Analysis of the Cyclability of Lithium-polymer Batteries

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INTRODUCTION: Lithium-ion batteries (LIBs) are key in the modern society. A lithium-ion polymer battery (LiPo) provide higher specific energy than other LIB types. LiPo cells have a flexible foil-type case; so they are relatively unconstrained. However, a LiPo expands at high levels of state of charge and average only 150–250 cycles. Cyclability analysis on commercial LiPo cells have been carried out using a Ivium VertexOne.

Figure 1. LiPo cell and Ivium VertexOne

Theoretical stored energy: $\xi = \int_0^t E_{\text{cell}} dt \cdot I$

State of Charge : $SoC(t) = \dfrac{\text{Energy storaged}}{\text{Present capacity}}$

State of Health : $SoH = \dfrac{\text{Present capacity}}{\text{Initial capacity}}$

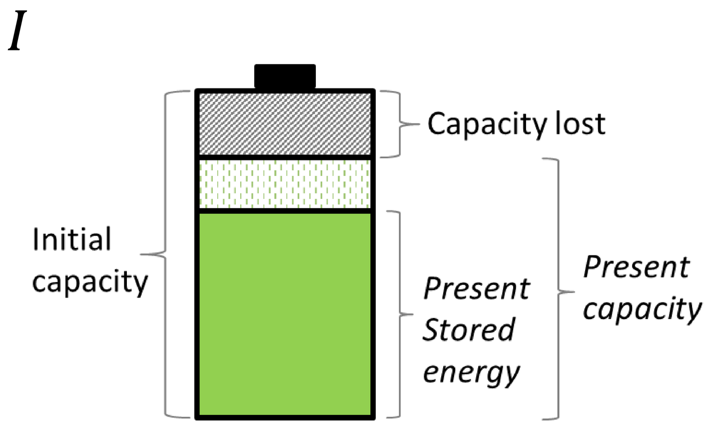


Figure 2. Battery capacity

COMPUTATIONAL METHODS: The Newman's model for pseudo-2D ionic transport in Lithium-ion batteries was used:

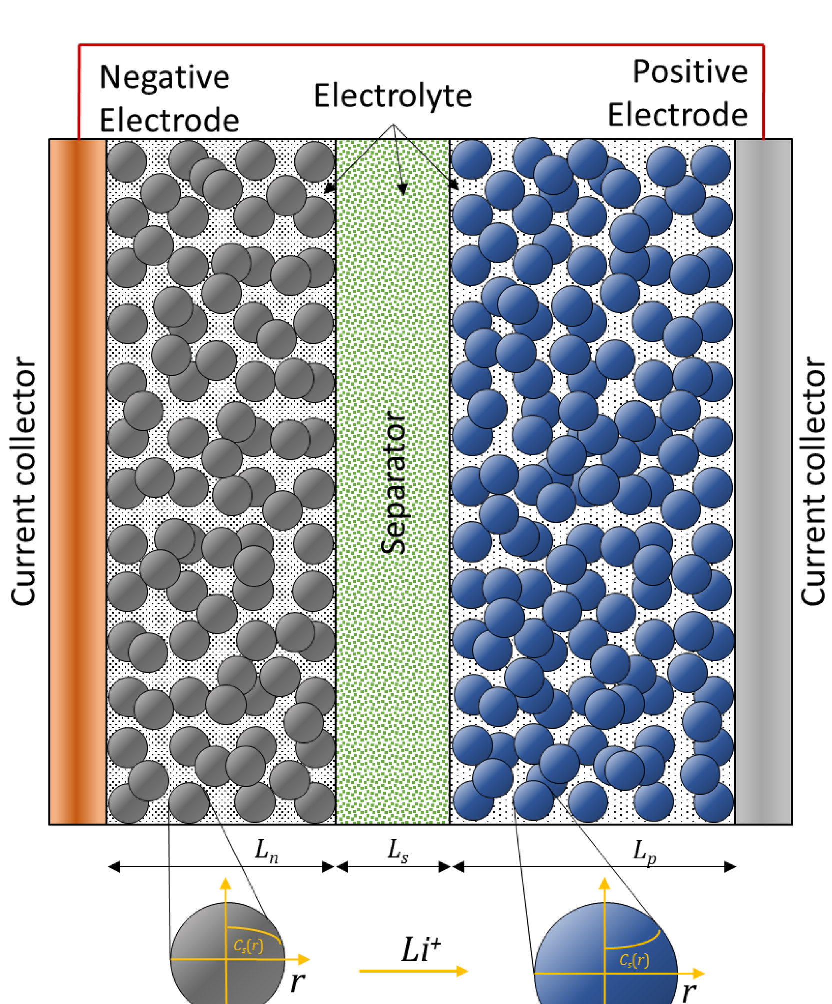
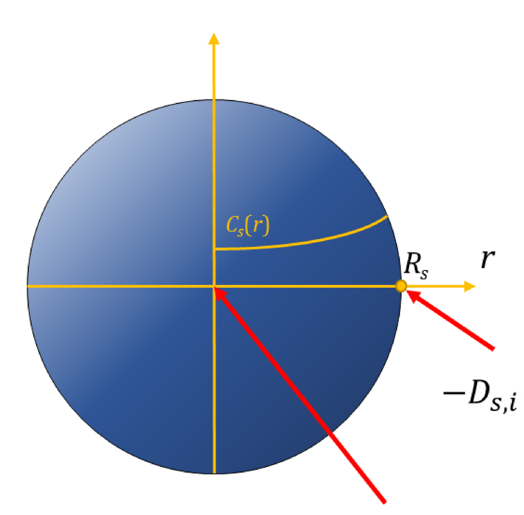


Figure 3. Schemed of a battery



$$-D_{s,i}\frac{\partial c_{1,i}}{\partial r}\bigg|_{r=R_{s,i}} = J_i$$

$$-D_{s,i}\frac{\partial c_{1,i}}{\partial r}\bigg|_{r=0} = 0$$

<u>**Mass balance in the solid particles**</u>

$$\frac{\partial c_{1,i}}{\partial t} = D_{s,i}\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial c_{1,i}}{\partial r}\right)$$

<u>**Charge balance in the solid phase**</u>

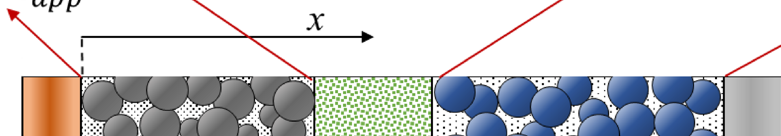
$$-\sigma_{\text{eff},i}\frac{\partial \phi_{1,i}}{\partial x^2} = a_i F J_i$$

<u>**Mass and charge balances in the electrolyte**</u>

$$\varepsilon_i\frac{\partial c_{2,i}}{\partial t} = \frac{\partial}{\partial x}\left(D_{\text{eff},i}\frac{\partial c_{2,i}}{\partial x}\right) + (1-t_+^0)a_i J_i$$

$$-\frac{\partial}{\partial x}\left(\kappa_{\text{eff},i}\frac{\partial \phi_2}{\partial x}\right) + \frac{2RT(1-t_+^0)}{F}\frac{\partial}{\partial x}\left(k_{\text{eff},i}\frac{\partial (\ln c_i)}{\partial x}\right) = a_i F J_i$$

<u>**Boundary conditions**</u>



$$-\sigma_{\text{eff},p}\frac{\partial \phi_{1,p}}{\partial x^2}\bigg|_{x=L_p} = 0$$

$$-\sigma_{\text{eff},n}\frac{\partial \phi_{1,n}}{\partial x^2}\bigg|_{x=L_p+L_s} = 0$$

$$-\sigma_{\text{eff},p}\frac{\partial \phi_{1,p}}{\partial x^2}\bigg|_{x=0} = I_{app}$$

$$-\sigma_{\text{eff},n}\frac{\partial \phi_{1,n}}{\partial x^2}\bigg|_{x=L_p+L_s+L_N} = 0$$

$$-D_{\text{eff},p}\frac{\partial c_{2,p}}{\partial x}\bigg|_{x=0} = 0$$

$$-D_{\text{eff},n}\frac{\partial c_{2,n}}{\partial x}\bigg|_{x=L_p+L_s+L_n} = 0$$

$$c_{2,p}\big|_{x=L_p^-} = c_{2,s}\big|_{x=L_p^+}$$

$$c_{2,s}\big|_{x=(L_p+L_s)^-} = c_{2,n}\big|_{x=(L_p+L_s)^+}$$

$$-D_{\text{eff},n}\frac{\partial c_{2,p}}{\partial x}\bigg|_{x=L_p^-} = -D_{\text{eff},n}\frac{\partial c_{2,s}}{\partial x}\bigg|_{x=L_p^+}$$

$$-D_{\text{eff},n}\frac{\partial c_{2,s}}{\partial x}\bigg|_{x=(L_p+L_s)^-} = -D_{\text{eff},n}\frac{\partial c_{2,n}}{\partial x}\bigg|_{x=(L_p+L_s)^+}$$

RESULTS: Experimental and simulation results are presented and compared for the different studies:

<u>Charge/discharge rate</u> (C-rate):

1, 0.8, 0.75, 0.6, 0.5, 0.4, 0.25, 0.1, 0.05.

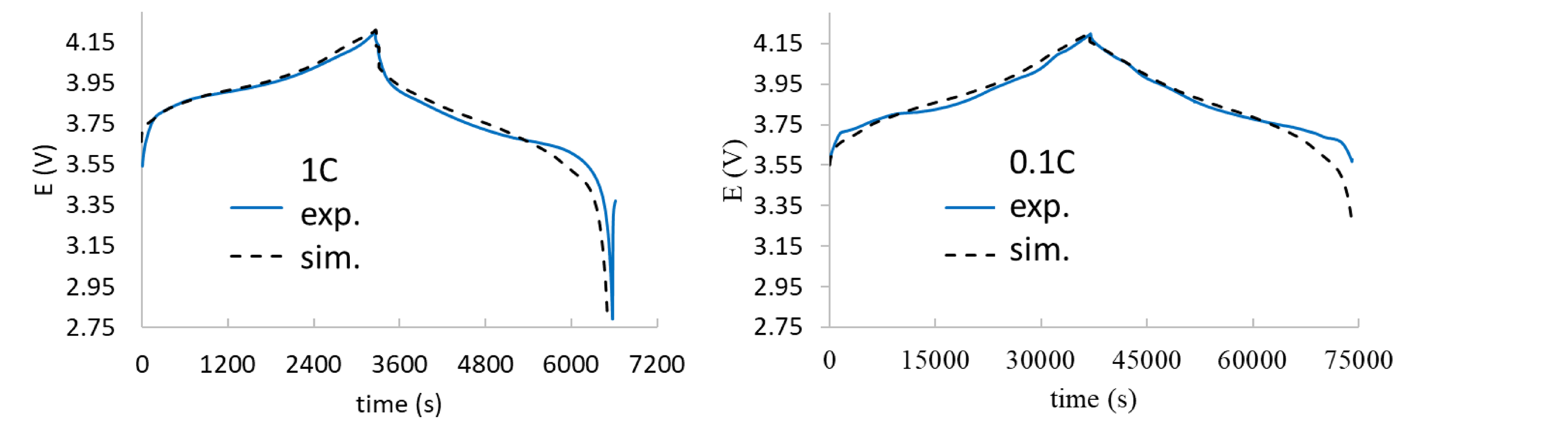


Figure 4. Results for 1C and 0.1C charge/discharge rate.

<u>Cyclability:</u>

Stored energy with the number of cycles at 0.67 C, to evaluate the *SoH*. The batteries show a decrease of the total capacity due to deterioration of the essential components with the number of cycles.

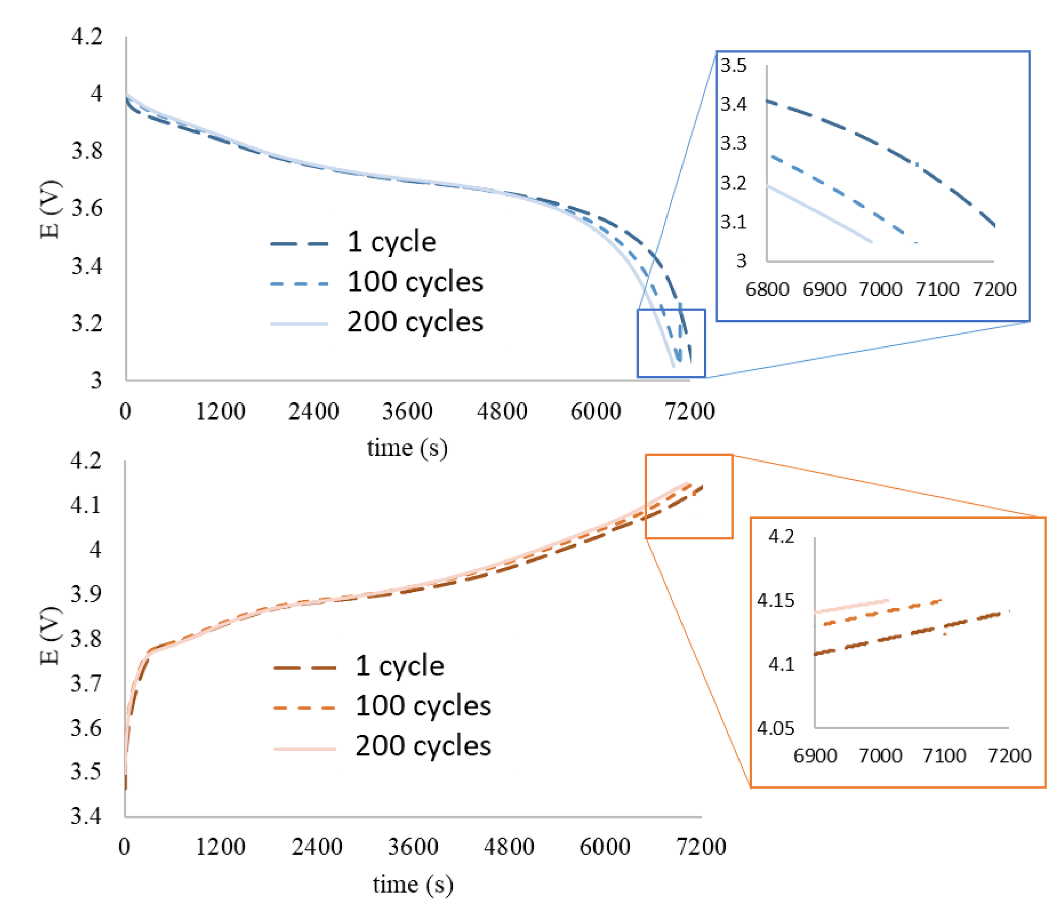


Figure 5. Capacity fade of the tested batteries with the number of cycles

<u>Temperature dependence:</u>

Capacity changes with charge temperature. It was observed that below ≈ 5 ºC the apparent capacity of the batteries decreased (measured as the time to get nominal potential). Simulations are obtained by estimation of the capacity at each temperature. This capacity lost was not permanent, recuperating the capacity with increasing temperatures.

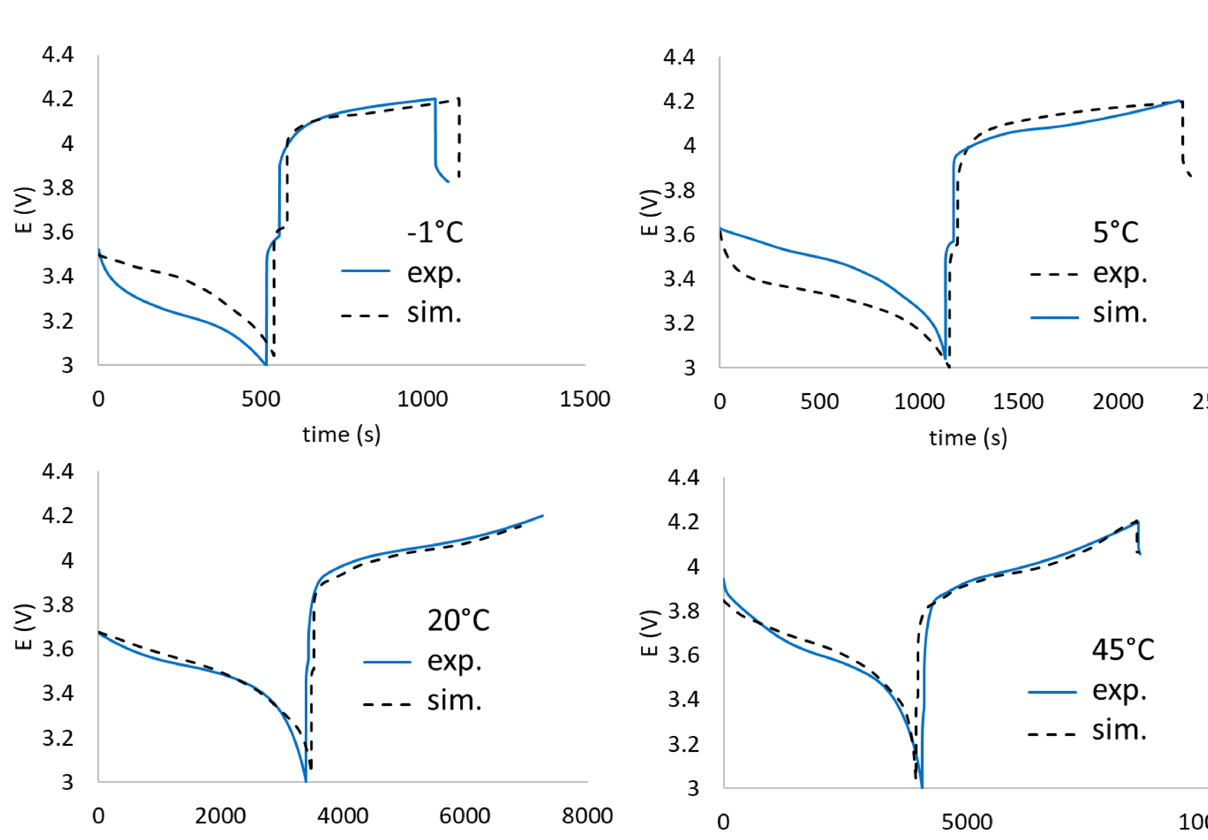


Figure 6. Charge/discharge cycles at different temperatures.

CONCLUSIONS: The Newman's model for LiPos behavior has been validated with experimental results at different C-rate and temperatures.

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