2015 DOE Vehicle Technologies Program Review Presentation

Dramatically Improve the Safety Performance of Li ion Battery Separators and Reduce the Manufacturing Cost Using Ultraviolet Curing and High Precision Coating Technologies

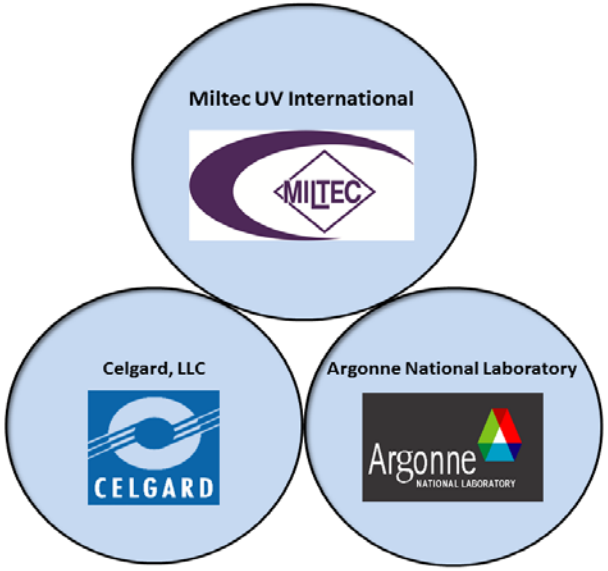
Project Timeline:

Start Date:10/01/2014
End Date: 9/30/2016
Percent Complete: 25%

June 10, 2015
Dr. John Arnold,
Principal Investigator

Project Budget

DOE Share $1,955,000
Cost share $ 399,000



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Major Milestones

Milestone	Date	Status
Complete UV curable binder characterization	**12/15/2014**	**Complete**
Complete UV Curable Binder formulation corrected for printing applications	**03/15/2015**	**Complete**
Complete Printing Pattern Characterization	**06/24/2015**	**In Process**
Separator Coating Laboratory Testing Complete	**08/24/2015**	**In Process**
Complete Coated Separator Electrochemical Evaluation (Go/No-Go)	**09/30/2015**	**Pending**
Complete Initial Printing Press application Validation Tests	**12/15/2015**	**Pending**
Complete Final Printing Press Tests	**08/20/2016**	**Pending**

Why Ceramic Coated Separators?

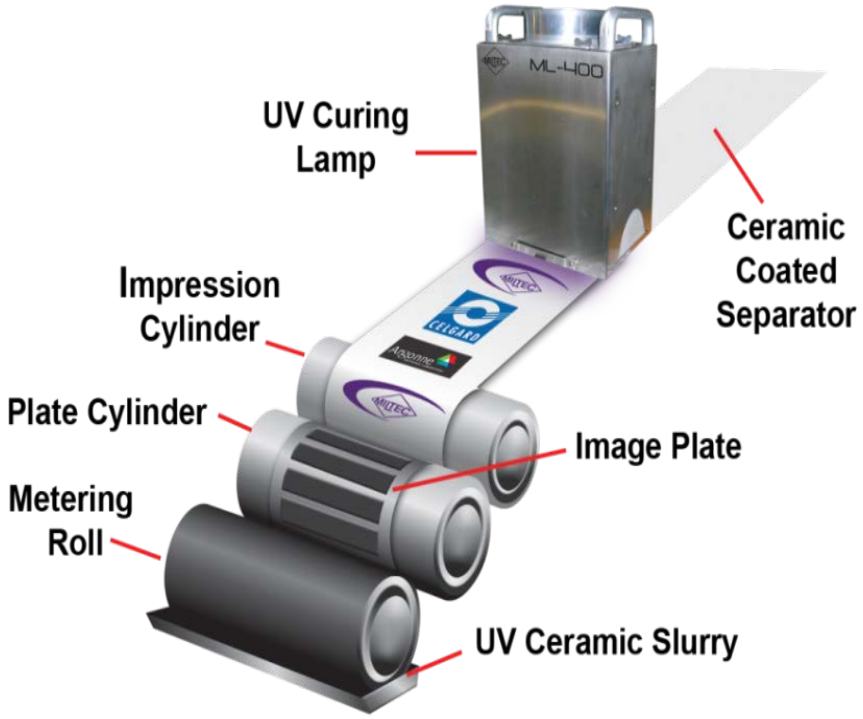
- Safety
- **Reduce Possibility of Thermal Runaway**
  - High melt integrity
  - Low shrinkage
  - High compression strength
  - Less hot spot propagation

Why Ceramic coated Separators?

- **Performance**
  - Reduce Dendrite Growth
  - Increase Ion Path Tortuosity
- **Reduce Oxidation of Separator**
  - High Voltage Stability

Ceramic Coated Separator using UV Curable Binder Process

- Start with liquid UV curable mixture (oligomers, monomers, photoinitiators)
- Add ceramic particles
- Apply slurry coating
- UV cure liquid slurry
- 2-6 µm ceramic layer
- No Solvent
- High Speed Coating



Ceramic Coated Separator using UV Curable Binder

Status

UV binder chemistries identified

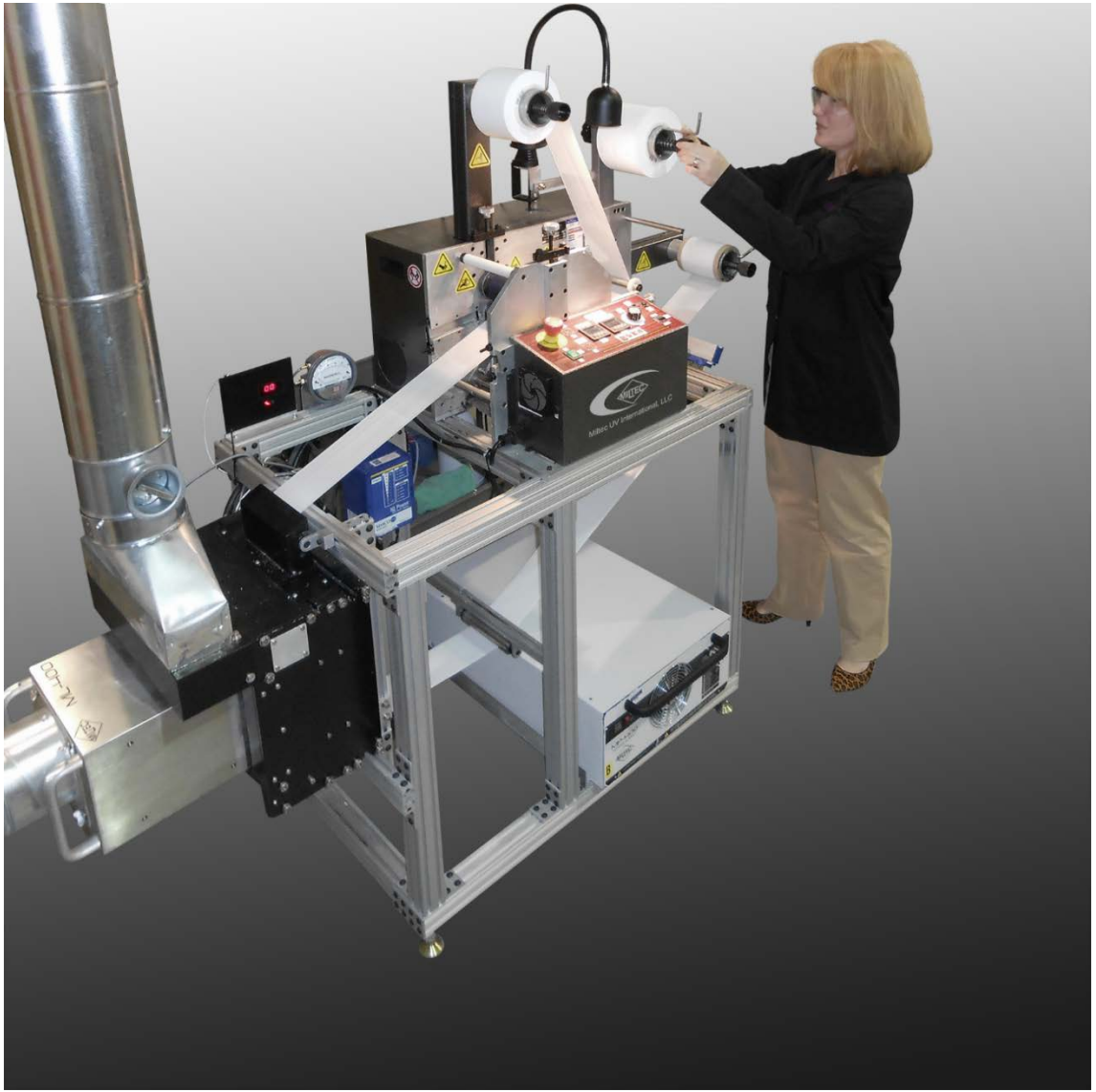
16-25 µm tri-layer and single layer separators successfully coated

Solid and patterned coatings applied

<10% decrease in porosity confirmed

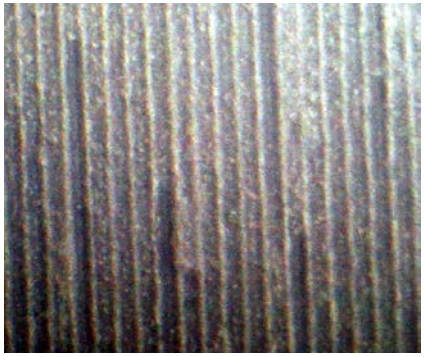
Shrinkage improved over base separator

Laboratory Press Printing at 200 fpm

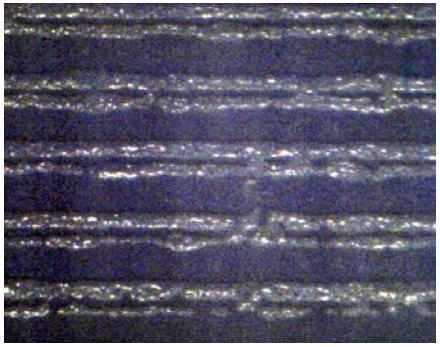


- Sub-micrometer Coating Thickness Control
- Thinner Coatings,
  - Less Weight
  - More Ion Flow
  - Reduced Cost
- Patterns for Higher Ion Flow
- Versatile Printing or Coating

Unexplored Technological Advantages



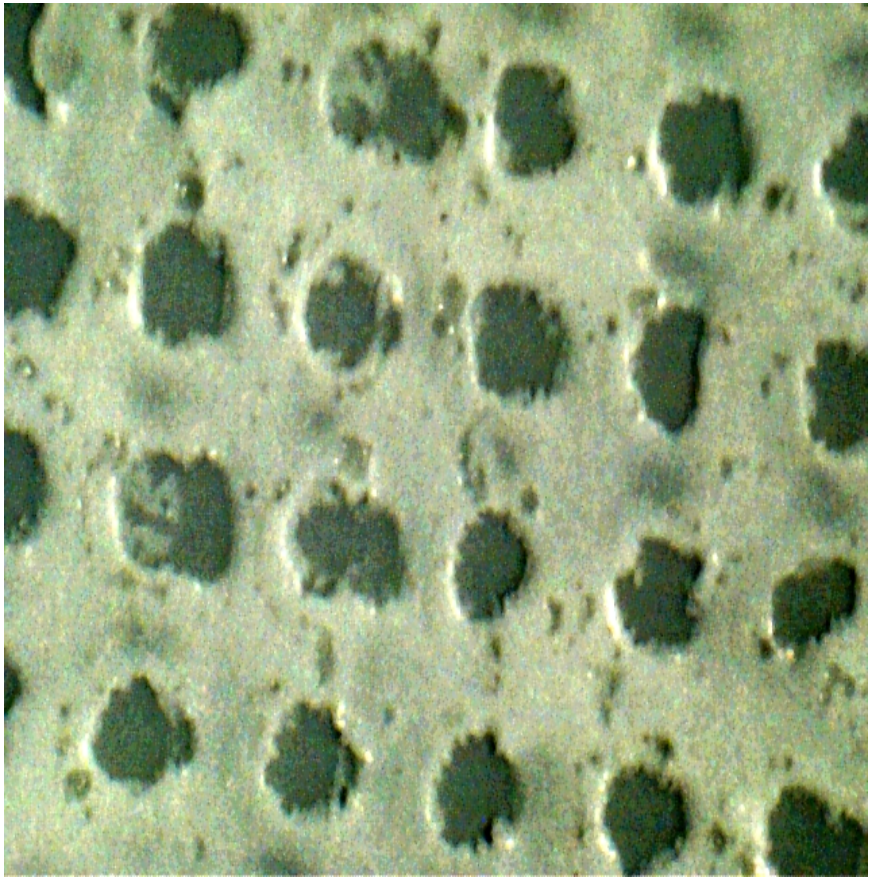
Printing in Machine Direction (MD) Reduces Shrinking

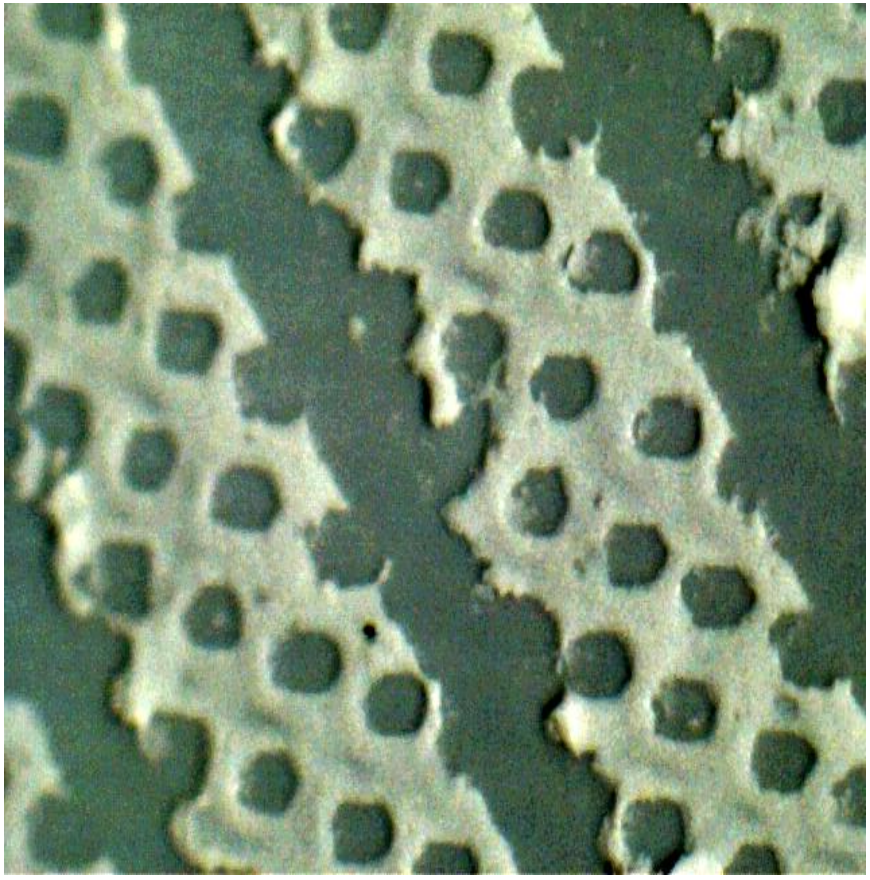


Printing in the Horizontal to MD Increases Tear Resistance

Print in Transverse Direction to Increases Some Tear Resistance and Some Shrinkage

Novel Printed Patterns

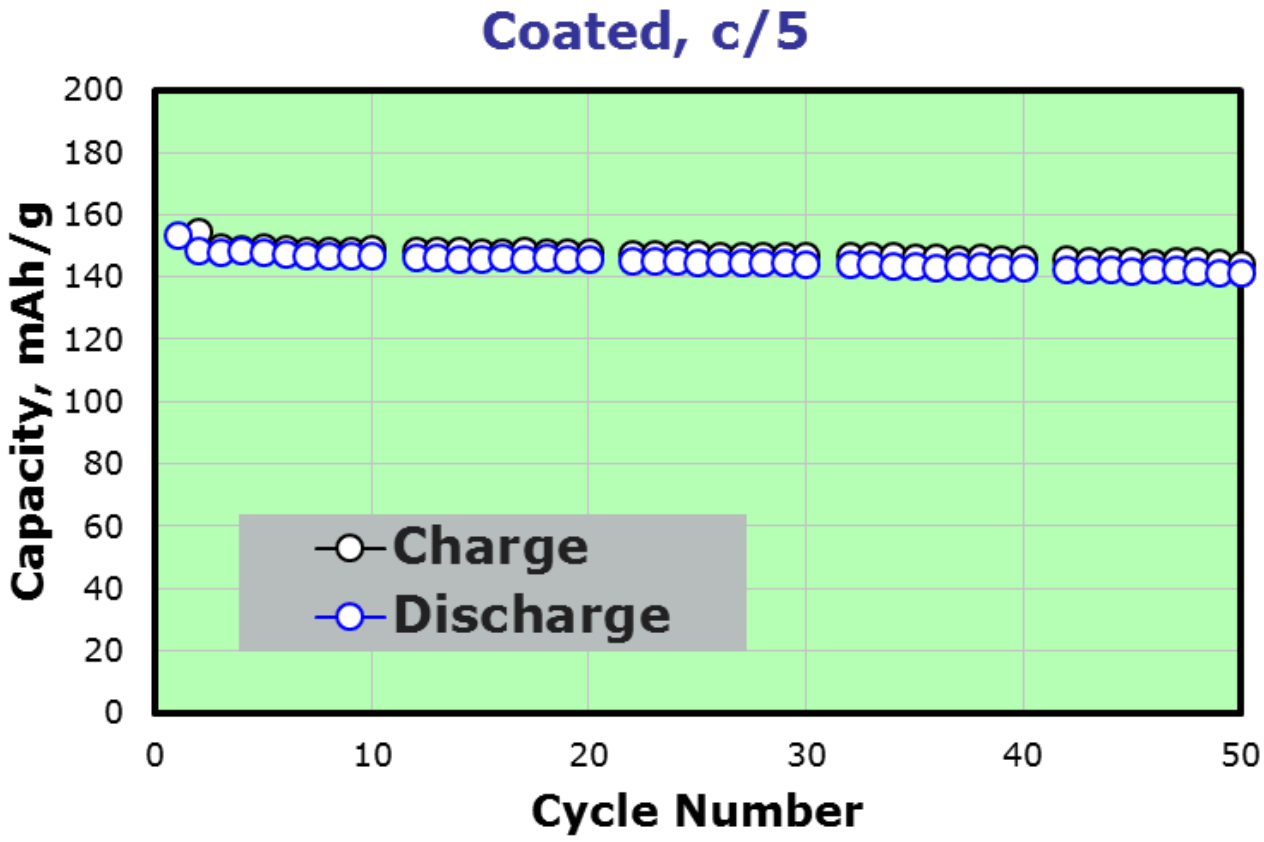




UV Ceramic Coatings have Excellent Adhesion and Porosity

Properties	Solid	Patterned	Base Film
Gurley	602	562	461
Shrinkage @ 100°C	<5%	<5%	<5%
Shrinkage @ 150°C	24%	28%	33%
Thickness	3 µm +16 µm	3 µm +16 µm	16 µm

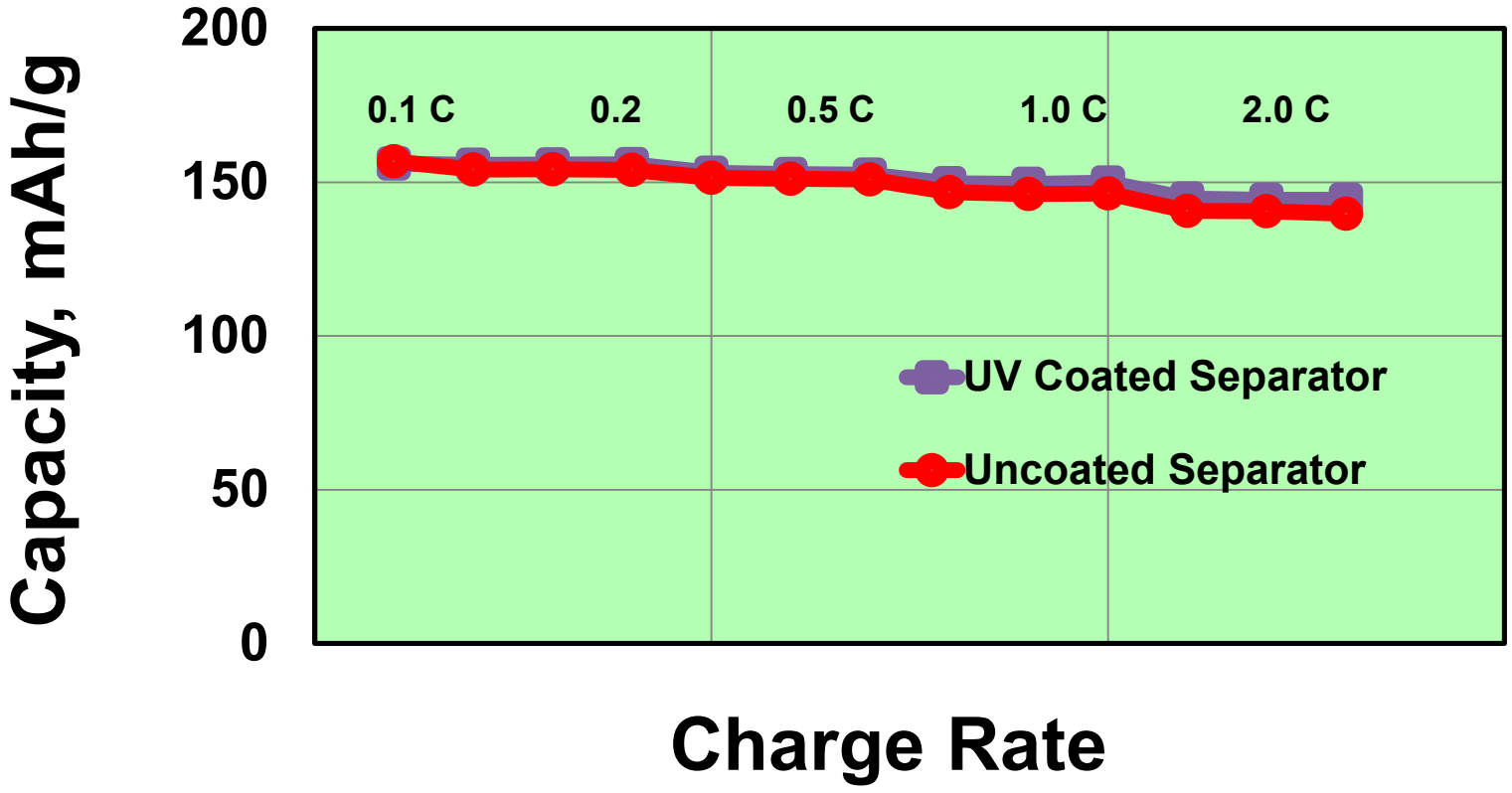
UV Ceramic Coating on Trilayer Separator does not Interfere with Cell



NMC-Lithium Metal Half-Cell

Charge Capacity/Charge Rate Same
UV Ceramic Coated & Uncoated

NMC Half Cell



Shut Down Coating On Single Layer PP Separator

Properties	Coated PPO	Uncoated PPO Separator
Gurley at 25°C	400	325
Gurley after 100°C	550	300
Gurley after 150°C	∞	825
Shrinkage @ 100°C	<5%	<5%
Shrinkage @ 150°C	20%	25%
Thickness	3 µm +16 µm	16 µm

Gurley Tester Measures Flow Through Coated and Uncoated Separator

Summary

- **Established Feasibility of UV Binder for Ceramic Coated Separator**
- **2-6 µm Thick Coatings and Patterns**
- **Minimum Increase in Gurleys – Less Than 10%**
- **Demonstrated High Speed Printing (200 ft/min)**
- **Demonstrated Capable of Printing Patterns**

Thank You

- DOE for their funding contributions and advice

- Partners