# Point absorbers in aLIGO coating

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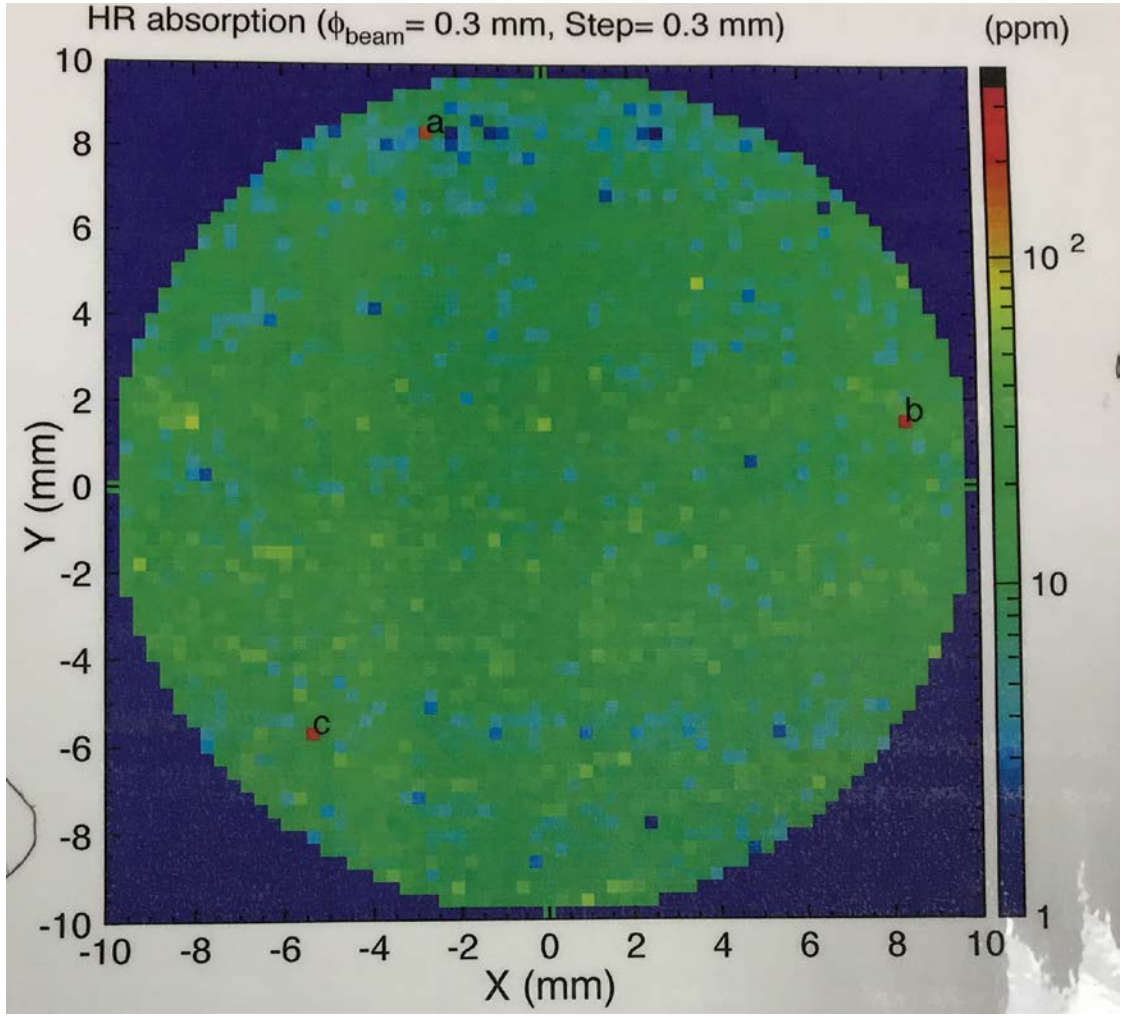
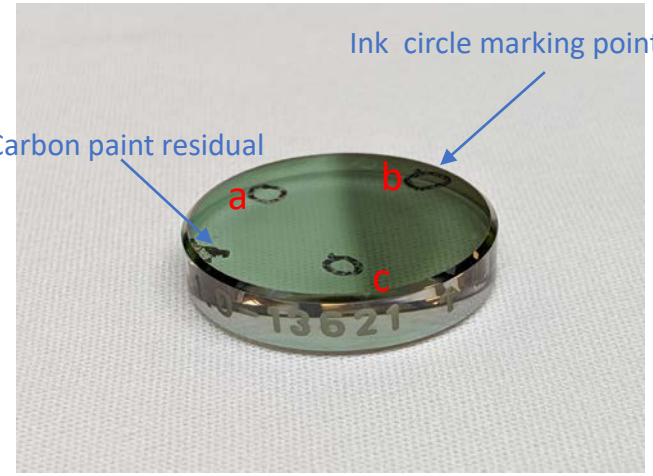
# Absorption Map: Caltech



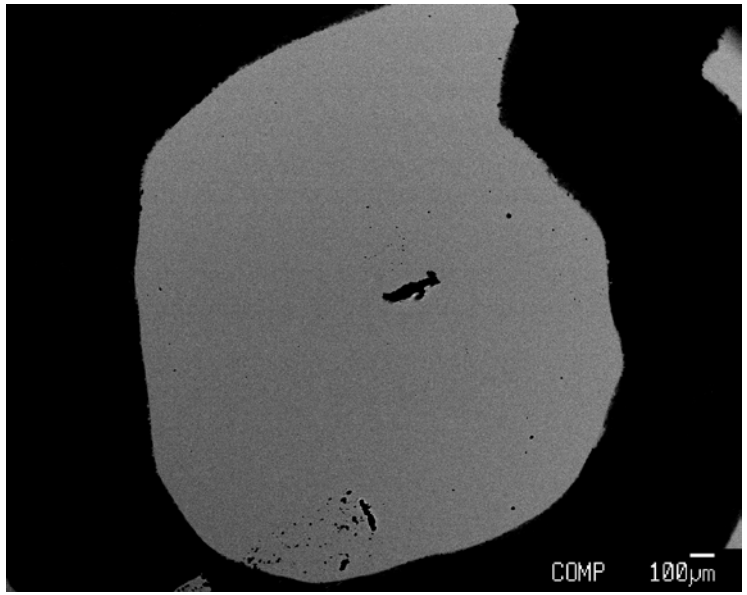

**DCC: T1900838**

- Witness sample SN#13621 ETM07/09 AR coating
  - material: $TiO_2$: $Ta_2O_5/SiO_2$
  - total thickness: ~ 1.6 µm
- 3 high absorption points identified during abortion measurement :
  - a ~ 180ppm
  - b ~ 270 ppm
  - c ~ 200 ppm
- The origin of the point absorbers unknown until now
- Many absorber candidates identified from the optical inspection are in fact missing coating.
- SEM/EDS/WDS analysis revealed aluminum is a likely absorber candidate.



# High contrast SEM images

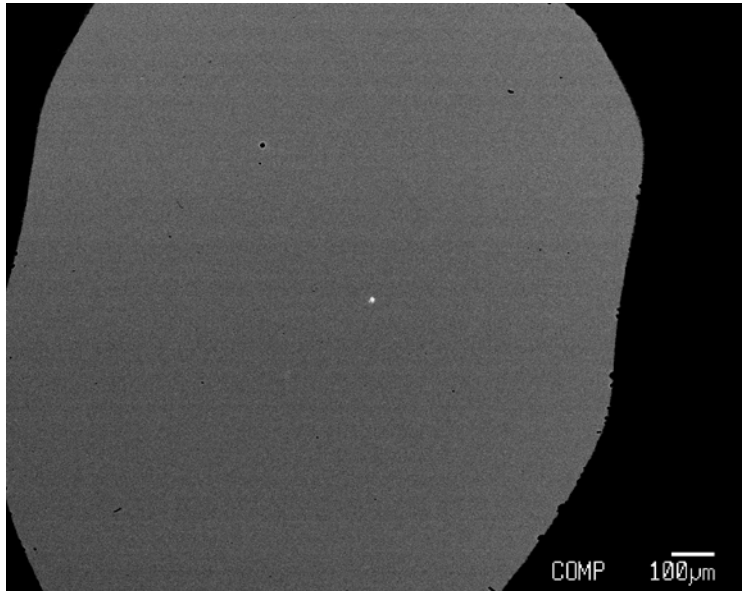
A area




B area

No picture taken

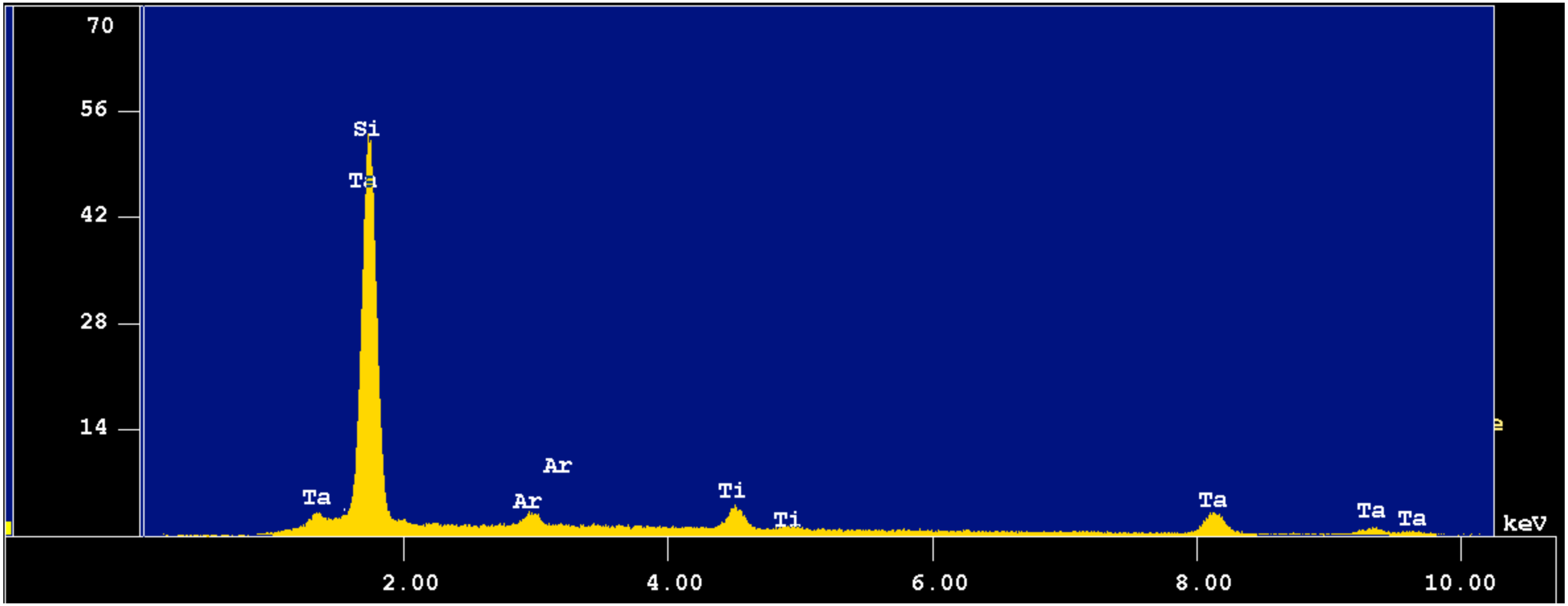
C area




The thick black contours correspond to the ink circles mark areas with high absorption. We left them on the coating.

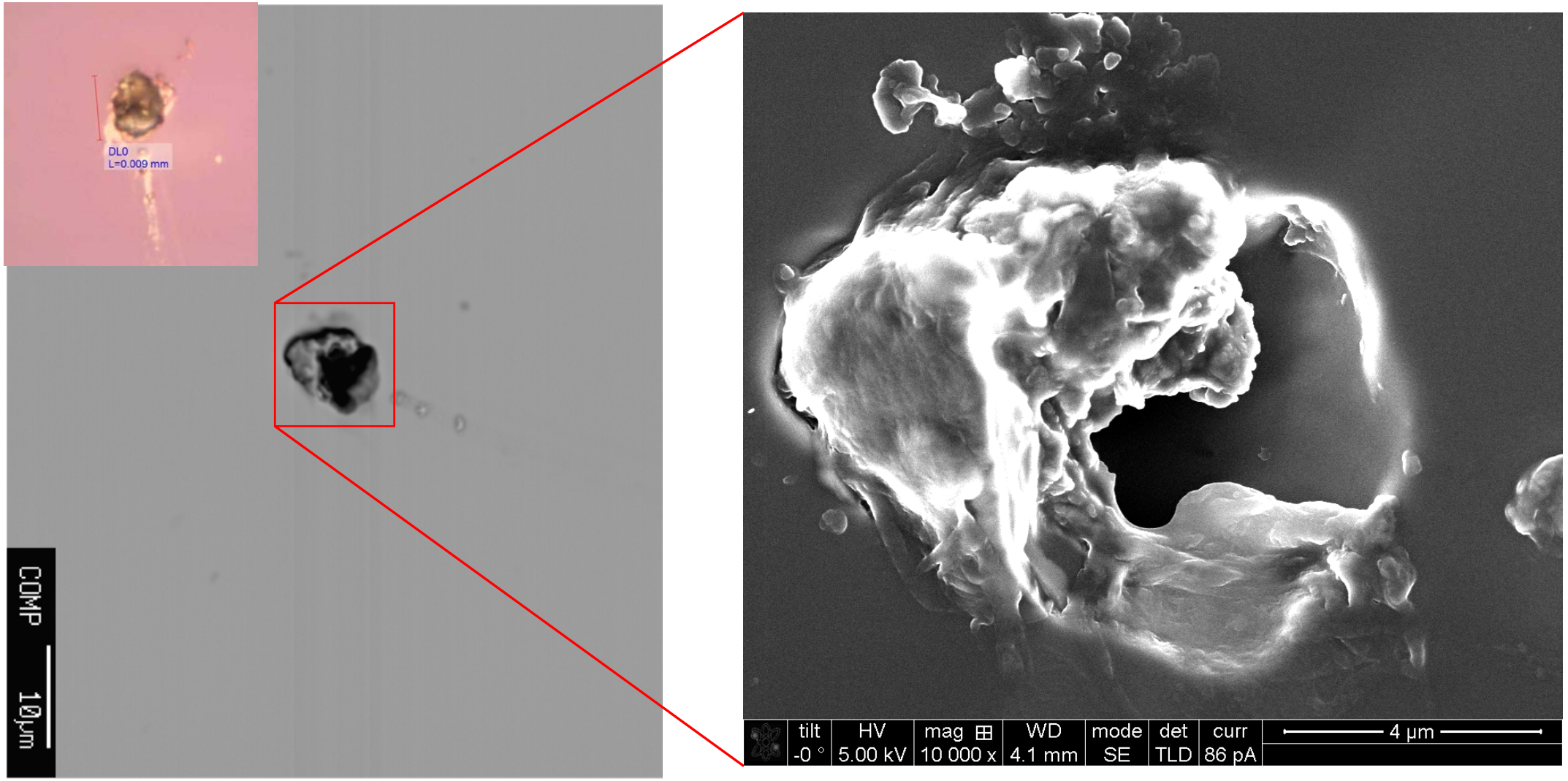
# Spectrum of clean coating

From: JEOL JXA-8200 , e-beam: 15 kV, 10 nA



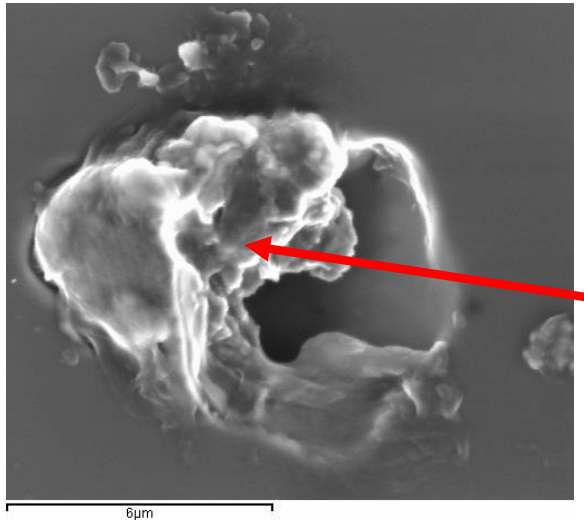

- We see multiple Si, Ta, and Ti lines from the coating
- Trapped Ar lines from IBS plasma
- Oxygen from metal oxides is below 1 keV and too weak to measure with this instrument
- Based on WDS:  Ta/Ti = 78.9/21.1

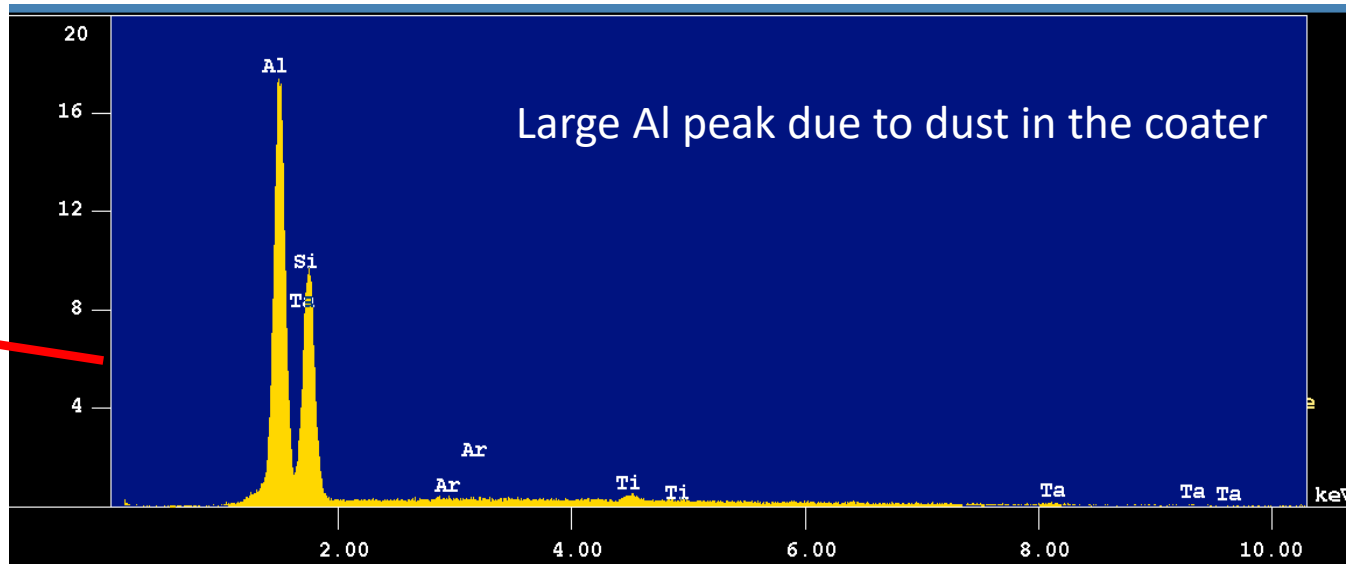
# Area B, point absorber B1



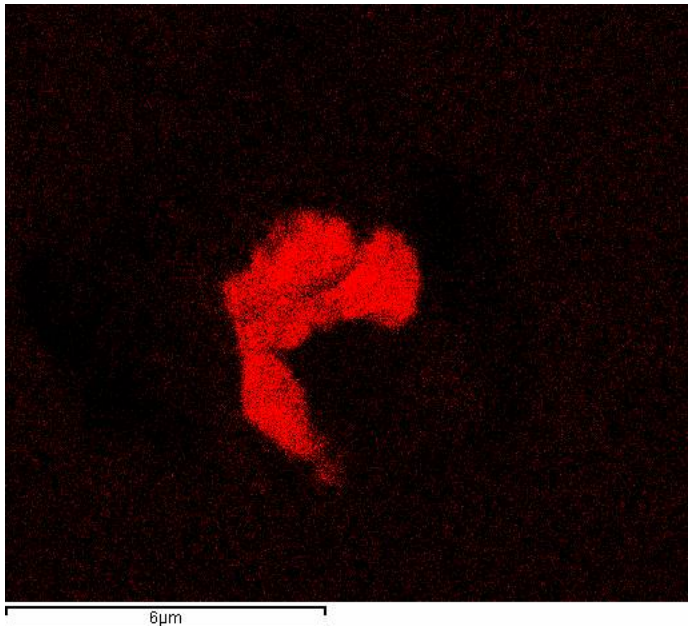

Located in Area B. This  defect is of ~ 6 µm in diameter, irregular shape, possibly located in the top layers of the coating

# Area B, point absorber B1

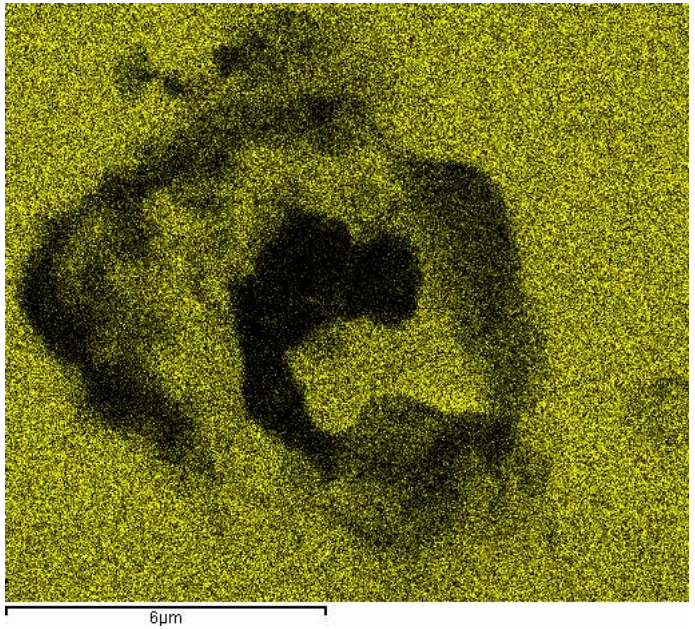


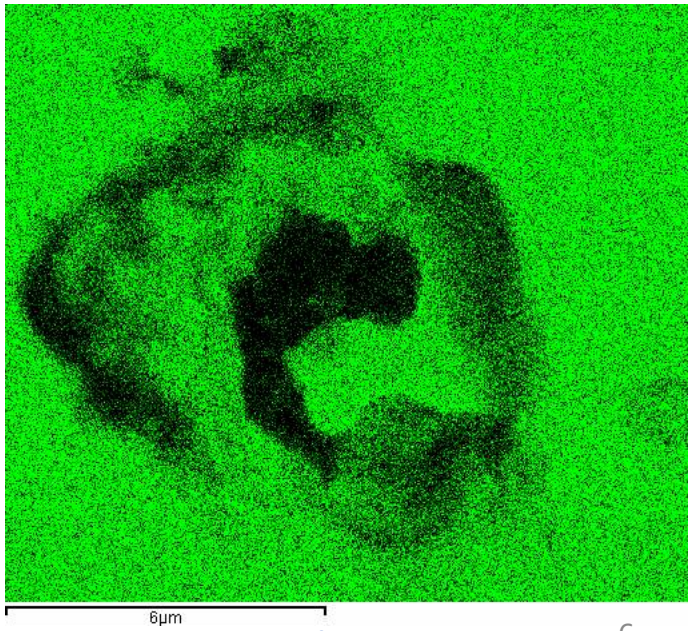

EDS spectral imaging:




Aluminum

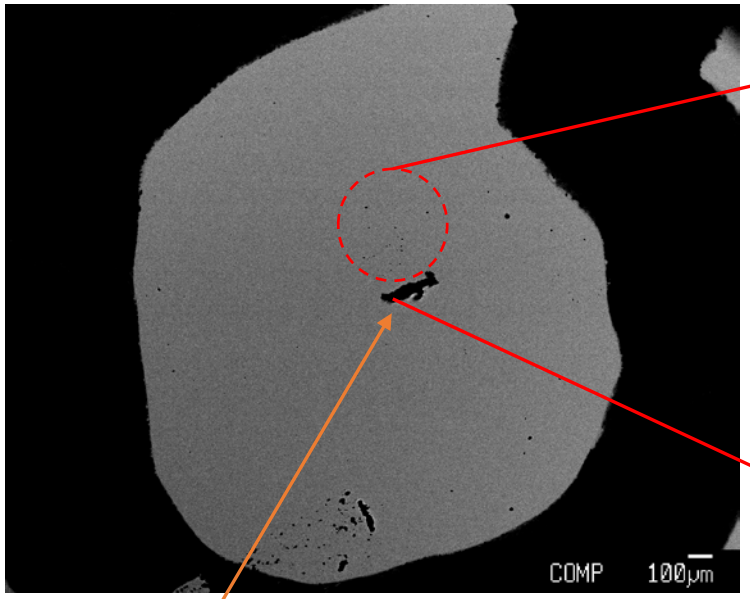



Tantalum



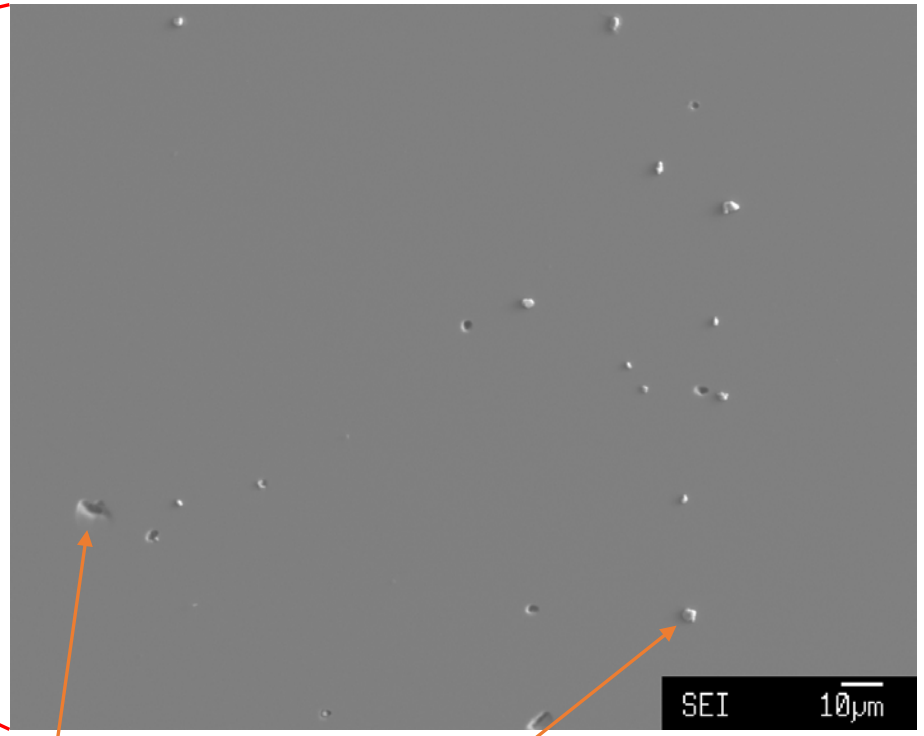

Silicon

# Overview of area A




Missing coating previously thought to be a point absorber > 100 µm

Debris field



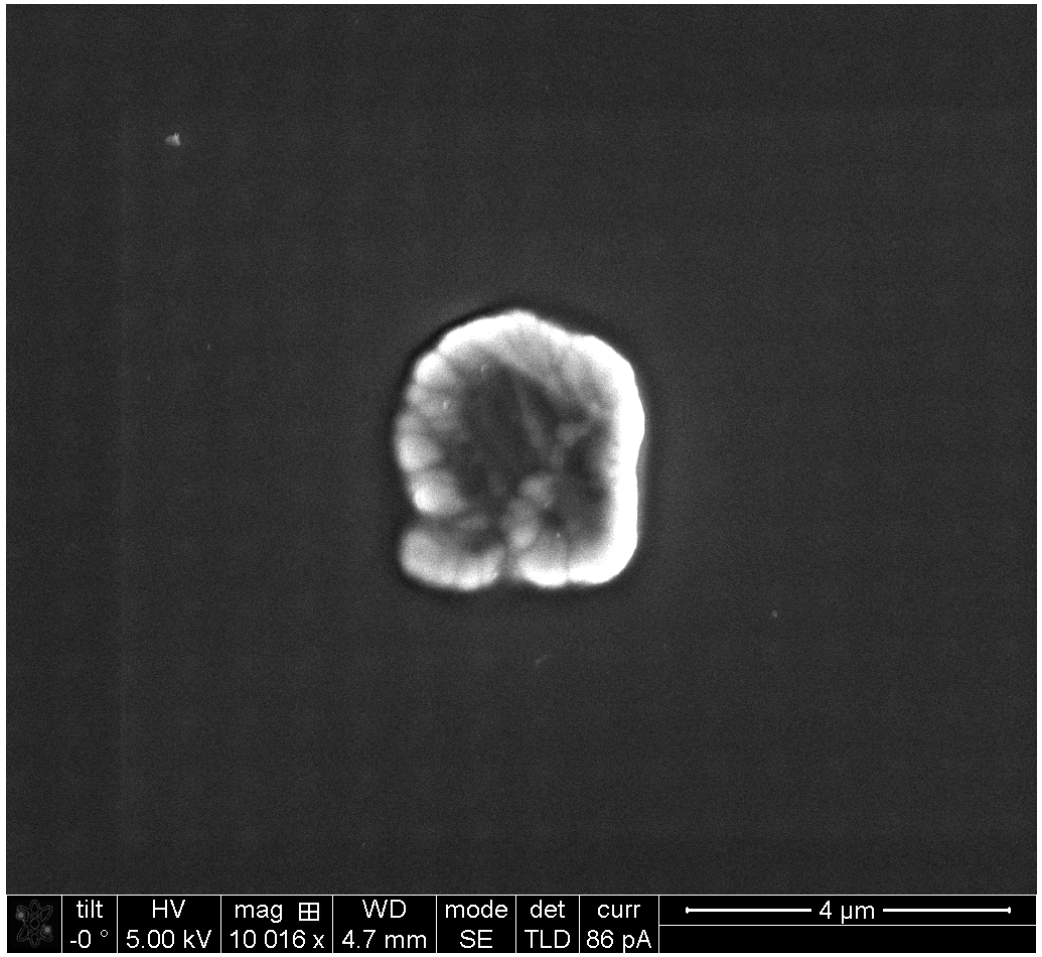

missing coating < 10 µm

point absorber A1

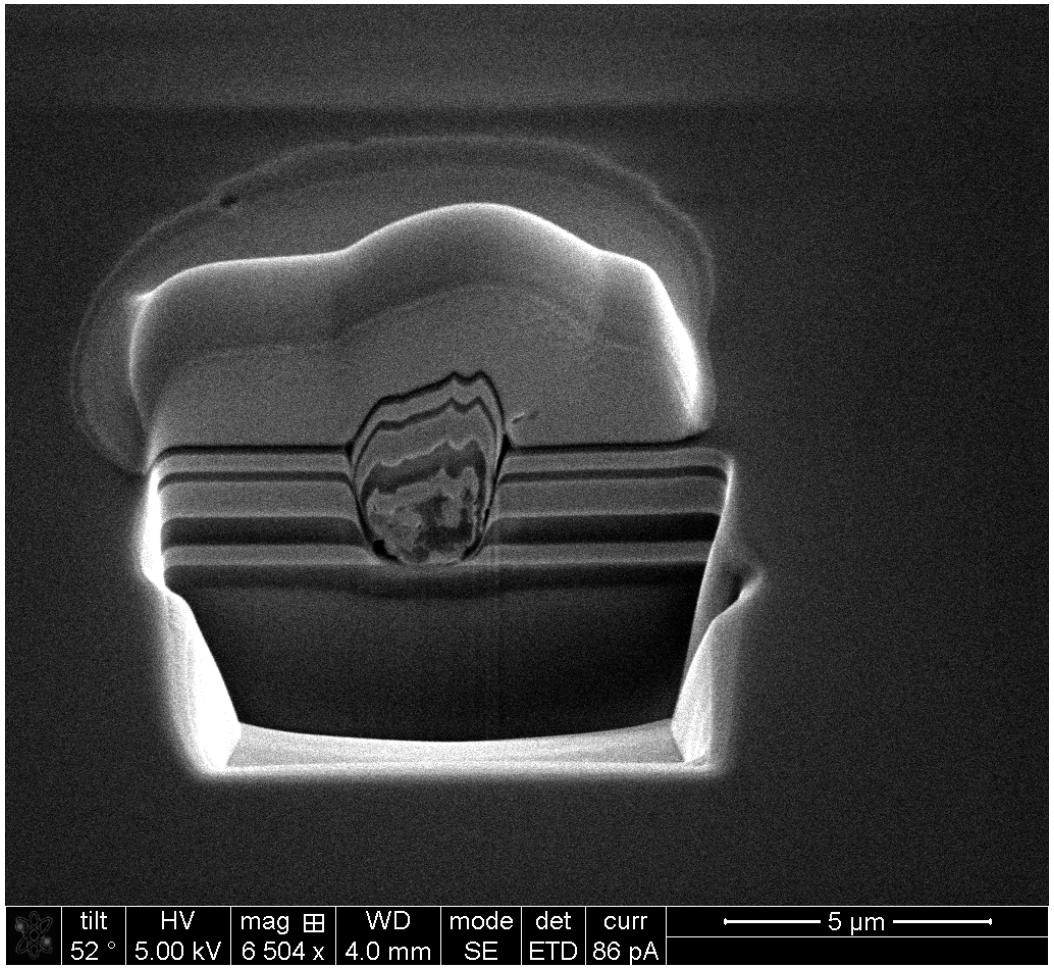
We observe many defects in this field; possible point absorbers, only one inspected so far

# Area A, point absorber A1

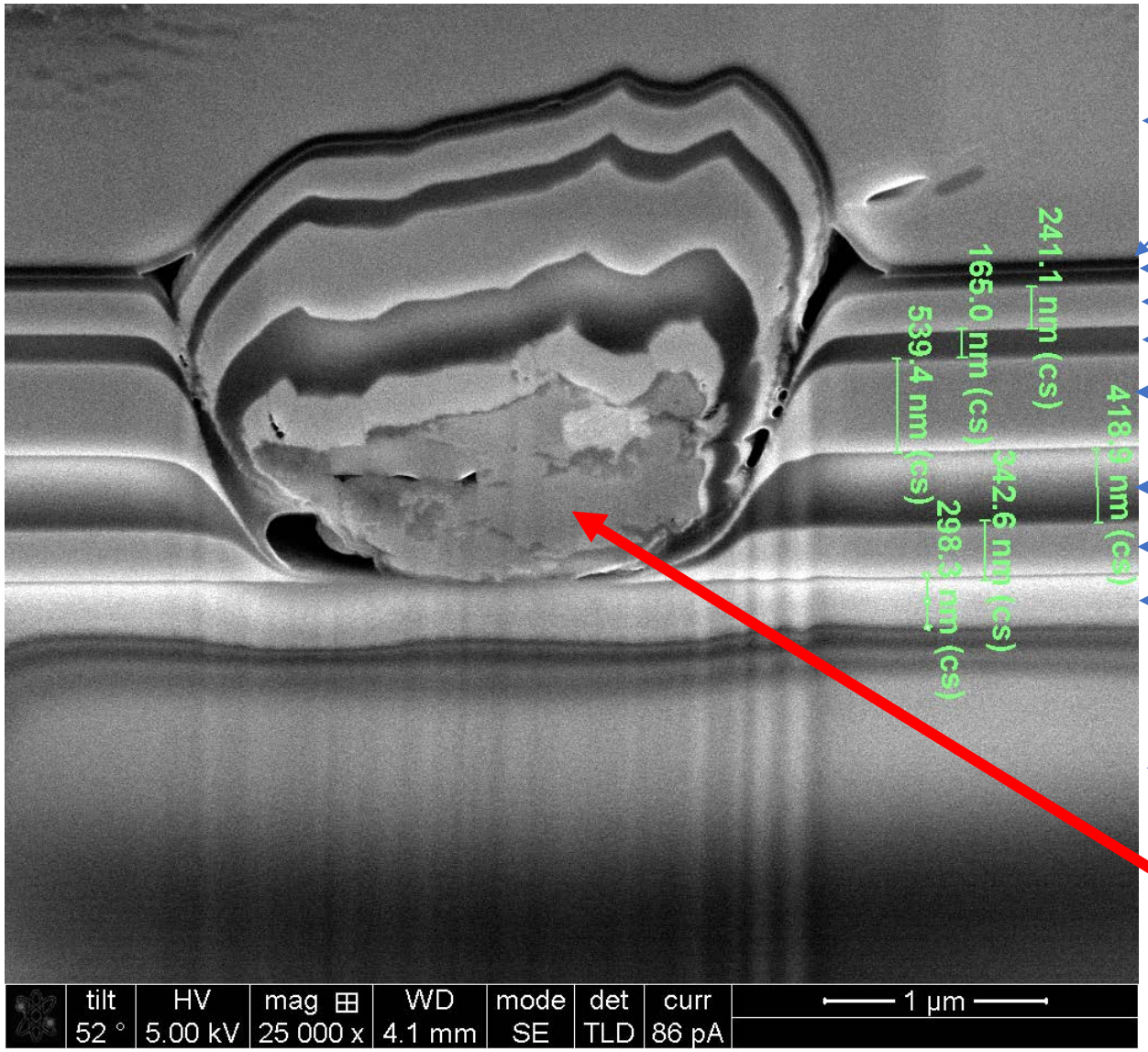
- This defect appears to be part of the coating; it does not look like a particle on the surface
- Spectrum on the surface is the same as that of the clean coating




- Used FIB to cut a cross section through the defect:



# Area A, point absorber A1, cross-section analysis




Likely Al point absorber

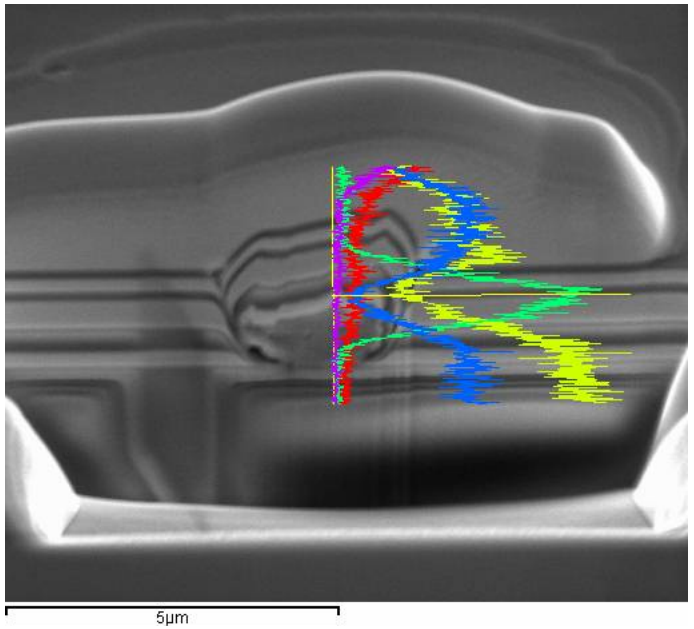
Point absorber cross section

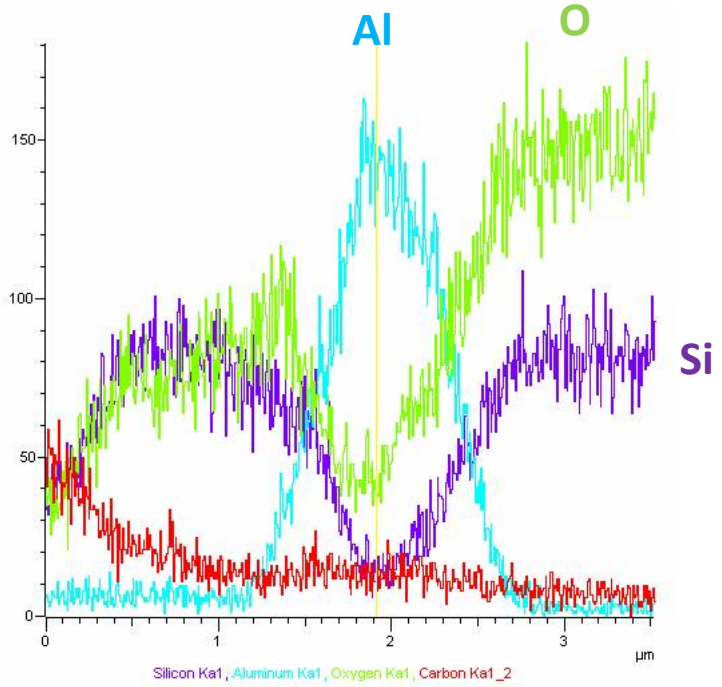
- Coating layer structure is evident
- The ~2 µm absorber was introduced after the first layer and the subsequent layers deposited on top of it
- Bright layers correspond to high index material; dark layers correspond to low index material

Remark: strange AR coating structure:

- Why are layers #1 and #2 made of the same material?
- Number and depths of layers is not consistent with any of the coatings specified by LMA.

# Area A, point absorber A1, line scan

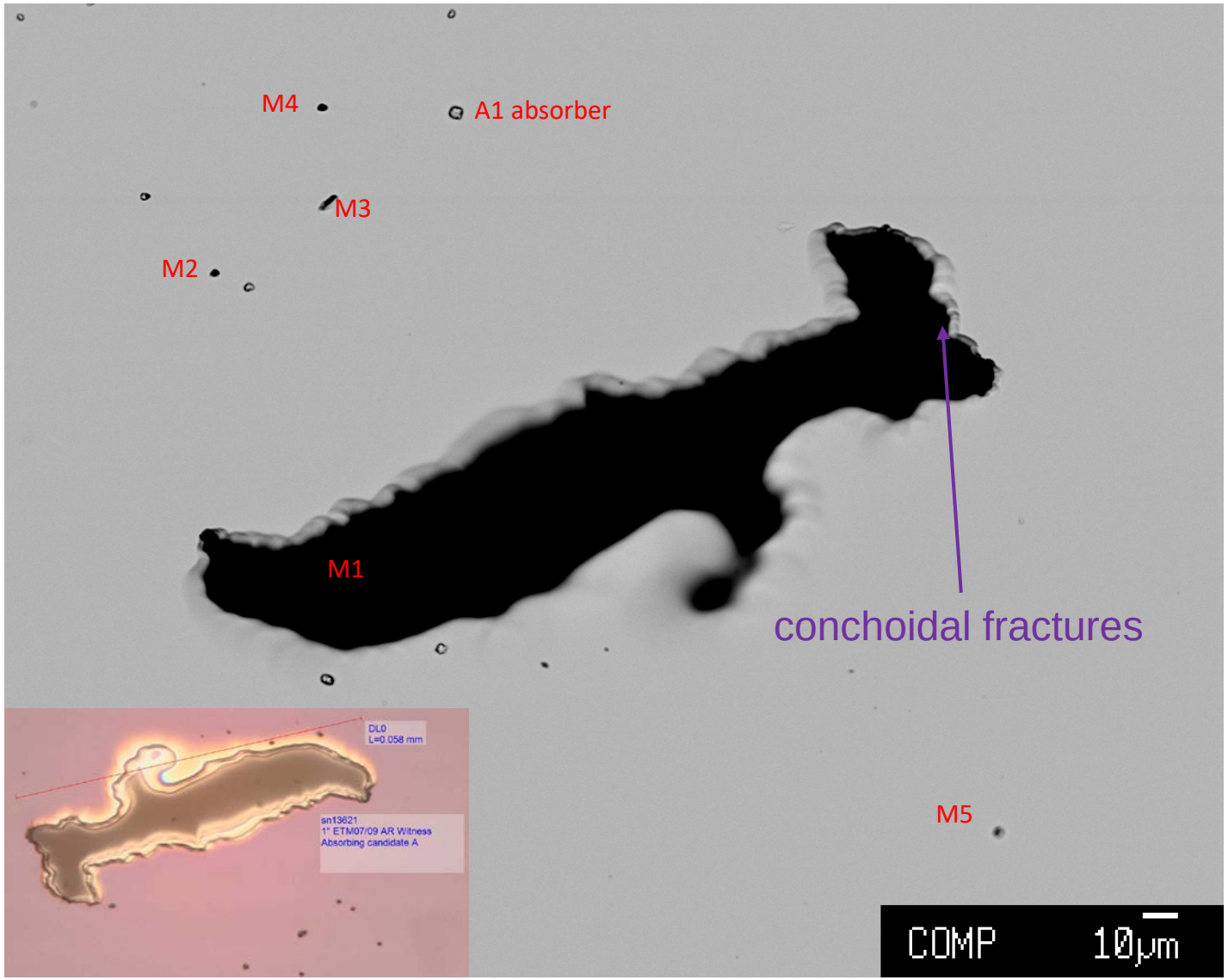


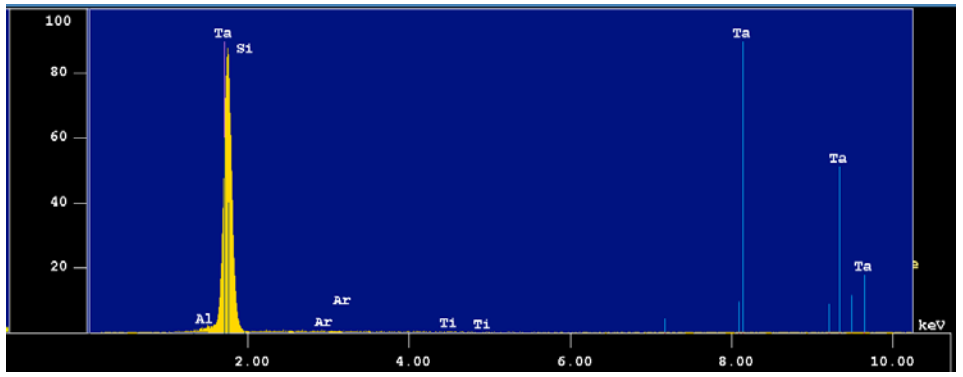

- Strong Al signal at the location of the particle
- Oxygen depletion at the particle location may indicate that we are dealing with pure metal rather than oxide?

There are many more such defects in area A; see slide #7. Are they also caused by Al dust? We are planning to analyze them as well.

# Area A, Missing coating



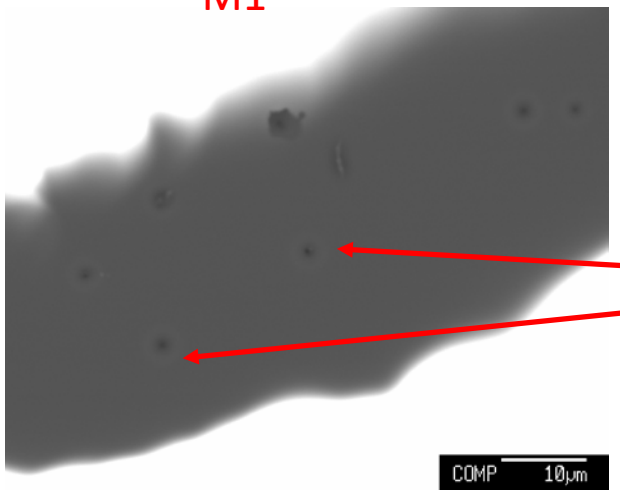

- The missing coating can be easily spotted on large contrast
- 5 places of missing coating with areas of various size, why?
- Conchoidal fractures due to the strain – burst during annealing process?
- Spectrum at M2, M3, and M4 show only Si above 1 keV – pure substrate, but… see next slide

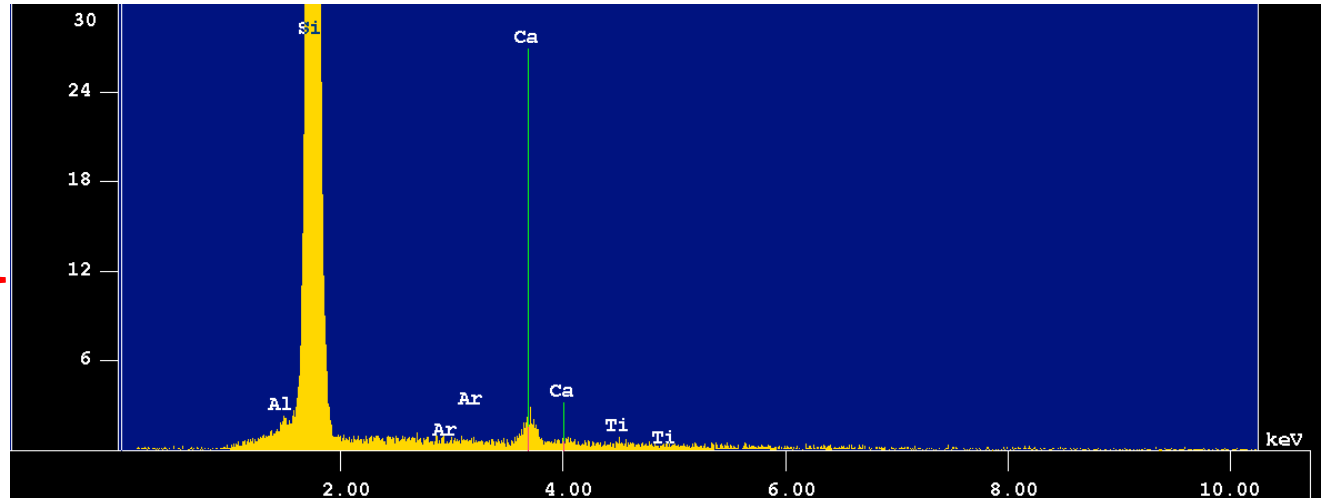



e-beam: 15 kV, 10 nV

# Area A,  Missing coating, contamination

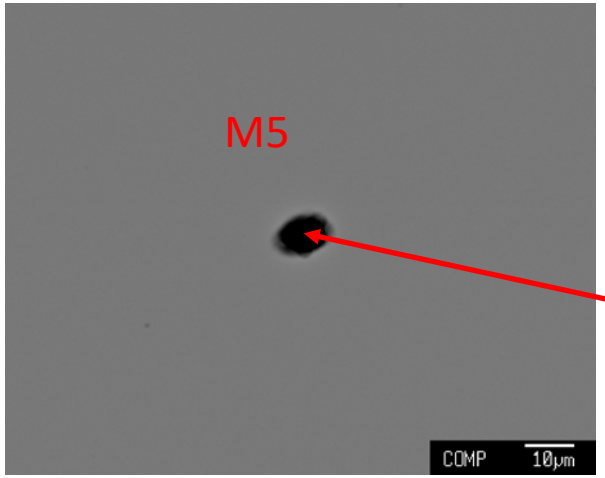
M1

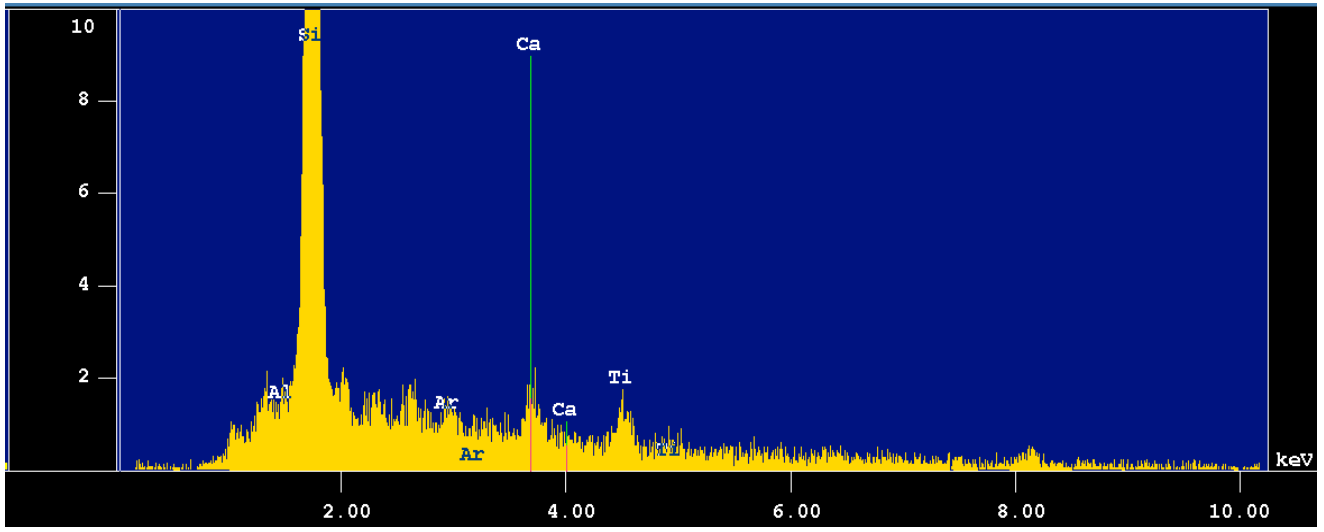



Ca compounds at the bottom of M1 at various locations

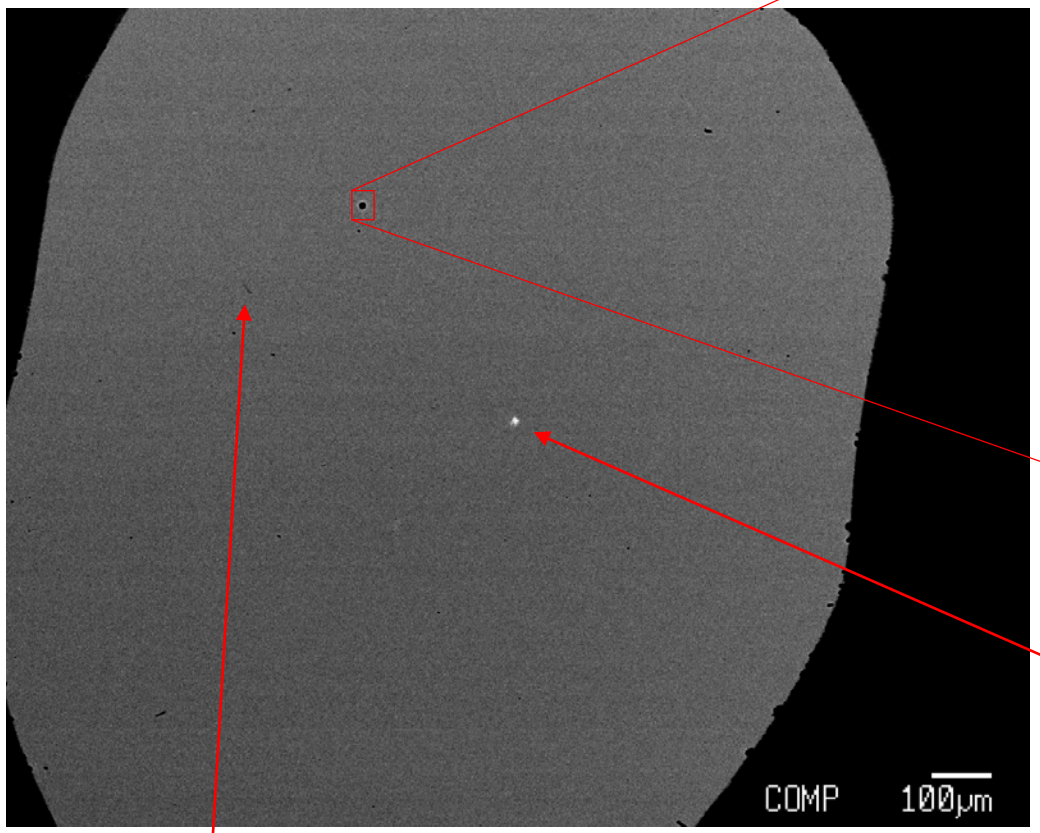
M5




More complex compounds at the bottom of M5

# Overview of area C



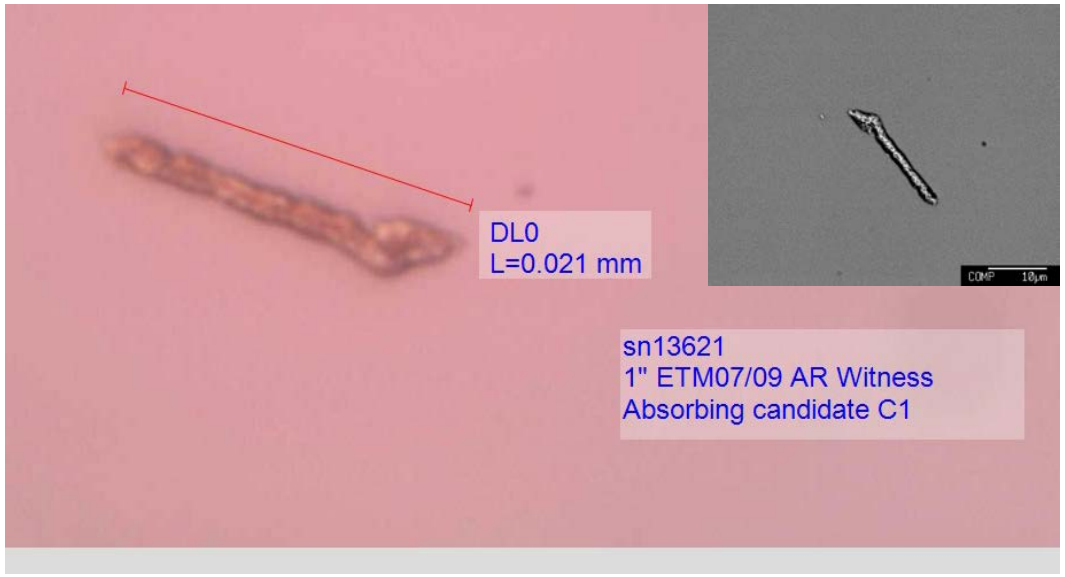


Dust particle- can be removed; not likely to be point absorber

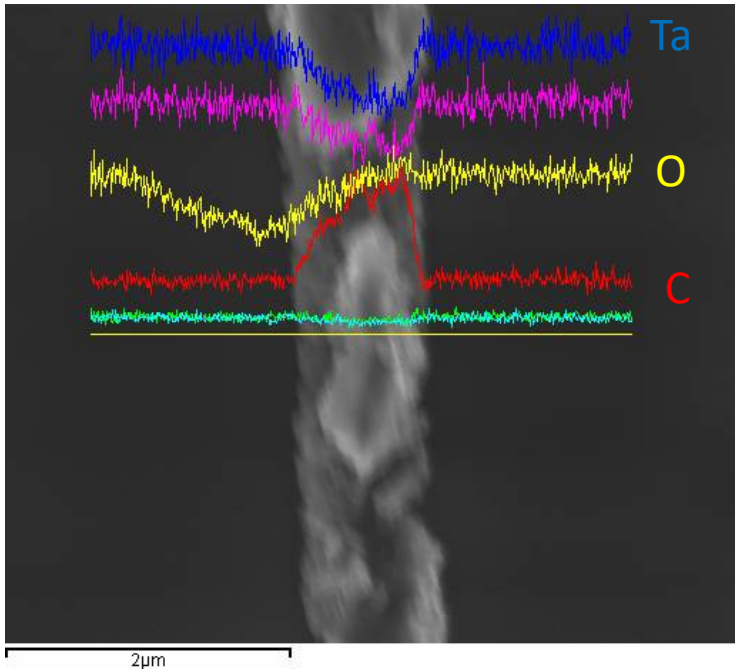
Looks like a flake; spectrum is consistent with that of the clean coating, but we will cut in the future to confirm.

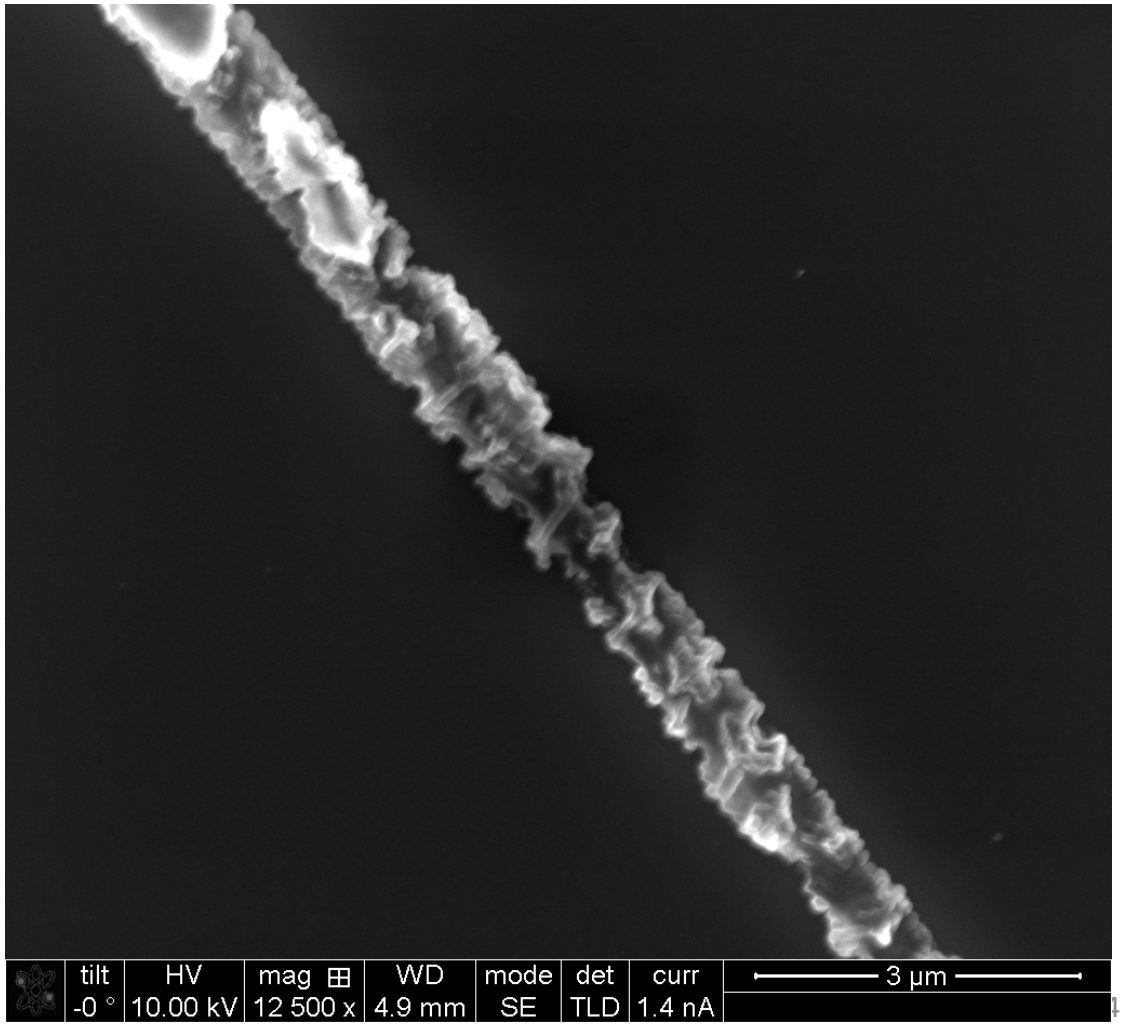
Carbon rod; see next slide

# Area C carbon rod




- Absorbing candidate C appears to be a carbon rod
- No evidence of aluminum but we will cut in the future to confirm



# Conclusions

- At high absorption locations we found Aluminum particles of size 2-5 µm , most probably metal dust
- Contamination occurs during the coating deposition – one defect found near the surface; one found after the first coating layer
- Origin of the Al dust in the coater is unknown at the moment (mask, ion gun components, shredding of the screws, etc. ?)
- Delamination of the coating my be caused by other contaminants  (Ca found in the delamination region)
- Planning on cutting remaining features to investigate Al content under the surface
- Will investigate further absorbing candidates near but outside area C

Thank you Dr. Shiahn Chen for SEM piloting assistance.