Safety Advancements in Lithium-ion for the Exploration Technology Development Program Battery Program

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The Exploration Technology Development Program that was changed to Exploration Technology Development and Demonstration had contracts awarded through NASA Research Announcements to obtain safety improvements from two companies—Physical Sciences Inc. (PSI) (Andover, Mass.) and Giner, Inc. (Newton, Mass.).

PSI worked on coating lithium-ion metal oxide cathode powders with a lithium cobalt phosphate coating to provide a safer cathode material. The advantages of using the coating included obtaining a coating that was a lithium conductor, achieving greater stability than the metal oxide counterparts, reaching higher energy density of the cathode material, and identifying common processing steps resulting in low-cost manufacturing. In the case of the coated material, the lithium metal phosphate layer remains in the reduced form even at full charge voltages, preventing the oxidation of the electrolyte. Figure 1 shows an illustration of the coating used by PSI.

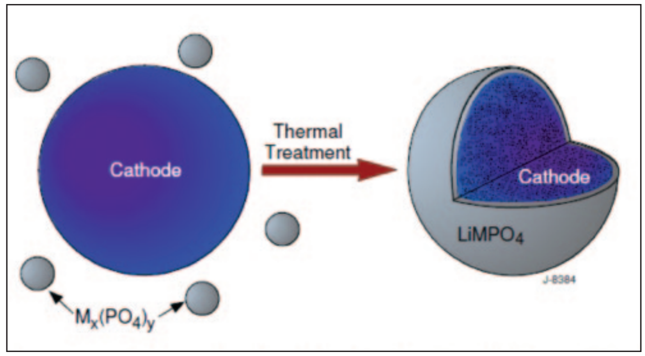

Fig. 1. *Illustration depicting coating of the cathode metal oxide powders with lithium metal phosphate.*

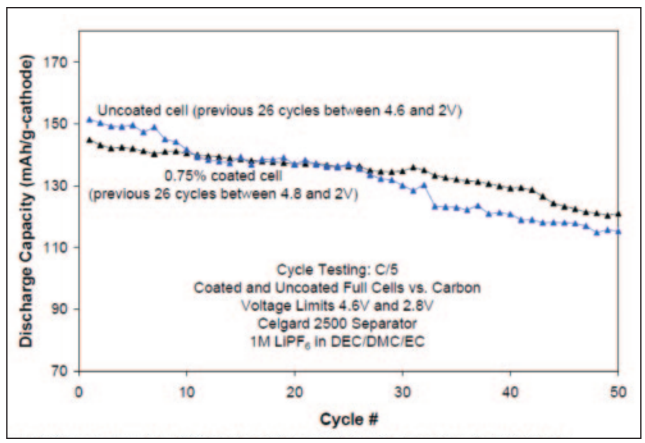

Fig. 2. *Capacity trend for Physical Sciences Inc. coin cells with and without the phosphate-coated cathodes.*

In Year 1, PSI coated commercially available lithium cobalt oxide with lithium cobalt phosphate, showing a suppression of the exotherm observed due to the heating of the delithiated material, using Differential Scanning Calorimetry studies. The electrochemical performance was demonstrated to be equivalent at C/10 rates at both room temperature and 0°C (32°F). Personnel observed greater than 89% capacity retention after 200 cycles, with the coated cathodes and overcharge testing in pouch cell configurations showing that the heat generation under this abuse condition was reduced. The coating was also performed on a Jet Propulsion Laboratory synthesized cathode and shown to shift the peak exotherm to higher temperatures although the total heat generated remained unchanged.

In Year 2, the application and scale-up of the coating developed in Year 1 was carried out with a mixed metal oxide cathode (TODA NMC-9100) supplied by SAFT America, Inc. (Cockeysville, Md.), per NASA Johnson Space Center (JSC) contract. Tasks included cycle life and safety testing of the coated material in coin cell and pouch cell configurations. In Year 2, the coating procedures were also optimized and testing carried out to show that the exotherms observed on heating the delithiated cathode material were reduced, the change in discharge capacity over 50 cycles at C/5 rate was less than 1 % (figure 2), and there was no reduction in discharge capacity in 1-Ampere-Hour (1Ah) pouch cells. The final optimized coating consisted of 0.75% phosphate coating of equal ratio of cobalt and phosphate.

Ten 1Ah pouch cells were delivered to JSC, and cycle life testing was carried out on these cells at the Energy Systems Test Area at JSC. The rate capability tests indicated that 77% of capacity retention was obtained after 10 cycles at C/5 discharge rate followed by 10 cycles at C/2 discharge rate.

NASA Research Announcements, with Giner, Inc., included the demonstration of a composite thermal

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switch (CTS™) material incorporated into the substrates in lithium-ion cells that would cause current flow to shut down when the cells experienced a temperature rise of over 80°C (176°F). In Year 1, feasibility was established. In Year 2, optimization of the mixing, coating, and curing conditions was carried out with delivery of coupons as well as coin cells that incorporated the CTS™. Giner, Inc. worked on optimizing the composition as well as the process for applying the CTS™ film on the cell electrode substrates. A spray method was adopted to obtain a more uniform pre-coat as well as coating of the CTS™. An orbital mixing and direct gravity feed method was used to reduce clogging of the nickel/Teflon® ink that was used to carry out the coating. The CTS™ was a mixture of nickel (Ni) nano-powders in a Teflon® solution.

Coupon testing of the CTS™ showed that with 8.4% Ni powders in 200 nanometer (nm) polytetrafluoroethylene (Teflon®) and curing at 146°C (295°F) with 500 pounds per square inch pressure used for calendaring the samples for 20 minutes, good switching characteristics were observed (figure 3). Some issues were encountered with this NASA Research Announcements contract as the source of the Ni powders seemed to be unreliable and had to be changed a few times through the course of the 2-year work period.

The authors would like to acknowledge the principal investigators—Dr. Chris Lang at Physical Sciences Inc. and Dr. Bob McDonald at Giner, Inc.—for their dedication and commitment to the contracts. The authors would like to acknowledge Jon Read for help with coordinating the PSI and Giner, Inc. sample tests carried out at JSC. They would also like to acknowledge Laura Baldwin, Tony Parish, Randall Parish, and David Dao for their efforts in getting the samples tested at JSC.

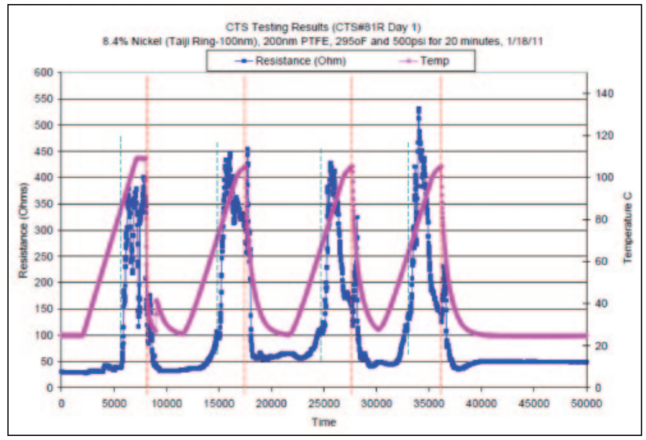

Fig. 3. *CTS™ Coupon showing successive switching behavior with increased temperatures.*