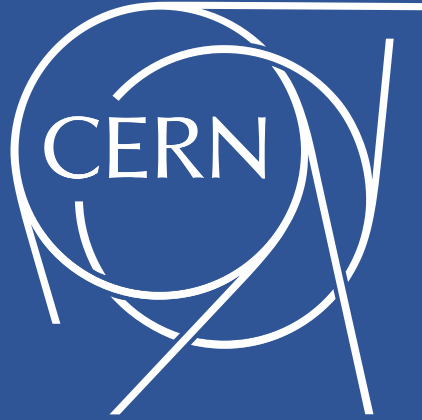


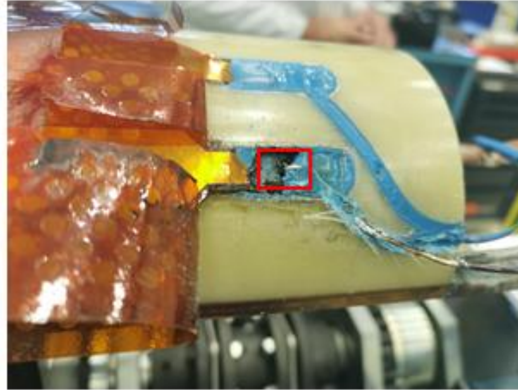
Soldering tests of quench heaters (QH)

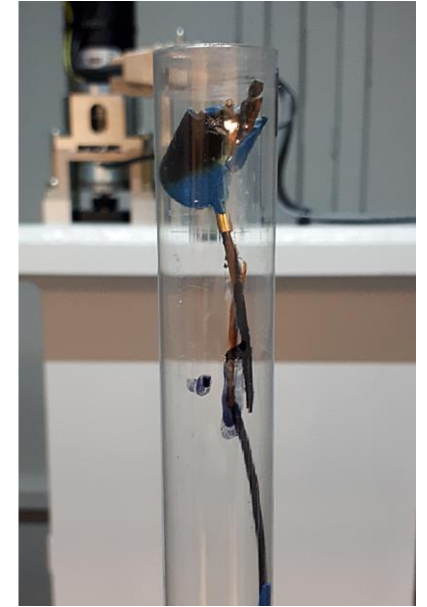
Computed tomography (CT) imaging and metallurgical investigations

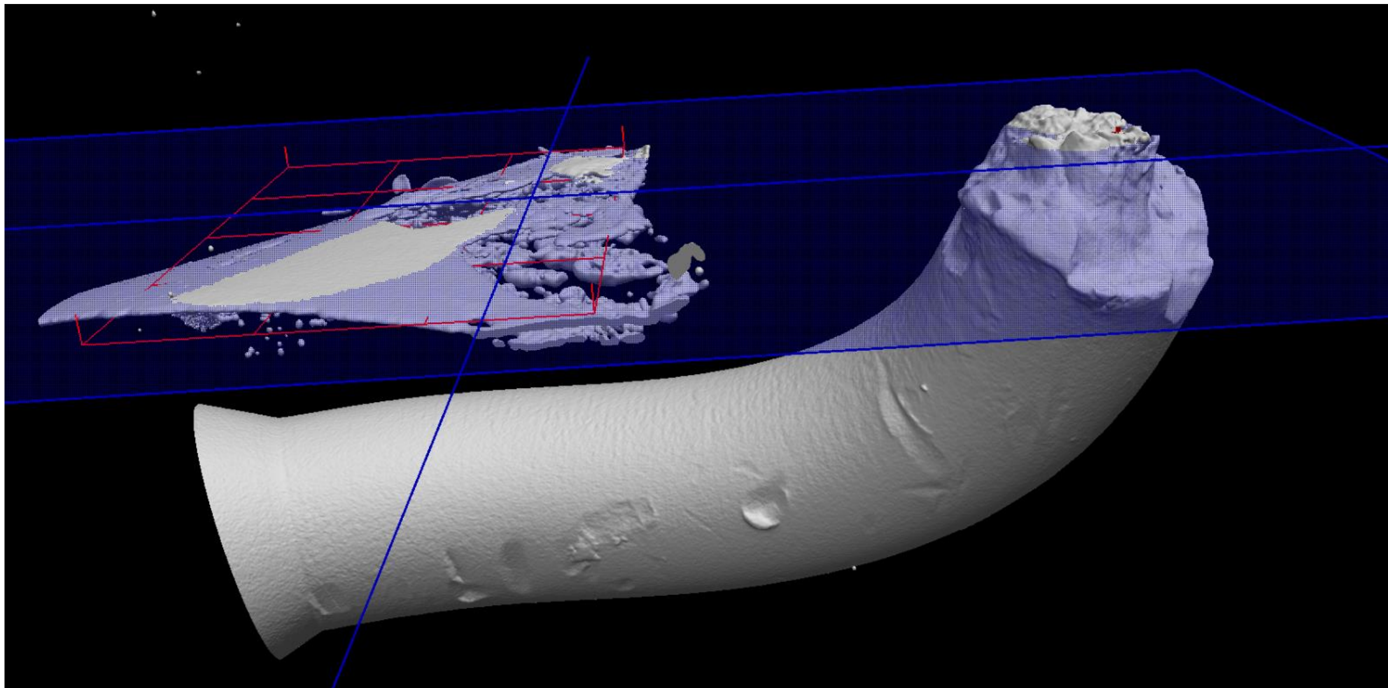
Mariusz Jedrychowski - Mickaël Crouvizier – Mickaël Meyer/Mechanical & Materials Engineering group, EN-MME-MM

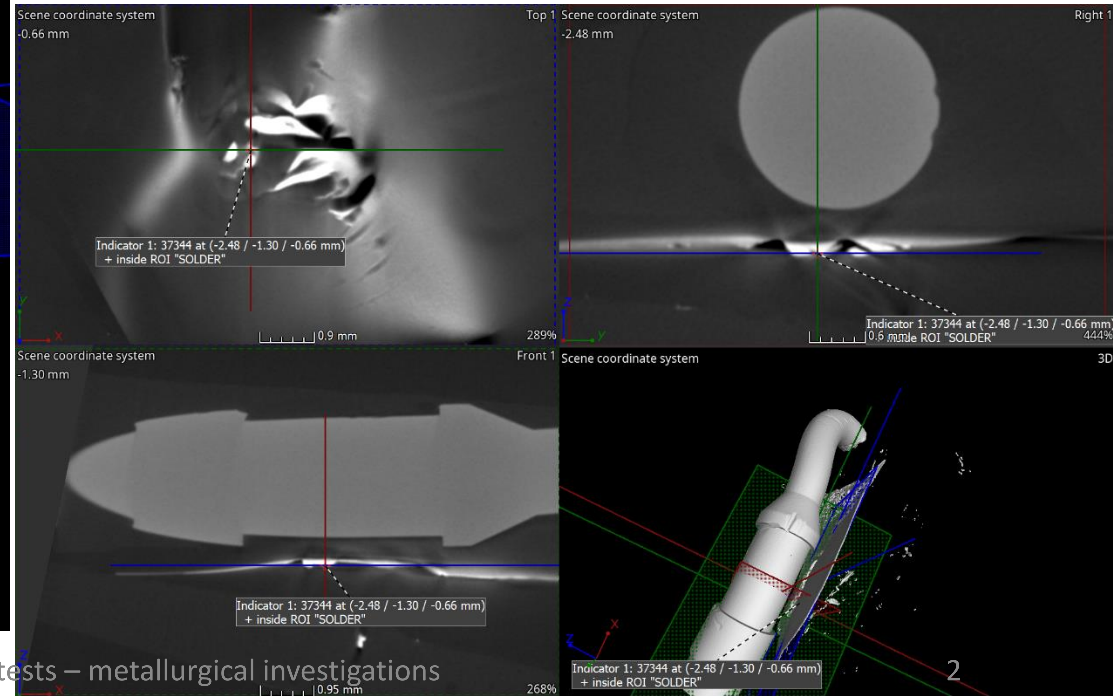
Post-mortem analysis CR14

First inspection August 2020









Post-mortem analysis CR14

Volume 1 ⇒ Cylinder 1 alignment system
0.83 mm
Top 1
0.3 mm
807%

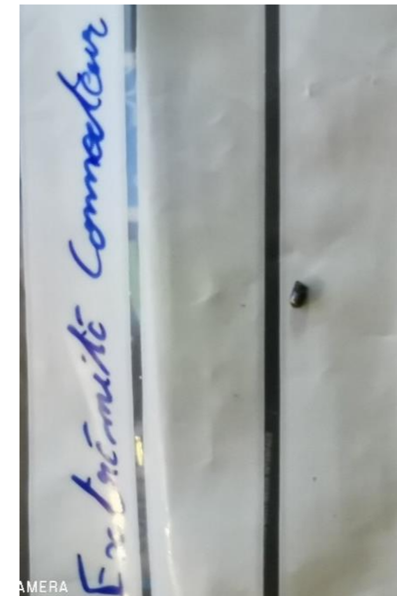
Volume 1 ⇒ Cylinder 1 alignment system
0.01 mm
Right 1
0.85 mm
415%

Volume 1 ⇒ Cylinder 1 alignment system
0.00 mm
Front 1
0.6 mm
426%

Volume 1 ⇒ Cylinder 1 alignment system
3D

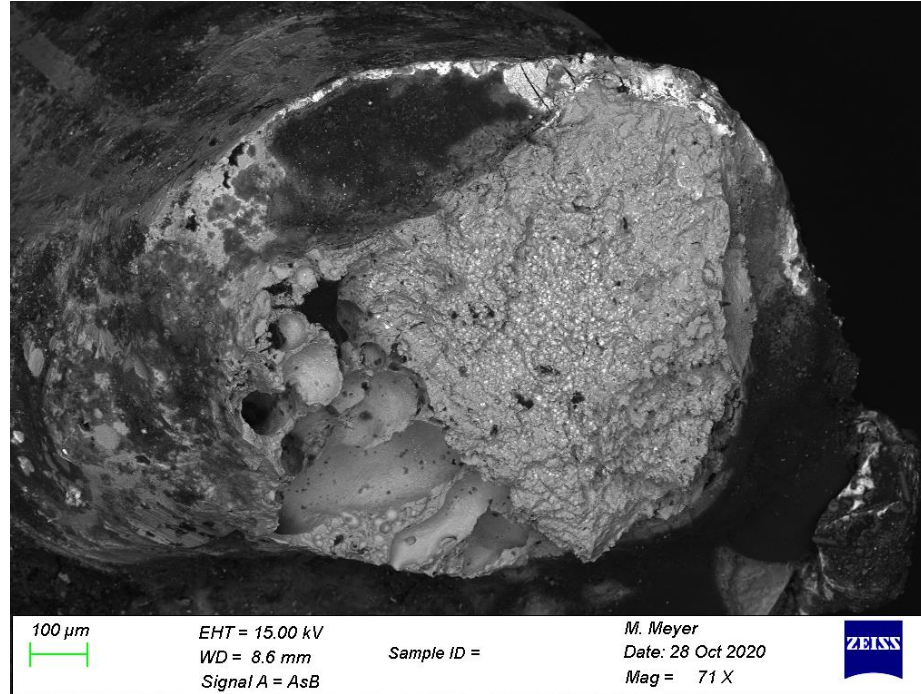
Volume 1 ⇒ Cylinder 1 alignment system
2.08 mm
Custom path 1
1.5 mm
189%

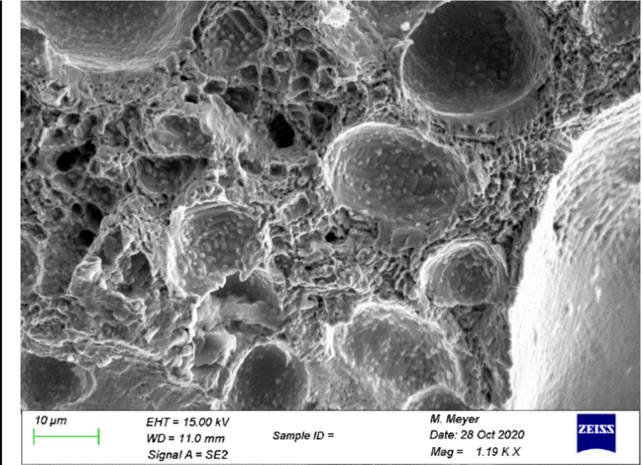
Non-planar coordinate system
0.01 mm
Non-planar 1
410%



Post-mortem analysis CR14

Detailed report on last investigations EDMS 2431738



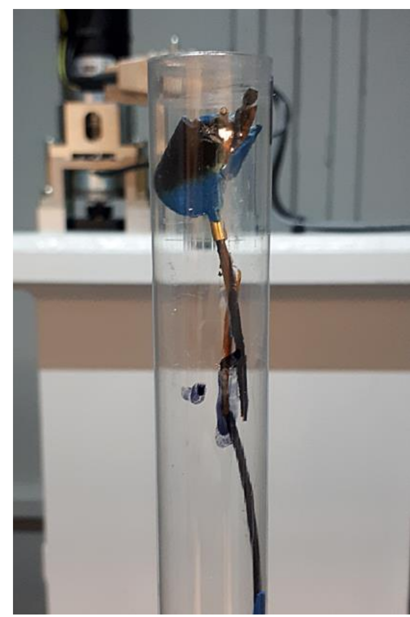


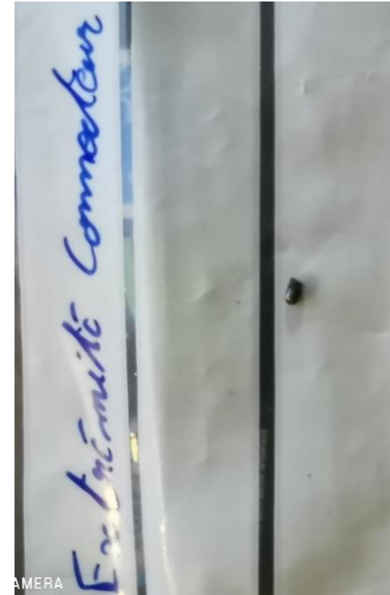
Reduced observable section → A significant part of the connector is missing
On the remaining observable section: indications of porosities, burnt organic compounds and mechanical tearing.

Post-mortem analysis CR14

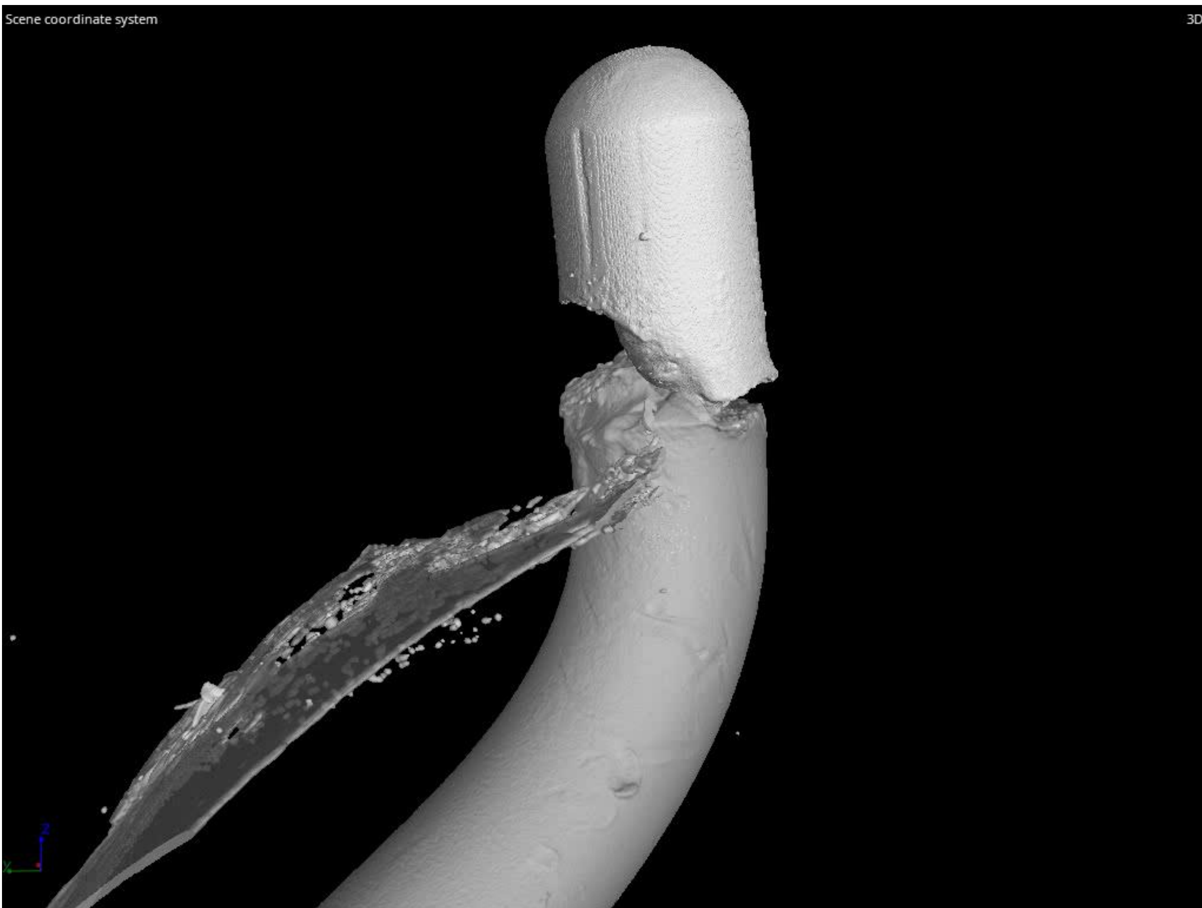
Scene coordinate system

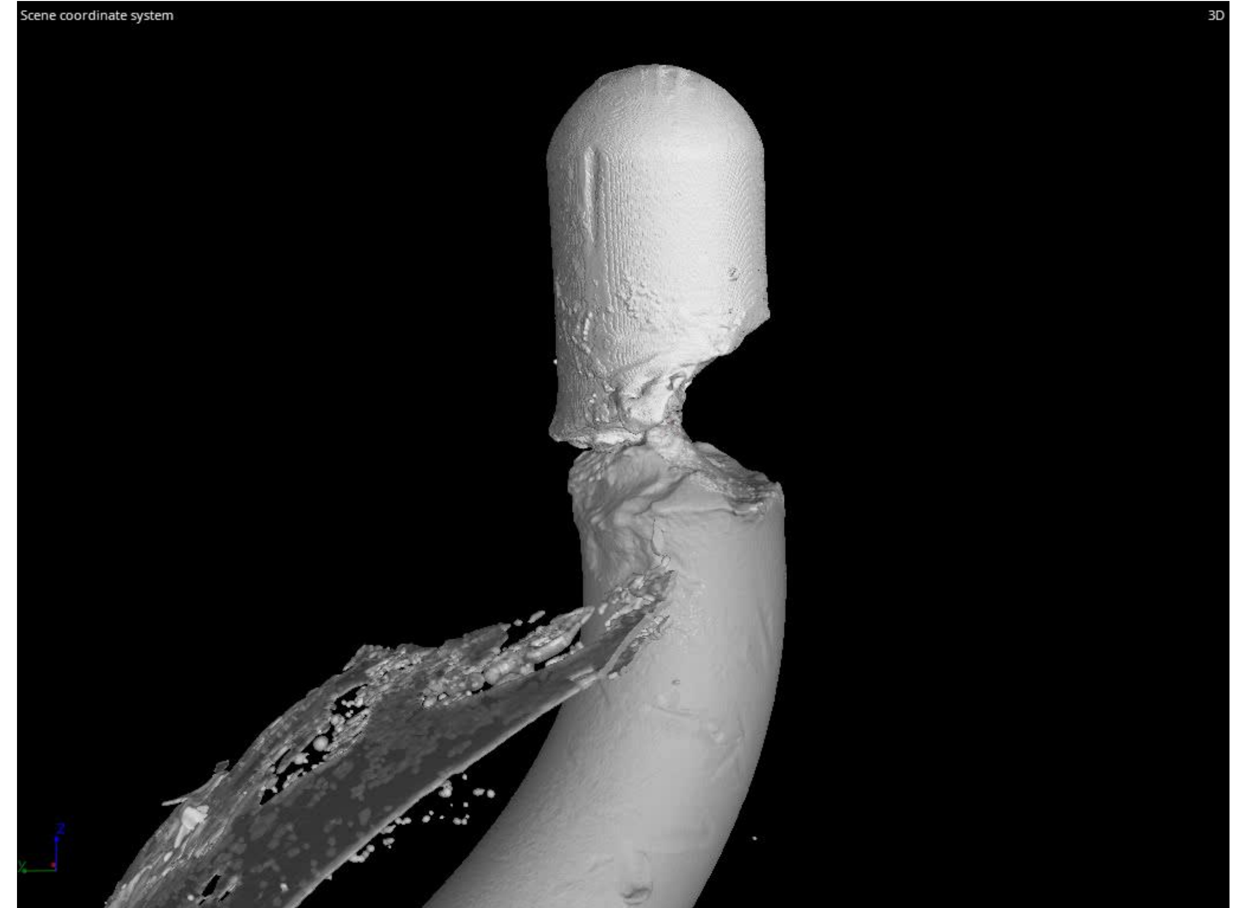
3D





Post-mortem analysis CR14





List of samples

Detailed report with all metallographic analysis EDMS 2424315

Sample reference	examined Sample #	Configuration	Tinning	Cleaning	Pickling
ES-AE	4 and 6; 5[1]	Standard*	X	X	X
ES-SE	1 and 3; 2[1]	Standard*		X	X
ENS-AE	1; 1[1]	Standard*	X		
ENS-AE-DP	1 and 2; 3[1]	Standard*	X		X (partial)
ENS-SE	1 and 2; 1[1]	Standard*			
ENS-SE-DP	5 and 6; 4[1]	Standard*			X (partial)
EGB-AE	2 and 3; 1[1]	Standard**	X	X	X
EF-AE	5 and 6; 4[1]	Wire on QH tape***	X	X	X
FCGB-SE	3 and 4; 2[1]	Flat connector****		X	X
FCGB-SE with Omega	2 and 3; 1[1]	Omega on flat connector		X	X

**with the 90° curved connector between the cable and the QH*

***with the 90° curved connector between the cable and the QH with the use of a dedicated tooling ensuring the geometry of the configuration*

****here the curved connector is not used, wires composing the cables are directly soldered on the QH tape*

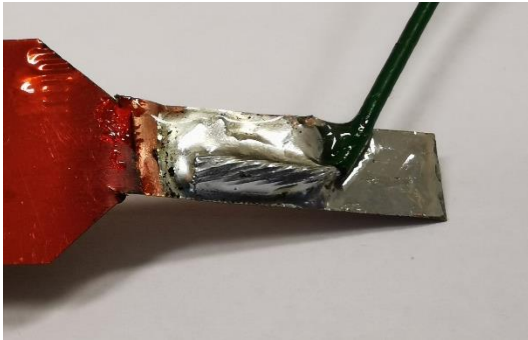
*****pressure is applied on flat connector during soldering process*

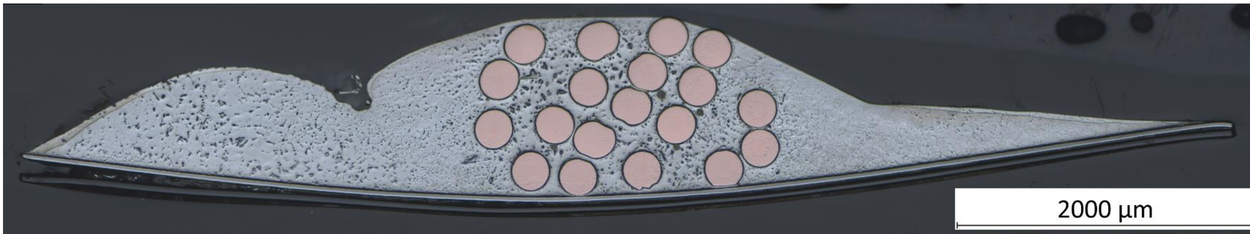
[1]*for examination by computed X-ray micro tomography*

EF-AE : Tinning, Cleaning, Pickling

4-EF-AE[frontView].avi (Command Line)

No significant defects were found. **General good quality**, both connector and QH copper surfaces are in contact with the solder.





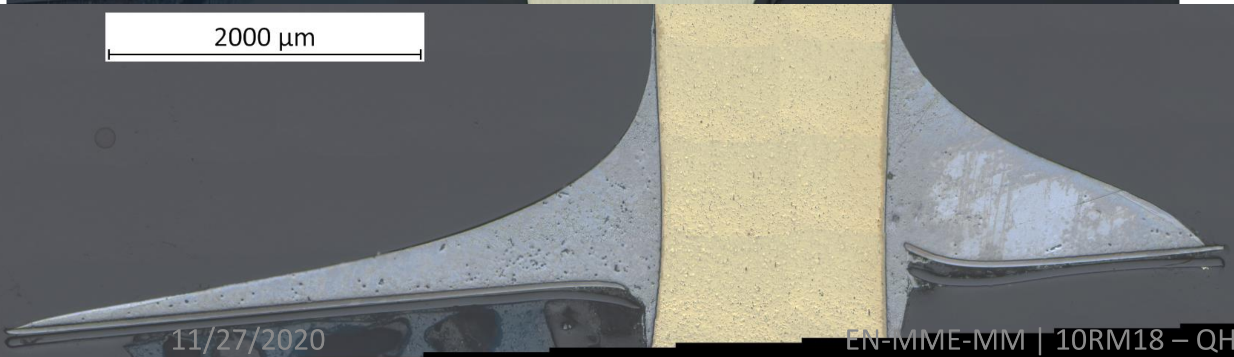
ES-AE : Tinning, Cleaning, Pickling

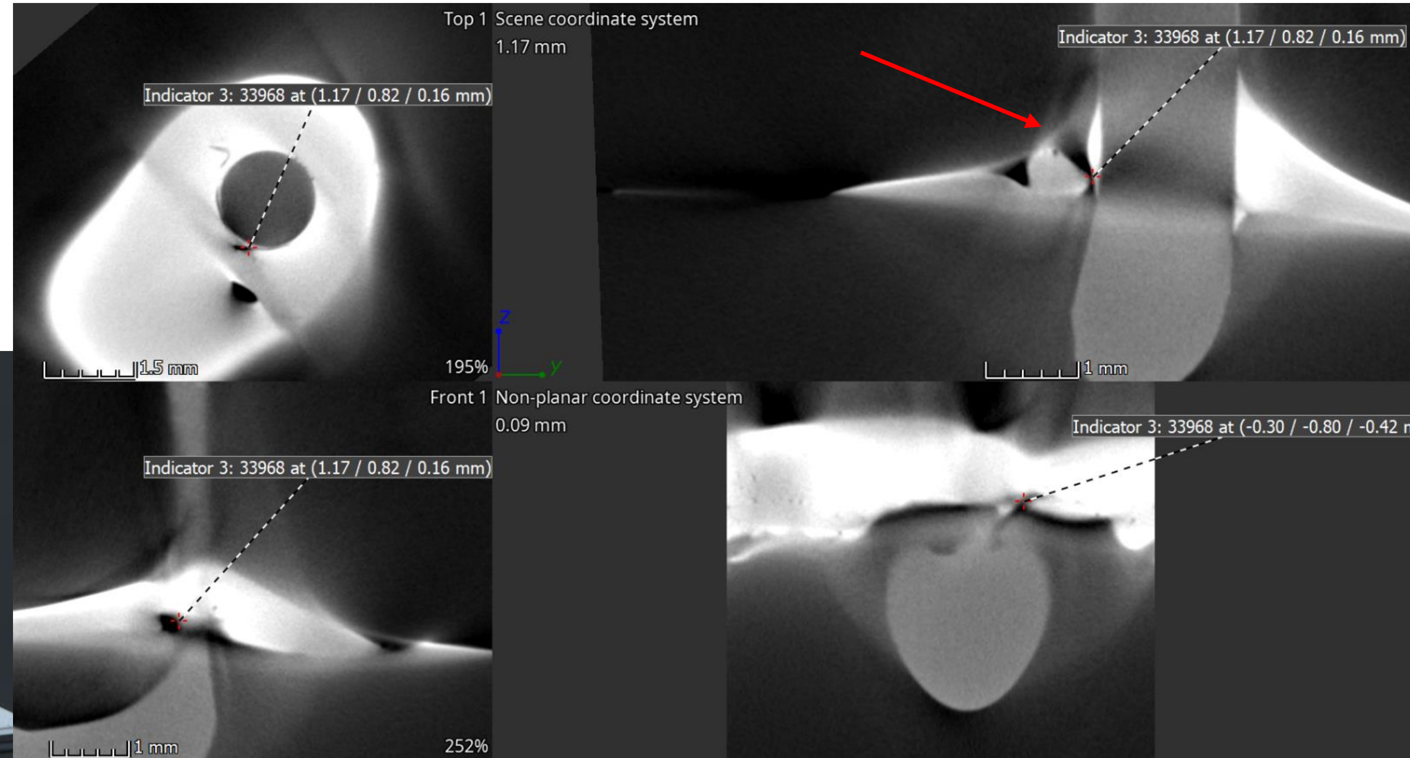
Minor defects were found (**QH tape embedded**), but overall the **quality** of the solder **is good**.

5-ES-AE[topView].avi (Command Line)

ES-SE : Cleaning, Pickling

Overall the **quality of the solder is good**, but one big open pore was found in CT scan.





2-ES-SE[topView].avi (Command Line)

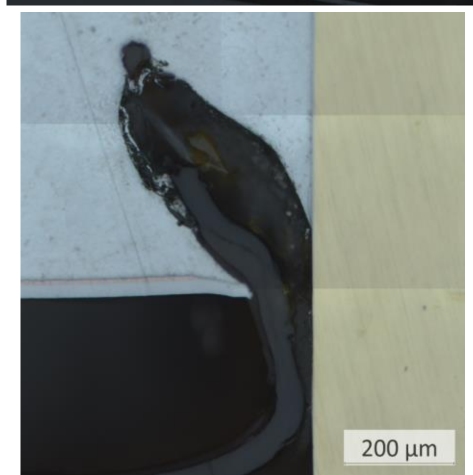
2-ES-SE[unrolledView].avi (Command Line)

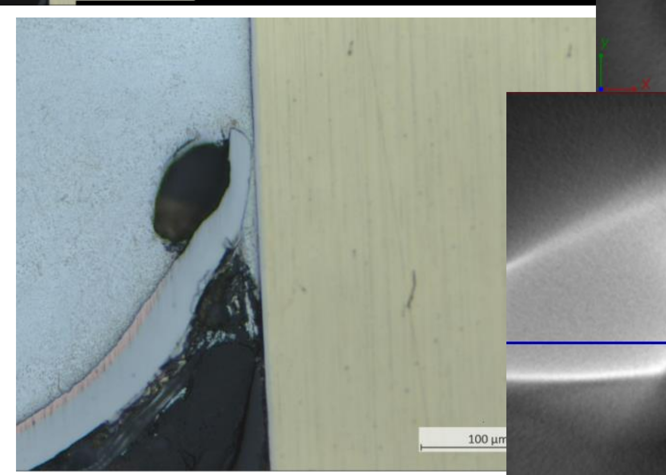
1-EGB-AE[unrolledView].avi (Command Line)

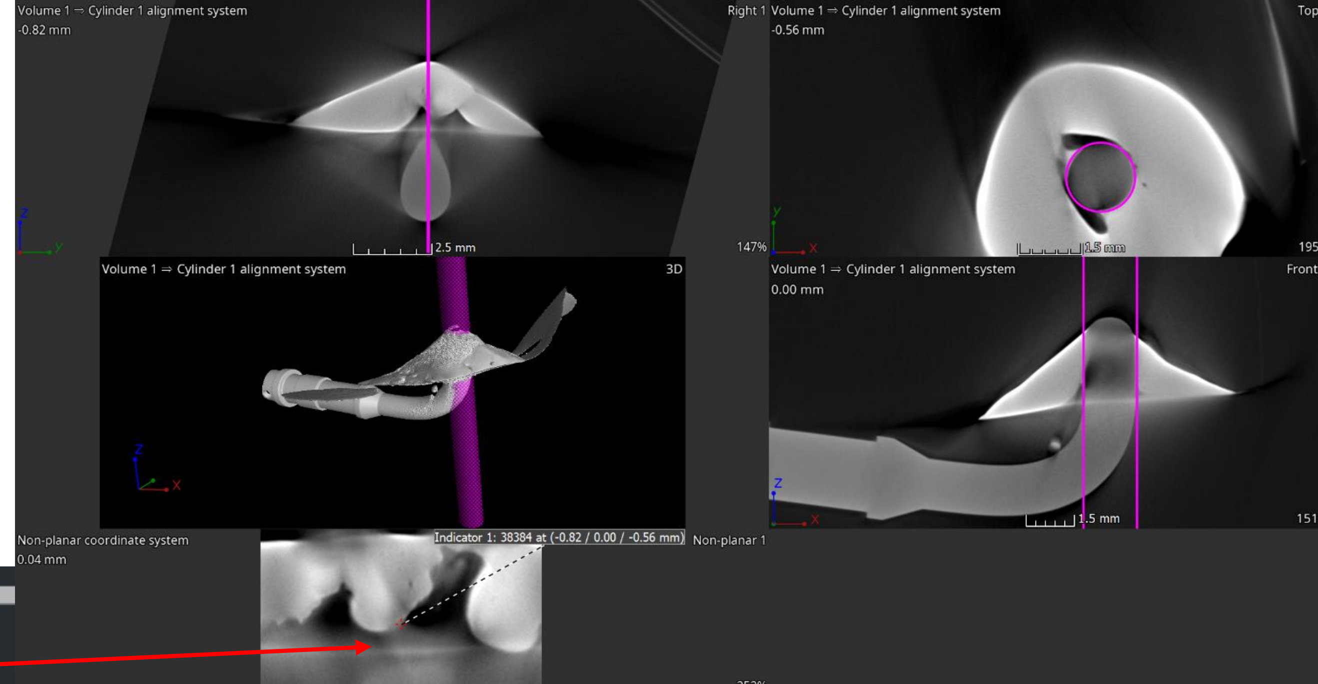
1-EGB-AE[topView].avi (Command Line)

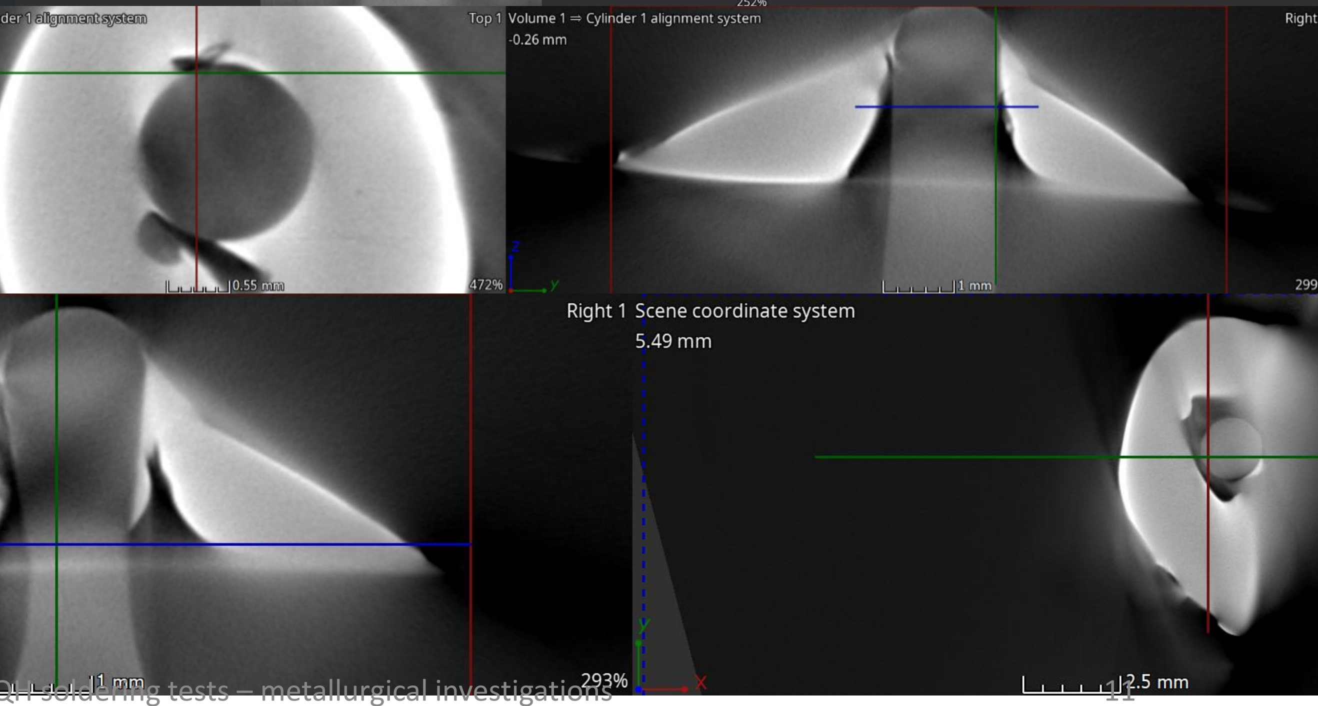
EGB-AE : Tinning, Cleaning, Pickling

Large bonding imperfections due the presence of polyimide film.



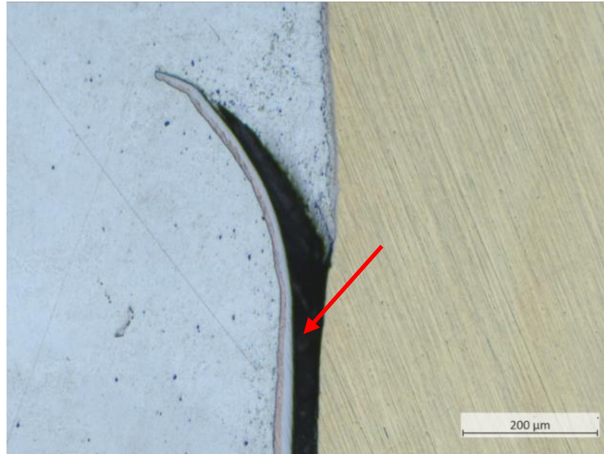


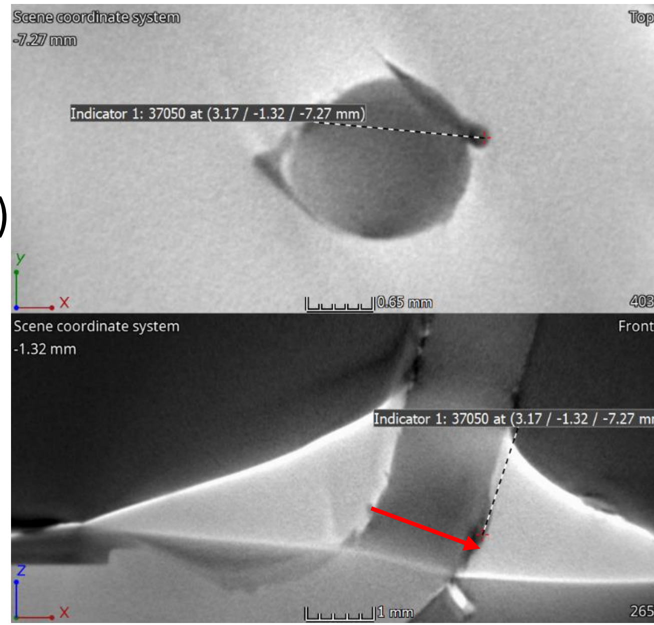


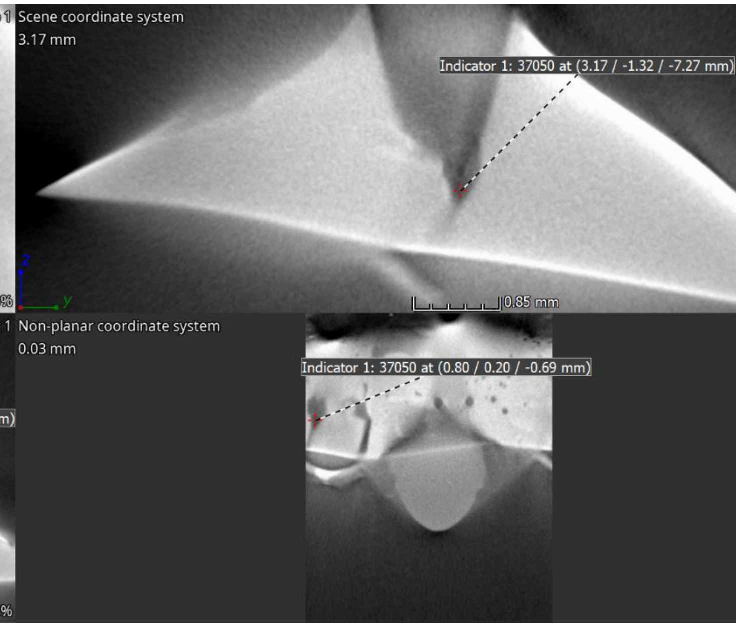


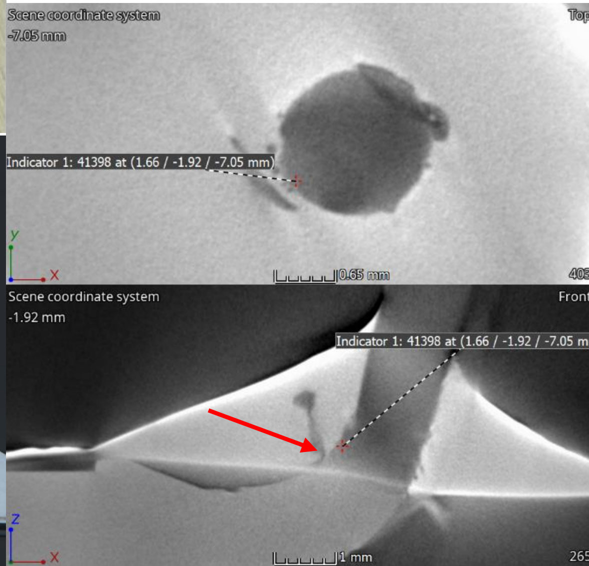
ENS-AE-DP : Tinning, Pickling

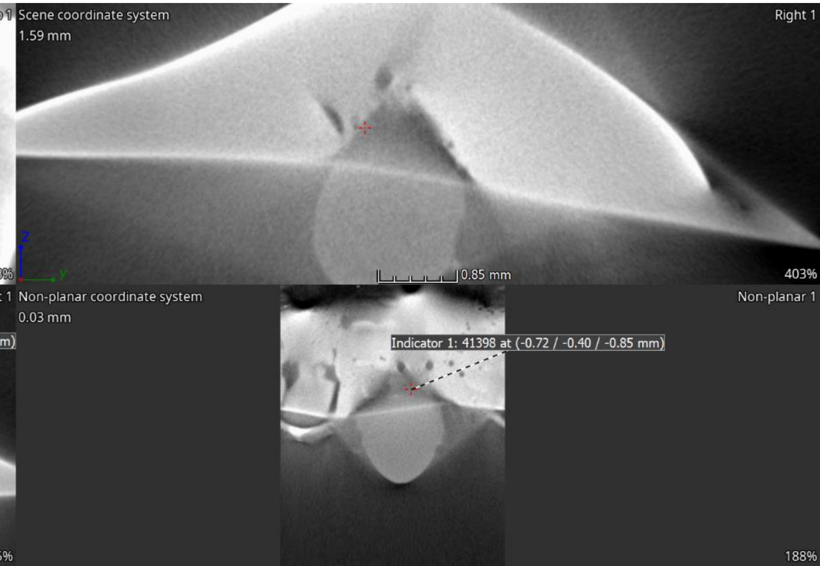
Reduced soldered interface due to embedded QH (arrows) and big void (CT scan).

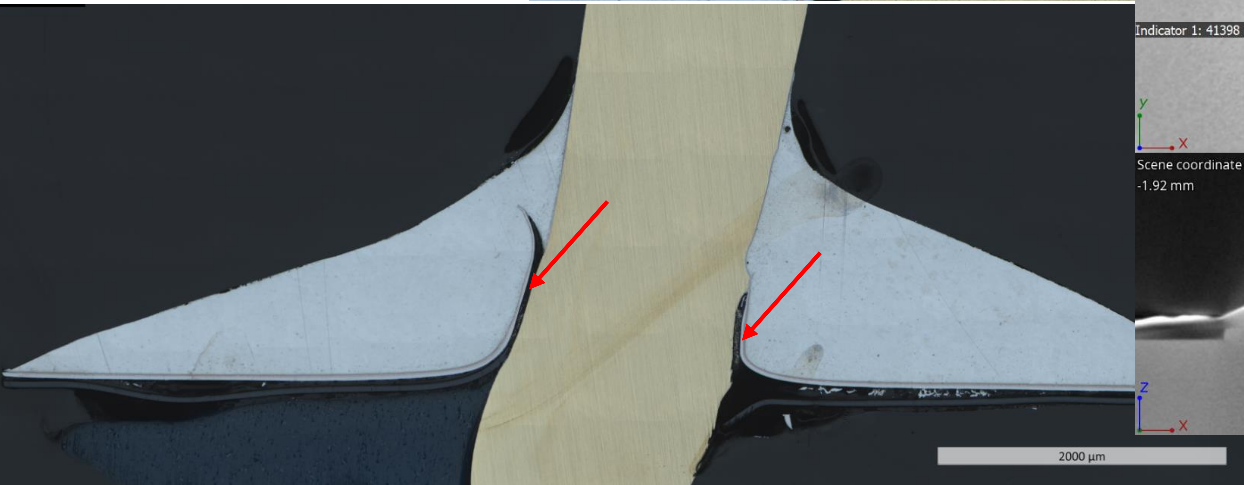








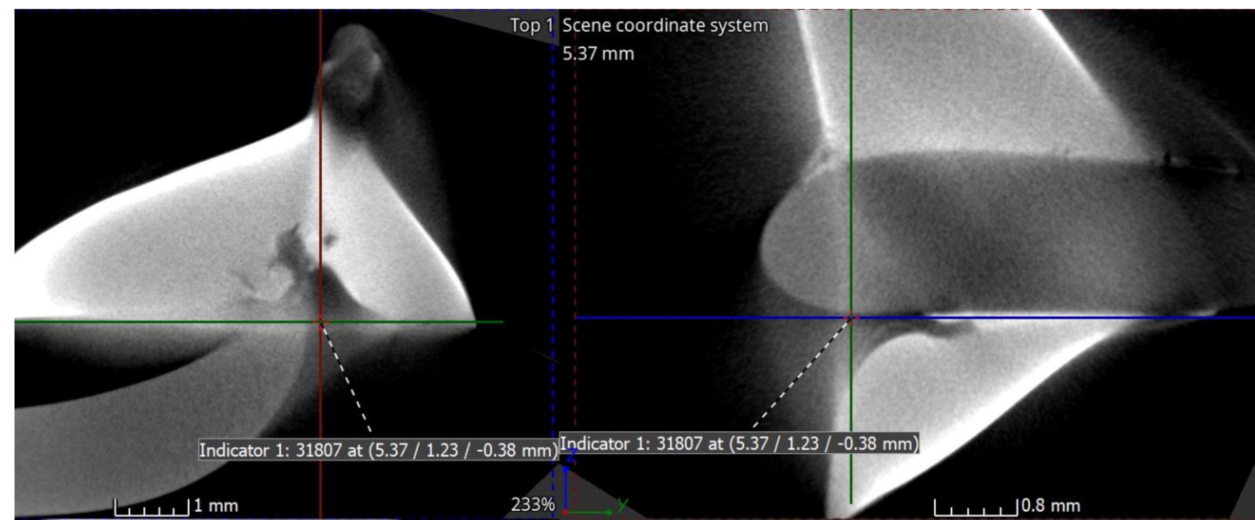


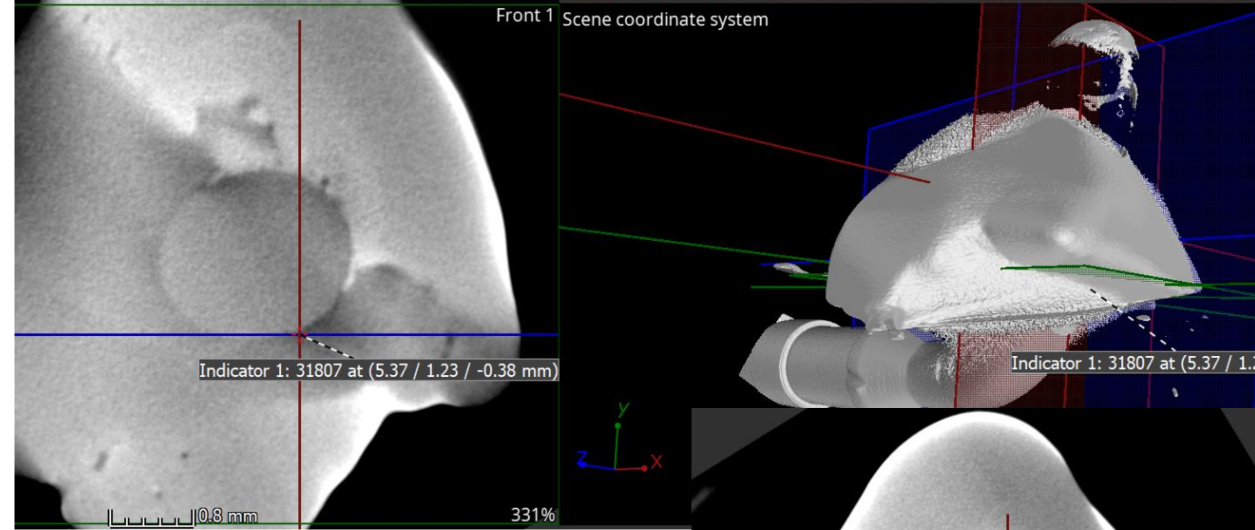


3-ENS-AE-DP[frontView].avi (Command Line)

ENS-SE-DP : Pickling (partial)

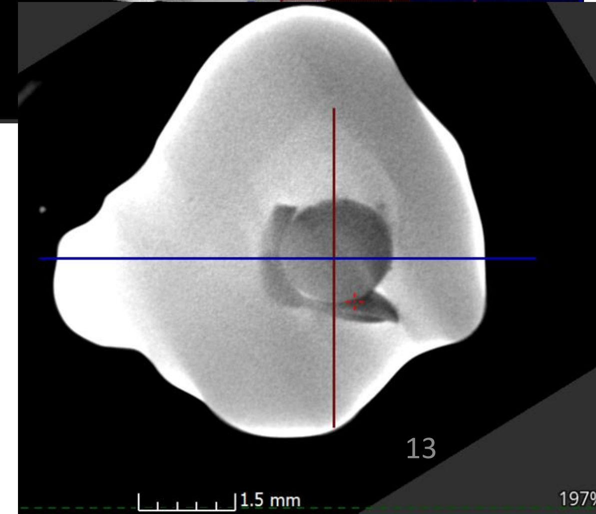
Partial bonding due to the presence of polyimide film, large void under the solder.





4-ENS-SE-DP[frontView].avi (Command Line)

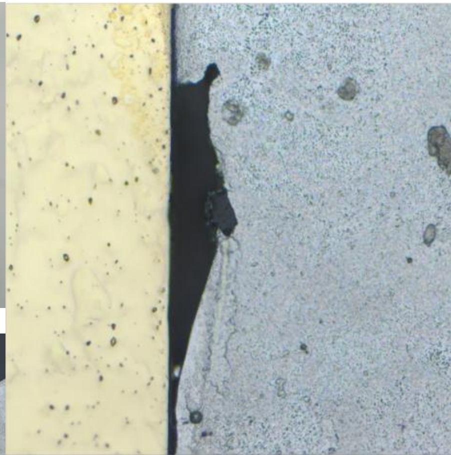
4-ENS-SE-DP[topView].avi (Command Line)

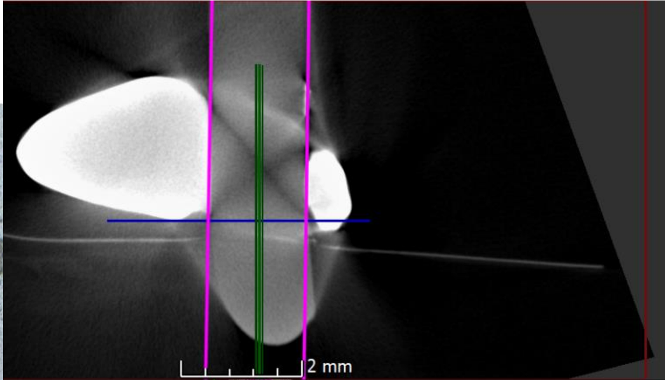


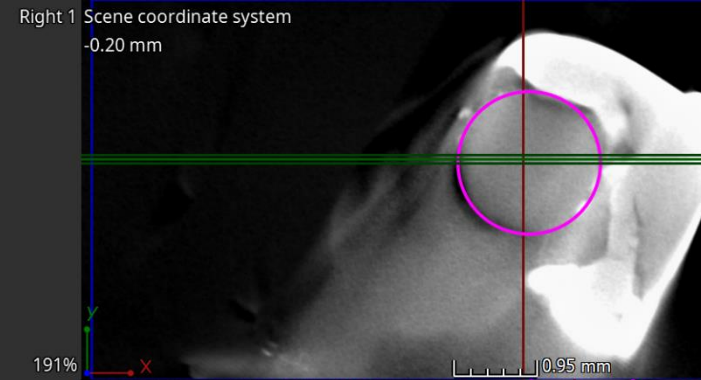
ENS-AE : Tinning

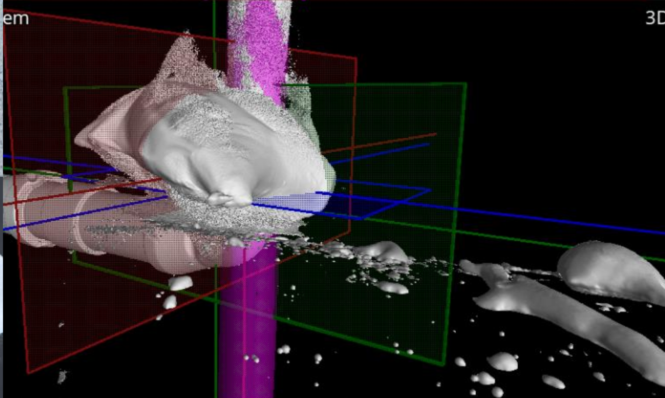
1-ENS-AE[frontView].avi (Command Line)

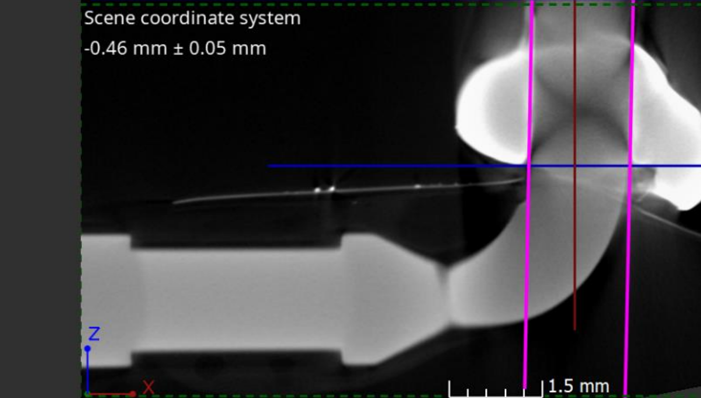
Solder is detached from QH copper tape.

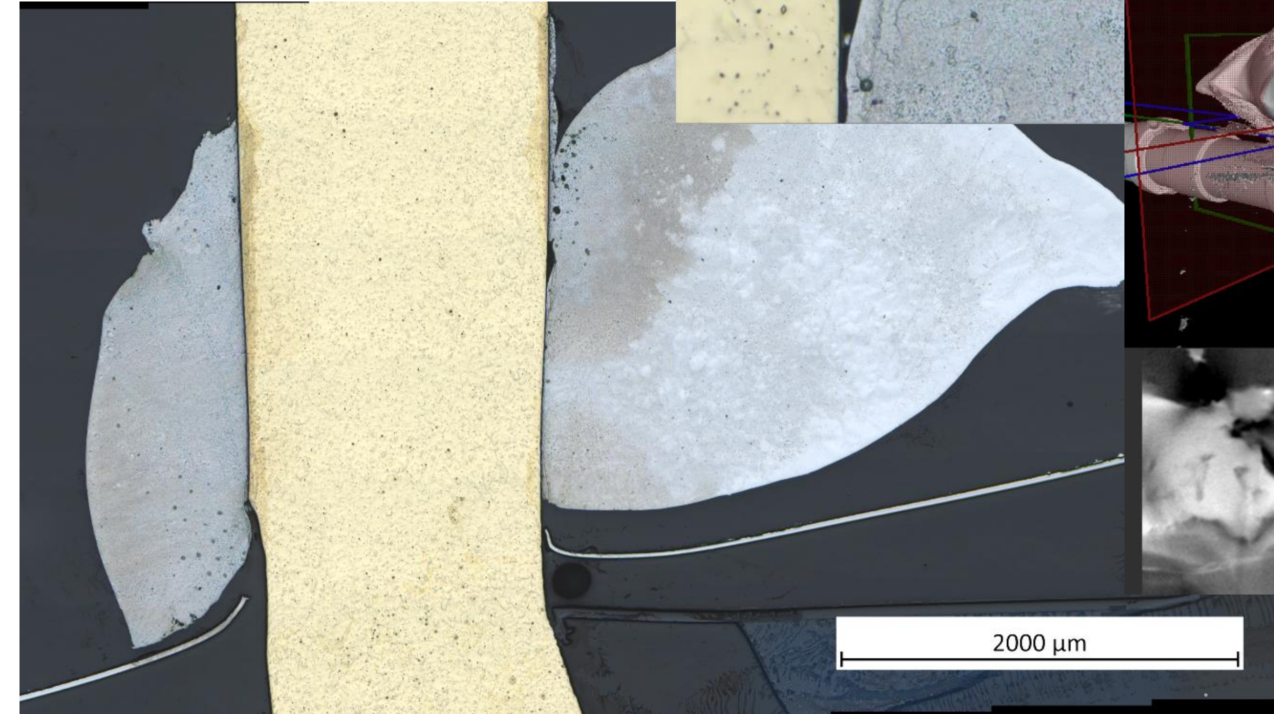


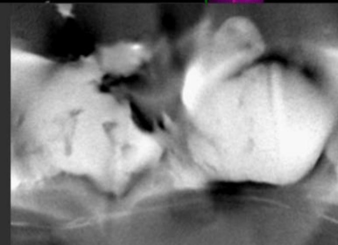






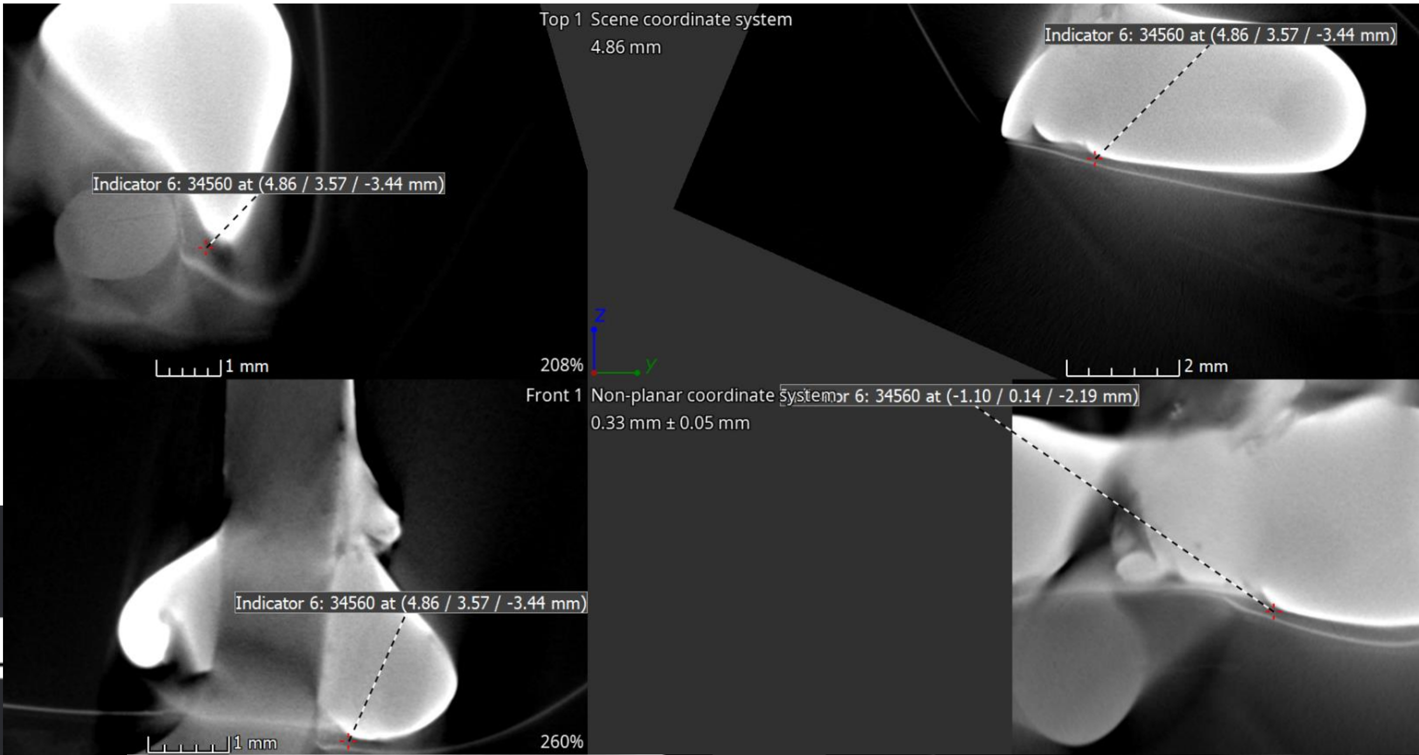


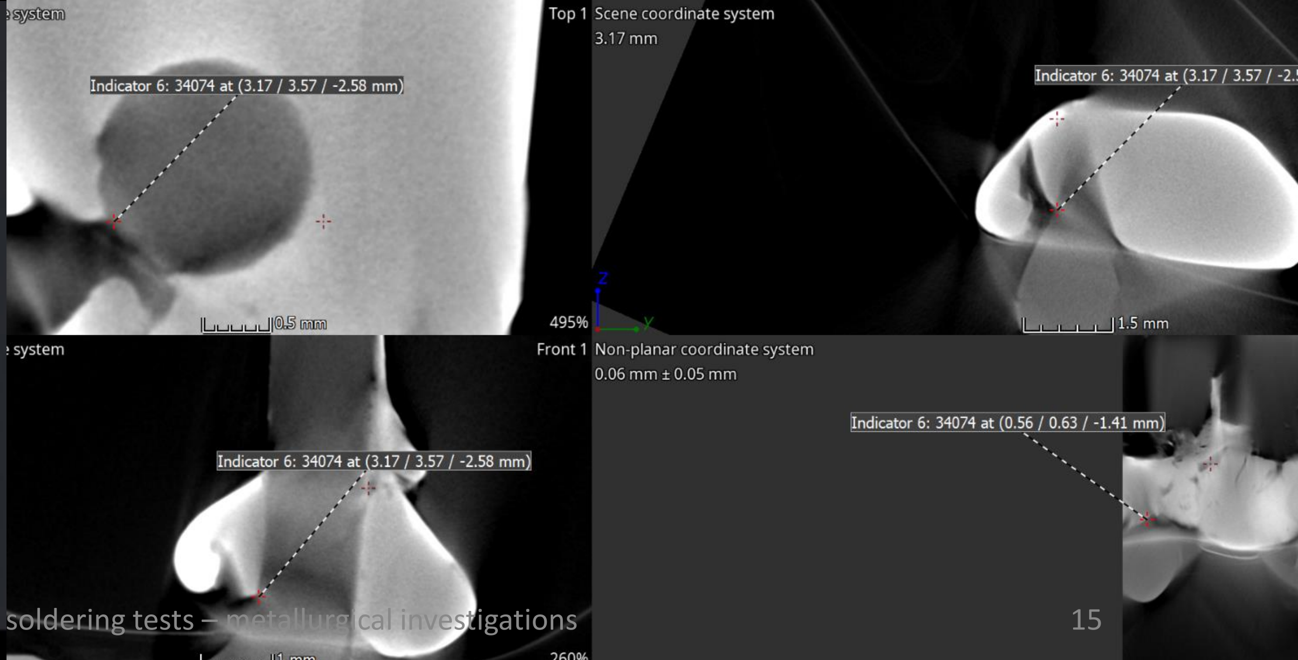




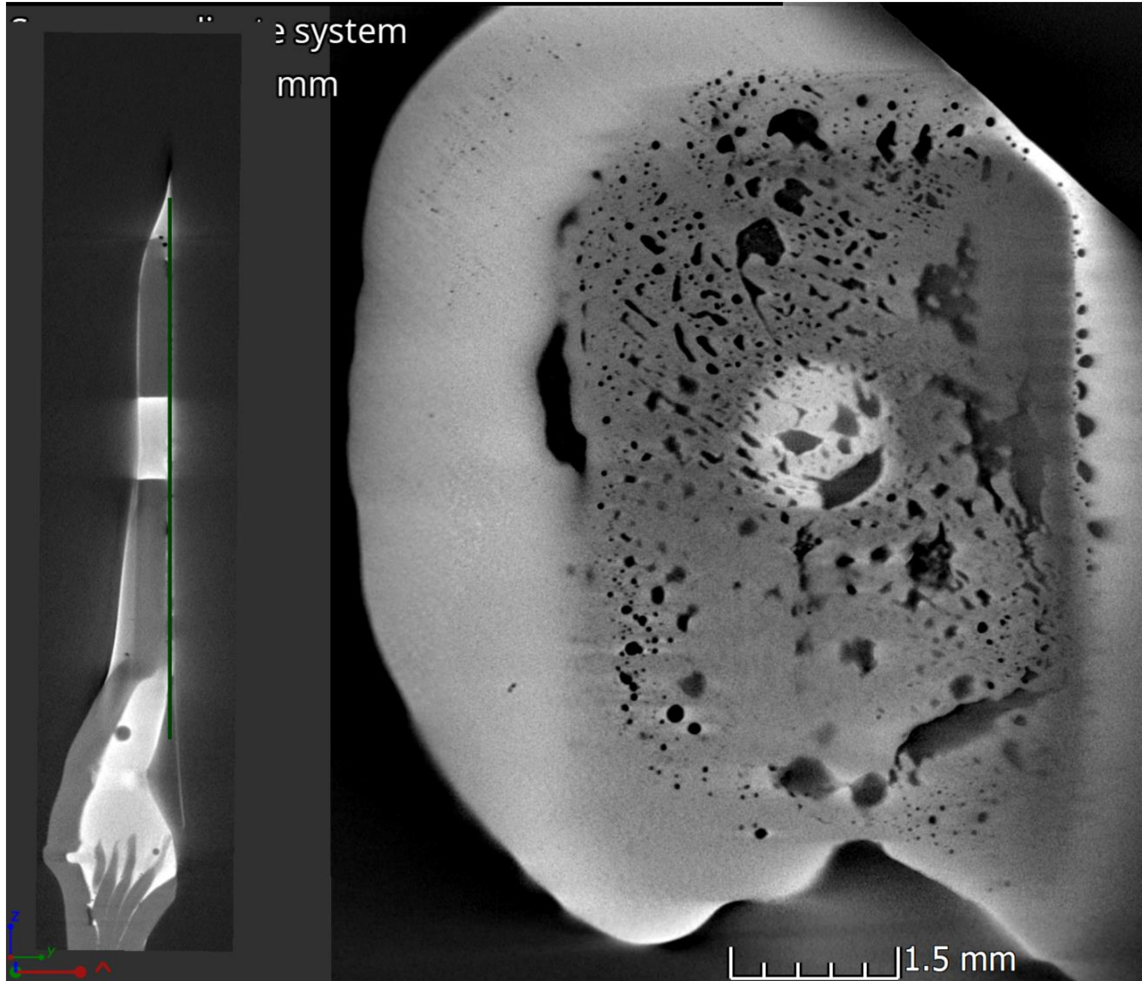
ENS-SE :without any preparation

Poor joint quality, the pin's connector is not soldered to QH copper tape

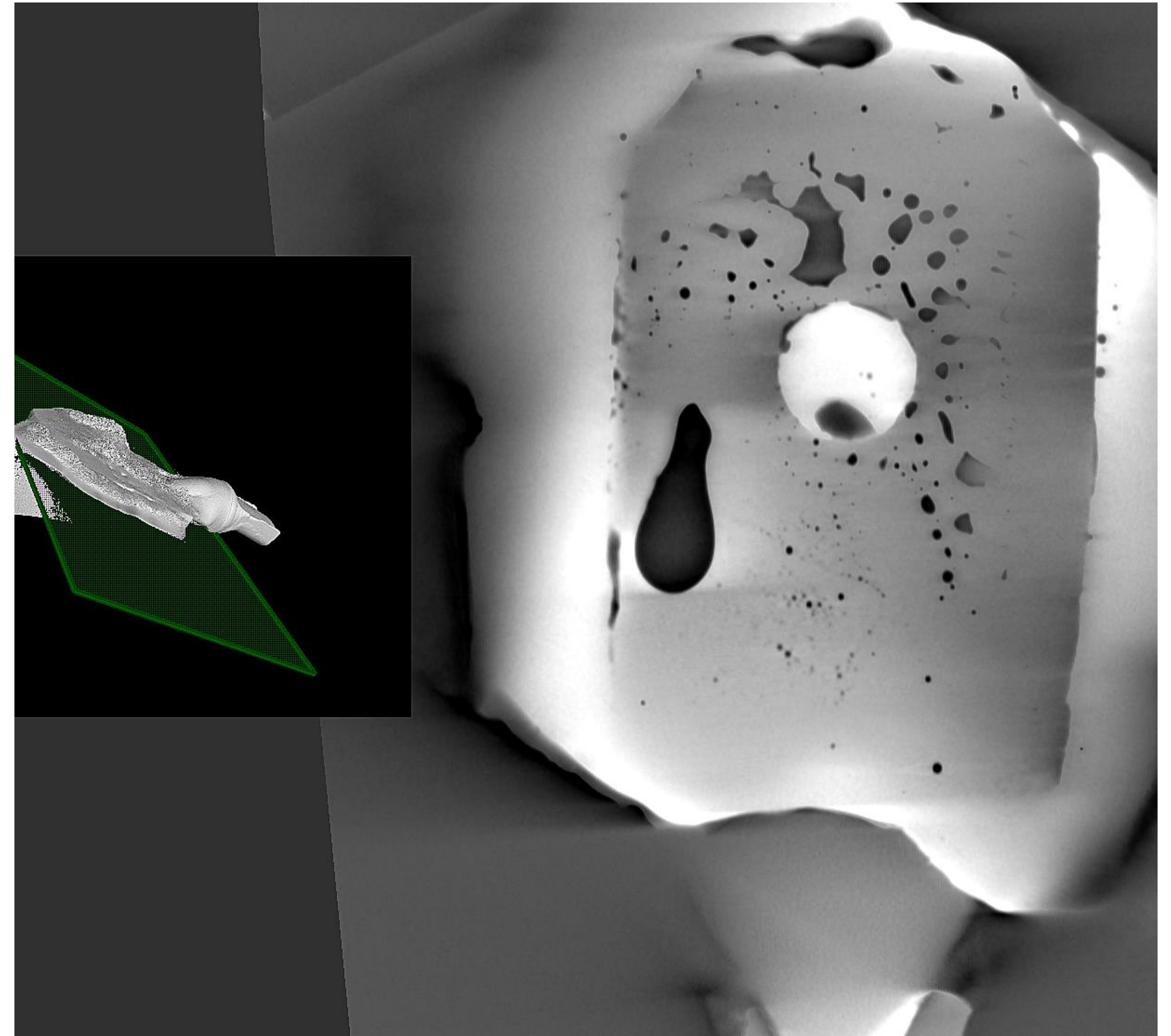




FCBG-SE (without pressure) :cleaning pickling

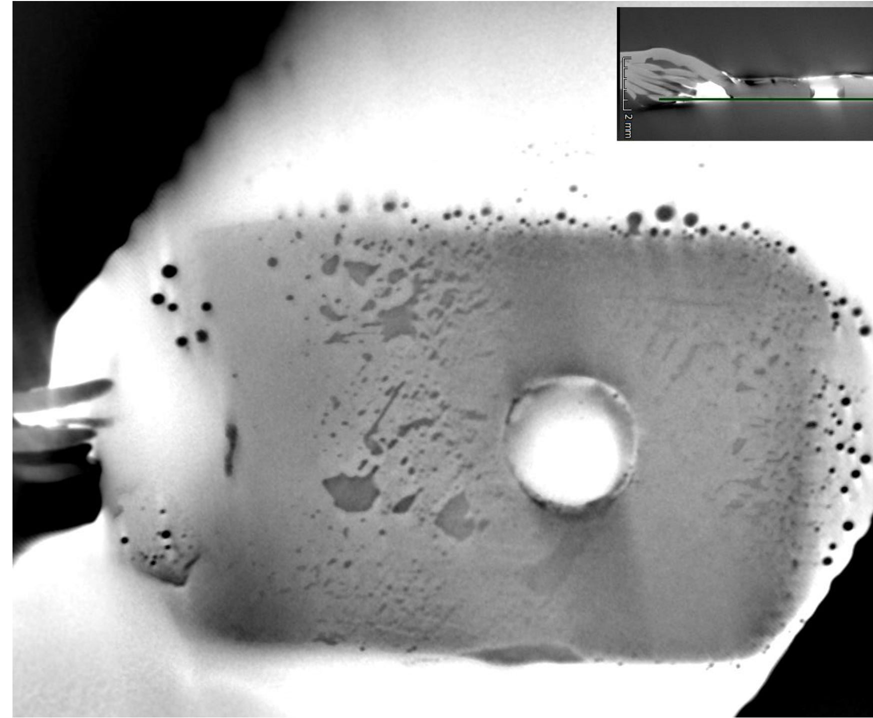


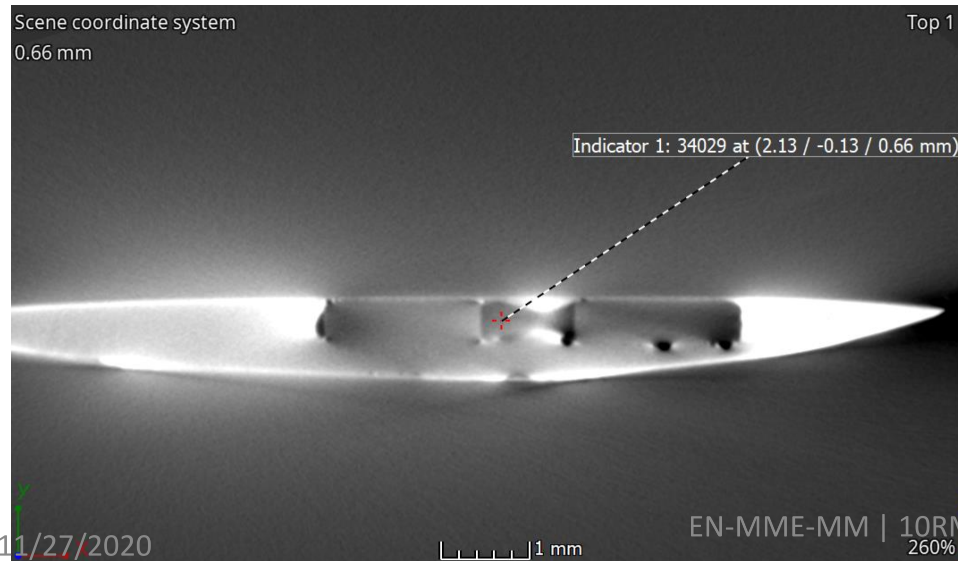
Sample 1

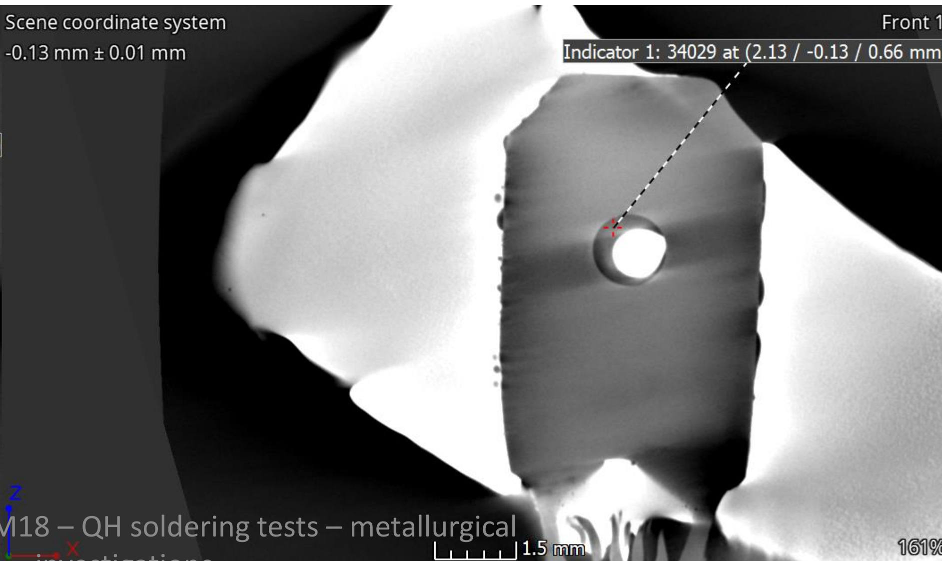


Sample 2

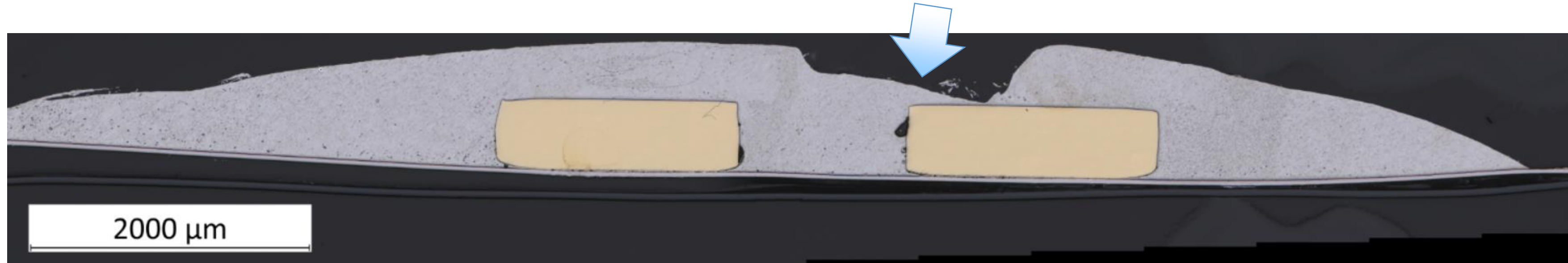
FCBG-SE with pressure



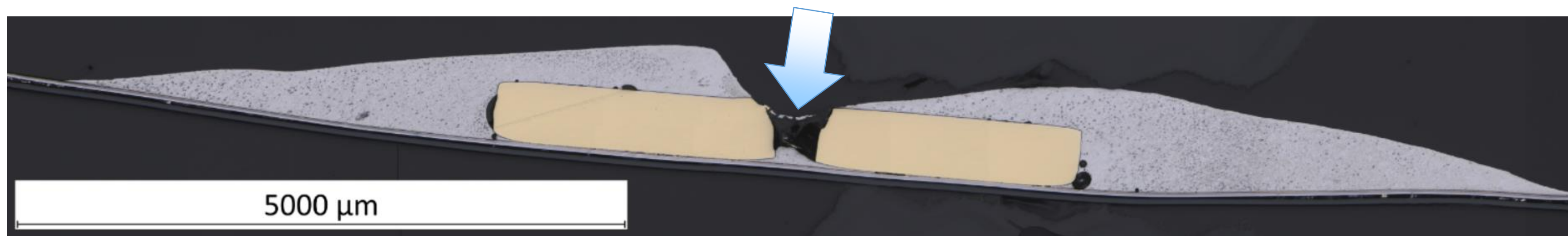




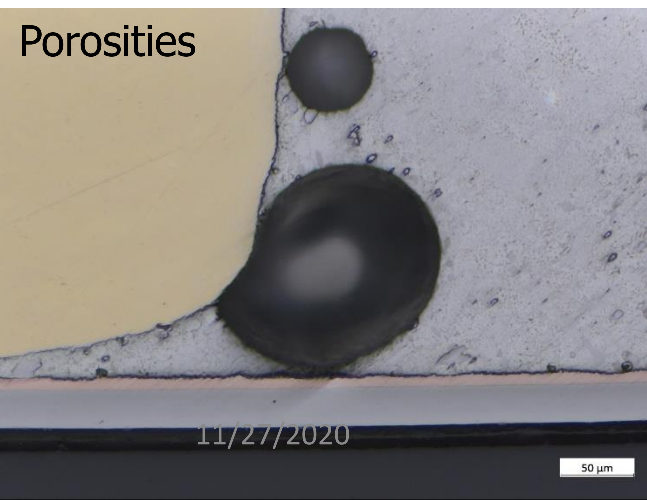
FCBG-SE with pressure

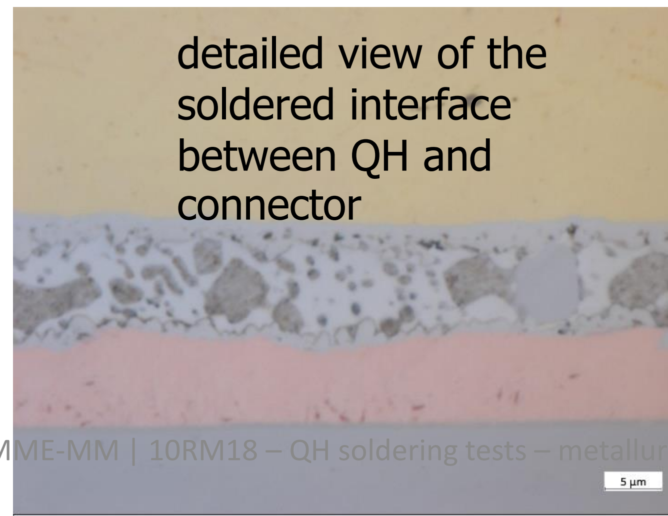


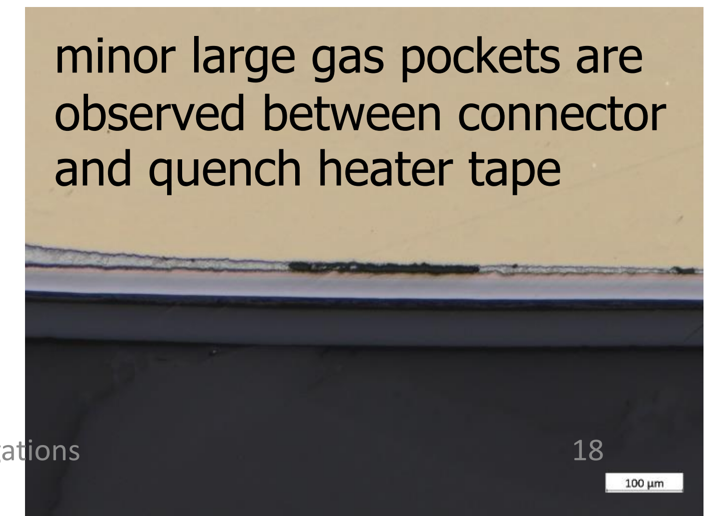
FCGB-SE #3 stitched picture, local depression at the solder due to pressure during soldering is visible (arrow)



FCGB-SE #4 stitched picture, local depression at the solder due to pressure during soldering is visible

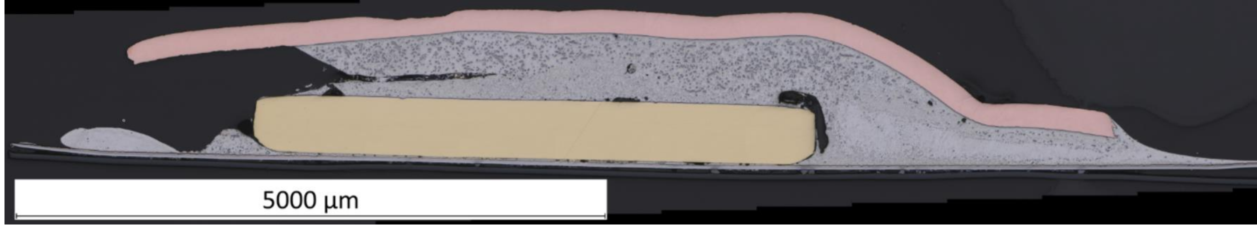




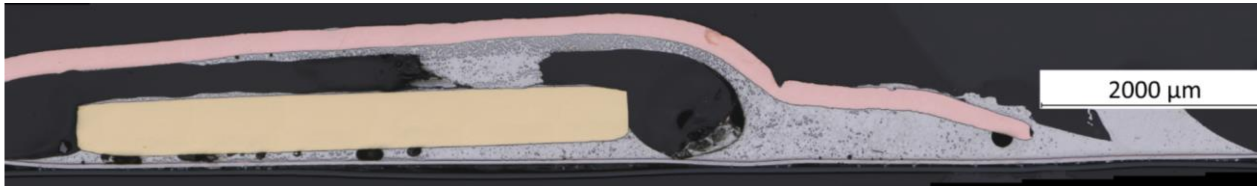


FCBG-SE with Omega : cleaning pickling

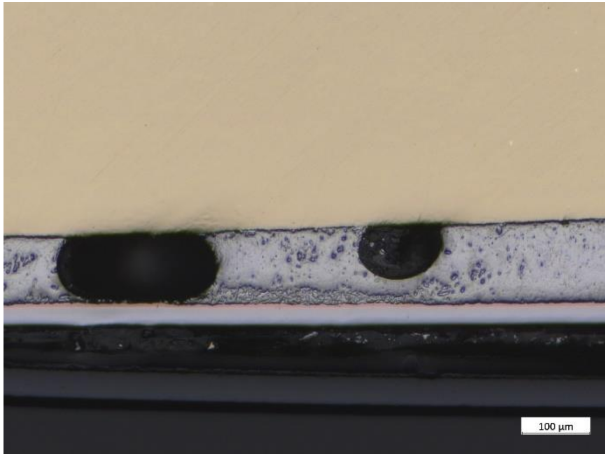
FCBG-SE with Omega



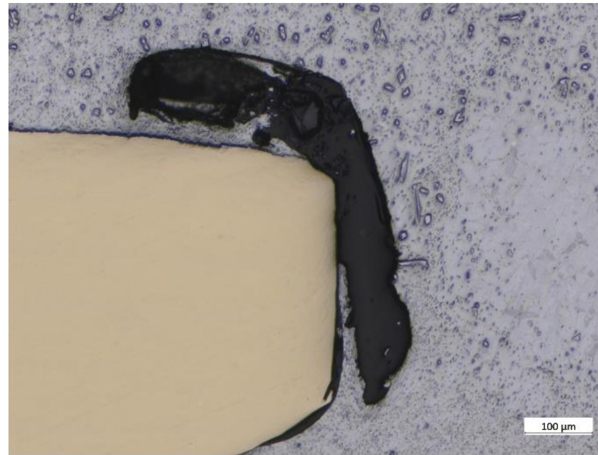
FCGB-SE with Omega #2, large porosities and bonding imperfections are observed



FCGB-SE with Omega #3, large porosities and bonding imperfections are observed

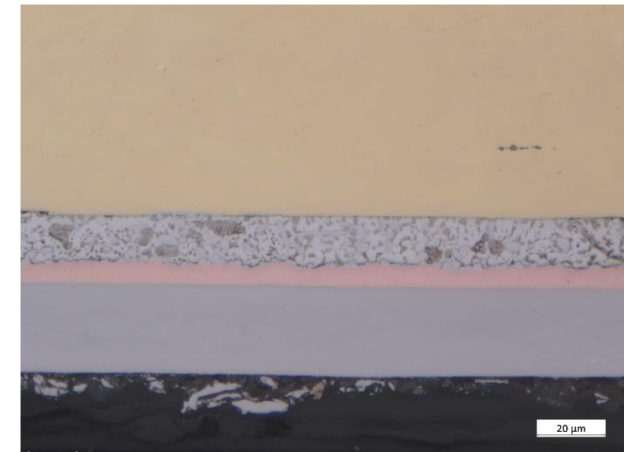


large gas pockets are observed between connector and quench heater tape



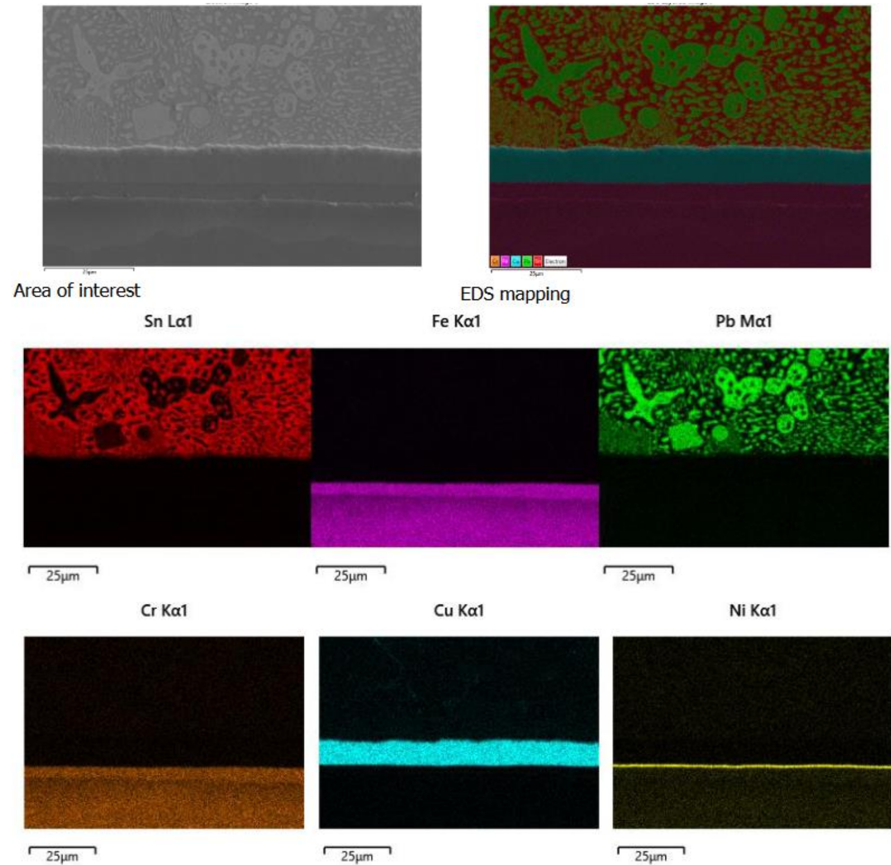
large porosities are observed all around the connector

interface between the connector and the solder

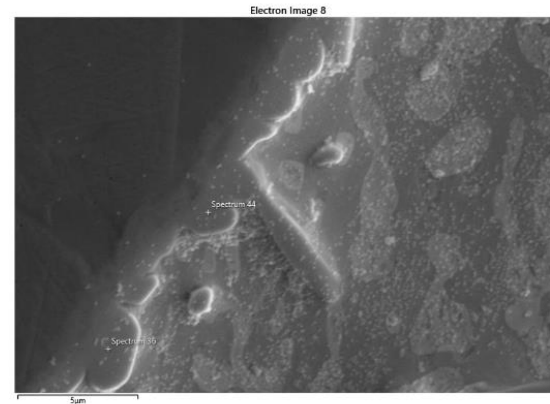


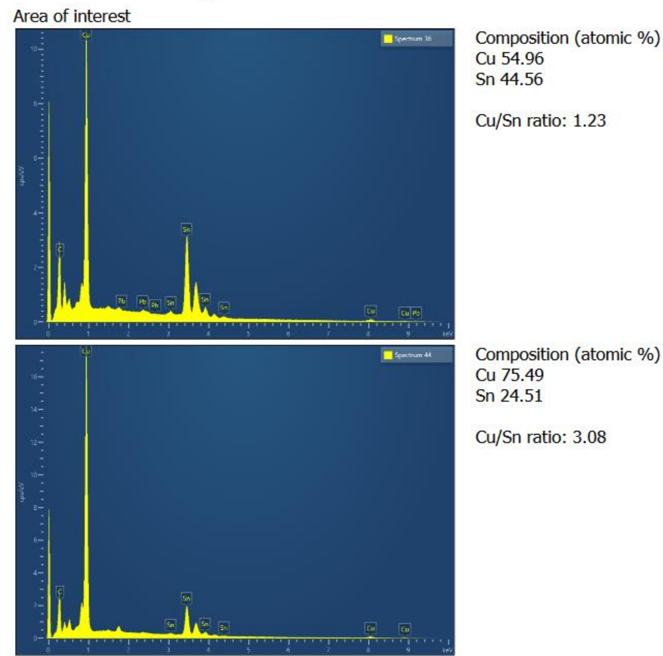
interface between the connector and the QH

Soldered interfaces analysis (SEM-EDS)



Solder/QH tape interface (EF-AE#6)





Solder/wire interface (EF-AE#6)

All examinations showed the presence of Cu_xSn_y, absence of Ni_3Sn_4 and extremely limited copper diffusion in the solder.

Here, some representative analysis of all inspected samples.

Conclusion

To the extent of present analysis, the best configurations seems to be: EF-AE, FGBG-SE and ES-AE, ES-SE.

- Tinning seems to be not mandatory to reach good quality of bonding, cleaning and pickling steps are of key importance,
- The influence of tape's edges appears to be 1st order factor. The presence of polyimide film at the solder led systematically to bonding imperfections,
- ENS-AE, ENS-SE exhibit nonfunctional electrical connections.

Sample reference	Configuration	Tinning	Cleaning	Pickling
ES-AE	Standard*	X	X	X
ES-SE	Standard*		X	X
ENS-AE	Standard*	X		
ENS-AE-DP	Standard*	X		X (partial)
ENS-SE	Standard*			
ENS-SE-DP	Standard*			X (partial)
EGB-AE	Standard**	X	X	X
EF-AE	Wire on QH tape***	X	X	X
FCGB-SE	Flat connector****		X	X
FCGB-SE with Omega	Flat connector with copper Omega on it		X	X

Conclusion

SEM-EDS analysis showed that:

- copper diffusion from QH tape or from brass connectors is absent or extremely limited,
- Nickel layer, which acts as a barrier diffusion, is observed between copper layer and stainless steel of the QH tape but also at surface of brass connectors (protection against corrosion),
- Intermetallic compounds formed at soldered interface are Cu_xSn_y with multiple stoichiometry observed: mainly Cu_6Sn_5 and some Cu_3Sn to the extent of present analysis,
- No free tin (leading to potential whiskers with time) have been noticed at interfaces between prior tin plated wire or connector and solder.