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Degradation study for 18650 NMC batteries at low temperature

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INTRODUCTION

Lithium-ion batteries demand is increasing considerably. For the year 2030, it is expected that the global demand for these batteries will multiply by 15 compared to the manufacturing figures today. Due to prolonged use, the capacity and power capability of Li-ion batteries decrease because to gradual degradation. Battery control and management are crucial to ensure safe use and maintain the best possible performance. For this reason, it is important the study of degradation mechanisms to predict remaining lifespan. Ageing mechanism of Li-ion batteries are a complex multi-causal process strongly affected by temperature. These could be grouped into three degradation modes: Loss of Conductivity (LC), Loss of Active Material (LAM) and Loss of Lithium Inventory (LLI).

METHODS

We studied the cycling ageing of 18650 commercial NMC lithium-ion batteries at 10°C. We carried out life cycle tests and performed galvanostatic Intermittent Titration Technique (GITT) tests in the voltage range for charge and discharge process for different state of health (SoH) (Fig.1). In GITT experiments, a short current pulse of current 1 A for charge and 3A for discharge was applied for a transient time of 13 min and 4 min, respectively; followed by a relaxation time of 30 min. Tests were performed on the Gamry Interface 5000E™ potentiostat/galvanostat. Diffusion time constant and the ohmic overpotential were determined from GITT for different SoH.We also performed Electrochemical Voltage Spectroscopy studies through incremental capacity (IC) curves. IC curves peaks and valley are associated with batteries phase transformations due to ageing phenomena and 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 to study the thermodynamic and faradaic effects separately (Fig. 2).

RESULTS
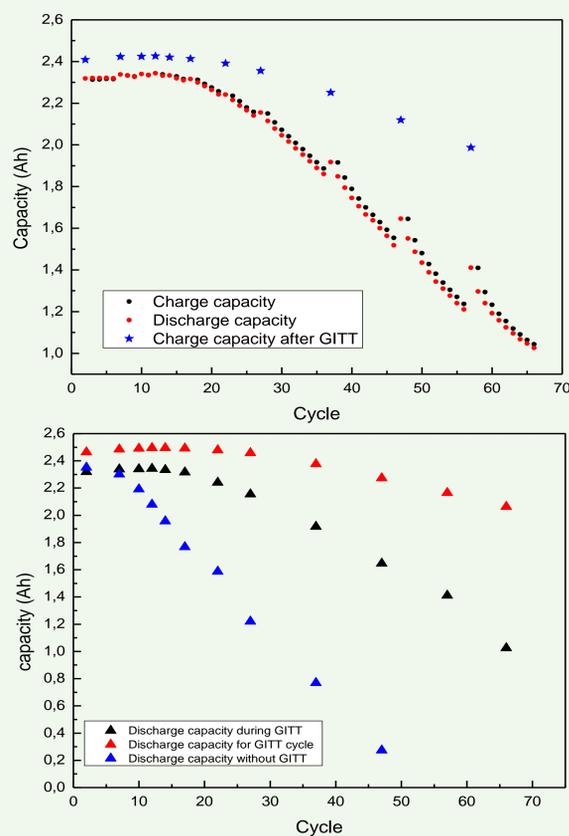
Figure 1. a-Charge and discharge capacity before and after GITT at 1A and 3A charge and discharge current, respectively. b-discharge capacity comparison for different cycle at different condition
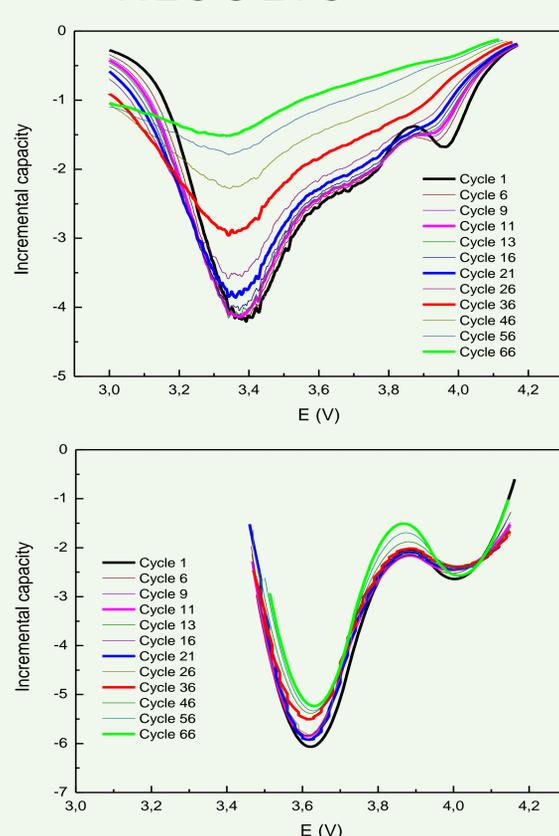
Figure 2. Incremental capacity (IC) curves for different cycles at (a) 3A and (b) OCP
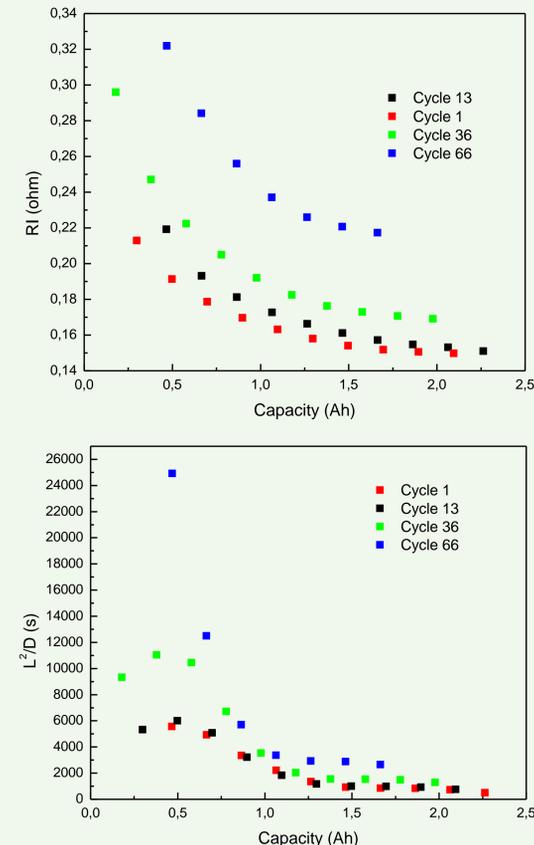
Figure 3. IR and diffusion time constant evolution

CONCLUSIONS

✓ For cycle 1, 13 and 66 the diffusion time constant was 2.50E+03 s, 3.44E+03s and 2.00E+04s; while the IR was 0.166V, 0.163V and 0.285V for the same SoHs. (see Figure 3)

✓ A degradation mechanism associated with kinetic effects (increase in ohmic drop overpotential) and a thermodynamic effect associated with changes in the active material (diffusional time constant) are observed.

✓ 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 height of this peak decreases over cycle number, and it is observed a shift of IC peak position towards lower voltages for the first 26 cycles. This behavior changes from cycle 36, where the peak shifts to higher potentials, probably due to a change in the dominant 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, LLI and LAM of both the positive electrode and the negative electrode.

ACKNOWLEDGMENTS