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2D – 2.5 D and CT Xray Imaging at Covalent Metrology

X-Ray imaging: What is it ?

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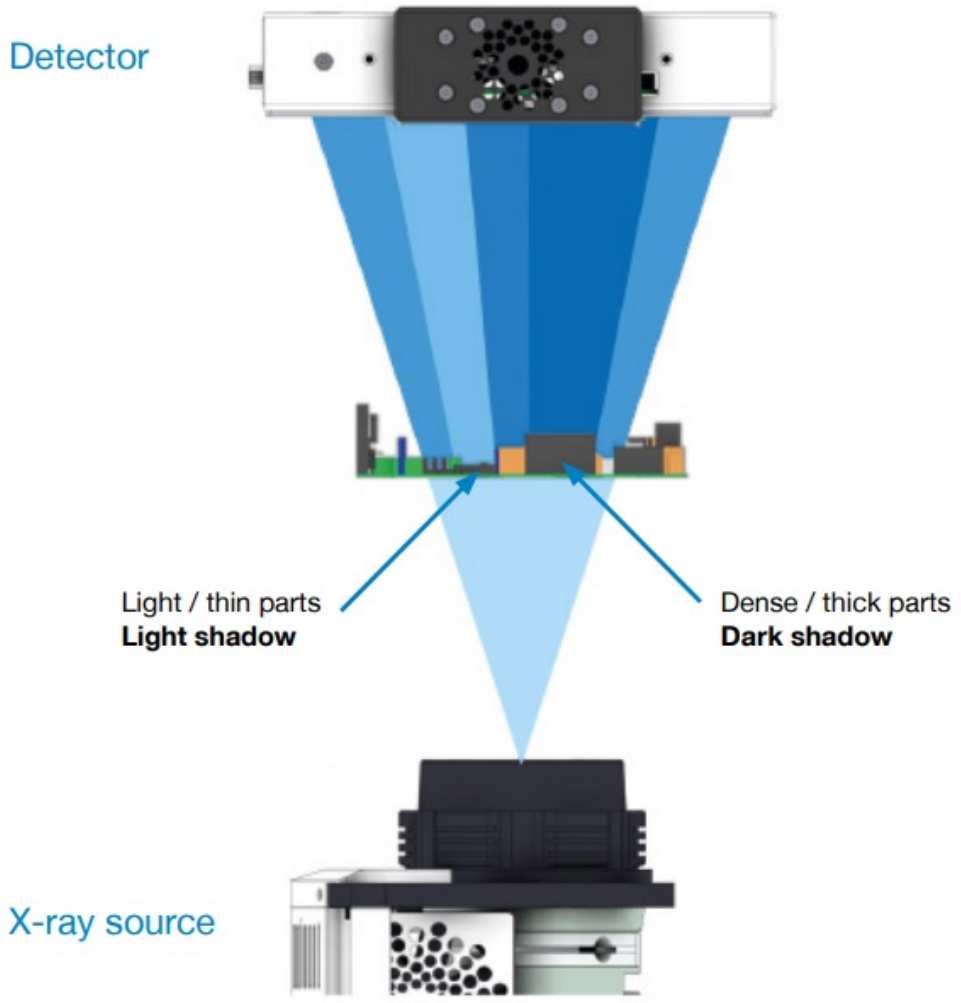
- X-ray imaging is a non-destructive method of creating images of the internal structures of objects. X-rays are a form of electromagnetic radiation that can penetrate through objects and are absorbed to different degrees by different materials. When X-rays pass through an object, they interact with the materials within it, and this interaction causes some of the X-rays to be absorbed while others pass through to varying degrees.

- X-ray imaging is commonly used in many fields, including medicine, engineering, and materials science, to non-destructively visualize internal structures that may be difficult or impossible to see using other imaging methods.

X-Ray Imaging: How Does it Work?



- X-ray imaging involves passing X-rays through a sample and capturing the resulting shadow image. Materials with higher density, such as solder, appear as darker shadows, while lower density regions like voids appear as lighter shadows. This makes it possible to visualize features such as voiding with ease.

- In X-ray imaging, a source of X-rays is directed at the object of interest, and the X-rays that pass through the object are detected on the other side. By analyzing the pattern of X-rays that have been absorbed or passed through the object, it is possible to create an image of the internal structure of the object. This is because different materials have different densities, and the X-rays interact with each material differently, producing a unique pattern that can be analyzed to create an image.

X-Ray: A Versatile Tool for a Wide range of Application

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- Medical imaging: diagnostic imaging in the medical field, such as for detecting bone fractures, tumors, and other abnormalities.
- Industrial inspection: defects and quality control of manufactured parts. Can also be used for non-destructive testing of materials such as welds and pipelines.
- Aerospace and automotive engineering: inspection of critical components such as turbine blades, engines, and other parts of aircraft and automobiles for quality assurance and safety purposes.
- Archaeology and art conservation: internal structure of artifacts and artwork without damaging them.
- Electronics: see next slide.

X-Ray Application: Electronics

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- Electronic circuit inspection: X-ray imaging is commonly used in the electronics industry to inspect the internal structure of electronic devices, such as printed circuit boards (*PCBs*), integrated circuits (*ICs*), and microelectromechanical systems (*MEMS*). This allows for non-destructive testing of the devices to identify defects, **such as voids, cracks, and delaminations**.
- Failure analysis: X-ray imaging is also used for failure analysis of electronic components, especially ICs. This may involve identifying defects in the packaging, such as **delamination or cracking,** or examining the internal structure to identify faults such as **bridging, opens, or shorts**.
- Counterfeit detection: X-ray imaging is used to **detect counterfeit electronic components**. Genuine components have a unique internal structure, which can be compared to reference images to identify fakes that have been re-labeled or re-packaged.
- IP infringement: X-ray imaging can be used to analyze electronic devices by creating 3D models of their internal structure. This is useful for analyzing the **design of a competitor's product or for identifying IP infringement.**

CT Systems at Covalent and Partner Labs

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Covalent has access to all tools shown below, either on-site or off-site.

Tool	Location	Max Volt (kV)	Max Power (W)	Max Resolution (um)*	Max sample size	Notes
Dage Quadra 7	Covalent	160	20	2.5 um	~1 inch^3	Includes X-Plane
Rigaku CT Lab HX 130	Covalent	130	39	5 um	150 mm D x 200 mm H	Best for light materials
VJ Technologies	External 1	225	320	5 um	500 mm D x 550 mm H	
Zeiss Metrotom 1500	External 2	225	500	4 um	300 mm D x 600 mm H	
North Star Imaging x5000	External 2	450		1 um	810 x 1210 mm	

*Max resolution is only achievable for small (sub-cm), average density samples

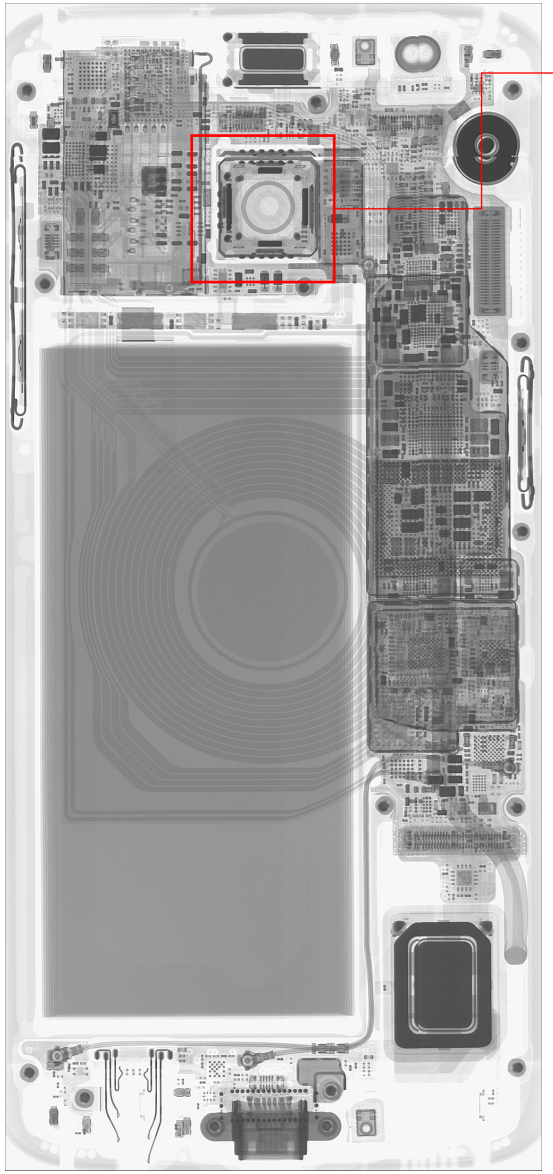
- Covalent also has access to an additional labs with x-ray energy up to 3 MV, although specs are not yet publicly available, projects can be scoped on a case-by-case basis
- Total available analyses include 3D and tomographic visualizations, CAD overlay, phase segmentation for volume ratios (including porosity analysis), although not all are available on all systems.

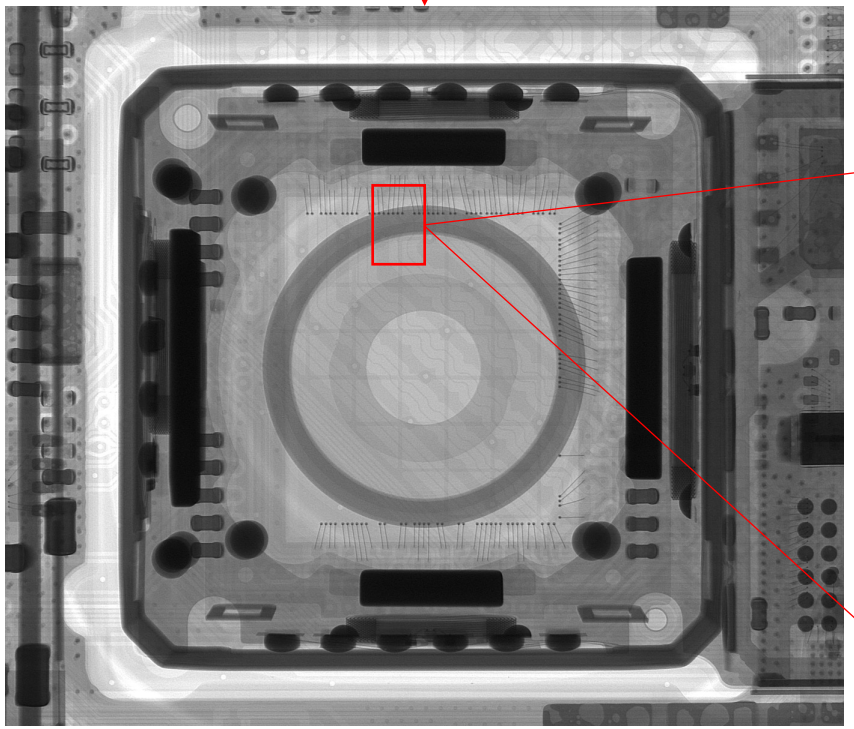
Covalent Tool: Nordson Quadra 7

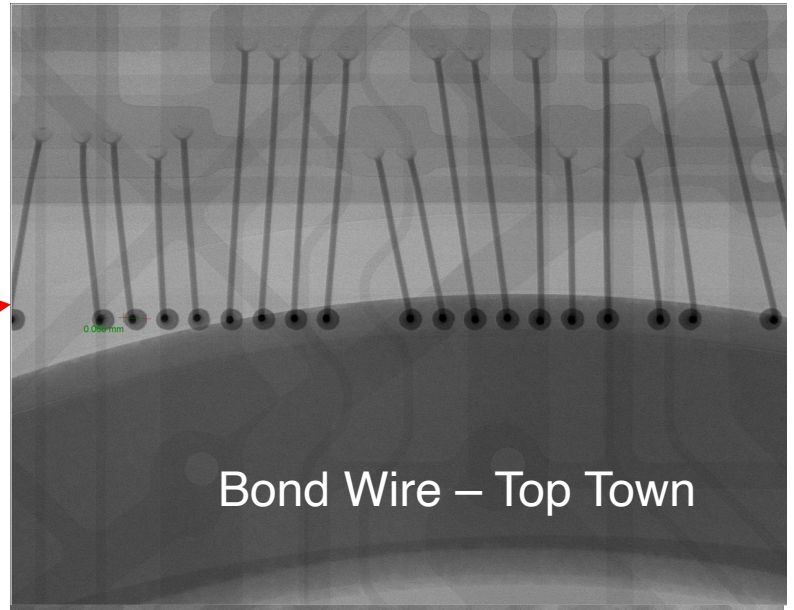
Aspire FP™ Detector	
Resolution	6.7 MP
Frame Rate	30 fps
Pixel Pitch	50 µm
Digital Imaging Processing	16-bit
QuadraNT™ X-ray Tube	
Type	Filament free transmissive
Feature Recognition	0.1µm (0.3µm above 10W)
Max. Power	20W
Voltage	30-160kV
Inspection	
Oblique Angle View	2 × 70° - No sample rotation required
Anti Vibration	AXiS - Active X-ray Image Stabilization
Display Resolution	185 PPI
Inspection Area	510 x 445 mm (20 x 17.5")
Geometric Magnification	2,500x
Total Magnification	68,000x
Display	Twin 24" 4K UHD 3840 x 2160 on Fully Flexible Arm Mount

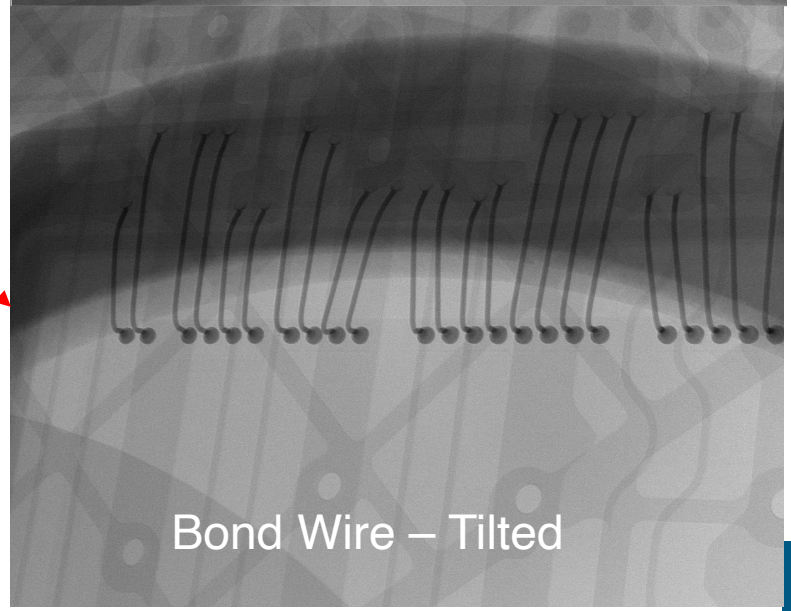
<u>Versatile Tool</u>:
- 2D
- 2.5D
- Cross-Section (X-Plane) and 3D reconstruction
  - *µ*CT and 3D reconstruction
  - Large Samples

Example: Cell Phone









Example: Cylindrical Li-ion Battery

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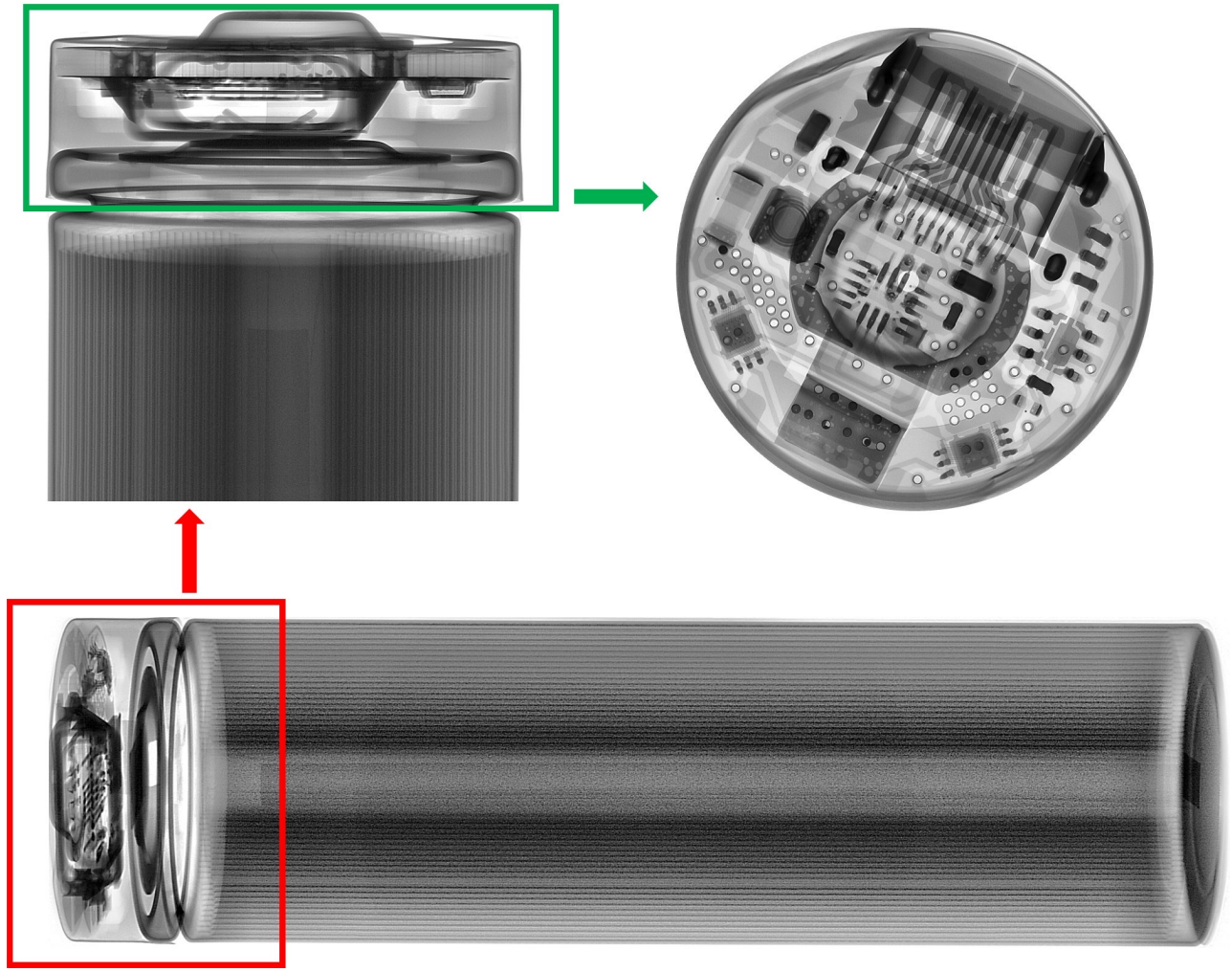

Example: Li-ion Battery Pouch Cell

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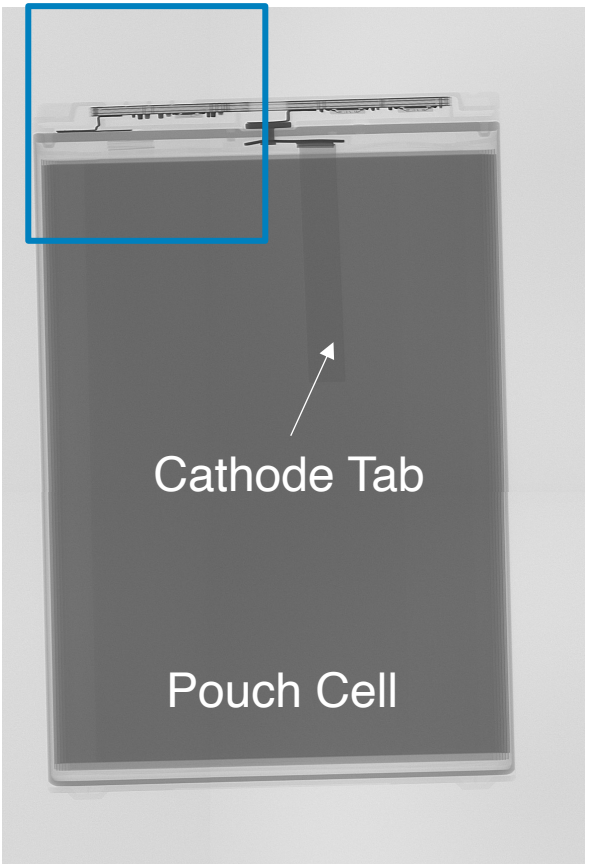
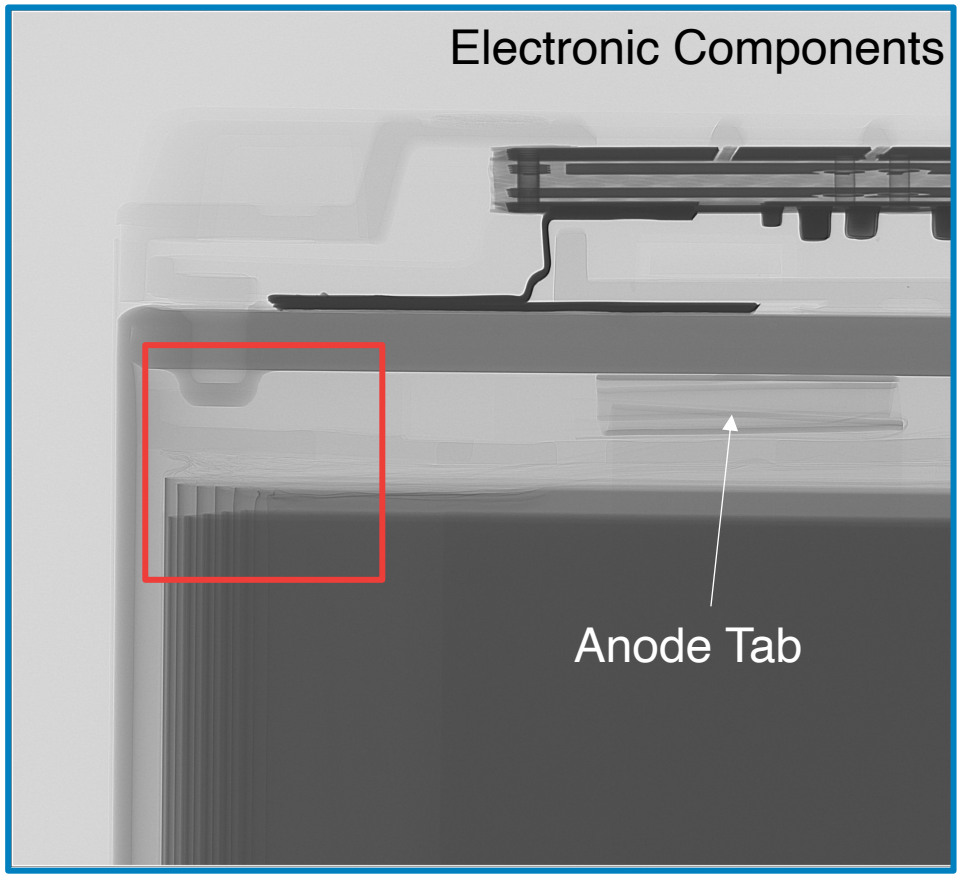
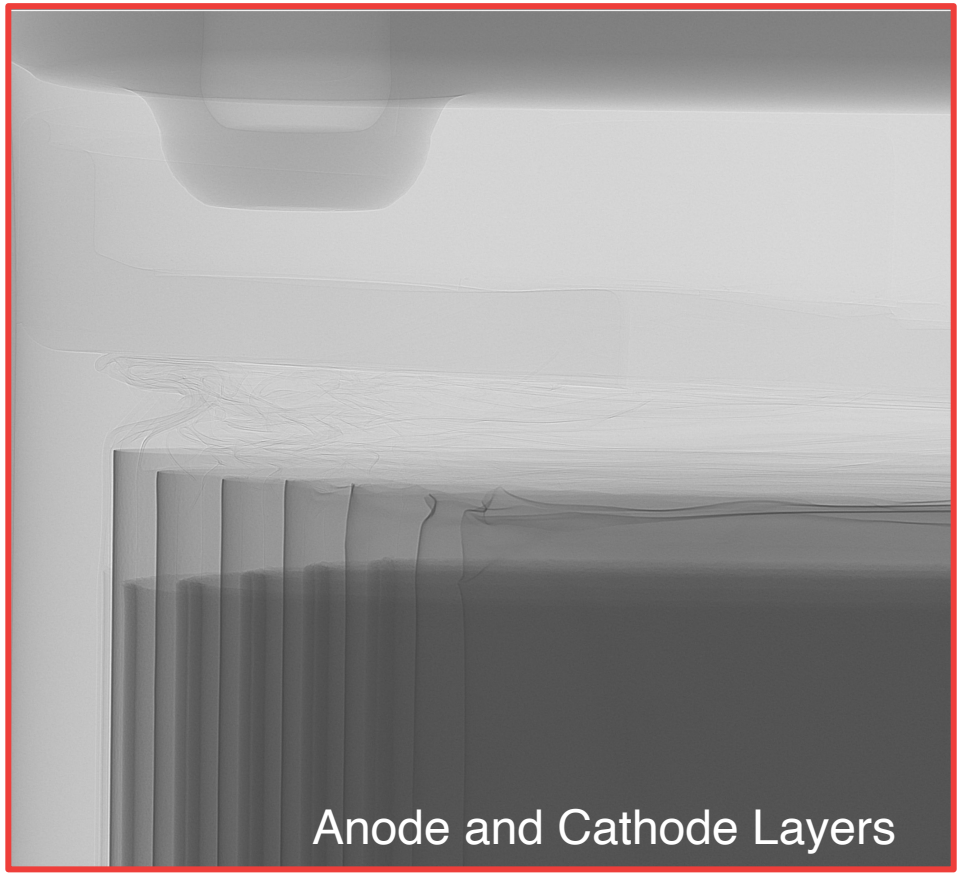
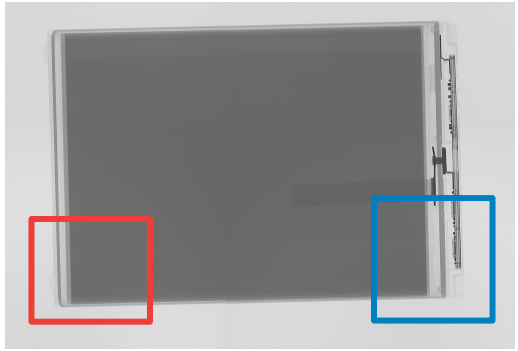


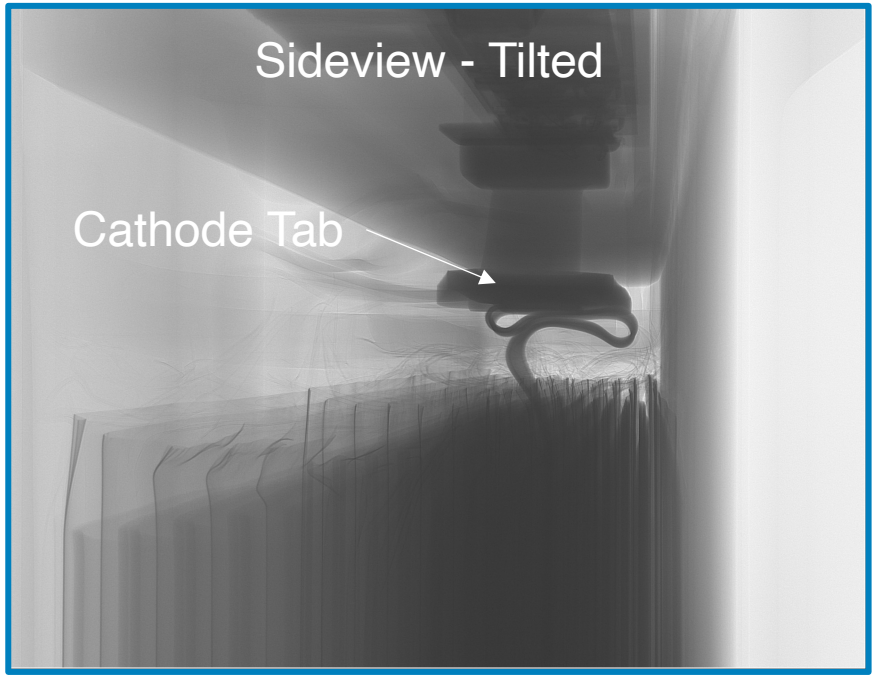


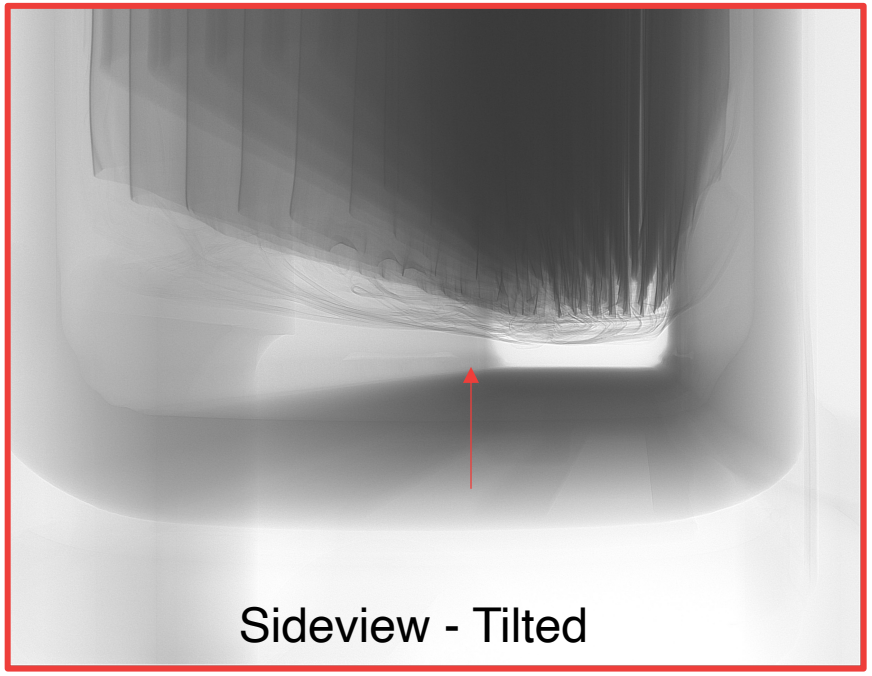


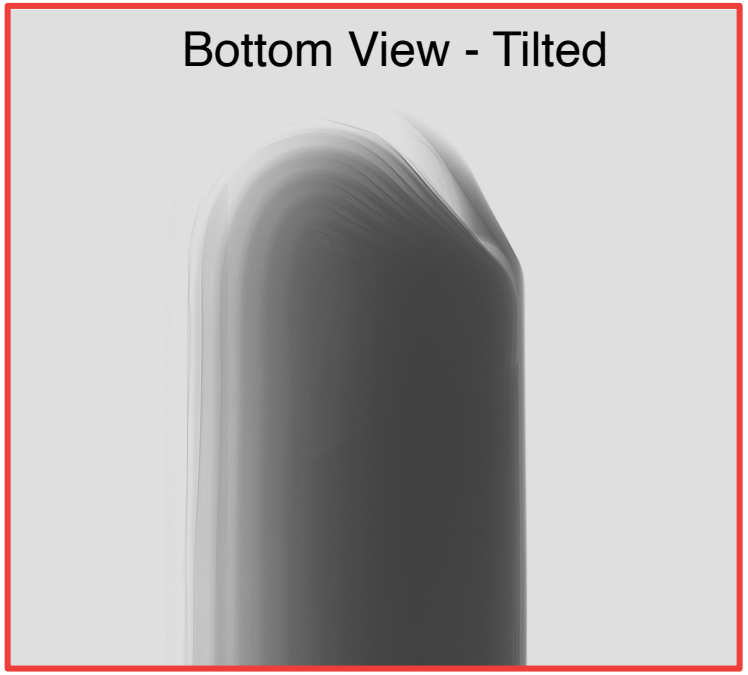
Example: Li-ion Battery Pouch Cell



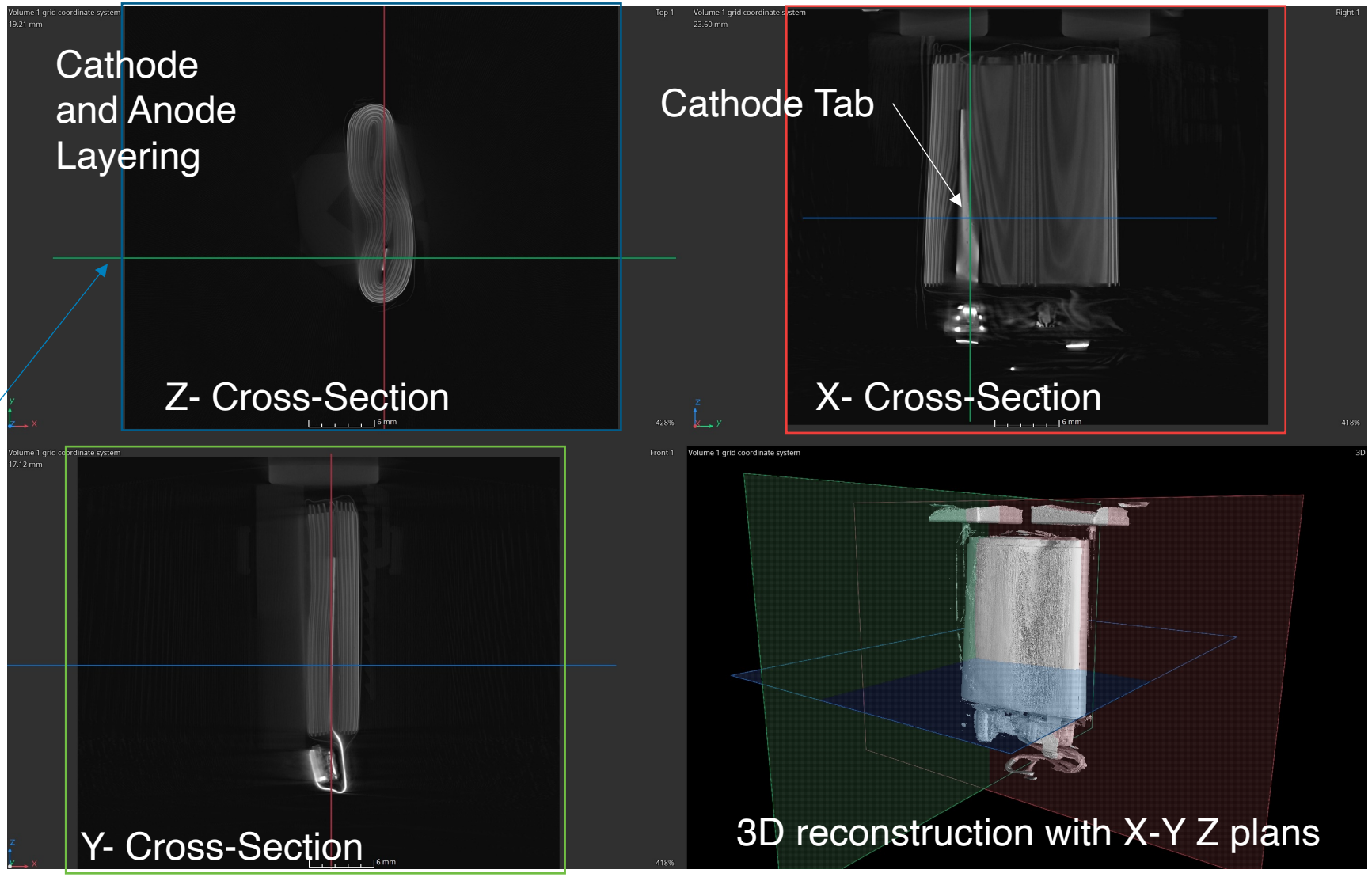
Anode and Cathode Layers



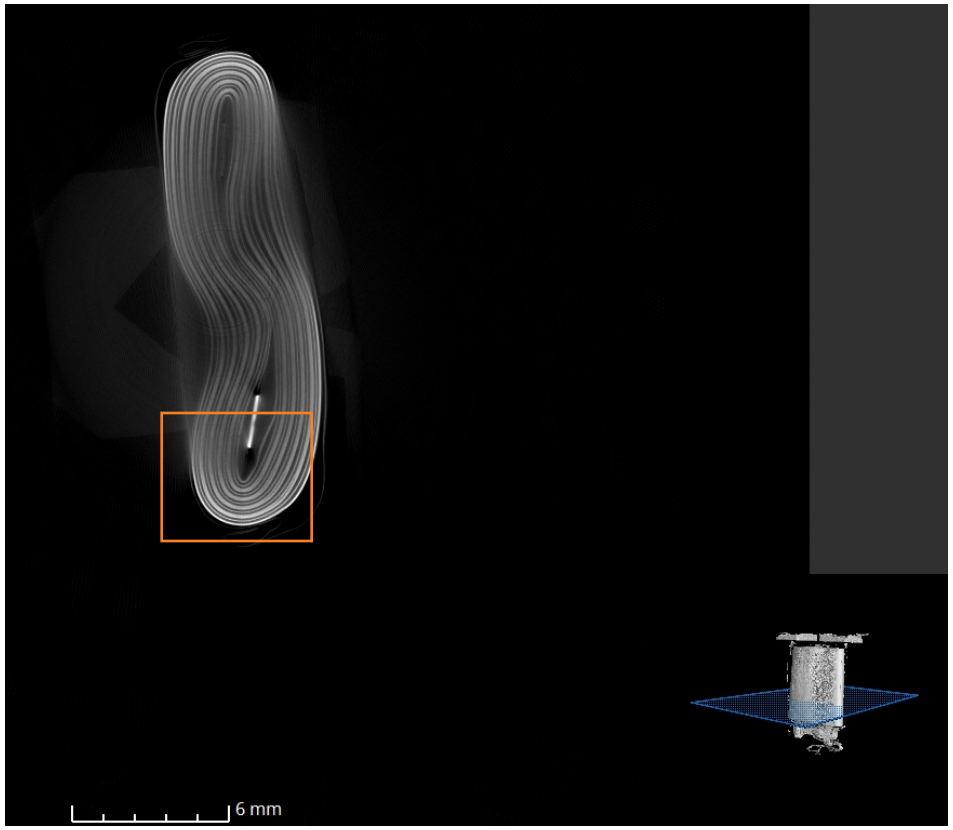


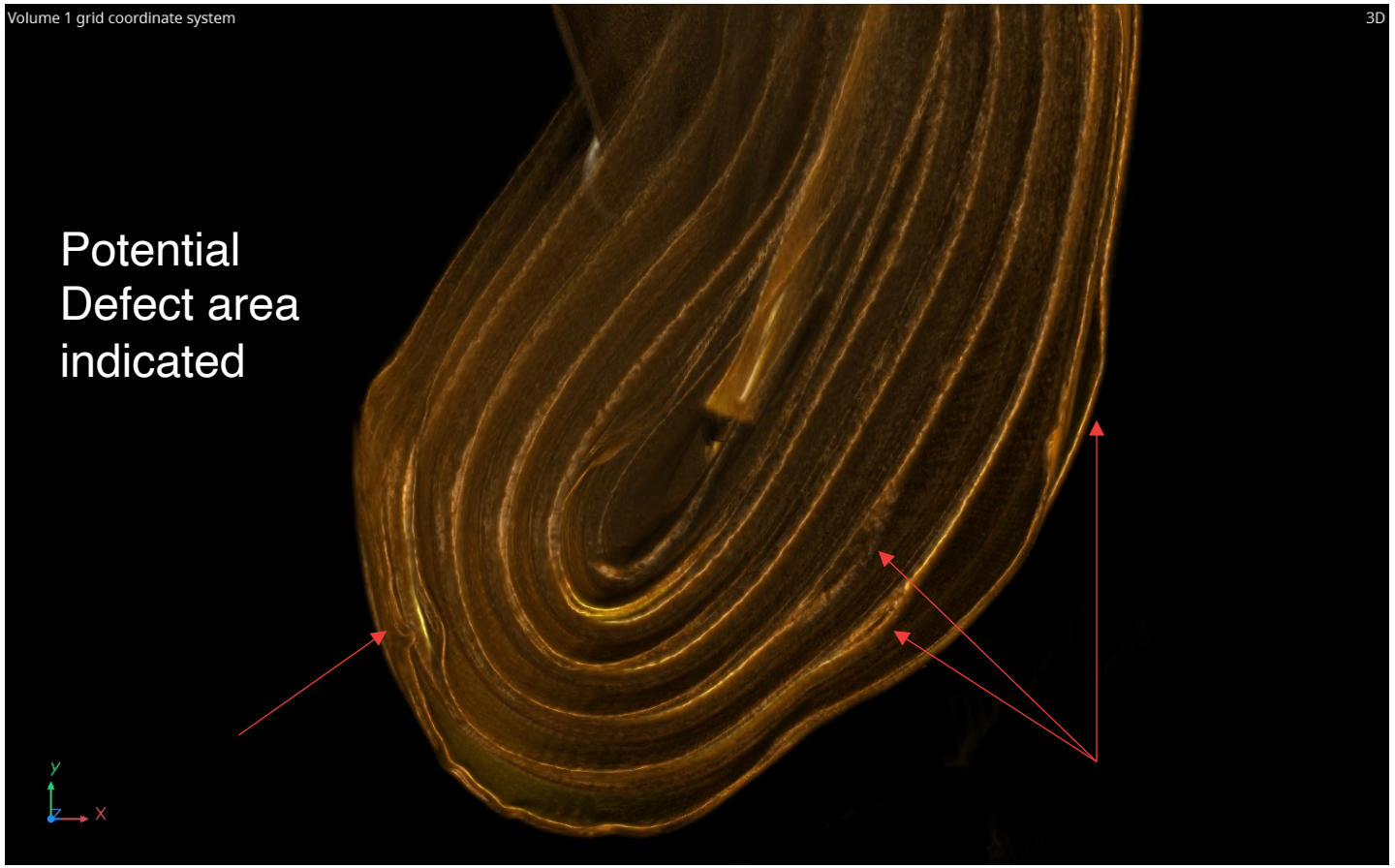


Example: Failed Pouch Cell CT



Example: Failed Pouch Cell CT





Example: Failed Pouch Cell CT– 3D Reconstruction

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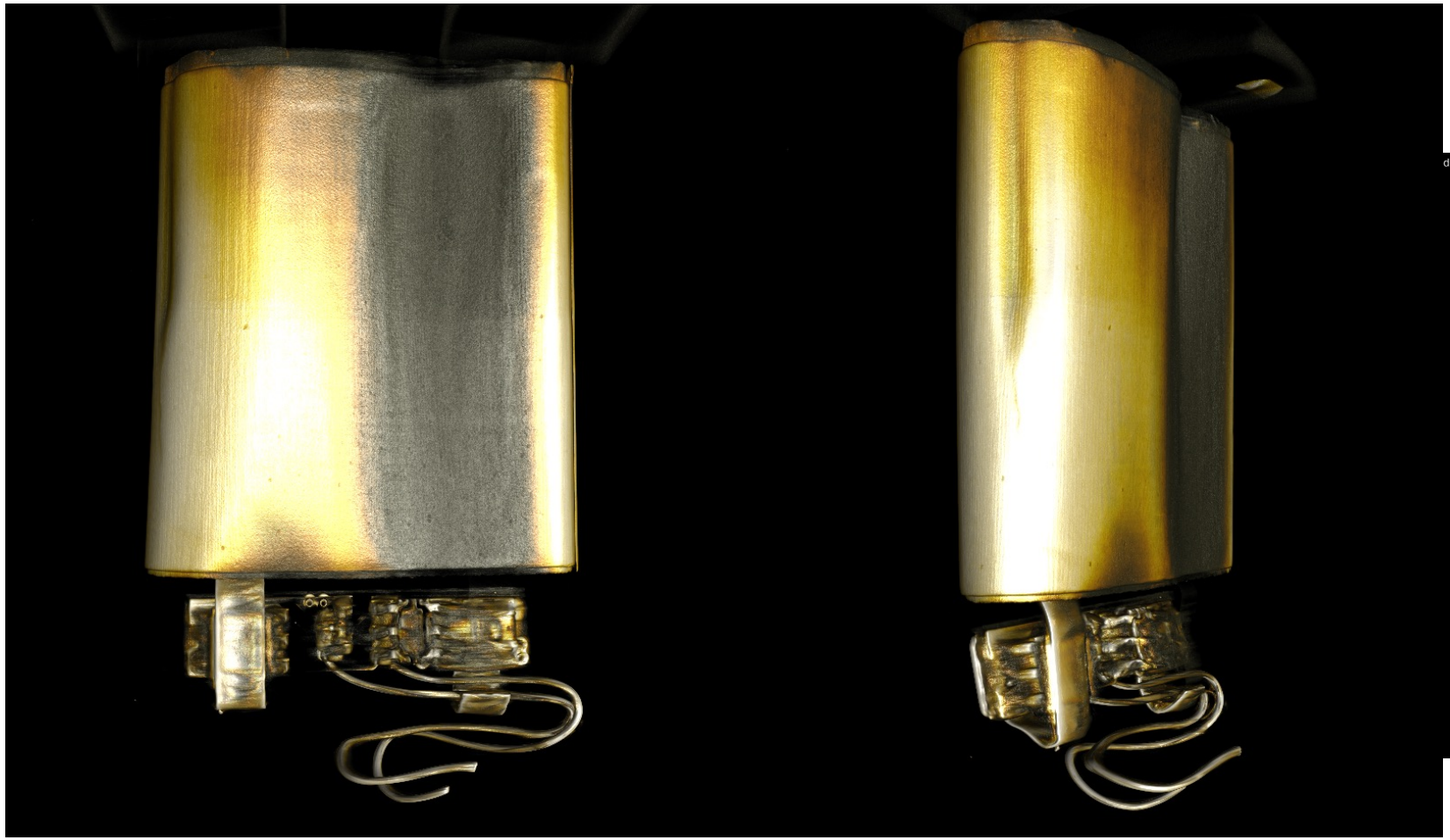
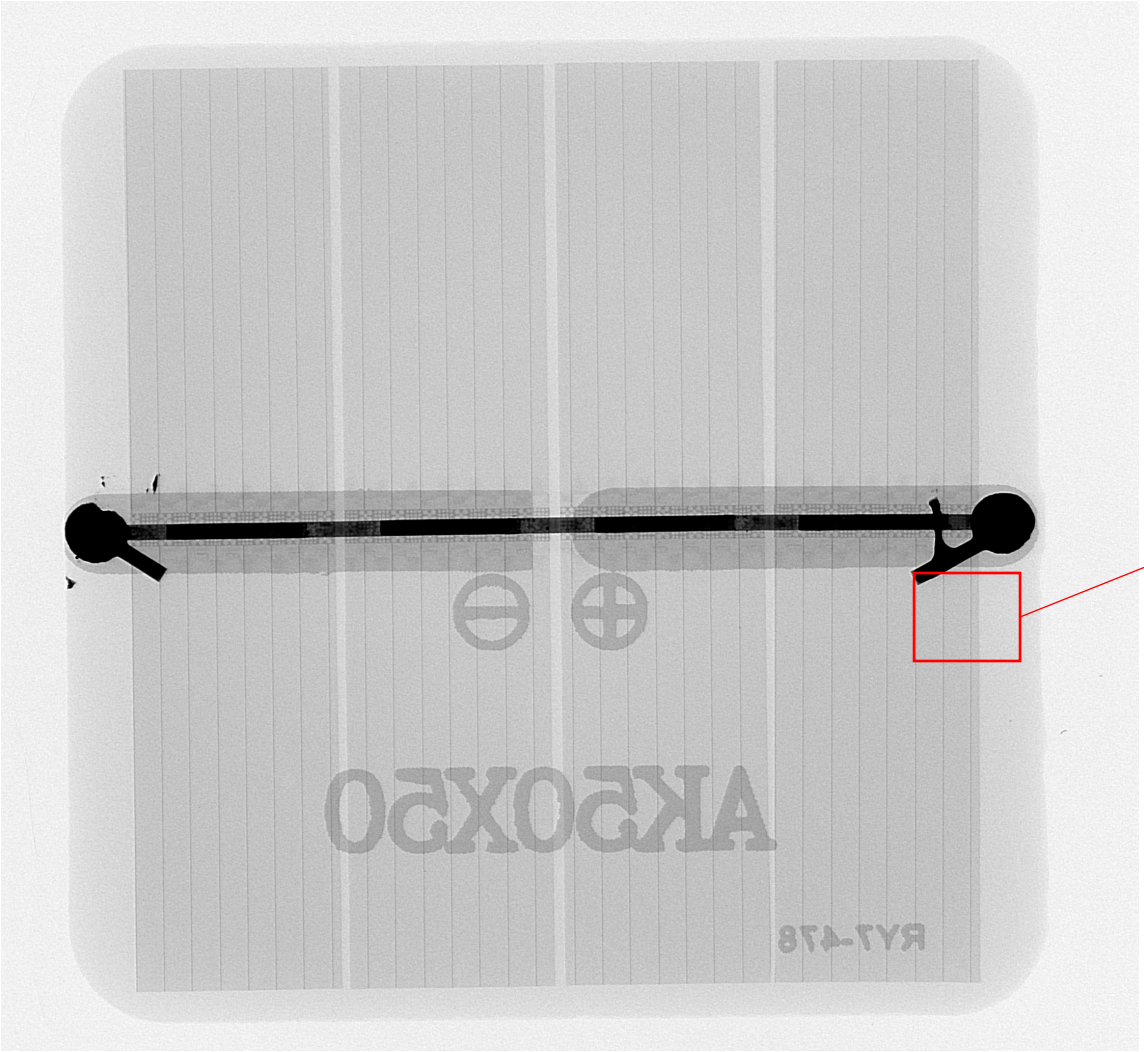
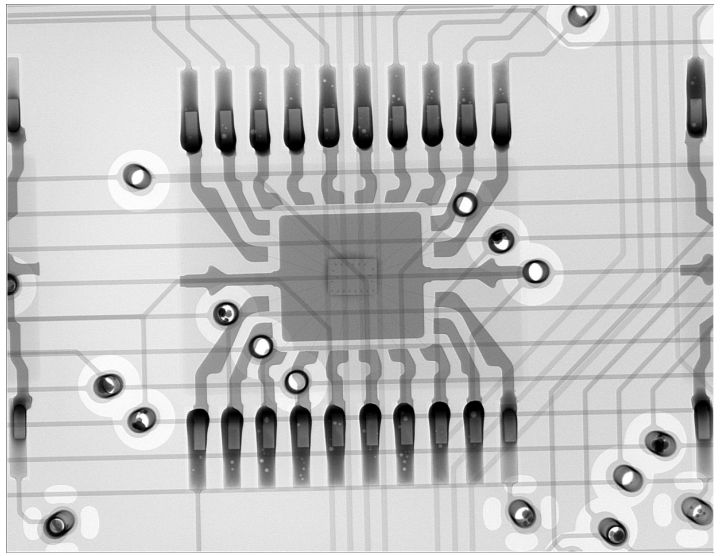
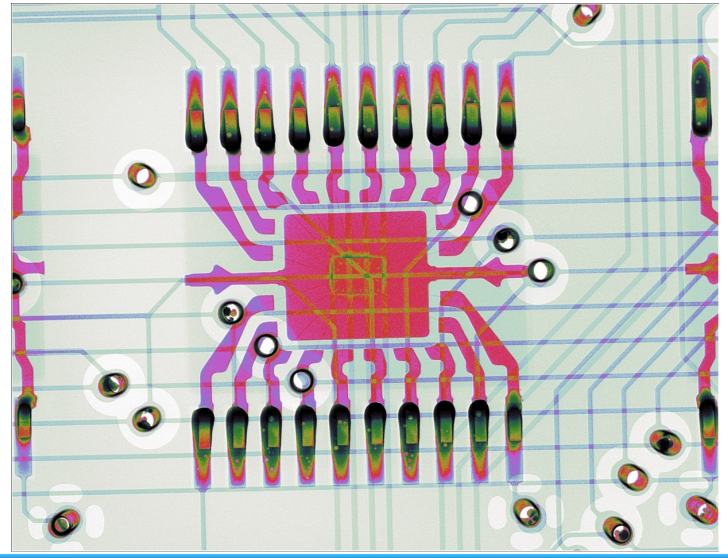


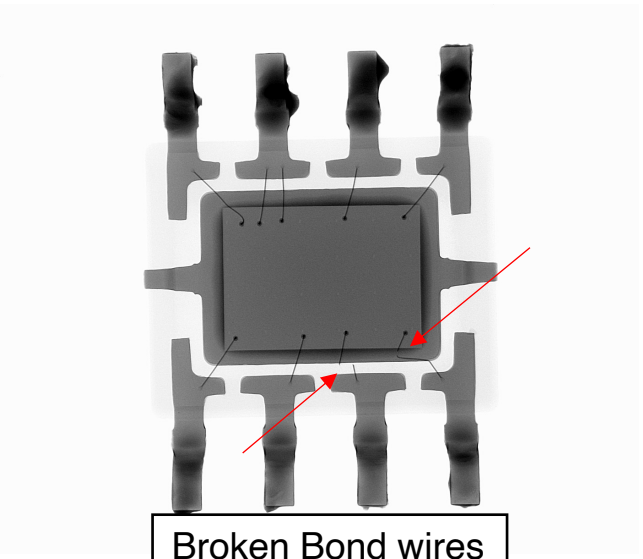
Example: Solar Cells

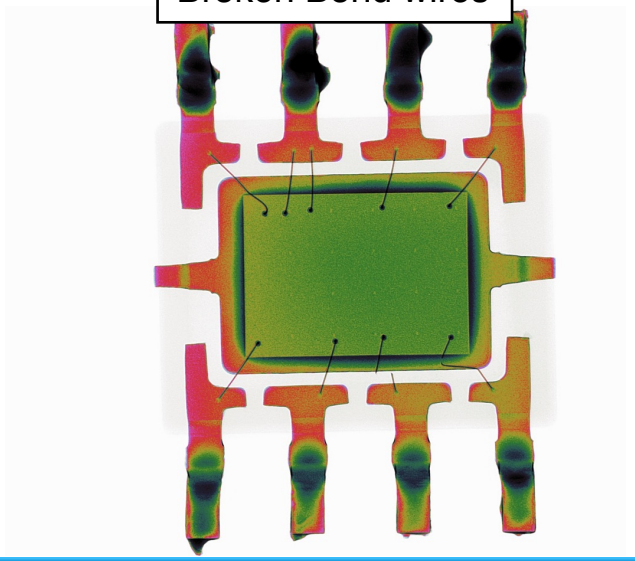


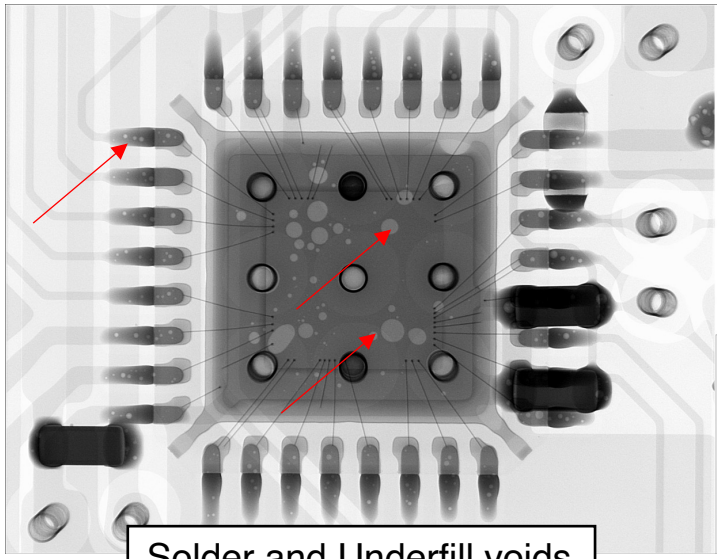
Example: Components and ICs

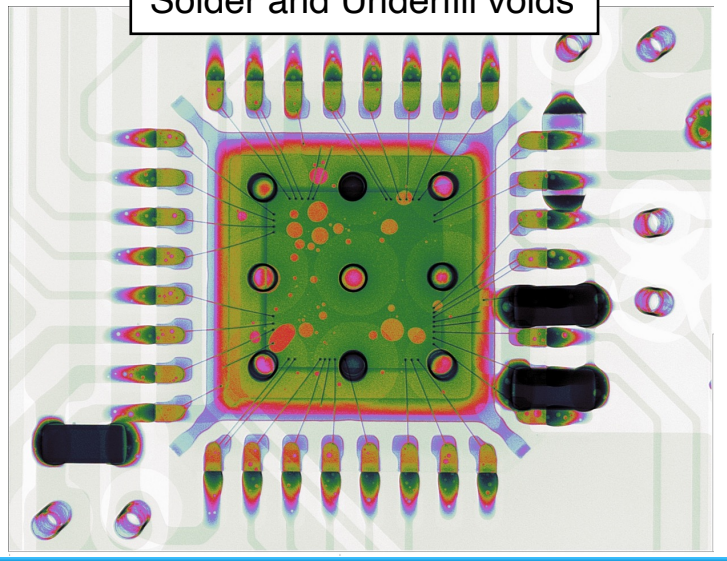




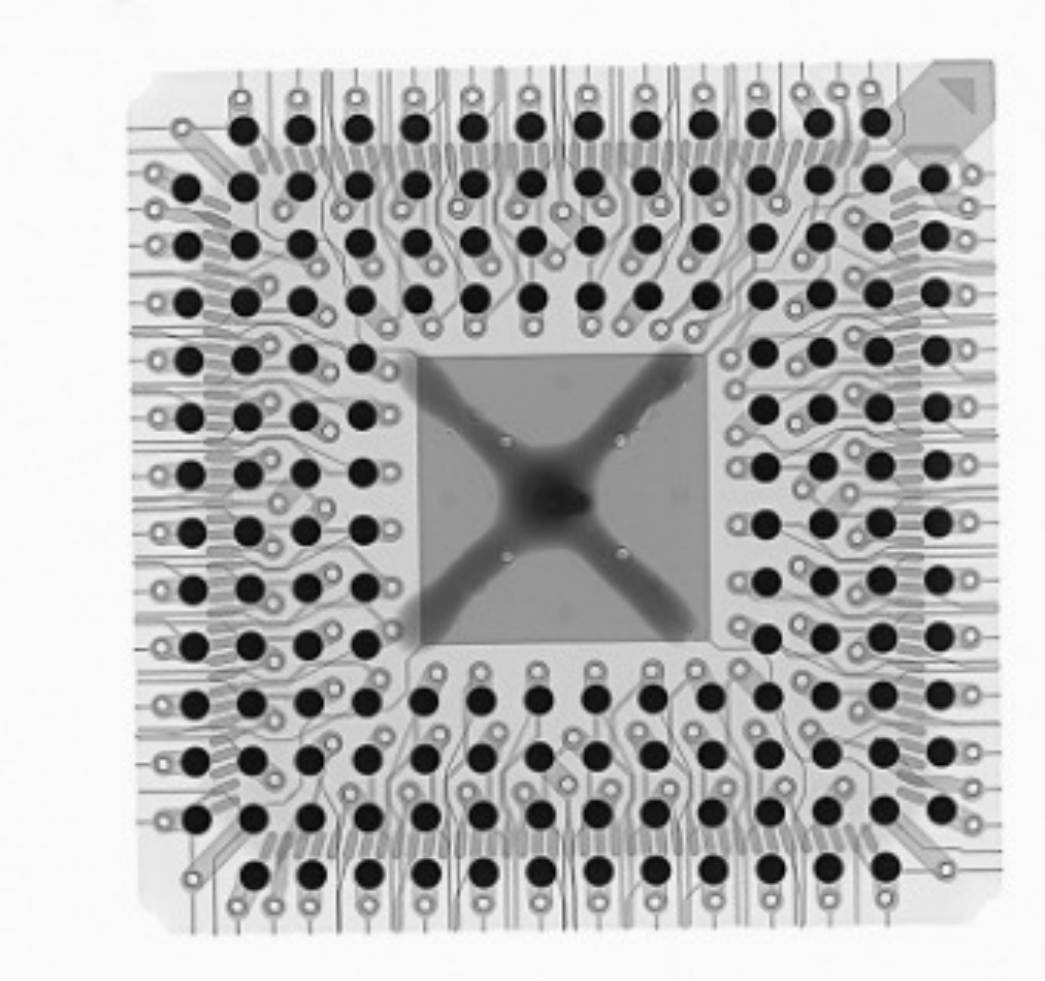


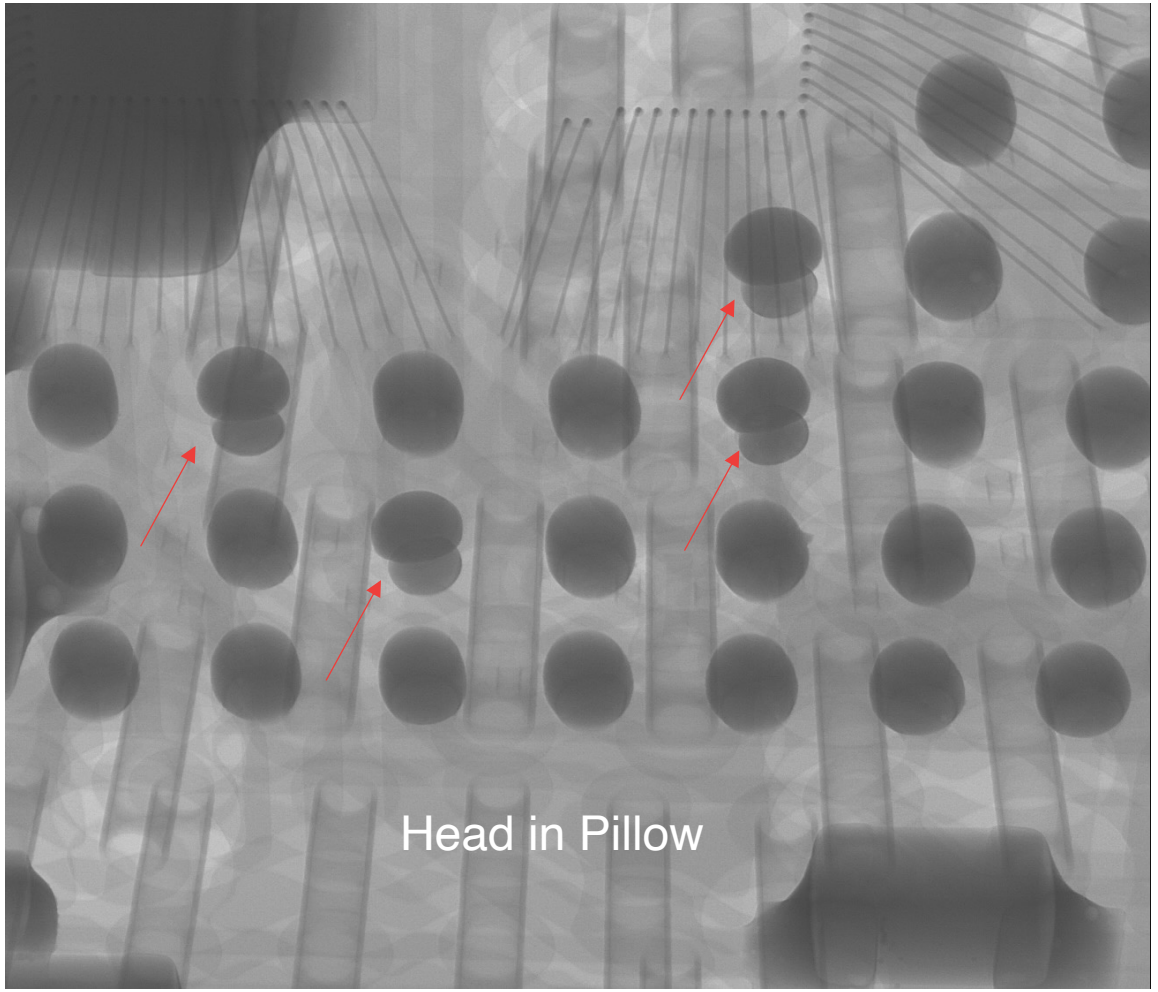




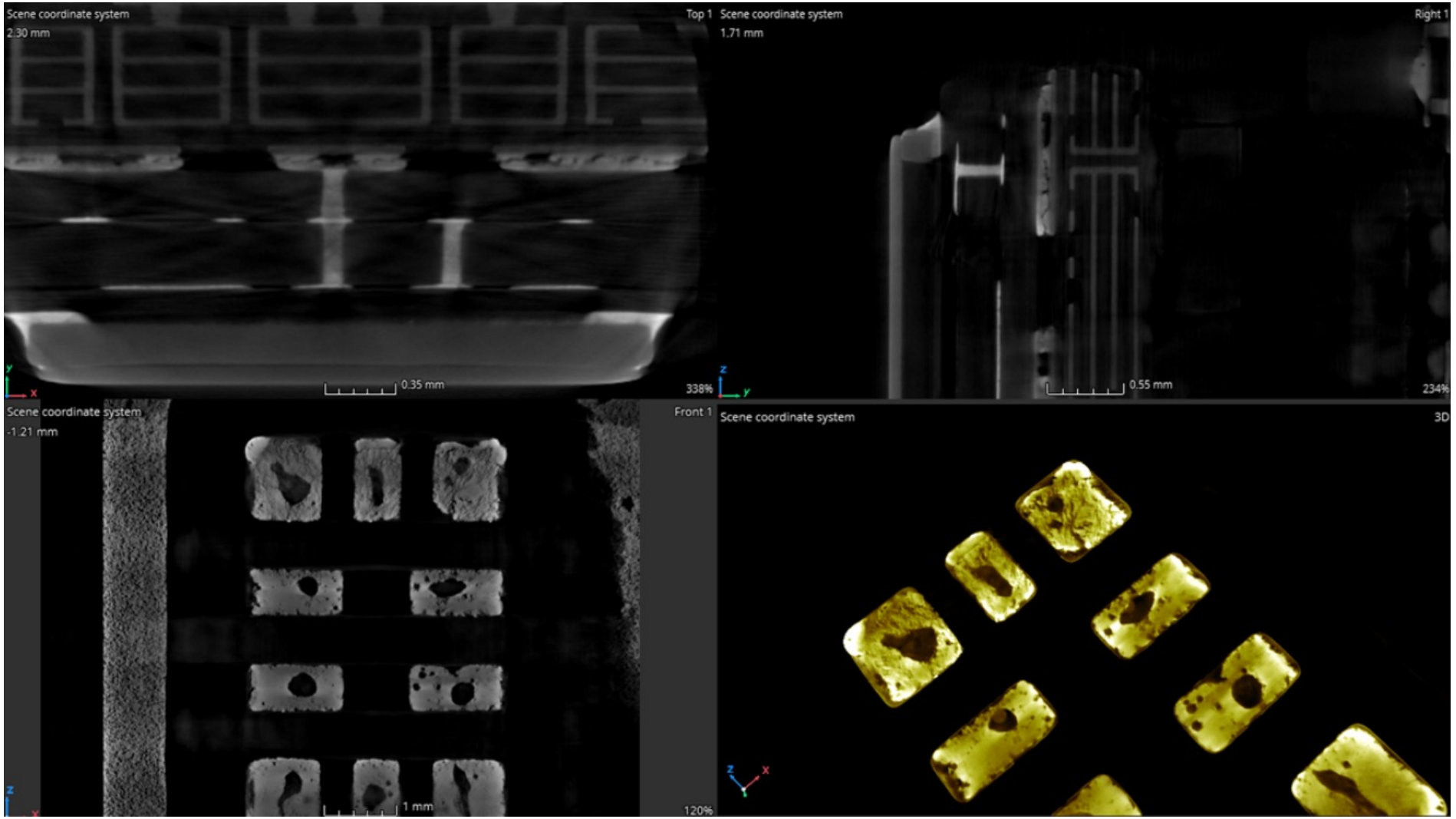


Example: BGA



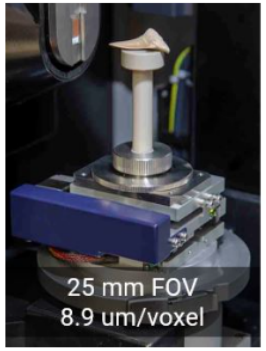


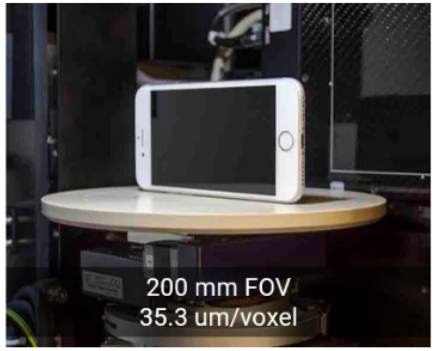
Example: Solder Joints CT



Covalent Tool: Rigaku CT Lab HX130

Voxel resolution	2.1 – 100 um
Field of view (FOV)	5 – 200 mm
Maximum sample size	200 mm diameter x 270 mm height
Speed (shortest scan time)	18 sec
Geometry	Cone beam geometry
X-ray source	39 W traditional micro source
X-ray energy	W anode, adjustable applied voltage 30 - 130 kV
Detector	Flatpanel
Detector pixel size	49.5 microns
Detector size	2352 x 2944 pixels
Dimensions	980 (W) x 580 (H) x 700 (D) mm (PC not included)
Weight	Approx. 380 kg





Do I need a large CT scanner to cover both high-resolution and large FOV?

No, you don't need a large floor standing type CT scanner to cover a wide range of resolution and FOV for most samples under 200 mm in size and made of elements lighter than aluminum.

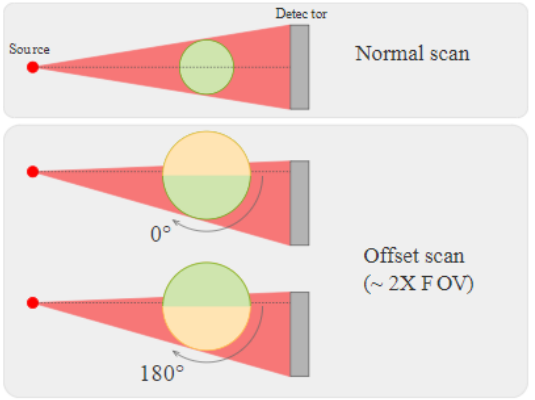
Rigaku CT Lab HX has the flexibility to change both SOD (sample-to-object distance) and SDD (source-to-detector distance) to cover from 2.1 um to about 100 um voxel resolution. And the offset scan mode can cover 200 mm FOV.

This flexible and compact design makes CT Lab HX an affordable research-grade micro CT scanner ideal for materials science imaging centers.

How do I achieve 200 mm FOV?

The FOV (field of view) you can cover in one scan is limited by the size of the detector. However, the offset scan mode doubles the effective detector width to cover a wide FOV without having to change the detector. Rigaku CT Lab HX utilizes this scan mode to achieve 200 mm FOV without having to change the detector or compromising its compact system size.

The 200 mm FOV enables a scan of an entire smartphone, 3D printed objects, fruits, etc.



CT of 3D Printed Covalent Logo

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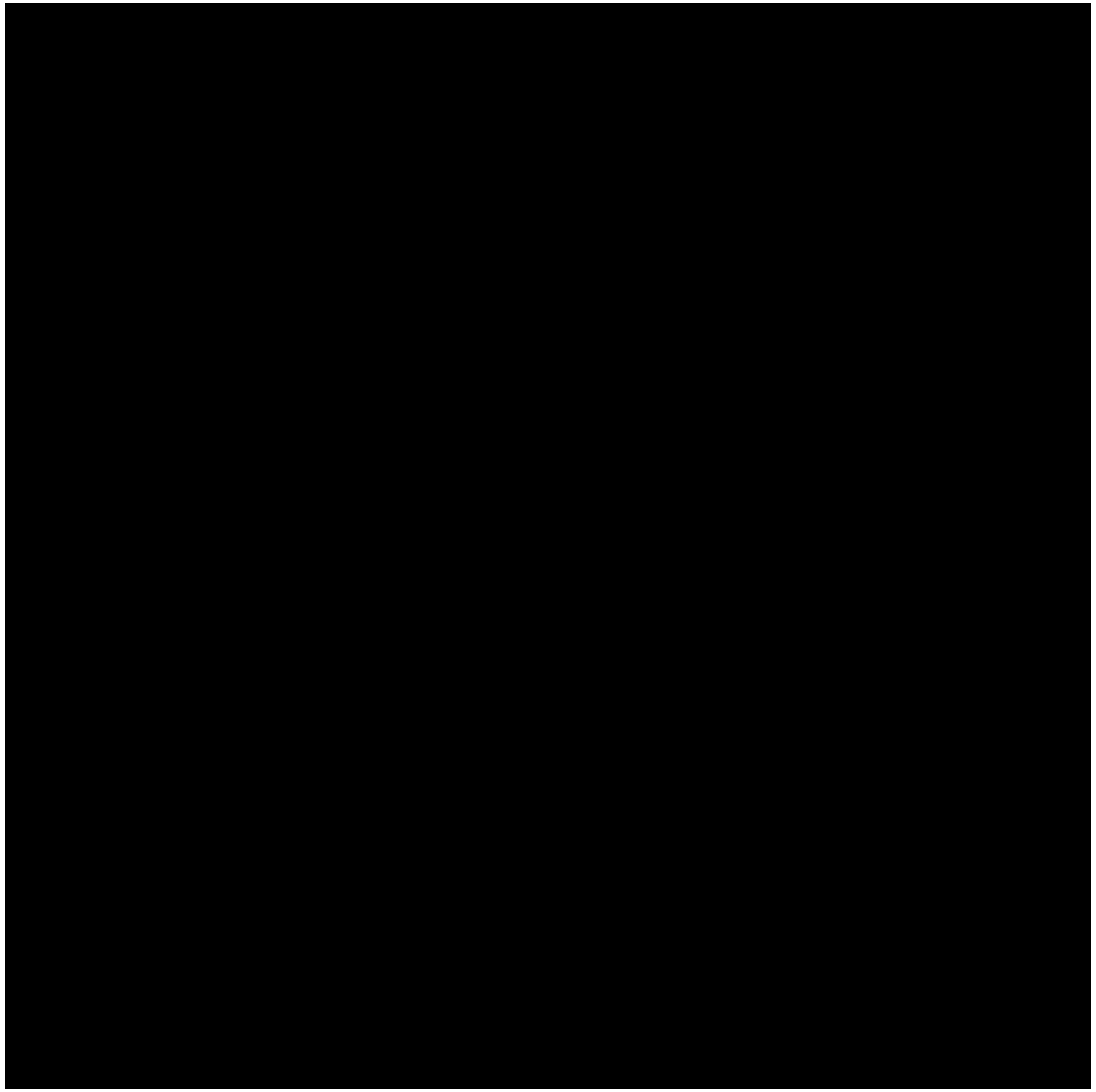

Walnut CT

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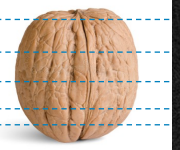
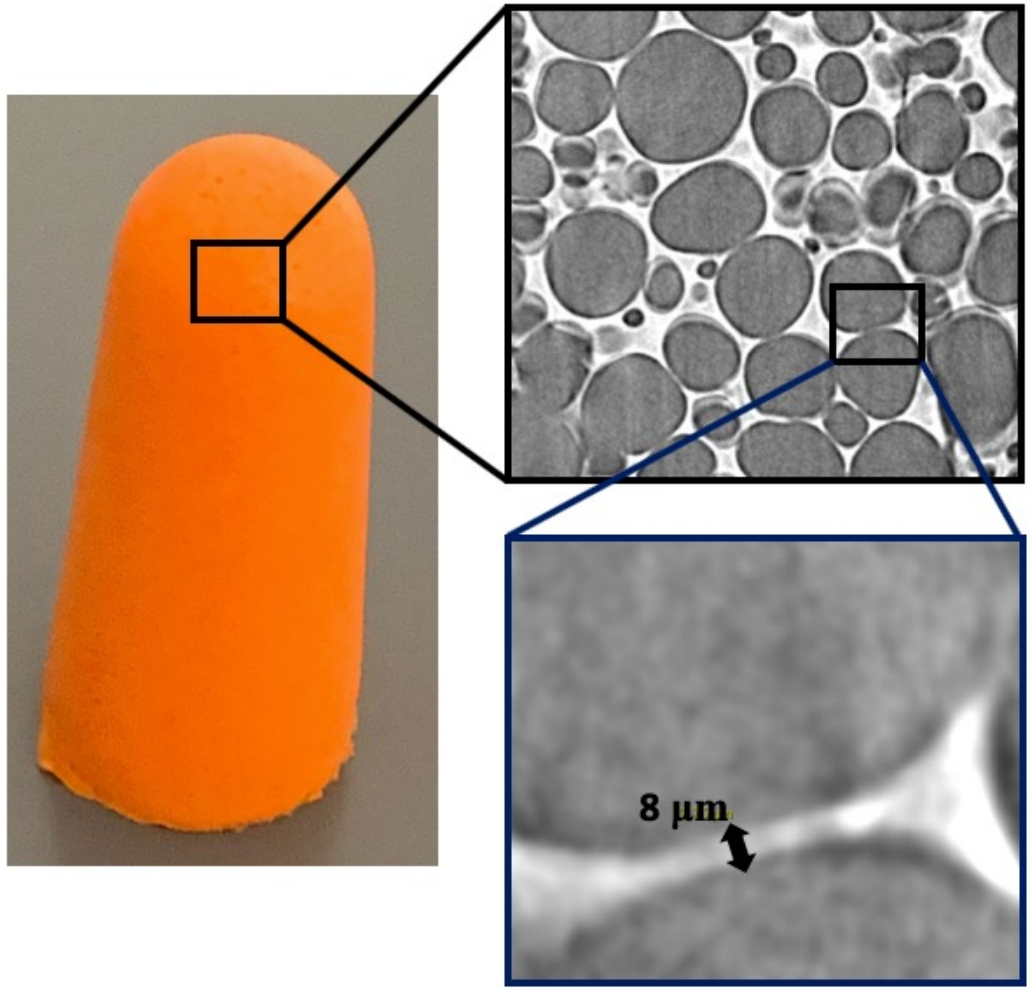


Ear plug



VJ Technologies: Cellphone

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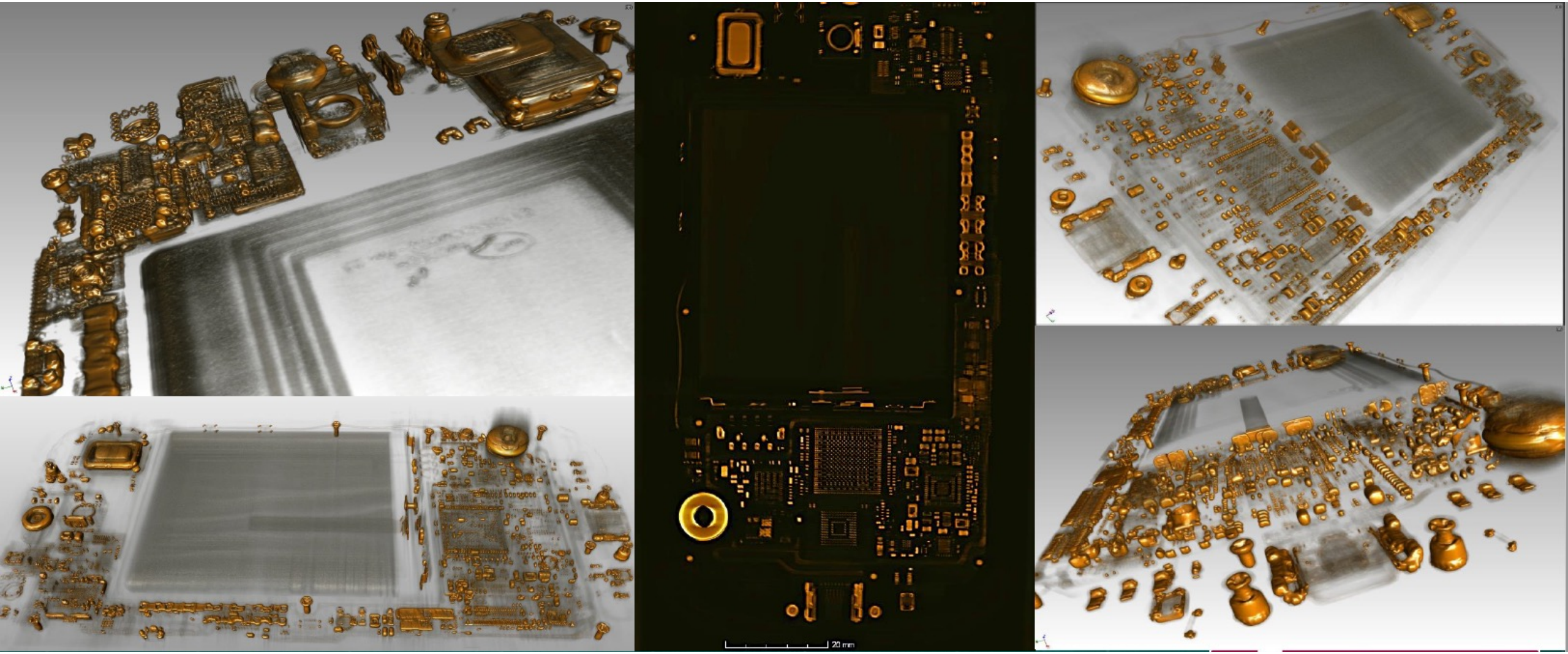

VJ Technologies: Hard Drive

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Zeiss Metrotom 1500: Example 1

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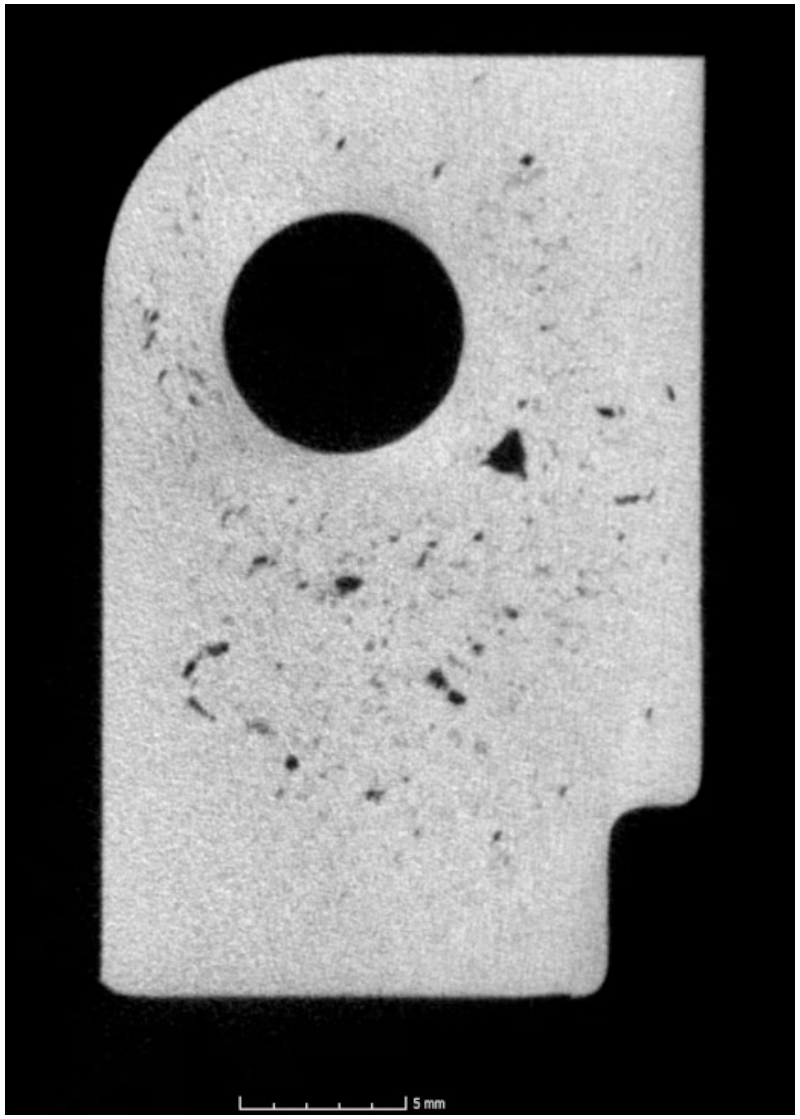

Northstar Imaging

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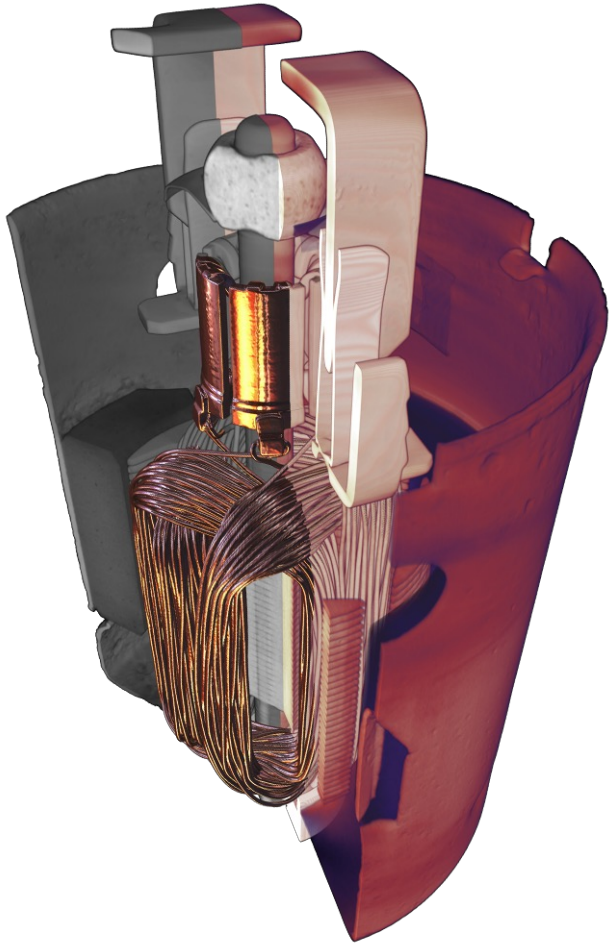

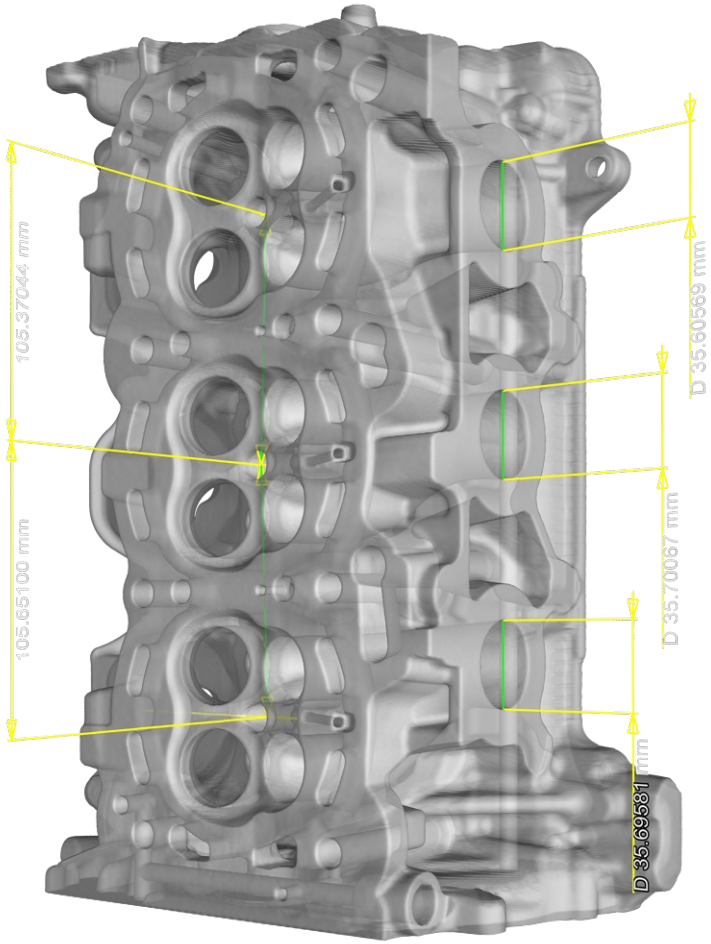

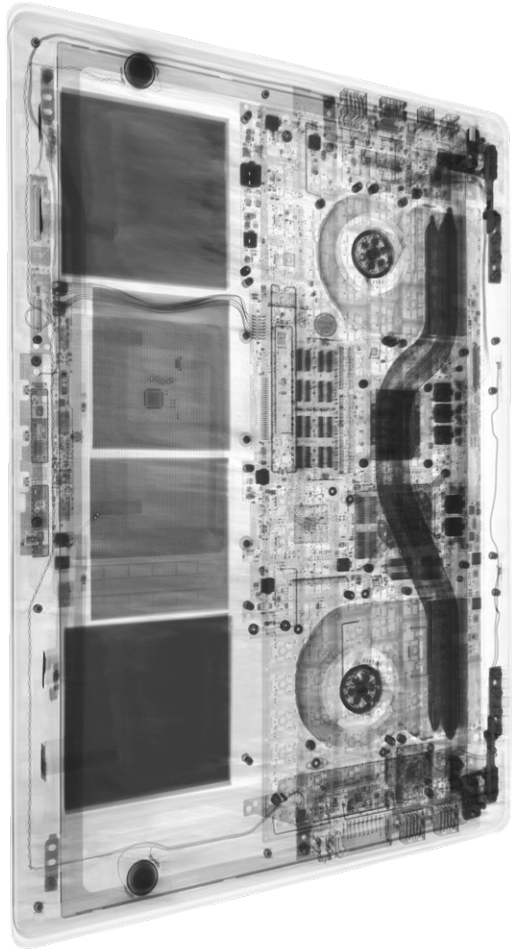

The Covalent Way

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- Domain Experts in Every Technique
- Advanced Analysis and Interpretation
- Expert Advisory Services

- Frictionless experience
- Solution for every budget
- Subscription options

- Fast & Easy Quotation Process
- Sample Pick-Up in Bay Area
- Full Service Analytical Lab for All Your Characterization Needs

- Strong partnerships with global instrument leaders
- Operational excellence
- Value & cost savings passed directly to customers