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Degradation study for 18650 NMC batteries at low temperature

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ABSTRACT

This research focuses on the identification and quantification of lithium-ion battery degradation indicators at low temperatures. We studied the cycling aging of 18,650 commercial NMC lithium-ion batteries at 10 °C. For this purpose, we carried out life cycle tests and performed Galvanostatic Intermittent Titration Technique (GITT) tests in the voltage range for the charge and discharge processes for different States of Health (SoH). The diffusion time constant and the ohmic overpotential were determined from GITT for different SoH. As the batteries degrade both parameters increase. A degradation mechanism associated with faradaic effects (increase in ohmic drop overpotential) and a thermodynamic effect associated with changes in the active material (diffusional time constant) is observed. Furthermore, we performed Electrochemical Voltage Spectroscopy studies through Incremental Capacity (IC) curves. IC curves peaks and valleys are associated with battery phase transformations due to aging phenomena. Each peak has a unique peak height, area, and position associated with a degradation mode. This research focuses on the IC curves derived from the discharge capacities at 3A and OCP (Open Circuit Potential) to study the thermodynamic and faradaic effects separately. The peak at 3.6 V and 3.4 V for the 3A and OCP studies, respectively, is the main feature for the detection of the degradation mechanism. The valley in the OCP curves intensifies with the decrease in SoH and is shifted to lower potentials, an effect that is not observed in the 3A curves. So, we could associate this with thermodynamic effects, Loss of Lithium Inventory (LLI) and Loss of Active Material (LAM) of both the positive electrode and the negative electrode.

1. Introduction

Lithium-ion batteries currently represent an excellent alternative to meet the growing demand for energy storage and the electrification of the transport sector. However, despite the great energy efficiency, high power and specific energy that these batteries provide, the requirements that they must meet are increasingly exigent every day, being crucial the increment of the life expectancy, the reduction in the intensity of use of certain raw materials and the safety improvements of these devices [1]. Also, the improvement of the energy density of these batteries is still being sought in order to achieve higher performance through the enhancement of materials [2].

During the lifetime of a battery its performance suffer the consequences of diverse degradation modes, being the processes by which these devices are degraded truly complex. This degradation process involves multiple mechanisms dependent on different factors [3,4].

Aging mechanisms can be grouped into three different degradation modes (DM): loss of conductivity (CL), which is associated with binder decomposition or current collector corrosion; loss of active material (LAM), associated with the change in structure that the active materials may undergo or the decomposition of the electrolyte; and finally lithium inventory loss (LLI), related to the amount of lithium ions that are available to be cycled [5].

Several parameters play a crucial role in the degradation process: depths of discharge (DoD), states of charge, applied currents, temperatures, calendar aging conditions, and pulses. Besides, those parameters cannot be controlled in real-life practice nor replicated in experimental settings in the laboratory [6].

As the temperature is referred, lithium-ion battery's electrochemical performance decreases drastically at low temperatures. This effect is sharply depicted especially under charging because the lithium ions are liable to deposit as lithium metal instead of intercalating into the solid

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