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Cycling ageing analysis in 18650 batteries at low temperature

Díaz V. [1]**, López-Vázquez C.** [2]**, Teliz E.** [1,3]

[1]Grupo Interdisciplinario Ingeniería Electroquímica, Instituto de Ingeniería Química, Facultad de Ingeniería, Universidad de la República (UdelaR), J. Herrera y Reissig 565, CP 11300, Montevideo, Uruguay.
[2]Laboratorio LatinGEO IGM+ORT, Facultad de Ingeniería, Universidad ORT, Cuareim 1451, C.P 11100, Montevideo,Uruguay
[3]Laboratorio de Electroquímica Fundamental, Grupo Interdisciplinario Ingeniería Electroquímica, Instituto de Química Biológica, Facultad de Ciencias (UdelaR), Universidad de la República, Iguá 4225, CP 11400, Montevideo, Uruguay.
eteliz@fing.edu.uy

Decarbonization efforts are motivated due to the need to reduce greenhouse gas (GHG) emissions and to anticipate the depletion of fossil fuels. Transport sector is one of the largest GHG producers where it is most difficult to reduce GHG emissions. Lithium-ion batteries currently represent an excellent alternative to meet the growing demand for energy storage and the electrification of the transport sector. However, there is still a considerable amount of research on degradation mechanisms to be performed to predict remaining lifespan. Ageing mechanism of Li-ion batteries are a complex multi-causal process strongly affected by temperature. Ageing mechanisms could be grouped into three degradation modes: Loss of Conductivity (LC), Loss of Active Material (LAM) and Loss of Lithium Inventory (LLI). In this work, we studied the cycling ageing of 18650 commercial NMC lithium-ion batteries at 10°C. For this purpose, we carried out life cycle tests at different charge and discharge c-rates (Fig.1). We also performed galvanostatic Intermittent Titration Technique (GITT) (Fig. 2) tests in the voltage range for charge and discharge process for different state of health (SoH). In order to perform 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, which is required for achieving electrochemical equilibrium for the system. Tests were performed on the Gamry Interface 5000E™ potentiostat/galvanostat. Furthermore, we performed Electrochemical Voltage Spectroscopy studies through incremental capacity (IC) curves. IC curves peaks 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 IC curves derived from discharge capacities. Deconvolution was carried out from these curves from Gaussian adjustments, determining the area, position, and height of resulted peaks. The height of the IC peaks decreases over cycle number, and it is observed a shift of IC peak position towards lower voltages. Peak at the lowest potential position results as an interesting health indicator for degradation evolution. Thermodynamics and faradaic effects were identified (Fig. 3). As a conclusion, LLI was identified as a critical degradation mode in the first cycles while LAM effects were depicted during last cycles.

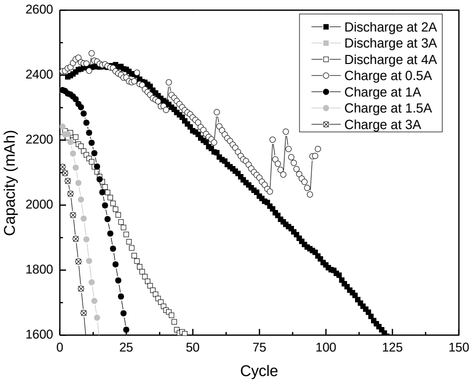

Fig. 1.- Life cycle tests at different charge and discharge c-rates

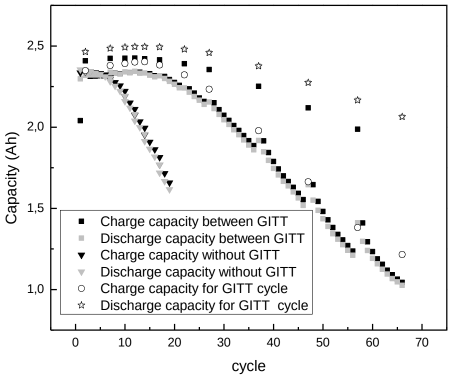

Fig. 2.- Charge and discharge capacity before and after GITT at 1A and 3A charge and discharge current, respectively

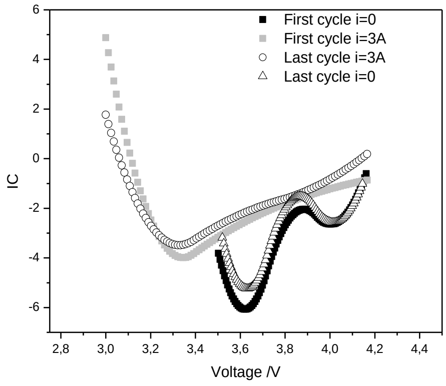

Fig. 3.- Incremental capacity (IC) curves