

LFP battery aging behavior: diagnosis of cell materials for second life applications

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At the end of the first use of batteries in industrial electric vehicles (EV), the state of health (SoH) is expected to be around 80-70%. Therefore, autonomy becomes insufficient for the original application. The management of recycling is the responsibility of the manufacturer, the cost of which is substantial for lithium iron and in particular for lithium iron phosphate (LFP) batteries. Second life applications for lithium-ion batteries are an opportunity for the industry to postpone recycling costs, improve lithium-ion batteries' economic value and reduce environmental impact.

This work presents a diagnostic method to detect electrode loss of active material in industrial cells. Loss of lithium inventory is the main aging cause in first life according to available literature. Electrodes aging may influence cell aging such as loss of active materials in the negative electrode. The predictability of those different aging processes is required to set up a sorting process for lithium-ion batteries in order to guarantee their use in second life.

The square root dependency between SoH and cycle number is commonly used to describe cell aging. This description comes from aging studies in first life use. However, this study shows inconsistencies in long-term aging, i.e. over 80% of SoH. Change of aging behavior may appear in long-term aging experiments, resulting in acceleration of capacity fade. In our aging study, a correlation appears between the acceleration of capacity fade and changes in negative electrode characteristics. Changes in electrode characteristics are detected using ICA and DVA analysis on low current charge to measure remaining electrode capacity and SoH.

These tests are being carried with two cell testers on twenty 18650 1.1Ah cells. Experiments are conducted under accelerated aging at 50°C. Discharge profile is calculated from the Worldwide harmonized Light vehicles Test Procedures (WLTP) standard. The cycle is used to approximate a typical operation of an electric vehicle during the aging study, with a peak C-rate of 2.5C and regenerative mode. The WLTP average discharge C-rate is C/3. Charge depends on the scenario: CC or CCCV charge with C-rate of C/3 or 2C, and cut-off voltage of 2,65V or 2,55V. For each cell, a characterization procedure is carried out on fresh cells at 25°C and 50°C. Then, the characterization procedure is repeated every 100 aging cycles to follow parameter evolution at 50°C. The characterization process consists of two tests: a C/3 CCCV charge and discharge from 0 to 100% State of Charge (SoC), and a C/25 charge and discharge for pseudo-open circuit voltage measurement. The first test defines the battery's SoH, and the second makes possible the estimation of negative electrodes SoH.

This work aims to consider electrode aging to enhance battery-aging law. In a future study, this diagnosis of cell and electrode capacity will be used in prognosis of the remaining useful life, which will decide potential reuse in a second life application.