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POS-13 Failure-mode history-dependence in single crystal NMC532 / graphite Li ion cells

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In a real-world situation, a battery is not cycled continuously until death nor stored endlessly at top of charge. Test conditions should mimic real-world situations to better understand different failure mechanisms occurring within cells of the same build and electrolyte. Three complimentary tests are proposed to probe cycle-dependent and time-dependent aging under a spectrum of voltage and temperature stresses.

First, single crystal LiNi0.5Mn0.3Co0.2O2 (NMC)/graphite cells were evaluated under continuous cycling conditions. Cells were charged and discharged continuously (3 hour charge and 3 hour discharge) between 3.0 and 4.2 or 4.3V at 20, 40, or 55oC. Every 50 cycles there was a slow (20 hour charge and 20 hour discharge) cycle to monitor capacity loss. The slow cycle is assumed to be unaffected by decrease in cell rate capability. The capacity loss of the slow cycles was well described by an expression following the square root of time, and that this expression followed Arhennius'law to describe the acceleration of failure due to increased temperature.

Next, cells were evaluated under storage conditions. Cells were stored at "shipping voltage", 4.0, 4.1, 4.2, and 4.3V at 20, 40, and 55oC with regular (two week diminishing to five month frequency) reference performance tests (RPTs). A RPT includes 3 hour and 20 hour cycles (as above) from 3.0-4.1V at 20oC. Standardized conditions allowed absolute capacity loss and impedance growth to be compared directly across temperatures and voltages. Similar to cycling, C/20 capacity loss is proportional to the square root of time. Increased temperature has a stronger detrimental effect on cells stored at high potential than on cycled cells.

Finally, cells were evaluated using a hybrid cycle-store protocol. Cells cycling with 3 hour charge and discharges were allowed to rest open circuit at top of charge for 0, 12, 84, or 180h. Cells were tested to 4.1, 4.2, and 4.3V at 40oC. Capacity retention and impedance growth is worst for cells with the 12h storage condition. This observation can be explained based on the results of the previous two experiments as will be demonstrated.

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