Final Report

Transformational electrode drying process

Performance period: January 6, 2012 – August 1, 2012

CPS agreement: 24789

December 19, 2012

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September 2012

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ACRONYMS AND ABBREVIATIONS

Ah	Ampere Hour
C	charge/discharge rate (e.g. xC = full charge/discharge in 1/x hours)
cc	Constant current charge/discharge
CCCV	Sequence of constant current – constant voltage charge/discharge
cm	Centimeter
g	Gram
HF	Hydrofluoric Acid
HVAC	heating, ventilation, and air conditioning
IR	Infrared
Mbar	Millibar
mg	Milligram
min	Minute
ppm	Parts Per Million
PHEV	Plug-in Hybrid Electric Vehicle
PPAP	Production part approval process
PVDF	Polyvinylidene Fluoride
RF	radiofrequency
ROH	Chemical compound (R) with alcohol functional group (OH)
SEI	Solid Electrolyte Interface
SLP	Single Layer Pouch cell
TGA	Thermal Gravimetric Analysis
TGA-MS	Thermal Gravimetric Analysis with mass spectrometer for chemical analysis of volatile compounds
V	Volt

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1. ABSTRACT/OBJECTIVE

This report includes major findings and outlook from the transformational electrode drying project performance period from January 6, 2012 to August 1, 2012.

Electrode drying before cell assembly is an operational bottleneck in battery manufacturing due to long drying times and batch processing. Water taken up during shipment and other manufacturing steps needs to be removed before final battery assembly. Conventional vacuum ovens are limited in drying speed due to a temperature threshold needed to avoid damaging polymer components in the composite electrode. Roll to roll operation and alternative treatments can increase the water desorption and removal rate without overheating and damaging other components in the composite electrode, thus considerably reducing drying time and energy use. The objective of this project was the development of an electrode drying procedure, and the demonstration of processes with no decrease in battery performance. The benchmark for all drying data was an 80°C vacuum furnace treatment with a residence time of 18 – 22 hours. This report demonstrates an alternative roll to roll drying process with a 500-fold improvement in drying time down to 2 minutes and consumption of only 30% of the energy compared to vacuum furnace treatment.

2. INTRODUCTION

The cathode material examined in this project is A123 System's commercial cathode composition consisting of their proprietary nano-phosphate with a chemical composition of LiFePO_4 and additions of carbon black conductive additive and polyvinylidene fluoride (PVDF) binder. This composite electrode is coated on an aluminum current collector foil.

After deposition and removal of solvents, the electrodes are exposed to moisture which hydrates them to average moisture levels of 5000 ppm of water content. Moisture has to be removed to lower than 500 ppm in order to allow for the integration of the material into a battery cell and allow for proper operation. Moisture can be damaging to battery operation by reacting with the electrolyte and forming hydrofluoric acid (HF) which in turn can travel to the anode and damage the needed passivation layer called the solid electrolyte interface (SEI). Damage to the SEI layer requires reformation of it, which consumes lithium and results in capacity fade and poor cycle life.

More aggressive thermal treatments to increase the moisture removal rates can cause oxidation of the active material or current collector, degradation of the binder, or unacceptable change of the dimensions of the electrode. This project focused on the development of a transformational reduction in time utilized to dry electrodes to the desired water content while not degrading the electrochemical performance.

Three preheat methods for drying and excitation and one final method for dehumidification of electrodes were selected to be studied in this project. Degradation in material has been characterized by fluorine distribution in the samples indicating distribution of PVDF binder, morphological characterization indicating microscopic damage to the electrodes, and study of the iron oxidation state in the cathode active material LiFePO_4 indicating degradation of active electrode material. As shown in the following sections of this report, the material did not show considerable degradation in any of these categories. The project was concluded with electrochemical testing of half- and full coin cells for initial performance and single layer pouch (SLP) cells for cycle life testing.

3. RESULTS AND DISCUSSION

3.1 DEHYDRATION AND REHYDRATION STUDIES

A thermal gravimetric analysis (TGA) has been used to study mass loss and mass gain during thermal activation of specimens. While mass loss can be contributed to residual solvent loss in addition to water loss and is therefore not fully quantitative for the total water removal, the mass gain in the experimental setup can be contributed to only water pickup from the ambient atmosphere. This analysis allows comparison of mass loss and mass gain and the associated time constants which in turn allow for a specimen handling procedure and understanding of rehydration behavior.

A drying study with quantification of water pickup was performed. As described below a successful drying was demonstrated ahead of schedule.

4 cm² strips of cathode material (120.01 mg) that have been previously exposed to ambient air had been dried in the TGA-MS instrument in a flow of dry air (100 cc/min) up to 150°C; the weight loss was 0.245 mg. Switching from dry air to vacuum for 2 hours did not cause more weight loss. Switching back to dry air gave a quasi-constant weight profile during the next 36 hours, with small variations showing the noise level in the instrument. Exposing the dry samples to ambient air (24% relative humidity at 20°C and 995 mbar) over 18 hours caused a weight gain of 0.247 mg, equal to the weight loss on drying. About 50% of the weight gain was recorded in the first 60 minutes of contact in uncontrolled air.

When normalized to the amount of cathode material (excluding the Al foil), the weight loss on drying represents 5177 ppm, and the weight gain on rehydration represents 5219 ppm. An areal density of coating material of 11.83 mg/cm² was assumed in calculation. Figure 1 shows the details of a drying – rehydration experiment. Figure 2 shows the result for rehydration.

Figure 1 Details of drying and rehydration data

Figure 2 Rehydration quantification as a function of time

3.2 PREHEAT CHARACTERIZATION

Several radiant preheat methods are of use in the industry in order to allow for a speedy energy transfer and faster drying operation. The team evaluated three methods, namely infrared heating, microwave heating, and radio frequency heating, in order to allow for data for future decision on production design. This section contains a summary of the tests which have been performed on these preheat methods. The final dehumidification method did not utilize the preheat methods but could potentially be integrated with them.

3.2.1 Infrared heating

Infrared heating is a commonly used preheat method for drying operations. The team has performed initial drying tests followed by dehumidification studies. Section 3.3 contains additional information about Karl Fischer titration as a method to determine moisture content.

Figure 3 shows temperature, downstream moisture, and resulting humidity level. Results demonstrate a large reduction in moisture content but do not reach the needed threshold of 500 ppm or lower.

Figure 3 Infrared treatment conditions, downstream moisture measurement, and resulting water content in double coated samples.

3.2.2 Microwave heating

We installed a microwave demo drying system at A123 Ann Arbor prototyping facility. The drying chamber is illustrated in figure 4. The water sensitivity of the A123 cathode requires that the demonstration and subsequent analysis of the dried electrodes be performed in the low humidity-controlled dry room atmosphere. The equipment vendor agreed to provide a demo unit at no cost. Program funding was used to support on-site engineering support by

the vendor to install the equipment and train A123 operators. Modifications to the A123 dry room were made to provide electrical and HVAC support for the drying system. The drying system was validated on test coupons using a variety of temperature control algorithms. Following validation, a drying Design of Experiments was initiated to screen the effects of ramp rates, temperatures, and drying time. Hermetic sample transfer protocols were developed to maintain samples under controlled atmosphere following removal from drying until water content analysis by Karl Fischer and/or VaporPro methods.

Figure 4 Schematic of curing cavity at A123 Ann Arbor prototyping facility

The evaluation using microscopy and X-ray photo-electron spectroscopy did reveal slight changes of PVDF decomposition and creation of inorganic fluorine compounds indicating that the selected conditions are the upper boundary for future treatments in order to prevent sample degradation.

Both as-received samples were mounted without any other preparation and an areas near the middle of each was chosen for analysis (see figure 5 for optical image). Two different analyses were performed. The first was a “single point” analysis done with the largest x-ray spot available on the K-Alpha XPS instrument (approx. 400 micron diameter, yellow circle on the optical image of figure 5). At this single point, both a large energy range survey spectrum and a set of narrow energy range core level spectra (figure 6) were obtained. They show all elements in its bonding state as expected for carbon black, PVDF, and active cathode materials.

Figure 5 Optical image of characterized sample area

Figure 6 Core spectrum of treated (green) and untreated (red) samples with slight changes in PVDF.

Survey spectra taken on both samples are used to check for unknown elements that may be on the surface. Surface composition results determined from the survey confirm expected composition. Both samples showed the expected elements, C, O, Fe, P, F and V.

Core level spectra for Fe 2p_{3/2}, P 2p, N 1s, and V 2p were acquired. The shape and position of the core level spectra indicate details about chemical bonding for this material. As far as Fe, P, N, and V are concerned, the spectra from the two samples look virtually identical and all have a bonding energy and shape consistent with the materials thought to be present and indicate no significant difference between the two samples. The only differences that were observed between the two samples concerned the C 1s and F 1s spectra (shown in figure 6; note that the spectra were normalized to constant height for comparison). The C 1s spectra

are made up of several components that can be related to (a) PVDF and (b) carbon black, as labeled. The slight decrease in the overall F content for the treated sample is also seen in the –CF₂– portion of the C 1s, and in the slight distortion of the –CH₂– feature. This indicates a slight difference due to heating.

3.2.3 Radiofrequency heating

The scope of this task was focused on heating response of the battery electrode structure due to excitation by radiofrequency (RF). The goal was to determine whether the composite battery electrode can be heated by this method, and to empirically measure the response in order to enable a preliminary ORNL determination as to whether this method shows potential as a viable electrode drying technology.

Experimental Details

Testing was based on the application of RF by two (2) methods. The first method was based on coupling the electric field component of the electromagnetic energy to the coating on the electrode. The second method was based on coupling the magnetic field component of the electromagnetic energy by inducing current flow in the metallic part of the electrode.

For these experiments, samples of carbon coated aluminum electrode material were cut to the size required for mounting in the field.

The second sample, shown in Figure 7, was placed on the inside of a Teflon tube. This sample, measuring 2 inches by 2.5 inches, was curled to conform to the interior shape of the tube. This second approach to sample mounting was done to better align the sample geometry with the magnetic field lines for the coil. Radio frequency power was applied for a fixed period of time. Temperature changes were monitored using infrared thermography.

Results

Figure 8 presents representative data for heating the electrode material using the flat line system. In the test, the surface temperature was measured as a function of time for the electrode.

Figure 7 Heating response

Figures 8, 9 are infrared thermographs of an axial and tubular mounted sample placed in the center of the induction zone.

Figure 8 R Thermograph of Axial Sample

Figure 9 IR Thermograph of Tubular Sample

Conclusions

The task was a feasibility study to determine if electrode material could be successfully heated using RF. The results indicate energy coupling could be achieved using either of the two approaches.

3.3 BASELINE CHARACTERIZATION, UNDERSTANDING OF PROCESS LIMITS FOR FINAL DEHUMIDIFICATION METHOD

Thermal activation and evaporation of water can be effectively used to remove moisture from specimens. In order to allow for the most rapid process, this project first focused on determining the process limits based on detrimental temperature at which samples show unacceptable damage. Then the thermal conditions were reduced to milder conditions until no damage could be confirmed. Electrochemical cycling confirmed that the selected conditions are producing a dry electrode which is operational in a battery.

In order to detect and monitor moisture content to low enough detection limits, Karl Fischer titration has been employed. Karl Fischer titration extracts water from a solid sample by dissolving it in alcohol (ROH). The alcohol (ROH) with the water is mixed with a base (B), SO₂ and I₂. Through the following reaction, the consumption of I₂ can be detected coulombetrically and the amount of water in the solution can be precisely detected.

This method is specific to water which allows a quantitative analysis of moisture content and moisture release.

As shown in figure 10, treatment of a specimen at 210°C for 30 minutes in air resulted in delamination and coating friability increased dramatically with increasing temperature. Oxidation of the substrate may be dominating near 200°C but the coating integrity is compromised above that temperature.

Figure 10 Treated specimens around decomposition temperature

As shown in figure 4, Karl Fischer titration confirms a fast and optimized extraction of water. After water is completely removed, the titration curve should become a horizontal line. However, due to water penetration and other effects, small amounts of water enter the system and continue to be titrated. This long term artifact is called Karl Fischer drift. In order to determine the real water content as a function of time, long term drift as an equilibrated constant slope is characterized and the resulting curve is being subtracted from the signal in order to calculate extracted water as indicated in red.

Figure 11 Water extraction as a function of time

In order to move forward on the optimization, it is important that initial cycling behavior is not negatively impacted. The team continuously fabricated half- and full-cells and monitored initial cycling behavior. Figure 12 shows capacity and initial cycling results for cathode half cells in which the cathode is cycled versus a lithium foil as the counter electrode. The data confirms that milestone 1.4 with a cathode capacity higher than 120mAh/g has been met and a further optimization can be started.

Figure 12 Electrochemical testing and initial cycling of cathode half cells

3.4 OPTIMIZATION OF FINAL DEHUMIDIFICATION

The ultimate goal of this project was to minimize the time of treatment in order to reduce residence time in the drying operation. Thus, the focus rested on a reduction in time or increase of moisture removal rate without reduction of electrochemical performance. Electrochemical performance benchmarked against the conventional drying operation as described above.

A desired timeframe for an optimized procedure has been decided to be 2 minutes in order to allow for an appropriate roll to roll operation with reasonable web length in dehumidification operation. A 2 minute operation with an expected web speed typical for battery manufacturing of 20-60 feet/minute would result in a 40-120 feet operation. Thus, the optimization of drying methods concentrated on reducing the treatment time and evaluating a condition for 2 minute drying time and a resulting water content below 500ppm. Figure 13 is a plot of sample temperatures for a 2 minute operation and resulting water content to determine the minimum drying temperature needed.

Figure 13 Samples with 2 minute treatment time.

3.4 ELECTROCHEMICAL BASE LINE CHARACTERIZATION

Electrochemical performance on dried electrodes is of high importance. For acceptance of the new procedure, initial electrochemical performance and cycle life are considered as two steps in the process. In order to characterize initial electrochemical performance, half-cells in which a cathode is placed versus a lithium foil as working anode are characterized. Figure 14 shows initial cycling performance of treated cathodes in such half cells. All cathodes in the figure have been treated with a medium set temperature and 30 minute treatment time. The data indicated adequate performance in order to move forward with the optimization.

Figure 14 Treated cathodes in half cell.

3.5 ELECTROCHEMICAL BENCHMARKING AND IRON OXIDATION VALIDATION

Electrochemical performance is characterized in capacity fade and power availability. These tests results are results from a round robin testing at ORNL and A123 Systems with one condition being the considered optimized 2 minute operation, one condition being considered a material damaging condition, and the baseline treatment being conventional drying.

- **Group 1:** conventional baseline drying
- **Group 2:** short mid-temperature optimum condition
- **Group 3:** short high-temperature condition

Group 1 was intended as a benchmark to quantify effectiveness of drying. Group 2 is the down selected short time medium temperature condition at which it has been quantified as a minimum of 500-fold time improvement with no degradation and good performance. Group 3 was a higher temperature condition at which it was expected the performance to be reduced due to degradation. Samples have been treated at ORNL under all conditions and tested at ORNL and A123, independently.

Electrochemical experiments were controlled by 16-channel BioLogic potentiostats. All of the cells were subjected to formation cycling per A123 protocol prior to performance testing. Experiments consisted of rate performance testing in which the series of discharge half-cycles with increasing C-rates have been applied to the cells while the charging rate was maintained at 1C. The rate performance tests were followed by capacity fade tests in which the cells had been cycled using constant current followed by constant voltage phases (CCCV) regime between 3.6 and 2.0V. The charge current had been 1C and the discharge current had been 2C. Each charge and discharge had been followed by voltage hold until the current dropped to 0.1C. Cathodes had been tested in both half-cell (versus Li metal anode) and full-cell configurations.

Both datasets confirmed acceptable performance compared to the baseline at mid-temperature range with 500-fold reduction in time, but with considerable performance drop with higher-temperature treatment.

Figures 15 and 16 demonstrate half-cell and full-cell C-rate plots for power performance and cycling plots for cycle life demonstration.

In addition, the team characterized treated and untreated material using Mossbauer spectroscopy and determined electrode porosimetry. Mossbauer spectroscopy had been selected to investigate possible harmful oxidation of iron in the cathode, and porosimetry has been selected to verify pore size distribution and understand potential material flow and PVDF pore clogging due to the electrode treatment. Mossbauer spectroscopy revealed no measureable change in oxidation state of the iron as shown in figure 17.

Figure 15 Rate performance testing

Figure 16 Cycle life testing

Figure 17 Mossbauer results showing no oxidation change in cathode through heat treatment.

3.6 LARGE FORMAT PRODUCTION PROCESS VALIDATION

In the initial work covered by this report, most of the validation data was collected in coin cell format. Coin cells are adequate to get initial capacity and rate data, but are not a reliable test vehicle to validate cycle life. Since residual moisture is known to degrade cycle life, it was critical to validate life in a different cell format. A123 typically uses a sequence of larger format cells to validate cycle life. The first step up from coin cells is in a single layer pouch (SLP) cell. At the initial stage, A123 uses production cathodes with 31.4 x 45.0 mm dimensions. All of the other cell components (anode, separator, and electrolyte) are identical to production cells as shown in the schematic in figure 18. The SLP cells are assembled in a dry room using a set of standard tooling and operating procedures designed to remove operator and environmental variables and produce a highly reproducible test vehicle. For cycle life validation this also entails the use of a test fixture that maintains compression on the cell consistent with the commercial product. SLP validation tests are done with a minimum of three replicate cells, and with an appropriate set of control cells.

Figure 18 Schematic of production pouch cell.

Figure 19 shows the results of the two rounds of SLP validation tests performed by A123. Electrodes have been dried in Oak Ridge with verified low moisture content, vacuum bagged, shipped to Ann Arbor, and assembled by A123 in SLP validation cells.

The first round of validation tests (red) demonstrated a steep capacity fade starting at about 400 cycles. This has been contributed to sample handling and higher moisture content at time of cell assembly due to shipment from Oak Ridge to Ann Arbor. A second round of electrodes has been prepared and double vacuum bagged for proper shipment. These cells (yellow) showed a much better behavior with a capacity drop not occurring until about 1000 cycles. It seems that capacity fading around 1,000 cycles increases compared to production-like baseline (green) and baseline (blue) cells. This behavior is still attributed to the shipment of the electrodes and the time between drying and assembly. The team expects cells which have dried electrodes and assembly at the same facility to behave appropriately for a production like comparison. This aspect will have to be verified in the future.

Figure 19 Cycle results for SLP cells.

4. BENEFITS ASSESSMENT

4.1 PROCESS BENEFIT

The optimized process for drying electrodes has been demonstrated to perform well. The optimized condition with 2 minutes of resident time is an improvement of 500-fold over 18-22 hours of drying operation. The new procedure is able to be performed in a roll to roll operation with an attractive footprint for a furnace operation compatible with the downstream roll to roll operation in battery cell assembly and is a transformation to the prior used batch process which posed a bottleneck.

4.2 ENERGY AND FINANCIAL PROCESS ANALYSIS

Figure 20 shows a process flow diagram with estimated energy needs for individual components. Figure 21 specifies calculated and designed component needs. The calculations result in an estimate for a system with a total of 193 kW power use. All calculations are made for the A123 coating composition and thermophysical properties and an estimated amount of water removal at a line speed of 20 ft/minute and a 2 minute drying operation at medium temperature condition defined earlier.

Figure 20 Flow diagram of new roll to roll process

Unit Description	HP	KW
Dryer		
Electric Heat Source		140
Preheat modules		2
Supply Fan	3	2.238
Exhaust Fan	3	2.238
Dehumidification System		42.75
Unwind	0	0
Rewind	1	0.746
Pull Roll	1	0.746
Control System		2
Total		193

Figure 21 Calculated and designed component needs

Using these figures, it can be estimated that this new process will consume about 926 MWh of electricity per year. The conventional treatment utilizes approximately 164 MWh for heating and 2,740 MWh for vacuum, resulting in an electricity consumption of 2,905 MWh. The new treatment represents a 68% reduction in energy consumption.

We assume maintenance cost to be about \$1000 per month and operational effort to be 25% full time equivalent. One person could operate up to four of these operations in parallel.

The dehumidification system can be integrated with the dry room operation and an additional 42.75kW of power can be saved.

5. COMMERCIALIZATION

The next step in commercializing the process following validation in lab SLP cells would be to implement a pilot scale dryer in the A123 pilot cell assembly operation. The new drying process would be tuned at pilot scale, and then qualified for use at prototype or limited volume production. This would likely be performed at 2-4 cell per minute (cpm) operation. We have discussed 2 cpm unit with a preferred domestic supplier and worked out a preliminary design. The supplier quote was over \$500K, which represents a significant capex commitment to make the next step. A123 has pursued various options to reduce this barrier, including reducing the capabilities of the demonstration unit, evaluating lower cost options, and pursuing next round financial assistance from DOE.

With regard to economizing on the pilot unit capabilities to reduce cost, we identified a key cost driver to be the air handling (dehumidification) unit. We are evaluating the possibility of piggy-backing the air handling with the dry room mechanical system, but this is likely to require additional equipment to manage industrial hygiene concerns or exposing dry room staff to the dryer effluent, as well as to remove the moisture from the effluent.

Pilot scale validation would require longer term cycle life validation in SLP and then scaled up to 63450 ~1Ah prototype stacks and 18650 or 26650 cylindrical cells that A123 uses for initial production validation. The validation would be internal to A123 and could be performed at cell level – i.e. not by customer and not at vehicle level. The internal approval goal would be to show that we get the same or better cycle life for electrodes dried to the same ppm level using the high speed radiant energy process.

Initial risk analysis for scaling up has identified a few concerns. The key point is the risk of transitioning from piece to roll-to-roll operation. We are not certain of the correct sizing of the roll-to-roll dryer and if we need to add time or energy to the drying step the benefits may be reduced through higher capex (larger system) and/or opex (lower throughput). An additional concern is the flexibility of the process with regard to the electrode thickness and the electrode web width. In general, the line is expected to produce a single thickness and width electrode design, but these may vary in future product designs and we would prefer to have flexibility in the production equipment to accommodate evolutions in product design and potentially in producing multiple designs on the same line to minimize cost, down-time, and requalification costs.

The pilot scale optimization results will be used to further tune the cost benefits of the radiant drying process. After this initial validation, A123 would initialize a defined process change management procedure in which new processes or significant process changes are qualified for high volume production. This would be performed in the actual high volume production cell format (e.g. the 20Ah prismatic PHEV cell) and possibly require customer audits, validation and approval, along with definition of standard operating procedure. Approval would consist of ‘re-PPAP’ing’ the drying process, where PPAP refers to *Production part approval process* used in the automotive supply chain to establish customer confidence in component suppliers and their production processes.

As these activities are supported by the A123 Advanced Manufacturing Engineering team

with a pilot drying system operated in the Waltham prototype facility, the process engineering team will be working with the equipment supplier engineering team to begin design and installation of the production equipment. One of the key objectives of this work will be to design a roll-to-roll dryer that operates in coordination with the electrode coating operation. Other objectives will include a materials handling interface to the downstream slitters and stackers/winders, plant floor layout, facilities modification, and operator training.

With the significant time and investment required in validation and new capital equipment, the process change-over is most likely to be coordinated with new production orders and capacity expansion. The time required for extended cycle life validation, customer approval, and production equipment validation would likely be 2-3 years to ramp to implementation in full volume production.

The next capacity expansion is expected to be driven by the emergence of the start-stop battery market. This market is well established in Europe where it is more easily implemented on vehicles with manual transmission. The application is being largely addressed through advanced lead acid battery technology, but with the realization that lithium ion batteries offer potential significant advantages in life and weight and eliminate lead, which may face a ban in EEC markets. Recent advances implementing start-stop technology on automatic transmission vehicles and more aggressive CAFÉ regulations has opened up the US market. A123 offers two unique advantages for start-stop: drop-in voltage parity with lead acid, and the EXT technology that enables meeting SAE cold-crank requirements. Lithium ion technology is still on the pricy side, particularly for the US market where 'off-the-lot' pricing is critical in consumer decision making. Nevertheless, A123 is beginning to see market penetration at the high end, and is expecting significant growth in the market.

To meet this market, A123 has finalized designs to capacitize a new plant and is ready to prove out the production equipment and process upgrades, including the high speed drying operation supported by this program. A123 has recently been acquired, and new ownership will drive the investment and schedule in the capacity expansion. Initial indications at the time of submitting this report are that they are committed to investing in this expansion of the Michigan operations.

6. CONCLUSION

The objective of this project was the development of a new electrode drying procedure and demonstration of the process at no decrease of performance compared to present baseline production performance. Baseline production is a batch drying process with electrodes requiring 80°C vacuum furnace residence of 18 – 22 hours. In this program we evaluated several alternative radiant energy drying processes that were compatible with implementation as a roll to roll drying process. The most promising process was able to reach target residual moisture values in 2 minutes, potentially a 500-fold decrease. A pilot drying instrument based on this process was designed and an initial engineering and economic analysis was performed. Electrodes dried using this process met wet and dry adhesion and dimensional stability requirements. The electrodes were validated in coin cell tests that showed no degradation in capacity, impedance or rate capability. Single layer pouch cells were assembled for cycle life validation. The initial cycle life results at the time of final report submission show a drop in capacity with an onset at 100 – 200 cycles. The root cause of the capacity drop remains to be determined, but it is possibly a consequence of the electrode drying procedure. It may be necessary to use a less aggressive drying schedule, but the radiant drying process is still expected to provide significant benefits in reducing drying time and materials handling (roll-to-roll implementation).