Naypyidaw nickel-cobalt-aluminum batteries nca

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Calendar aging comprises all aging processes that lead to a degradation of a battery cell independent of charge-discharge cycling. It is an important factor in many applications of lithium-ion batteries where the operation periods are substantially shorter than the idle intervals, such as in electric vehicles.1

There are many studies on calendar aging of lithium-ion batteries which present the capacity fade of the cells over time but do not provide explicit investigations on anodic or cathodic side reactions causing the capacity fade.9-17 Furthermore, calendar aging is mostly examined only for a few SoCs: Refs. 11-17 examine three SoCs or fewer. By contrast, this paper presents investigations on calendar aging with a large number of SoCs examined to obtain a comprehensive understanding of the dependency of the capacity fade on SoC. Moreover, side reactions are analyzed.

In this paper, two experimental studies on calendar aging of nickel cobalt aluminum oxide (NCA) lithium-ion batteries are presented and evaluated. Differential voltage analysis (DVA) and coulometry are employed to gain a deeper understanding of the degradation mechanisms and side reactions leading to calendar aging. These two methods are introduced in the following sections and allow to identify predominant aging mechanisms without opening the cells to insert reference electrodes or the need for post-mortem analyses.

DVA is an advanced technique for electrical characterization of battery cells. From a constant current charging or discharging sequence, the derivative dV/dQ is computed, which represents a linear superposition of the derivatives of the anode and cathode potential.18

Figure 1. Reconstruction of the 18650 full-cell by a superposition of anode and cathode half-cell curves, demonstrating the contributions of the graphite anode and the NCA cathode to (a) the full-cell voltage and (b) the differential voltage spectrum.

Figure 2. Assignment of slopes and peaks to anode (A) and cathode (C). The characteristic capacities Q1, Q2, and Q3 allow to assign calendar aging contributions to anode degradation, cathode degradation, and changes in the electrode balancing.

In contrast to the conventional low-current cycling approach, we perform coulometry evaluations with the data from our calendar aging studies, in which the cells are not cycled continuously but are stored in open circuit condition. We only perform occasional checkups at the battery test systems to determine the actual capacities of the cells and bring them back to their respective storage SoCs before they are disconnected from the test system again and returned to the storage compartments.

Figure 3. Exemplary representation of the coulomb tracking method: (a) Repetitive test sequence of checkup procedure, bringing the cell to storage SoC, and storage period in open circuit condition. (b) Charge balances of the individual measurements. (c) Continuous charge balance after post-processing for coulomb tracking, where the last ampere-hour value of each test dataset is used as offset for the subsequent measurement dataset. The dashed lines illustrate the slippage of specific charging and discharging endpoints.

In principle, coulometry can detect such side reactions that alter the degree of lithiation of one or both of the electrodes. For lithium-ion batteries, these side reactions can be categorized in the three cases which are illustrated schematically in Figure 4: Anodic side reactions, cathodic side reactions, and coupled side reactions, which represent a combination of the two previous cases.

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