Introduction to Failure Analysis

Wed., April 24, 10 am CDT

Presenter: Angela Criswell | **Co-presenter:** Ted Huang | **Host:** Viral Vaghela

- *You will be muted during the workshop*
- *You can ask questions using the Q&A tool.*
- *You should hear music if your sound is working*

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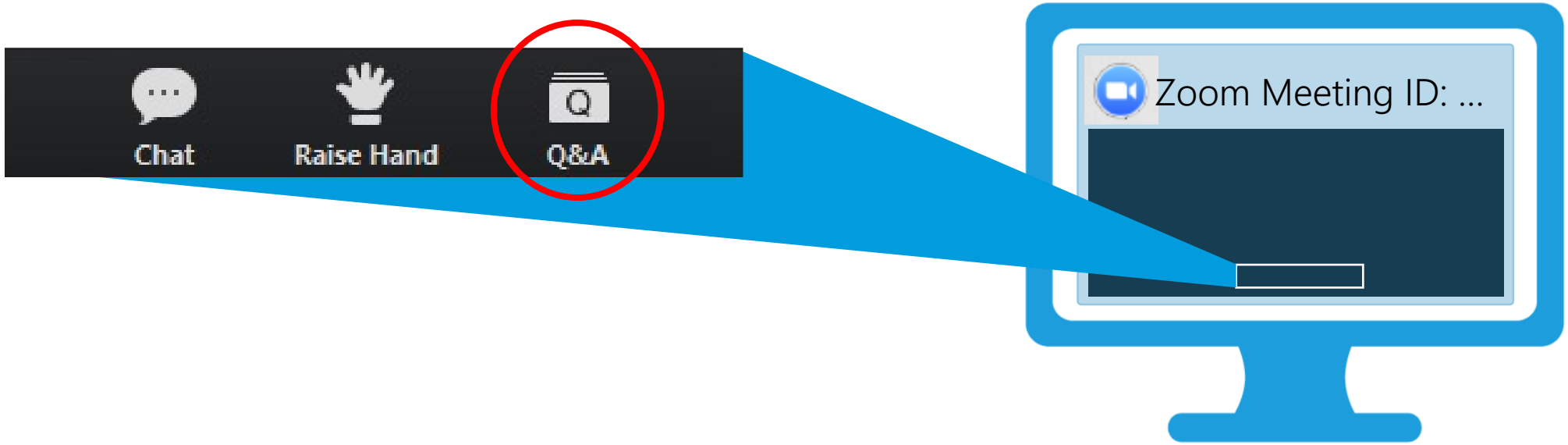
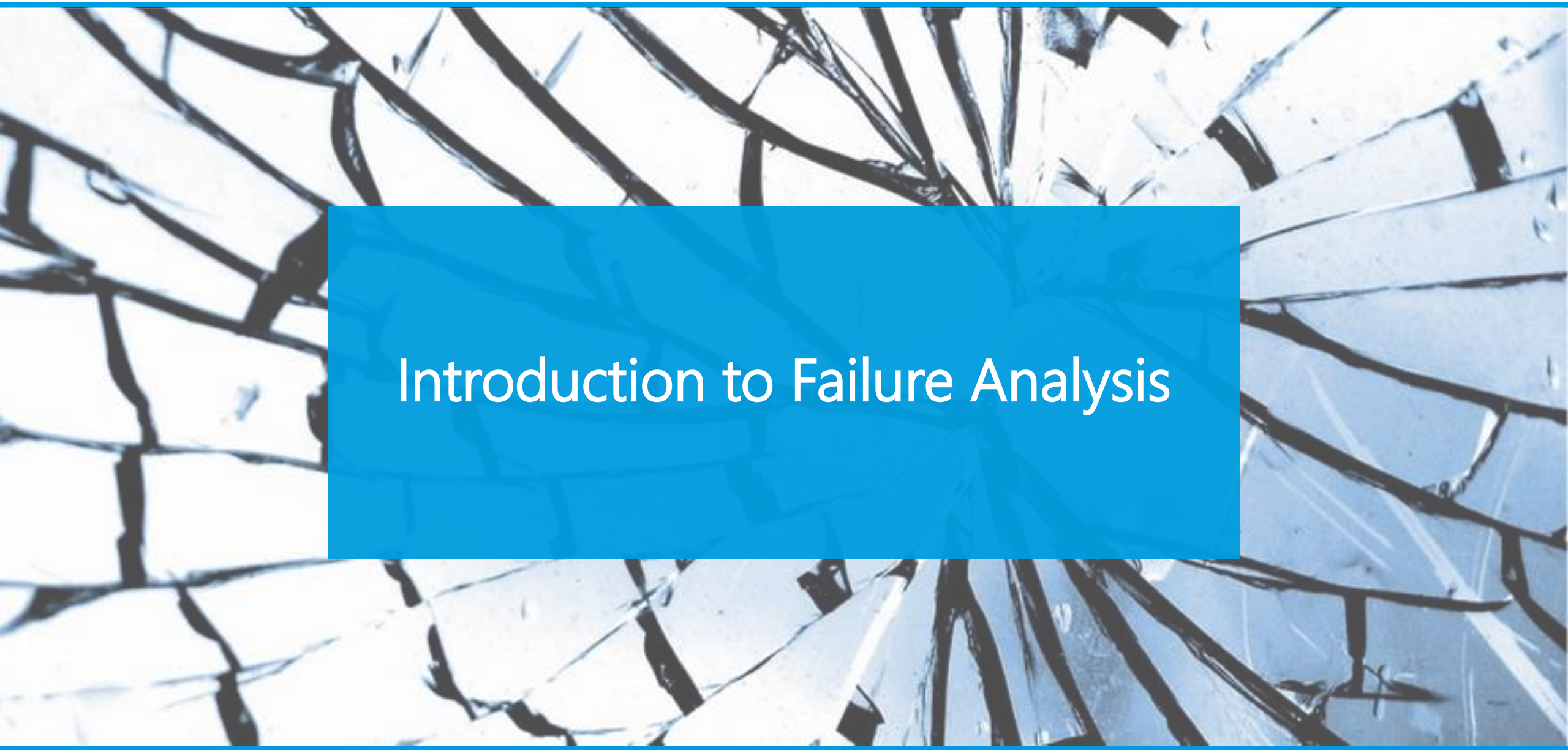
We are starting now…

- Presenter: **Angela Criswell** | Director of X-ray Imaging
- Co-Presenter: **Ted Huang** | Application Scientist
- Host: **Viral Vaghela** | Account Manager



You can send us questions during the presentation.
They will be addressed at the end of the presentation.

A recording of this webinar will be available.
You will receive an email with a link to it tomorrow.



Introduction to Failure Analysis

Polling Question #1

Polling Question #2

Why study failure?

GOOGLE / MOBILE / BREAKING

Samsung recalls Galaxy Note 7 worldwide due to exploding battery fears

MOBILE / BUSINESS / TECH

Samsung formally recalls the Note 7 in the US

/ There are now 92 incidents of overheating batteries

https://www.theverge.com/2016/9/15/12933410/samsung-galaxy-note-7-recall-us-cpsc

By Nick Statt, is a Senior Producer on Decoder. Previously, he wrote about technology and gaming for Naavik, Protocol, and The Verge.
Source US CPSC

Sep 15, 2016, 3:26 PM CDT

0 Comments (0 New)

Why study failure?

NEWS

Samsung Electronics

Samsung Galaxy Note 7 banned on all U.S. flights due to fire hazard

Bart Jansen USA TODAY

Published 3:46 p.m. ET Oct. 14, 2016 | **Updated 10:54 a.m. ET Oct. 16, 2016**

Samsung Galaxy Note 7 phones will be banned from all airline flights after nearly 100 incidents of the devices overheating and sometimes injuring owners, the Transportation Department announced Friday.

https://www.usatoday.com/story/news/2016/10/14/dot-bans-samsung-galaxy-note-7-flights/92066322/

The Samsung Galaxy Note 7 is officially banned from airplanes

By Hayley Tsukayama

October 14, 2016 at 4:43 p.m. EDT

https://www.washingtonpost.com/news/the-switch/wp/2016/10/14/wp/2016/10/14/samsung-galaxy-note-7-banned-from-airplanes/

DOT Bans All Samsung Galaxy Note7 Phones from Airplanes

Friday, October 14, 2016

WASHINGTON – The U.S. Department of Transportation (DOT), with the Federal Aviation Administration (FAA) and the Pipeline and Hazardous Materials Safety Administration (PHMSA), today announced it is issuing an emergency order to ban all Samsung Galaxy Note7 smartphone devices from air transportation in the United States. Individuals who own or possess a Samsung Galaxy Note7 device may not transport the device on their person, in carry-on baggage, or in checked baggage on flights to, from, or within the United States. This prohibition includes all Samsung Galaxy Note7 devices. The phones also cannot be shipped as air cargo. The ban will be effective on Saturday, October 15, 2016, at noon ET.

"We recognize that banning these phones from airlines will inconvenience some passengers, but the safety of all those aboard an aircraft must take priority," said Transportation Secretary Anthony Foxx. "We are taking this additional step because even one fire incident inflight poses a high risk of severe personal injury and puts many lives at risk."

Device owners have experienced documented incidents of dangerous evolution of heat with both recalled and replacement Samsung Galaxy Note7 devices. Samsung and the U.S. Consumer Product Safety Commission (CPSC) acknowledged this imminent safety hazard with the company's September 15, 2016 and October 13, 2016 recalls. Additionally, on October 11, 2016, Samsung suspended the manufacture and sale of the Samsung Galaxy Note7 device.

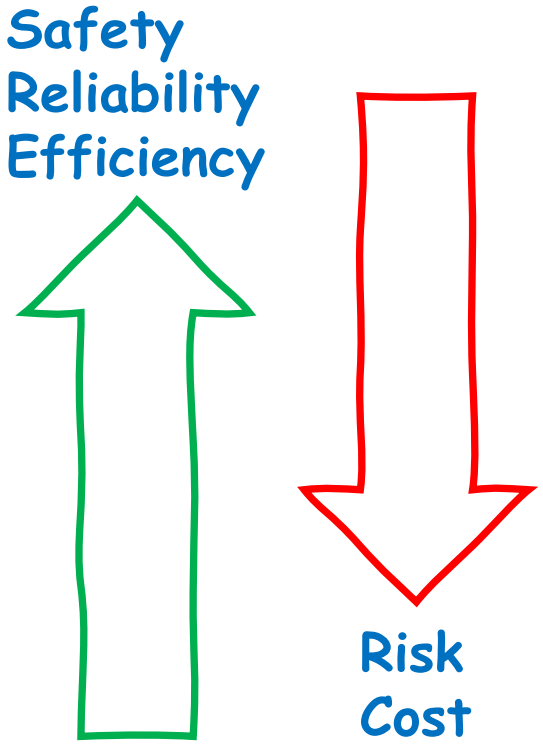
You will learn

- What is failure analysis?
  - Why and when should we perform failure analysis?
  - What steps are involved in failure analysis?
- What are common failure analysis techniques?
  - Destructive techniques
  - Non-destructive techniques
- Considerations when using X-ray CT for failure analysis
- Failure analysis examples

What is failure analysis?

Failure analysis is the examination of a failed component and the failure situation to determine the causes of failure.

Why and when should we perform failure analysis?



- Design development
- Design improvement
- After product failure
- Establish liability

What steps are involved in failure analysis?

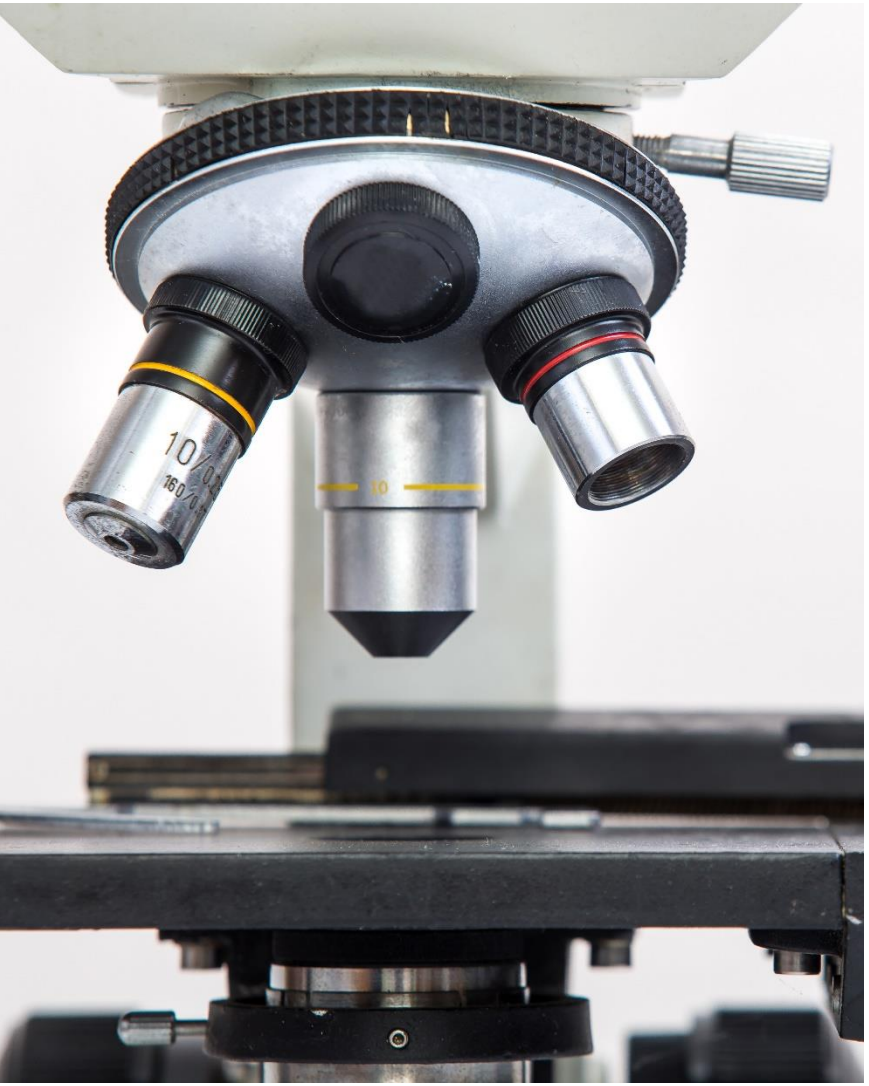
- Describe the failure situation
- Visual inspection
- Decide what to analyze further
- Choose the appropriate techniques for analysis
- Data collection
- Data analysis to determine root cause
- Determine corrective actions

What are common failure analysis techniques?

Pixabay

Destructive techniques

- Decapsulation
- Cross-sectioning
- Fracture and mechanical testing
- Fatigue testing
- Corrosion testing
- SEM/TEM, FIB



Pixabay

Non-destructive techniques

- Visual/Optical inspection
- Electrical characterization
- Liquid dye penetrant
- Ultrasonic testing
- Acoustic microscopy
- Infrared imaging (IR)
- X-ray radiography
- X-ray CT

Visual/Optical testing

- Uses human vision and/or any specialized inspection equipment.
  - Microscopes

Microsoft stock

Visual/Optical testing

- Uses human vision and/or any specialized inspection equipment.
  - Microscopes
  - Borescopes, fiberscopes

Wikipedia image courtesy of LandyAtkinson,
CC BY-SA 3.0, File:BorescopeApplication.png)

Visual/Optical testing

- Uses human vision and/or any specialized inspection equipment.
  - Microscopes
  - Borescopes
  - Camera and video systems

Wikipedia image courtesy of Hustvedt,
CC BY-SA 3.0, File:Three Surveillance cameras.png

Visual/Optical testing

- Uses human vision and/or any specialized inspection equipment.
  - Microscopes
  - Borescopes
  - Camera and video systems
  - Robotic vision systems

Meet the Robots of Fukushima Daiichi › A cleanup crew of automatons will go where humans fear to tread

BY ELIZA STRICKLAND | 28 FEB 2014 | 0 MIN READ |

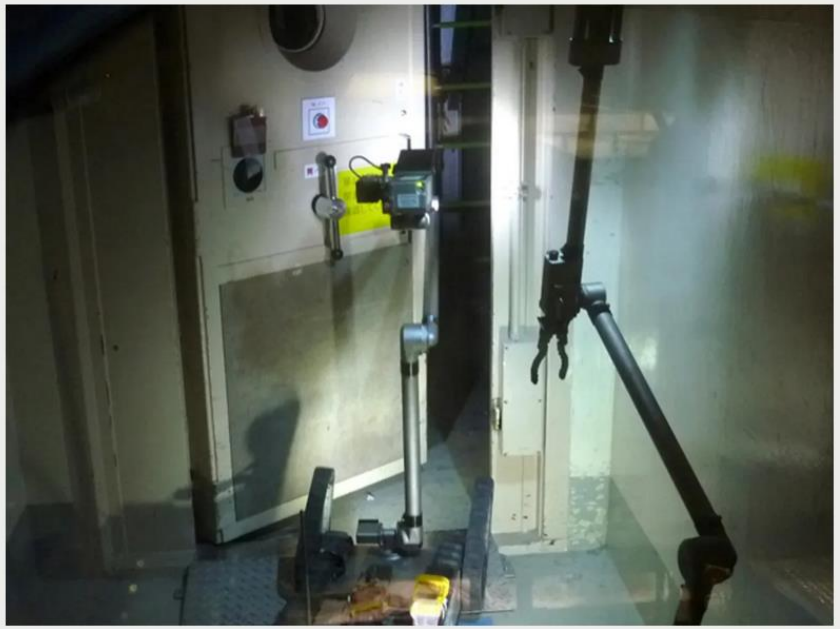
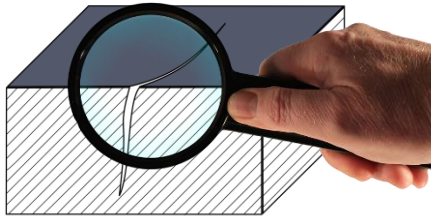


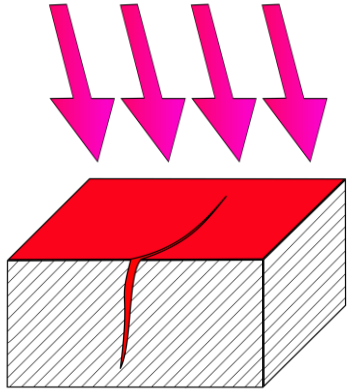
Image courtesy of IEEE

Liquid dye penetrant testing

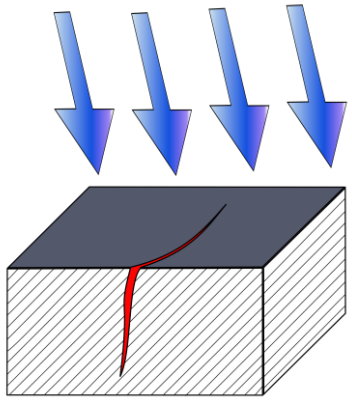
Suspected crack identified by visual inspection



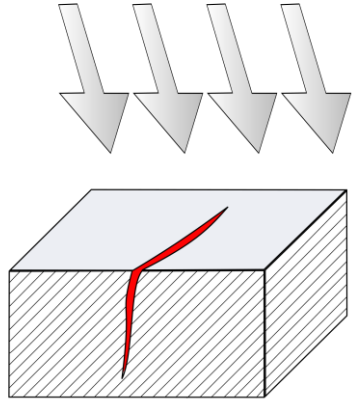
Apply penetrant



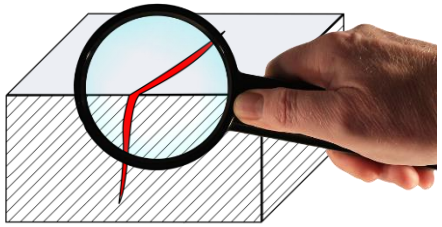
Remove excess penetrant



Apply developer

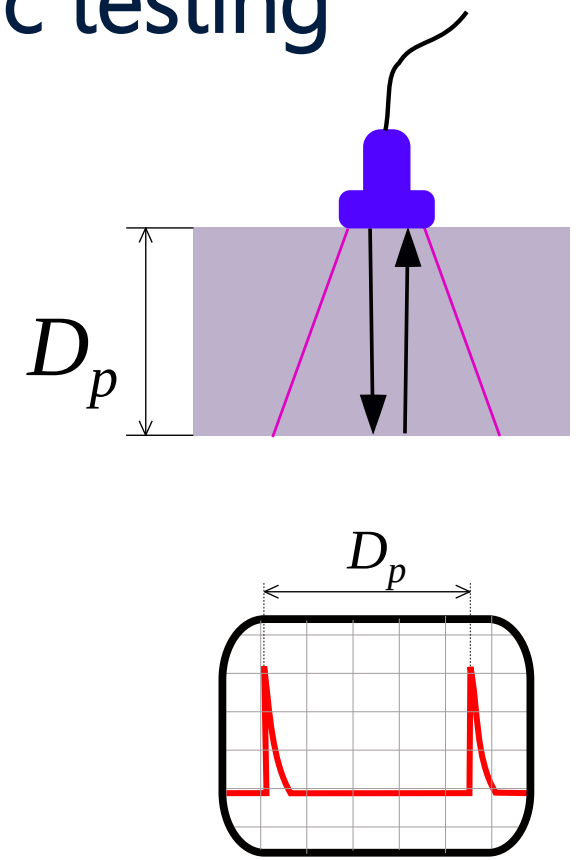


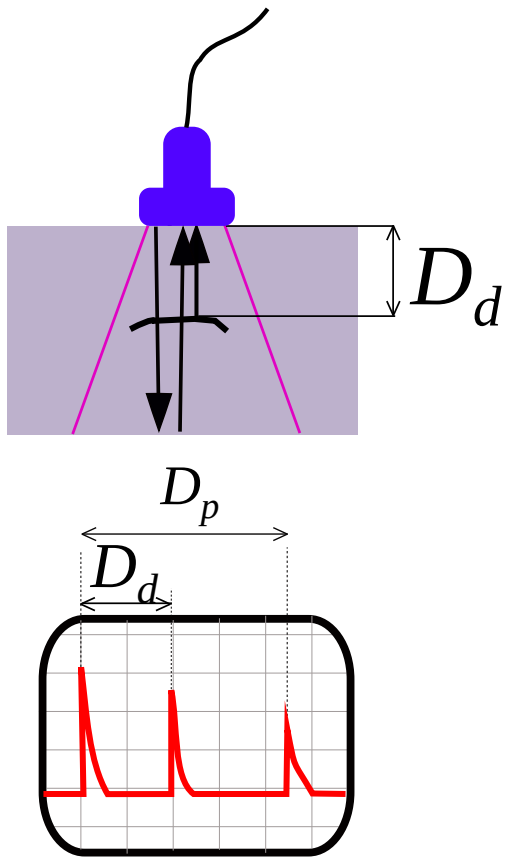
Inspect



Pixabay, Wikipedia image courtesy of Romary juillet/July 2006, CC BY 2.5, Ressuage_principe_2.svg

Ultrasonic testing





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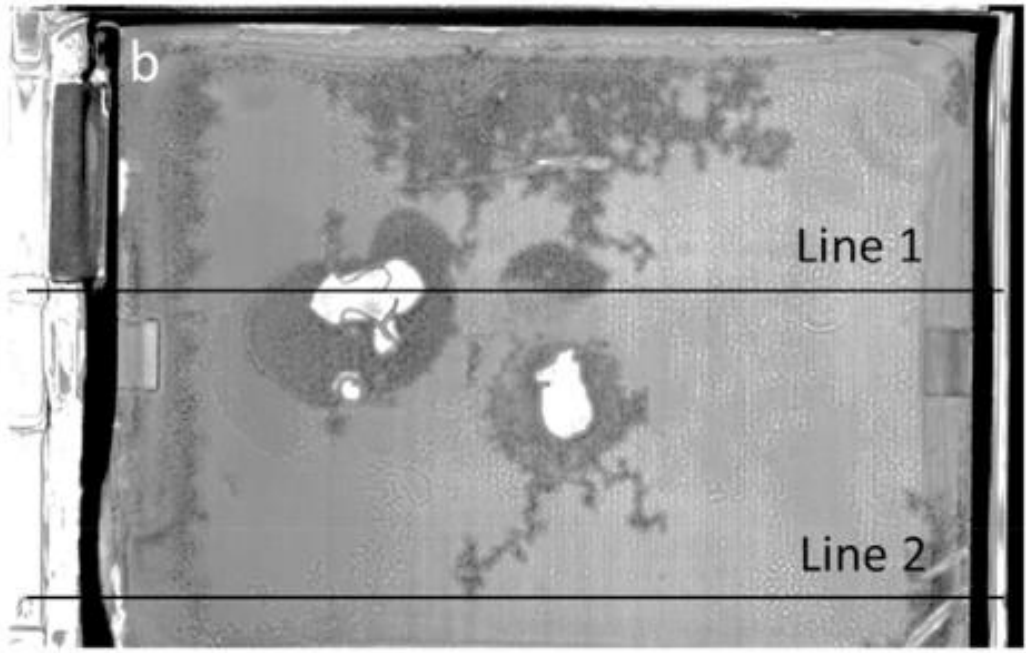
Acoustic microscopy

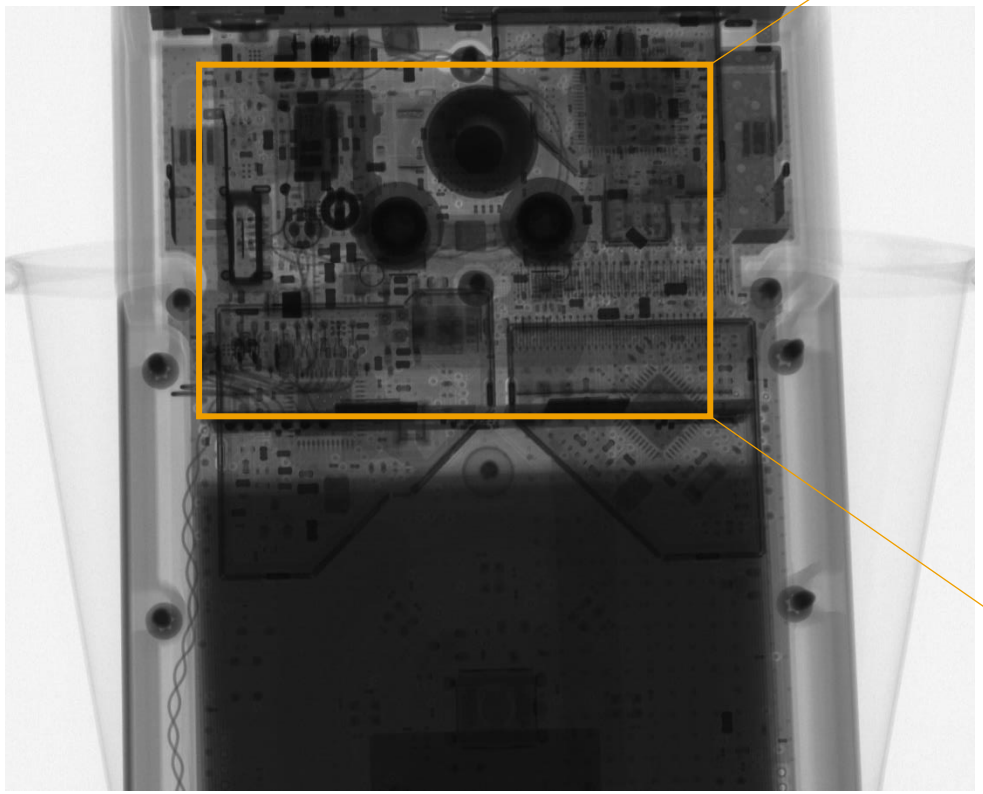
Battery pouch cell

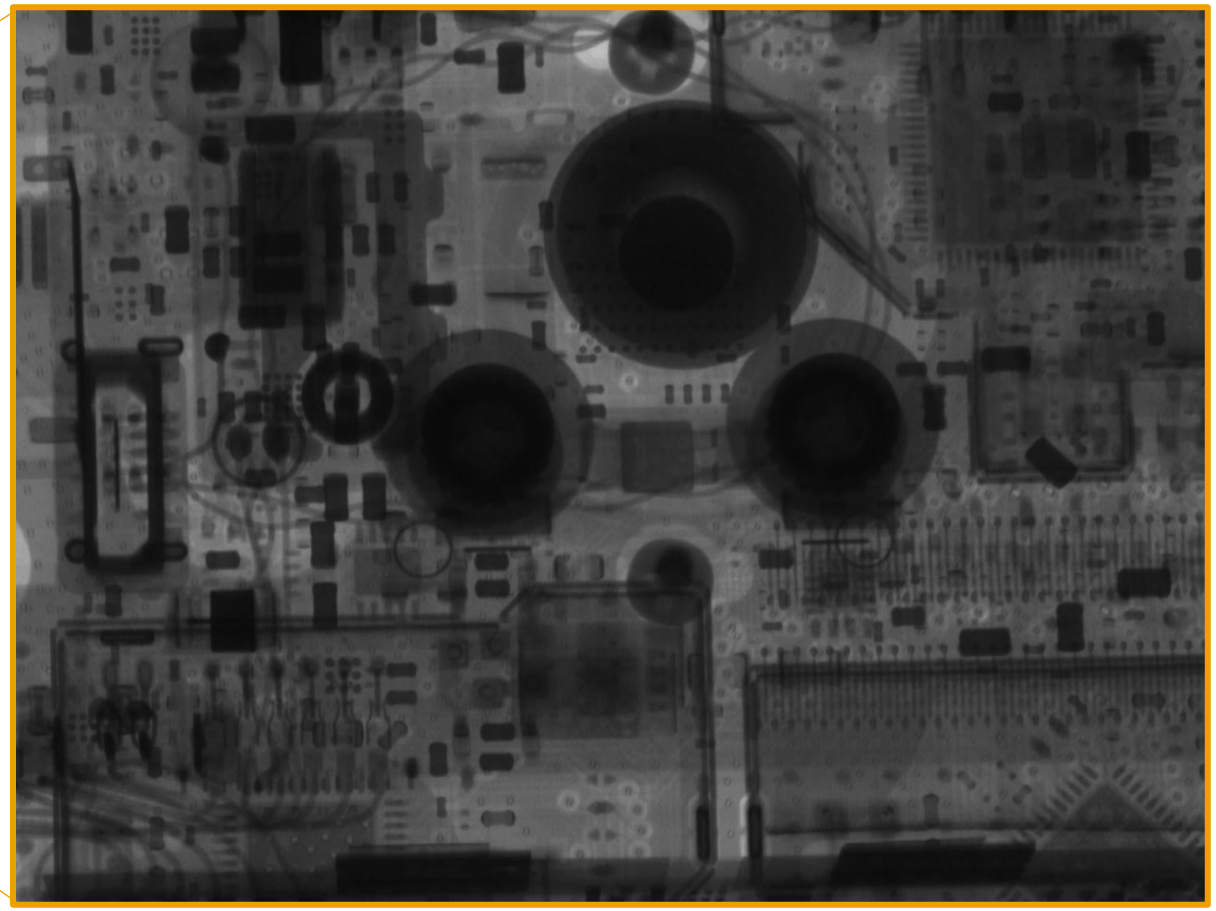


Scanning acoustic micrograph

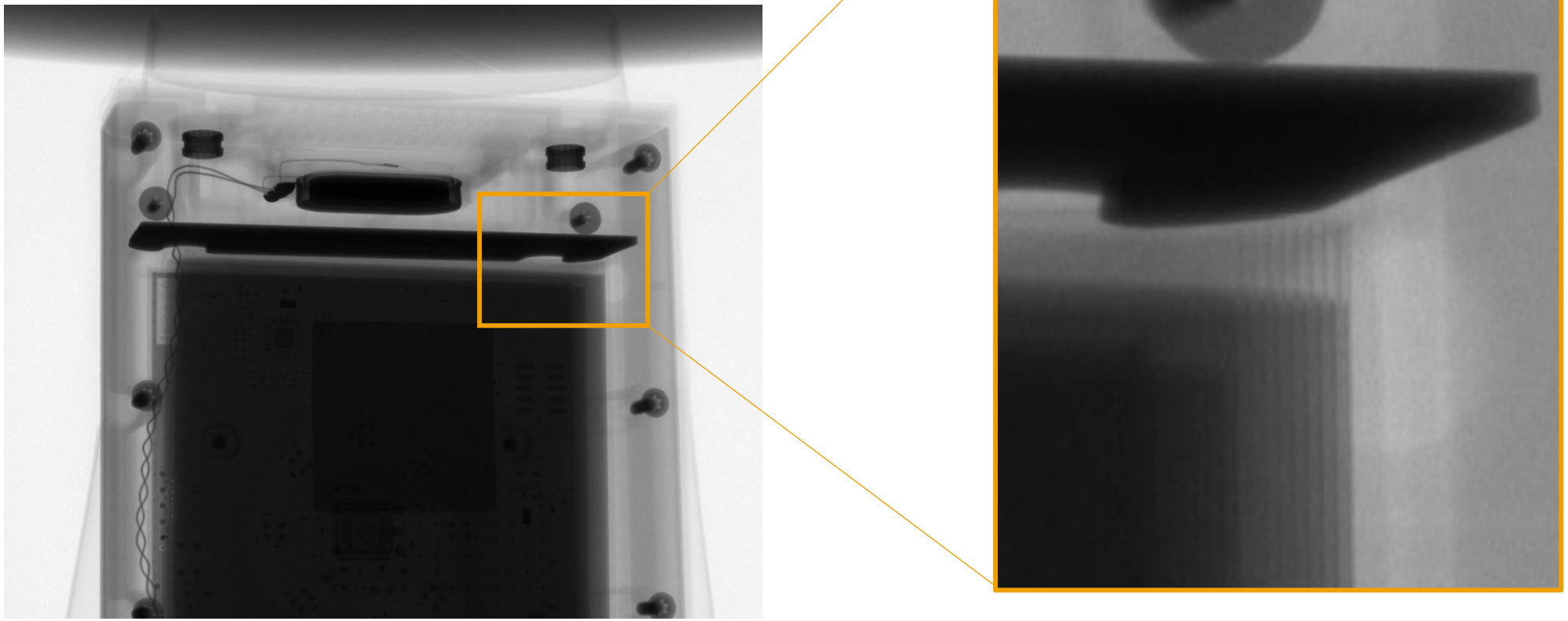
Bauermann, L.P., et. Al.., 2020. Journal of Power Sources Advances 6, 100035

X-ray radiography

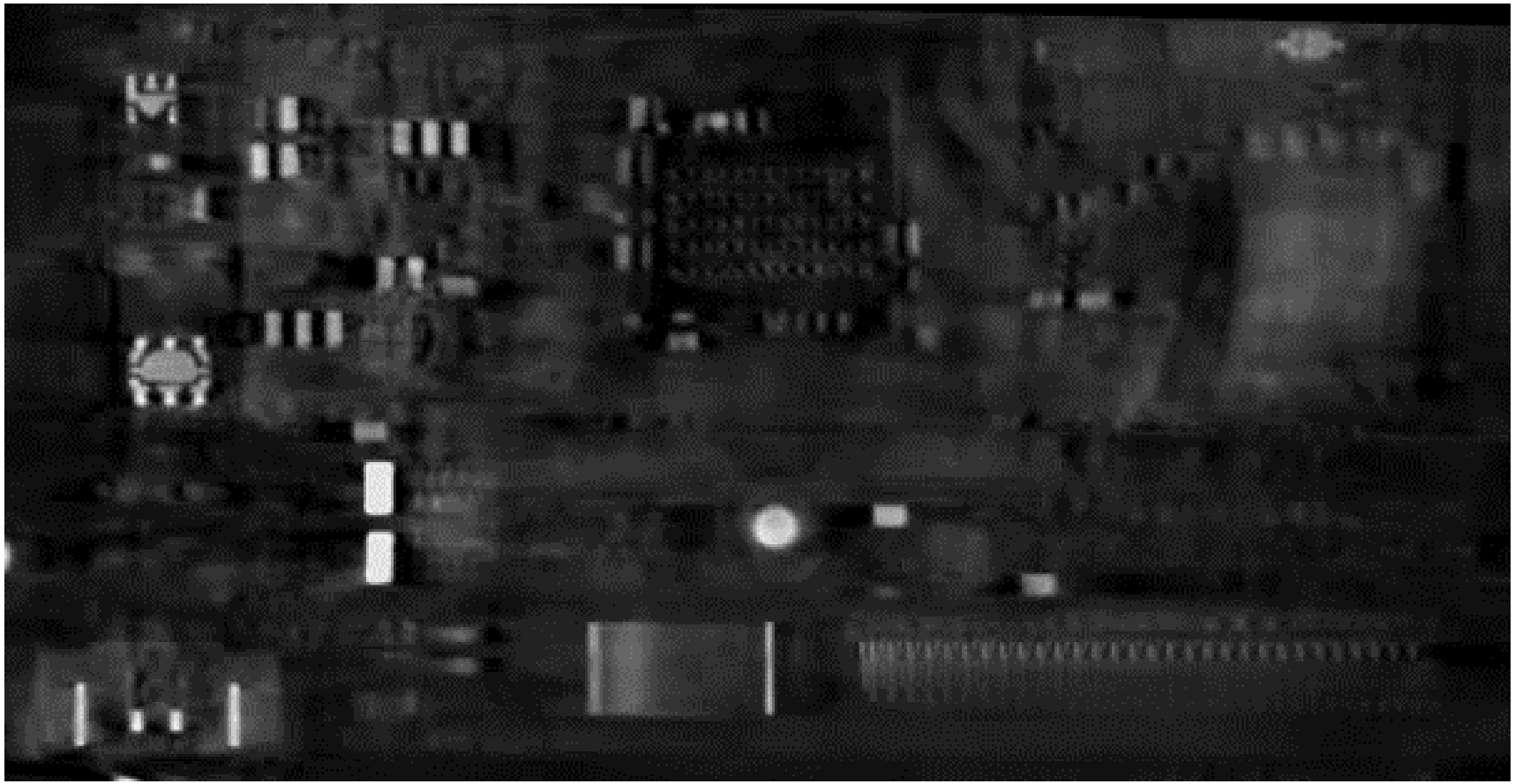




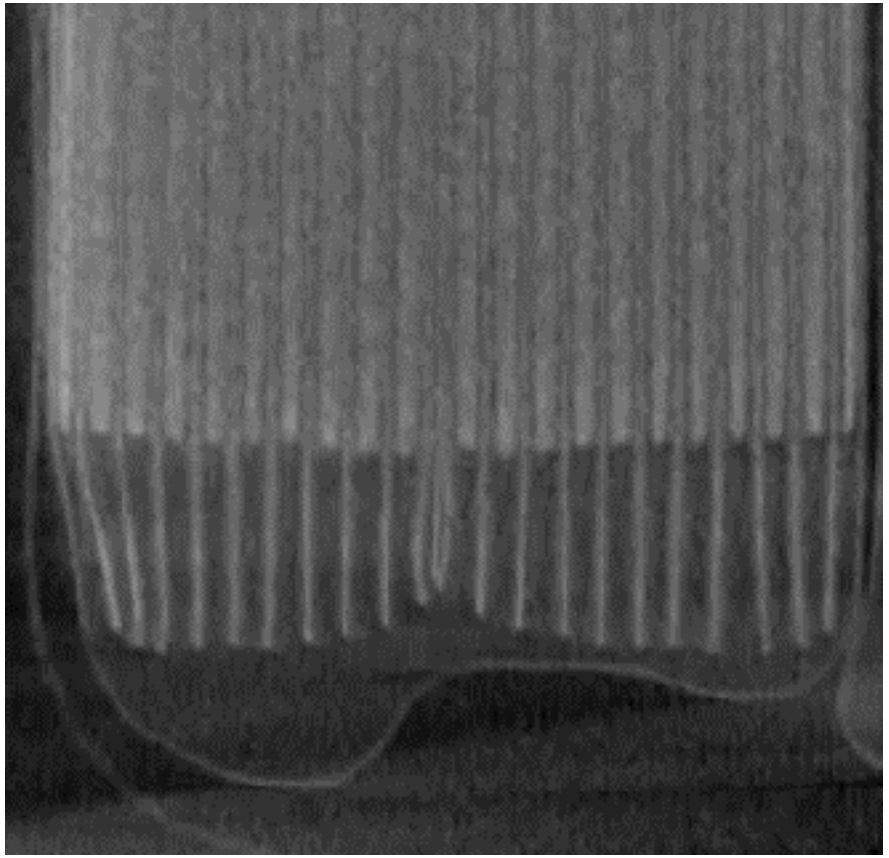
X-ray radiography



X-ray computed tomography



X-ray computed tomography

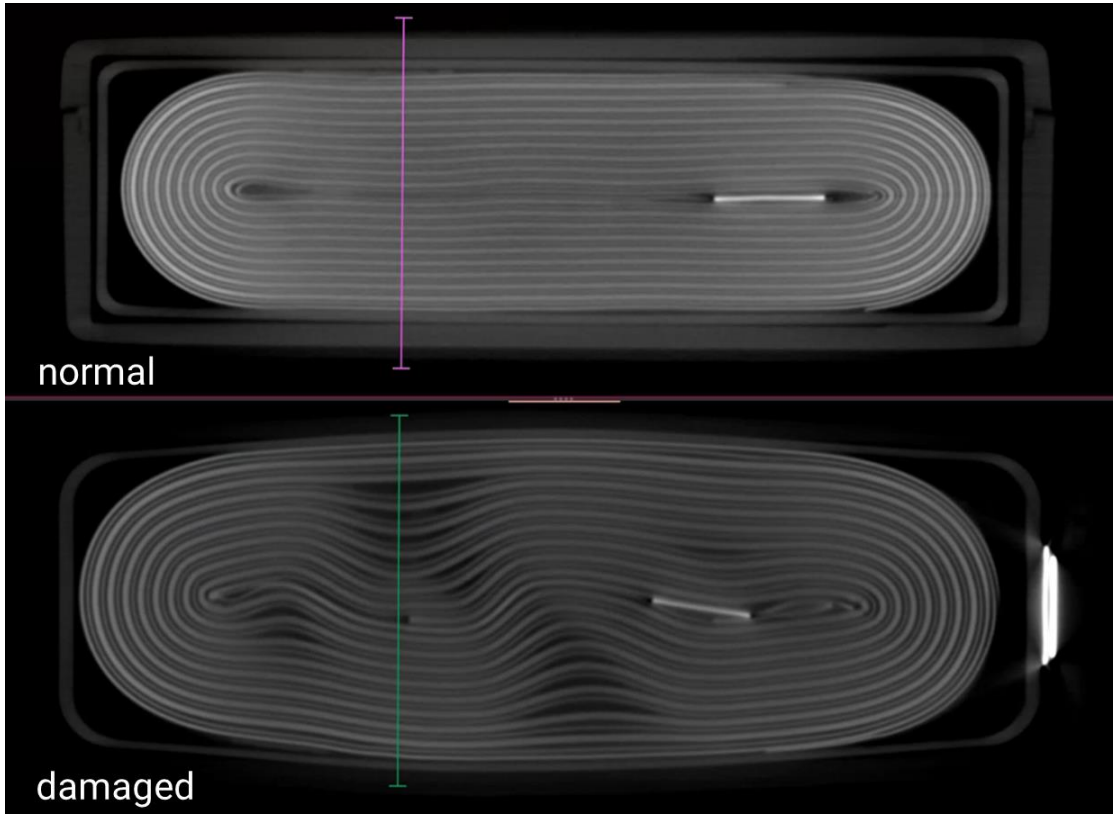


X-ray computed tomography

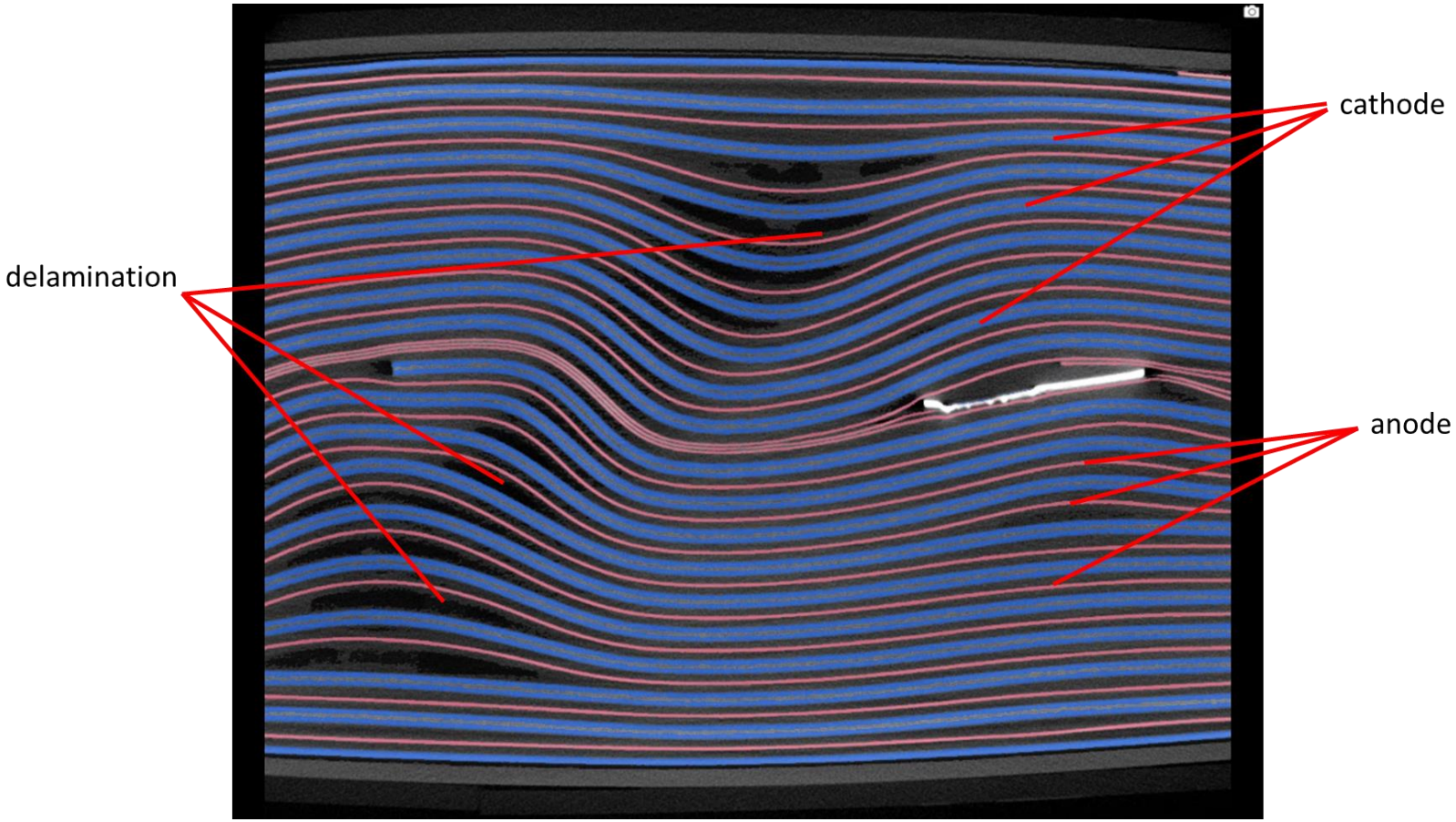
Normal

Damaged

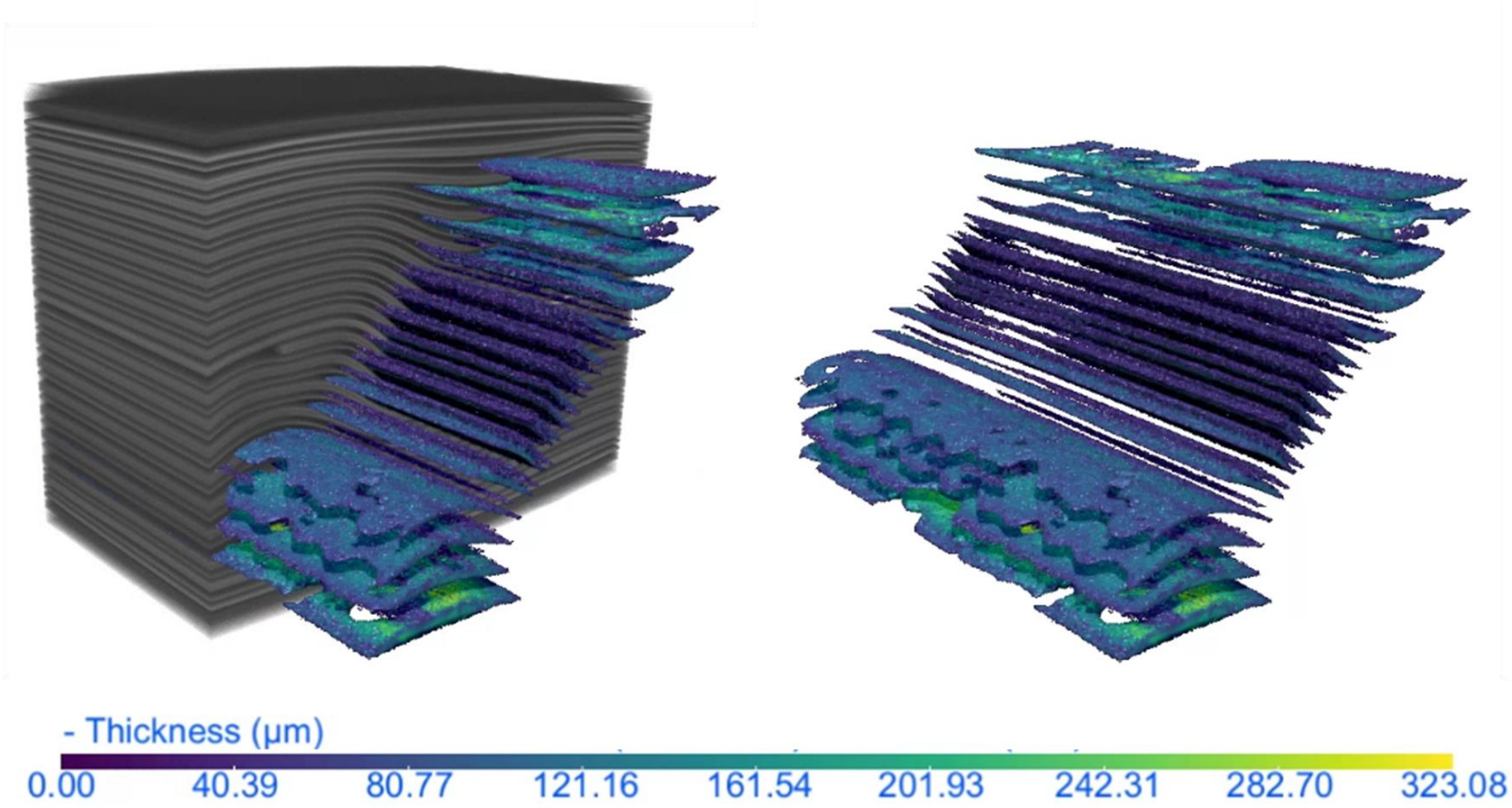
X-ray computed tomography



X-ray computed tomography



X-ray computed tomography



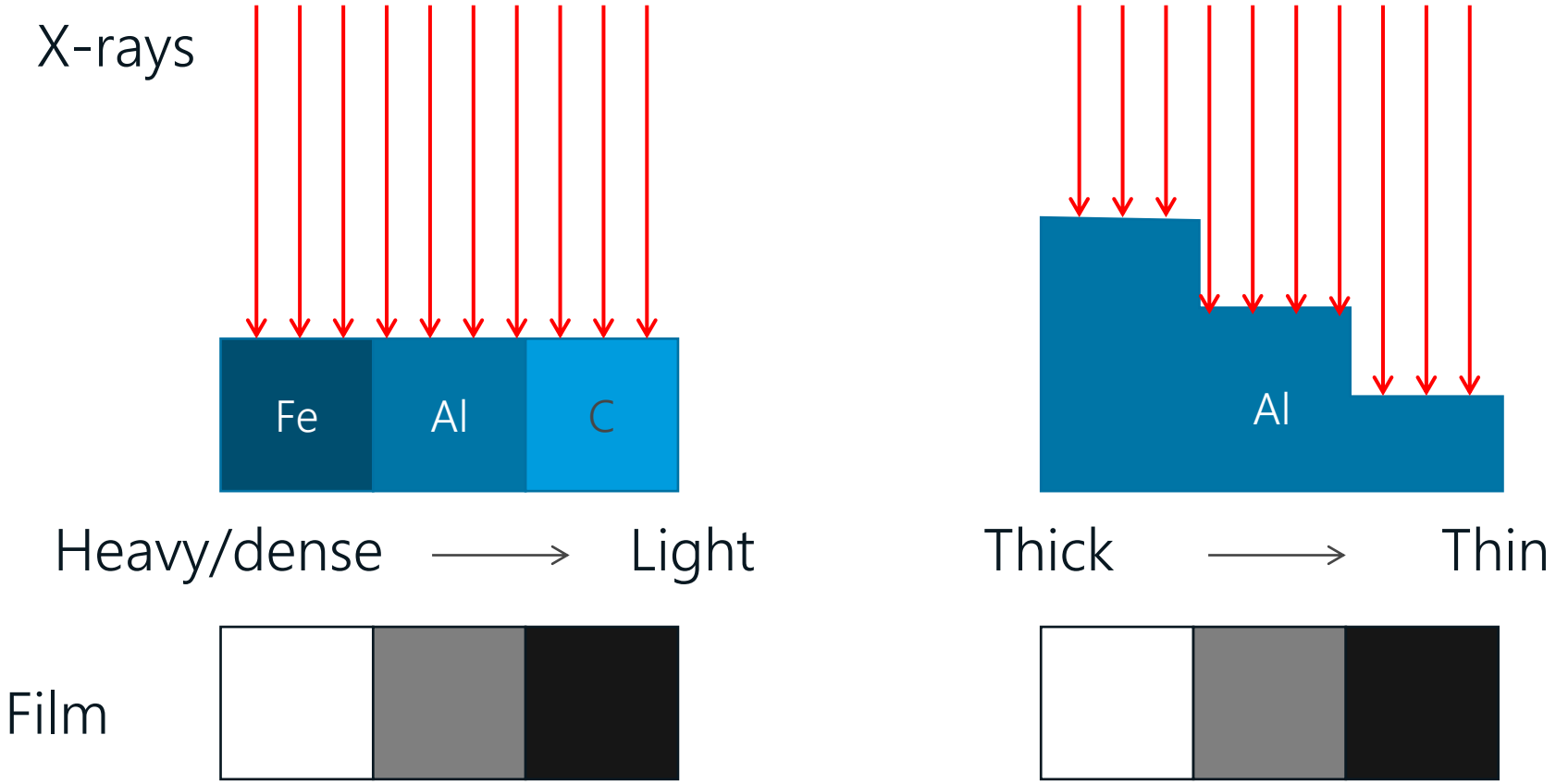
Polling question #3

Considerations when using X-ray CT for failure analysis

Considerations when using X-ray CT for Failure Analysis

- What is the size of the sample?
- What is the sample made of?
- What resolution is required?
- How will I analyze my CT data?
- Should I perform 4D experiments?

X-ray CT is an X-ray absorption technique



Small, low density
Low energy X-rays

Large, high density
High energy X-rays

CT Lab HV

225 kV

CT Lab HX

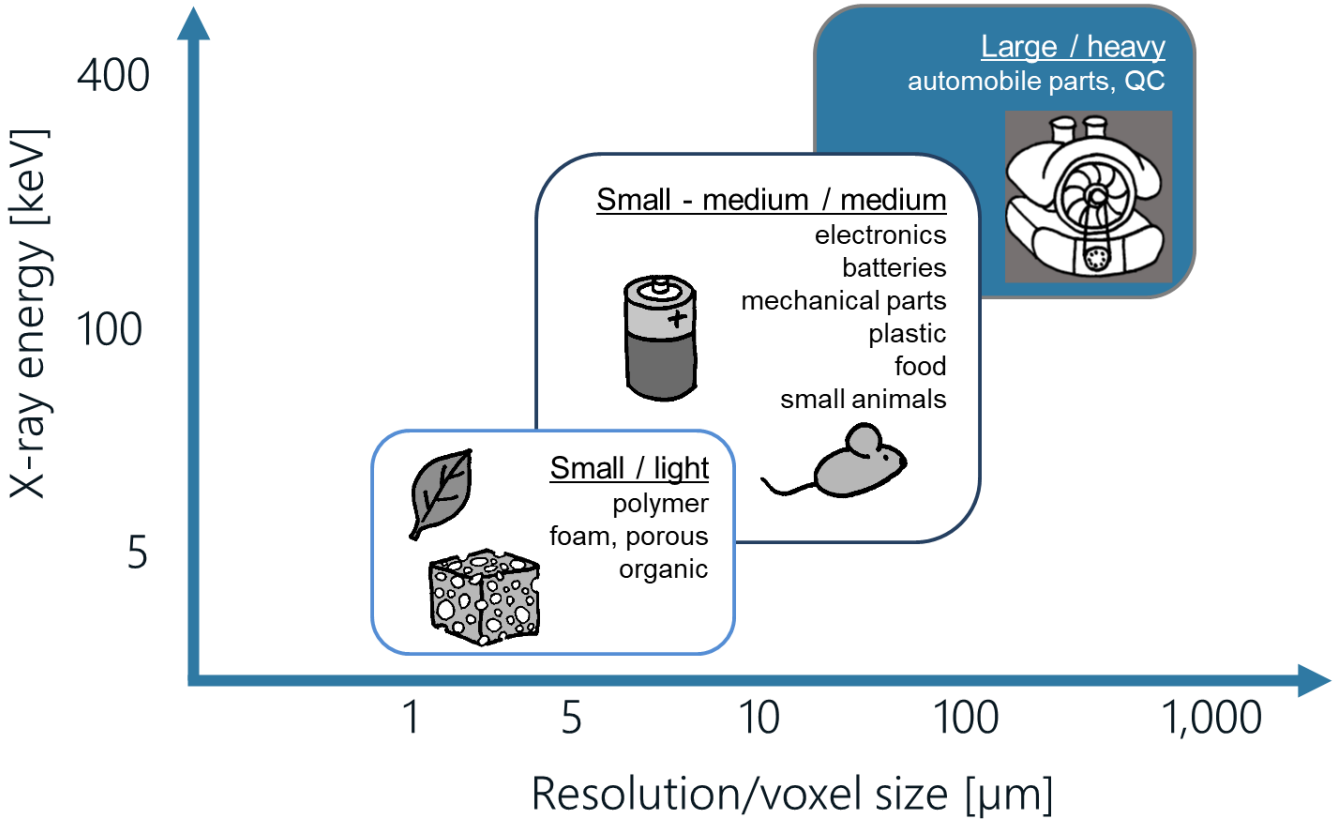
130 kV

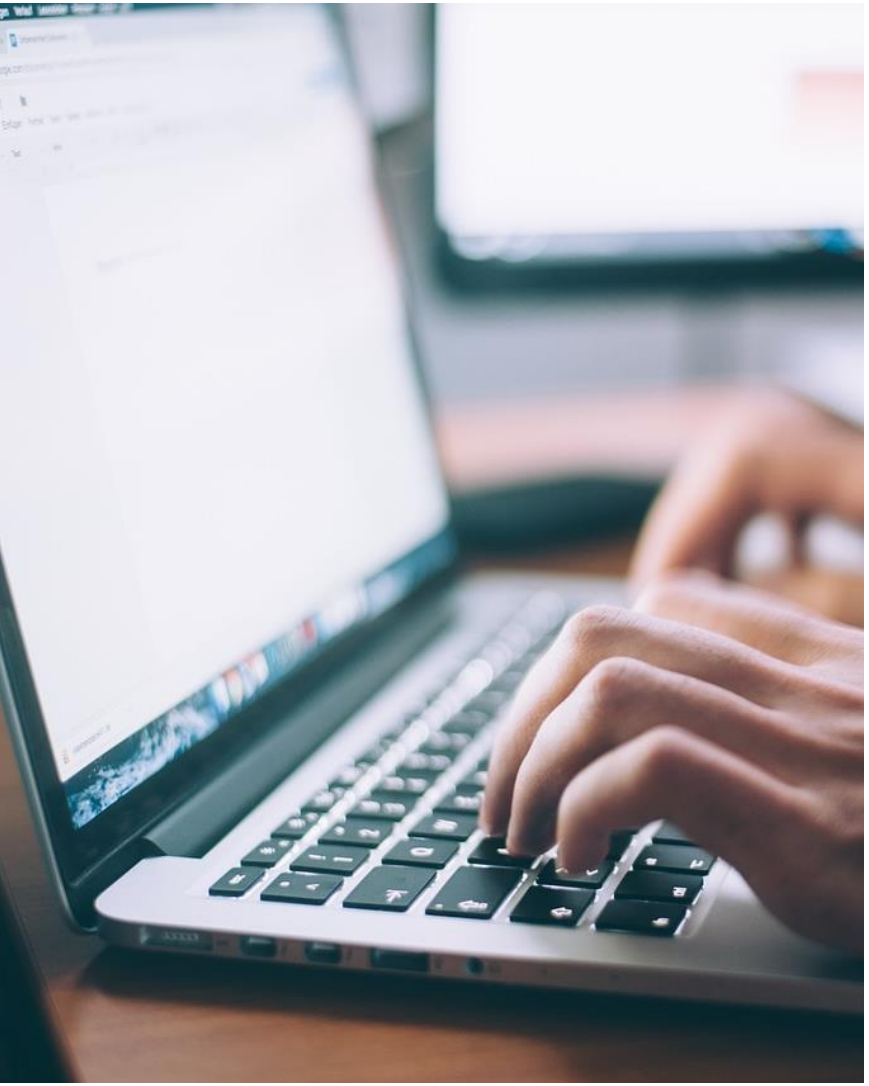
Sample size
Instrument size
Instrument cost

Benchtop

Room size

X-ray source vs. resolution





How will I analyze my CT data?

- VGSTUDIO MAX
- Dragonfly
- GeoDict

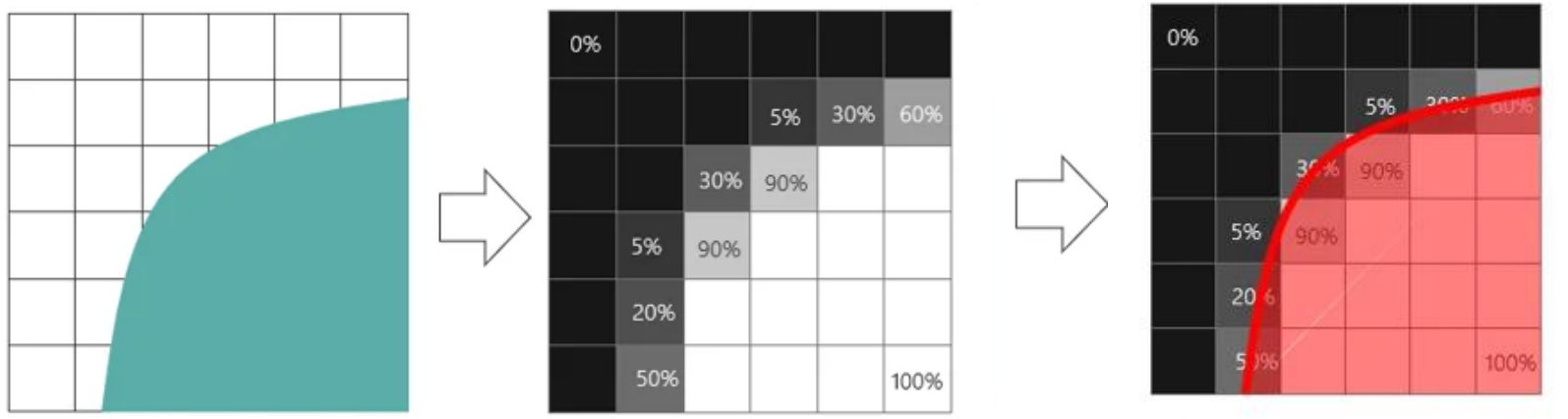
VGSTUDIO MAX

- Sophisticated ISO50 surface determination

Actual sample surface

CT scan of sample

Advanced ISO50 surface determination

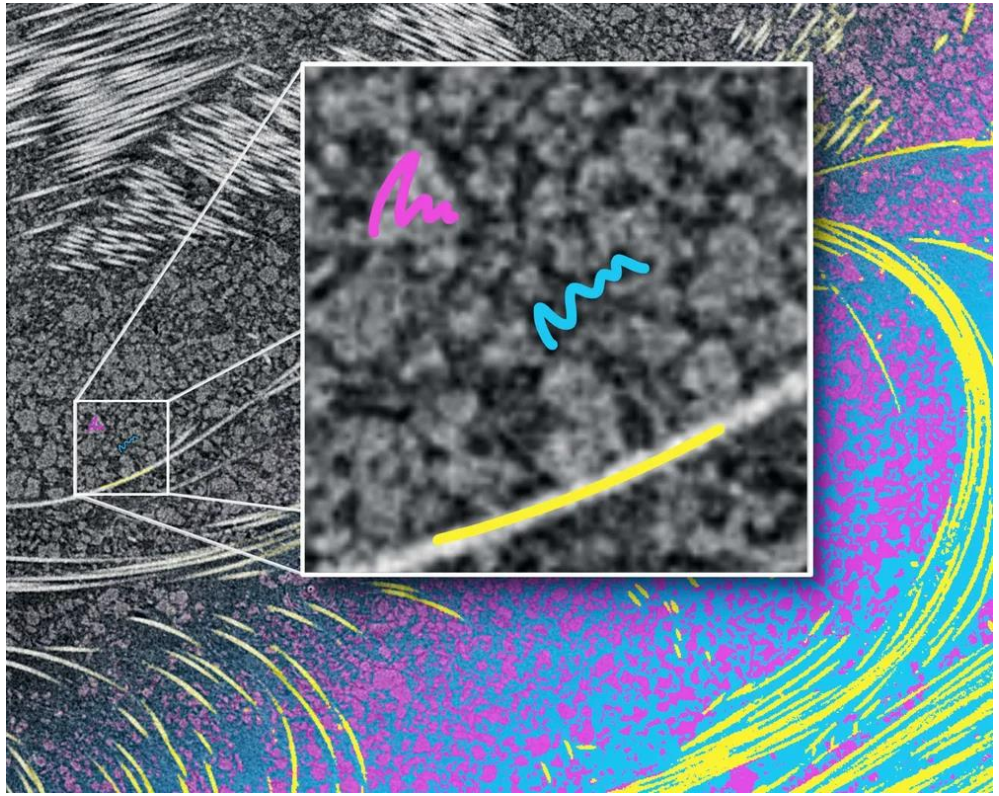


https://www.volumegraphics.com/en/products/vgsm.html

CT Analysis Software Product Review: VGSTUDIO by Volume Graphics

VGSTUDIO MAX

- Machine learning segmentation

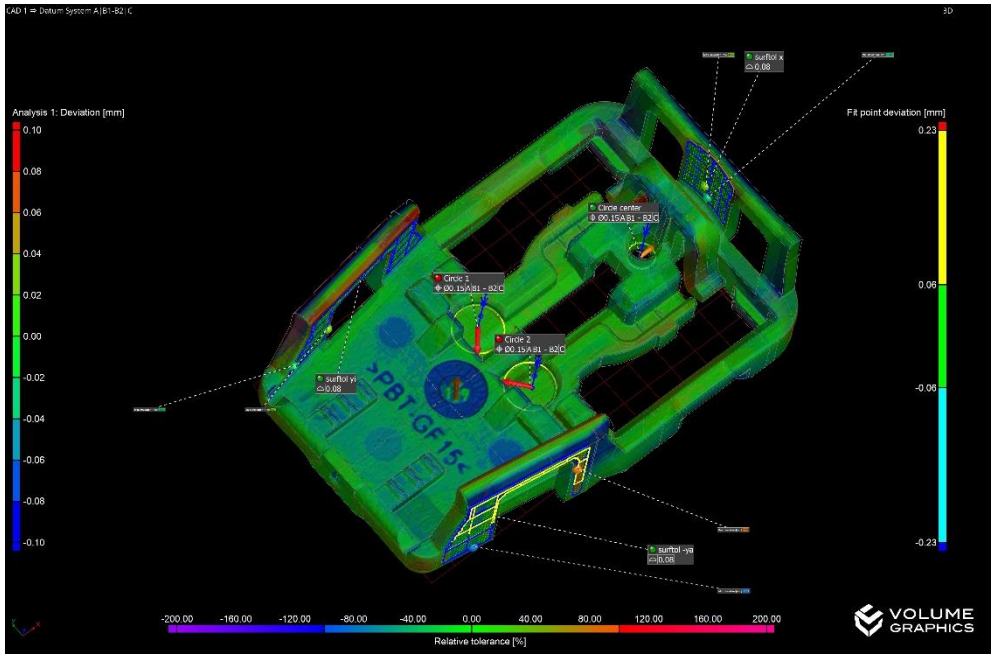


Hexagon

https://www.volumegraphics.com/en/products/vgsm.html

VGSTUDIO MAX

- Extensive dimensional analysis and quantitative tools
  - Nominal actual comparison



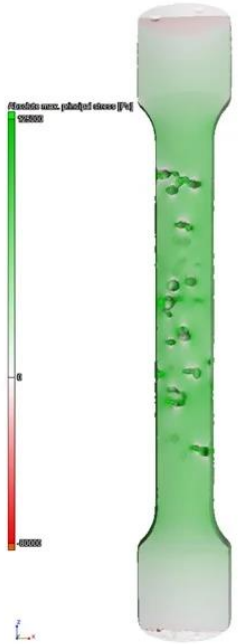
https://www.volumegraphics.com/en/products/vgsm.html

Hexagon

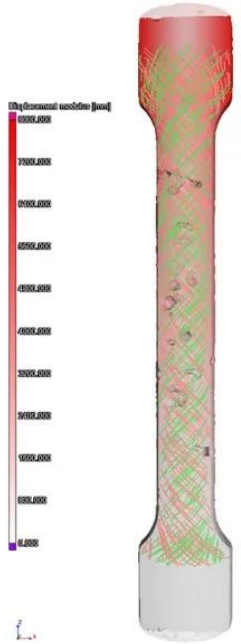
VGSTUDIO MAX

- Simulation tools for
  - structural mechanics
  - thermal conductivity
  - electric conductivity
  - capillary pressure
  - molecular diffusion
  - absolute permeability
  - and others

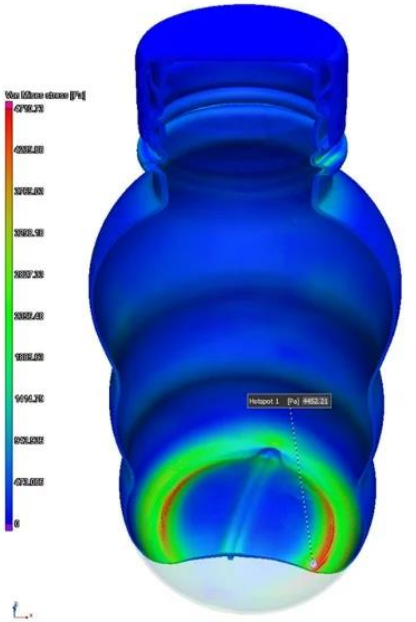
- Absolute maximal principal stress



- Displacement + Force lines



- Von Mises stress + Hotspots

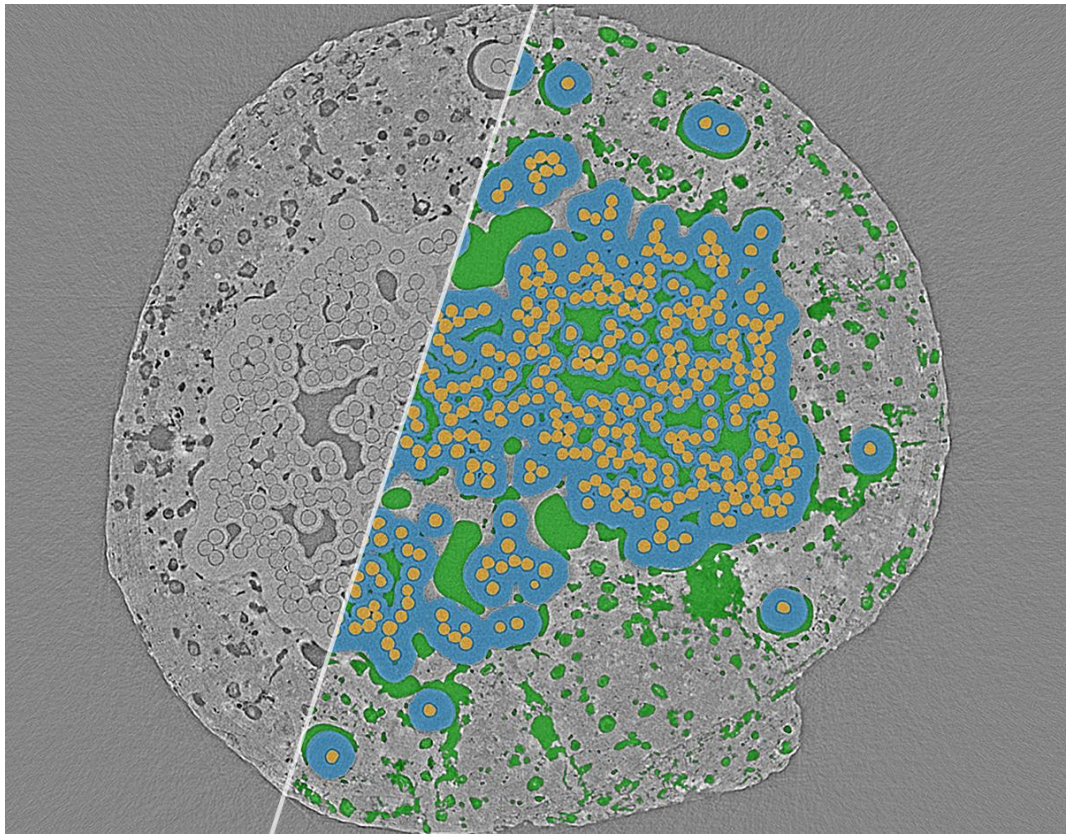


Hexagon

https://www.volumegraphics.com/en/products/vgsm.html

Dragonfly

- Advanced segmentation tools
  - Machine learning
  - Deep learning
  - Segmentation wizard

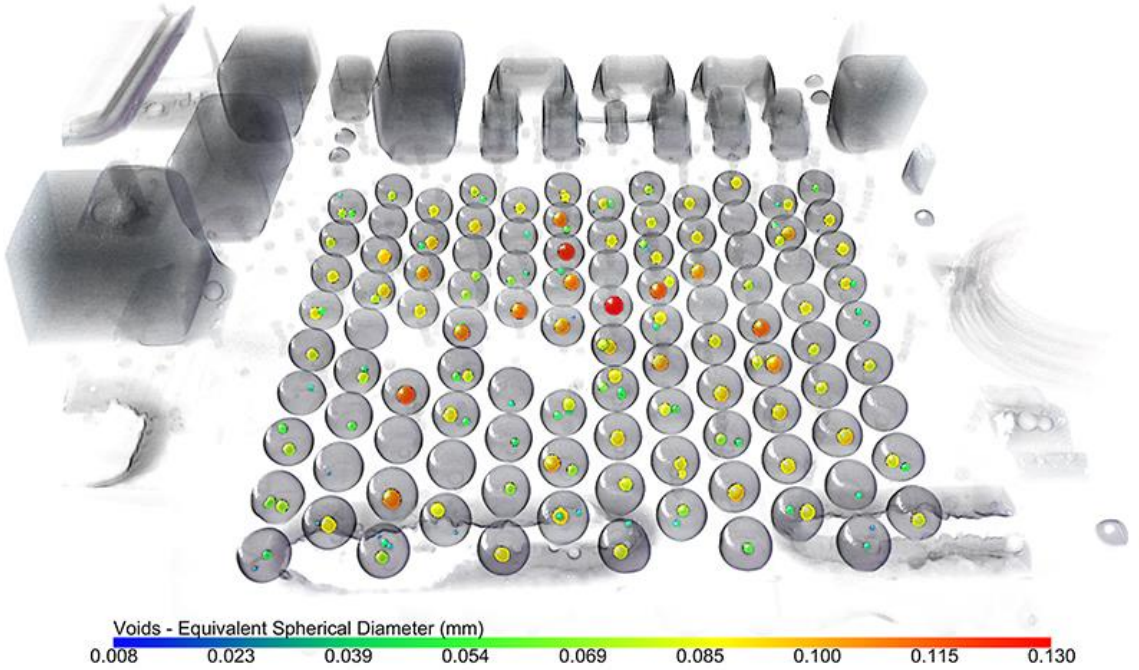


Comet

https://dragonfly.comet.tech/en/product-overview/dragonfly-3d-world

Dragonfly

- Quantitative analysis tools
  - Porosity
  - Thickness Analysis
  - Bone analysis
  - Core analysis

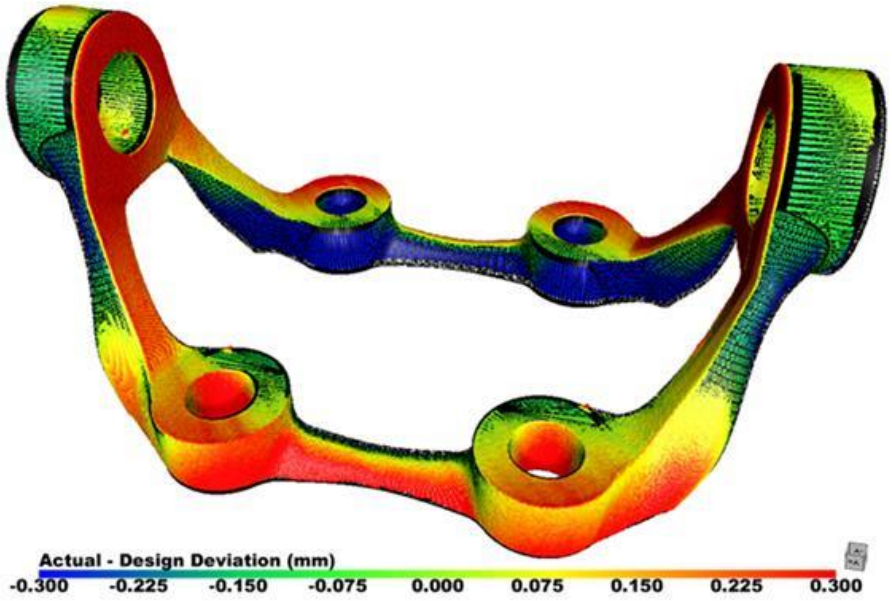


Comet

https://dragonfly.comet.tech/en/product-overview/dragonfly-3d-world

Dragonfly

- Examine deviation from design



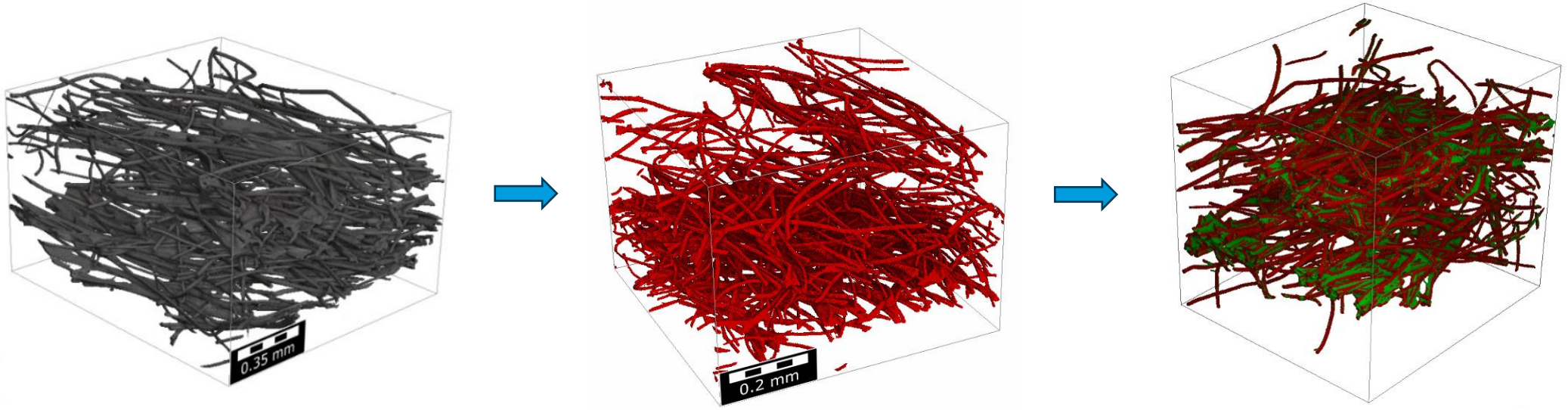
Comet

https://dragonfly.comet.tech/en/product-overview/dragonfly-3d-world

GeoDict

GEODICT
The Digital Material Laboratory

- Machine learning segmentation and object separation tools



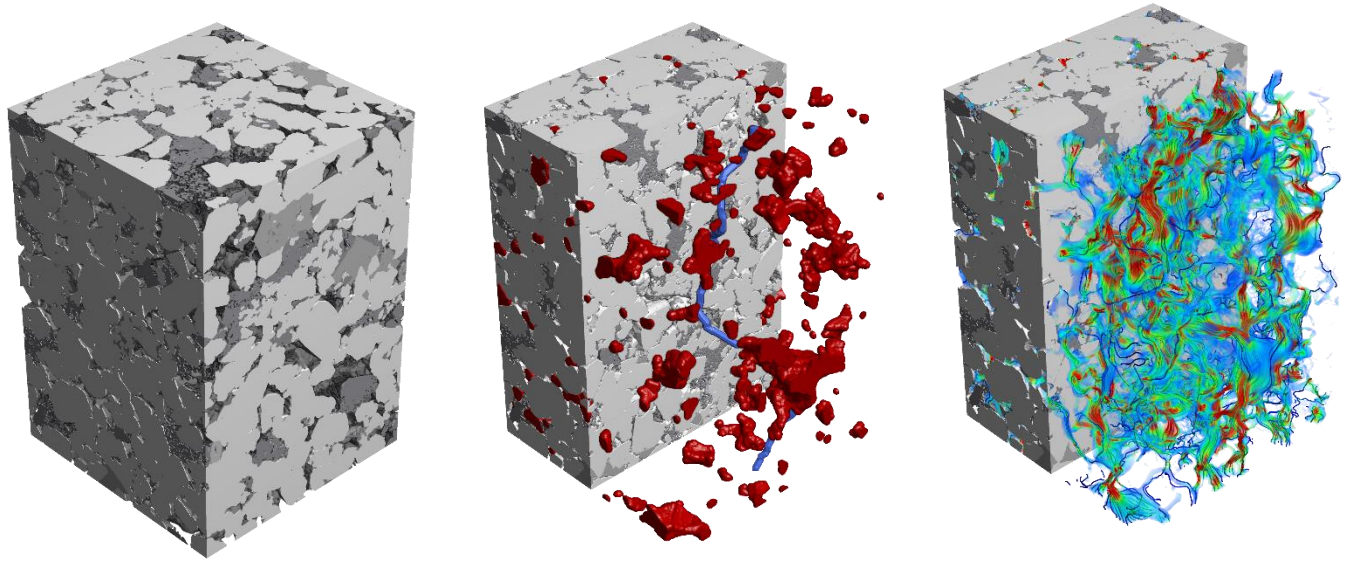
https://www.math2market.com/index.html

Deep Dive Virtual Workshop – Filtration Analysis

GeoDict

GEODICT
The Digital Material Laboratory

- Physical property simulation and prediction tools
  - Digital rock physics,
  - Filtration
  - Battery
  - Acoustic absorption
  - Diffusion
  - Thermal conductivity
  - Diffusivity and tortuosity
  - Elastic properties



Math2Market

https://www.math2market.com/index.html

Failure analysis examples

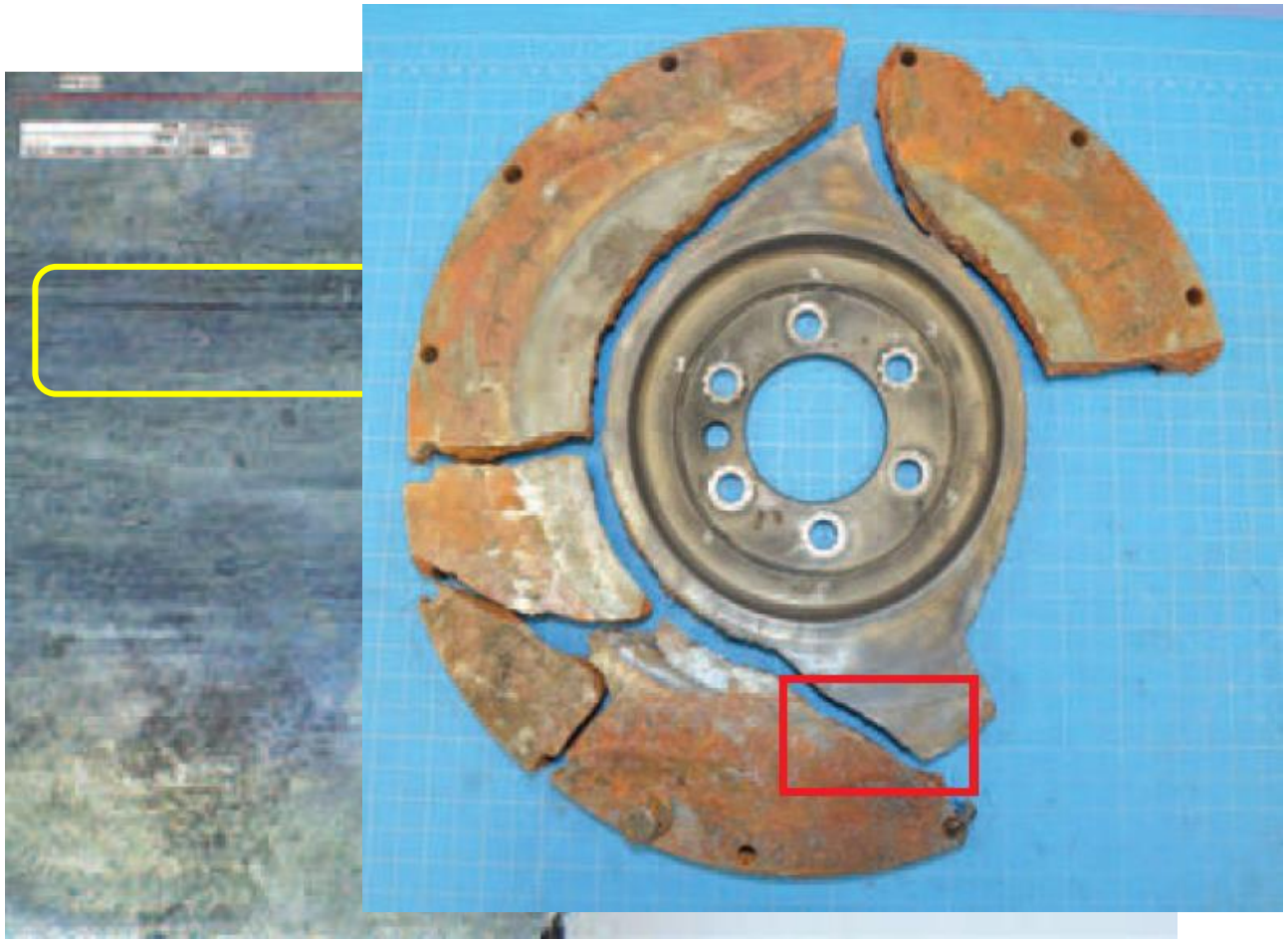
Gray cast iron flywheel

- Aftermarket flywheel
- Driven 24 miles until failure
- Techniques used
  - Fractography
  - X-ray CT
  - Metallography & Microstructure characterization
  - SEM

Kar, N., 2021. *JotNAFE* 37.

Gray cast iron flywheel

- Fractography
  - Revealed heat tinting
  - Fractures



Kar, N., 2021. *JotNAFE* 37.

Gray cast iron flywheel

- Fractography

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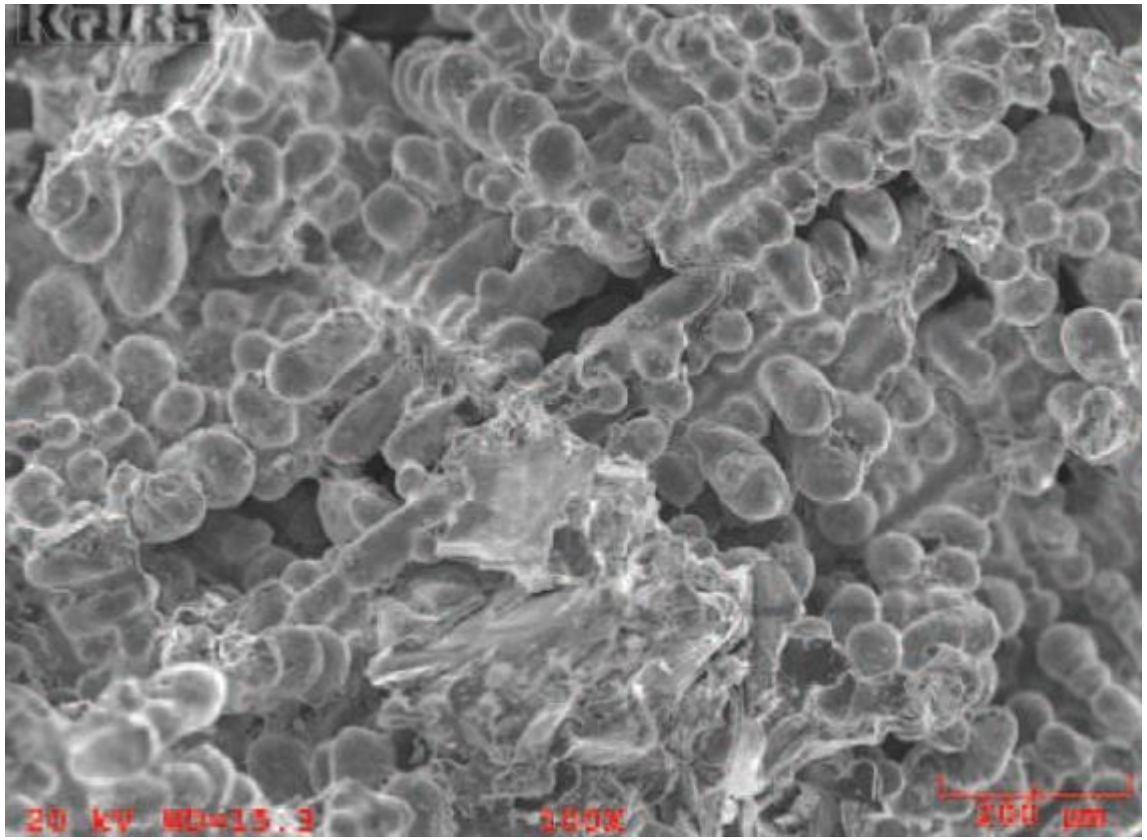
Gray cast iron flywheel

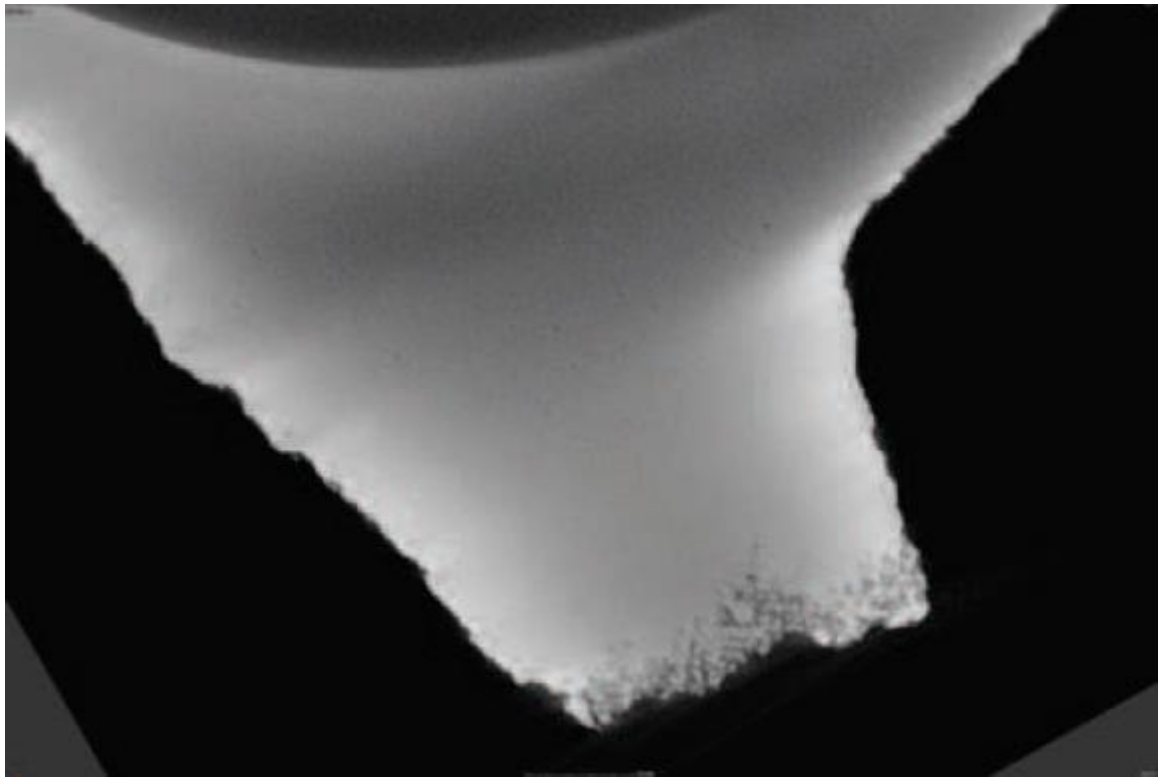
- SEM
  - Revealed porosity



Kar, N., 2021. *JotNAFE* 37.

Gray cast iron flywheel

- X-ray CT

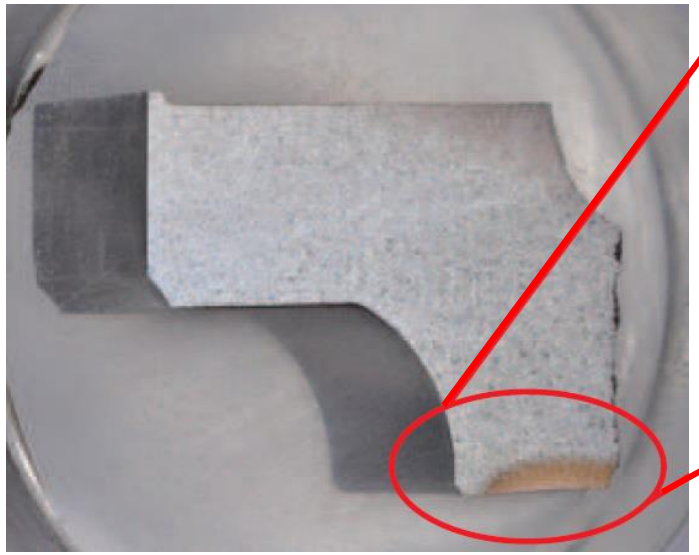


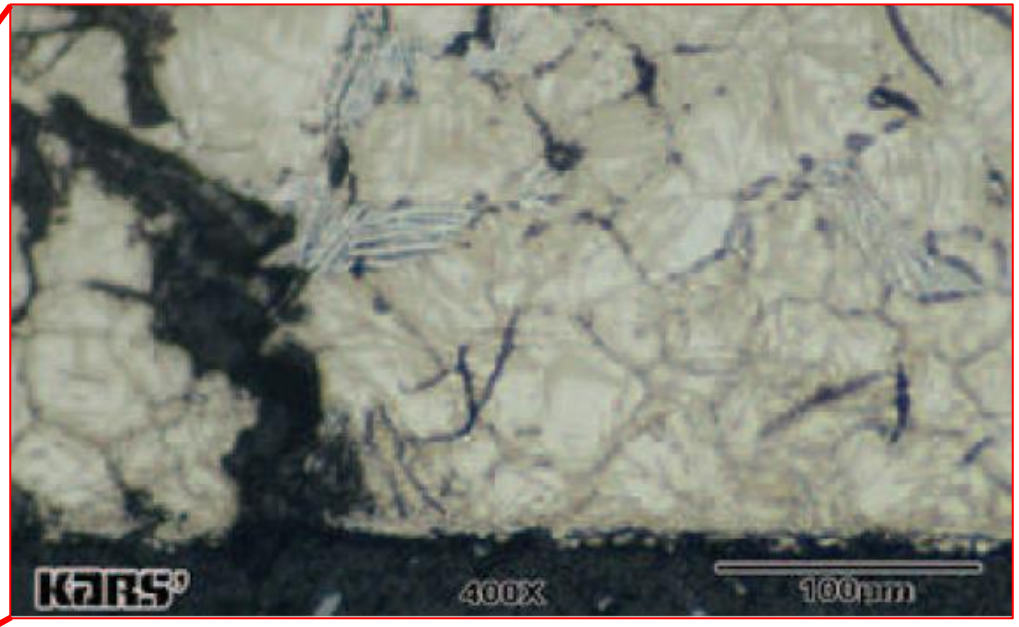
2D cross-section

Kar, N., 2021. *JotNAFE* 37.

Gray cast iron flywheel

- Metallography & Microstructure characterization

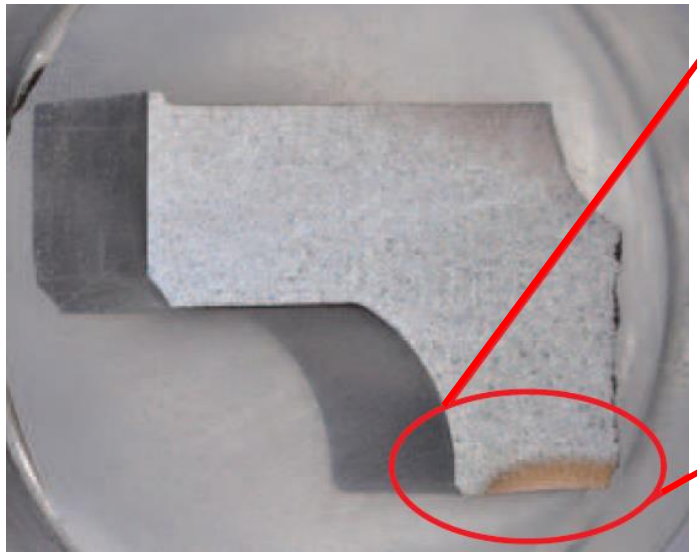


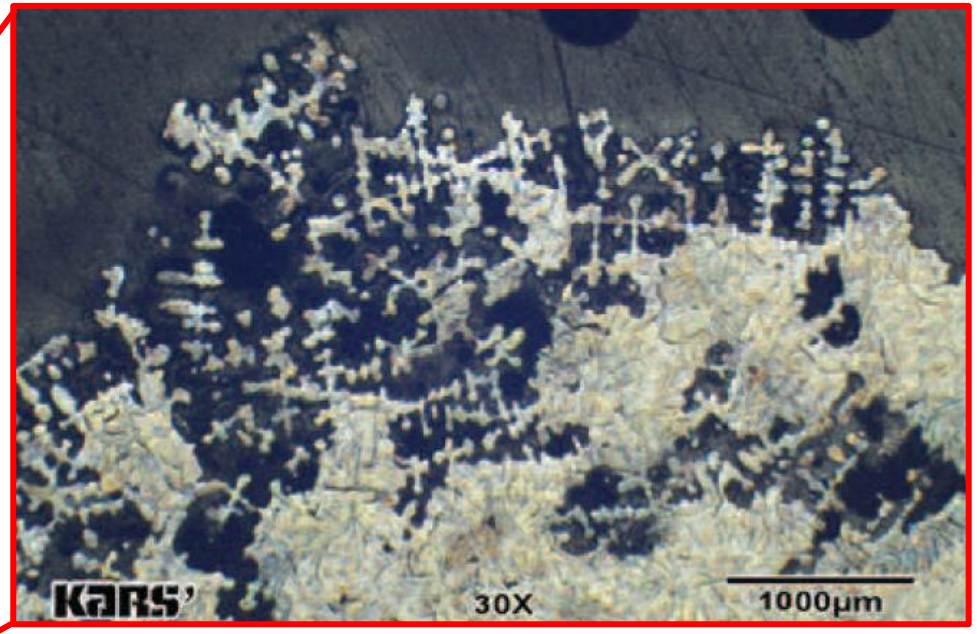


Kar, N., 2021. *JotNAFE* 37.

Gray cast iron flywheel

- Metallography & Microstructure characterization





Kar, N., 2021. *JotNAFE* 37.

Samsung Galaxy Note7

World

Note 7 fiasco could burn a $17 billion hole in Samsung accounts

By **Se Young Lee**

October 12, 2016 3:56 AM CDT · Updated 8 years ago

Aa

Reuters

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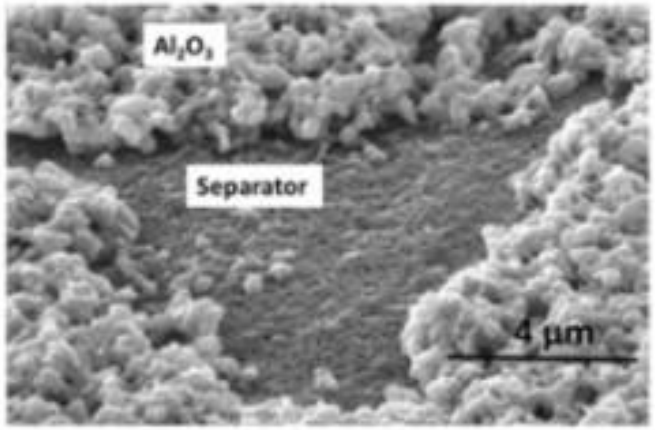
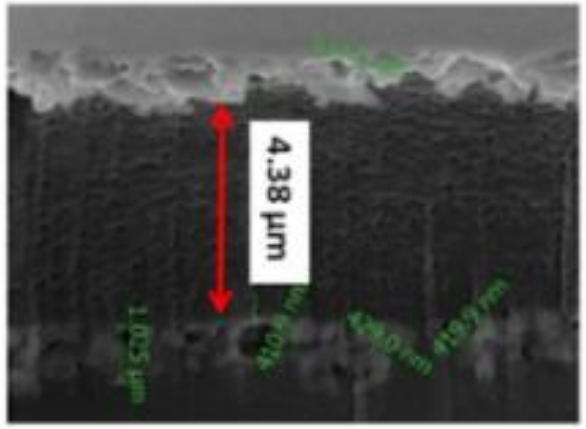
- Issues localized to battery
- Techniques used
  - X-ray CT
  - SEM

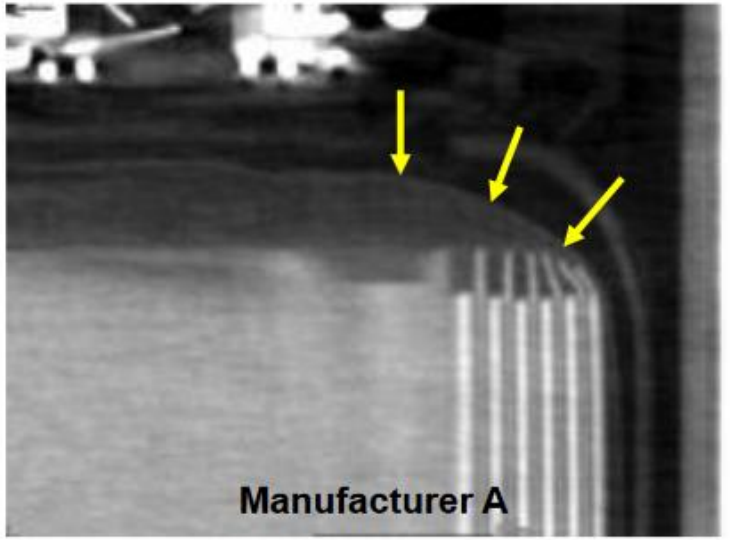
Samsung Galaxy Note7

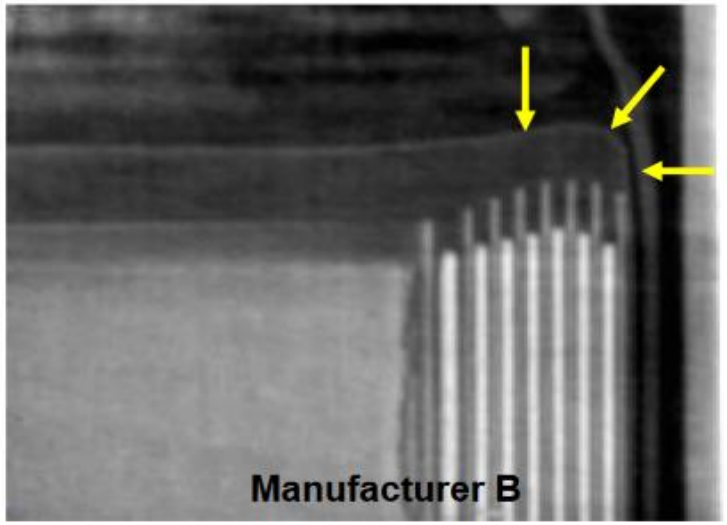
- X-ray CT
- SEM





Loveridge, M.J., *et. al.*, 2018. *Batteries* 4, 3.

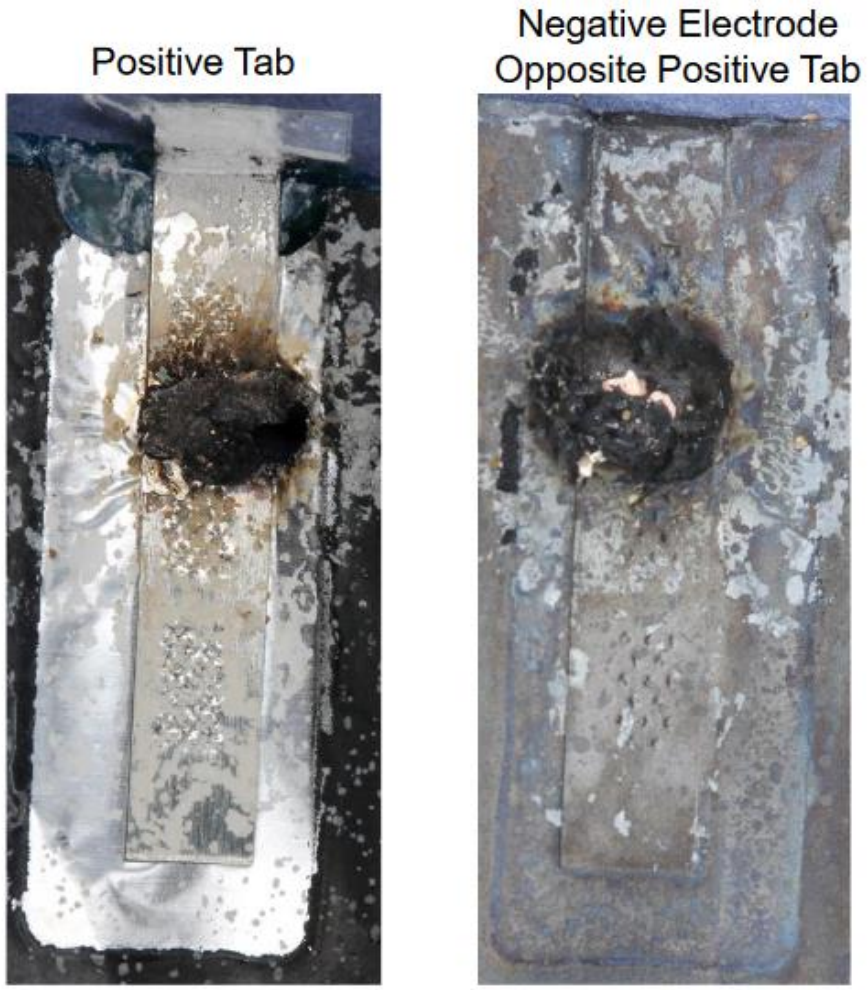




White, K., 2017. "Samsung Recall Support Note7 Investigation."

Samsung Galaxy Note7

- X-ray CT



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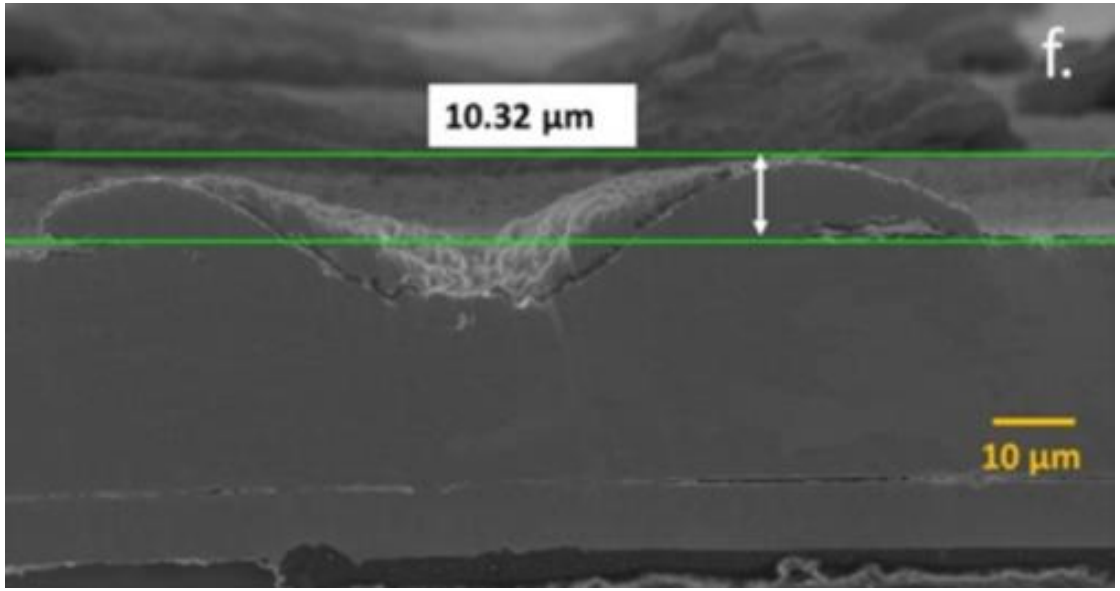
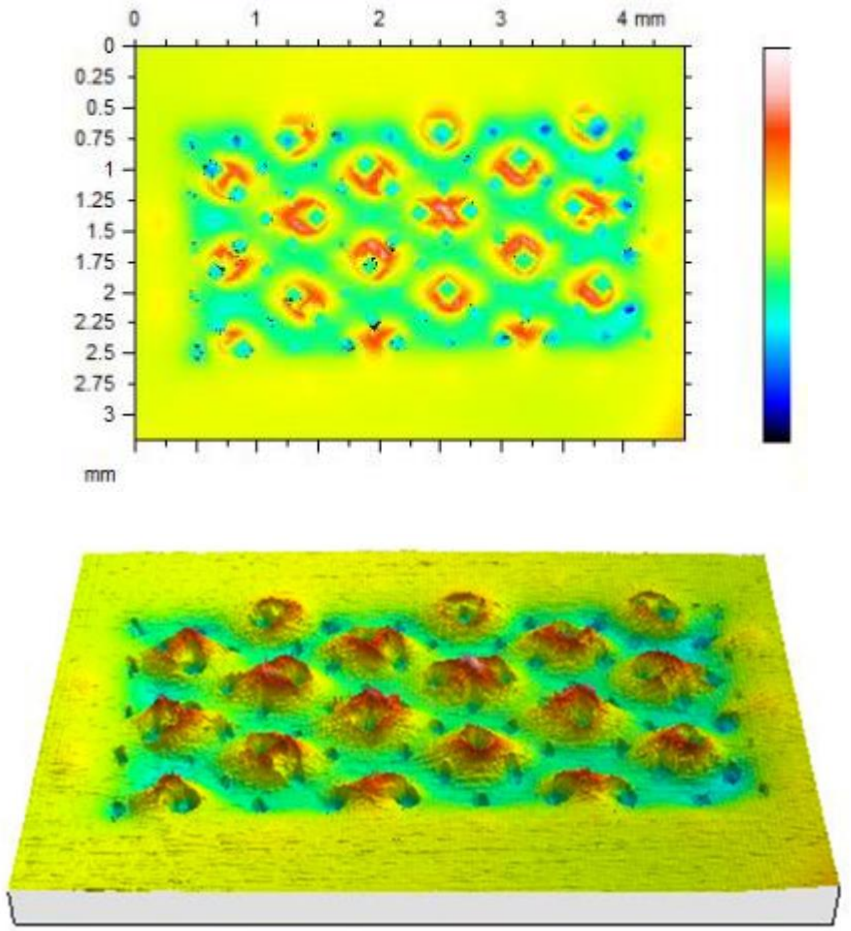
- X-ray CT
- SEM



Loveridge, M.J., *et. al.*, 2018. *Batteries* 4, 3.



White, K., 2017. "Samsung Recall Support Note7 Investigation."

Samsung Galaxy Note7

- Samsung implemented a broad range of internal quality and safety processes.
- Samsung formed a Battery Advisory Group of external academic and research experts.

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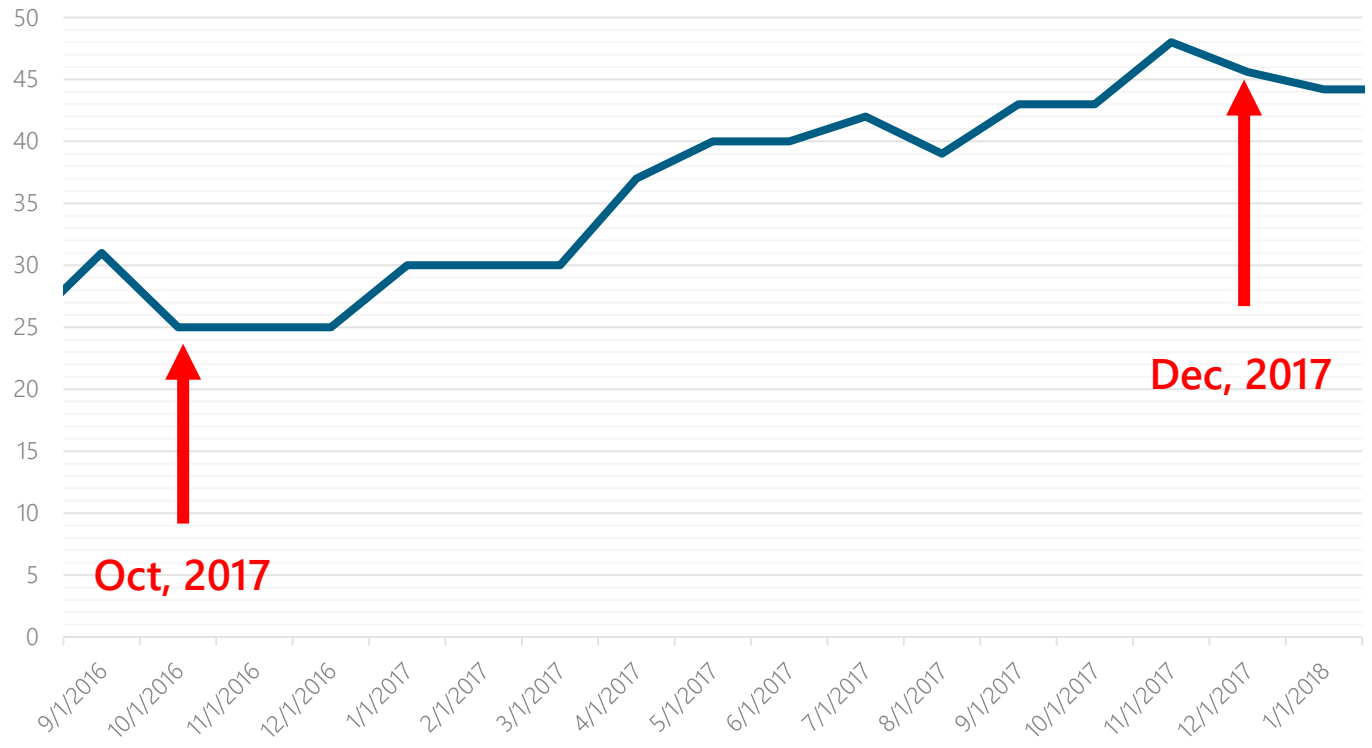

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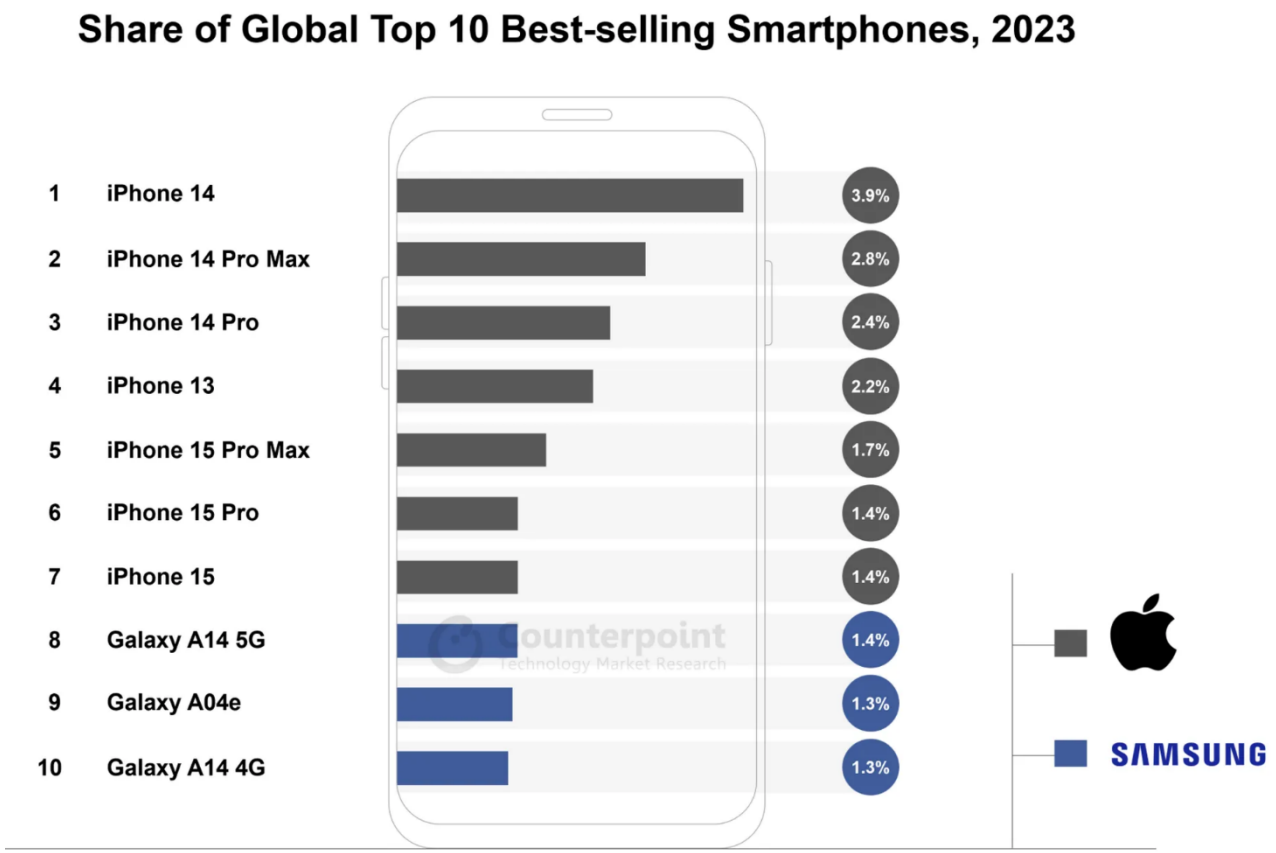

Source: Counterpoint's Global Monthly Handset Model Sales (Sell-Through) Tracker, Dec 2023

You just learned

- What is failure analysis?
  - Why and when should we perform failure analysis?
  - What steps are involved in failure analysis?
- What are common failure analysis techniques?
  - Destructive techniques
  - Non-destructive techniques
- Considerations when using X-ray CT for failure analysis
- Failure analysis examples

Q & A Session

Structural Failure Analysis

Wed., May 22, 10 am CDT

Presenter: Ted Huang | **Co-presenter:** Angela Criswell | **Host:** Viral Vaghela