2014 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 17th, 2014

Principal Investigator:
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Presented by:
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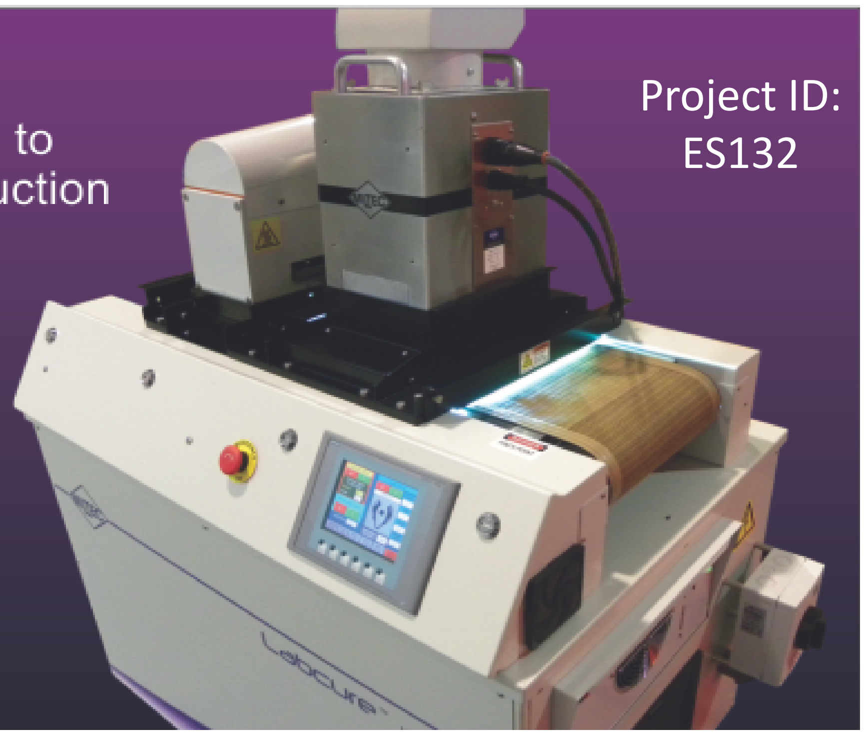
Project Director



Project ID:
ES132

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Project Timeline:
- •Start Date:10/01/2011
- •End Date: 05/31/2015
- •Percent Complete: 50%

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**
- **Add carbon for conductivity and active material that produces an electrode potential**

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

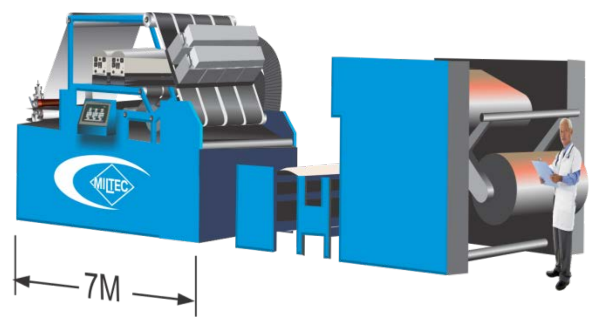
UV vs conventional

Conventional Solvent Drying

UV Curing

Instant UV curing reduces space, capital, and operating costs

One UV system @ 46 m/m (150 fpm) has output of four conventional systems @ 20 m/m (67 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 Cathodes	Aug 2012	Complete
Finalize UV Binder for Interim Cell Anodes	July 2013	Delayed June 2014
Deliver Interim Cells to INL	Jan 2014	Complete
Go-No-Go Decision	Nov 2013	Complete
Contract Amendment, include ceramic coated separator , extend May 2015	Feb 2014	Complete

Mix, Coat, Cure & Fabricate

Baseline Cathode:

87% NMC
8% Binder
5% Carbon

Baseline Anode:

92% Graphite + Carbon
8% Binder

Cathode resistance through dry coating:
Measured in mΩ:
0.10 = Achieved
0.30 = Target
0.45 = Acceptable

Coating Adhesion:
Tape Pull Test
- Poor = Moderate Flaking
- Good = Minimal Flaking
- Excellent = No Flaking

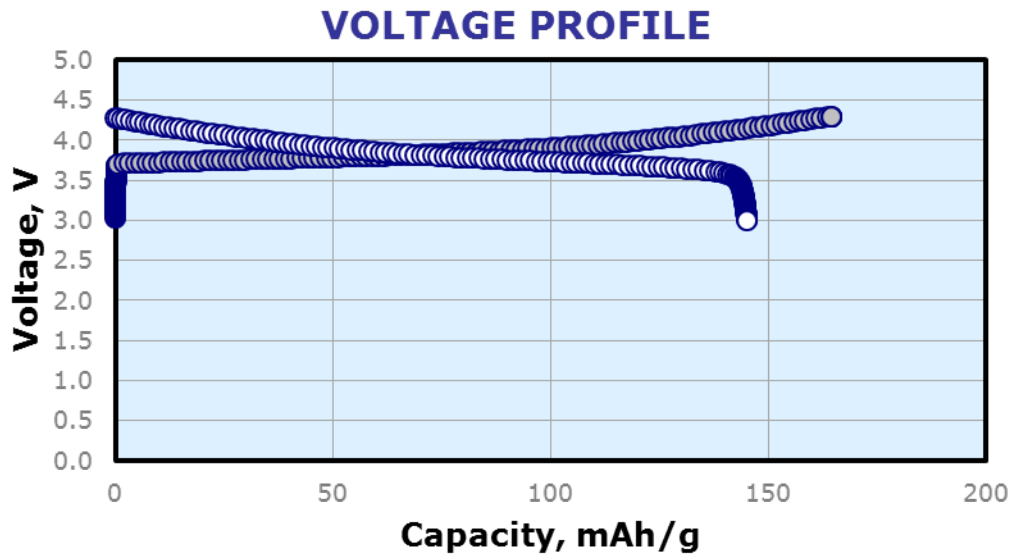
Electrochemical Testing
Recent Results

Typical Coating, Curing, and Testing Conditions

- 50-75 micron coating before curing and calendering, single layer
- 75-150 fpm, 2 lamps
- 87% NMC, 5% Carbon, 8% UV curable binder
- Nominal 1200-2000 lb/in^2 calendering
  - Nominal 40-55 micron thickness after calendering
  - Porosity calculated, nominal 20-35%
- ANL, coin cell, half and full
- Adhesion and conductivity passed before shipment to ANL

Reference Cell

- **Cathode:**
- NCM/Carbon/PVDF: 87/5/8
- NCM: BASF 111
- Carbon: Timcal C-45
- 50 microns

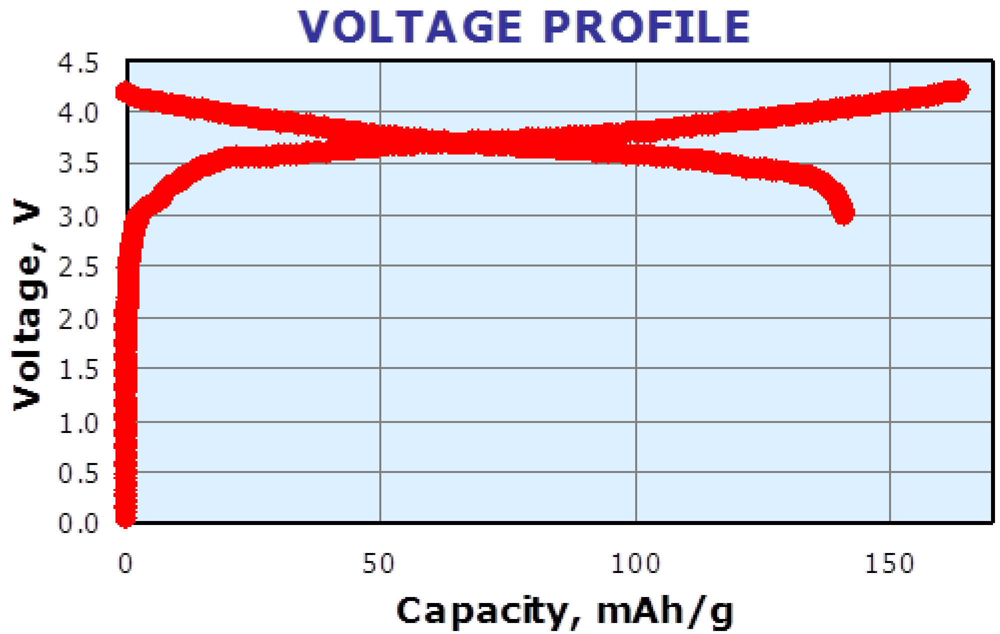


		Ch. mAh/g	Dischar, mAh/g	Ah eff,%
First cycle	C/10	164.56	145.11	88.179
	C/3		141.0	
	1C		136.3	

Performance of NMC full cell with UV Binder

Full-cell cycling conditions

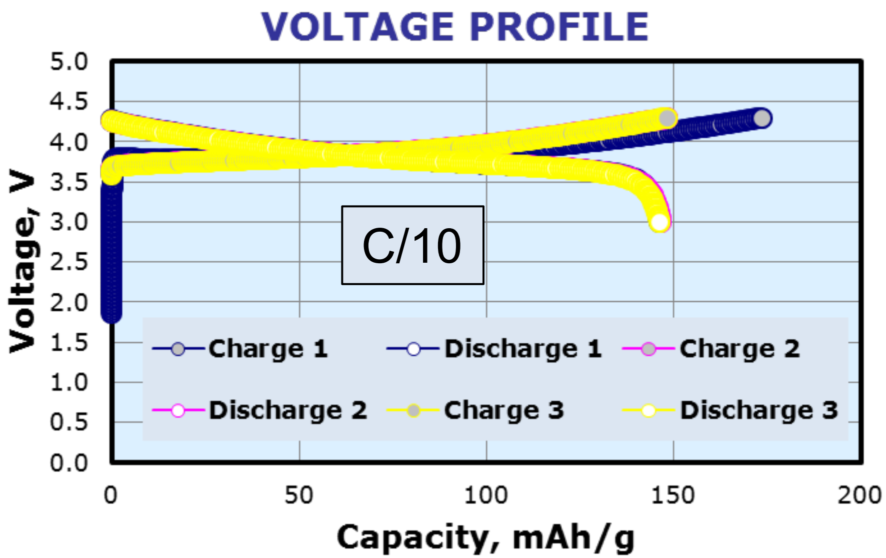
Anode: ConocoPhillips A12 graphite as anode, anode/cathode=~1.1
Electrolyte: Gen 2, 1.2 M LiPF6 in EC:EMC (3:7 by wt.)
Separator: Celgard 2325 -Potential window: 3.0-4.2 V

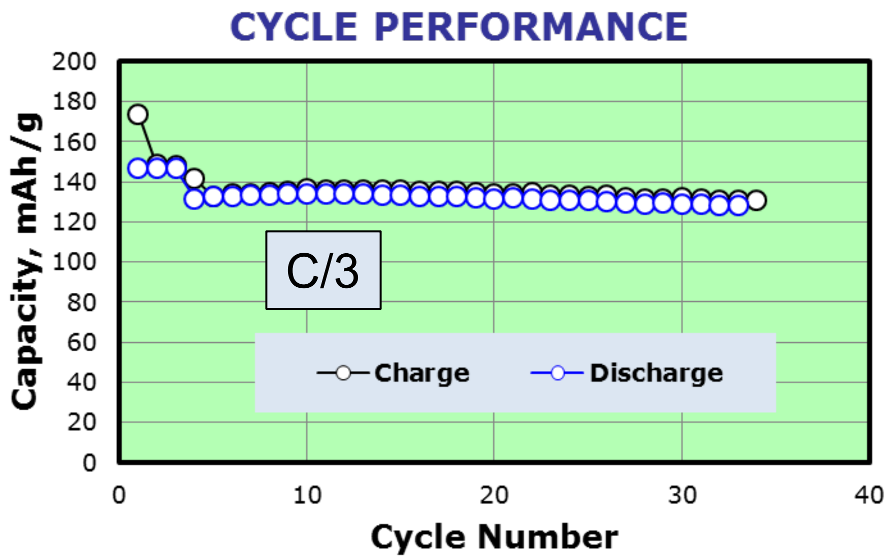


Formation cycle @ C/10 between 3.0-4.2 V
First charge capacity: 163.8 mAh/g

First discharge capacity: 140.9 mAh/g
First cycle Efficiency: 86.03%

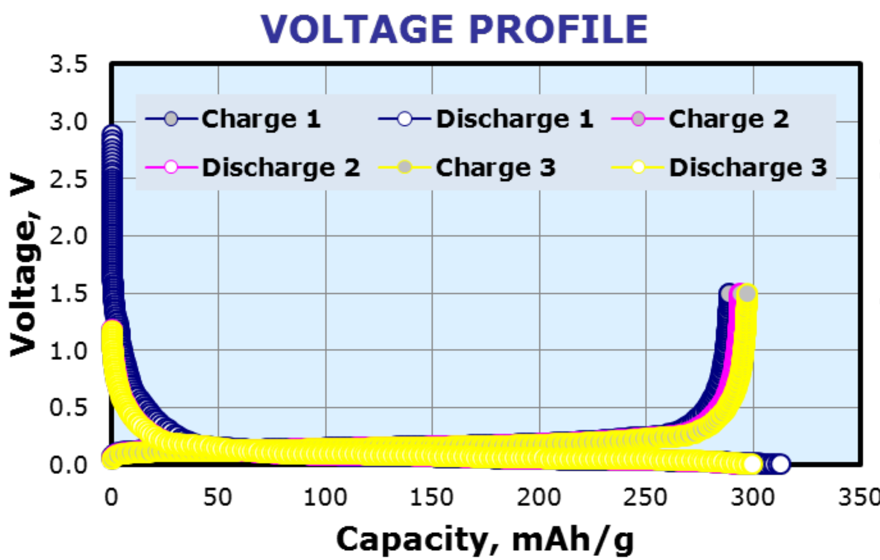
NMC (111) half cell with UV Binder: Miltec 497

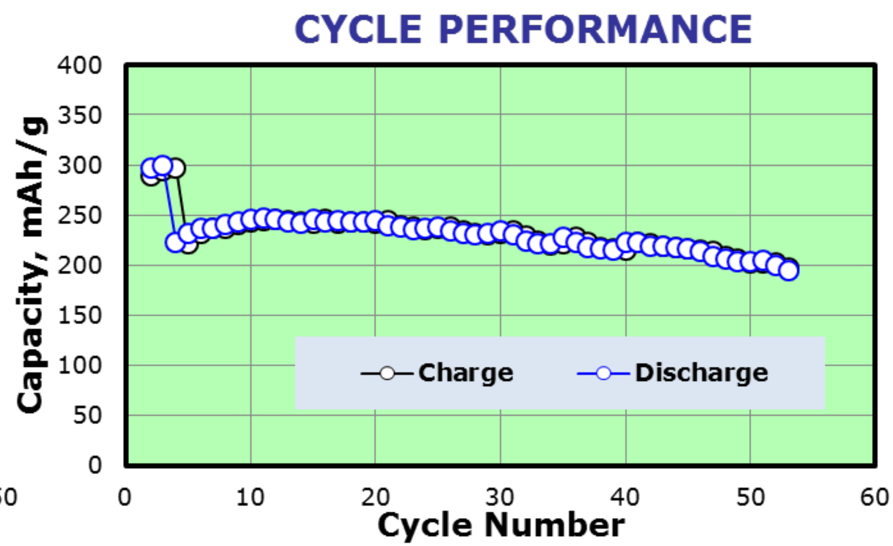




Current density: 14 mA/g (C/10)
Cut-off: 3.0-4.3V
Li-half cell

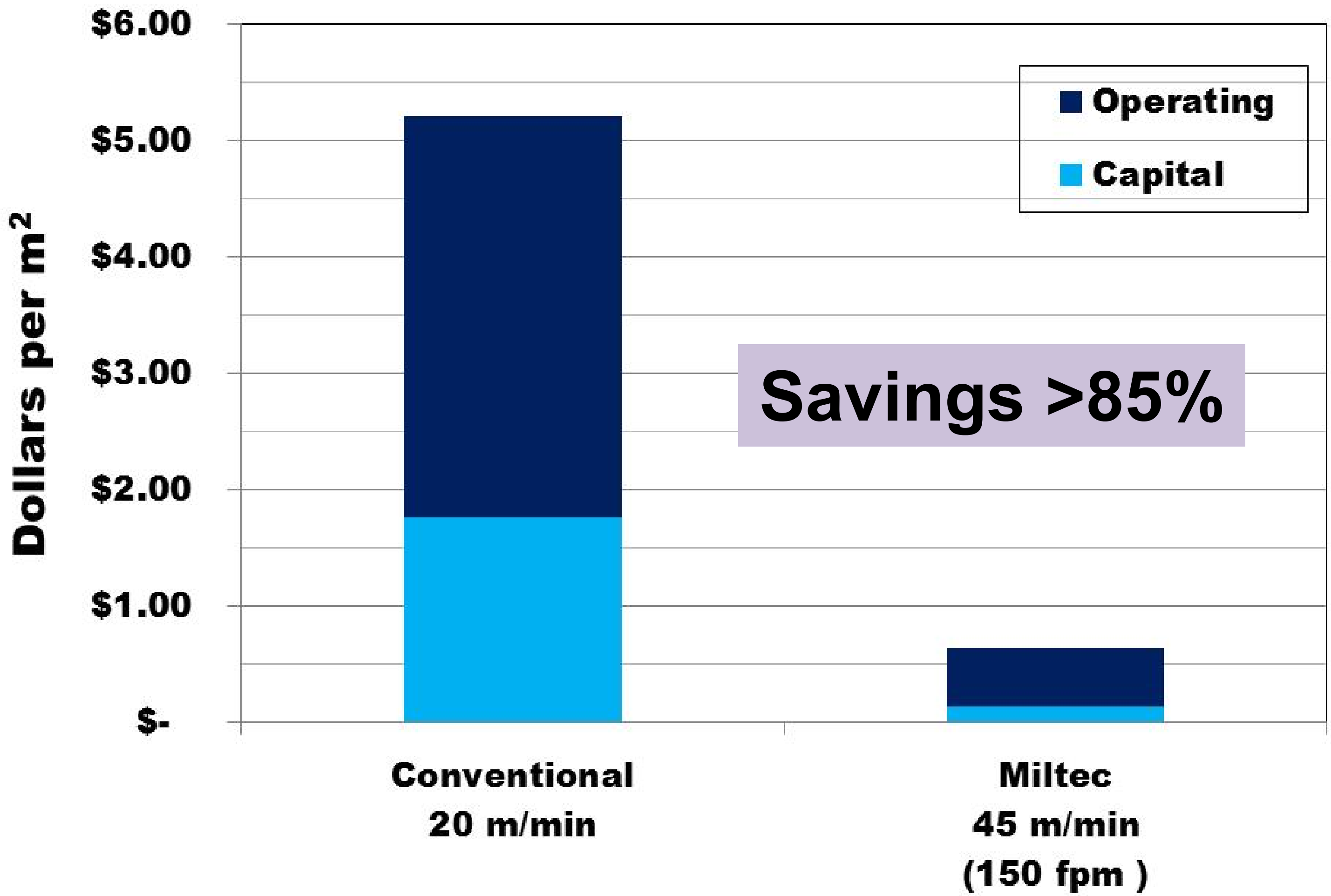
NMC (111) half cell with UV Binder: Miltec 448



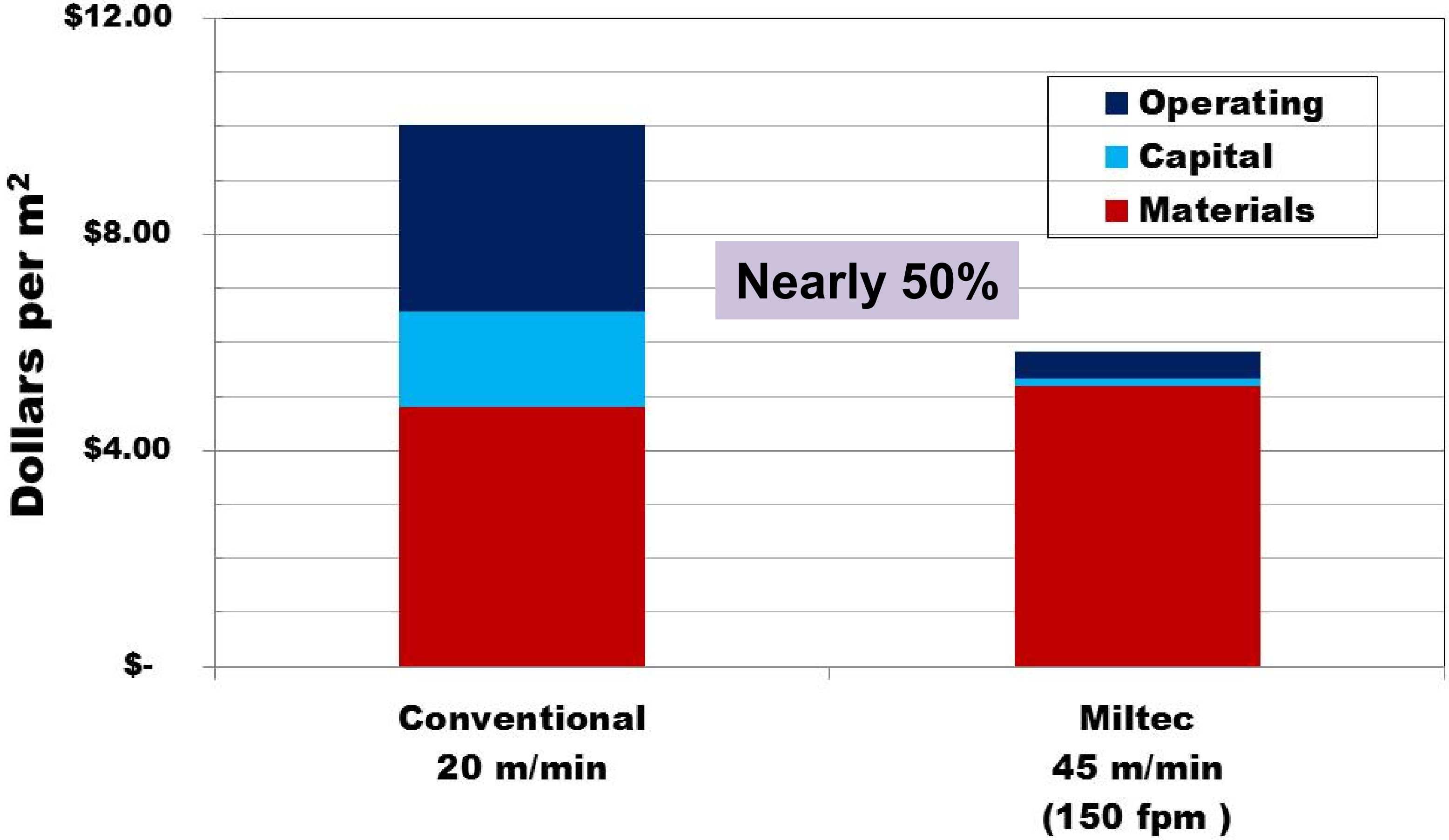


Current density: 30 mA/g (C/10)
Cut-off: 0.001-1.5 V
Li-half cell

UV Cathode Manufacturing Cost

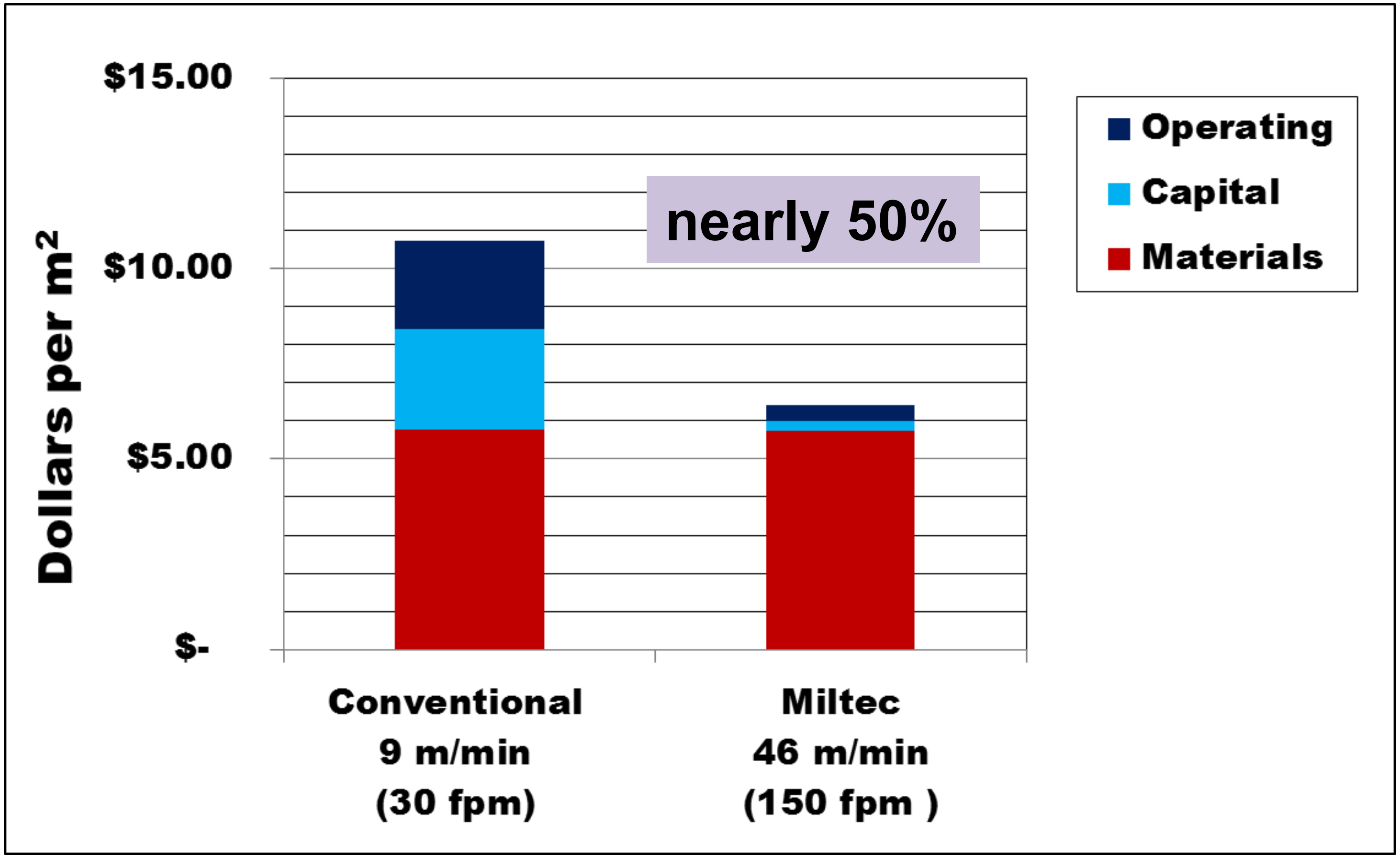


UV Cathode Cost Savings



UV Anode Manufacturing Cost

UV Anode Cost Savings

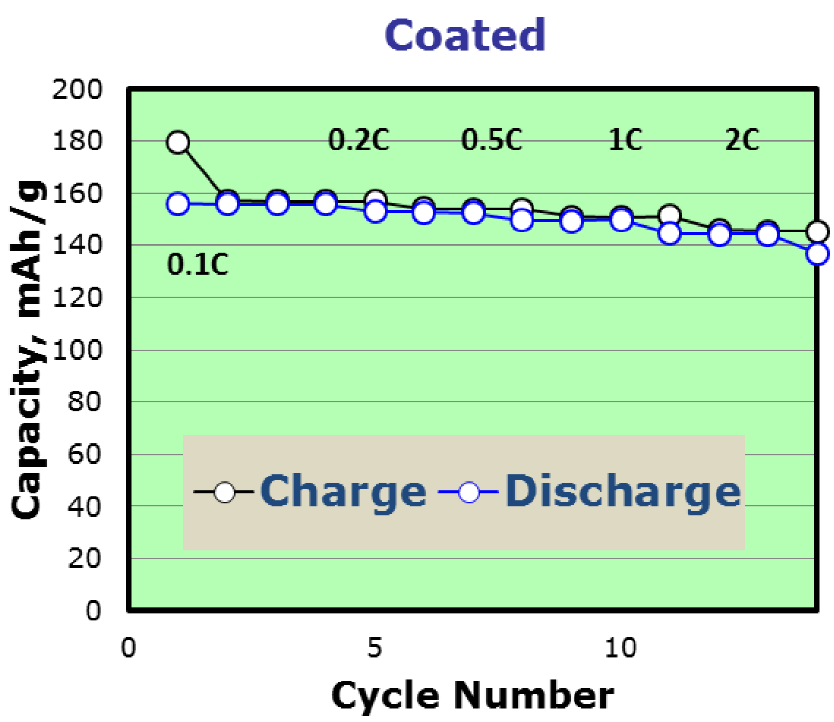


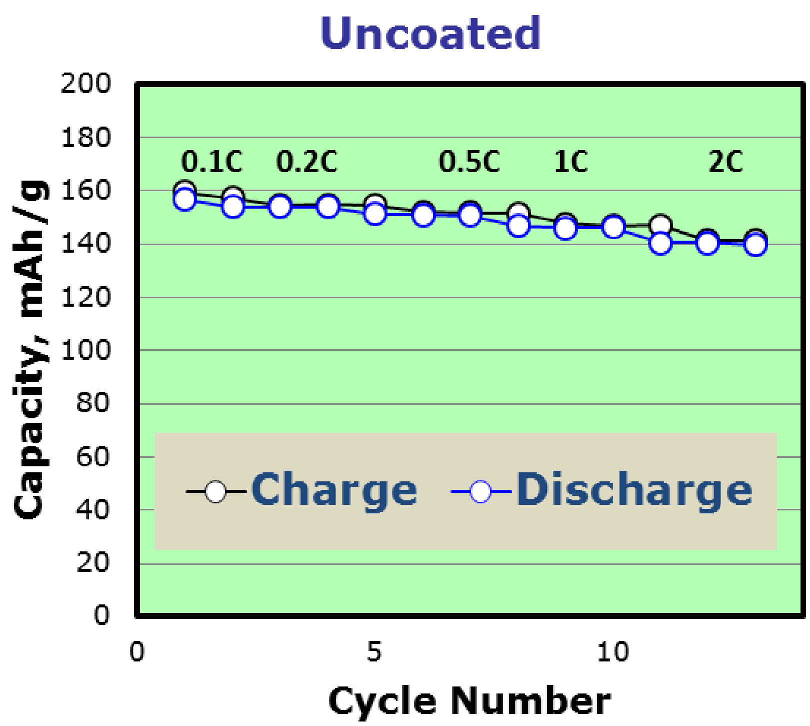
Ceramic Coated Separator with UV Binder

- Approach
  - 2-3 micron ceramic layer using UV curable binder
  - No solvent
  - High speed coating
- Status
  - UV binder chemistries identified
  - Coated separator provided performance equal to uncoated separator
  - Patent applied

UV Ceramic Coating on Trilayer Separator, a possible new technology

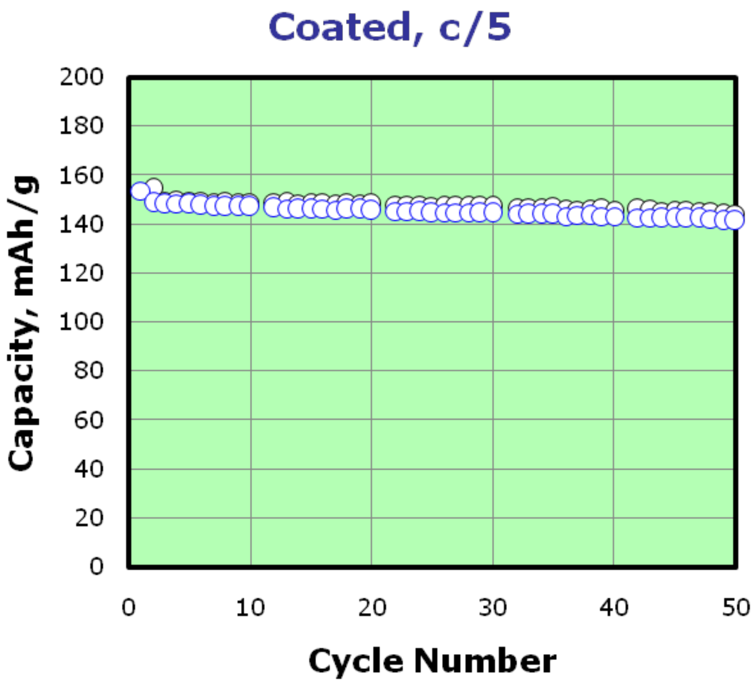
Half-Cell; Cathode: NMC-Lithium Metal

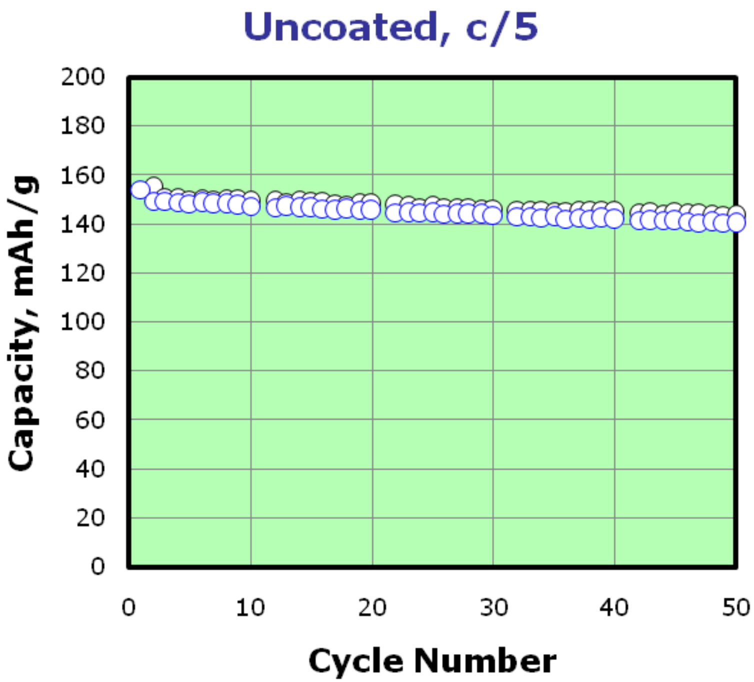




Durable UV Ceramic Coating on Trilayer Separator

Half-Cell; Cathode: NMC-Lithium Metal





Summary

- Foundations in place:
  - ✓ Personnel, equipment, materials, and new facility
- Since October 2011, Miltec UV has successfully qualified candidate UV Curable constituents including: Oligomers, Monomers, Photoinitiators, and Dispersants
- NMC based cathode tests confirmed:
  - ✓ Layered coating
  - ✓ Success at lower porosity
  - ✓ Confident of making NMC cathode with performance at least equal, most likely better than baseline
- Ceramic coated separator effort initiated:
  - ✓ UV binder identified
  - ✓ Initial tests promising

MILTEC

Entire Two-Sided Electrode Coating & Curing Process