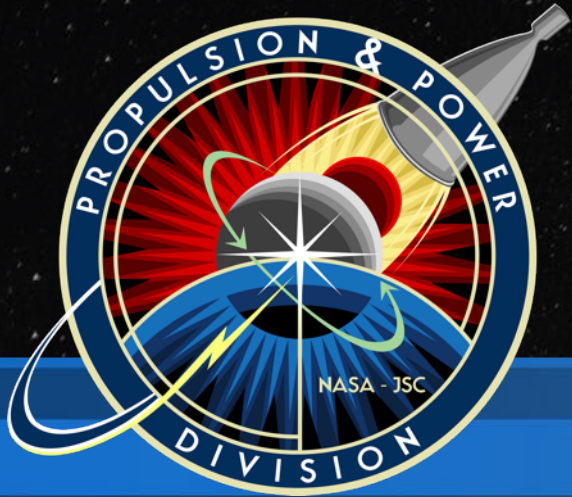




CT Scanning of Commercial Cells for Space Flight Applications

IAPG CWG Safety Panel Meeting

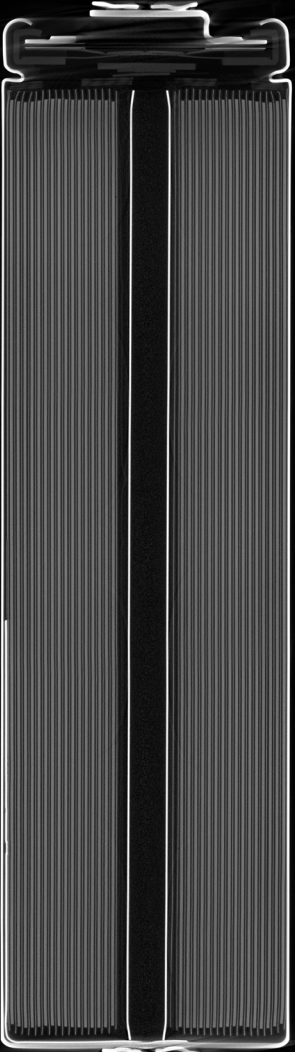
NSWC Panama City, February 18-19

David Delafuente, NASA JSC

Trade names are used in this presentation for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration



Background

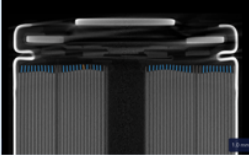
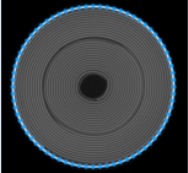
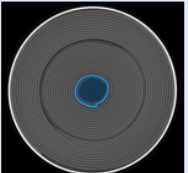
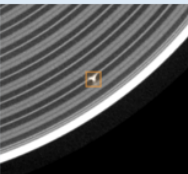


- Computerized Tomography (CT) scans of a minimum of 3 cells is required for all custom battery based on JSC 20793 crewed space flight requirements
- At the time of the requirement was written CT scanning technology was slow and expensive
 - An 18650 cell would take approximately 8 hours to conduct a high-resolution scan
 - Cell was scanned in 3 or 4 sections and required a significant amount of labor to review each slice for defects
- Technology improvements in CT scanning hardware along with computer algorithms have improved the scanning capabilities greatly allowing for short scanning times and automated detection of irregularities
 - Significantly lower cost: From \$3-5k/cell to <\$100/cell

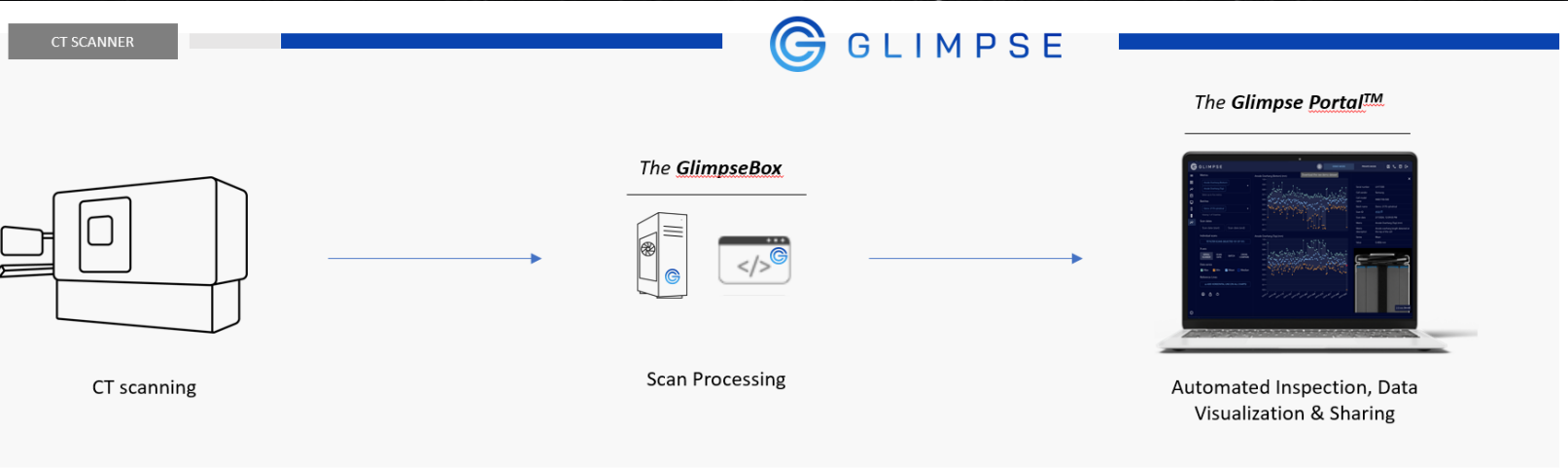
Pass/Fail Criteria Summary



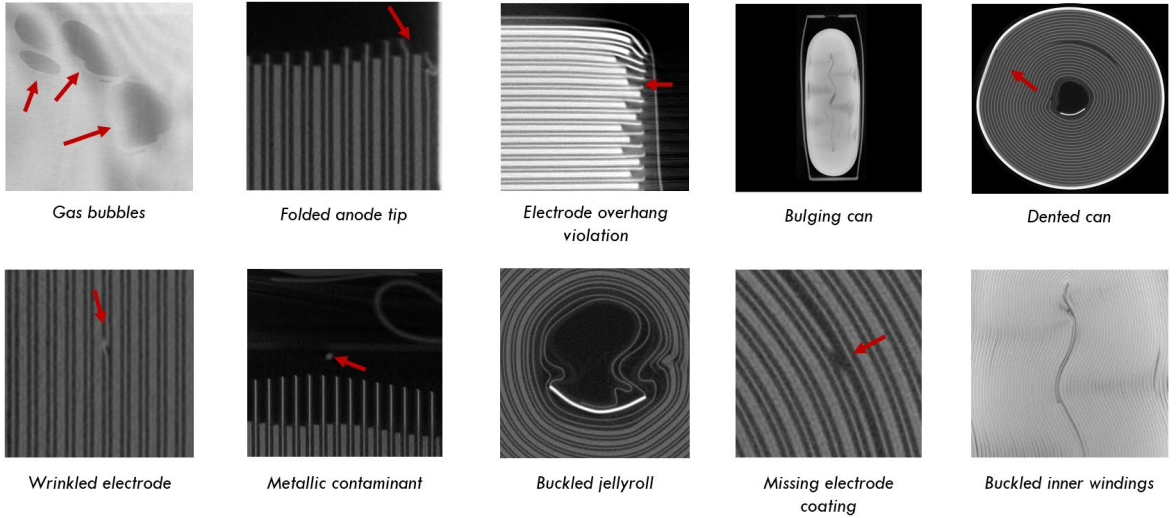
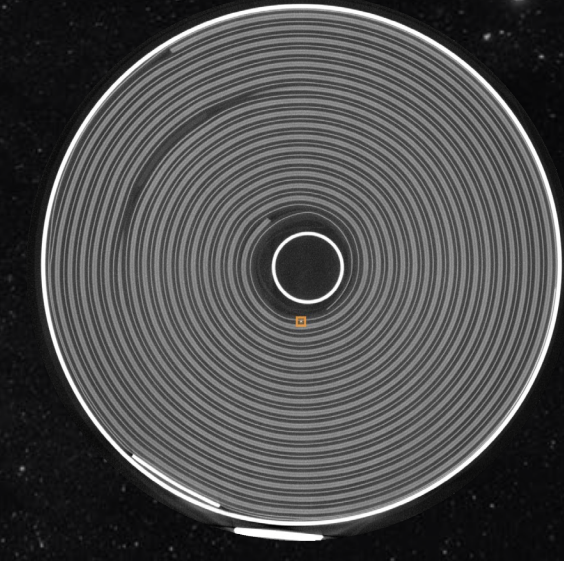
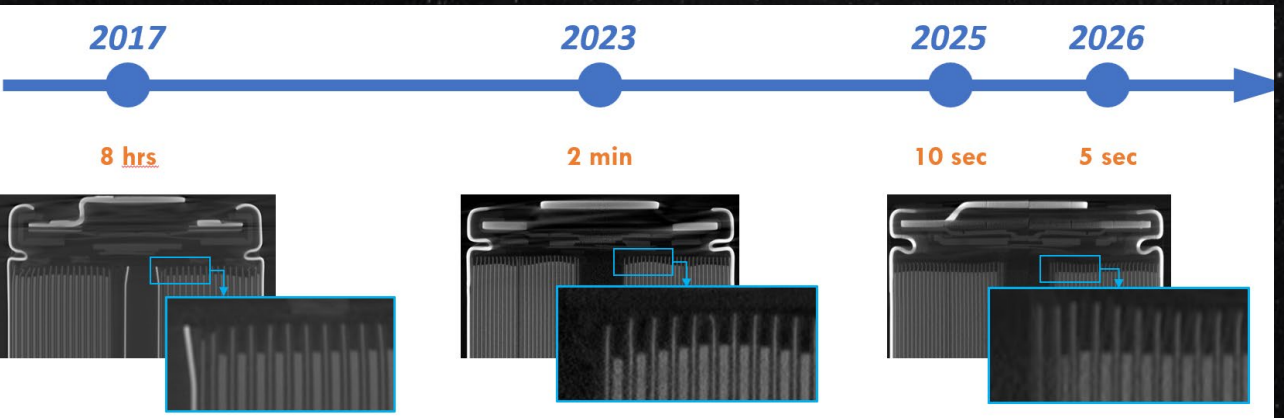
- ✓ Improper seating or pinching of the plastic seal ring
- ✓ Improper routing of the positive tab from the CID to the JR.
- ✓ Internal crimp seal corrosion pitting on the inside of the can next to the seal ring.
- ✓ Excessive telescoping of the JR to the point where anode current collector edge overlap relative to the cathode edge is <100 microns on any of the JR windings either at the top or bottom. Excessive bending or deformation of the anode current collector overlap in the top or bottom of the JR.
- ✓ High density anomalies outside the JR could be indications of weld splatter.
- ✓ High density anomalies inside the JR could be indications of electrode wrinkles, foreign object debris (FOD), or native object debris (NOD).
- ✓ Anomalous can wall thin spots, dents, scratches.
- ✓ Deflected CID that indicates high internal pressure.
- ✓ JR core compression.
- ✓ Anode or cathode active layer delamination or buckling.
- ✓ Anode or cathode active material absent, thin or thick spots.
- ✓ Electrode wrinkles.

Electrode	• Overhang (top & bottom) • Asymmetry	
Can	• Max denting • Circularity • Inner & outer diameter • Wall thickness	
Crimp	• Crimp height • Groove gap	
Jellyroll Core	• Area • Concentricity • Effective diameter • Circularity • Jellyroll buckling	
Foreign Objects	• Metallic-particle detection	

CT Scan Capability



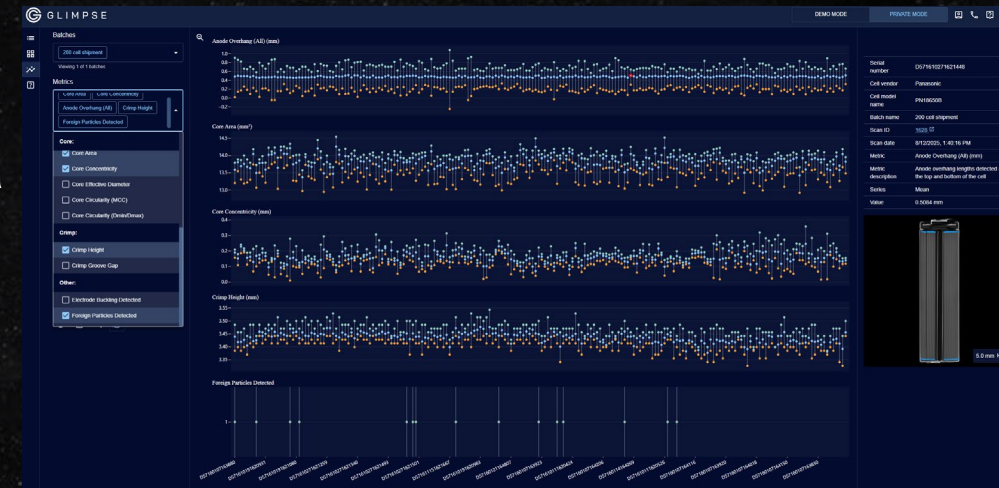
Scan time:	2 min / cell	→ Increase scans per day
Analysis time:	<1 min / cell	→ Automated inspection results available instantly
File size:	< 100 MB	→ Digital system of record for long-term traceability



CT Scanning



- Glimpse conducted 2 min fast scans on 200, 18650 cells from a lot of 20K cells
- The Glimpse system takes the raw CT scans and conducts a variety of analysis looking for:
 - Anode overhang, Can parameters, Dents, Core area concentricity/circularity, Crimp height, Electrode buckle and Dense particles
- To be able to view the data over the internet (NASA portal) the raw data is compressed significantly but the analysis is conducted prior to compression
 - The compressed data will show a slice every 0.1mm to 1mm depending on location
 - For dense particle detection the software captures the particle size and moves the image to the nearest slice
- JSC received the raw data on select cells of interest for more thorough analysis



Example scan of the cell header region and analysis for multiple parameters



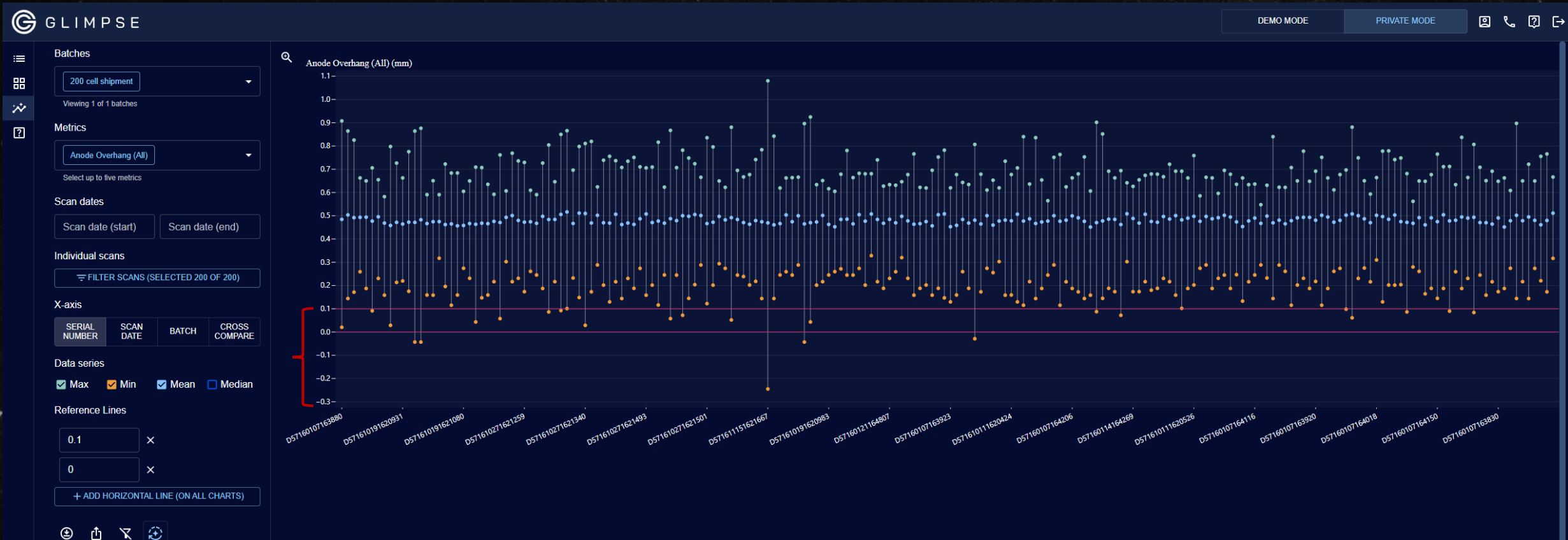
Pass/Fail Criteria Summary

- ✓ Improper seating or pinching of the plastic seal ring
- ✓ Improper routing of the positive tab from the CID to the JR.
- ✓ Internal crimp seal corrosion pitting on the inside of the can next to the seal ring.
- ☒ Excessive telescoping of the JR to the point where anode current collector edge overlap relative to the cathode edge is <100 microns on any of the JR windings either at the top or bottom. (0/200 to pass)
- ✓ Excessive bending or deformation of the anode current collector overlap in the top or bottom of the JR.
- ☒ High density anomalies outside the JR could be indications of weld splatter. (0/200 to pass)
- ✓ High density anomalies inside the JR could be indications of electrode wrinkles, foreign object debris (FOD), or native object debris (NOD).
- ✓ Anomalous can wall thin spots, dents, scratches.
- ✓ Deflected CID that indicates high internal pressure.
- ✓ JR core compression.
- ✓ Anode or cathode active layer delamination or buckling.
- ✓ Anode or cathode active material absent, thin or thick spots.
- ✓ Electrode wrinkles.

Anode Overhang Results



- Industry standard IEEE 1725-2021 for minimum anode overhang to the cathode is 0.1mm
- 5 cells with negative anode overhang (below the 0.0 line)
- 19 cells with less than the industry standard for anode overhang (between purple lines)
- 12% of the cells do not meet the industry standard



Negative Anode Overhang, 1569

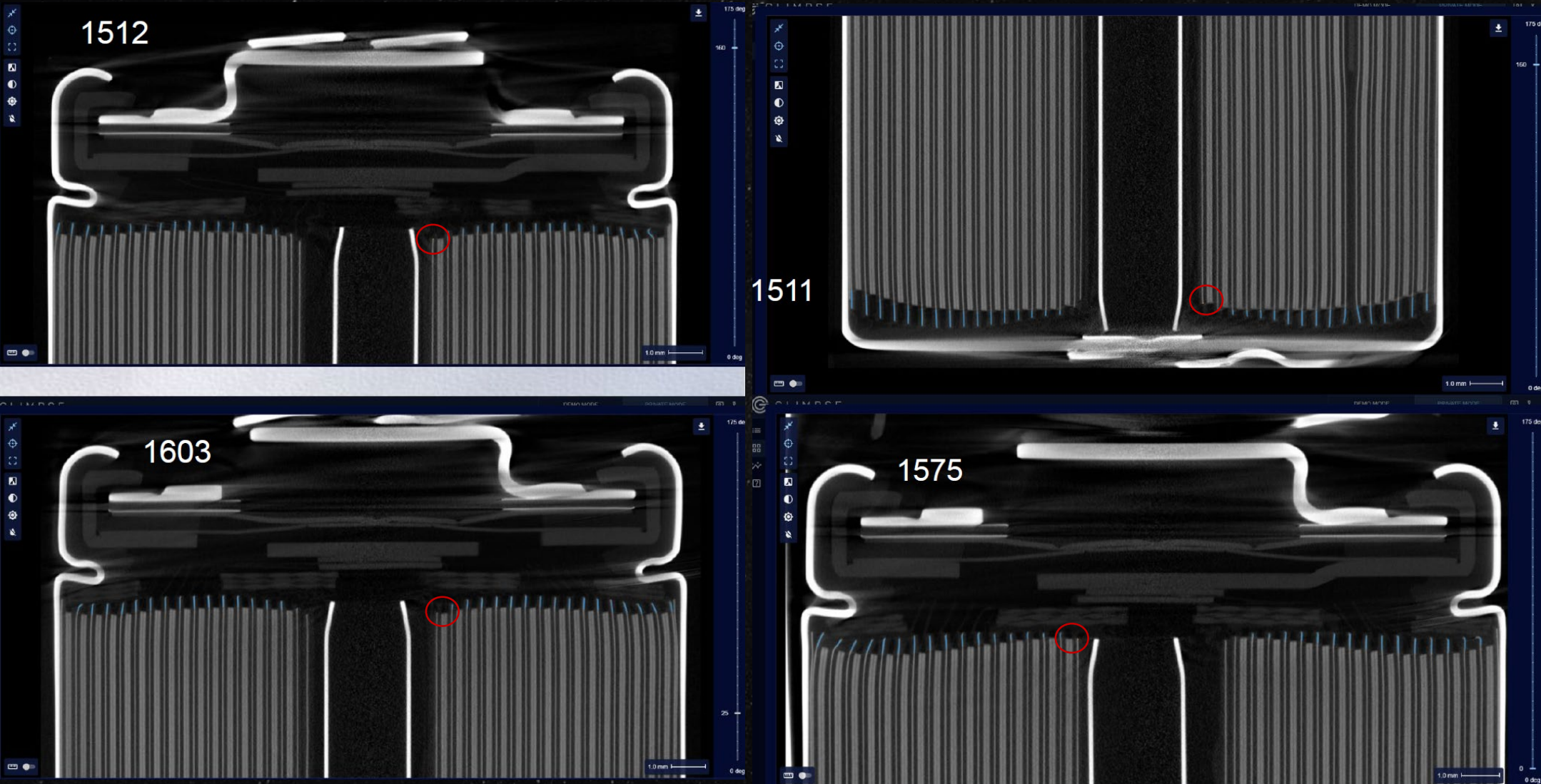


- Cell 1569 exhibited the greatest negative overhang at -0.245mm
- Industry standard for 18650 cells is a minimum 0.1mm positive overhang of the anode
- No corresponding cathode across from the anode causes lithium plating and dendritic growth which can lead to internal shorts
- The telescoping of the jellyroll occurs generally during assembly of the cell
- Cells are under internal pressure, and the jellyroll is taped tightly to prevent moving
- Vibe testing of 18650 cells following SAE J2380 is 100k mile driving equivalent without any damage or displacement of the jellyroll including the Panasonic NCR18650B cell*



*Philipp Berg, Markus Spielbauer, Michael Tillinger, Matthias Merkel, Maik Schoenfuss, Oliver Bohlen, Andreas Jossen. Durability of lithium-ion 18650 cells under random vibration load with respect to the inner cell design, Journal of Energy Storage, Volume 31, 2020, 101499, ISSN 2352-152X

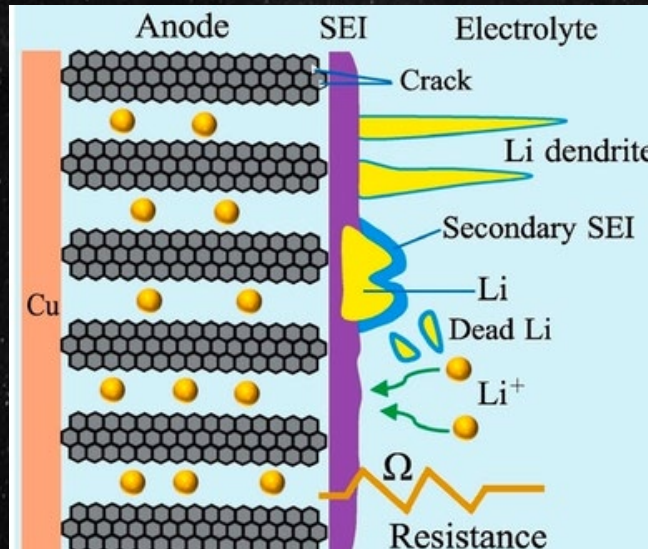
Other Cells with Negative Anode Overhang



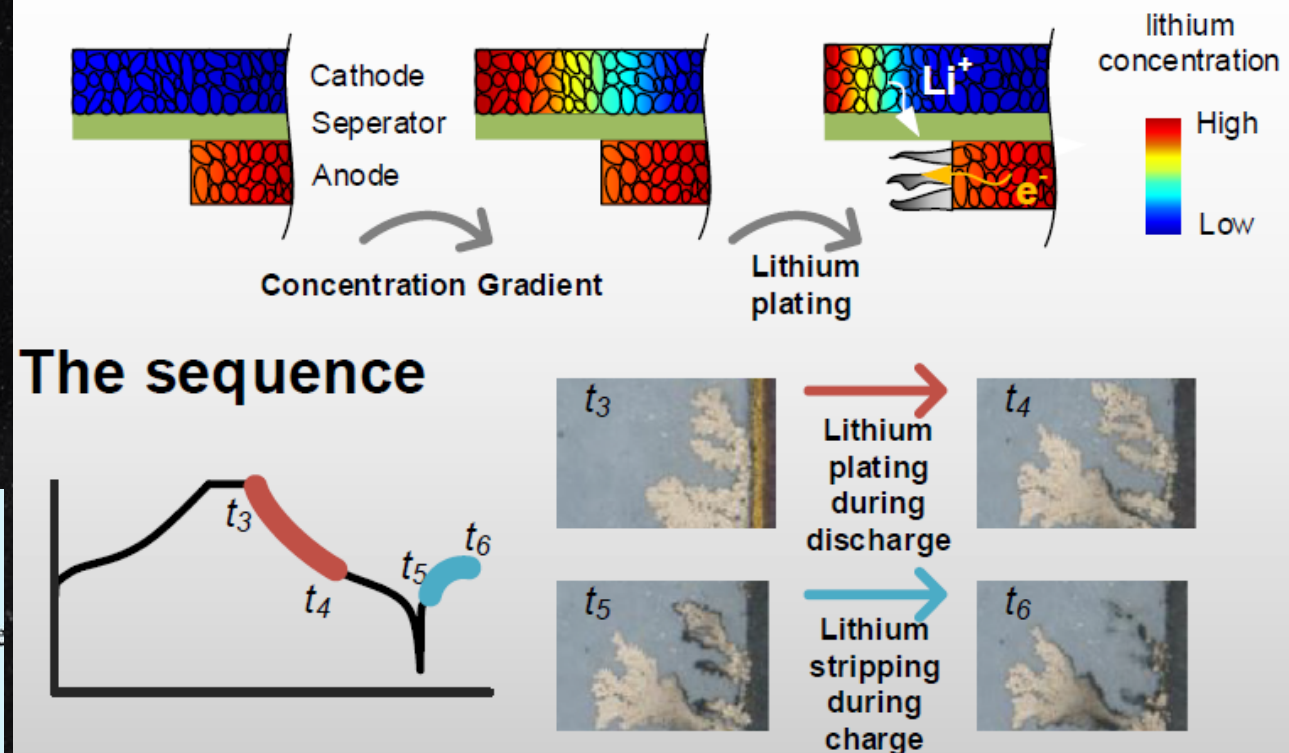
Lithium Plating and Dendrite Growth



- Lithium plating occurs when lithium metal particles pile up on the anode surface during discharge (anode potential $< 0V$) as the lithium atoms are moving to the anode
- Lithium plating can be reversible but not all of the lithium particles resolubilize into the electrolyte
- Generally, lithium plating occurs during charge and can be stripped during discharge however, with negative anode overhang the plating is delayed and occurs during the discharge



Z. Li et al. 40 Years of Low-Temperature Electrolytes for Rechargeable Lithium Batteries. Angew. Chem. Int. Ed. 2023,62



Y. Huang, et al. Mechanism of lithium plating and stripping in lithium-ion batteries induced by overhang failure defects, Cell Reports Physical Science, Volume 5, Issue 12, 2024

Lithium plating leads to dendrites which can pierce the separator causing an internal short and thermal runaway



Lithium Plating due to overhang issue Video (1 Cell Cycle)



Overhang
experiment

Lithium plating leads to dendrites which can pierce the separator causing an internal short and thermal runaway

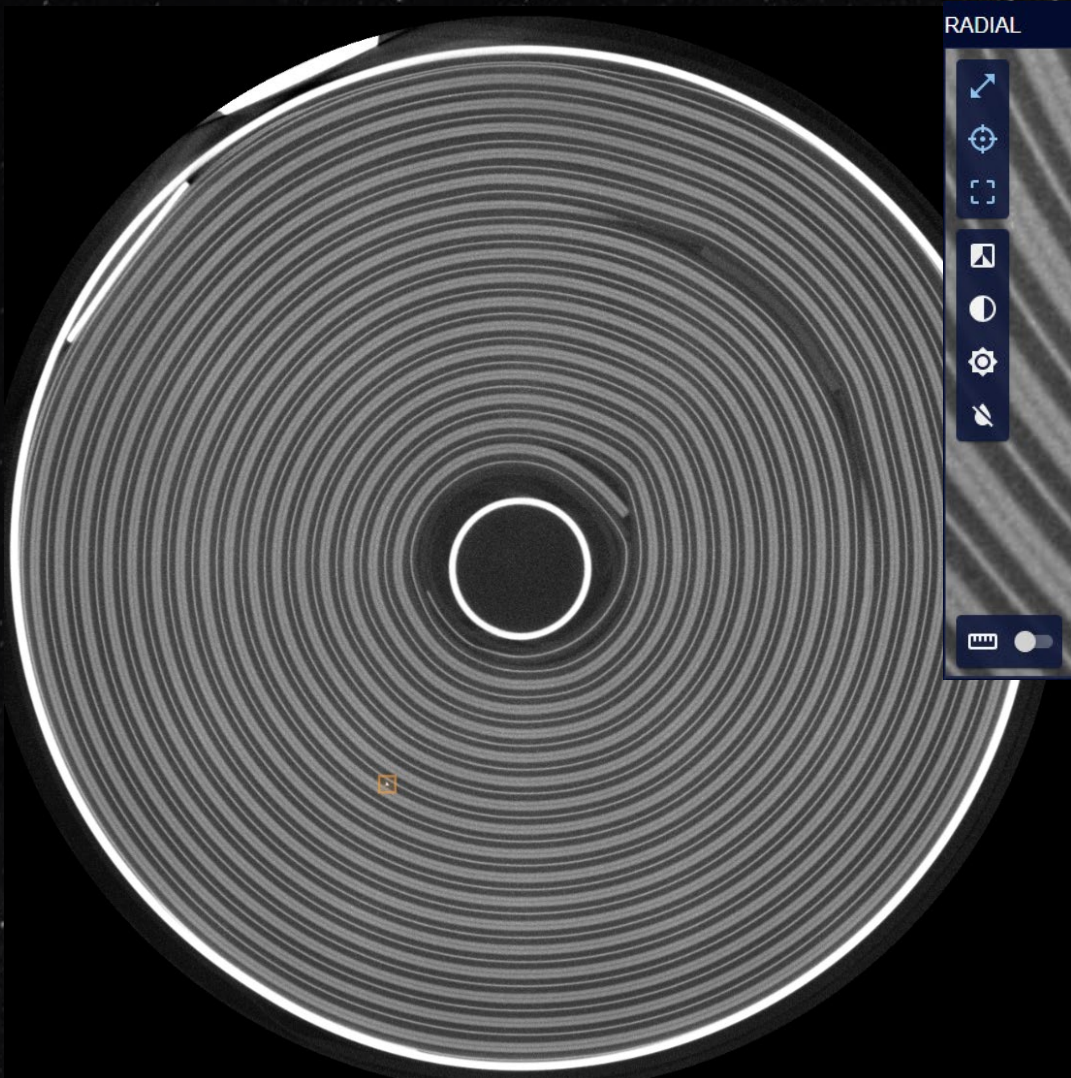


Dense Particles

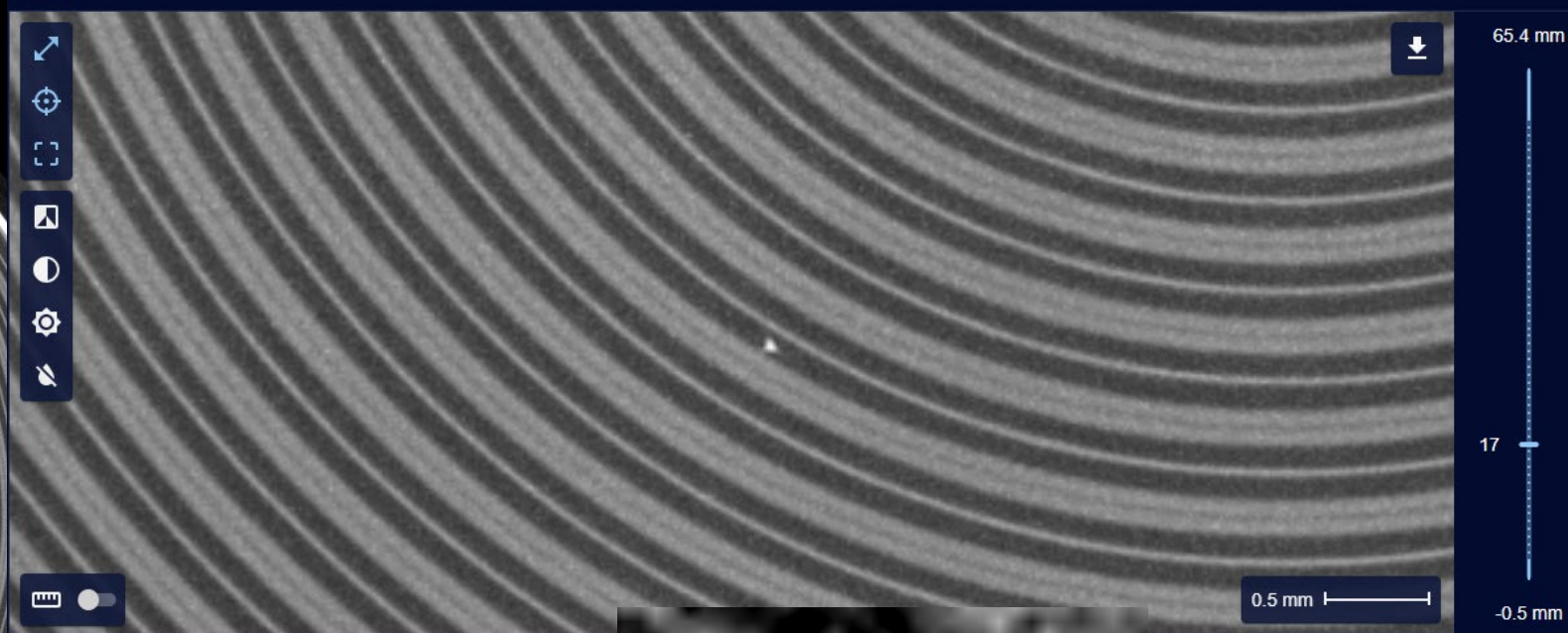


- 15 dense particles detected in the 200 cells screened
 - 8 dense particles found inside the anode
 - 7 dense particles found outside the jellyroll
- These dense particles are bright spots in contrast and are metallic in nature to be observed by x-rays
- Particles observed were ranging from 50 μ m up to 210 μ m
 - 50 μ m is around the size limit for a person to see with the naked eye
 - A particle of approximately 60 μ m is large enough to cause the worst case short between the aluminum current collector and the anode active material
 - Smaller particles can still cause a short in the cell but may not be large enough for current collector to active material short but rather active material to active material short
- Cell Destructive Physical Analysis (DPA) is still necessary to determine the actual dimensions and composition of the contamination

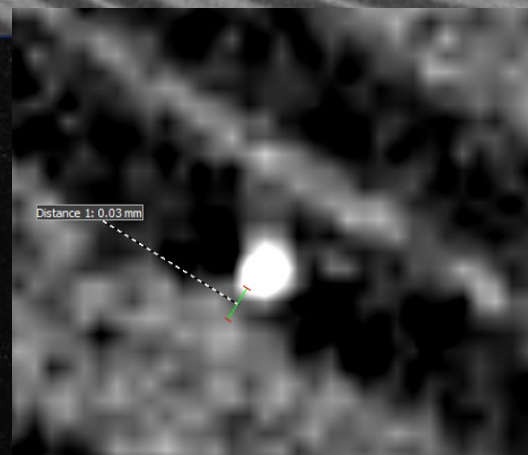
Scan 1506



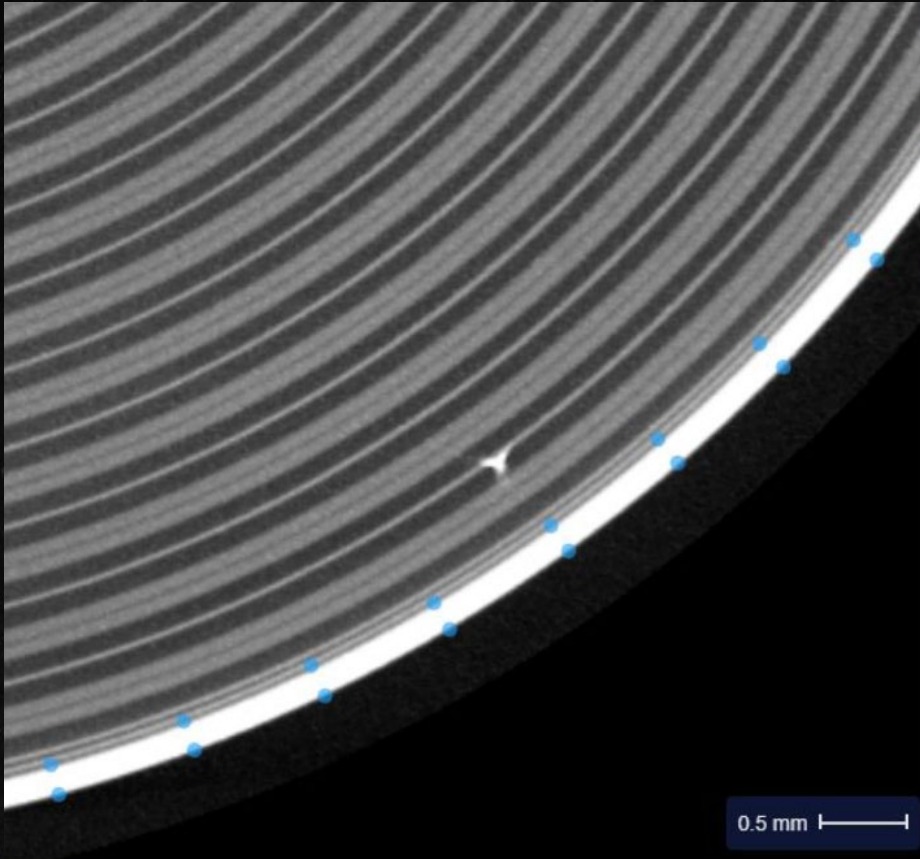
RADIAL



~50 μ m in size



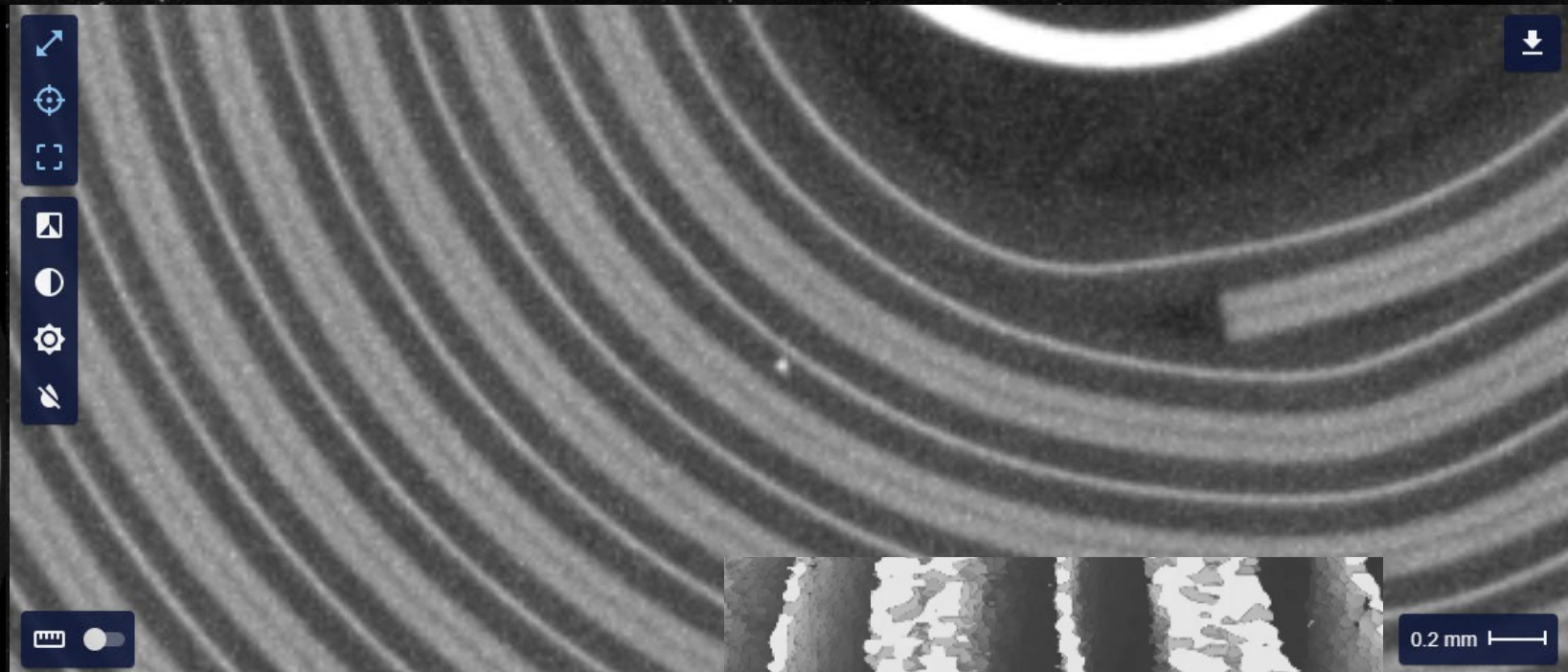
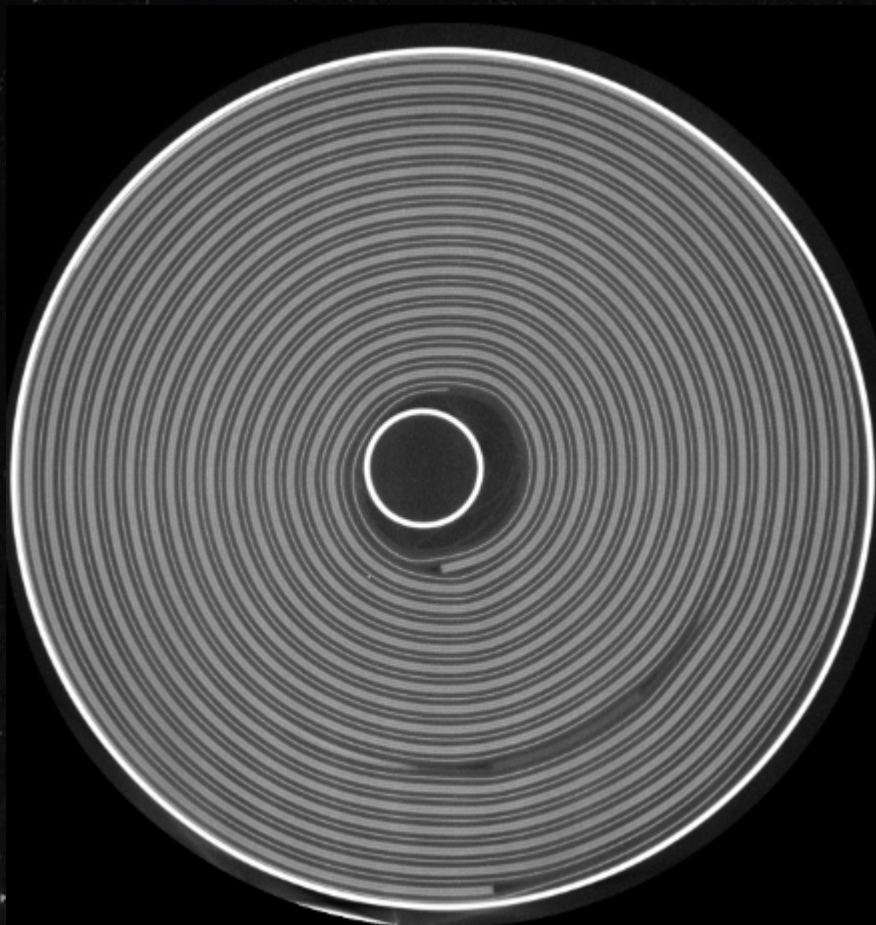
Scan 1517



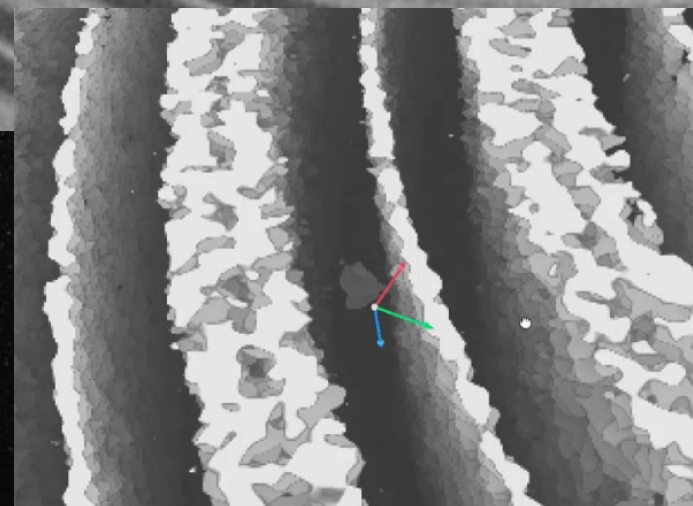
~180 μ m x 120 μ m x 60 μ m in size



Scan 1571



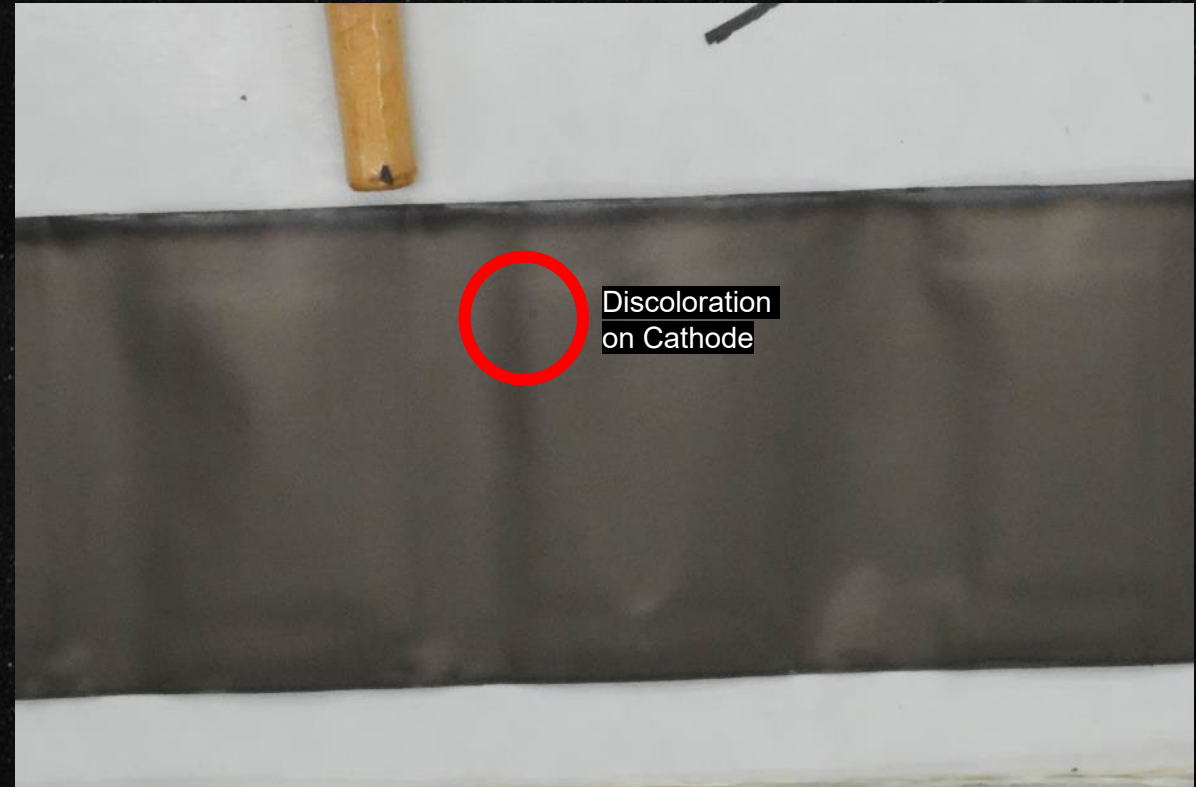
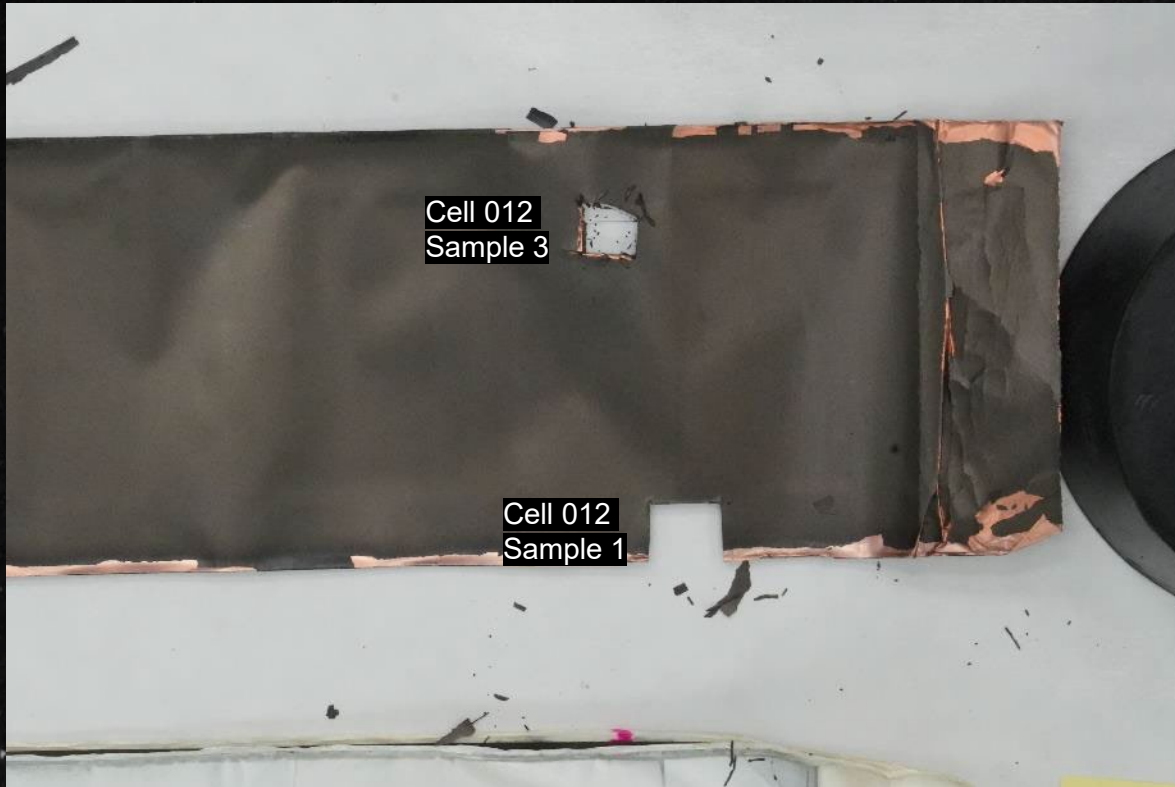
~60 μ m in size



0.2 mm



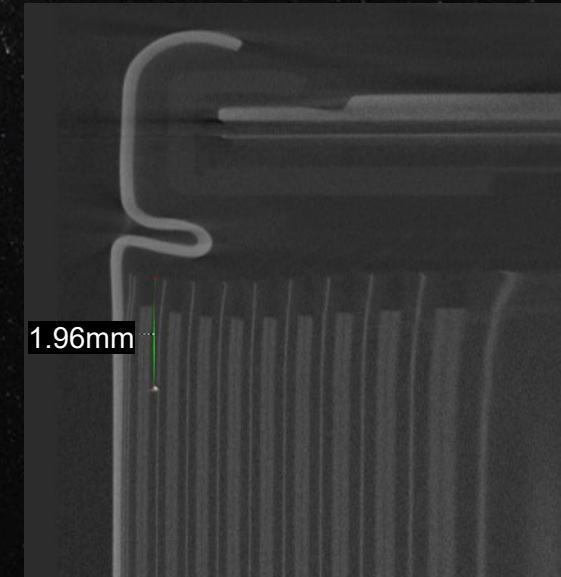
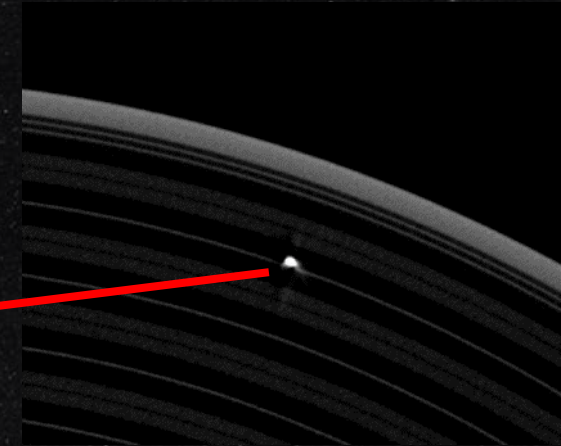
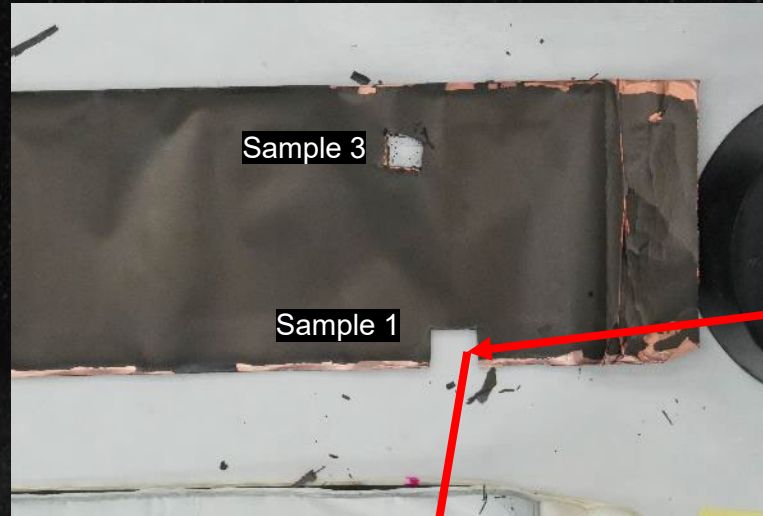
Cell 1517 – Samples Taken & Defects



Cell 1517, Sample 1



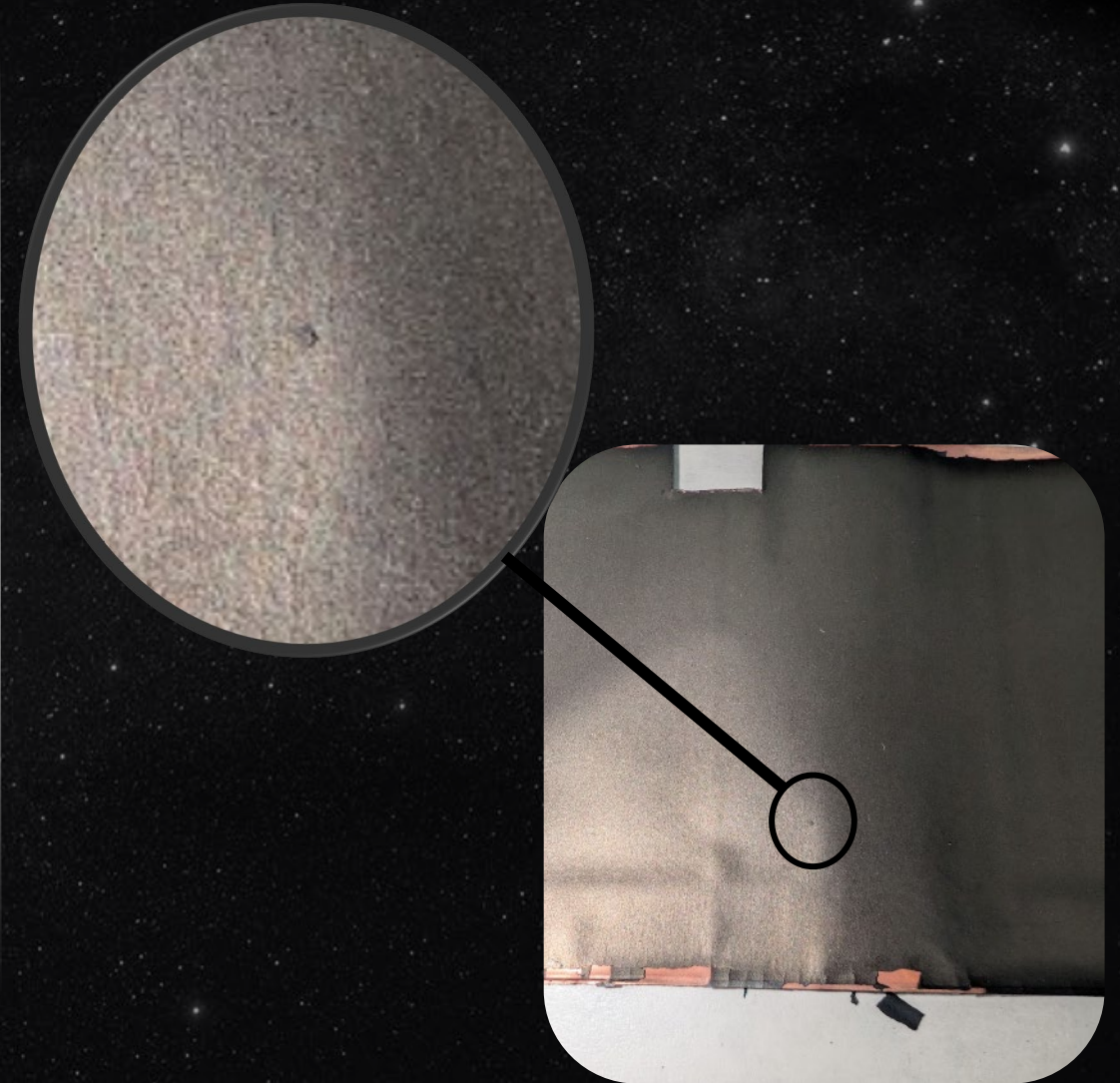
- CT Scan found metallic particle
- Sample 1 taken to search for this particle based off where it should be in cell
- Nothing was found matching CT scan
- More noticeable particle seen on Sample 3, on opposite side of cell



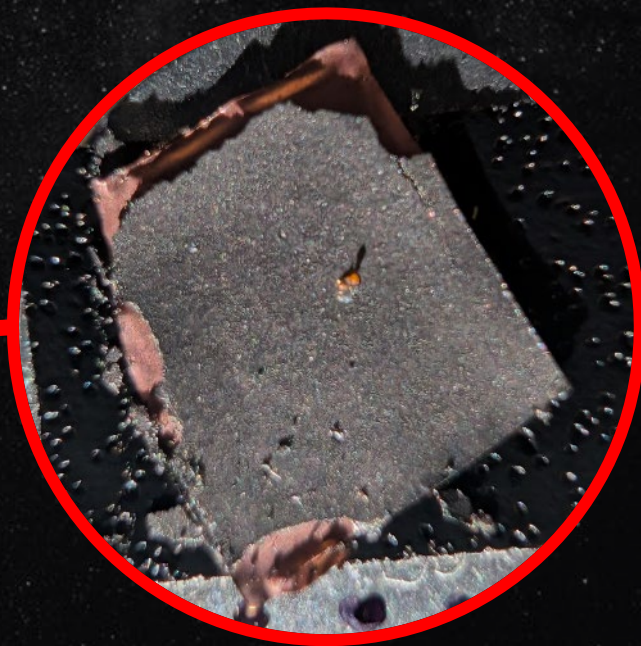
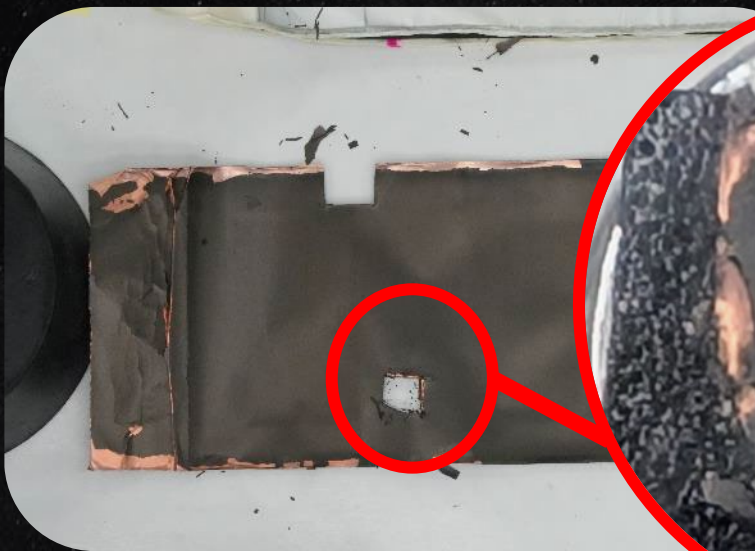
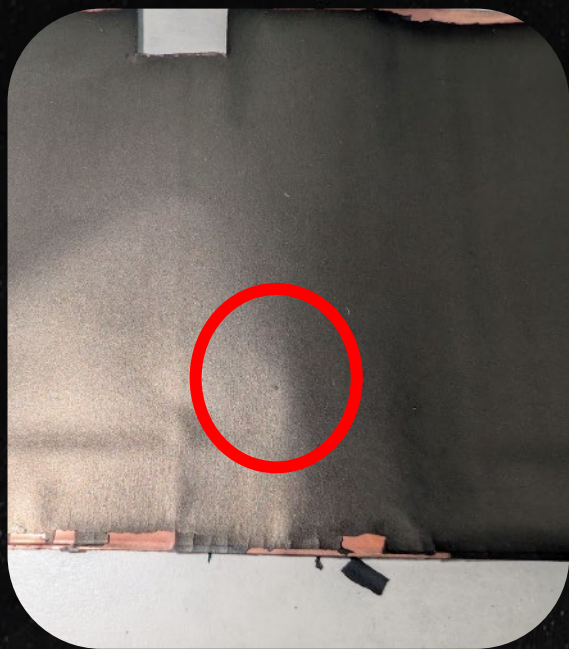
Cell 1517, Sample 3



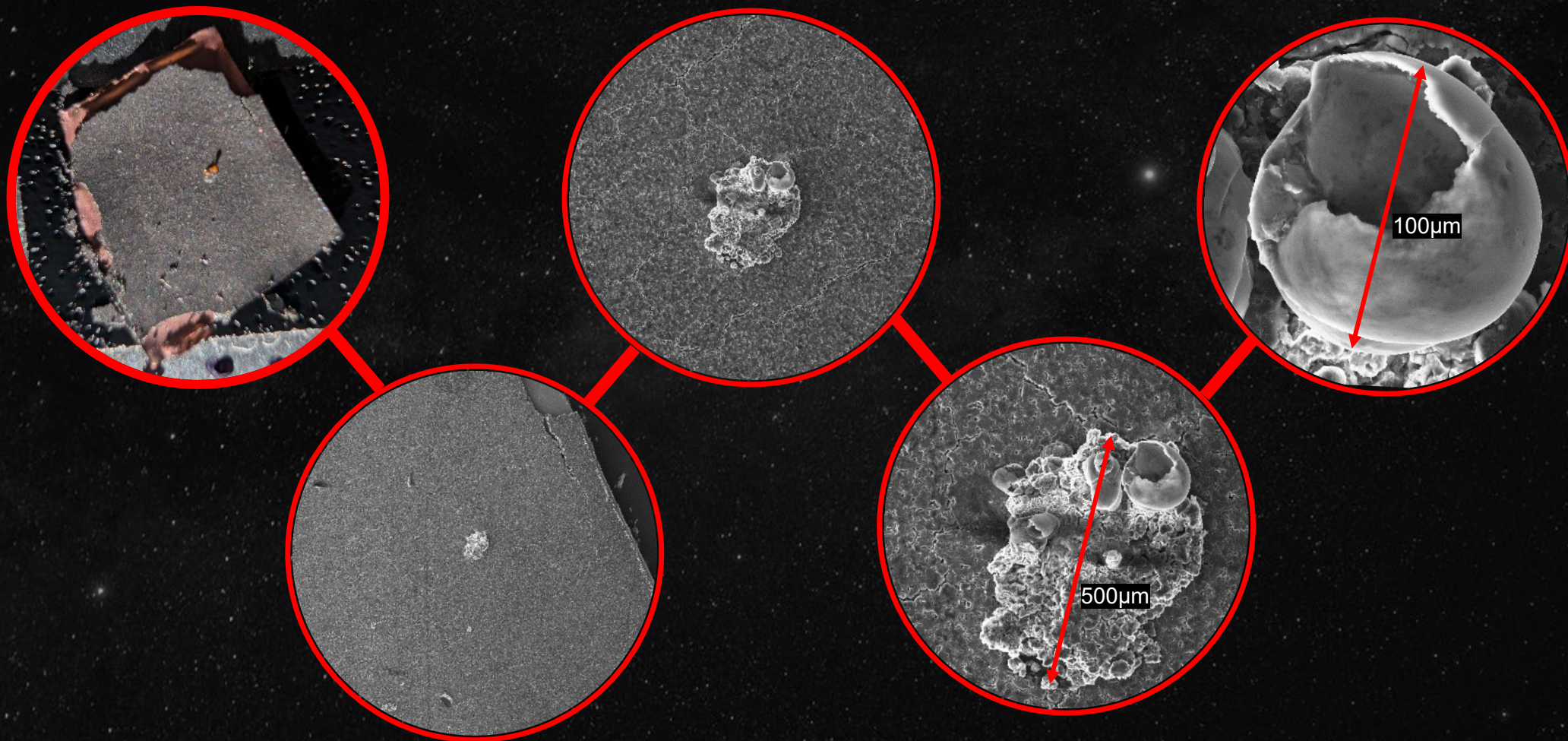
- Small bump seen on Anode Side C
- Not seen in CT scans
- Perhaps there was somehow a migration from one location to another? Seems unlikely
- Unlikely to be FOD from DPA process or something that fell on this while unrolling jellyroll. Saw this right as jellyroll was unrolled
- SEM & EDS seen in next slides



Cell 1571, Sample 3



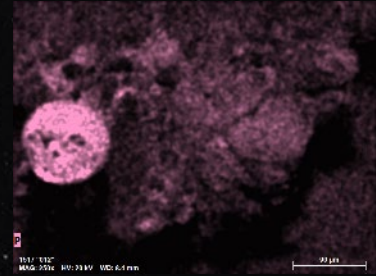
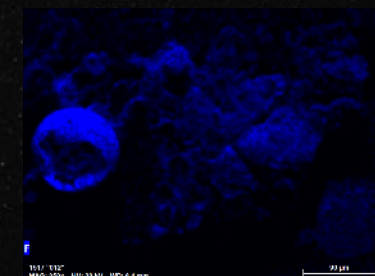
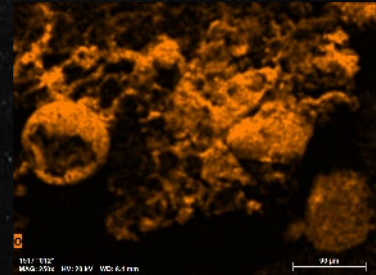
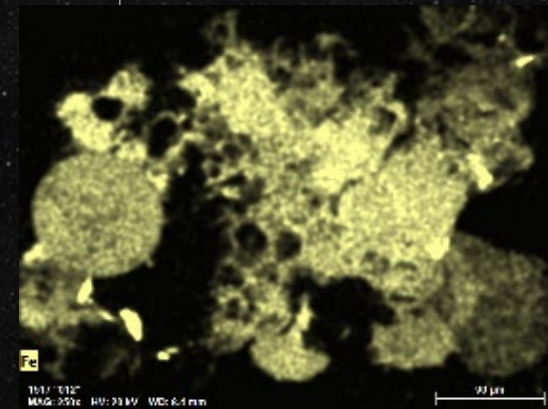
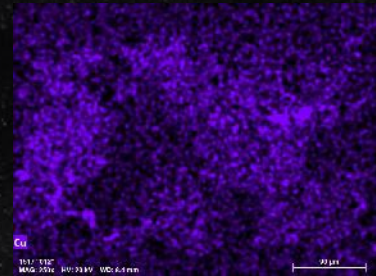
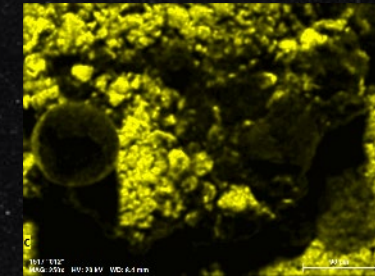
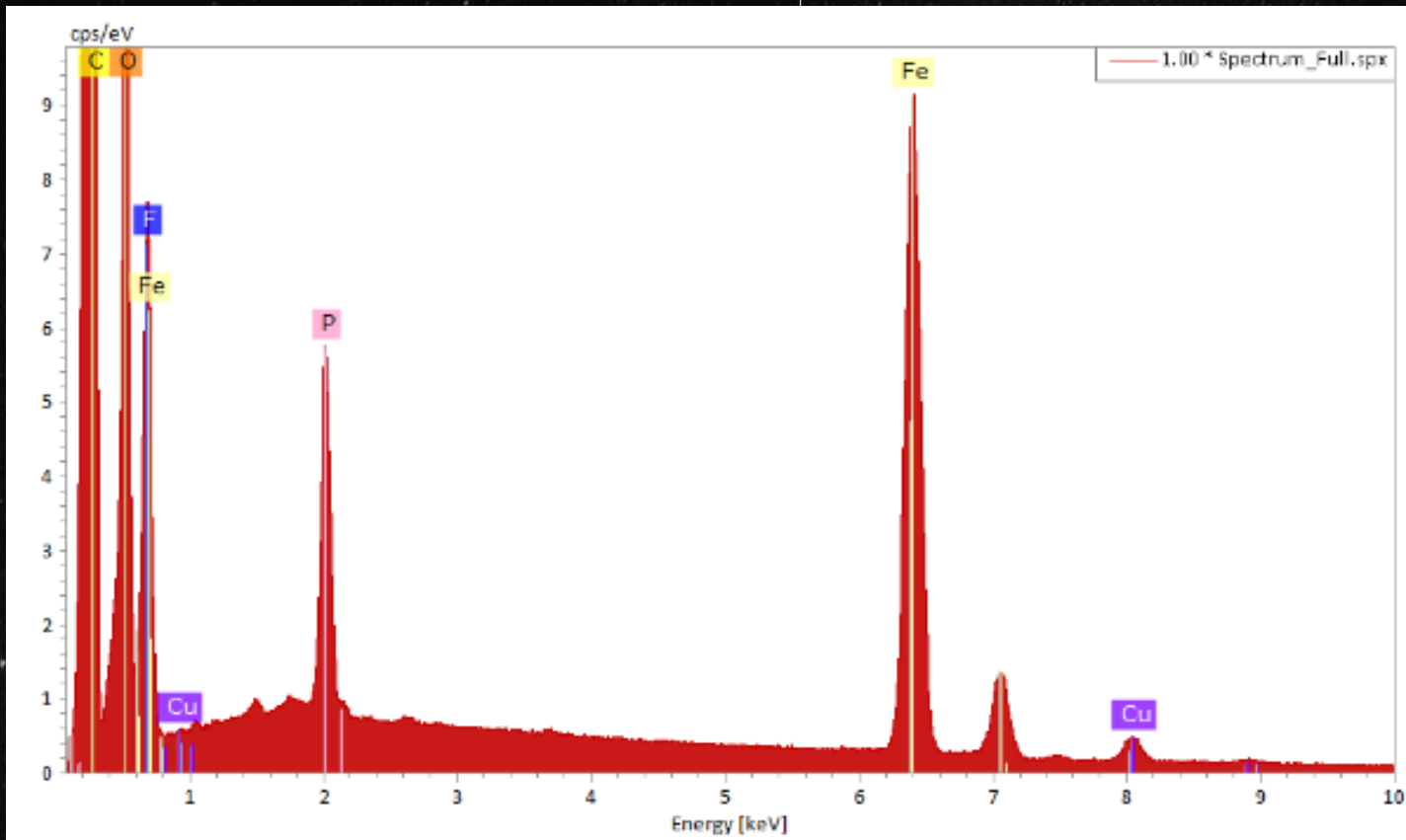
Cell 1517, Sample 3



Cell 1517, Sample 3



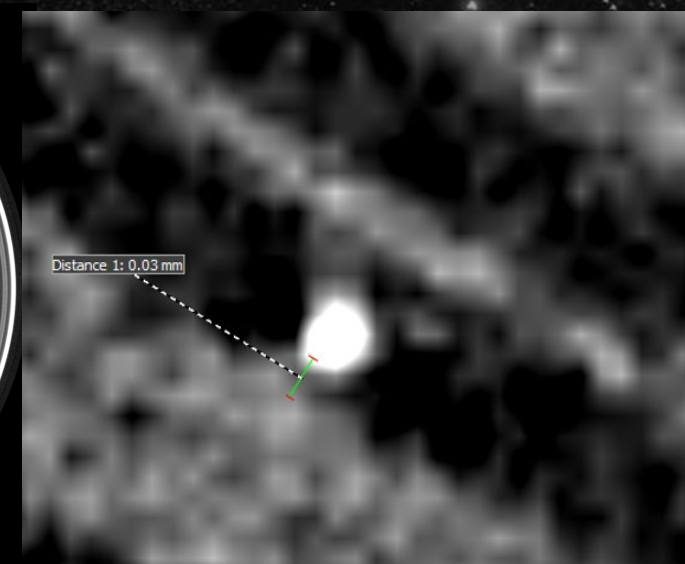
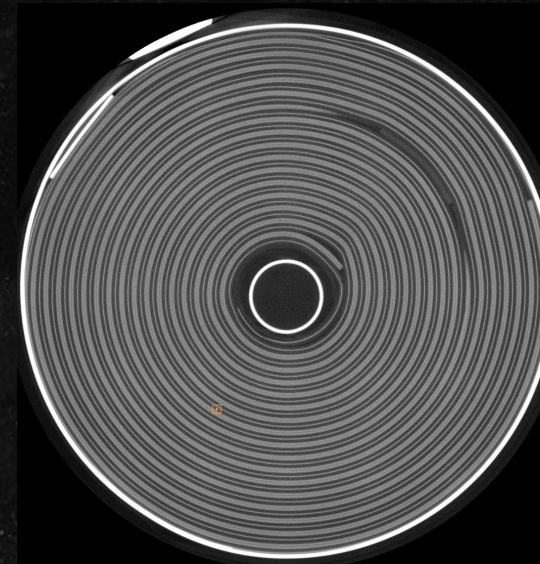
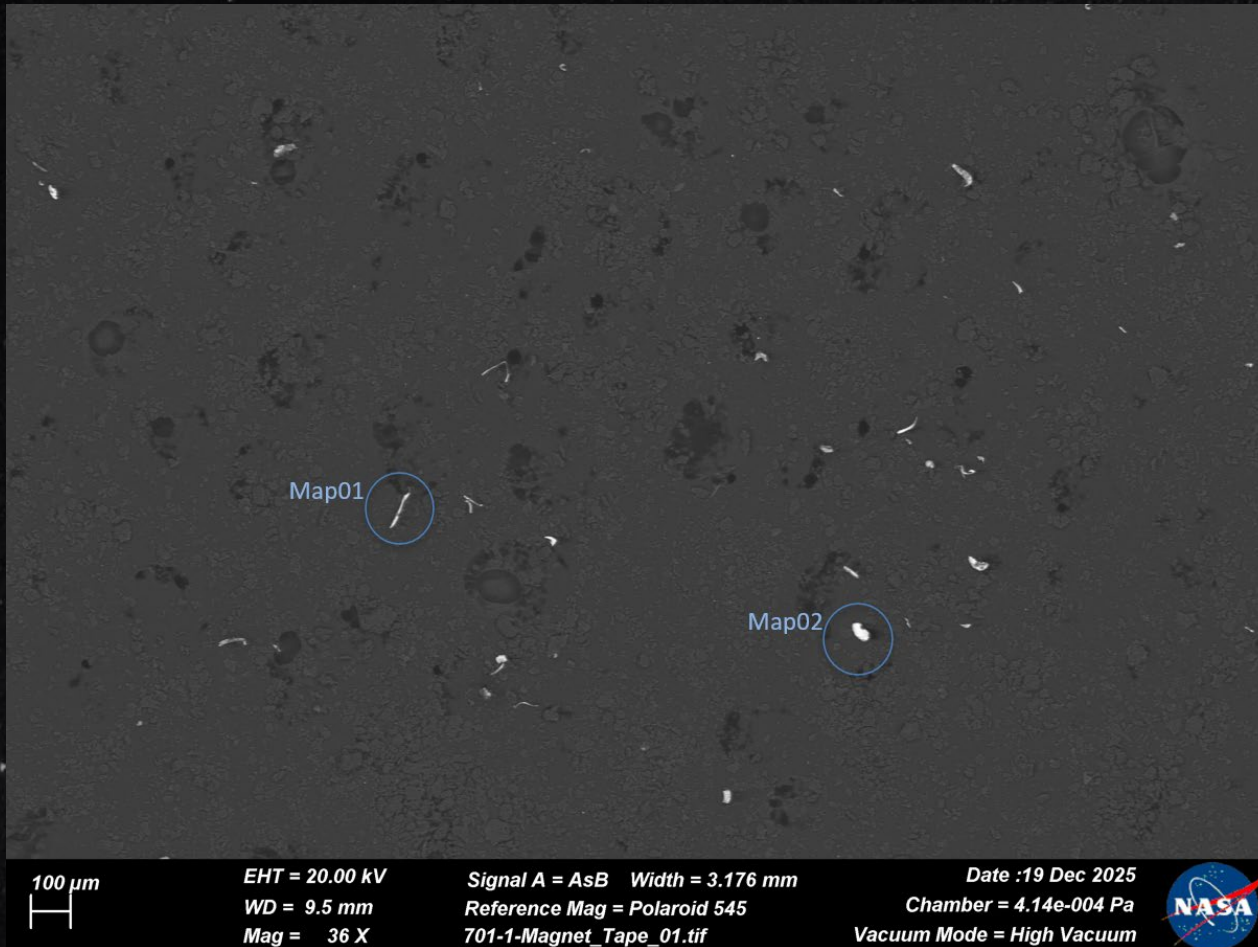
- EDS indicates this is composed of mainly iron, oxygen, fluorine, phosphorus



Anode Scraping



- Anode was scraped and collected using a ceramic blade then using a magnet to extract the particles onto carbon tape



1506, particle of interest



EHT = 20.00 kV
WD = 9.5 mm
Mag = 36 X

Signal A = AsB Width = 3.176 mm
Reference Mag = Polaroid 545
701-1-Magnet_Tape_01.tif

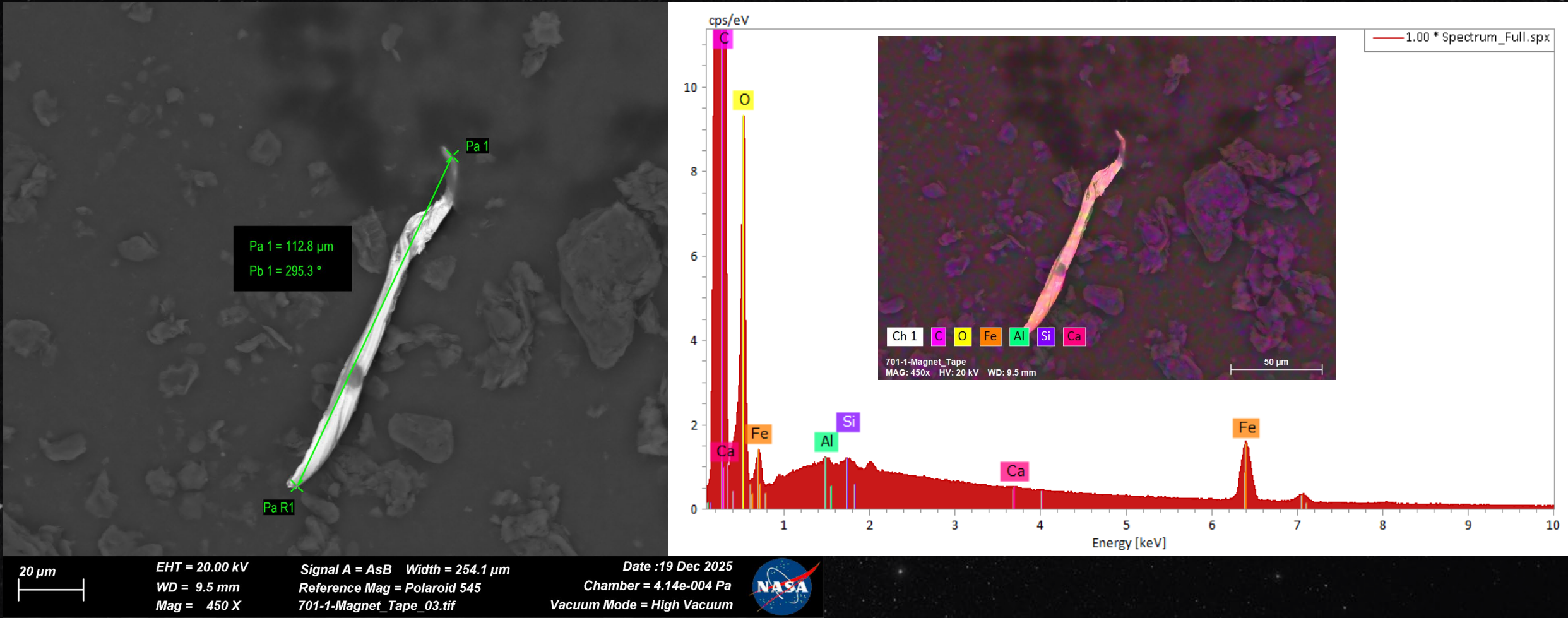
Date :19 Dec 2025
Chamber = 4.14e-004 Pa
Vacuum Mode = High Vacuum



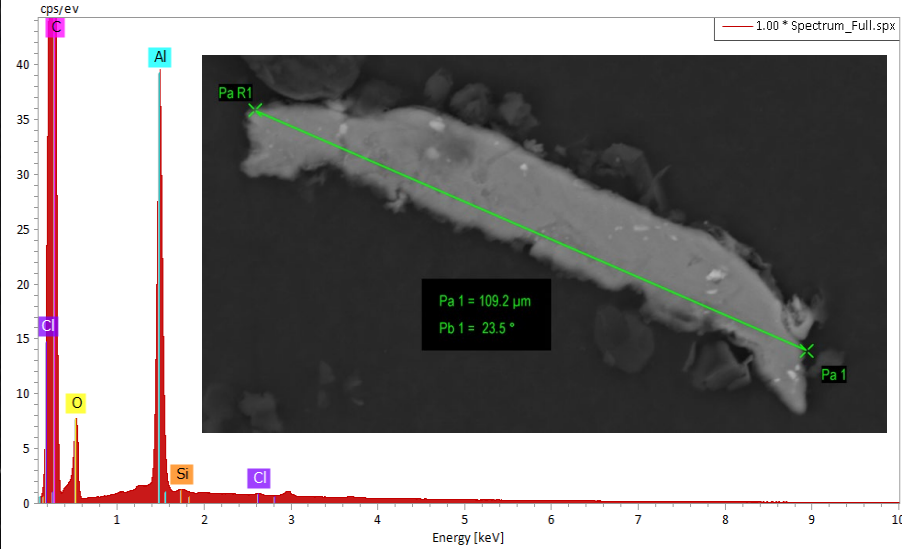
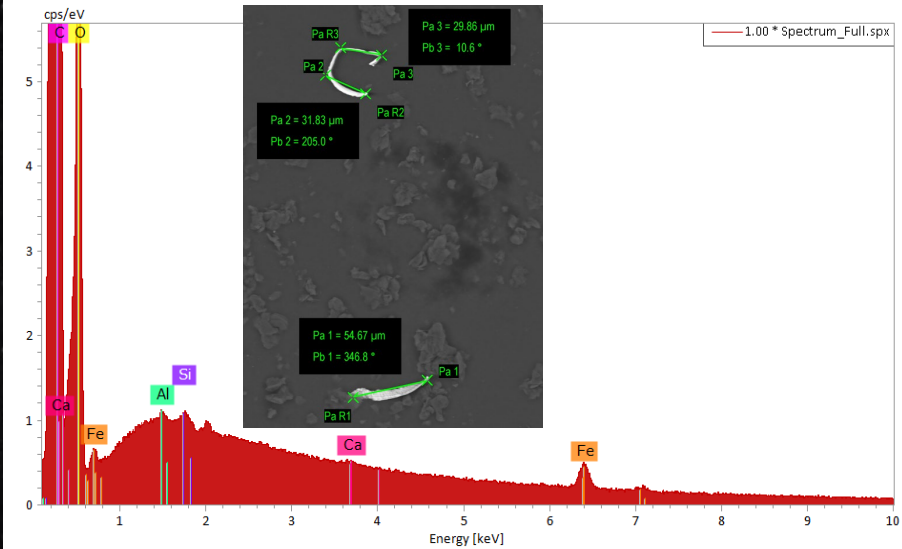
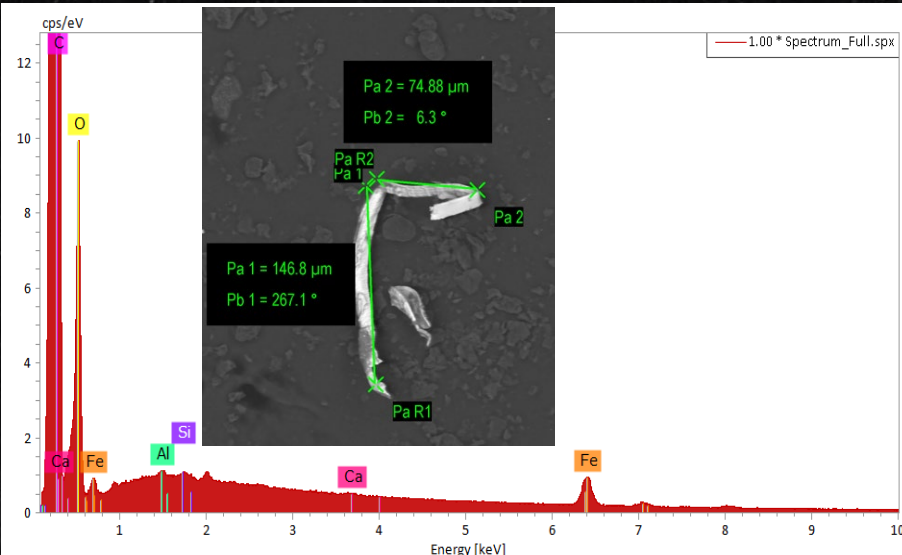
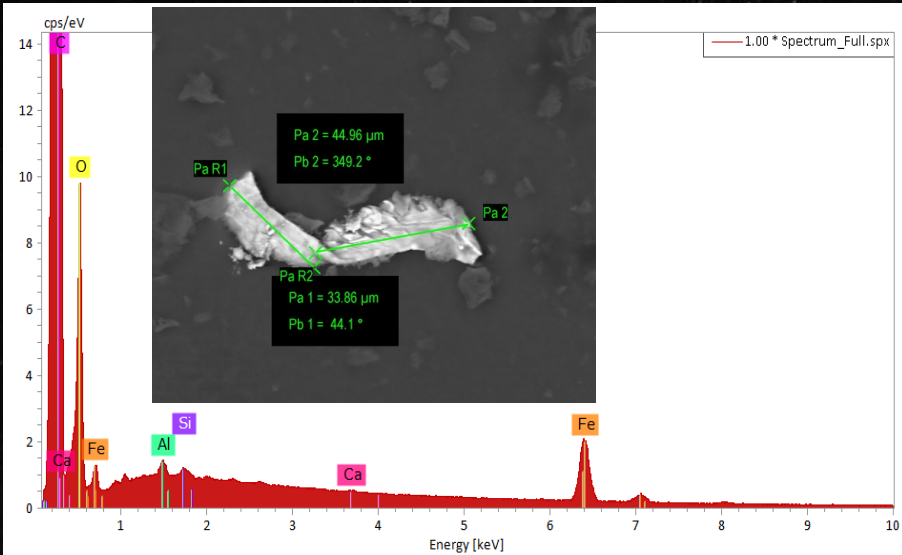
Cell 1506, Map 01



- Long thin particle potentially from a manufacturing process



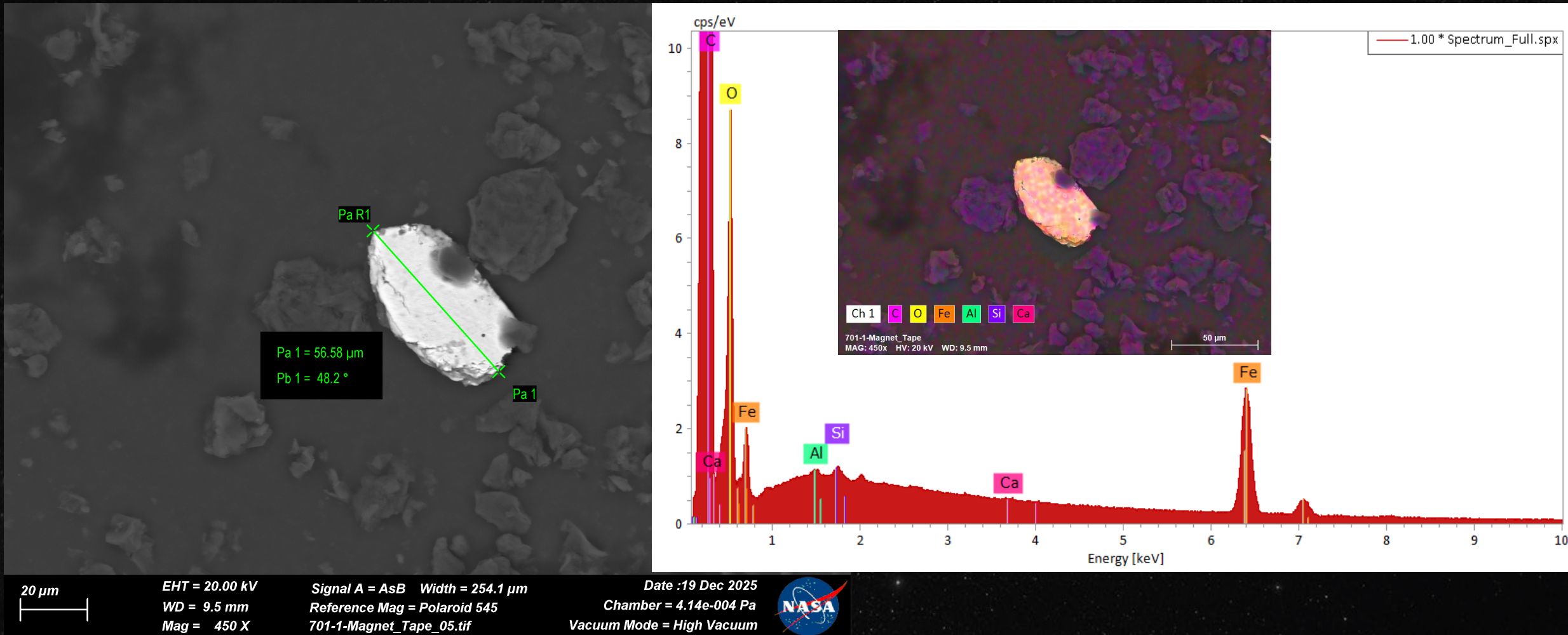
Other Magnetic Particles Found in the Anode



1506 Map 02



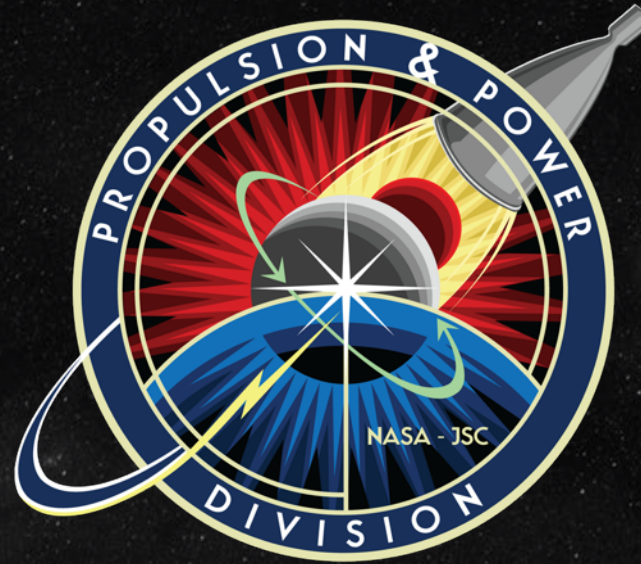
- With blooming effects from CT this could be the particle of interest



Future work



- Cycle the cells with poor anode overhang at and above mission profiles to determine if li-plating is generated under the mild flight conditions
 - Conduct ultrasound scans and DPA of the cells
- Evaluate other cells to determine if metallic particles are common in other cell manufactures anode material or just from the manufacture of flight lot at the time of production
- Refine the particle extraction technique to better find particles of interest



Questions?

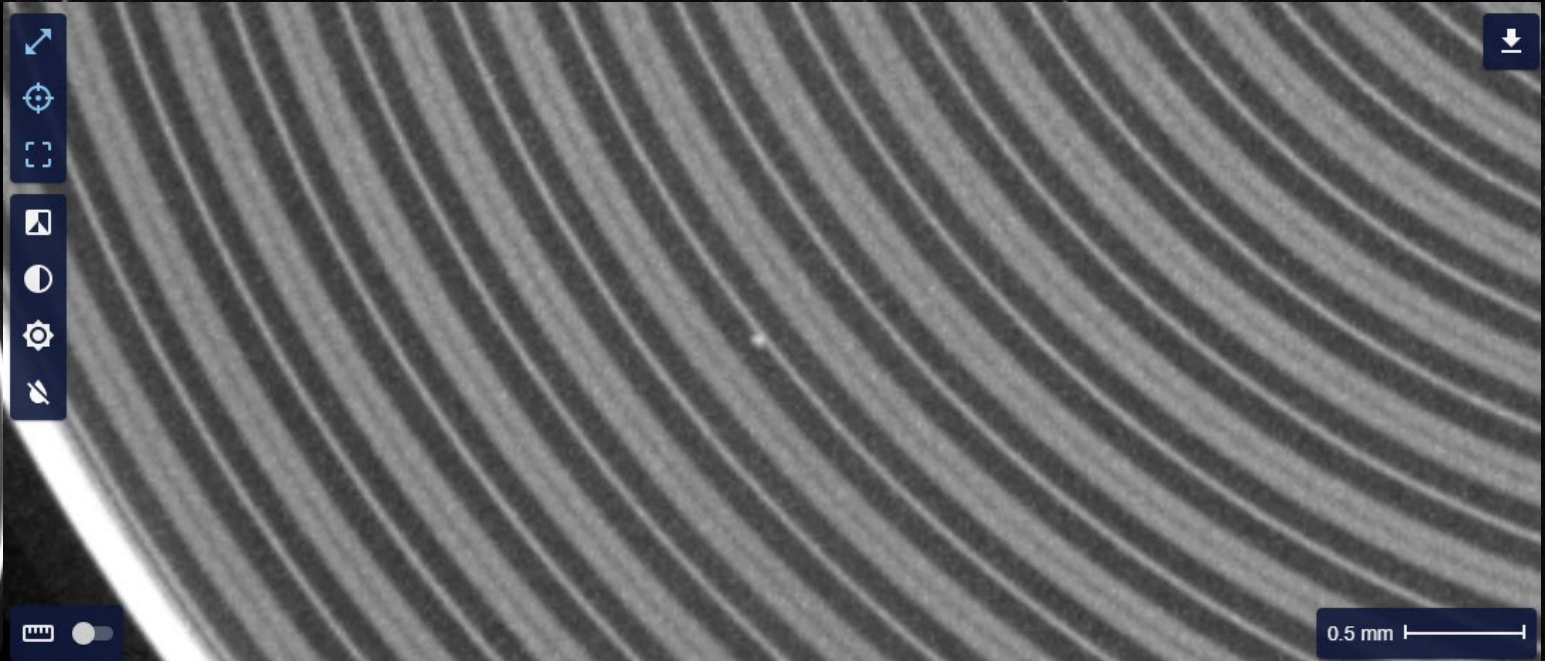
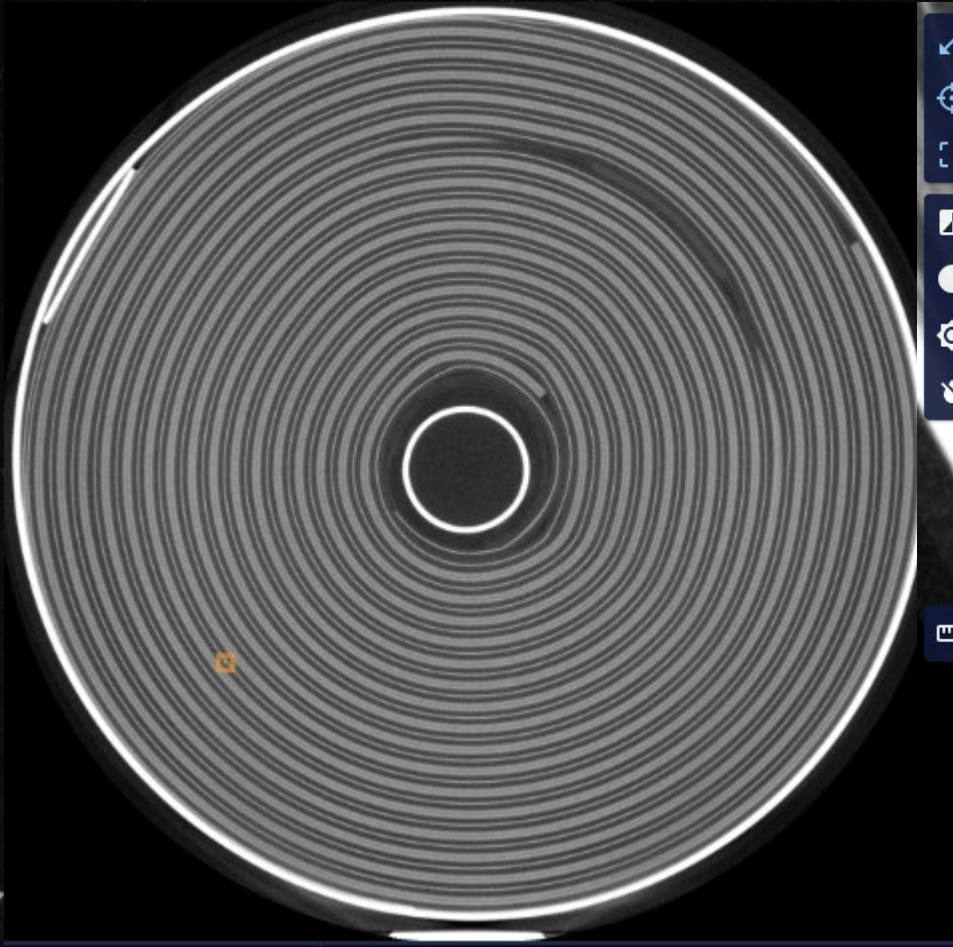
Thank you to Jacob Darst, Aiden Byrne, Eric Darcy, Bobby Jacobs, Lenny Sues
and the Glimpse team



Backup

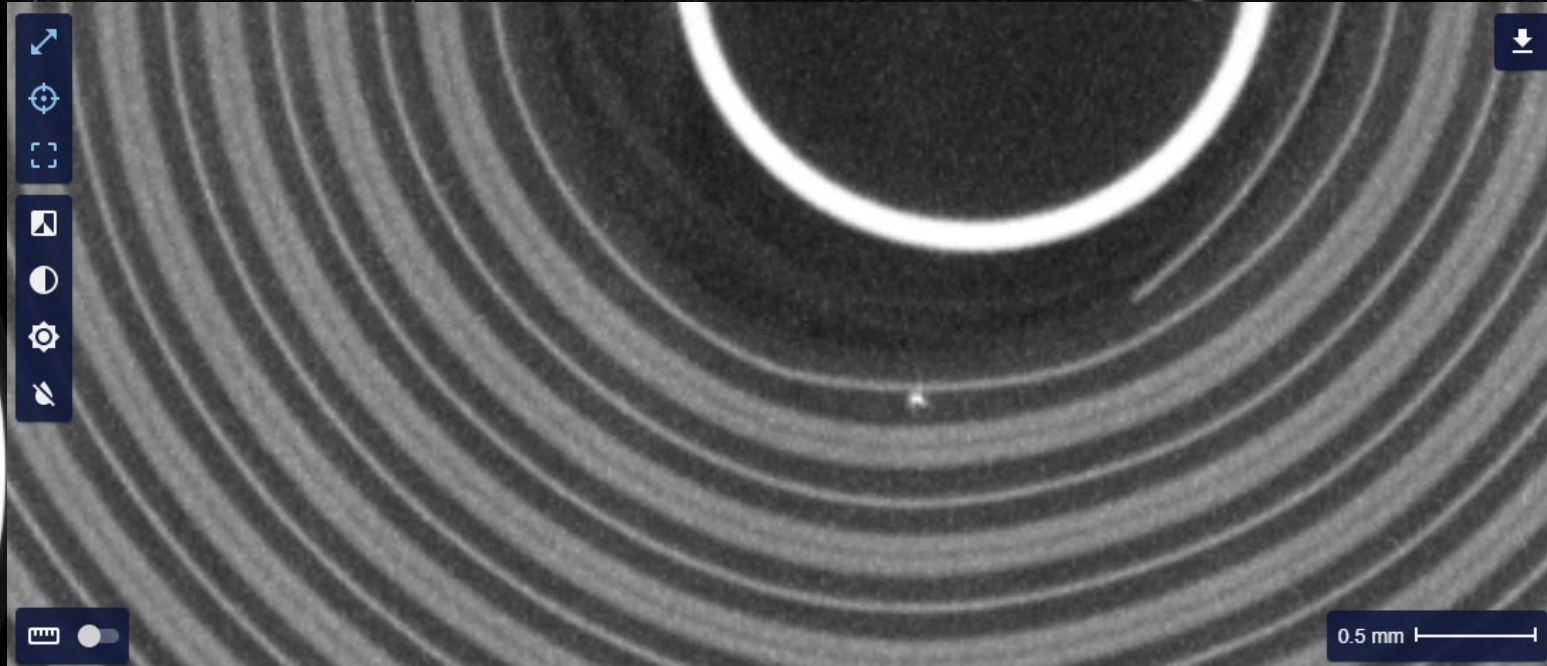
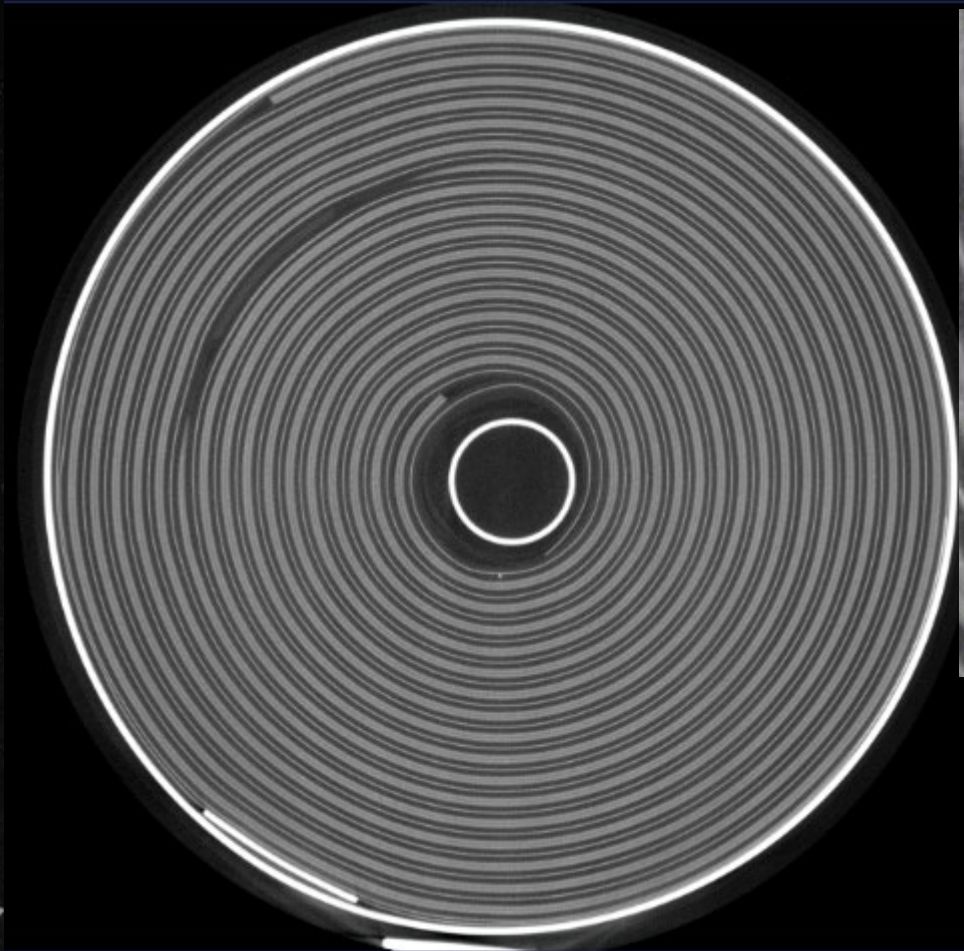


Scan 1520



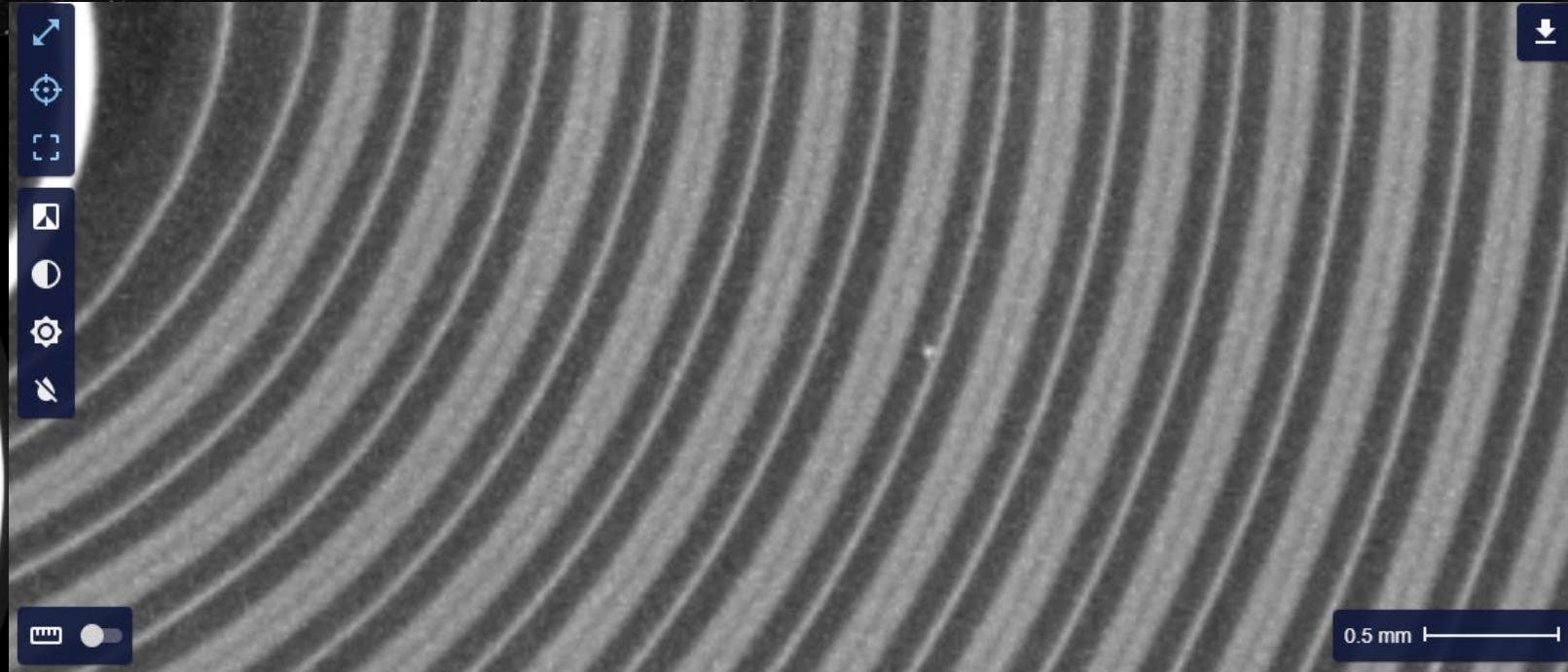
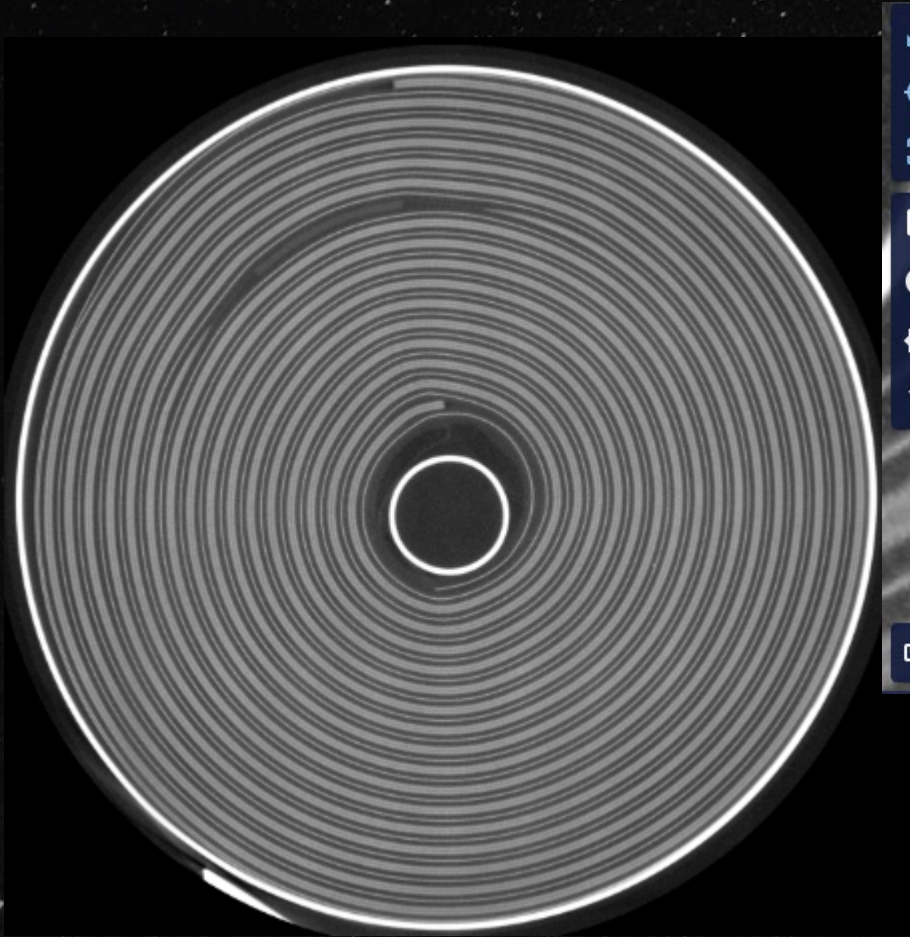
~50 μ m in size

Scan 1555



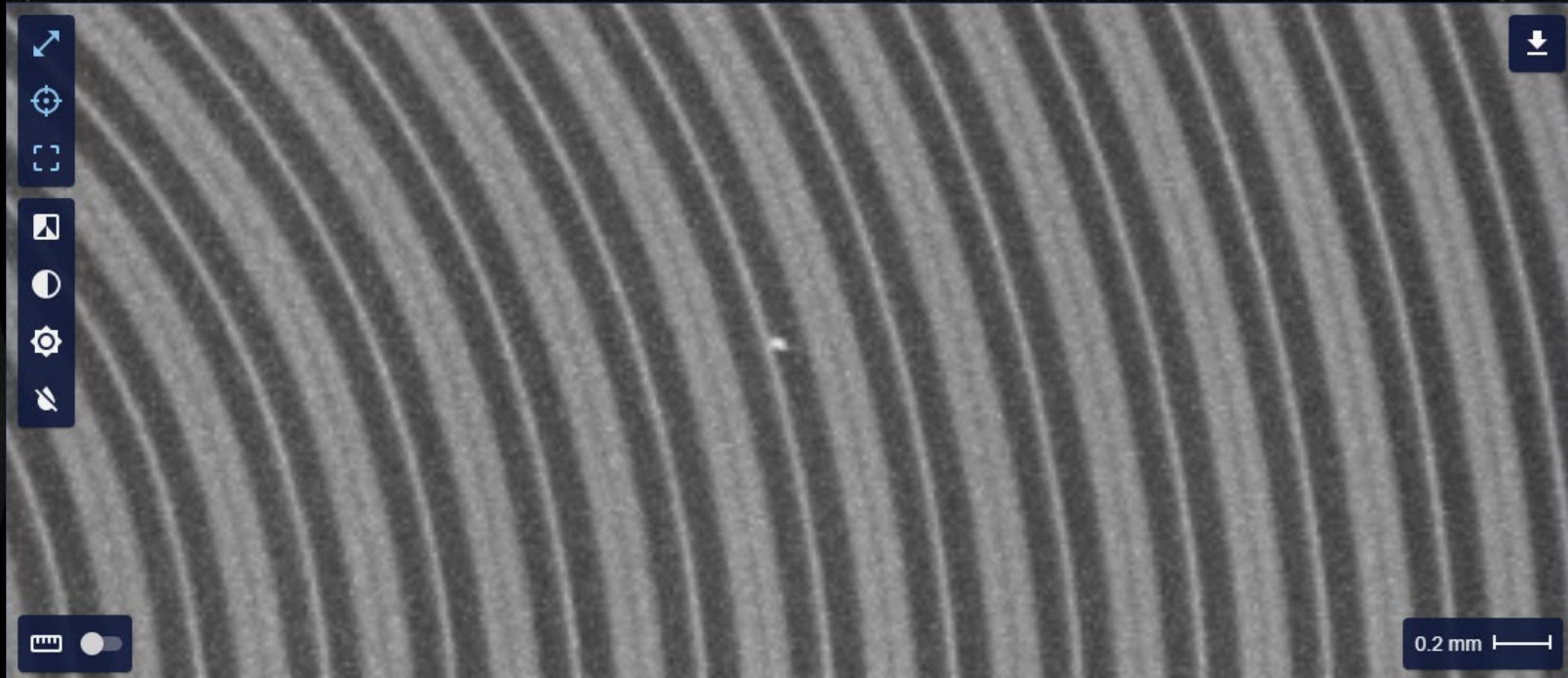
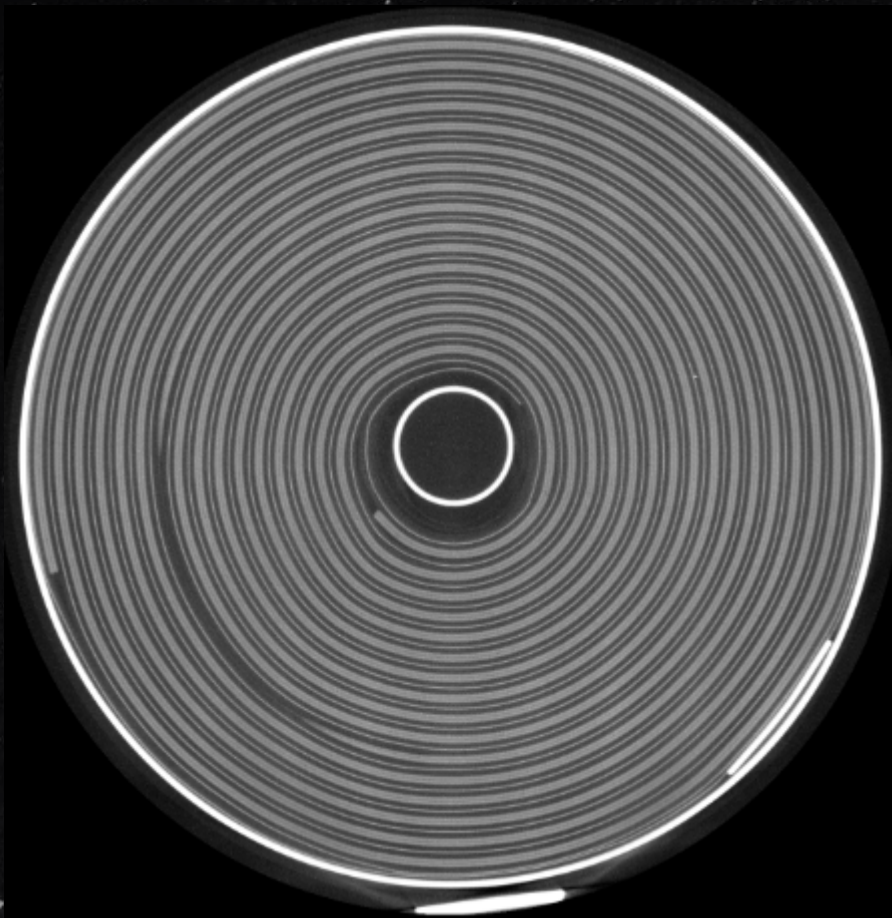
~70 μ m in size

Scan 1585



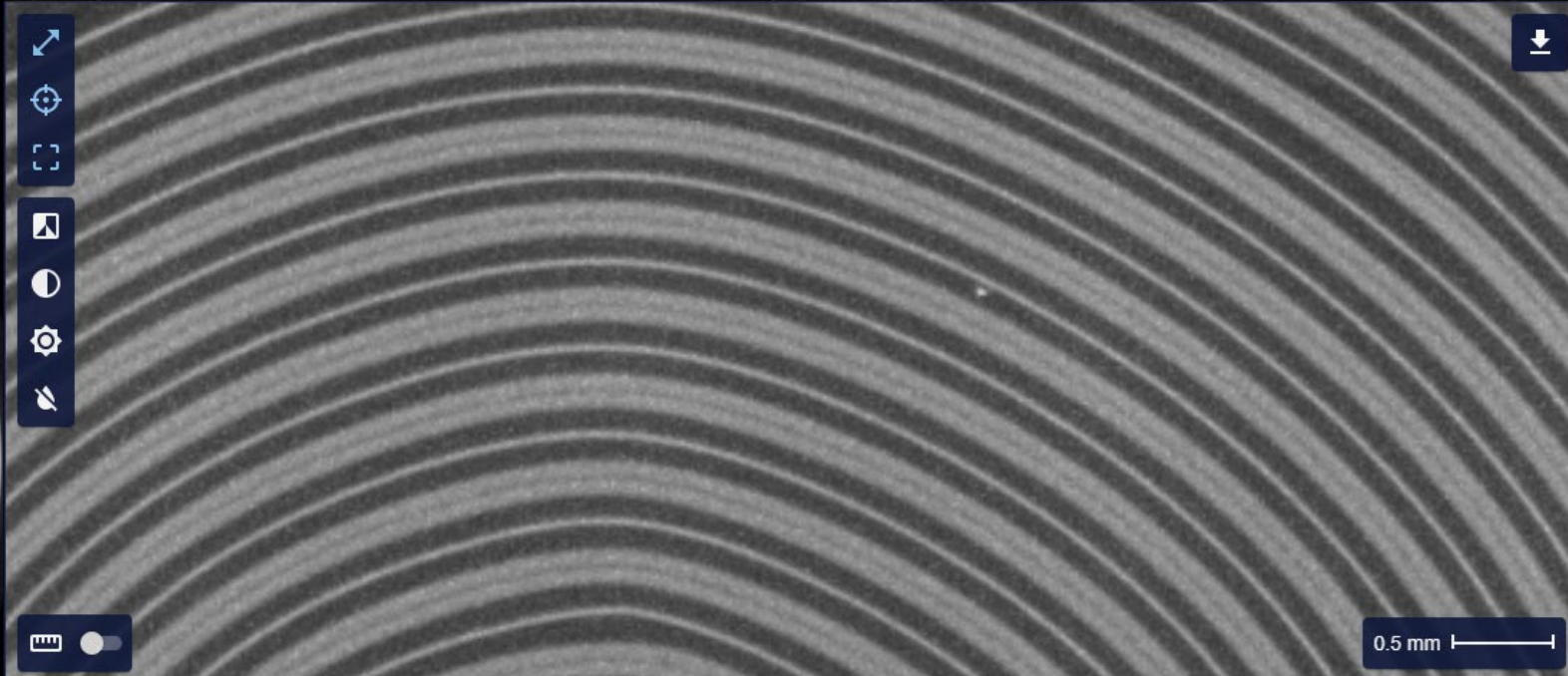
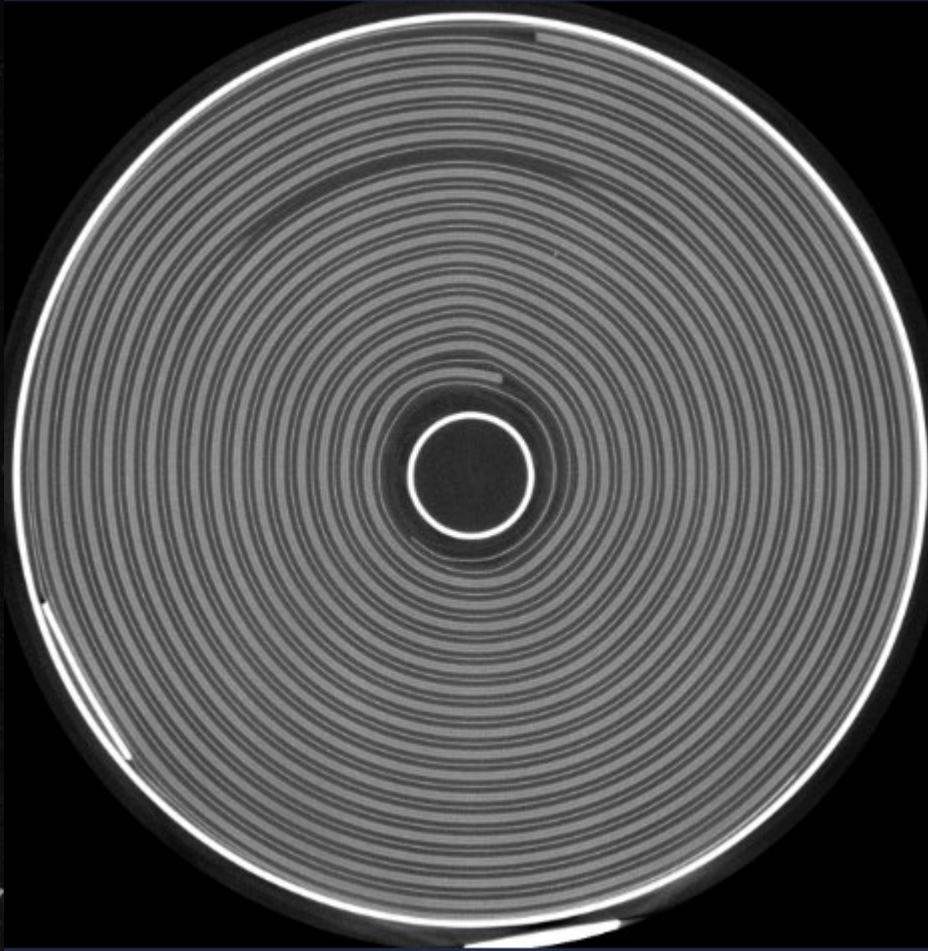
~60 μm in size

Scan 1598



~50 μ m in size

Scan 1604



~40 μ m in size