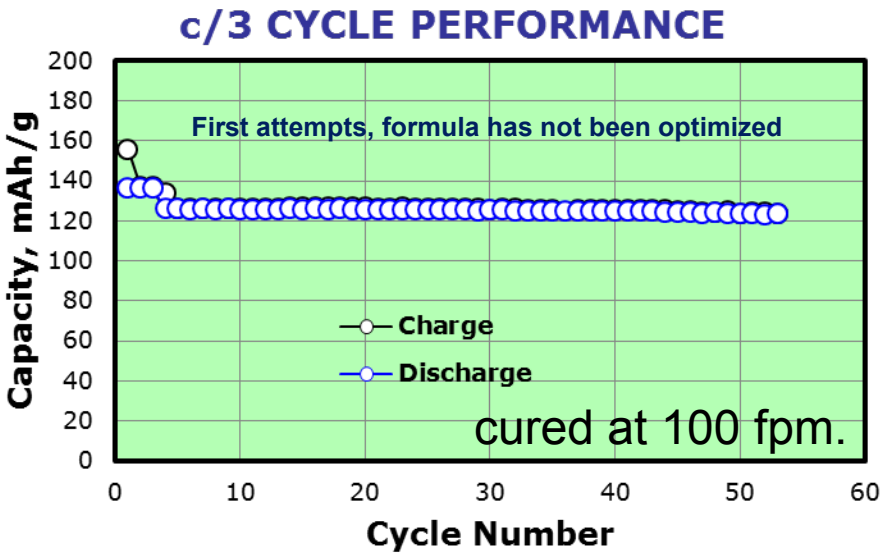


Additional reformulation led to a "FAST" formula (cures to 328 fpm)

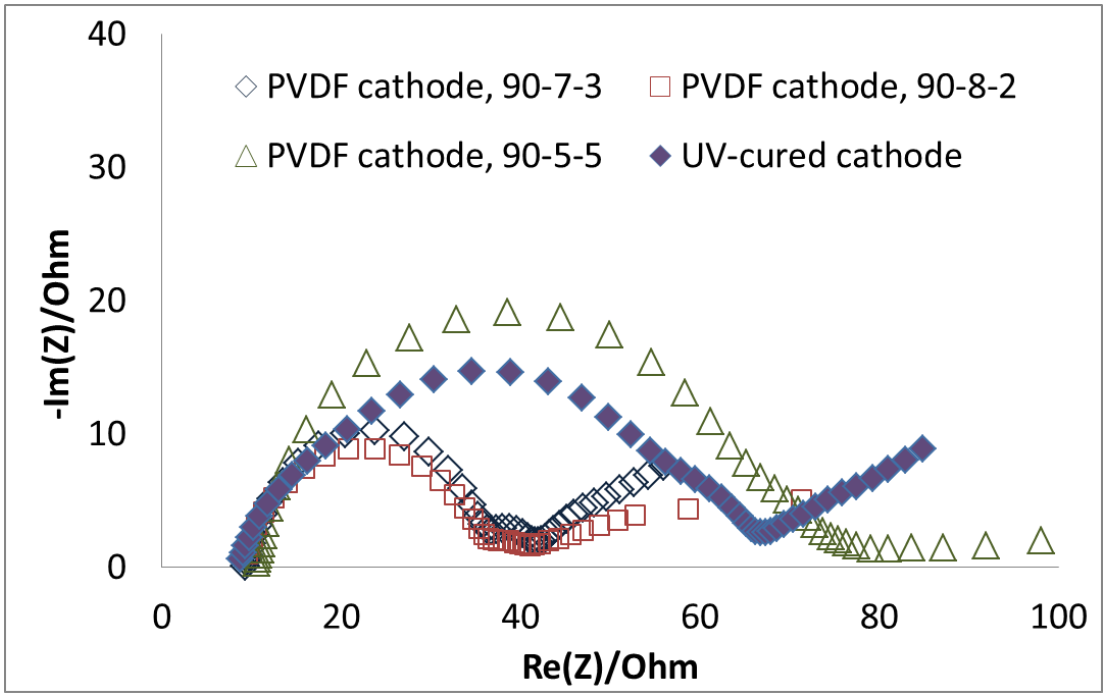
Miltec 817: "FAST" 90-5-5



Miltec 747 : "FAST" 90-7-3



Impedance of the current best UV-cured cathode

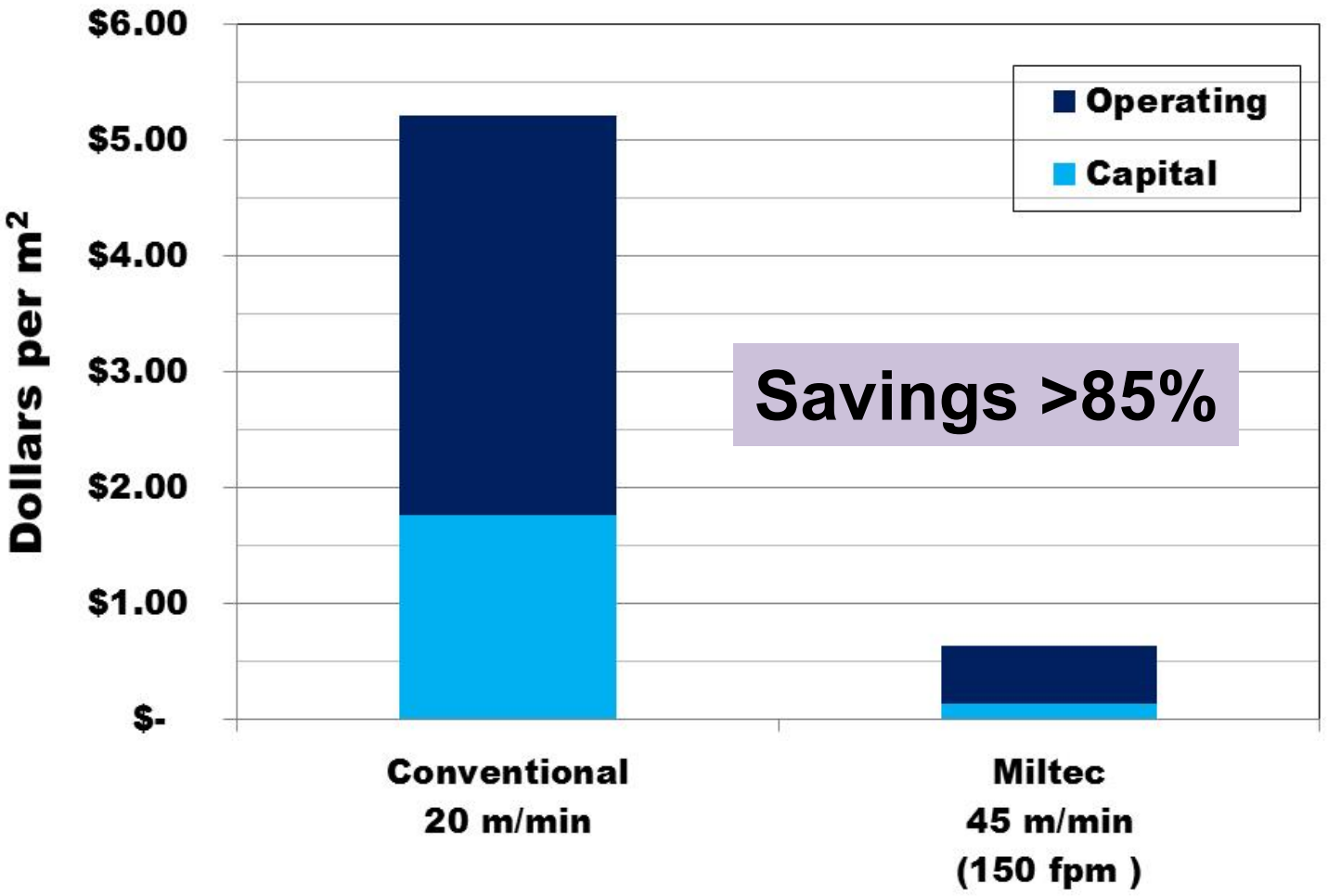


- Achieved impedance of the slot-die UV cured cathode comparable to the hand-draw down PVDF cathode
- Next step: compare impedance of the UV-cured cathode with the impedance of the industry's best cathode

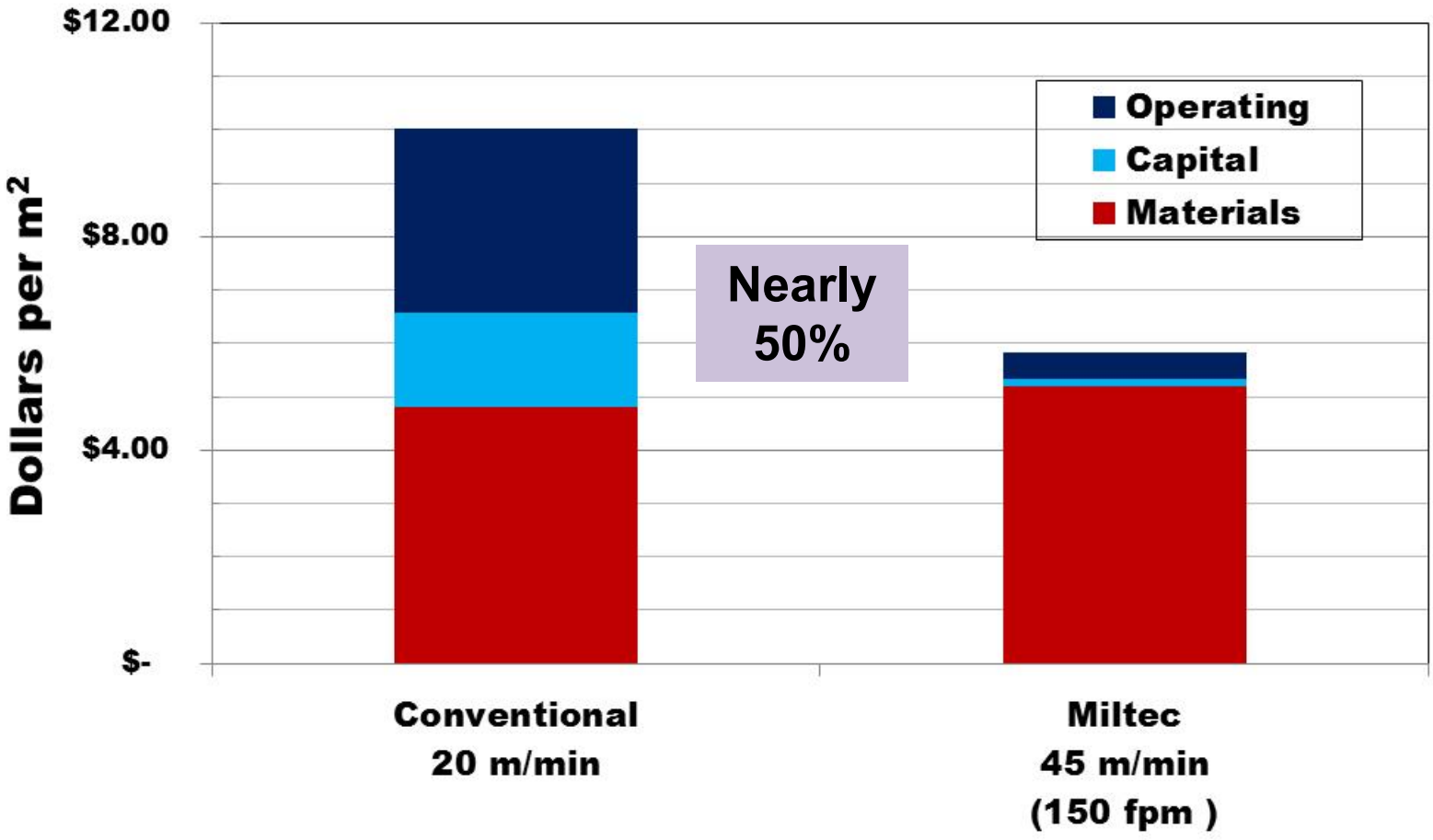
Miltec Cost Model complied from ANL, NREL, TIAX Cost Models

- **Electrode Model includes:**
  - **MATERIAL COSTS:**
    - **NMC, Graphite, Carbon, Foil**
    - **Binder, Lost Solvent (95% recycled)**
  - **CAPTIAL COSTS:**
    - **Building (HVAC, Clean Room, Solvent Recovery)**
    - **Equipment (Mixers, Coaters, Dryers or Curing)**
  - **OPERATING COSTS:**
    - **Labor, Electricity, Fuel**

UV Cathode Manufacturing Cost



UV Cathode Cost Savings



Summary

- Miltec UV has successfully qualified candidate UV Curable constituents including: Oligomers, Monomers, Photoinitiators, and Dispersants

- NMC based cathode tests confirmed:
  - ✓ Layered coating
  - ✓ Confident of making NMC cathode with performance at least equal, most likely better than reference with PVDF

- Moved from baseline of 87/8/5 (cathode material/binder/carbon) to 90/5/5 and 90/7/3

- Successfully cured 90/5/5 at 100 meters/minute

Thank You

- DOE for their funding contributions and advice

- Partners

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