Final Report

Utilization of UV Curing Technology to Significantly Reduce the Manufacturing Cost of LIB Electrodes

Miltec UV International

OBJECTIVES

- Reduce lithium ion battery electrode manufacturing costs by 50% by replacing solvent-based binder with UV curable binder.
- Demonstrate battery cells made from UV cured binder electrode coatings perform equal to or greater than equivalent cells made using solvent based binders.

John Tabacchi (NETL Program Manager)
DE-EE0005421 Recipient: Miltec UV International

Gary Voelker PD
Dr. John Arnold PI
146 Log Canoe Circle
Stevensville, MD 21666
Phone:410-604-2900; Fax: 410-604-2906
Email: gvoelker@miltec.com, jarnold@miltec.com

Subcontractors:
Argonne National Laboratory
Oak Ridge National Laboratory

Start Date: October 2011
Projected End Date: November 2015

TECHNICAL BARRIERS

The technical barriers to realizing the full cost saving potential of UV curable binder technology in these applications are:

- Development of mixing techniques applicable to solvent-free slurries that ensure homogeneous mixing and viscosities compatible with electrode coating techniques.
- Confirmation that the UV cured binder materials retain chemical inertness and adhesion after long term electrochemical exposure.
- Development and demonstration of high speed coating and UV curing techniques that ensure complete curing of the electrode coating.

TECHNICAL TARGETS

- Cathode Targets: 90/5/5% NMC/Carbon/UV Curable Binder (originally 87/5/8%);
- Manufacturing cost reduction > 50% over conventional PVDF cathode binder
- Pouch cell performance $\geq$ conventional PVDF
- Process speeds >50 meters/minute

ACCOMPLISHMENTS

- Demonstrated cathode with 90/5/5 NMC/Carbon/UV curable binder with excellent adhesion, calendering and performance essentially equal to conventional 90/5/5 PVDF cathode in high and low accelerated cycling tests.
- Demonstrated a 90/5/5 cathode coating could be UV cured at 100 meters/minute with good capacity retention (half cell 50+ cycles).

- Final project year began with 8% binder. Now all work uses 3-5% binder. Reactive impedance and IV impedance were significantly reduced (>200%) so that Miltec produced a single layer pouch cell that was equal to reference PVDF cathode. This improvement was accomplished by continuous improvement of binder ingredients, cure conditions, mixing, and application techniques.
- Delivered Final Pouch Cells to DOE with 90/5/5 NMC/carbon/binder for independent testing.
- Completed cost model showing the UV curing process reduces manufacturing costs by approximately 90% over PVDF process. Total electrode cost decrease 25% for two-side coated electrodes and 50% for single-side coated electrodes, including materials over that of the conventional solvent process.
- As the contract comes to a close Miltec continues to make very good progress toward producing UV cathodes with the performance required for commercial Lithium ion batteries, including some of our first 90/7/3 pouch cells.

INTRODUCTION

Previously identified novel binders and associated UV curing technology have been shown to reduce the time required to apply and finish electrode coatings from tens of minutes to less than one second. This revolutionary approach can result in dramatic increases in process speeds, significantly reduced capital (a factor of 10 to 20) and operating costs, reduced energy requirements, and reduced environmental concerns and costs due to the virtual elimination of harmful volatile organic solvents and associated solvent dryers and recovery systems. The accumulated advantages of higher speed, lower capital and operating costs, reduced footprint, lack of VOC recovery, and reduced energy cost is a reduction of 90% in the manufacturing cost of cathodes. When commercialized, the resulting cost reduction in Lithium batteries will allow storage device manufacturers to expand their sales in the market and thereby accrue the energy savings of broader utilization of HEVs, PHEVs and EVs in the U.S., and a broad technology export market is also envisioned.

APPROACH

The objectives outlined have been accomplished by an iterative research and development process. Multiple lithium ion battery cells were fabricated using various approaches to UV curing technology; performance of the cells evaluated; and analytical testing used to further improve the performance of the cells. Final pouch cells made with UV curable binders were submitted to the DOE for independent testing and performance verification. It was learned in the first year of the effort that the use of UV curable binder technology on conventional carbon anode material was problematic because of the extreme absorptive qualities of the anode carbon. The project has therefore focused on cathode preparation and the results have exceeded the goals. NMC pouch and coin cells using UV curable binder have been prepared with performance at the baseline goal. Miltec began operation of a slot die coater installed on an existing UV lamp system designed for Lithium ion battery electrodes. The slot die coater is capable of coating on a 10” current collector at a width of 8” and operating at coating speeds up to 200 fpm. Initial problems with operation of the reel to reel subsystem have been corrected and testing on the Slot Die/UV Curing system completed. Because of the success of UV curing hand drawn samples at 100 meters/minute, a modified printing technology was added to the Miltec laboratory UV system for evaluation. We believe printing technology can coat at the higher speeds (100 meters/minute) without the extreme solvent dilution that would be necessary with a slot die process.

RESULTS

Miltec has achieved the following progress:

Developed and demonstrated performance of the cathode with 5% UV binder, 5% of carbon and 90% NMC.

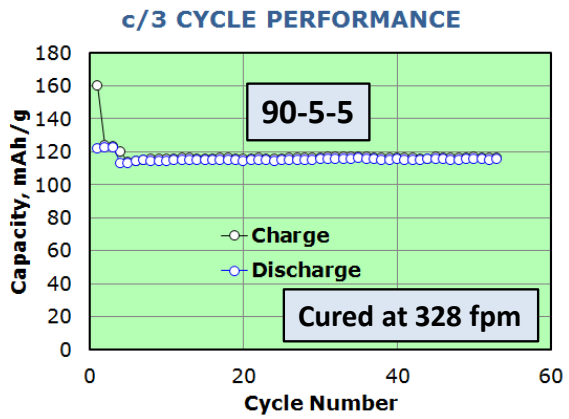

Figure 1. Capacity over 50 cycles of the 90-5-5 sample (NMC:carbon:binder) cured at 328 fpm (100 meter per minute) under 3 lamps.

At the beginning of FY 2015 Miltec started actively pursuing developing 90-5-5 formulations (NMC-carbon-binder). These developments overcame issues with poor adhesion, excessive shrinkage and depth of cure. Miltec developed coatings with excellent adhesion that at the same time could be cured at 100 meter per minute (328 fpm) and have good battery performance. The sample shown in Figure 1 is at a loading of approximately 5.5 mg/cm^2.

Developed and demonstrated performance of the cathode with 3% UV binder, 7% carbon and 90% NMC.

At the end of the project all developments from the coatings with 5% UV binder allowed us to advance and demonstrate a successful coating with good cure with only 3% UV binder which had excellent adhesion and calendered well. Samples showed good electrochemical performance. This pouch cell performance was also at a 5.5 mg/cm^2 loading.

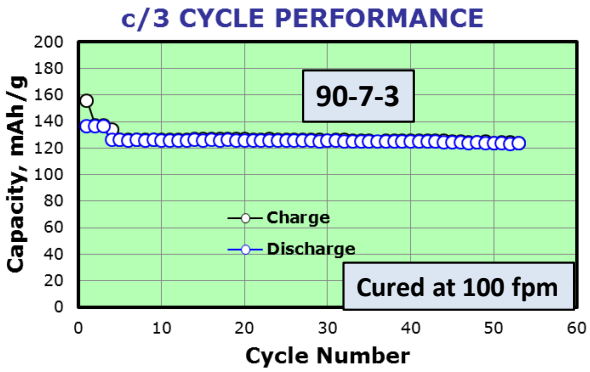

Figure 2. Capacity over 50 cycles of the 90-7-3 sample (NMC:carbon:binder) cured at 100 fpm (~ 30 meters per minute) under 3 UV lamps.

Significantly decreased impedance of cathode with 3% UV binder that approached the PVDF reference.

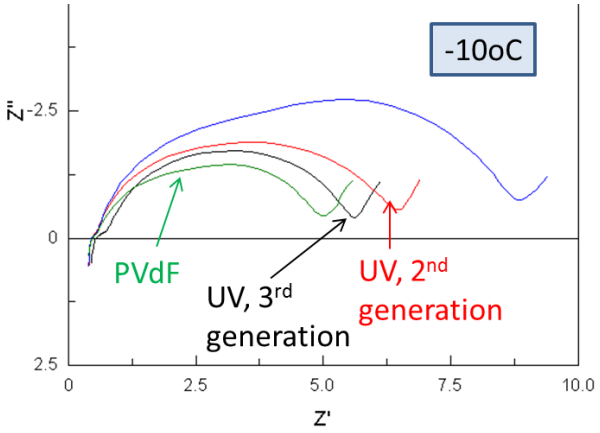

Figure 3. AC impedance comparison of cathode with 3% PVDf and UV binder taken at -10ºC.

Miltec significantly decreased AC impedance and IV resistance through the iterative research of binder combinations, cure conditions as well as mixing and application techniques: by the end of the contract AC impedance and IV resistance were reduced by 200% and 50%, respectively, and were approaching the desired levels of the reference PVDF pouch cells.

Current cathode with 3% UV binder Developed with capacity retention over 200 cycles equal to PVDF reference.

Significantly lower impedance and resistance allowed Miltec to produce a single-layer pouch cell that equaled a PVDF reference.

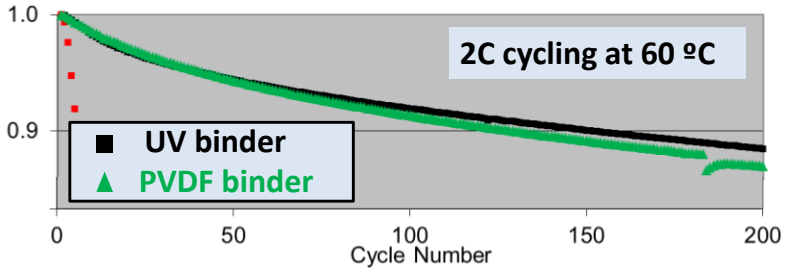

Figure 4. Cathode with 3% UV binder demonstrated capacity retention equal to cathode with 5% PVDF binder

CONCLUSIONS AND FUTURE DIRECTIONS

Miltec UV with the support of Argonne National Laboratory and Oak Ridge National Laboratory have made dramatic progress in demonstrating the potential cost savings attributable to the use of UV curable binder to replace conventional binders in the manufacture of LIB cathodes. All major milestones of the project were successfully completed. Pouch cells with performance equal to a conventional reference cell have been made at binder content comparable to commercial products and UV curing at 100 meters/minute has been demonstrated. A cost model indicates the manufacturing cost for a 2 sided coated cathode can be reduced by 90% and the overall cost of the cathode reduced 25% including materials. Miltec UV International is committed to continue efforts to commercialize this revolutionary technology.