

Schlieren, Natural Luminosity and OH* tracking for Thermal Runaway Phenomenon understanding



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NTSB says electric vehicle battery fires pose risks to 1st responders



This updated photo provided by National Transportation Safety Board. The Orange County Fire Authority battles a fire on a burning vehicle inside a garage in Orange County, Calif. When firefighters removed the SUV from the garage to assess the fire, they identified the fuel source as the SUV's high-voltage battery pack. U.S. safety investigators say electric vehicle fire pose risks to first responders, and manufacturers have inadequate guidelines to help them safe. (Orange County Sheriff's Department/National Transportation Safety Board via AP)

[1]

GM expands recall of Chevy Bolt electric cars over battery fire risk



Latest recalls affects more than 10,000 vehicles in Canada

The Canadian Press - Posted: Aug 20, 2021 6:18 PM ET | Last Updated: August 21



A 2021 Chevrolet Bolt EV is displayed with 2020 models in Saline, Mich., on Feb. 25. General Motors says it has expanded a recall of its Chevy Bolt electric vehicles to include all model years because of a risk the battery cells could catch fire. (Carlos Oronoz/The Associated Press)

[2]

While they were asleep, their Teslas burned in the garage. It's a risk many automakers are taking seriously.

A fire inspector cited the thermal management system in one of the Tesla Model S sedans as one of two possible causes of the blaze, which showed what can happen when one electric car ignites another in a garage.

Listen to article 5 min



A fire inspector cited the Tesla Model S's thermal management system and a fault in the electrical system as two possible causes in the fire. (Jonathan Barnes/The Washington Post)

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1 Microsoft is going password-free for consumer accounts

2 Analysis Facebook keeps researching its own harms — and burying the findings

3 The government helped Tesla conquer electric cars. Now it's helping Detroit, and Elon Musk isn't happy.

[3]

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GM Tells Chevy Bolt Owners to Park It Outside After Two Electric-Car Fires

Last November, General Motors recalled nearly 69,000 Bolts from the 2017-19 model years, including roughly 51,000 sold in the U.S.



How the EV Industry Is Trying to Fix Its Charging Bottleneck

Electric-vehicle entrepreneurs are working on the industry's biggest bottleneck: charging infrastructure. Companies are building more chargers, but it may not be enough to make EVs work for people who can't plug in at home. Photo illustration: Carlos Waters/WSJ

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[4]

Chevy Bolt EV Being Recalled In Face Of Fires

Affects 2017 to 2019 model years.



Nov 13, 2020 at 1:15pm ET

130

By: Domenick Yoney



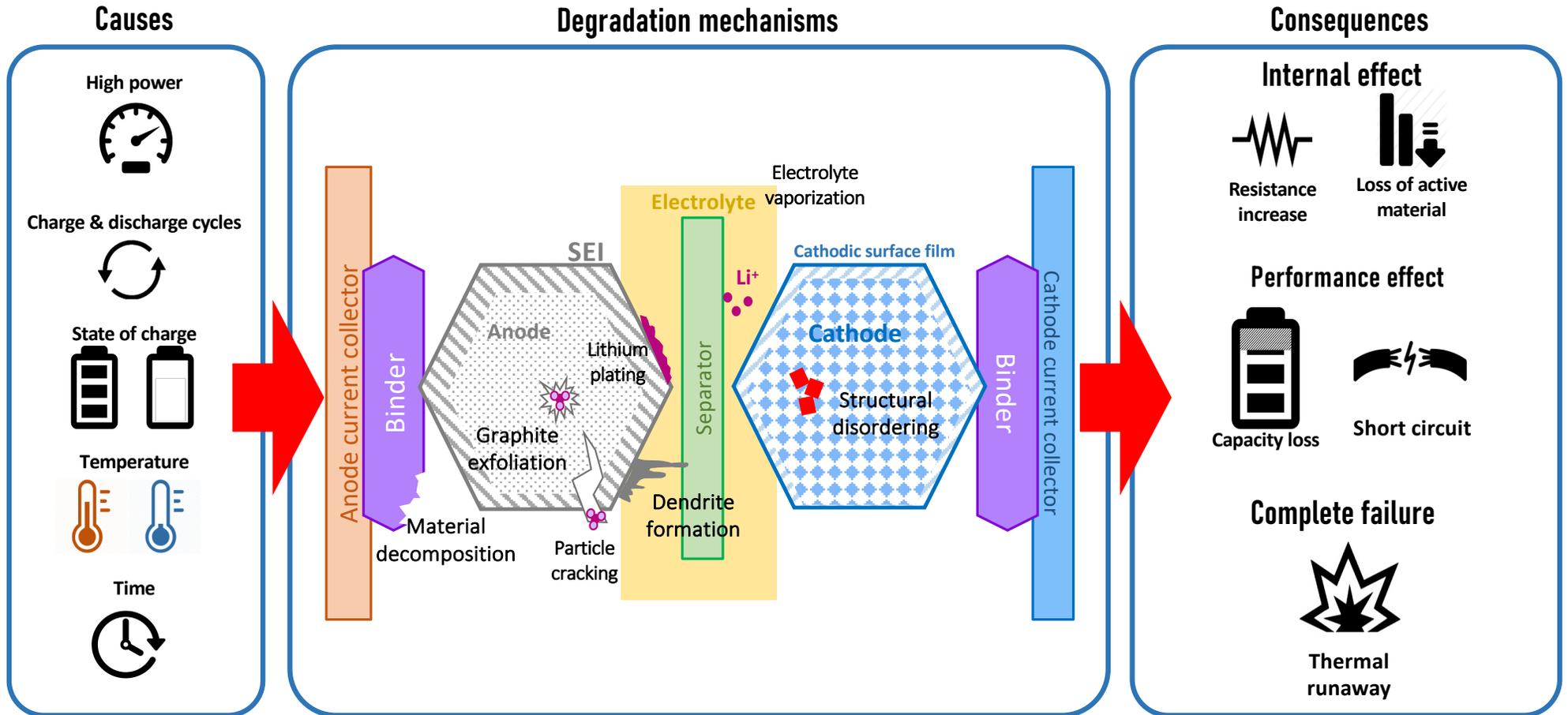
Sources

[5]

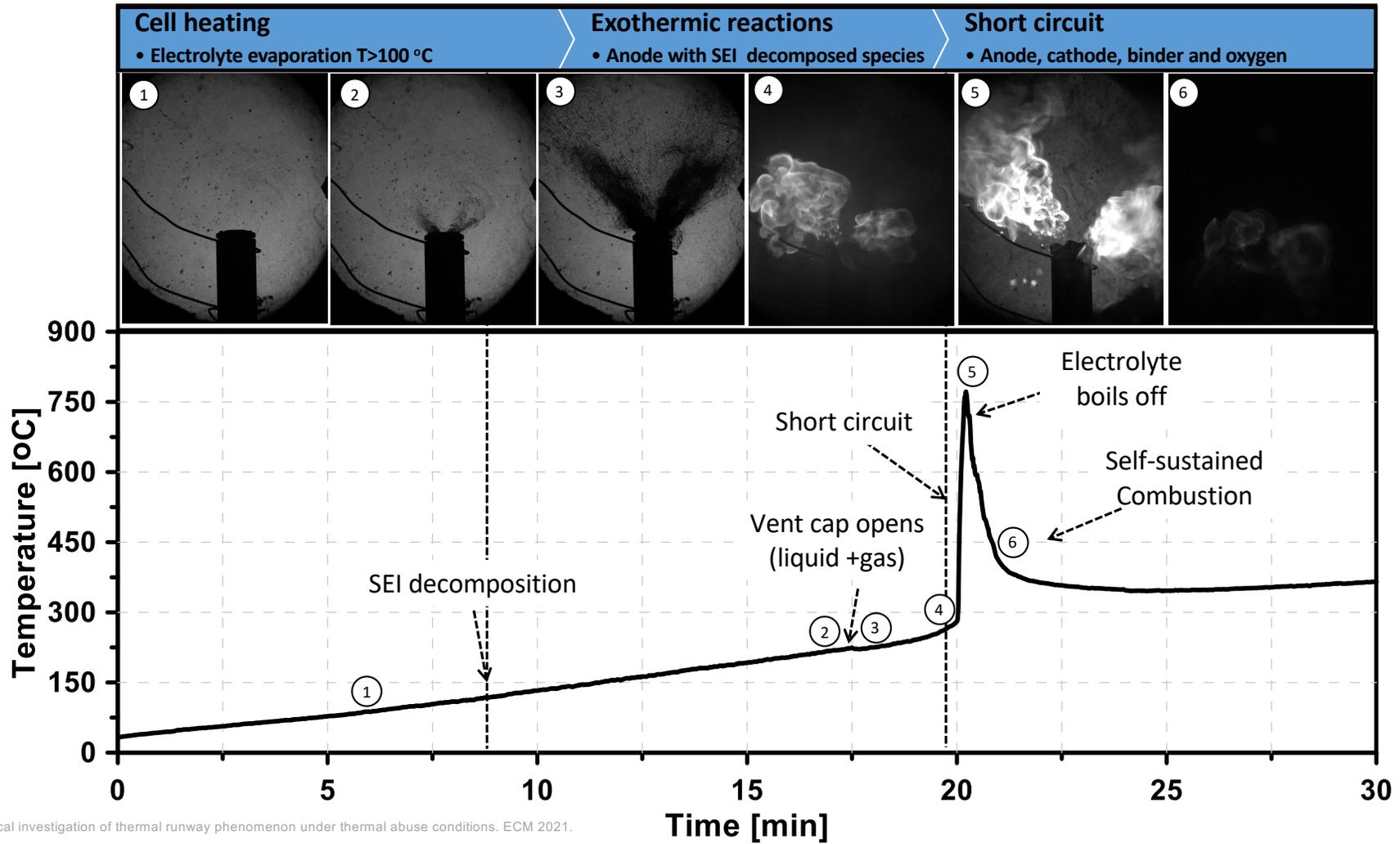
General Motors is voluntarily recalling the 2017-2019 Chevy Bolt EV. The automaker is

3

Why do the battery fail and burns?



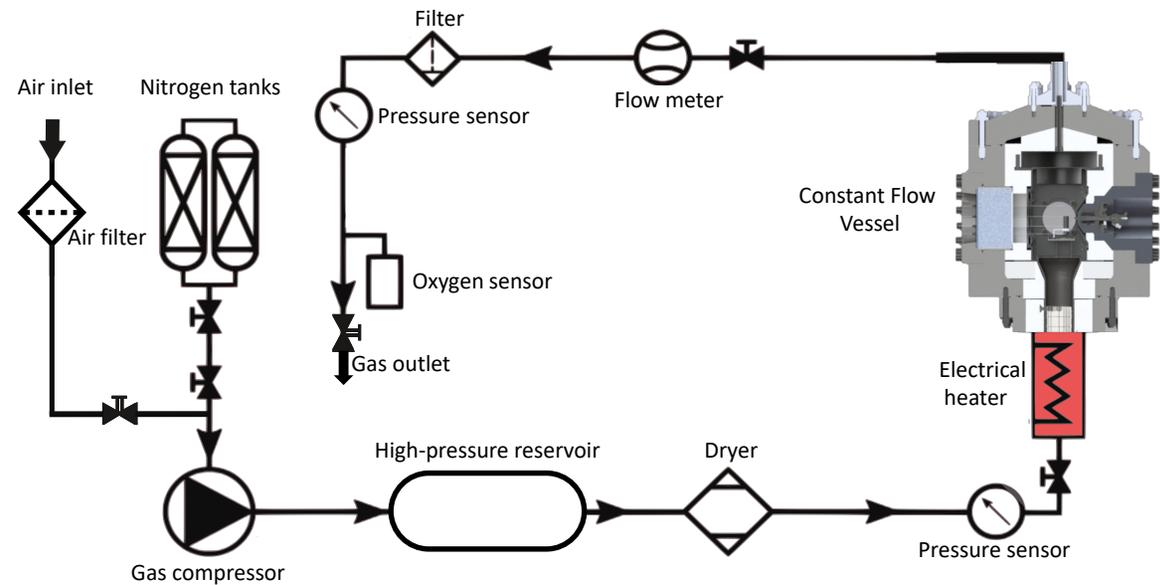
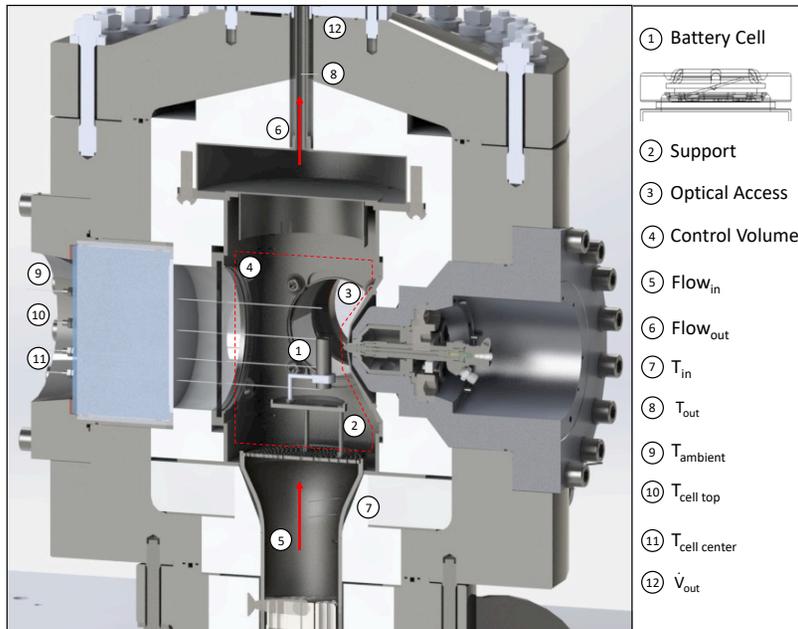
Thermal runaway description



How to assess the thermal runaway?

Experimental test: Continuous Flow Vessel (CFV)

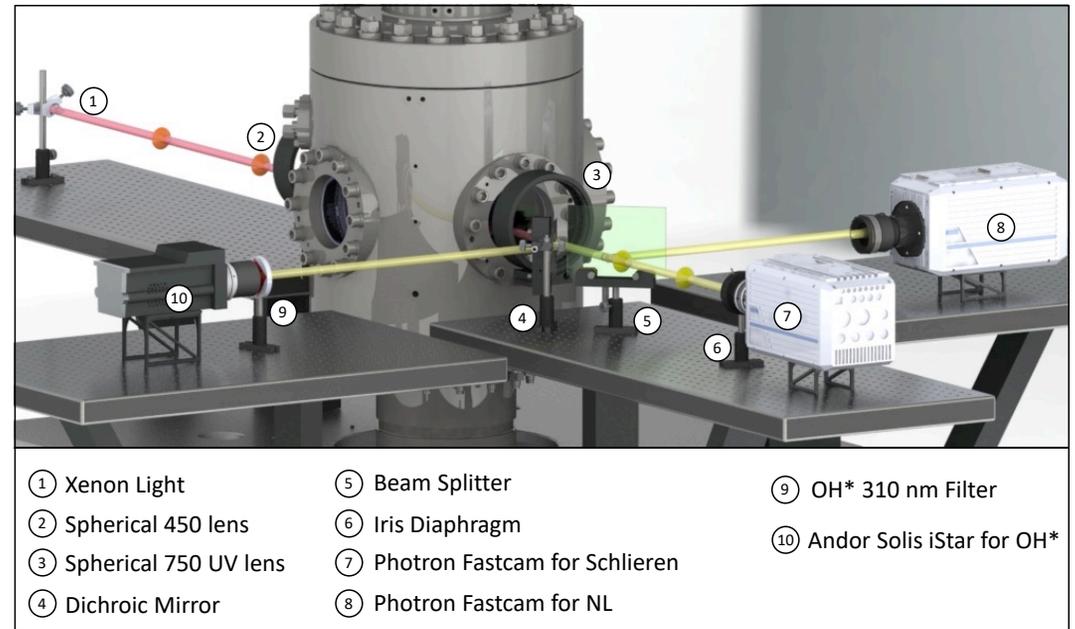
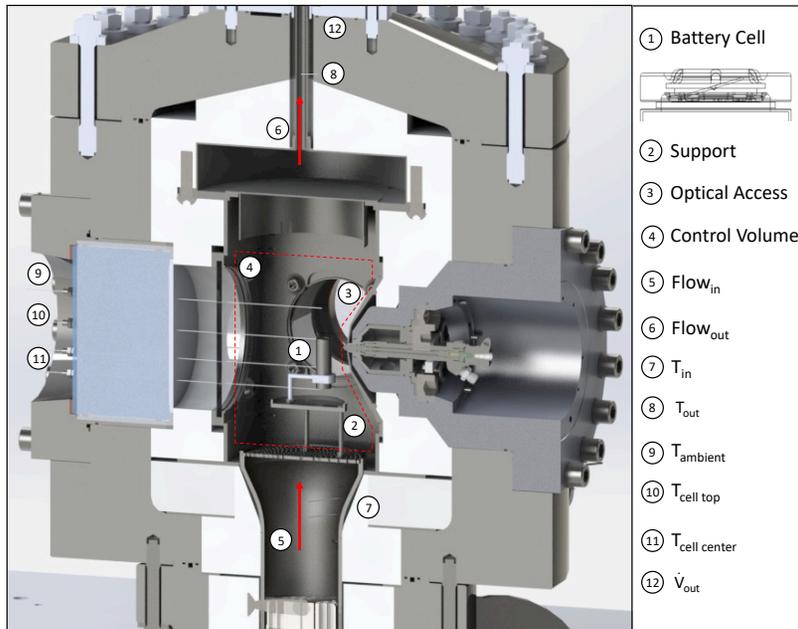
- Non-reactive and reactive environments.
- Spatial temperature resolution.
- Different heating rates.



Experimental test: Continuous Flow Vessel (CFV)

➤ Capability of application of simultaneous optical techniques.

- Schlieren Technique
- Natural Luminosity
- Emission Spectroscopy



■ Lithium-Ion Battery Cells Studied:

Parameter	LCO	NMC	LFP
Manufacturer	Samsung	Samsung	NX
Model	26J	20R	7063
Type	18650 Cylindrical Cell		
Nominal Capacity [Ah]	2.6	2.0	1.8
Battery Energy [Wh]	9.36	7.20	5.76
Vent Cap Holes	6	3	3
Full Charge Voltage [V]	4.0	4.2	3.6
Cut-off Voltage [V]	2.75	2.5	2.5

■ Experimental Conditions Evaluated

➤ Different Heating Rates



➤ Reactive and Non-reactive



➤ Different State of Charge



Effect of heating rate

Thermodynamic Analysis

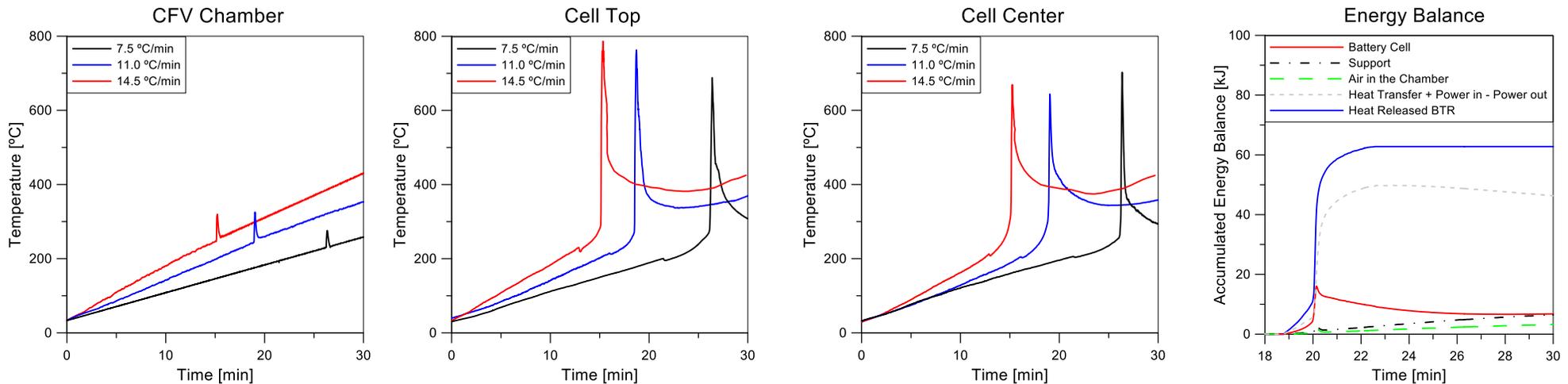
➤ Experimental investigation: LCO cell + heated with different heating rates

- Three different heating ramps: 7.5 °C/min, 11.0 °C/min, 14.5 °C/min.
- SOC = 100%



➤ Results

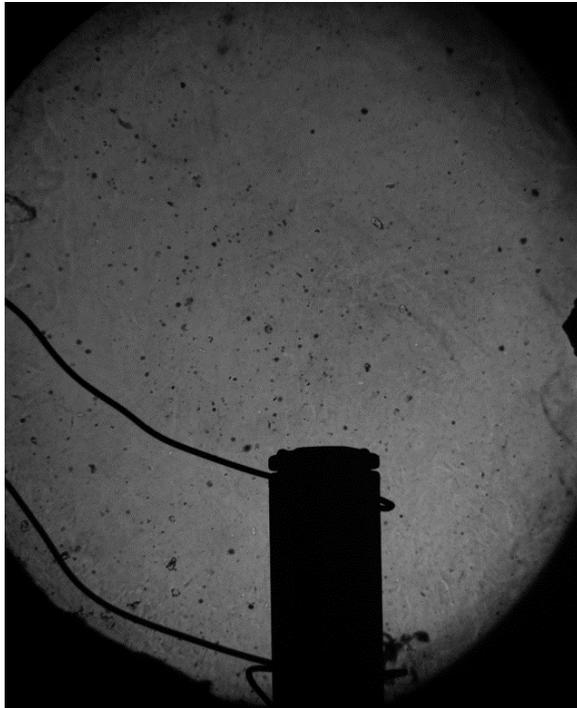
- Heating rates do not affect the temperature onset for thermal runaway occurrence.
- Peak of temperature is reduced for slower heating rates.
- The use of the high-pressure high temperature vessel allows the quantification of the heat released of the battery cell.



Optical Techniques

➤ Venting Process

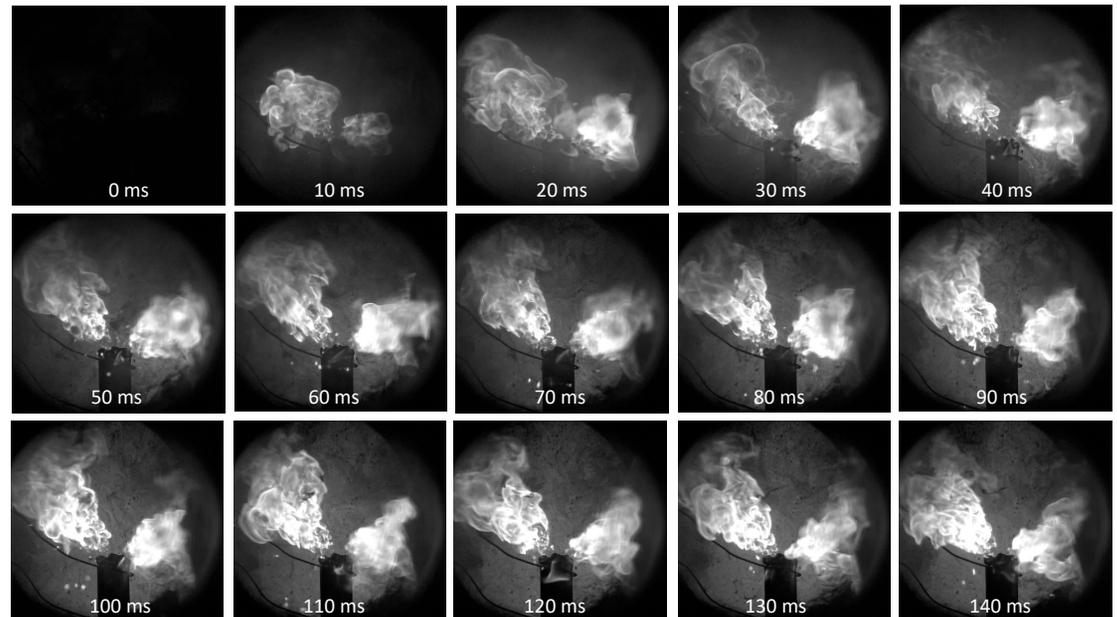
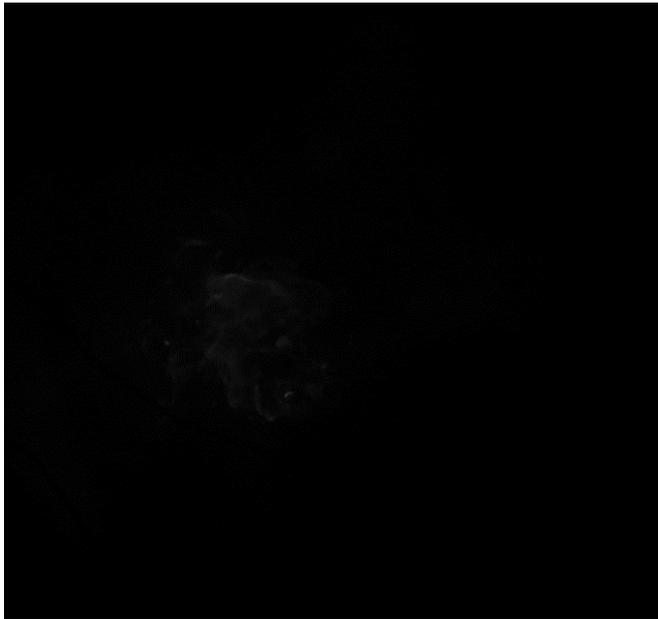
- The venting process is seen around 200°C.
- Schlieren visualization of the venting process for an INR 18650 26J battery cell evidencing the liquid, solid and gaseous components in different time instants.



■ Optical Techniques

➤ Thermal Runaway

- Natural luminosity images of the thermal runaway process.
- 0 ms stands for the first visible light, indicating the ignition time out of the cell.
- Shape of the flame allows to understand the radiation heat transfer to the vicinity cells.
- Characterization such as flame length, area and angle can be used to develop high fidelity numerical models.



Effect of Ambient Oxygen Content

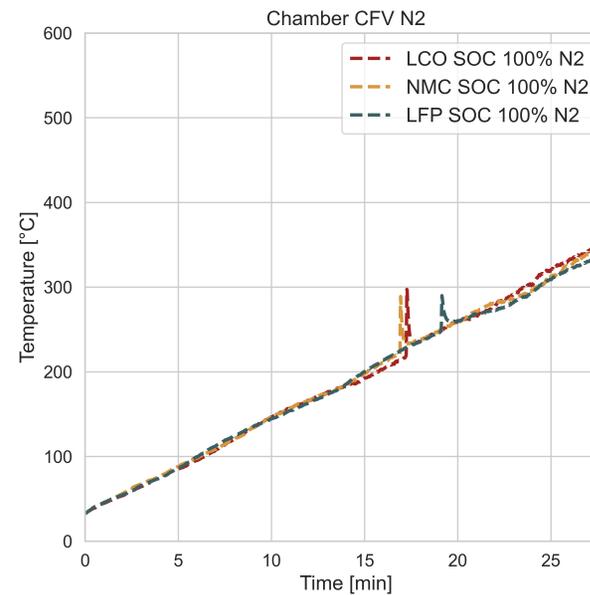
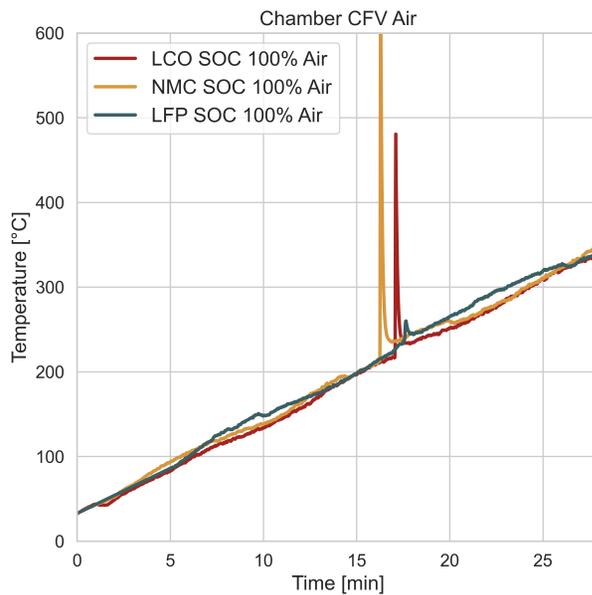
Thermodynamic Analysis

Experimental investigation: LCO, NMC and LFP cell with 21% O₂ and 0% O₂

- Heating ramp: 11.0 °C/min
- SOC = 100%

Results

- The LFP was the last cell to enter in TR and with the lowest peak temperature.
- The absence of oxygen generated lower chamber temperatures than in the case with O₂.



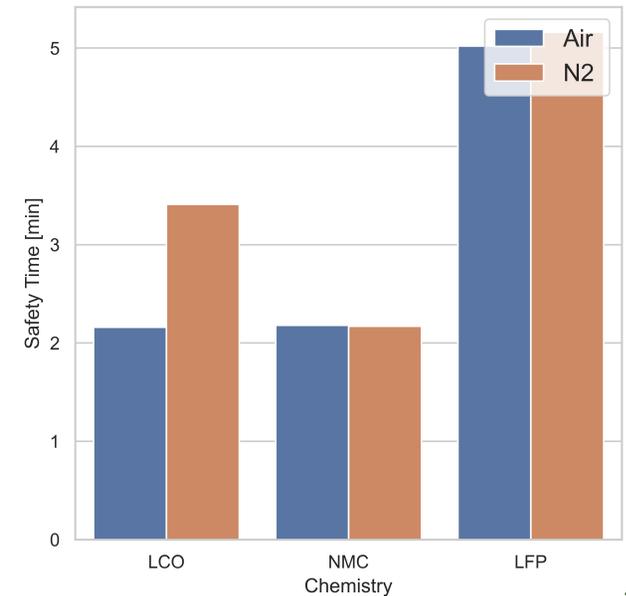
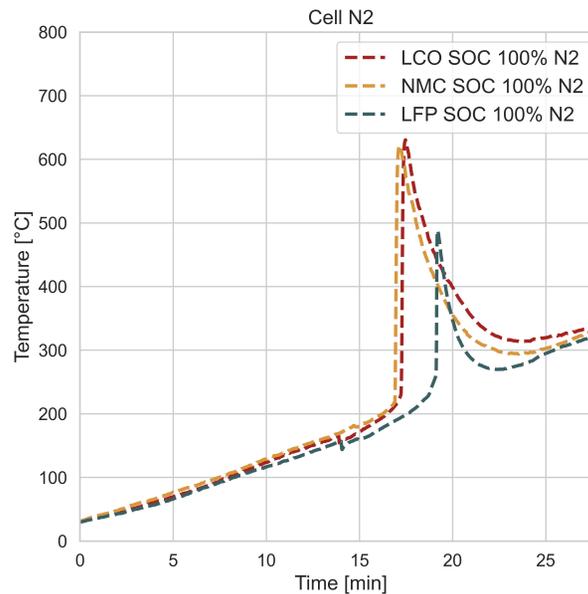
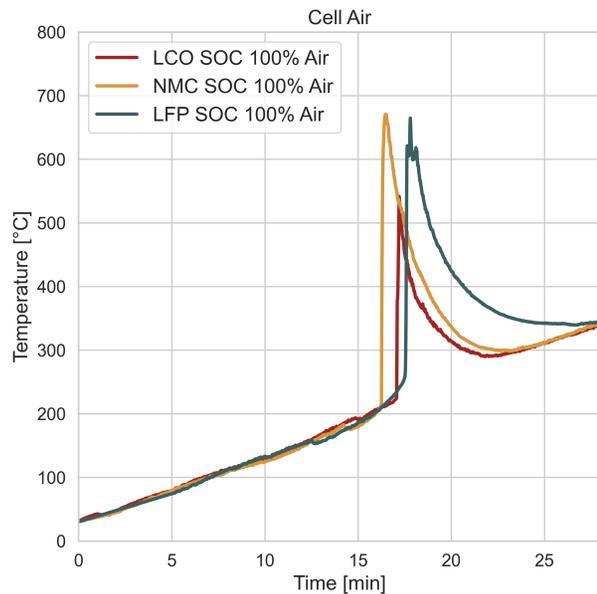
Thermodynamic Analysis

Experimental investigation: LCO, NMC and LFP cell with 21% O₂ and 0% O₂

- Heating ramp: 11.0 °C/min
- SOC = 100%

Results

- In spite of the lower chamber temperatures for the 0% O₂, the cell temperature increases close to the baseline.
- LFP shows the highest safety time (lapse between venting and TR).



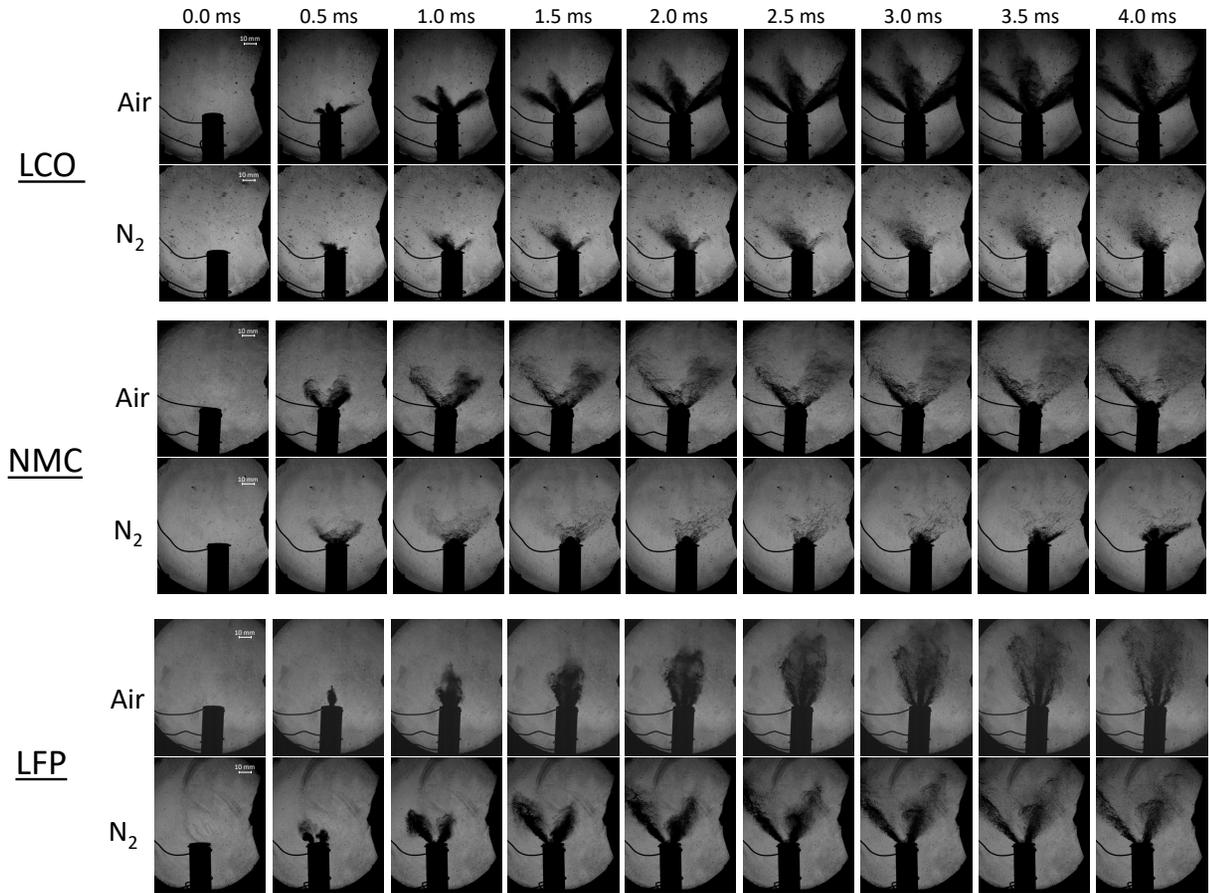
Optical Techniques

➤ Venting Process

NMC Air



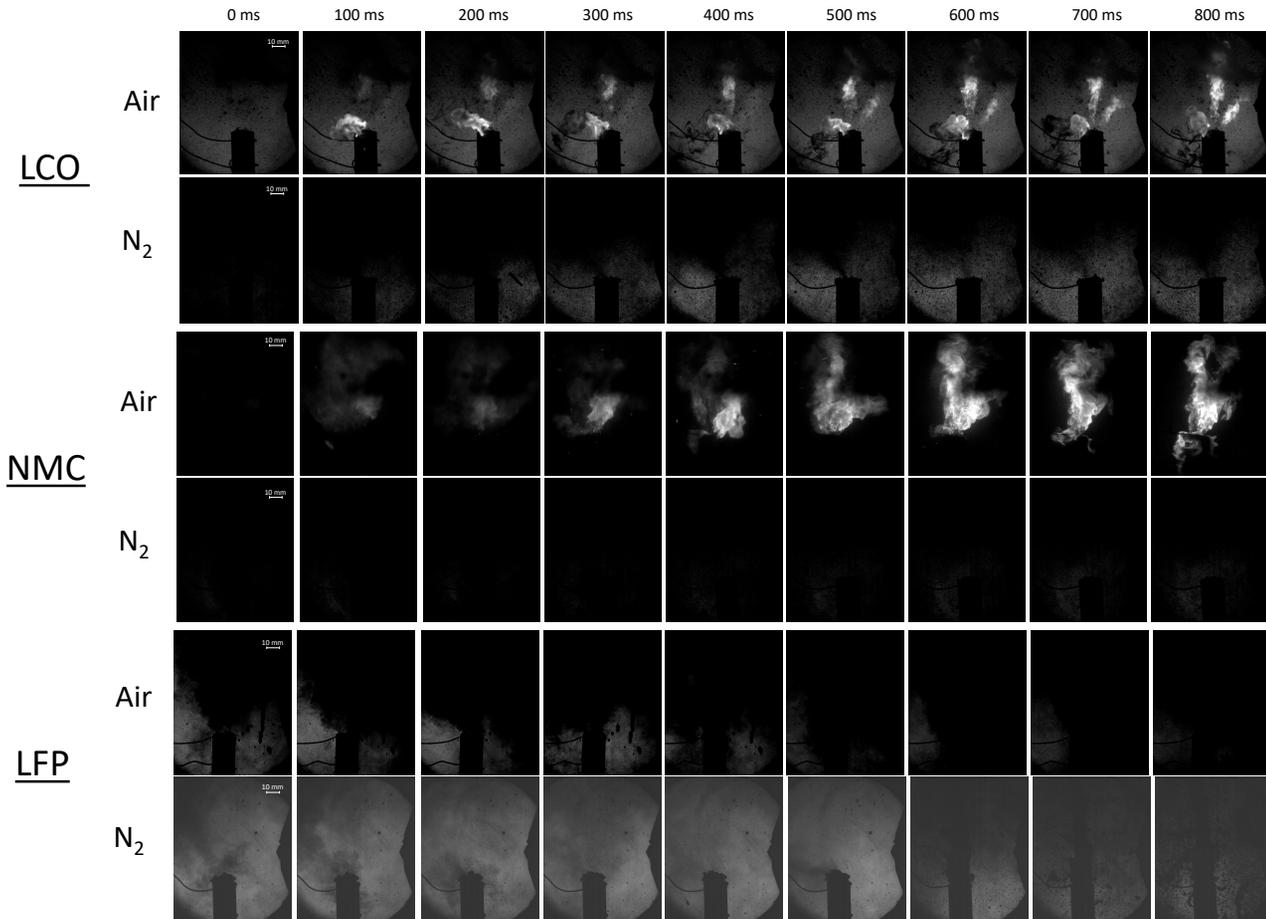
LFP Air



Optical Techniques

Thermal Runaway

- The images show the natural luminosity of the thermal runaway process.
- LCO and NMC show flame propagation outside the cell when O_2 in the atmosphere is present.
- On the other hand, LFP cell shows only a large amount of smoke without any visual flame emissions.
- In all cases, large amount of smoke is seen in the initial stage.
- It is important to note that the flame can be seen thanks to the open system environment.



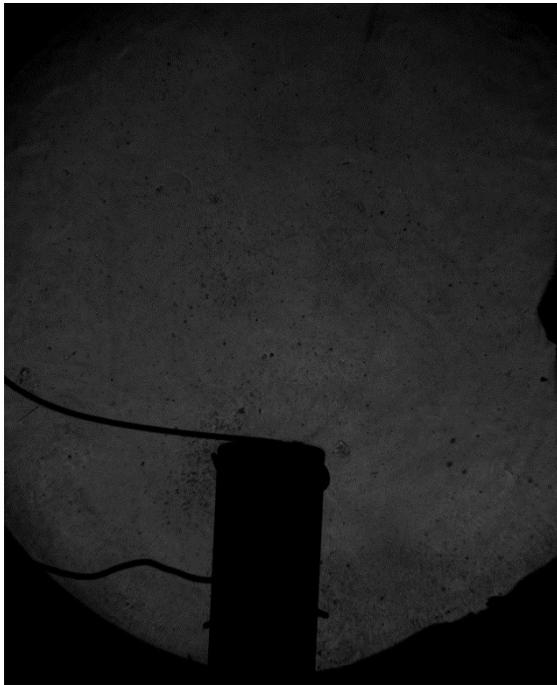
Effect of battery initial SOC

■ Optical Techniques

➤ Venting Process

- The vent gas intensity and quantity are reduced with the SOC.

NMC SOC 100%



NMC SOC 50%



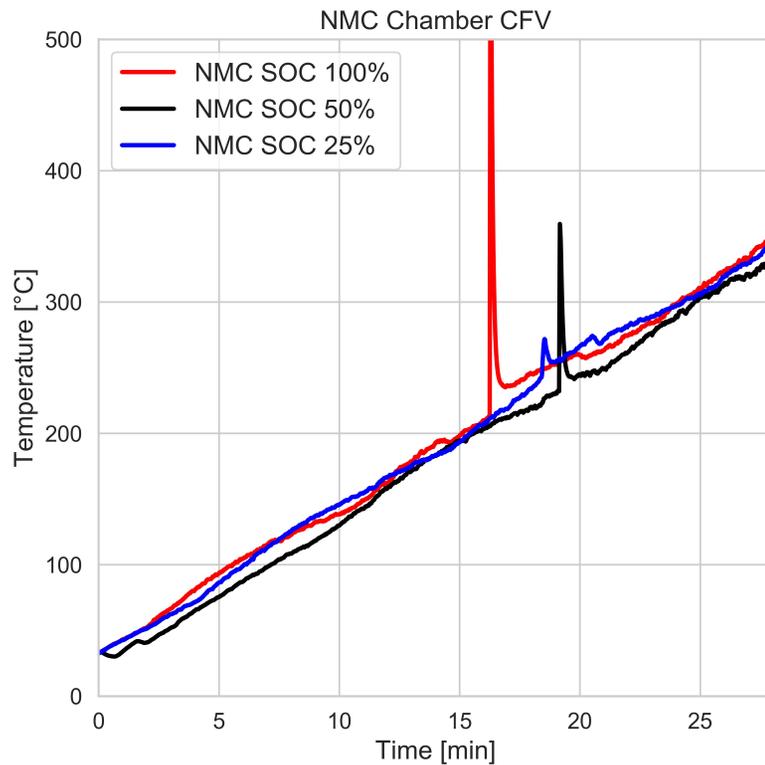
NMC SOC 25%



Optical Techniques

Thermal Runaway

- The SOC directly influences the flame propagation process



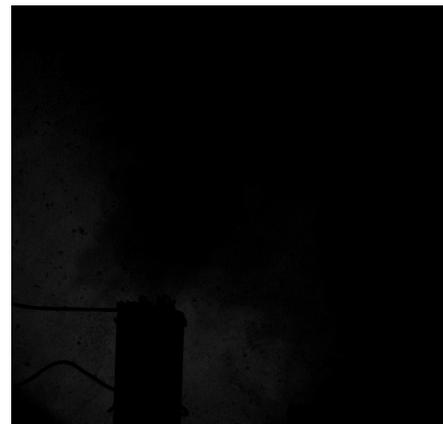
NMC SOC 100%



NMC SOC 50%



NMC SOC 25%

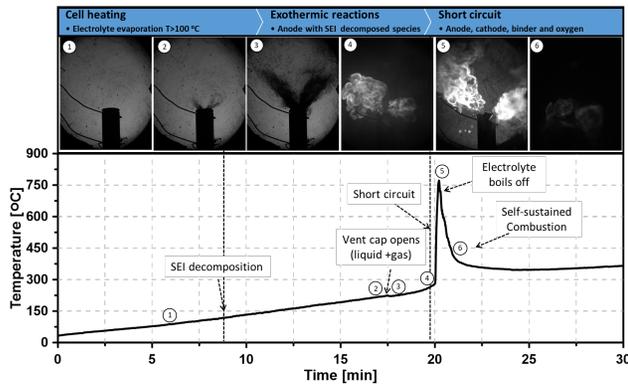


Takeaways

- **This work has investigated in detail the battery thermal runaway phenomena of 18650 cylindrical battery cell using a novel continuous flow high temperature vessel together with advanced optical techniques.**
- **The novel assessment device allowed to visualize in detail the BTR phenomenon, since the continuous flow removes the smoke that is originated during the process and generally hinders the applications of optical techniques in devices such as accelerated rate calorimeter.**
- **The measurement of the safety time, defined as the time between venting detection and the thermal runaway, shows that LFP allows up to 5 min in comparison with NMC that allows only 2 min.**

Ongoing investigations

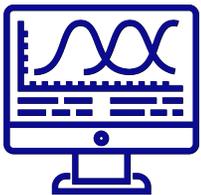
Laboratory environment



Identify the dominant parameters for TR:



Propose predictive modelling:

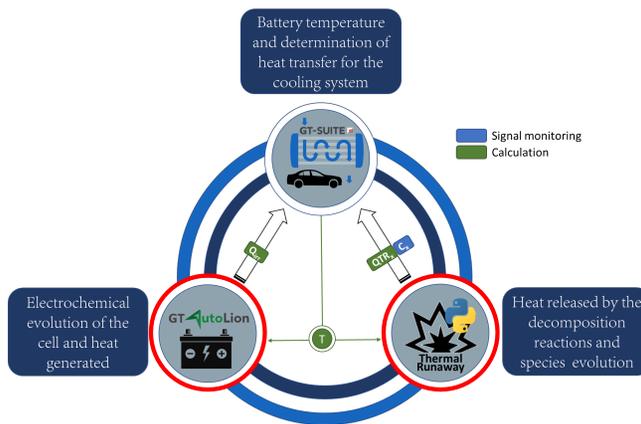


Thermal degradation with respect to operating conditions

Arrhenius bases description

Virtual environment

Model testing by multi-physics approaches



Model testing by multi-physics approaches

Validate the accuracy of the proposed model

Reduce calculation time

Integration with vehicle ECU

Development of advanced sensing strategies

Real world application

Implementation



Power demand



Adaptative safety limits



NASA Aerospace Battery Workshop



Thank you for your **kind** attention

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■ Sources

➤ Slide 5

- [1] <https://www.mercurynews.com/2021/01/13/ntsb-says-vehicle-battery-fires-pose-risks-to-1st-responders/>
- [2] <https://www.cbc.ca/news/business/general-motors-gm-chevy-bolt-electric-car-recall-fire-risk-1.6148270>
- [3] <https://www.washingtonpost.com/technology/2021/08/04/tesla-fire/>
- [4] <https://www.wsj.com/articles/two-fixed-chevy-bolts-catch-fire-months-after-vehicle-recall-11626307113>
- [5] <https://insideevs.com/news/454290/chevy-bolt-ev-recall-fire/>