Minimum AC impedance determination in Li-ion batteries by experimental measurements

O. Bruj and V. Surducan

National Institute for Research and Development of Isotopic and Molecular Technologies, 67-103 Donat, 400293 Cluj-Napoca, Romania

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Introduction

Significant interest has been showed to Lithium-ion rechargeable battery (accumulator) investigation in the last years. Different battery charging methods have been studied in order to improve the capacity and life cycle of the Li-Ion batteries, [1]. The optimal frequency of a battery obtained at the minimum impedance represents the starting point in a discharging pulsed technique. Different battery charging methods have been studied in order to improve the capacity and life cycle of the Li-Ion batteries. The pulsed current charging-discharging techniques have shown that the capacity fall of the battery can be enhanced [2]. Healthy Li-Ion accumulators present low AC impedance or DC internal resistance. These two parameters are increasing during charging-discharging cycles until the accumulator becomes unusable.

Materials and methods

In order to determine the minimum ac impedance, electrochemical impedance spectroscopy (EIS) measurements have to be set. EIS is a complex technique used to characterize electrochemical processes occurring in a battery by perturbing the cell with a sinusoidal signal of small amplitude. Three types of new 3.6V Li-Ion 18650 accumulators with different rated capacities (Sony 2600mAh, Samsung 3000mAh and Sanyo 3450mAh) have been used.

The measurements were set on a Biologic VSP potentiostat device from Biologic, as shown in **Figure1**.

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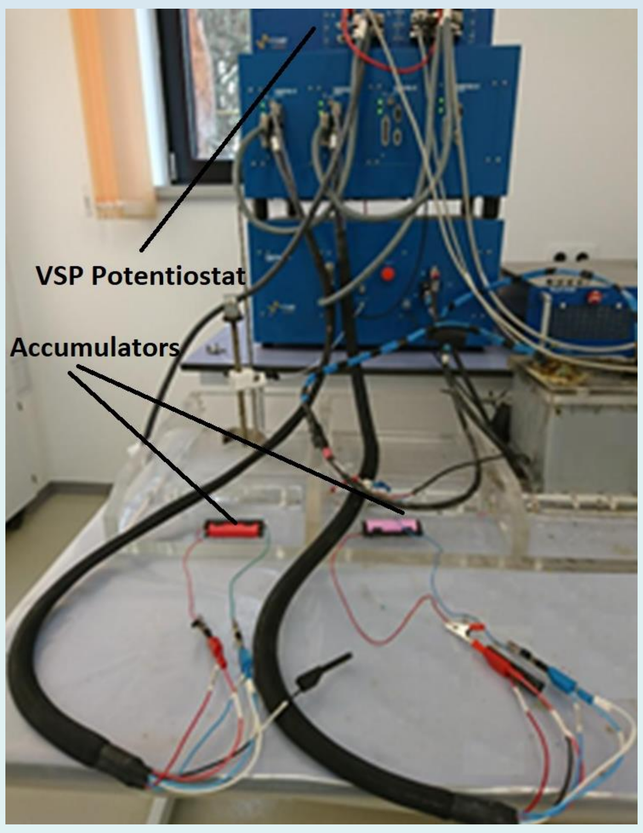

Figure 1. Experimental set-up

The accumulators were charged up to 2000mAh and then AC impedance in 1Hz-10KHz range has been measured using galvanostatic electrochemical impedance spectroscopy (GEIS) technique from EC-Lab software.

Results and discussions

A comparative plot, presented in **Figure 2,** has been highlighting that the optimum frequency of 3 different types of 18650 Li-Ion accumulators, corresponding to the minimum AC impedance (0.08-0.14) Ω, lies in the range (1.3-1.5)kHz. As the cycle number increased, the AC impedance has started to grow.

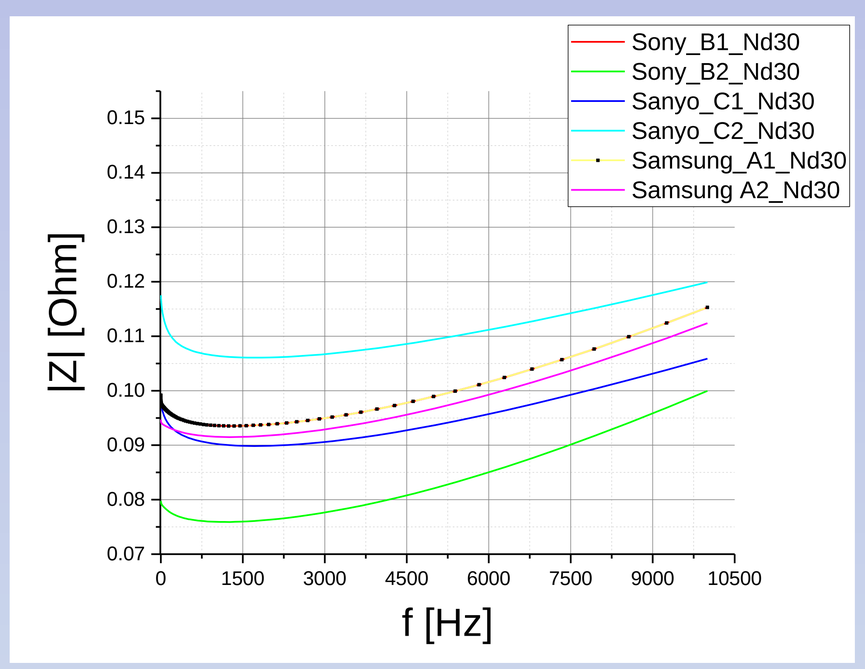

Figure 2. AC impedance variation

A Samsung accumulator has been subjected to an aging process. Close to a 1000 charging/discharging cycles were needed for the battery to die off. As seen in **Figure 3** the impedance is growing as the battery is getting old.

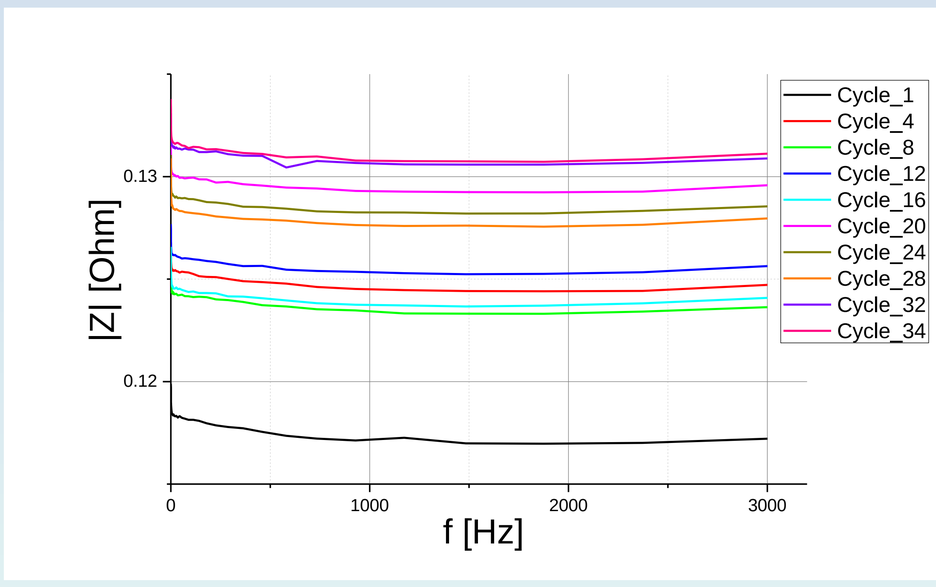

Figure 3. AC impedance of a Li-Ion Samsung accumulator

Conclusions

The minimum frequency for Li-Ion accumulators lies between 500Hz up to 1500Hz. As the AC impedance has increased with cycle number, the minimum frequency has remained in the same range. An improved voltage discharging curve has been obtained in switching mode discharge, compared with continuous discharge. This work is in progress. This result indicates a method to supply sensitive electronic devices for longer accumulator usage.

References : [1] L.-R. Chen et all, “Improvement of Li-ion Battery Discharging Performance by Pulse and Sinusoidal Current Strategies, *IEEE Transactions on industrial electronics*, 60, no.12, (2013).

[2] Lv. H. Huang, X. & Liu, Y. “Analysis on pulse charging–discharging strategies for improving capacity retention rates of lithium-ion batteries”, *Ionics* **26,** 1749–1770 (2020).

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