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LITHIUM-ION CELLS SAFETY ASSESSMENT

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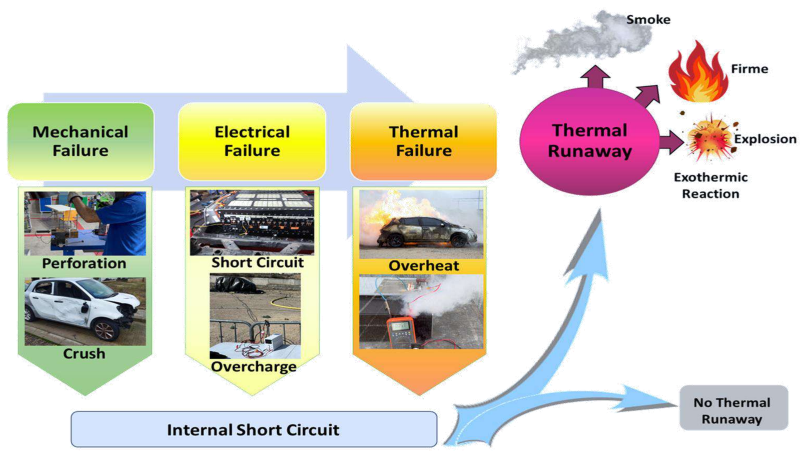
Introduction

Lithium-Ion Batteries (LIBs) are widely used in a variety of applications because they are able to store a lot of energy and last a long time. To ensure optimal performance and safety, it's essential to implement measures that prevent overheating, overcharging, or internal short circuit in these batteries. **Thermal Runaway (TR)** represents the most dangerous unwanted event that leads to the cell damage with the possible development of fire, explosion and the releasing of toxic gases. Possible causes of TR are mechanical, electrical and thermal failures. The hazard associated with TR can be investigated with the **Accelerating Rate Calorimeter (ARC)**, able to simulate adiabatic conditions with the aim to study the heat released during the abuse tests. In this work, several **aged commercial cylindrical** cells were characterized following a specific galvanostatic cycling procedure.



Cell characterization

Commercial cylindrical cells with NMC cathode (nickel-manganese-cobalt oxide) and a nominal capacity of **2,85 Ah** (Samsung INR 18650 29E) were characterized by using a **break-in cycle** with a protocol Constant Current-Constant Voltage (CC-CV) followed by the **Reference Performance Test (RPT)** lasting around 100 h [1]. This has allowed the calculation of **capacity fade** and **resistance growth** due to aging by using the two equations below.

Break-in cycle

Voltage limits: 4,2-2,5V

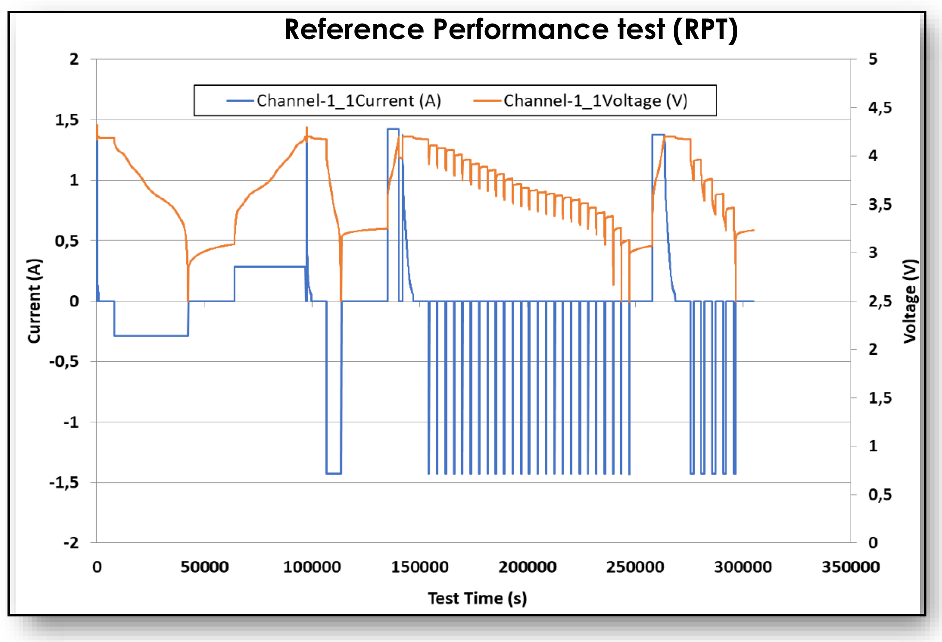
C-rate:C/5

Constant current-Constant Voltage (CC-CV)

Reference Performance test (RPT)

Four subtest:

- CC-CV (C/10)
- CC-CV (C/2)
- Two **Galvanostatic intermittent titration technique** (GITT) discharge test (C/2)



$$\text{Cap. Fade (\%)} = \frac{Capacity_{BoL*} - Capacity_{0,1C}}{Capacity_{BoL}}$$

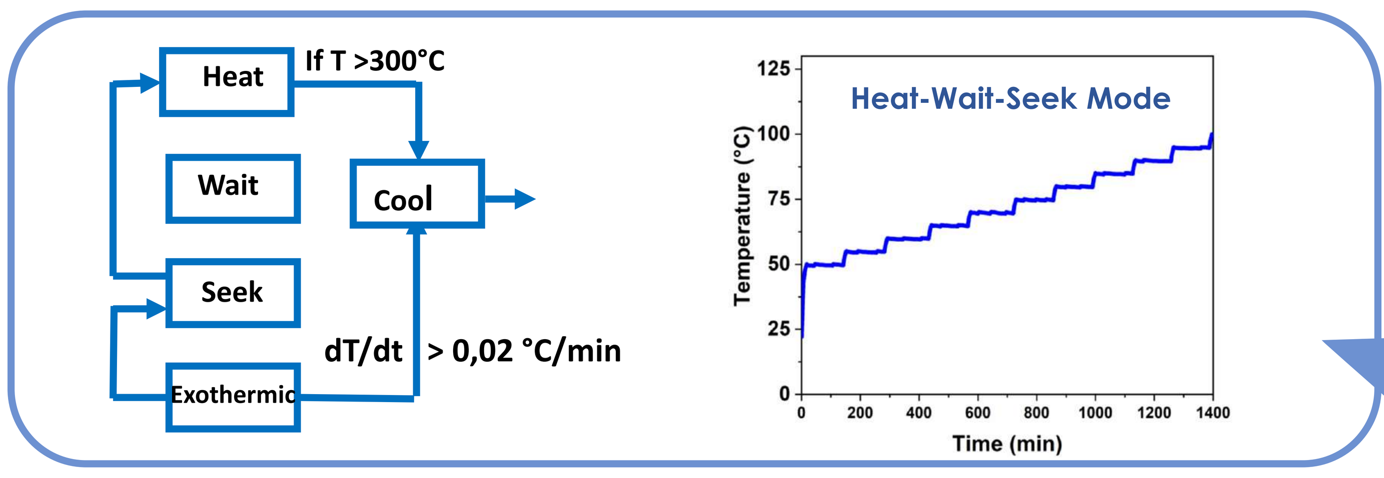
*BoL=Begin of life

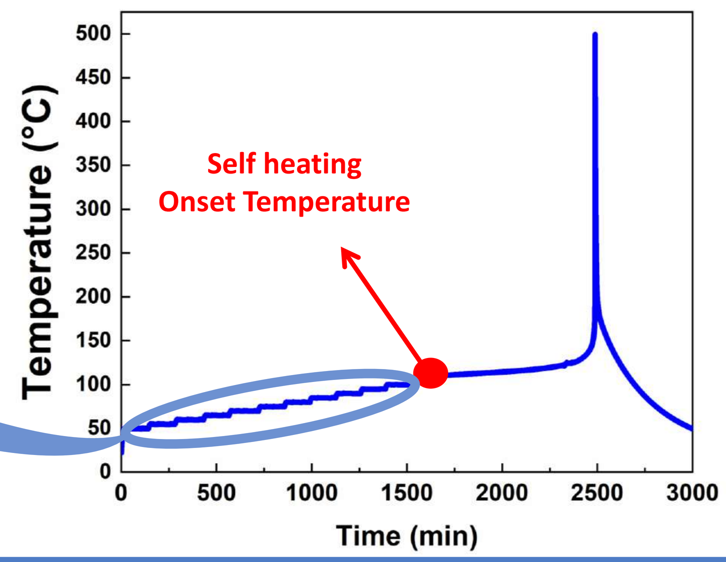
$$\text{Resistance}(\Omega) = \frac{V_2 - V_1}{I_2 - I_1}$$

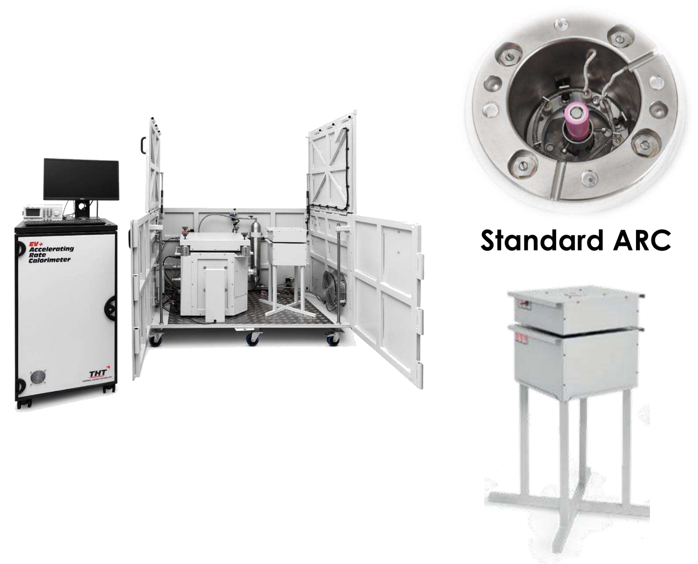
N° cell	Capacity Fade [%]	Resistence ~50% SOC [Ω]
1	1,3684	0,1763
2	2,689	0,1972
3	4,0381	0,1703
4	5,942	0,1973
5	5,694	0,2334
6	4,6227	0,1794

Accelerating rate calorimeter

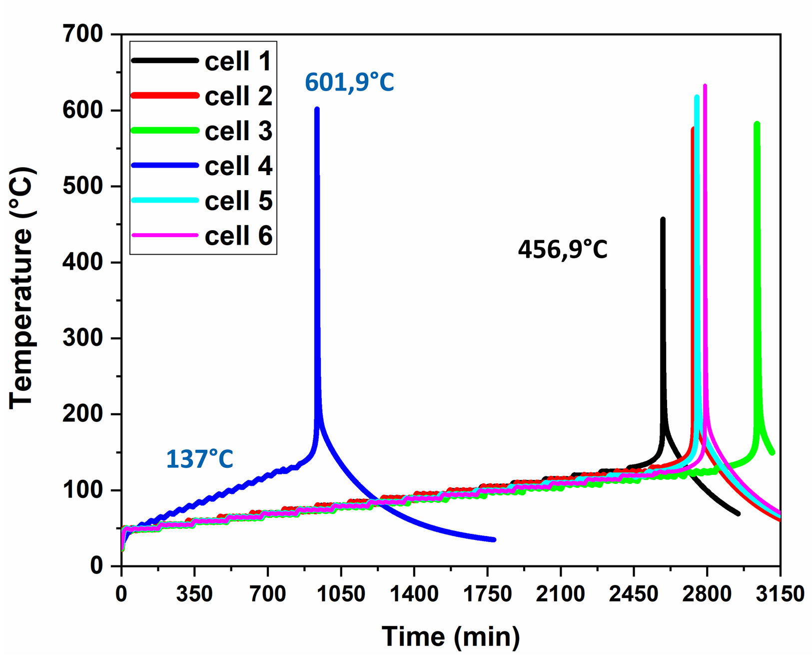
The tested cells fully charged are then fixed in the standard **ARC (Accelerating rate calorimeter)** to perform thermal abuse tests by using the **heat-wait-seek mode**[2]. Thanks to the instrument and the applied protocol, the adiabatic environment can be exploited to identify key temperature characteristics associated with thermal runaway.

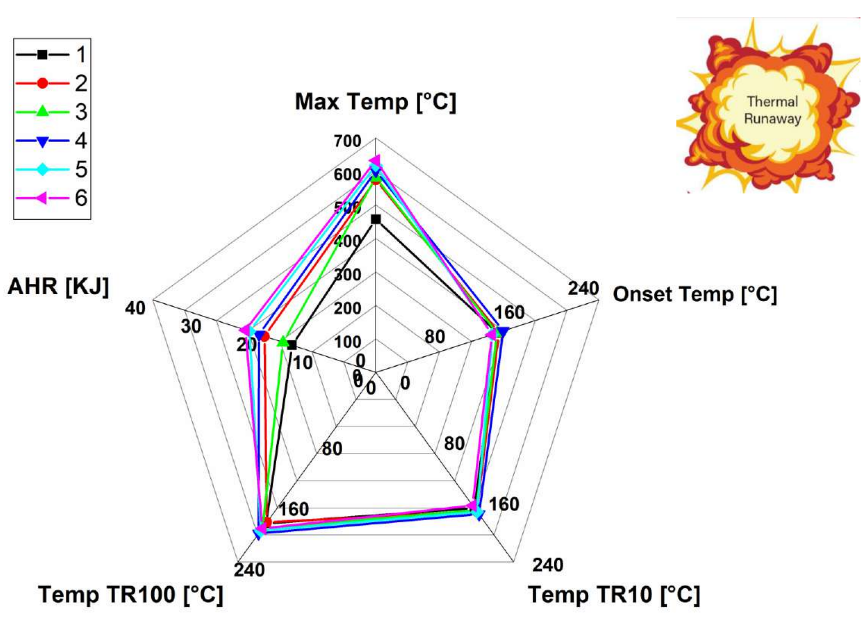


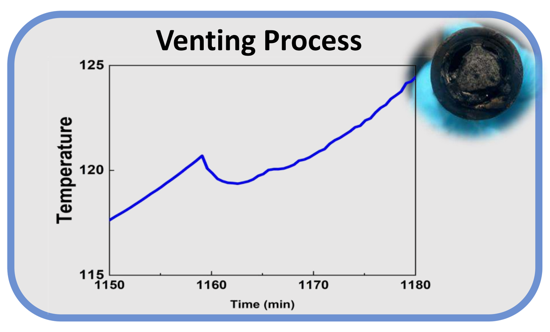




Thermal Runaway







N° Cell	Weight Loss [%]	Self Heat. Time [min]
1	45.65	129.896
2	43.48	121.46
3	42.55	157.917
4	40.00	65.8
5	52.17	165.203
6	50.00	145.793

Conclusion

- **Aim of the work:**

The ARC was employed to evaluate key parameters of thermal runaway, including the venting process and the self-heating temperature, as well as to analyze the thermal behavior of the aged cells. This work highlights ARC as a valuable technique for assessing the safety of high energy-density commercial cells and for validating innovative solid-state cell technologies.

- **Future work:**

ARC will be employed to assess the safety of high energy-density cells manufactured using water-based binders characterized by high voltage cathodes (LNMO) and high capacity anodes (Si rich).

References:

[1] Kirkaldy, Niall, et al. "Lithium-ion battery degradation: Measuring rapid loss of active silicon in silicon–graphite composite electrodes." *ACS applied energy materials* 5.11 (2022)

[2] Zhang, Liwen, et al. "Cell-to-cell variability in Li-ion battery thermal runaway: Experimental testing, statistical analysis, and kinetic modeling." *Journal of Energy Storage* 56 (2022):

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