

FAILURE ANALYSIS OF SAMSUNG NOTE 7

JANUARY 23, 2017

UL & THE SCIENCE OF BATTERY SAFETY

UL HAS DEEP KNOWLEDGE IN THE SCIENCE OF LITHIUM-ION BATTERY SAFETY



- Research staff includes scientists and engineers with backgrounds in material science, electrochemistry, mechanical and electrical engineering



- Research capabilities include failure forensic analysis, internal short circuit (ISC) simulation, thermal electrochemical modeling, aging simulation and others
- Prior research work includes US National Transportation Safety Board (NTSB) investigation into safety of lithium-ion batteries on airplanes



- Published 10+ standards on battery & energy storage technology safety

SCOPE OF PROJECT – COMPANY A

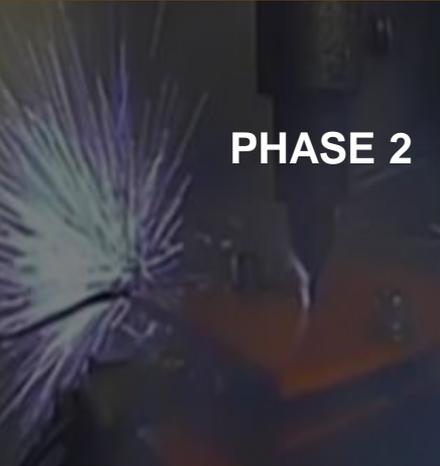
All samples provided by Samsung



PHASE 1

FIELD EVENT SAMPLES ANALYSIS

Tear-down examination of 10 damaged Note 7 devices with COMPANY A's batteries to understand the failure mechanism and potential causes of failure



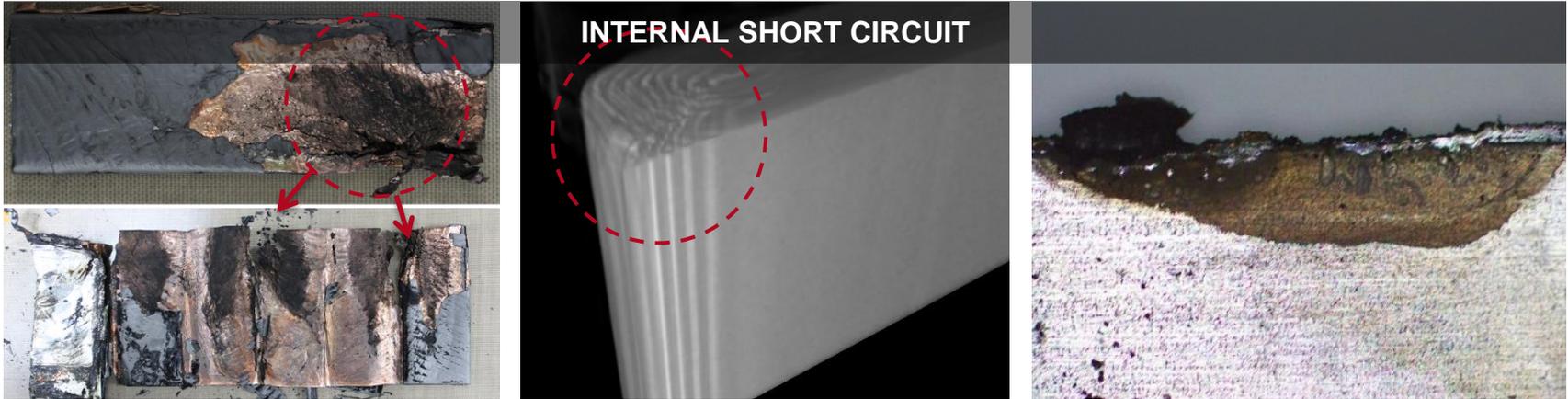
PHASE 2

BATTERY SAFETY BOUNDARY CHARACTERIZATION

Study battery failure mechanisms on 110 new COMPANY A batteries under various abuse conditions to identify potential battery safety issues

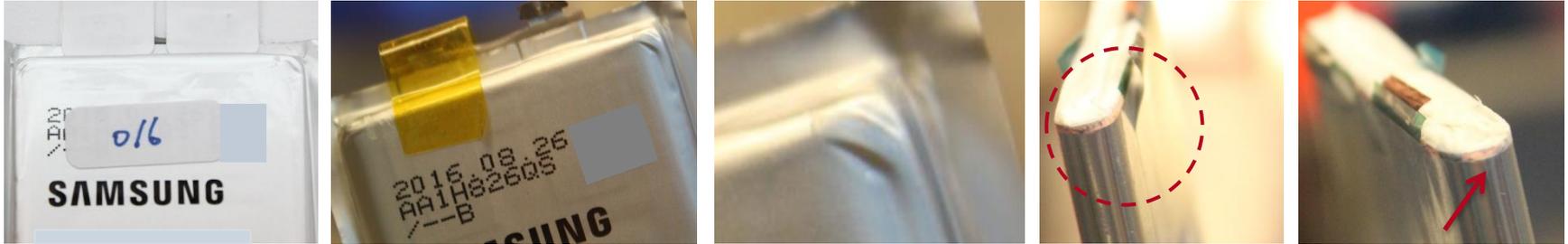
PHASE 1 KEY FINDINGS – COMPANY A

- Signs of internal short circuit (ISC) at the upper right corner of the cells from 6 damaged devices
- Signs of ISC at the upper right corner of 4 swollen cells



PHASE 2 KEY FINDINGS – COMPANY A

- CT scan of 30 cells and disassembly of 20 cells found only minor anomalies such as small void/bubble or uneven stress.
- Samples show a similar pattern of deformation at upper corners. Upper right corner deformation appears to be deeper than upper left.
- Tear down analysis shows repeating deformation areas on separator at the corner locations.



REPEATED DEFORMATION PATTERNS CAN BE OBSERVED AT THE CORNERS OF THE SEPARATOR

ASSESSMENT – COMPANY A

- I. There may be multiple contributing factors relating to battery assembly/manufacturing and design that when combined led to the failure of the Note 7 in the field
 - A. Battery assembly/manufacturing:
 - Deformation at the upper corners
 - B. Battery design:
 - Thinner separator could lead to poorer protection and reduced tolerance to manufacturing defects
 - Higher energy density in general can exacerbate the severity of a battery failure
- II. One major failure mechanism is likely:

A combination of deformation at the upper corners + thin separator + repeating mechanical stresses due to cycling, causing higher possibility of separator damage leading to an ISC between aluminum and copper foil at the corner
- III. Additional investigation is needed to understand the root-cause of the deformations at the upper corners

SCOPE OF PROJECT – COMPANY B

All samples provided by Samsung



PHASE 1

FIELD EVENT SAMPLES ANALYSIS

Tear-down examination of 10 damaged Note 7 devices with COMPANY B's batteries to understand the failure mechanism and potential causes of failure



PHASE 2

SYSTEM LEVEL COMPATIBILITY CHARACTERIZATION

Testing of 40 new Note 7 devices with COMPANY B's batteries under various conditions – to determine whether the device contributes to battery failure



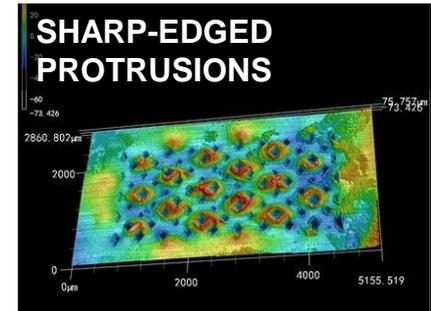
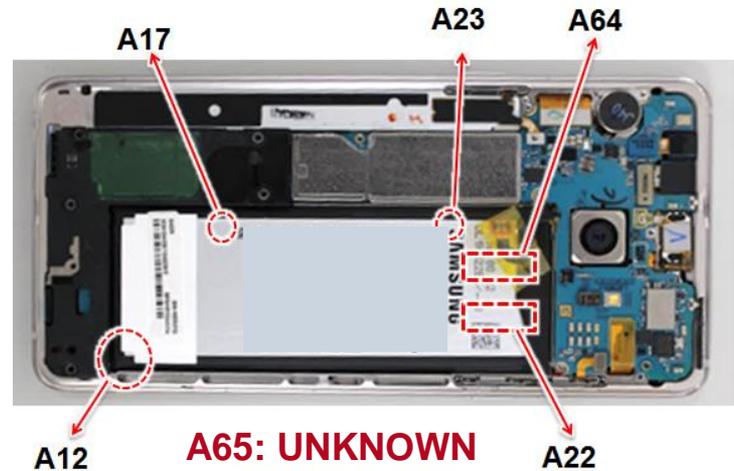
PHASE 3

BATTERY SAFETY BOUNDARY CHARACTERIZATION

Study battery failure mechanisms on 354 new COMPANY B batteries under various abuse conditions to identify potential battery safety issues

PHASE 1 KEY FINDINGS – COMPANY B

- Signs of internal short circuit (ISC) at different locations of the cells from 5 of the damaged devices
- Signs of ISC at the tab locations of swollen cells
- Missing insulation tape on the cathode of swollen cells
- Sharp-edged protrusions on the tab welding spots of swollen cells

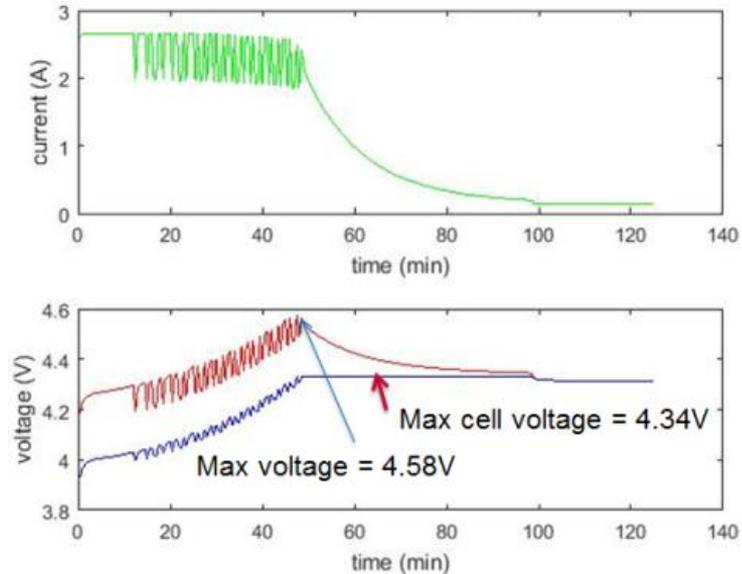


PHASE 2 KEY FINDINGS – COMPANY B

- Note 7 components do not increase the battery cell temperature to a level higher than the specified threshold

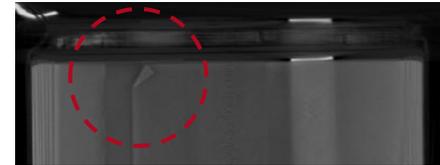
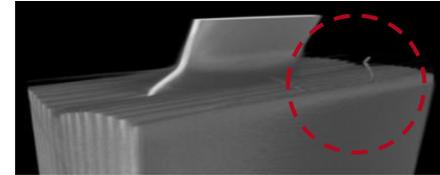
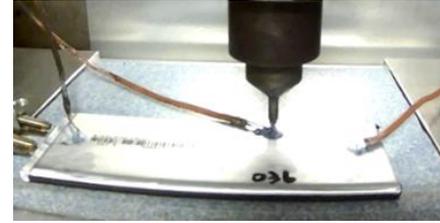


- Note 7 maximum current drain meets the specifications provided by Samsung
- The maximum charging current, the maximum temperatures and the maximum cell voltage are within the specifications with the standard adapter provided by Samsung



PHASE 3 KEY FINDINGS – COMPANY B

- The failure mode (ISC in winding edge) observed in field event samples can be reproduced by UL's ISC or localized heat pad tests
- Flaws were readily found from 3D CT scan of some samples
- Tear-down analysis findings include:
 - Uneven charge status on multiple samples
 - Signs of internal short circuit
 - Poor alignment and inconsistent shape and dimension of tabs and insulation tapes
 - Sharp edge protrusion of welding joints



ASSESSMENT (1/2) – COMPANY B

- I. No evidence of device-level compatibility issues that may have contributed to the failure of the Note 7 in the field
- II. There may be multiple contributing factors relating to production quality and battery design that when combined led to the failure of the Note 7 in the field
 - A. Production quality:
 - Missing insulation tape on tab could result in higher possibility of ISC
 - Bigger protrusion of welding points in tab could lead to higher possibility of separator puncture
 - Misalignment of insulation tape and/or tab could bring more risk of ISC
 - B. Battery design:
 - Thinner separator could lead to poorer protection and reduced tolerance to manufacturing defects
 - Higher energy density in general can exacerbate the severity of a battery failure

ASSESSMENT (2/2) – COMPANY B

III. One major failure mechanism for field incidents is likely:

The combination of (1) missing insulation tape + (2) sharp edged protrusions on tab + (3) thin separator, all leading to a high possibility of an ISC between cathode tab and anode, subsequently resulting in heating and fire

IV. Further analysis is needed to understand the root-cause of the damage to the edge/corner of the battery which results in ISC at that location

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BATTERY EXPERTISE AT :**

[UL.com/batteryscience](https://www.ul.com/batteryscience)



SPEAKER BIOGRAPHY



Sajeev Jesudas
President, Consumer Business Unit, UL

Sajeev Jesudas leads UL's focus on product quality, performance, security and safety for UL customers in the consumer, retail and financial payment services industries globally. He joined UL in 2001 as President for Asia-Pacific operations and since then has served in many leadership positions with increasing responsibilities, including the role of Chief Operating Officer and that of President, International Operations. Jesudas is the current Chairman of the board of directors of the UL-CCIC joint venture company in China, and sits on the board of more than 20 UL affiliate companies globally.

Before joining UL, Jesudas worked in areas of sales and marketing and general management with a leading global manufacturer of electrical and electronic products for commercial, industrial, utility, and telecommunications markets, where he also held senior positions with Middle East and Asia Pacific regional responsibilities.

Jesudas holds a Bachelor of Science degree in Electrical Engineering from the University of Kerala, India, and an MBA degree from the University of Texas, Austin.



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Dedicated to promoting safe, sustainable and secure living and working environments, UL helps safeguard people, products and places, and builds trust in the the goods, solutions and innovations of today and tomorrow.



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12,000+
ASSOCIATES

180+
FACILITIES

North America
4,000+ People

Africa, Europe,
Latin America,
Middle East
2,000+ People

Asia Pacific
4,000+ People



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