# Test Methodology for Mitigating Internal Short-Circuit and Self-Discharge Risks

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# Agenda

- Challenges and Opportunities
- LI Battery Introduction
- Design Challenges
- Solutions
- Our solution
- Device/Features and PD analysis

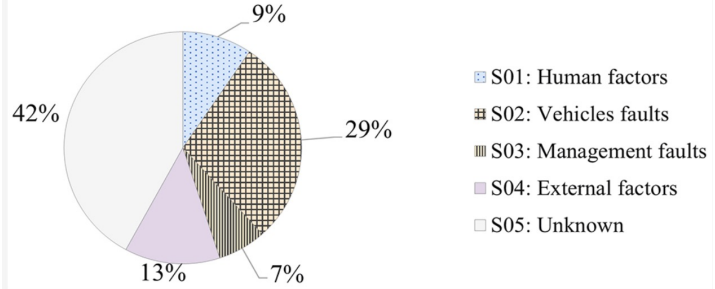
# Challenges and Opportunities

In 2022 in London, there were 87 e-bike and 29 e-scooter fires.

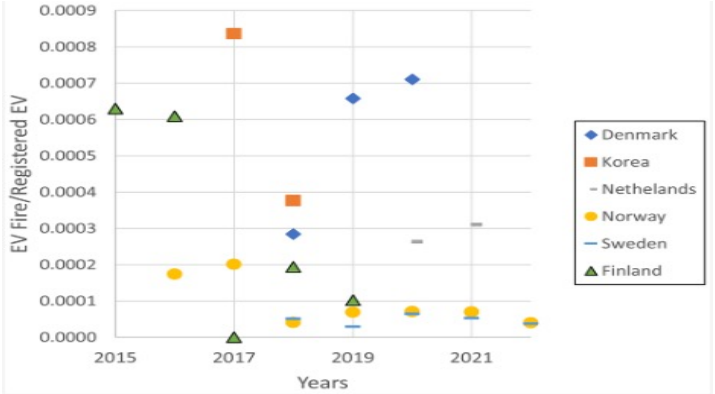
**Top 10 regions with the most electric vehicle battery fires during 2022/23**

| Region | Vehicle Battery Fires |
|---|---|
| Greater London | 219 |
| Lancashire | 16 |
| Merseyside | 14 |
| Bedfordshire | 12 |
| West Midlands | 11 |
| East Sussex | 9 |
| Greater Manchester | 9 |
| Humberside | 9 |
| Berkshire | 8 |
| Surrey | 8 |

Source: CE Safety FOI

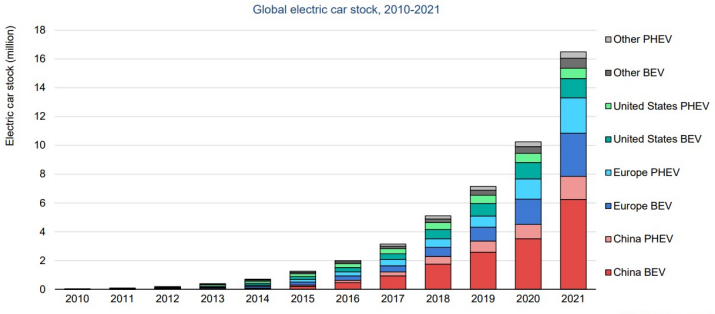



l Representation of Initiating Causes for Electric Vehicle Fires.



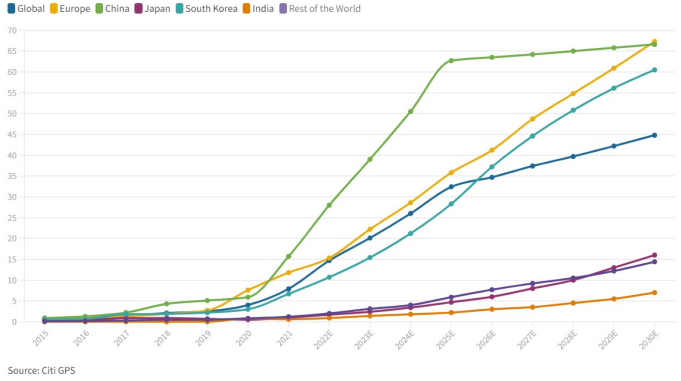
# Opportunities- Present and Future

## Over 16.5 million electric cars were on the road in 2021, a tripling in just three years



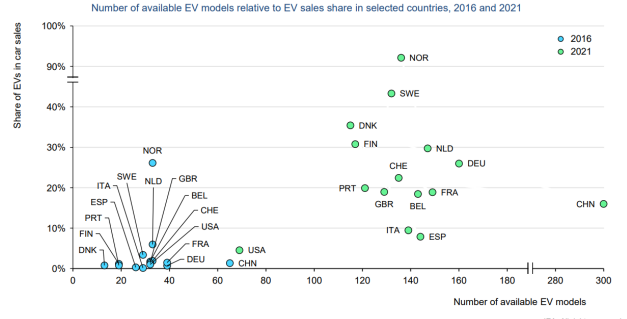



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Electric car stock in this figure refers to passenger light-duty vehicles.
"Other" includes Australia, Brazil, Canada, Chile, India, Japan, Korea, Malaysia, Mexico, New Zealand, South Africa and Thailand. Europe in this figure includes the EU27, Norway, Iceland, Switzerland and United Kingdom.
Sources: IEA analysis based on country submissions, complemented by ACEA; CAAM; EAFO; EV Volumes; Marklines.




Source: Citi GPS

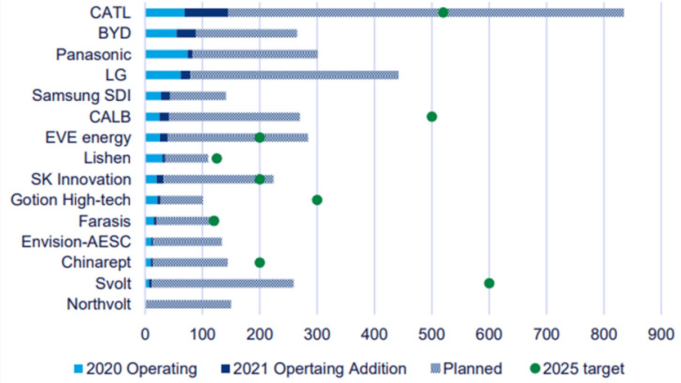
## EV model availability and sales share have increased significantly






Notes: EVs = BEVs and PHEVs. Vehicle models do not include the various trim levels.
Sources: IEA analysis based on EV Volumes.

## Cell manufacturing capacity (GWh)



# Introduction- LI-Ion Battery

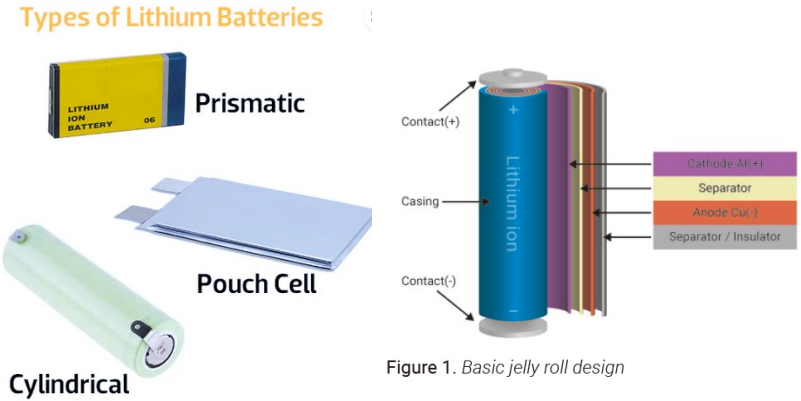
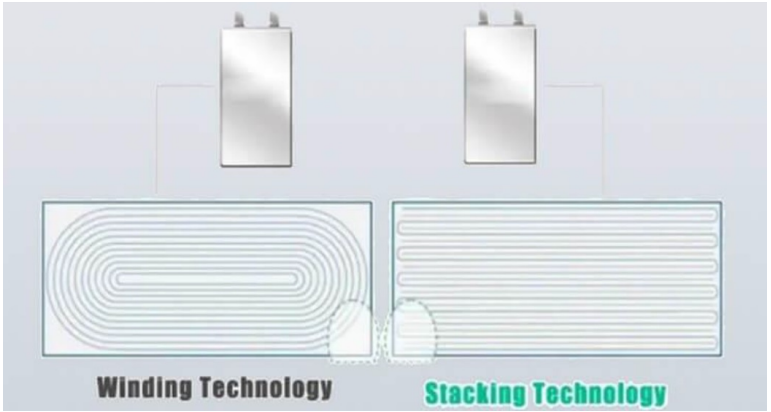



Figure 1. *Basic jelly roll design*



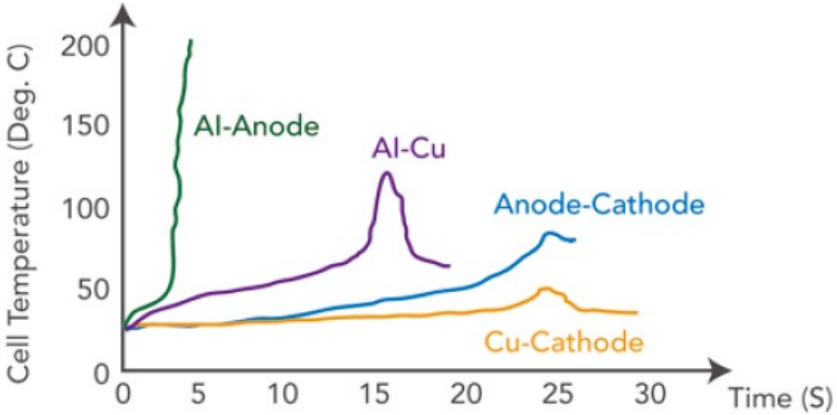
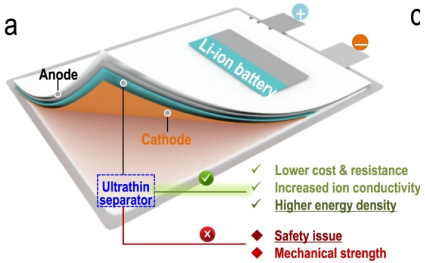




***Figure 2.*** *Temperature rising of different short circuit scenarios*

In case of Internal short circuit, there can be a rapid rise of cell temperature, which might lead to fire and explosion

# Design Challenges

- Thinning of Separator (from 25 micron to even 5 micros in last 2 decade)
- Conductive particles in separator and impurities, unevenness in separator
- Anode inflation



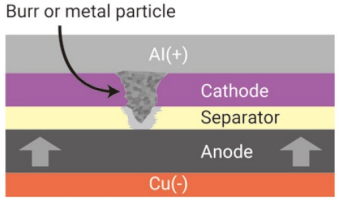
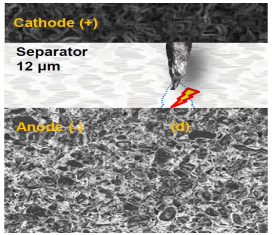
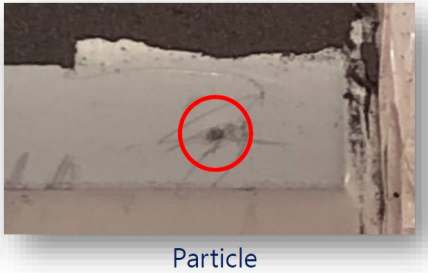




*Figure 3. A burr extruded from the positive electrode coming in contact with the material coated on the negative electrode will cause an internal short circuit*





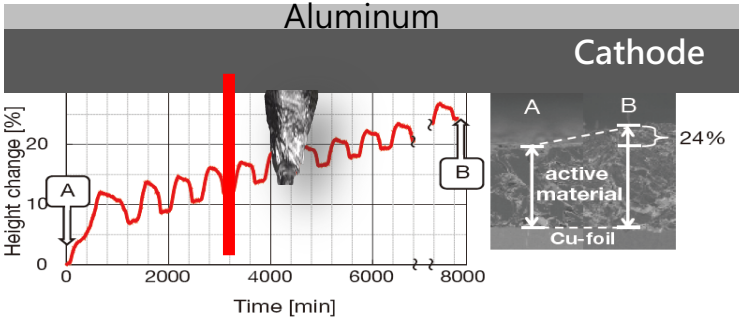
As lithium-ion battery technology advances towards higher energy densities, preventing internal short circuits has become a critical challenge

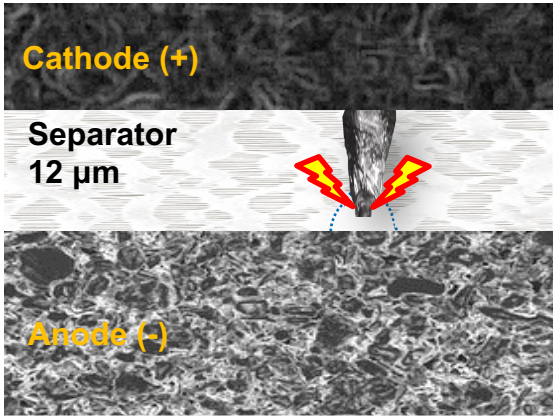
# Anode Inflation

## Insulation test requirement of LIB (Lithium-ion battery)

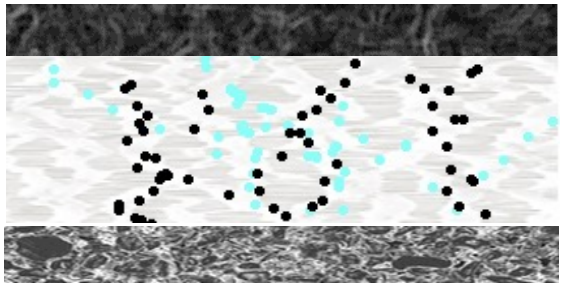
### 1) Effective gap distance between + & - electrodes

Main reason LIB gets fire is: The anode inflates while charging because of intercalation of Li+ ions (SEI generated etc.) (24% @ 10 cycles on graphene), and then short with metal burrs on anode ignites the fire in electrolyte.




2nd. Charge & Discharge



### 2) Electron conductive impurity in separator (leakage current)

The function of the separator is to prevent +/- electrodes short directly, and to provide ion conductivity with organic electrolyte. The e- conductive micro impurities in separator may not cause fire but may cause higher self discharge. Therefore, it is necessary to measure the leakage at lower voltage level.


**The trend of LIB developing is higher energy/power density, but this will cause more battery fire risk.**

How to prevent battery internal short circuit is a challenge …

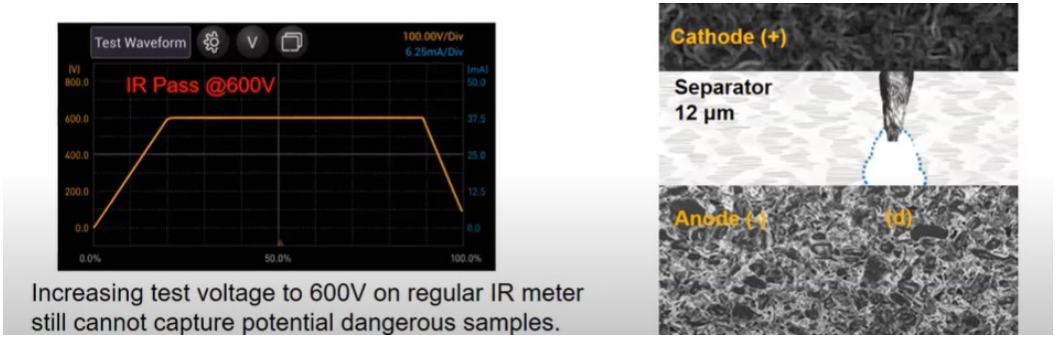
# Solution

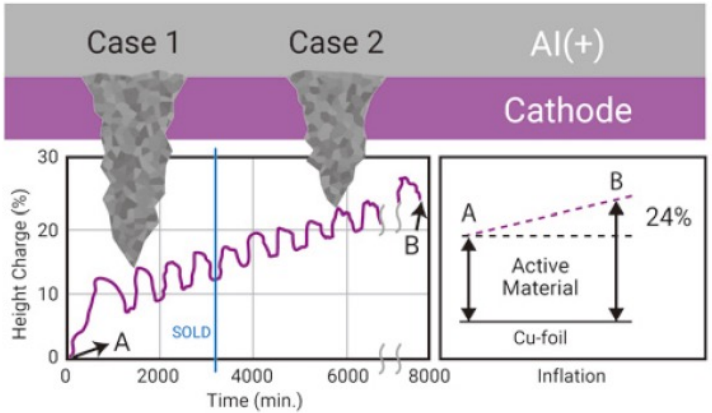
The existing solution is focused on measuring leakage current or internal resistance of the dry cell.

**A complete test solution should measure, detect and analyse**

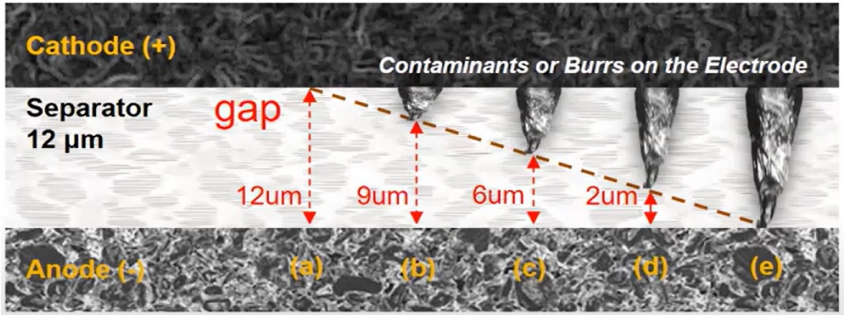
- Leakage current (LC)/ Insulation resistance (IR) measurement.
- Partial Discharge (PD)/ Electrical flashover detection and analysis

Partial Discharge/Electrical flashover detections helps the identification of imperfection/burrs or other defects in the LIB dry cell.

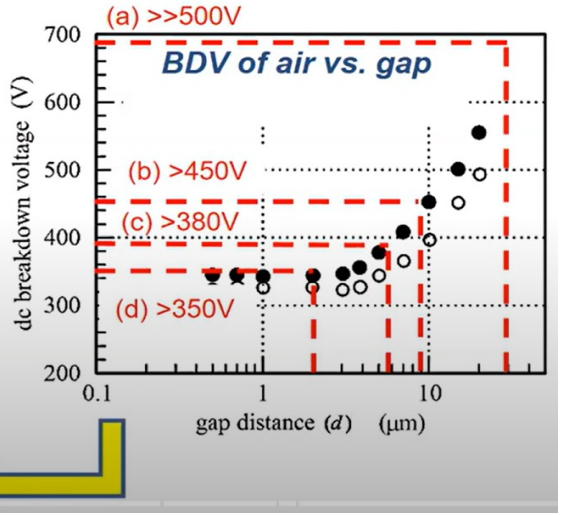


# Solution- (a) Effective gap




| Condition | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| Burr or particle size (µm) | 0 | 3 | 6 | 10 | 15 |
| Breakdown voltage (V) | >>500 | >>450 | >380 | >350 | N/A |




IR/ Hi-Pot can easily detect (e) type of imperfection as there will be a high leakage current. Type (a) is not a problem. However, type b, c, and d requires further analysis. Only IR/LC measurement-based test solution is not sufficient.

Adequate insulation test requires two tests

1. Effective distance test
2. Leakage current test

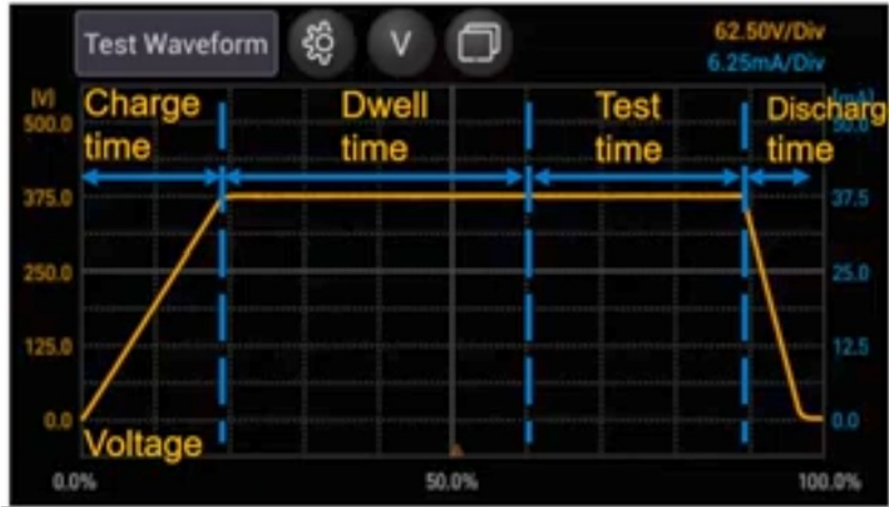
Measuring only **insulation resistance/Leakage Current** is not sufficient**.**

Regular IR meter or Hi-Pot tester can only measure average leakage current during the "Test Time" or a specified time interval and not during entire cycle of charge, dwell, test and discharge. Also, It will not detect any PD/Flash

May cause missing detail

- Voltage change
- Leakage current

during charge time, dwell time or discharge time




There is a need for a solution that analyses the entire process of charge time, dwell time, and test time

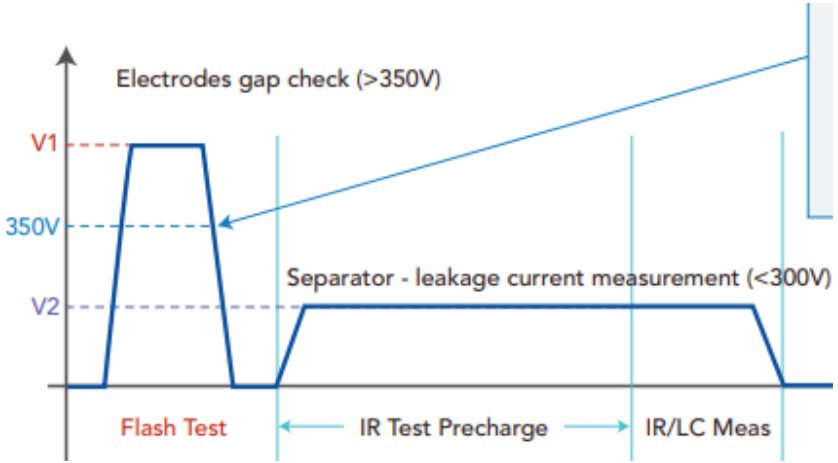
# Our Solution

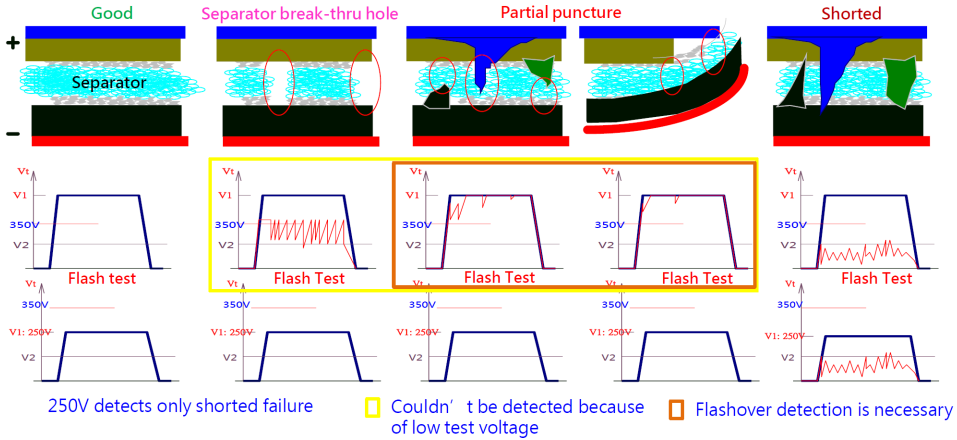
Two step test method

1. High voltage Flash Test
2. Low voltage LC/IR test

Monitors the entire process of testing for flashover due to PD, quantifies the data in in numbers and recordable waveform.

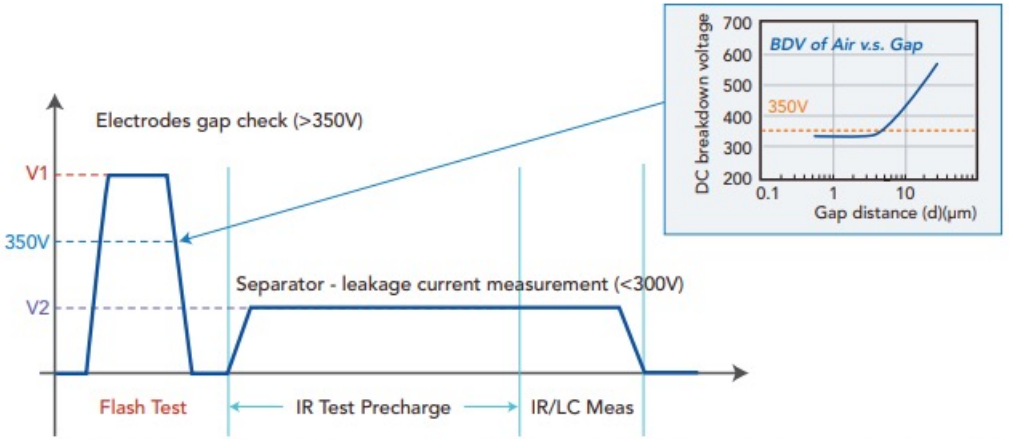
+Flash function provides two stage intermittent high and low voltage, detects the DUT's withstand voltage under high voltage and leakage current under low voltage.



Variety of test condition including

- Test voltage
- Charging current
- Measurement range
- Judgement conditions




[Figure 9] Application of Chroma 11210 + Flash Test function during inspection of Li-ion Battery insulation quality

**Test judgement condition for the distance test and leakage current test differs significantly in terms of voltage and duration.**

# Setting-up Voltage (V1 and V2)- Typical Example

## Test conditions

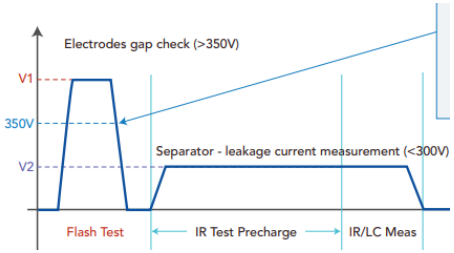
1) Mode: It is recommended to test with +Flash mode as explained to cover all LIB insulation test requirement.
2) Test voltage ($V_T$) level:
   - ① V1: To make sure effective gap distance between electrodes can cover the inflation from Negative electrode after cycles charging

     Ex: δn = 50μm, graphene inflation 24% after (10) C/D cycles

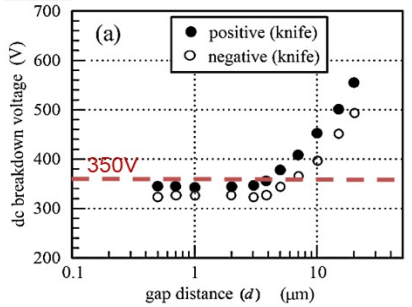
     ➔ > 12 μm gap distance is necessary. BDV of air @ 12 μm is above 450Vdc. Therefore ***Vt > 450V is necessary in this case.***

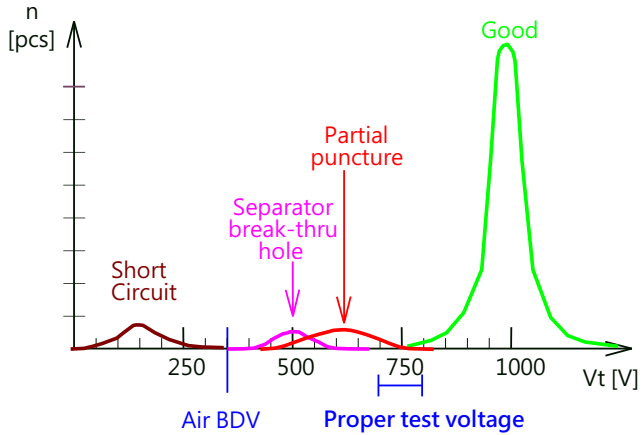
     (Note, for a δsep = 25μm; BDV is > 800V ~ 2.5kV for normal separator)

   - ① V2: To make sure the leakage current cause by electron conductive impurities is low enough. The Vt should be lower than 300V (below air BDV). 50 V (10 times of LIB working voltage, lower C/D level for shorter test time, ..) should be enough.




Air breakdown curve



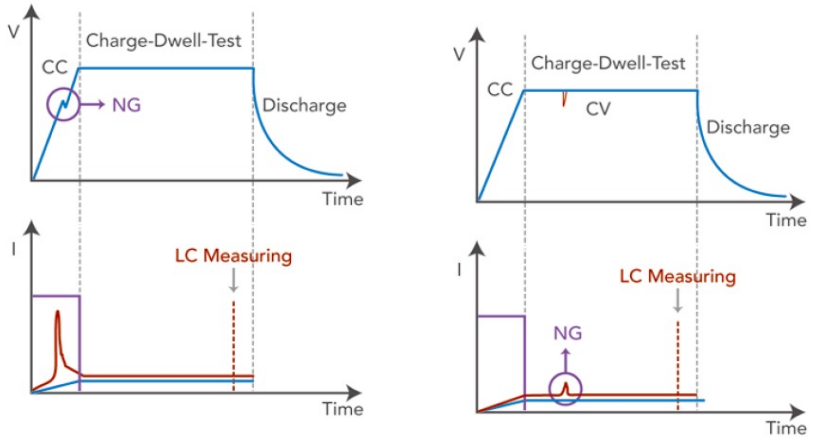
# Analysis: P.D. / Flashover Detection And Measurement Function

Designed to charge at constant current. Option card analyses the voltage curve transition. During dwell time, in case of flashover, there will be spike in Leakage current.

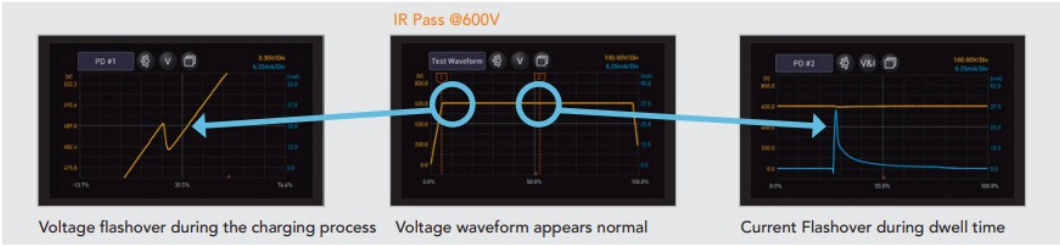
Threshold level can be set by the user both magnitude or number of occurrences.

It can also measure the abnormality in current and voltage waveforms

It has zoom function to analyse PD waveforms in details




Constant current charging



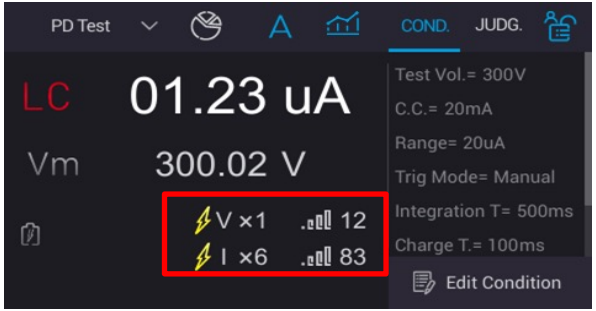

[Figure 8] Chroma 11210 can record the voltage waveform of PD for every defective product

**PD/Flashover can be reliably detected during charging, dwell and discharge phase of LIB cell**

# Our Solution - 11210

- Test voltage :  up to 1KV
- Programmable charging current (High current with fast measurement): 0.5~50mA
- Wide Range of Leakage Current Measurement (1 pA - 20 mA) with 7 ranges and Auto range selection feature
- High speed testing : (20mS/min)
- Contact check within 5 milliseconds (pre-test, post-test or both)
- Fully automatic tests (charge-dwell-measure-discharge)
- Full color display with touch panel
- USB, RS-232, Ethernet interfaces


- Partial discharge/flashover detection for inspection on potential internal short circuits (option of A112100):
  - PD level and number of occurrence display
  - PD events and V/I waveform monitor
  - Programmable PD level limit setting
  - PD and V/I waveform logging (option of A112101)
- Zoom-in functionality for detailed analysis



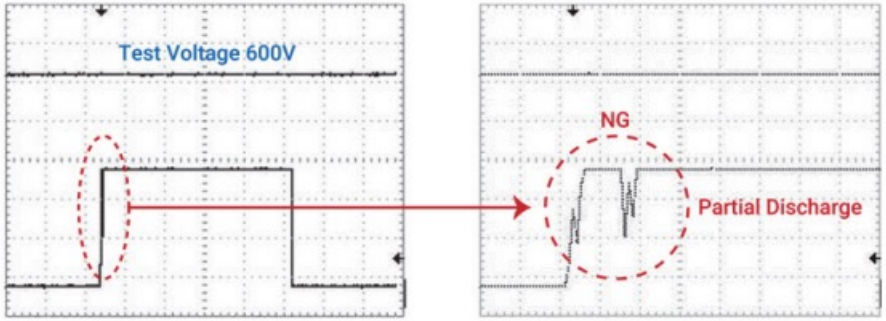
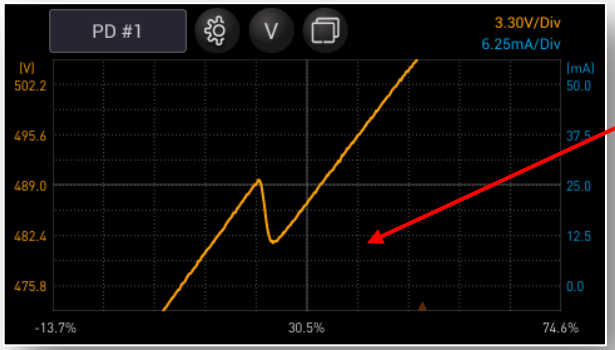




*Figure 8. PD Without looking into the details of the voltage waveform (left), you see nothing abnormal. With the Chroma 11210 zooming into the details, we can see two PD events have occured; one in CC mode, the other in CV mode (right)*

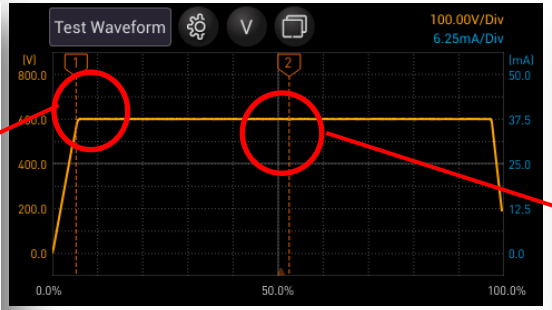
**Option(PD detection and analysis) features make 11210 more versatile and user friendly**

## Real case of electrical flashover occurred during a cell insulation test.

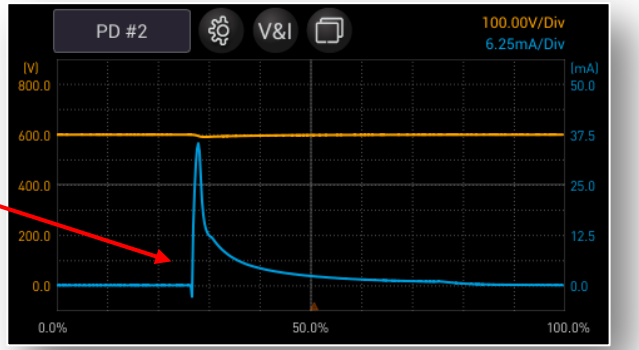
IR Pass @600V



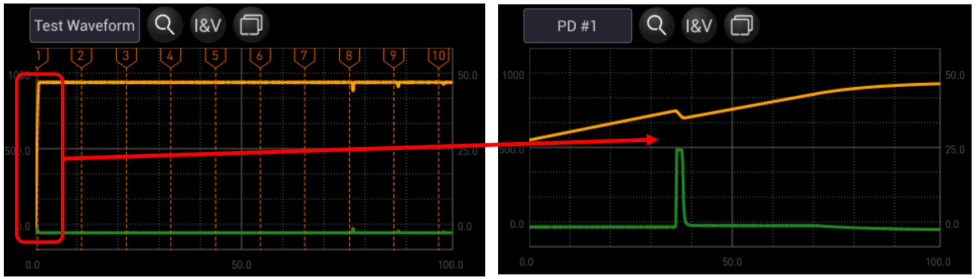

Voltage flashover occurred during the charging process.




Voltage waveform looks normal..




Current flashover occurred during dwell time.




PD Analyzer function – PD/flashover failure waveforms zoom in

# Complete Solution

11210 with Two Options

1. Partial Discharge Detection Card
2. Partial Discharge Analyzer Card

1. Touch panel display
2. Power button
3. High voltage output terminals
4. USB (host) interface (A-type)
5. Start button (starts the test)
6. Stop button (stops the test)
7. DANGER indicator
8. PASS indicator
9. FAIL indicator
10. AC power input
11. AC input Fuse
12. Input voltage range selector
13. Grounding terminal
14. Ventilation fan
15. Interlock protection terminals
16. Handler interface (Amphenol 57-30240 type)
17. PD tester/PD analyzer card slot (option)
18. USB (device) interface (B-type)
19. Ethernet interface (RJ-45)
20. RS-232 interface (D-sub 9-pin)



Early detection is the key to prevention; mitigate problems before they escalate. let's continue advancing safety in battery technology together.

**Thank You**

Chroma

# Empowering future technologies for a better world

**Thank you**


## Stand B9

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