X-ray CT investigation of defect on niobium coated copper RF cavity

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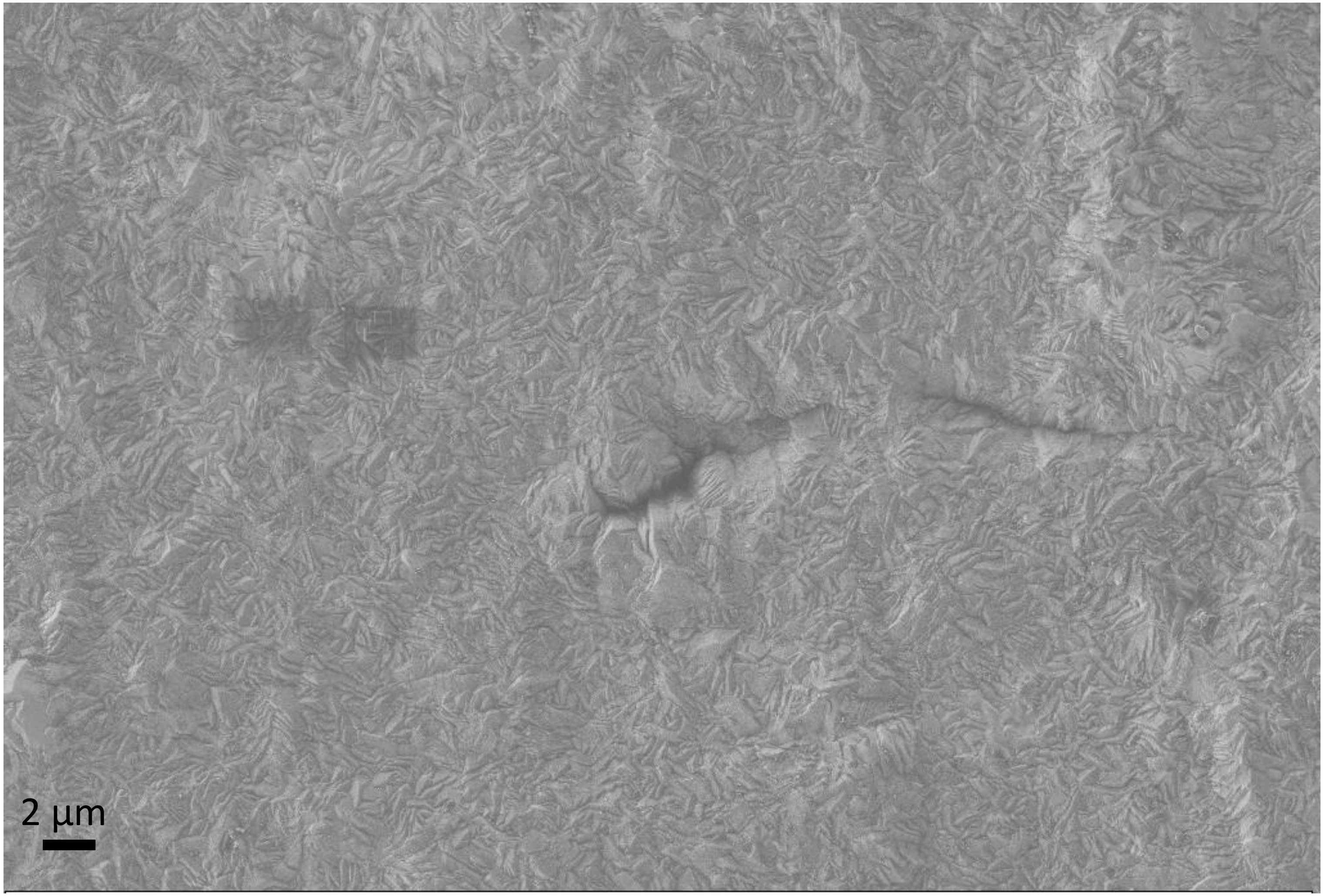
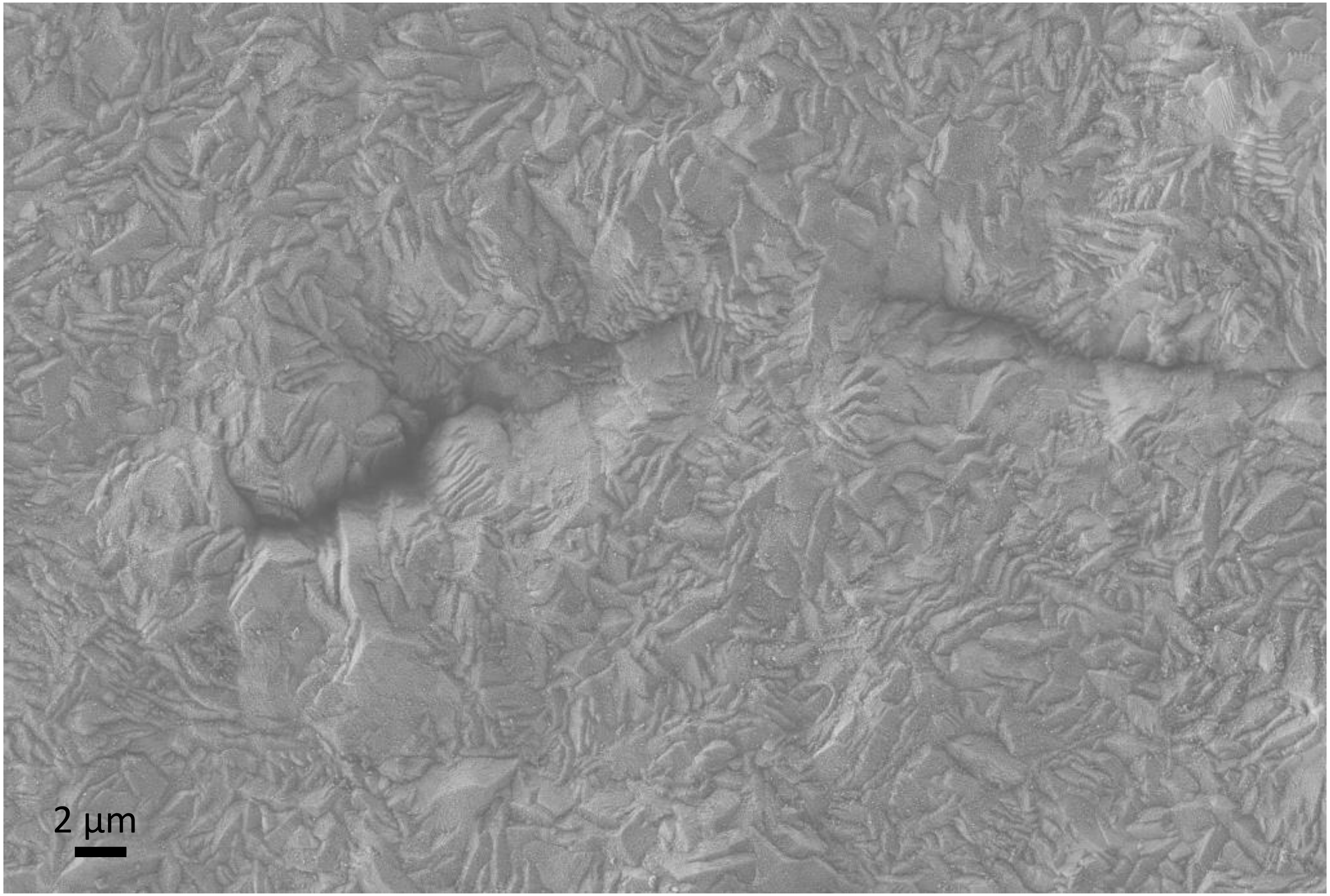
Superconducting radio frequency cavity (SRF)

Surface

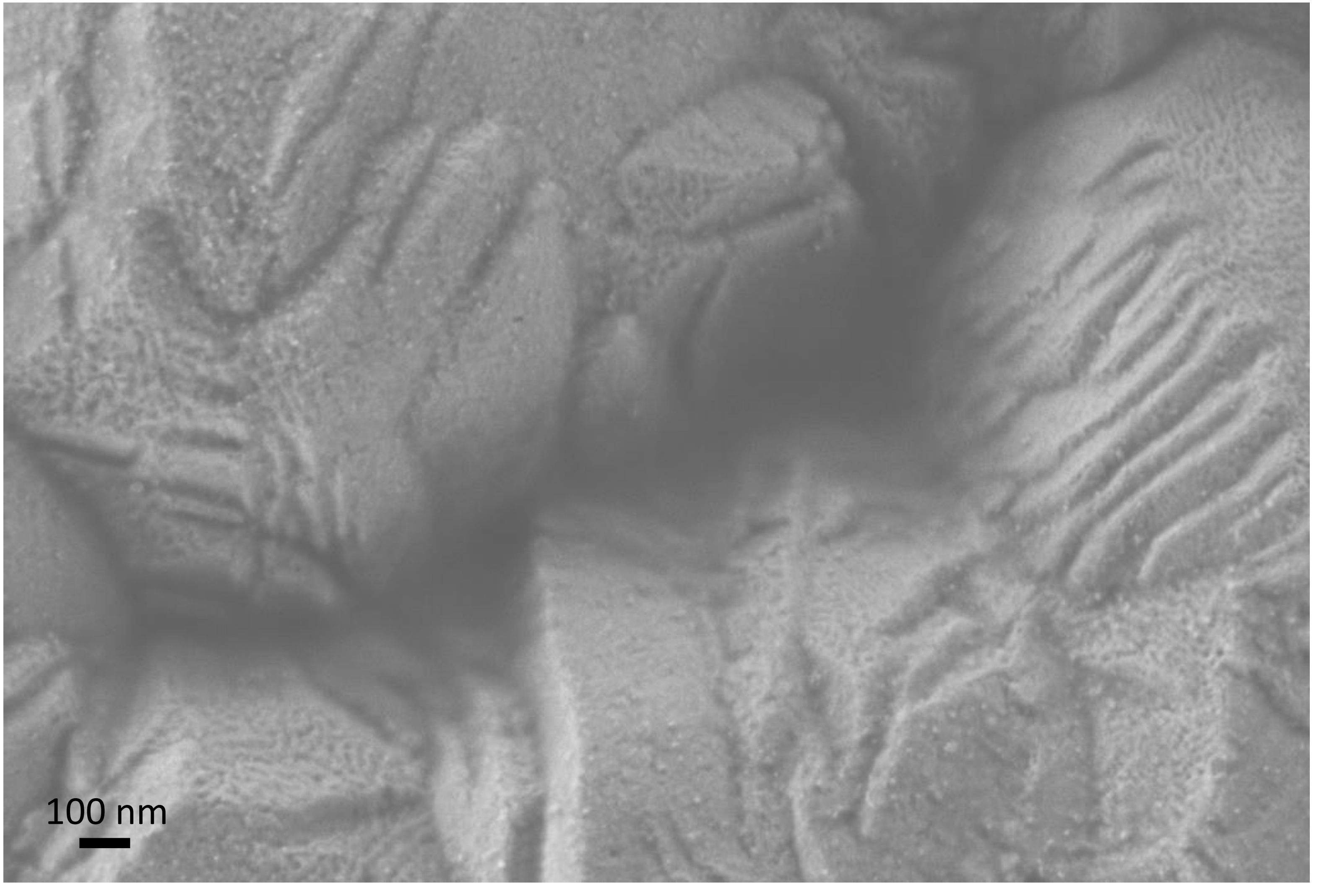


Surface

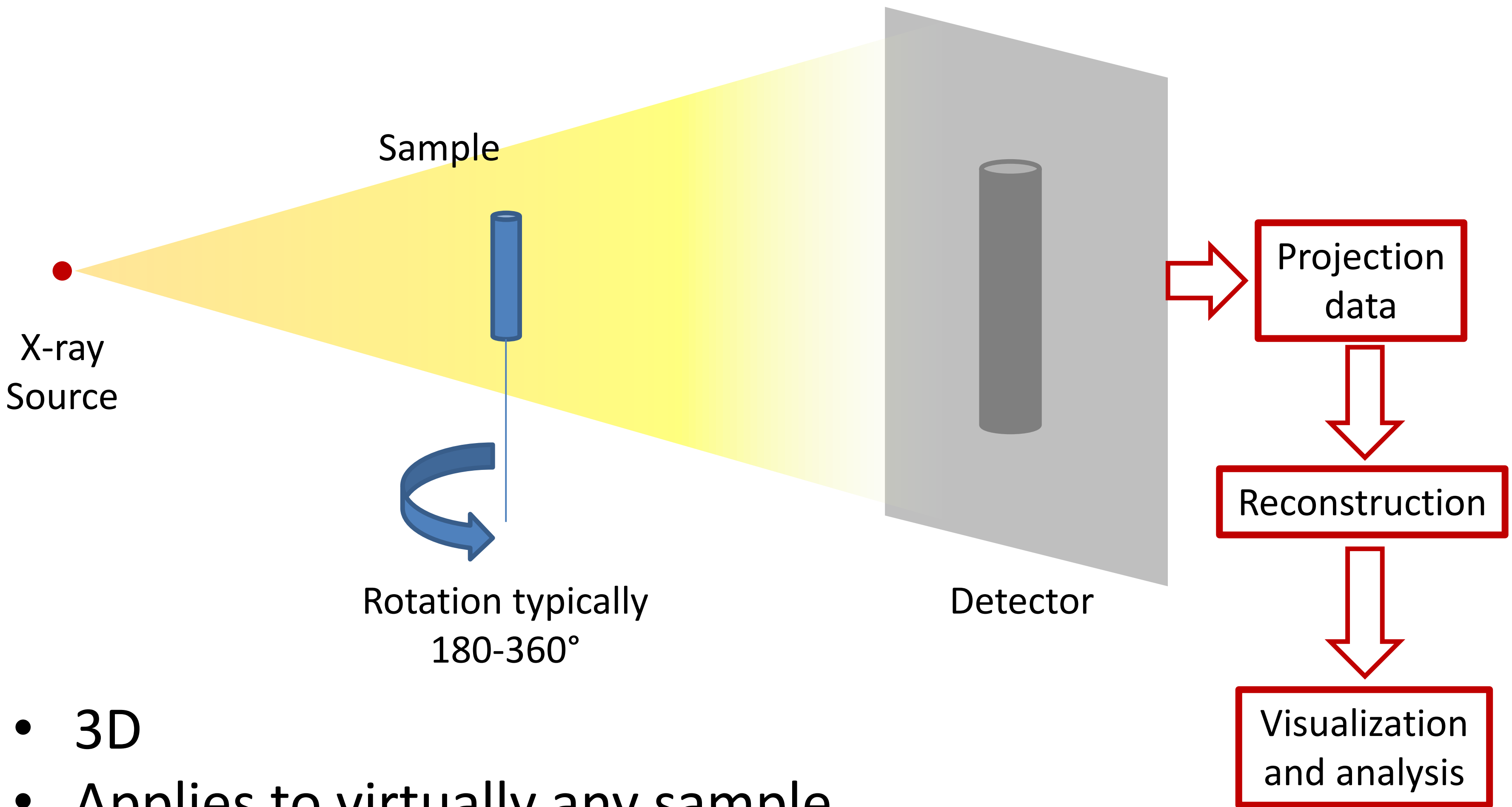


Surface

Surface



X-ray Computed Tomography



- 3D
- Applies to virtually any sample
- Multiscale
- Non-destructive

X-ray CT

As you can X-ray CT involves 3 steps

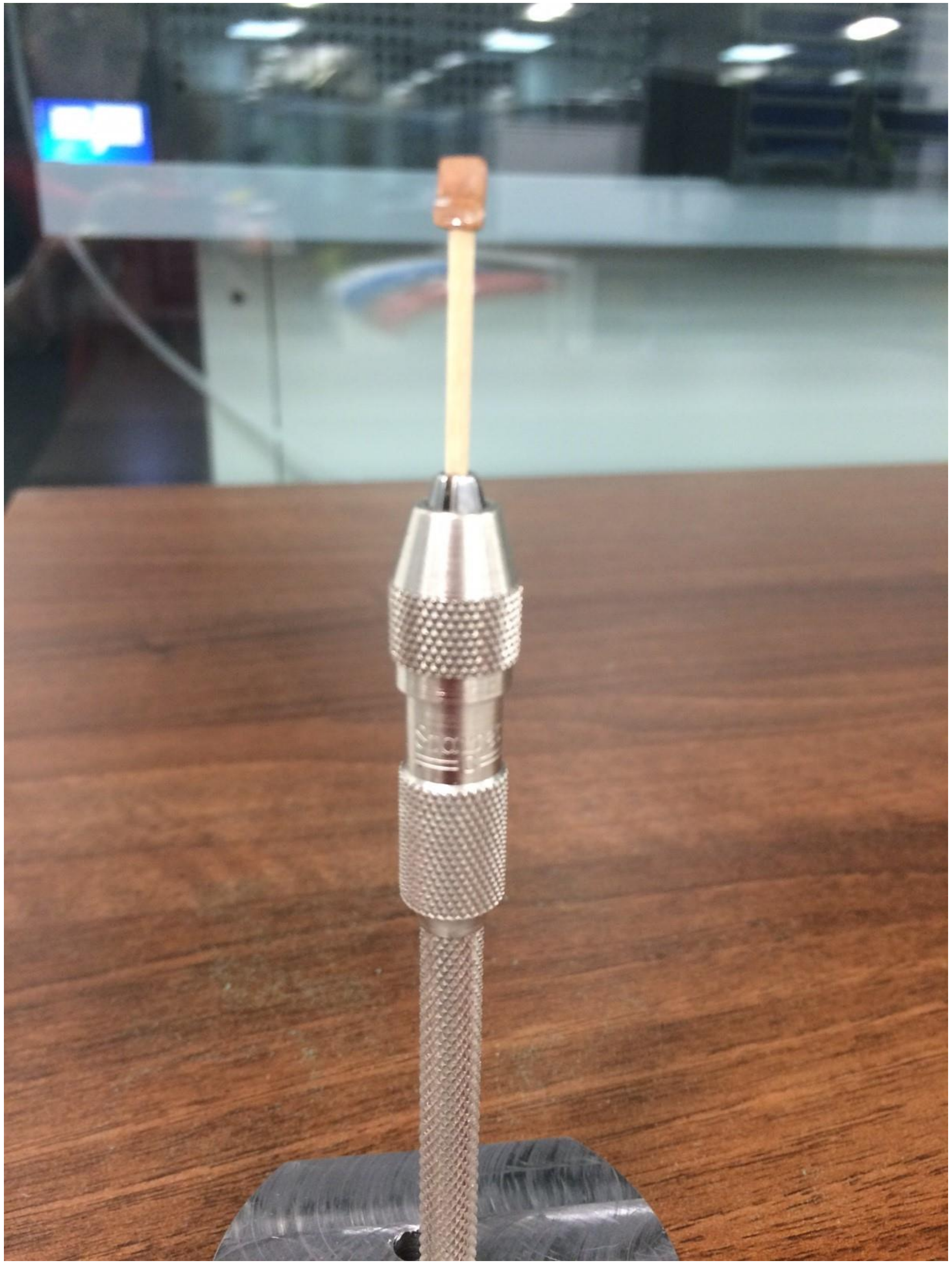
1) the acquisition of x-ray images, also called radiographs or projections whilst the sample rotates through 360 degrees
2) The projections need to be reconstructed to construct a 3D image which is a virtual replica of the object scanned
3) The 3D image still needs to be visualised and importantly measurements taken and analysis made using special software.

Important point are that it provides a 3D image and can be applied to virtually any object (although it is difficult to look at very dense objects such as those made from lead) we can use it at different length scales and because it is non destructive we can look at changes to samples over time.

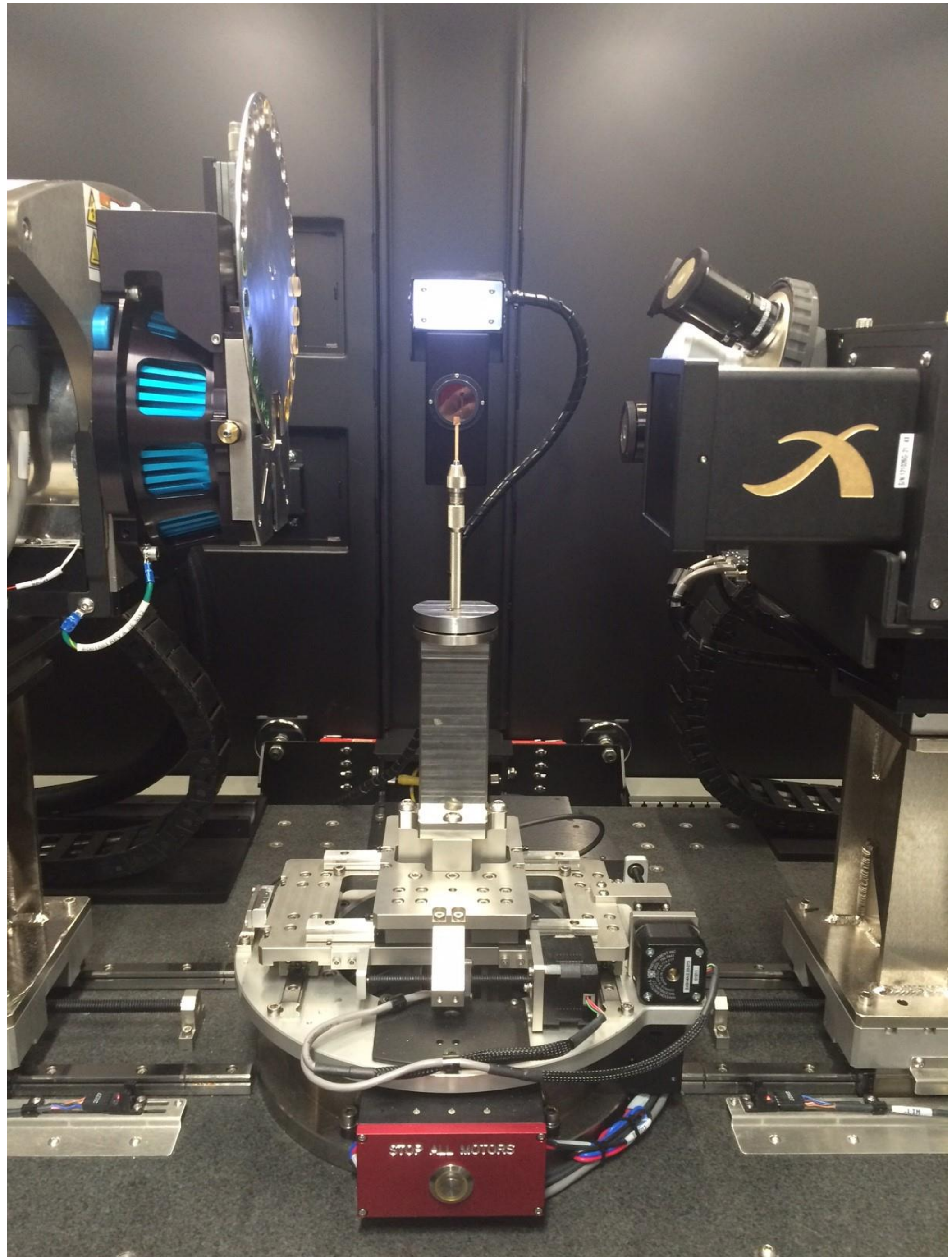
Trichuris muris

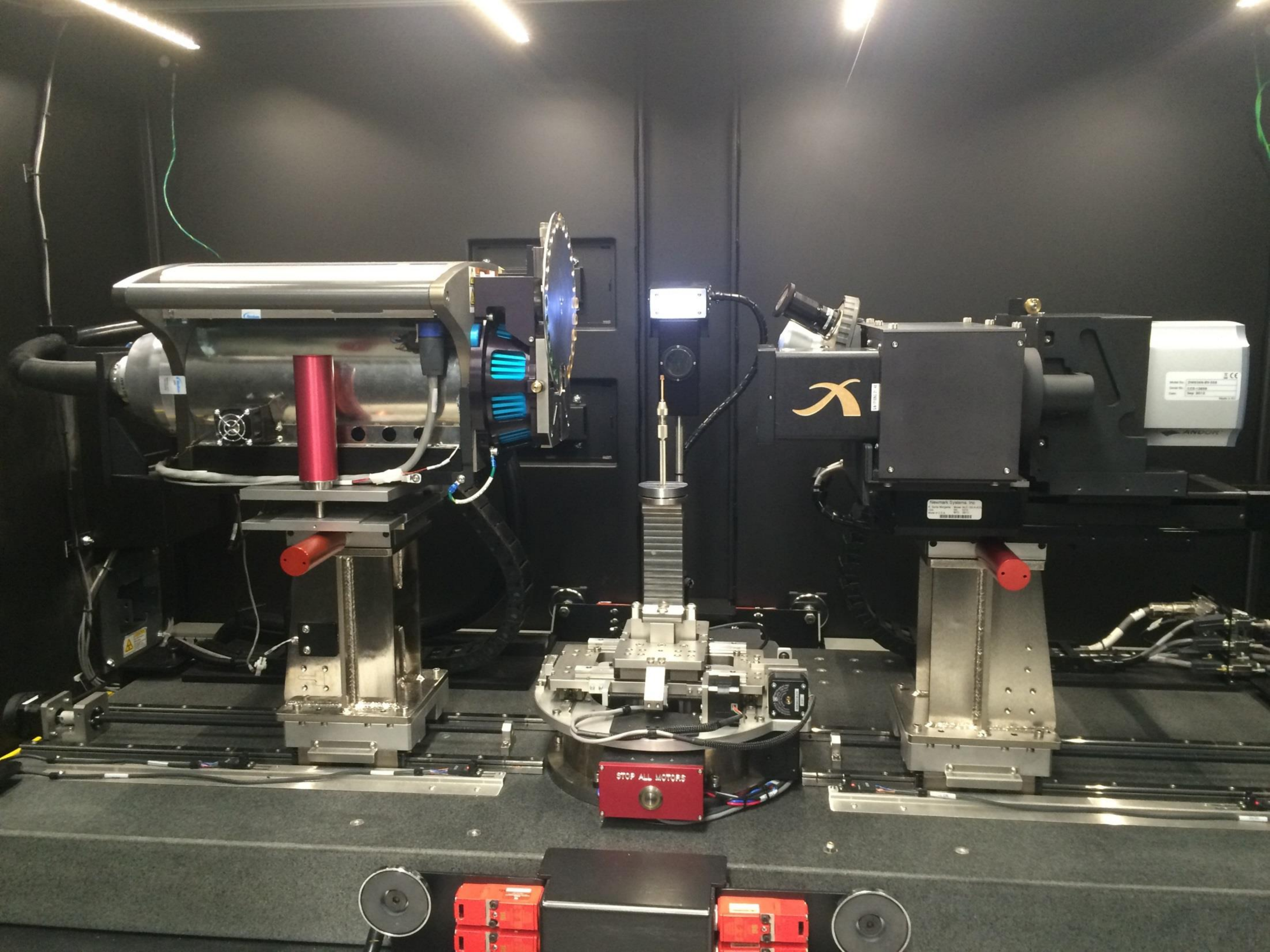
The University of Manchester

Sample preparation



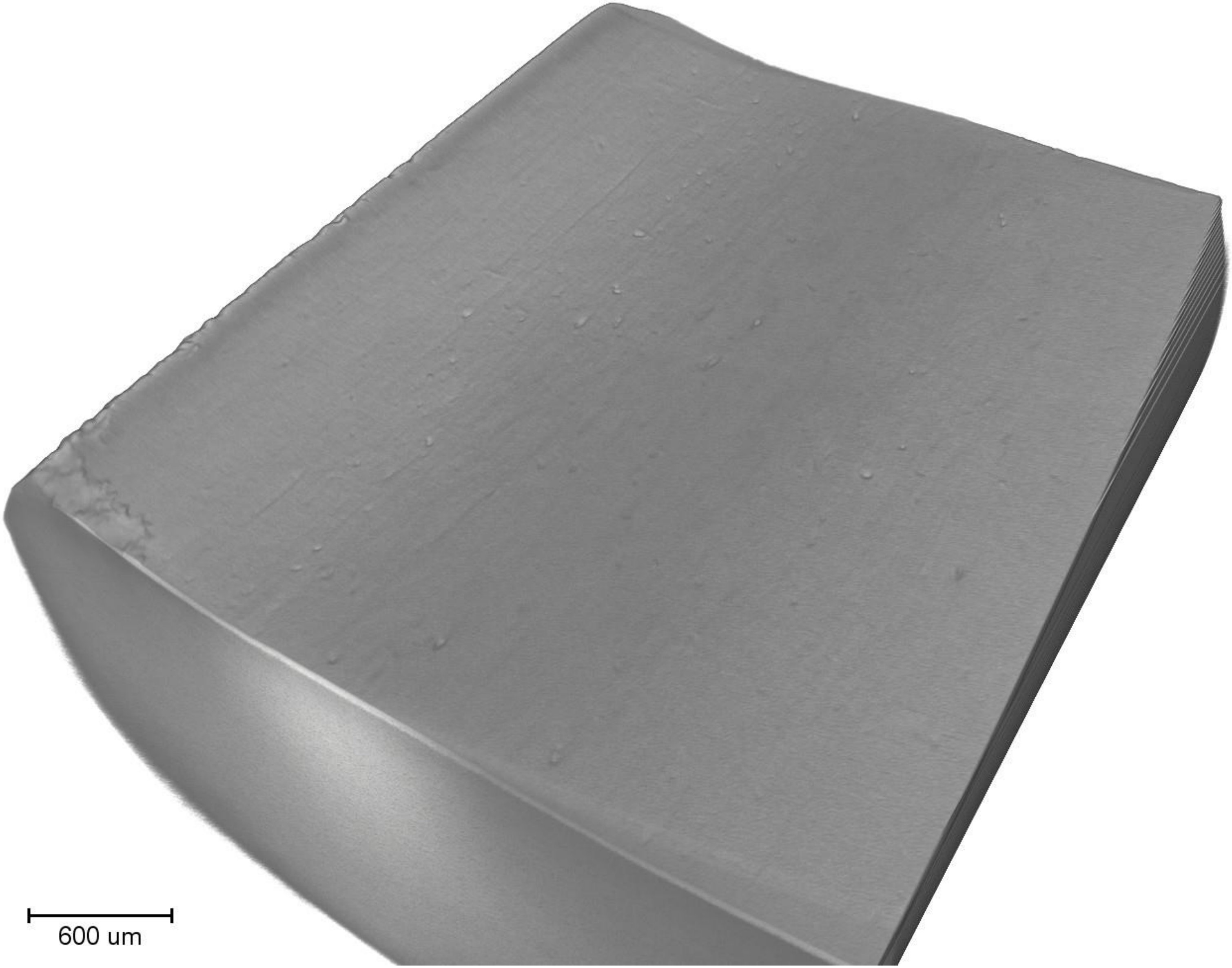
X-ray CT instrument




STOP ALL MOTORS

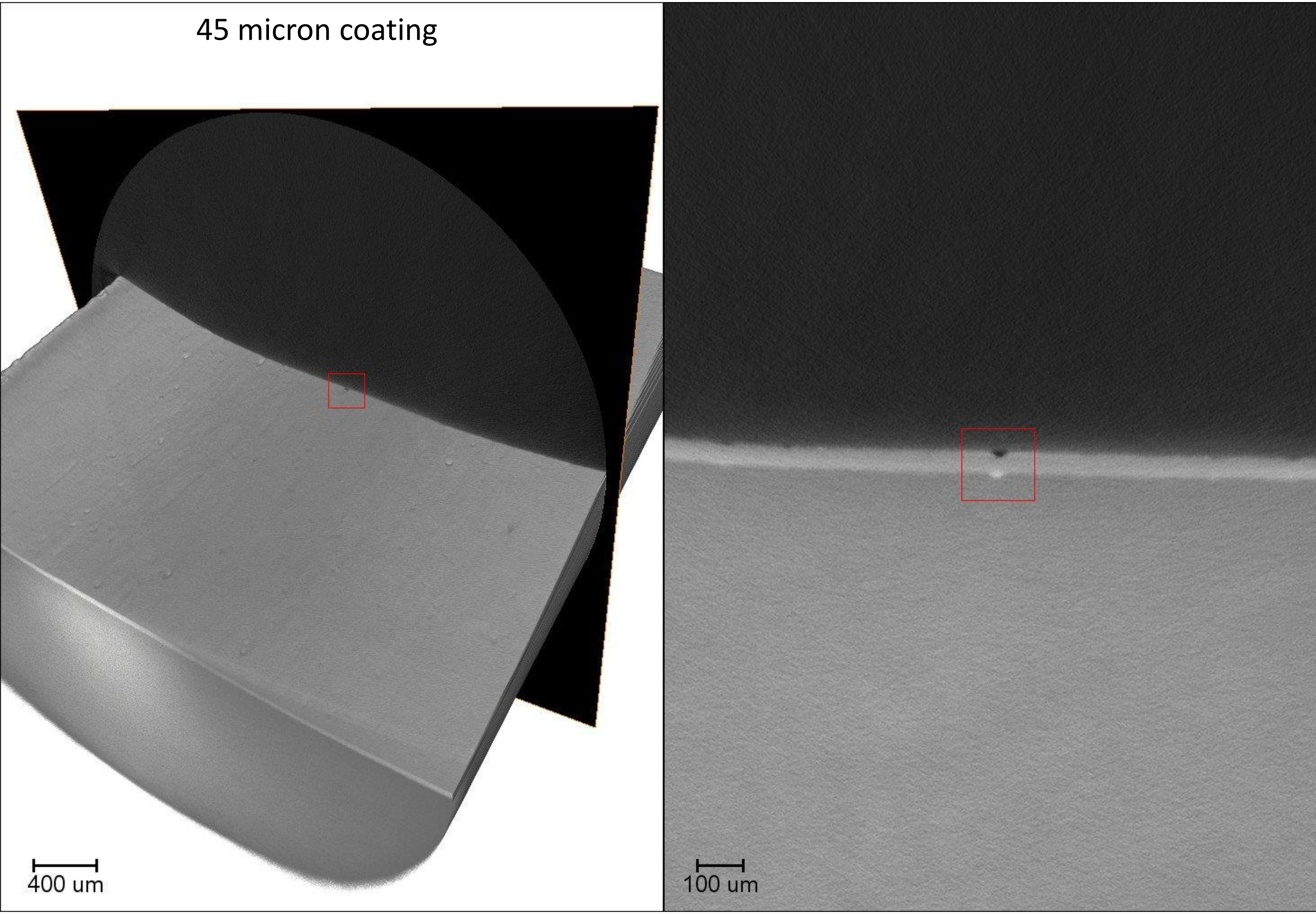
Acquisition Settings

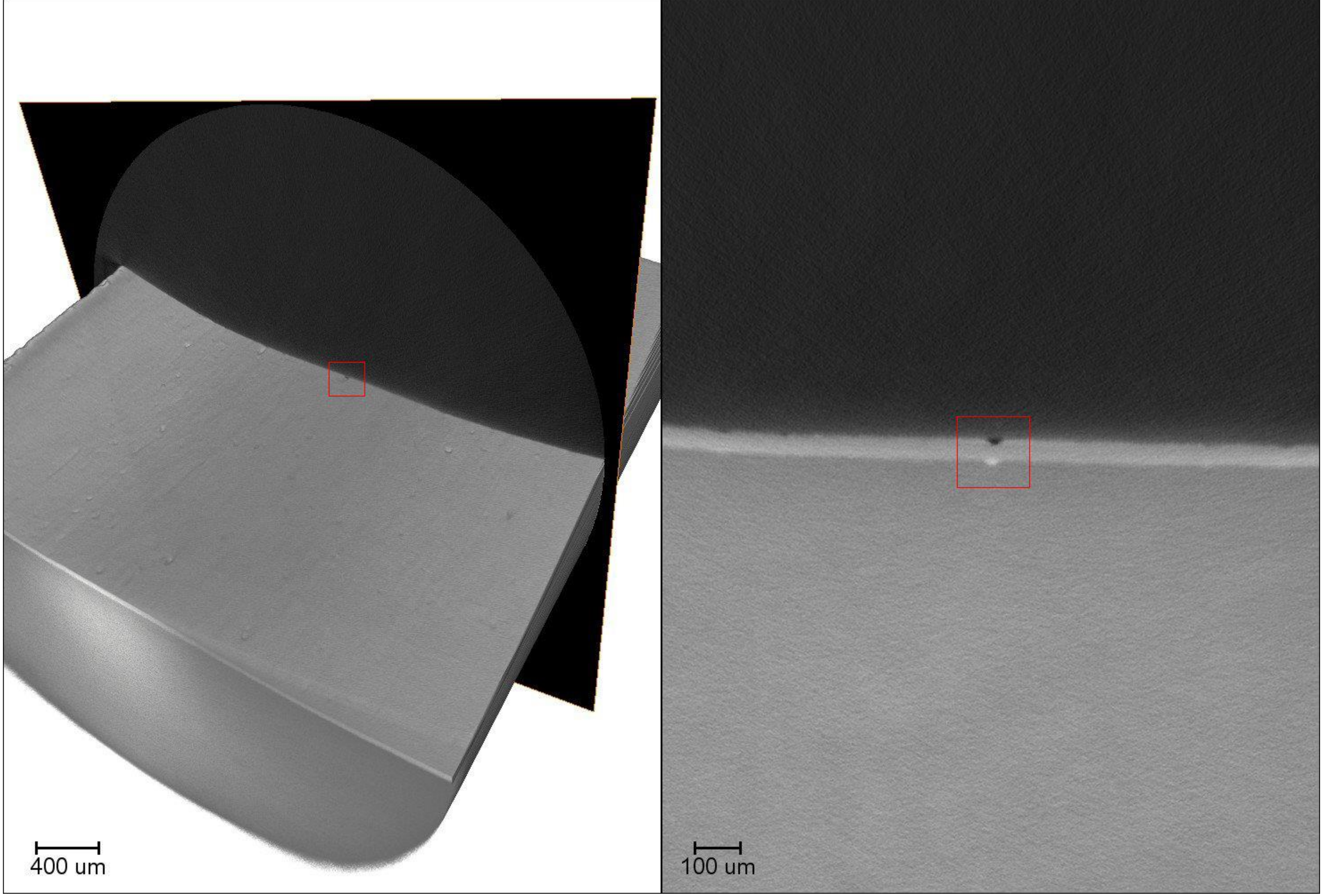
Instrument: Zeiss Xradia Versa 520 XRM
Filter: LE5
Energy: 140 keV
Current: 71 μA
Exposure time: 20 s
Sample size: 4 mm * 2 mm
Number of projections: 2001
Voxel size: 1.89 μm



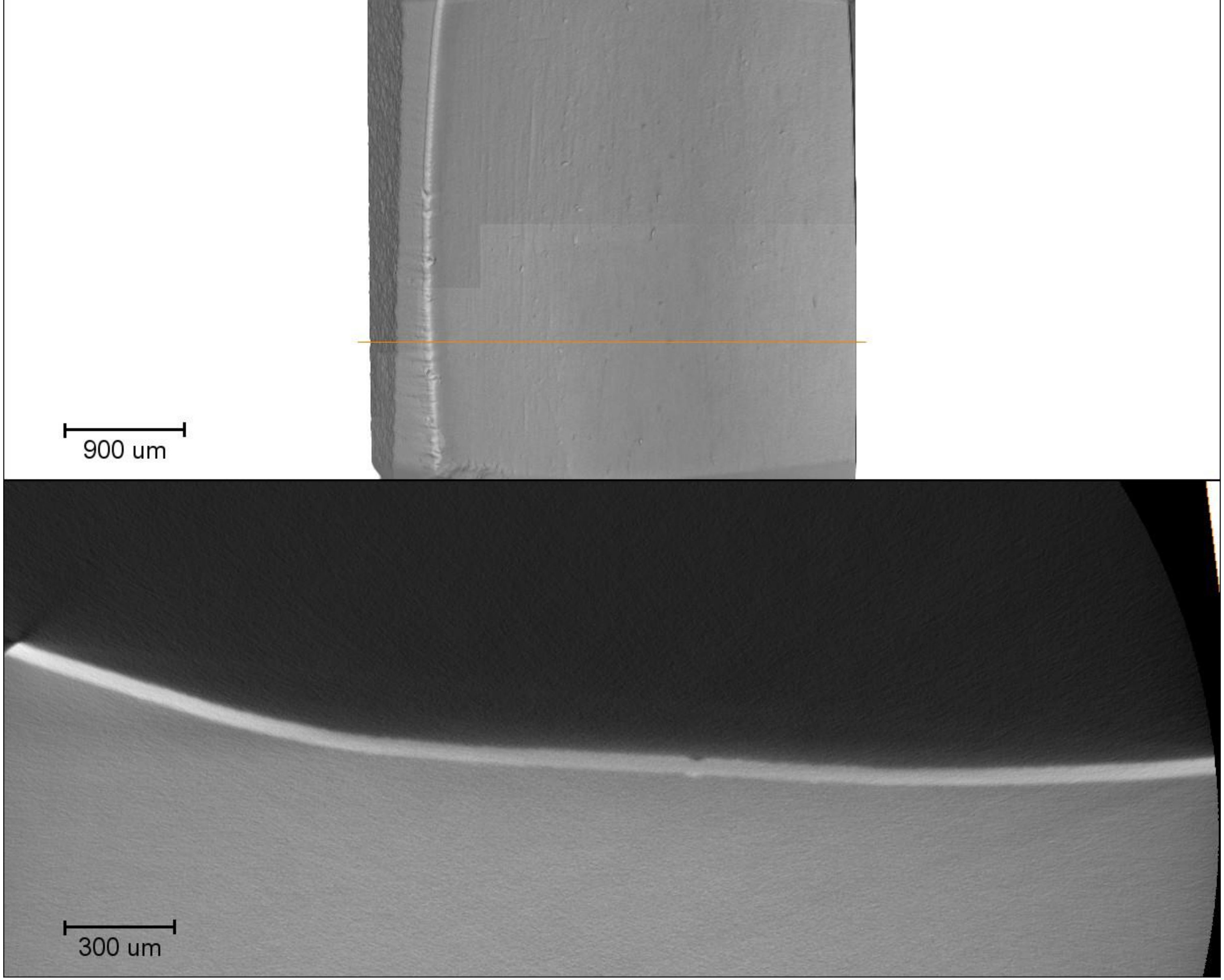
A volume rendering of the Nb-coated Cu sample.

45 micron coating

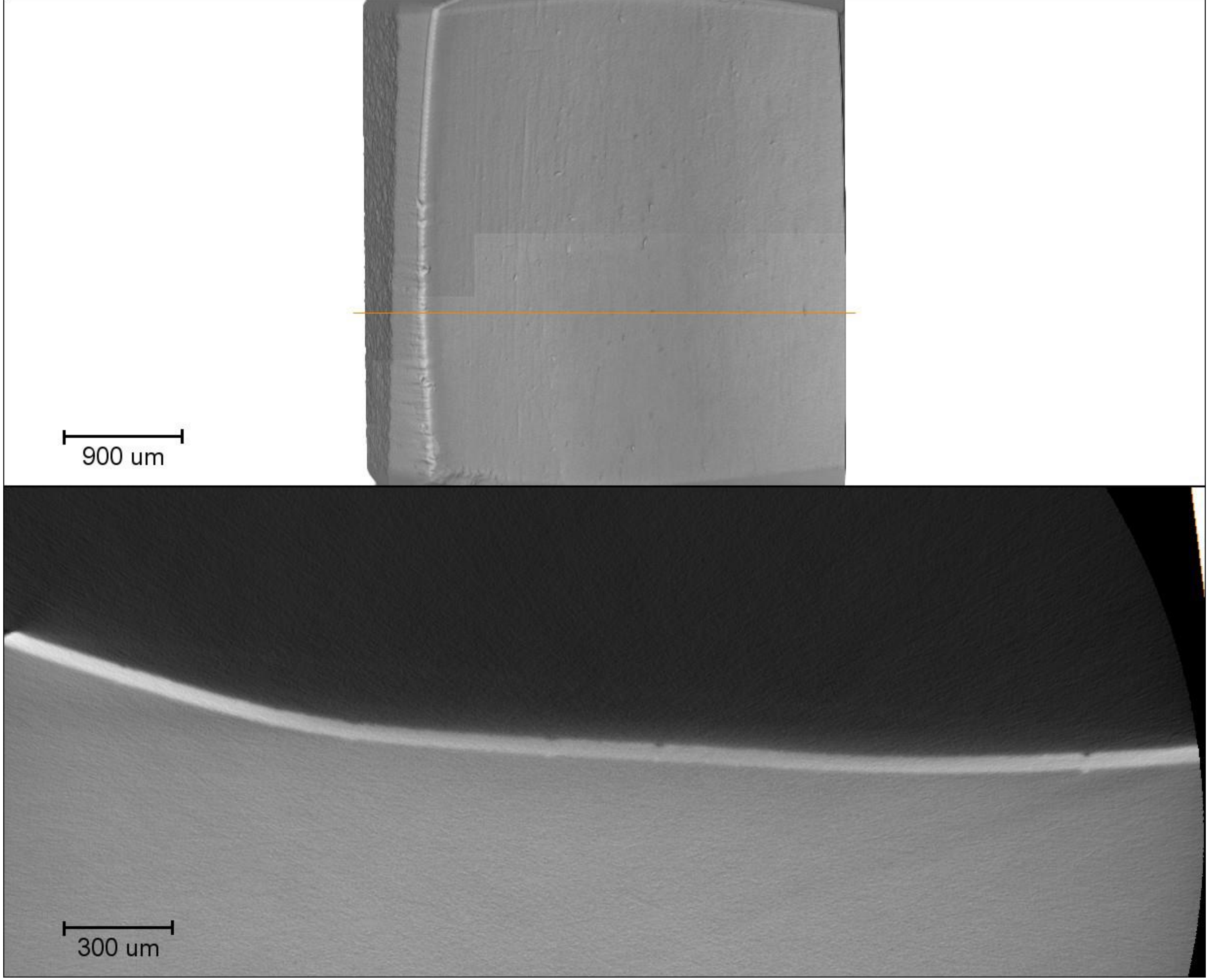




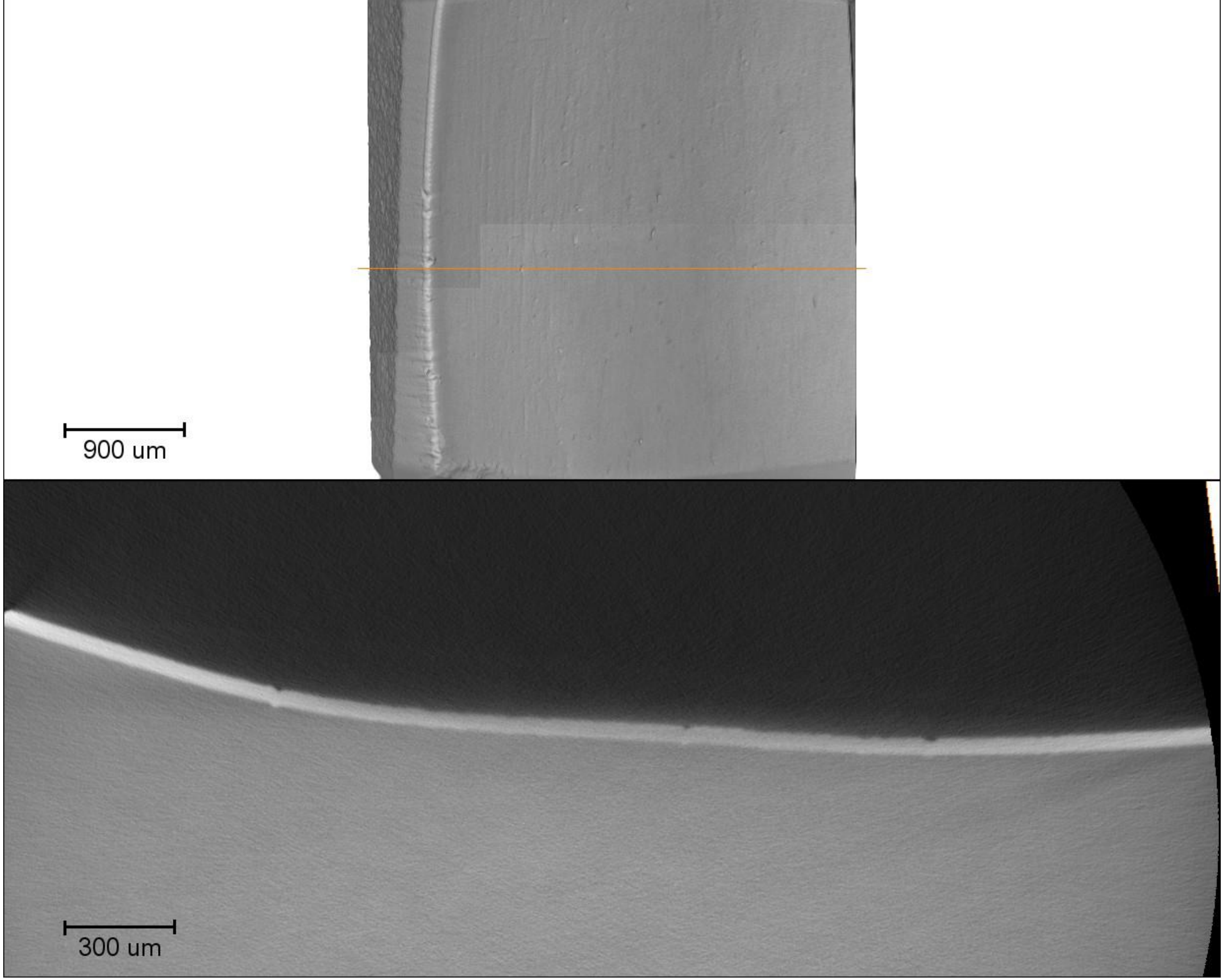
A volume rendering of the Nb-coated Cu sample with the location of the virtual cross section shown (left) and the virtual cross section showing the defect (right).



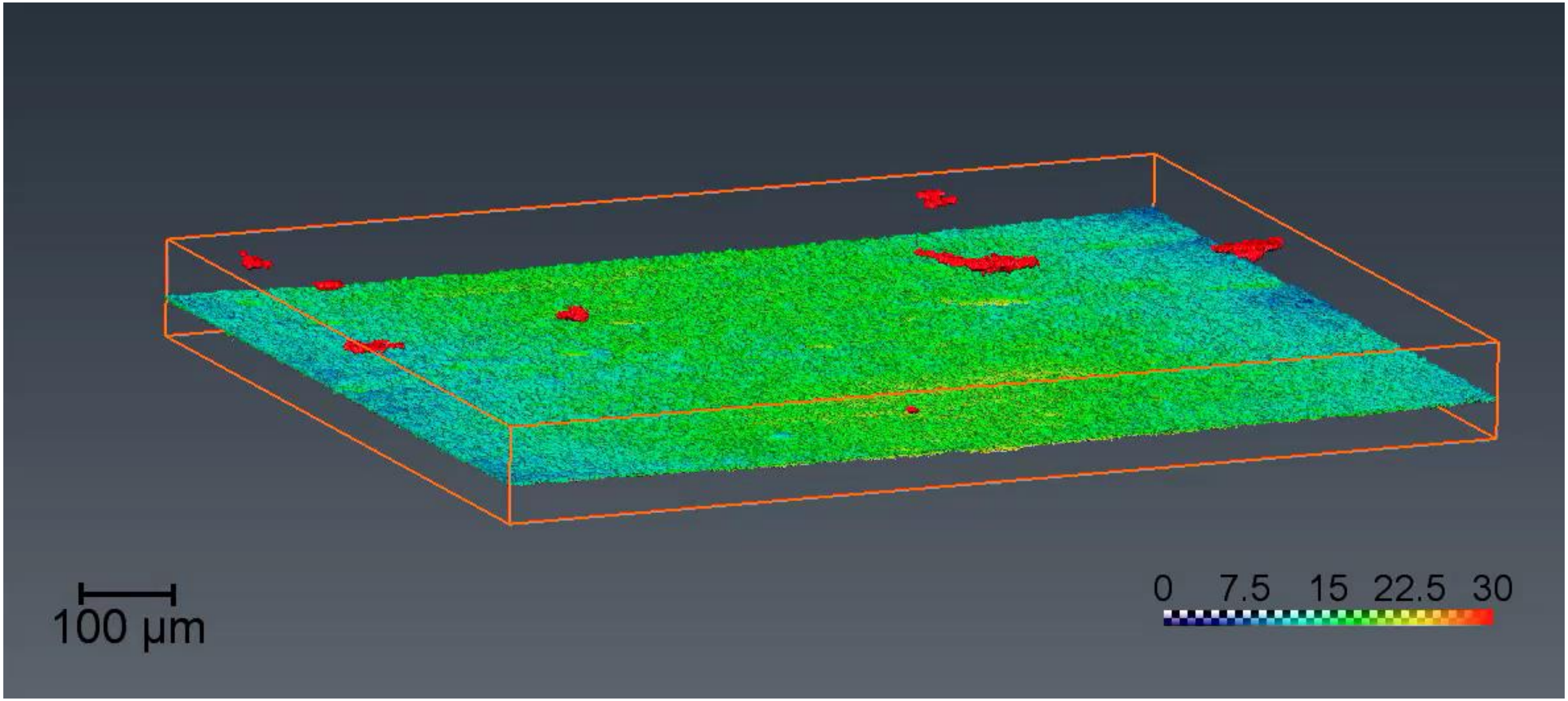
A volume rendering of the Nb-coated Cu sample with the location of the virtual cross section shown (top) and the virtual cross section (bottom).

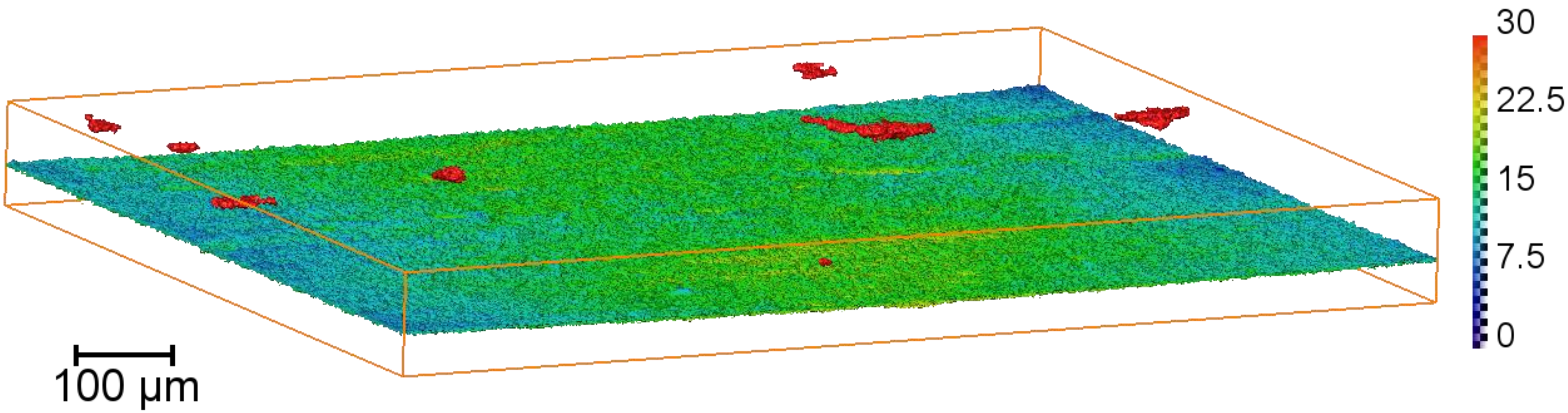


A volume rendering of the Nb-coated Cu sample with the location of the virtual cross section shown (top) and the virtual cross section (bottom).

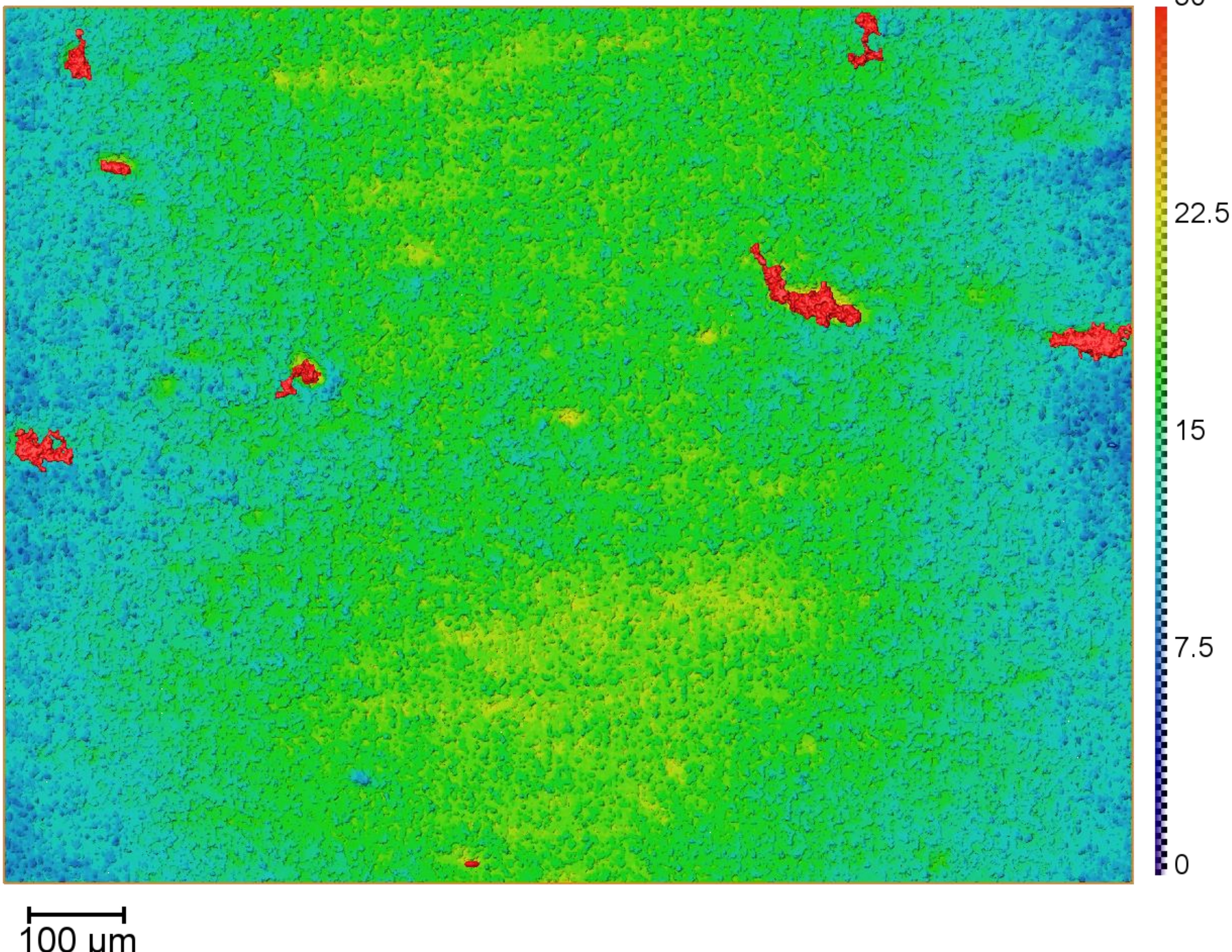


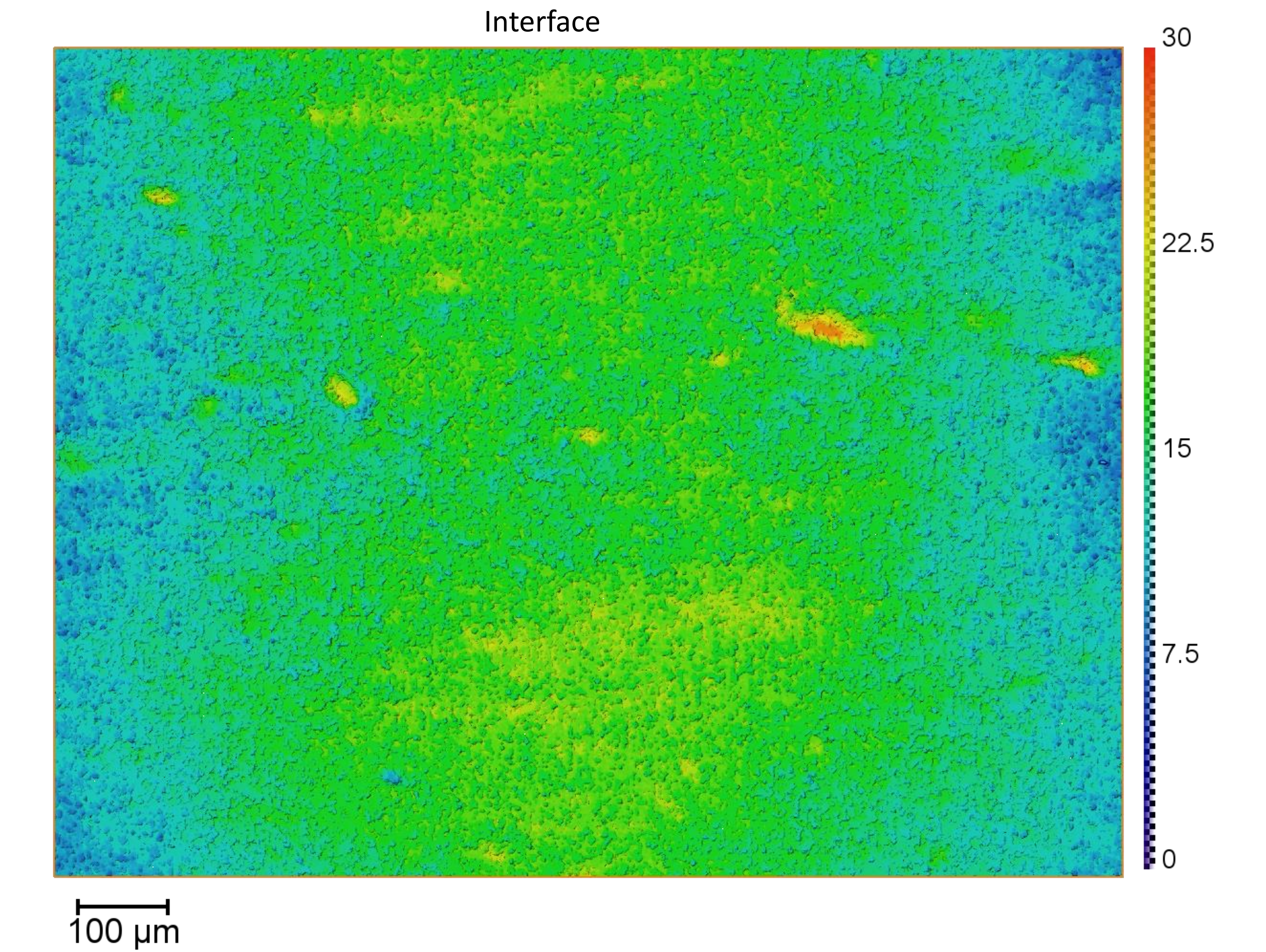
A volume rendering of the Nb-coated Cu sample with the location of the virtual cross section shown (top) and the virtual cross section (bottom).


100 µm
0 7.5 15 22.5 30

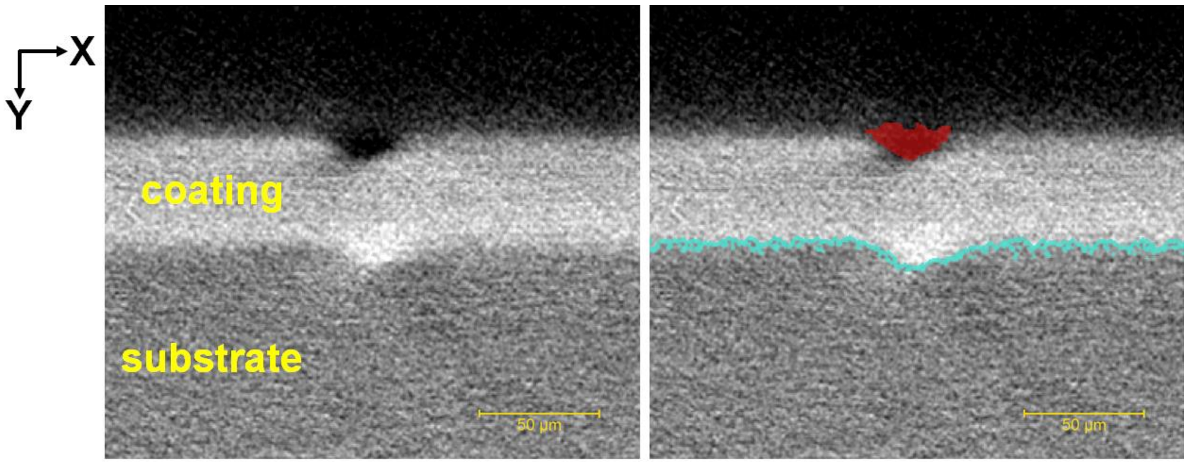

30
22.5
15
7.5
0
100 µm

Surface of Nb

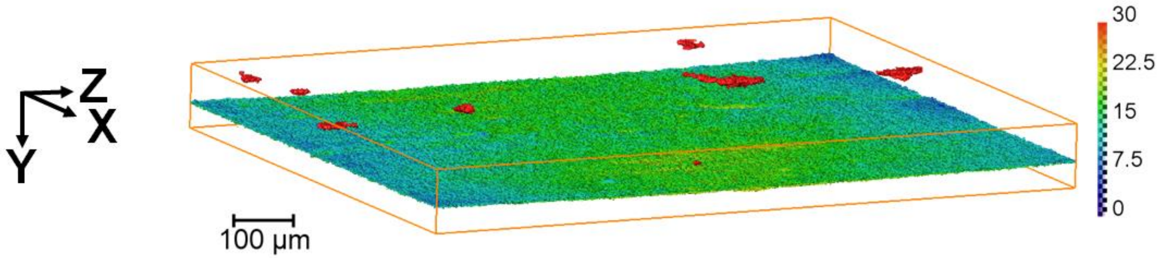



Interface
30
22.5
15
7.5
0
100 µm

Virtual cross-section showing the coating and substrate. The interface is highlighted in cyan and the defects at the coating surface is highlighted in red.



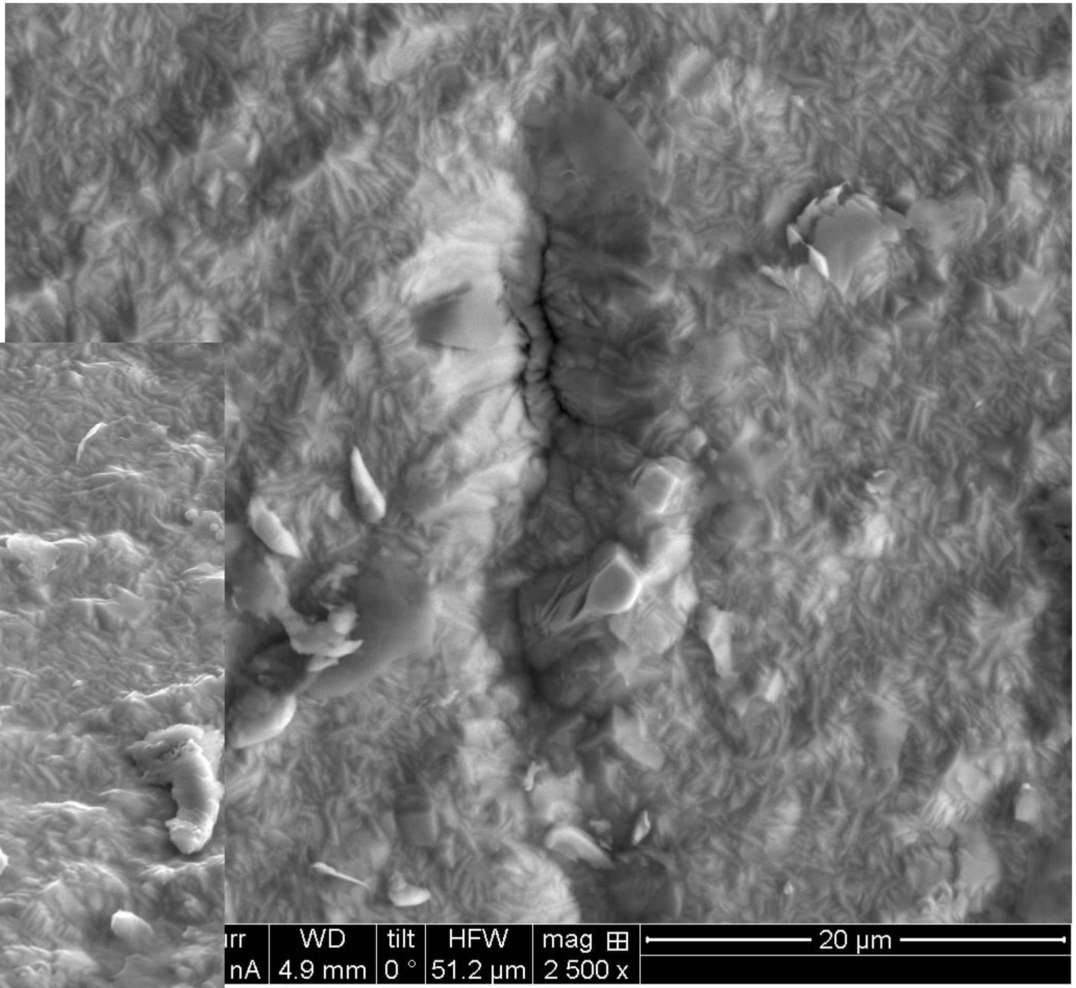
3D view of the interface coloured using the y-coordinate of the interface. The defects on the coating surface is rendered in red.

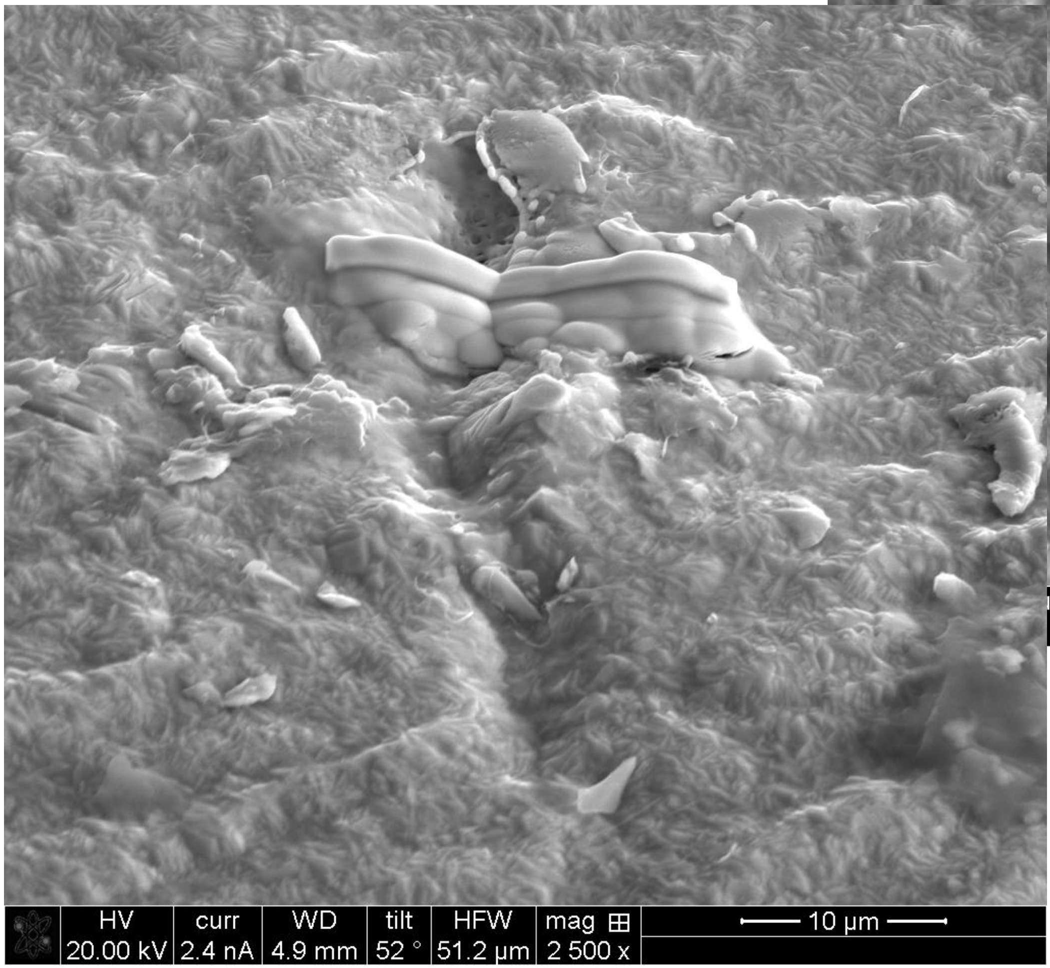


FIB on cross section

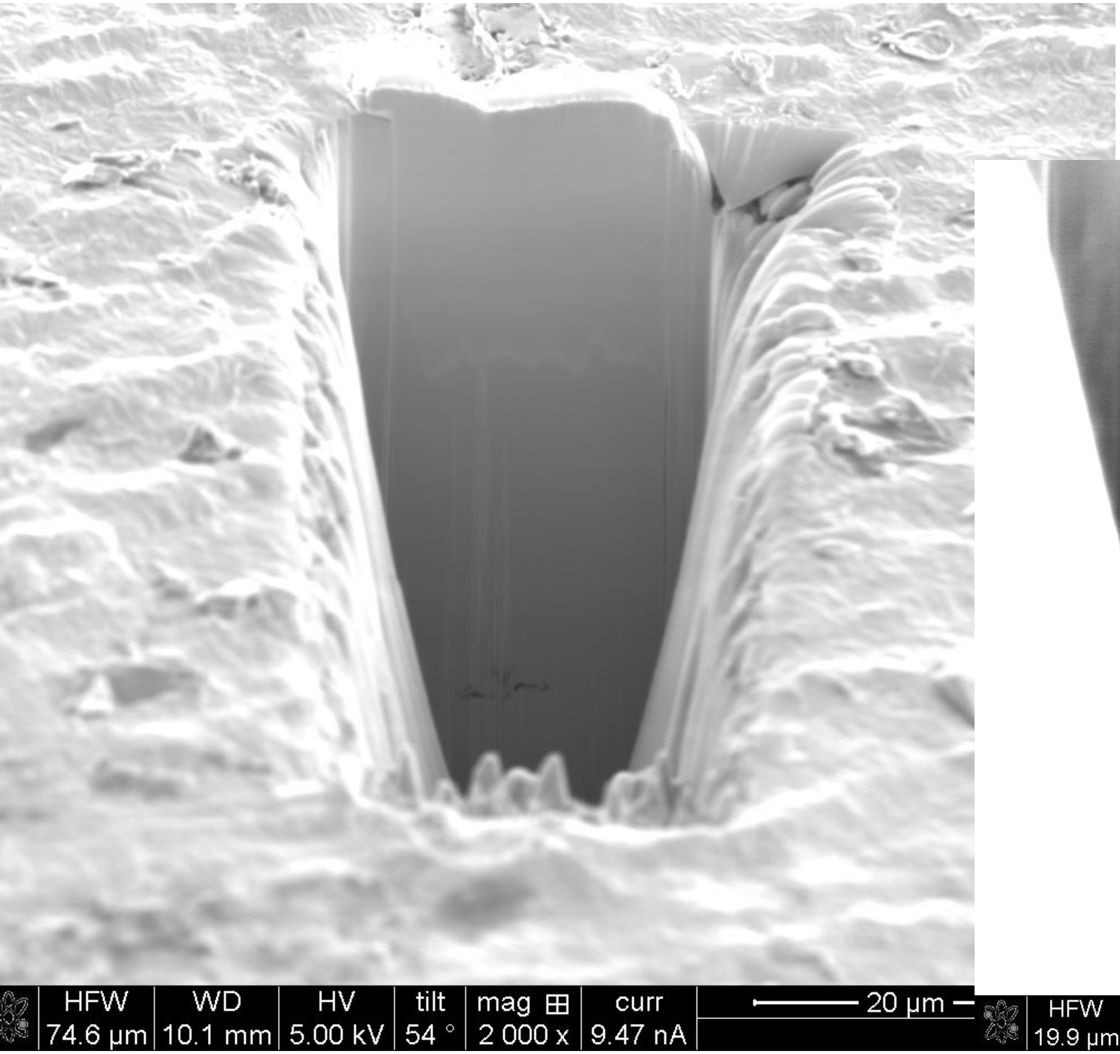
Where is origin the crack

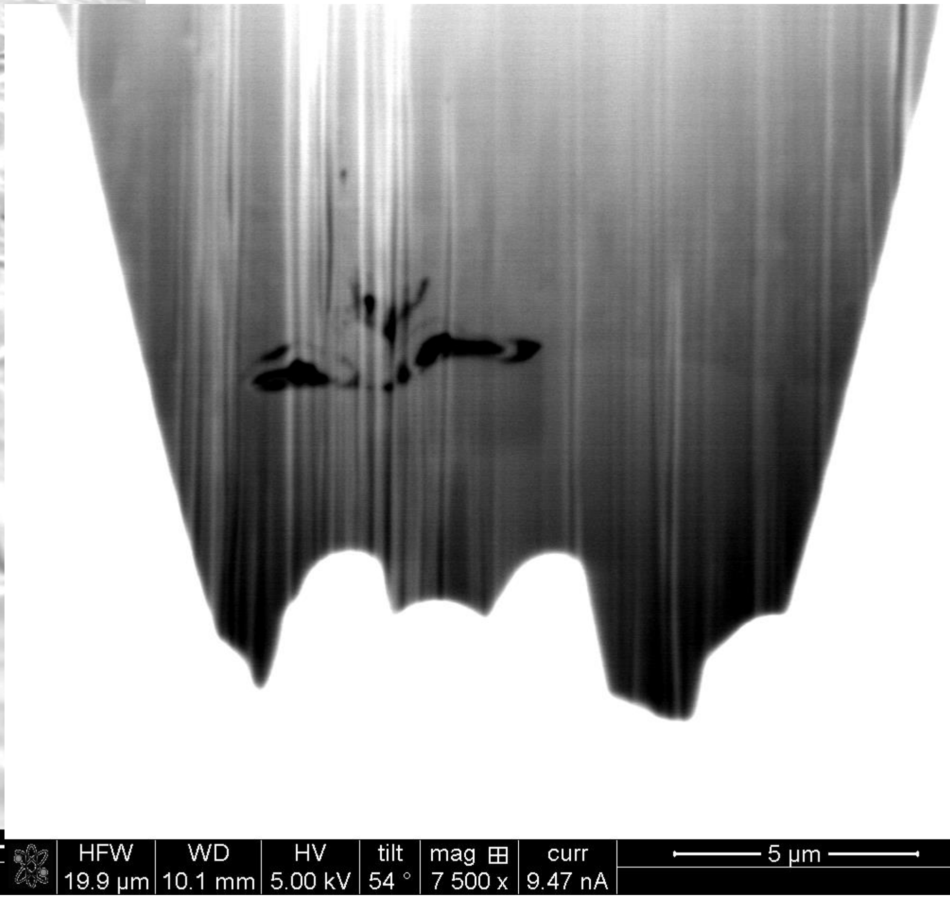
a) Film deposition
b) interface
c) Bulk substrate



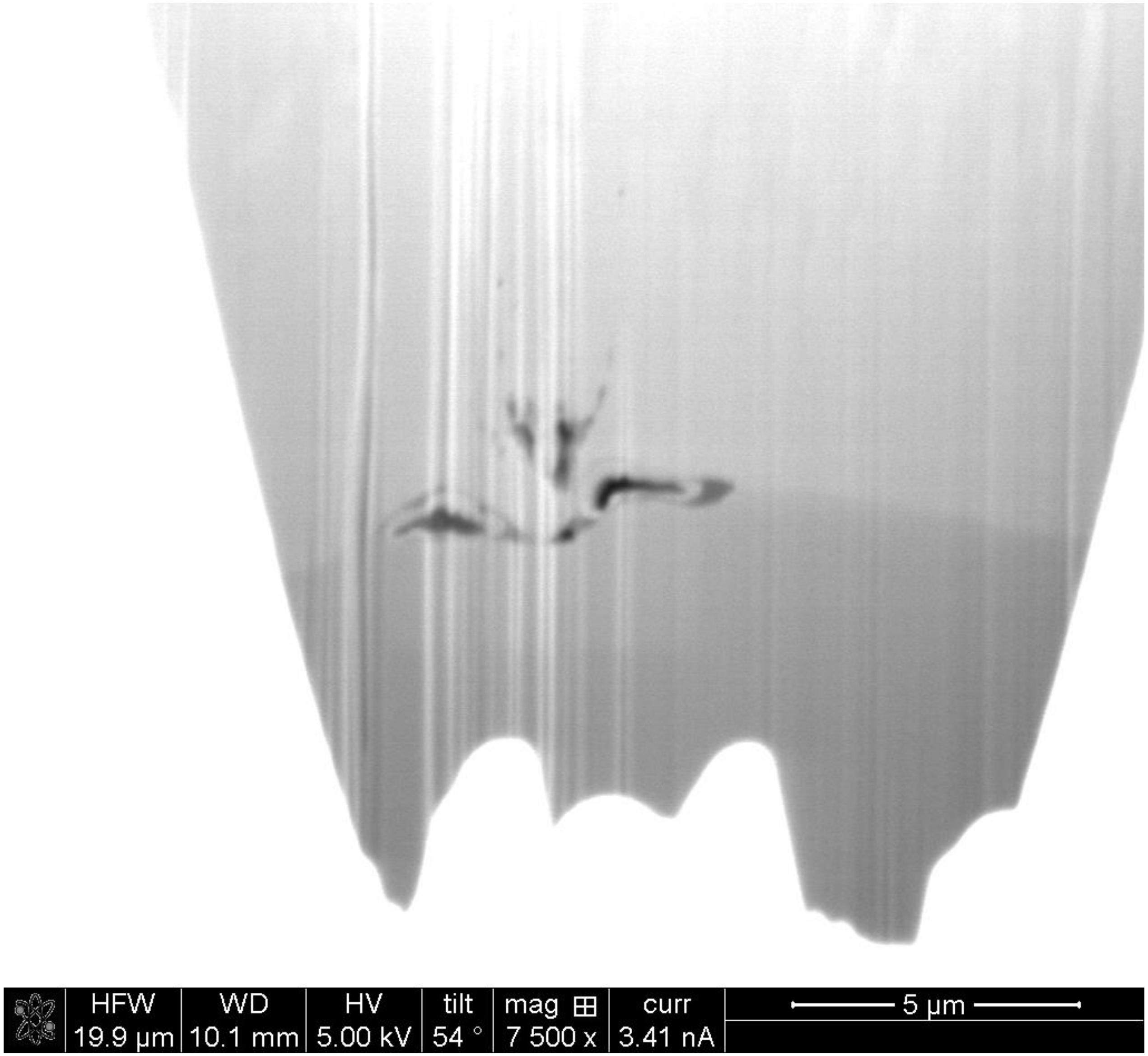


FIB on cross section

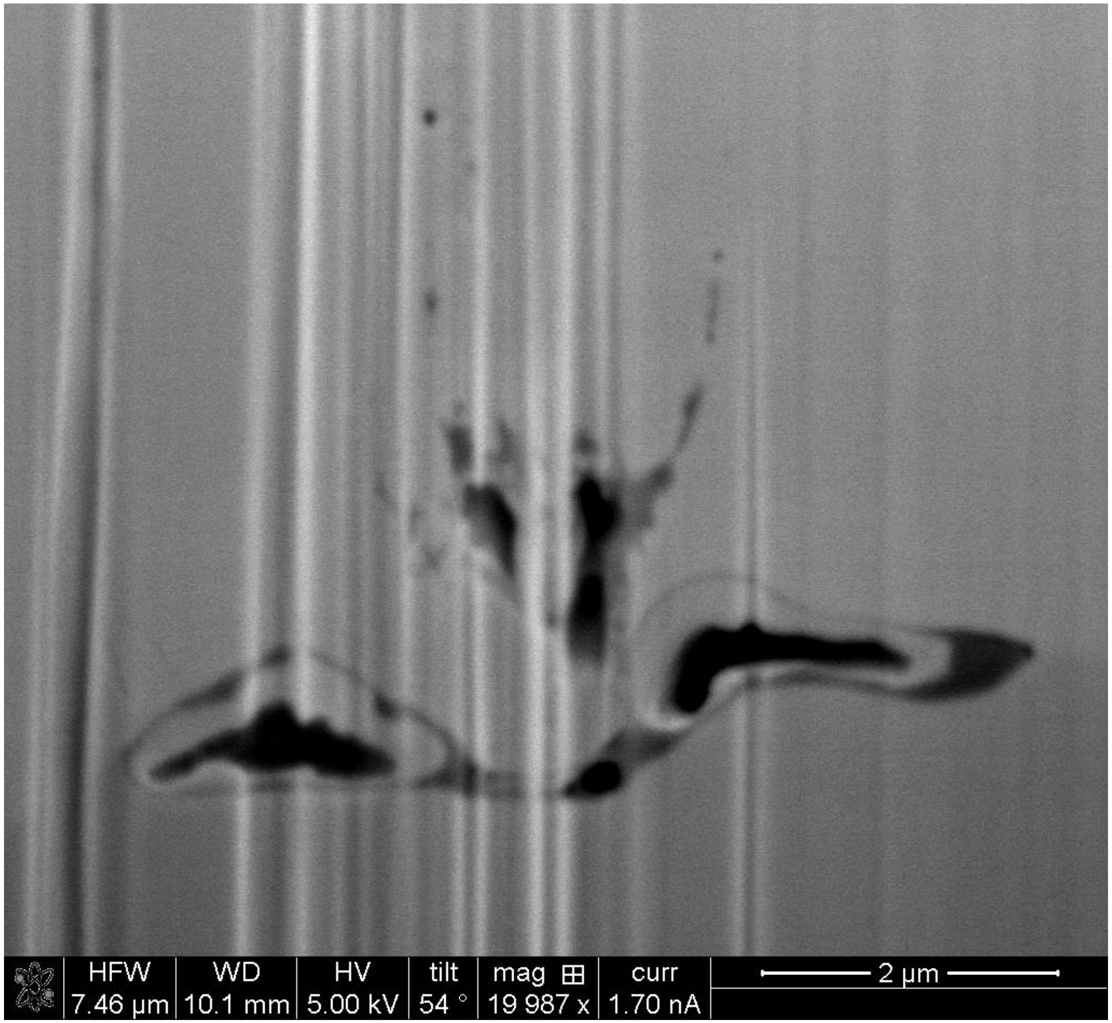




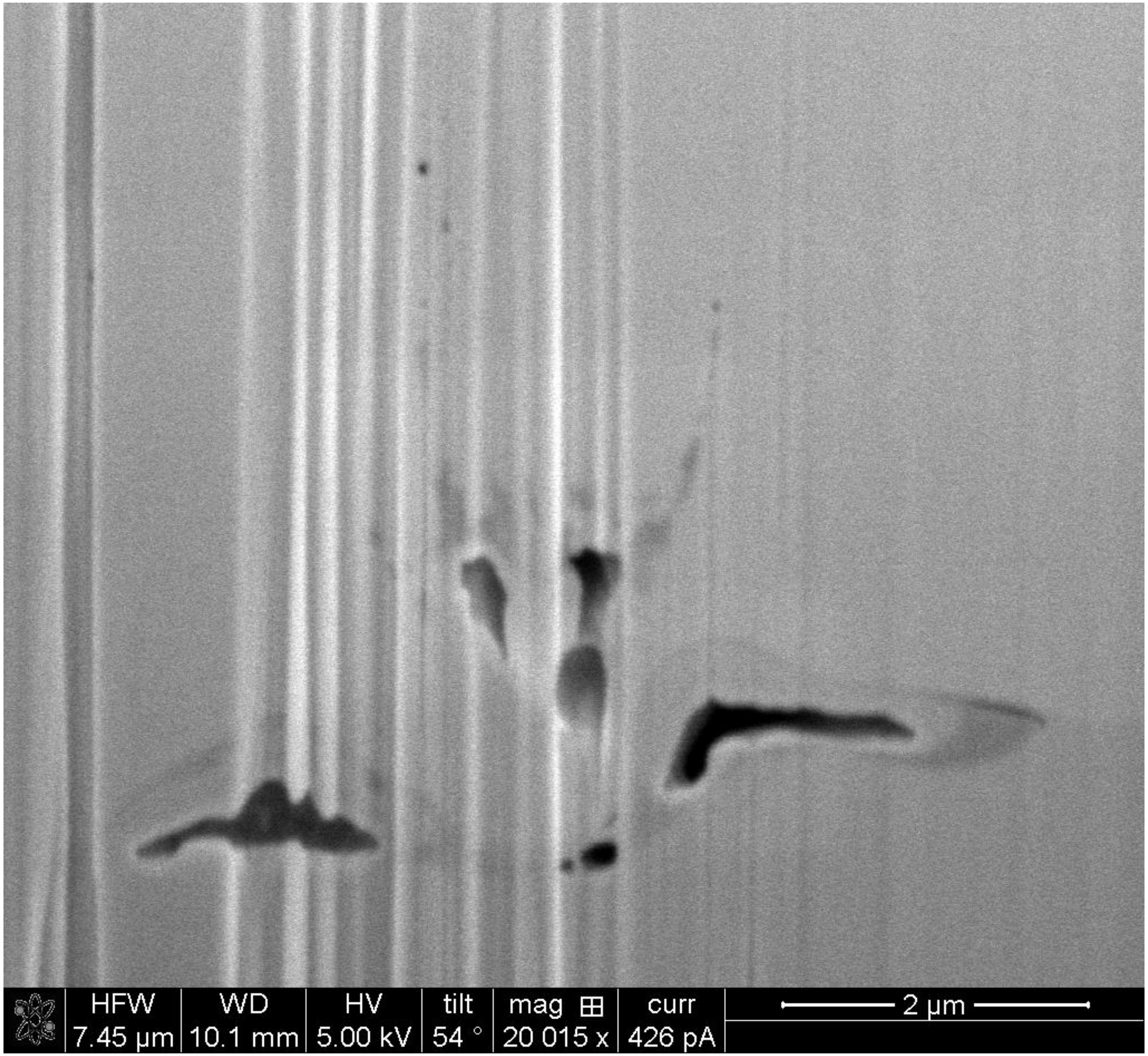
Defect



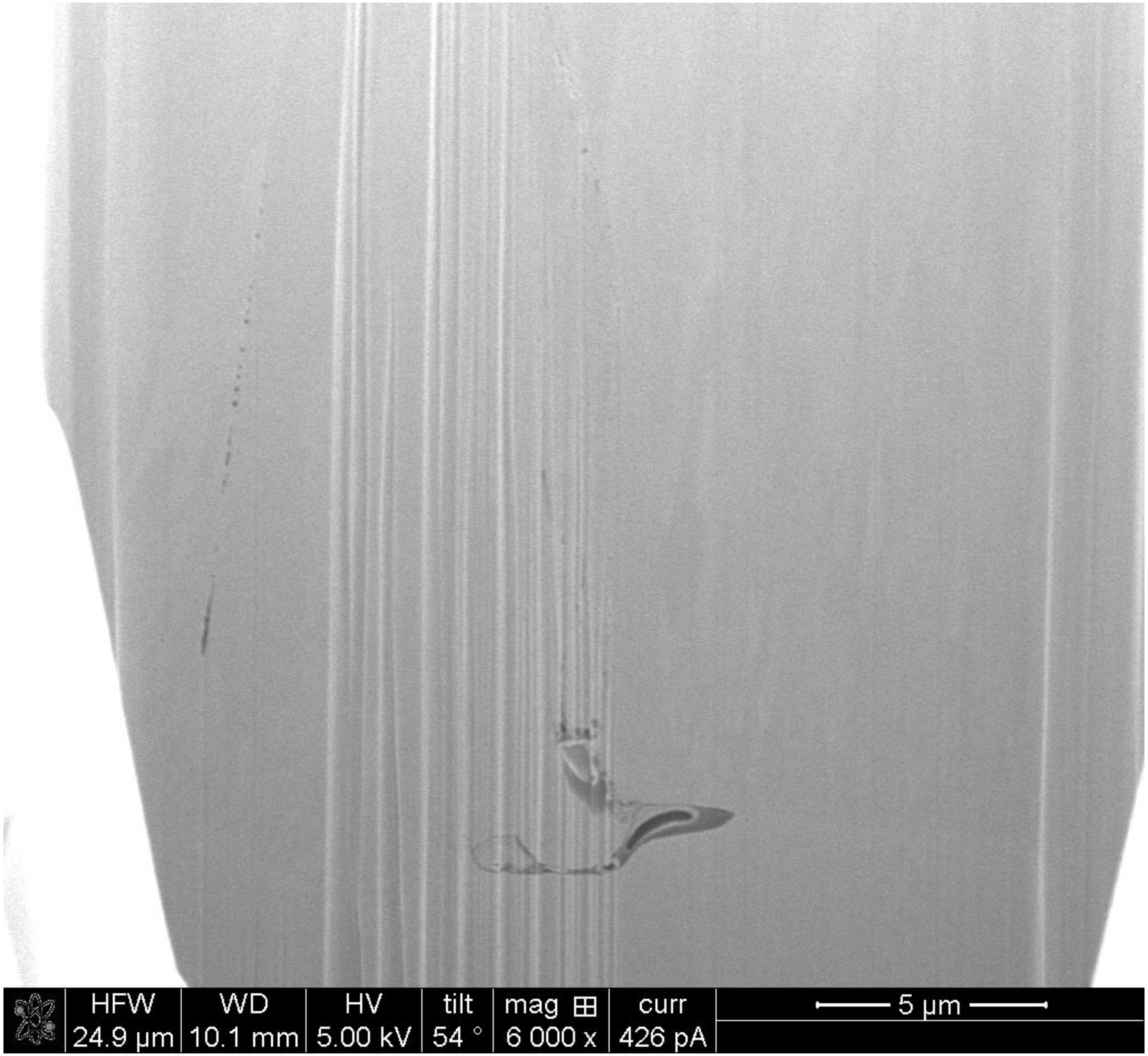
Defect



Defect

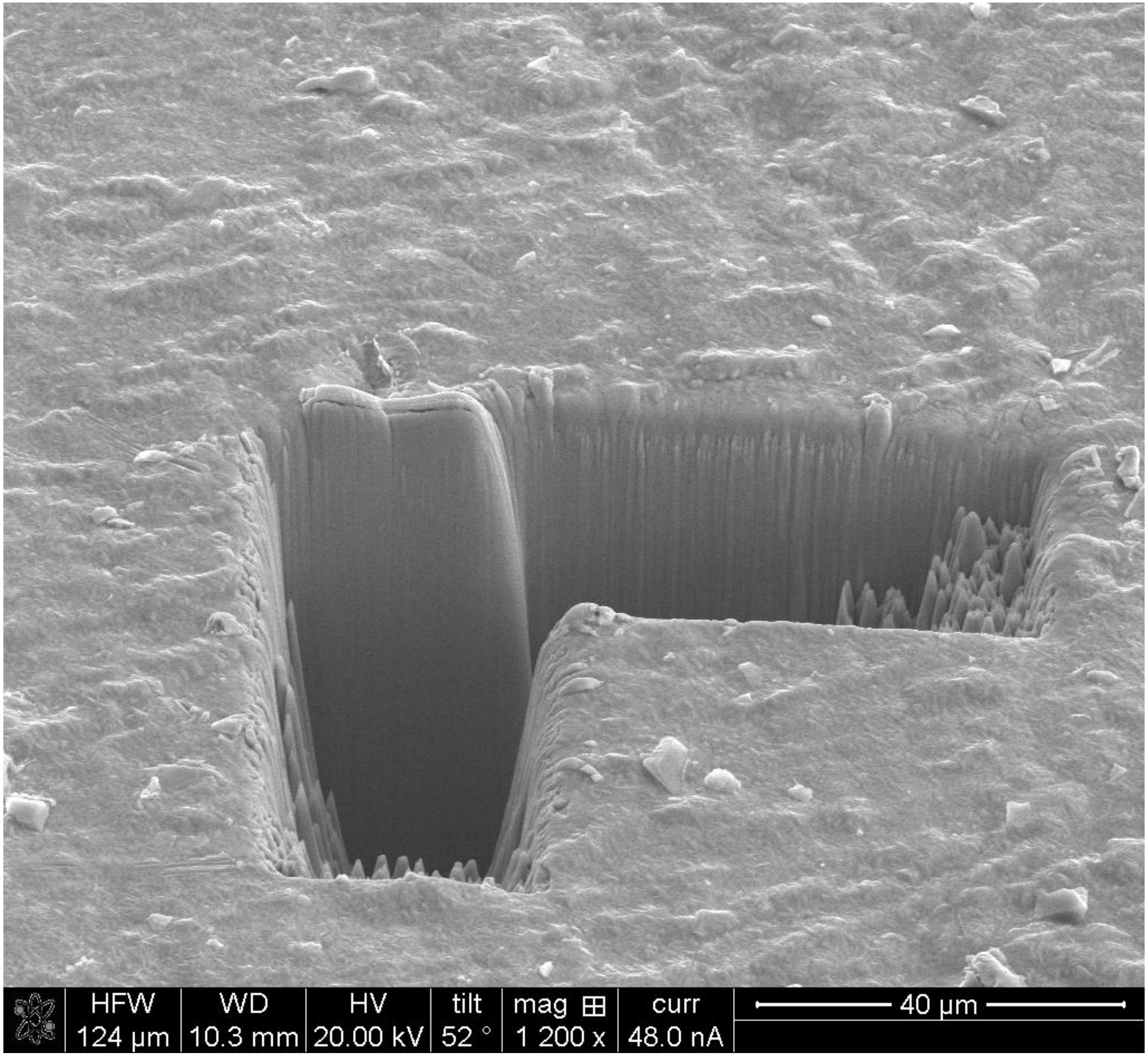


Crack propagation

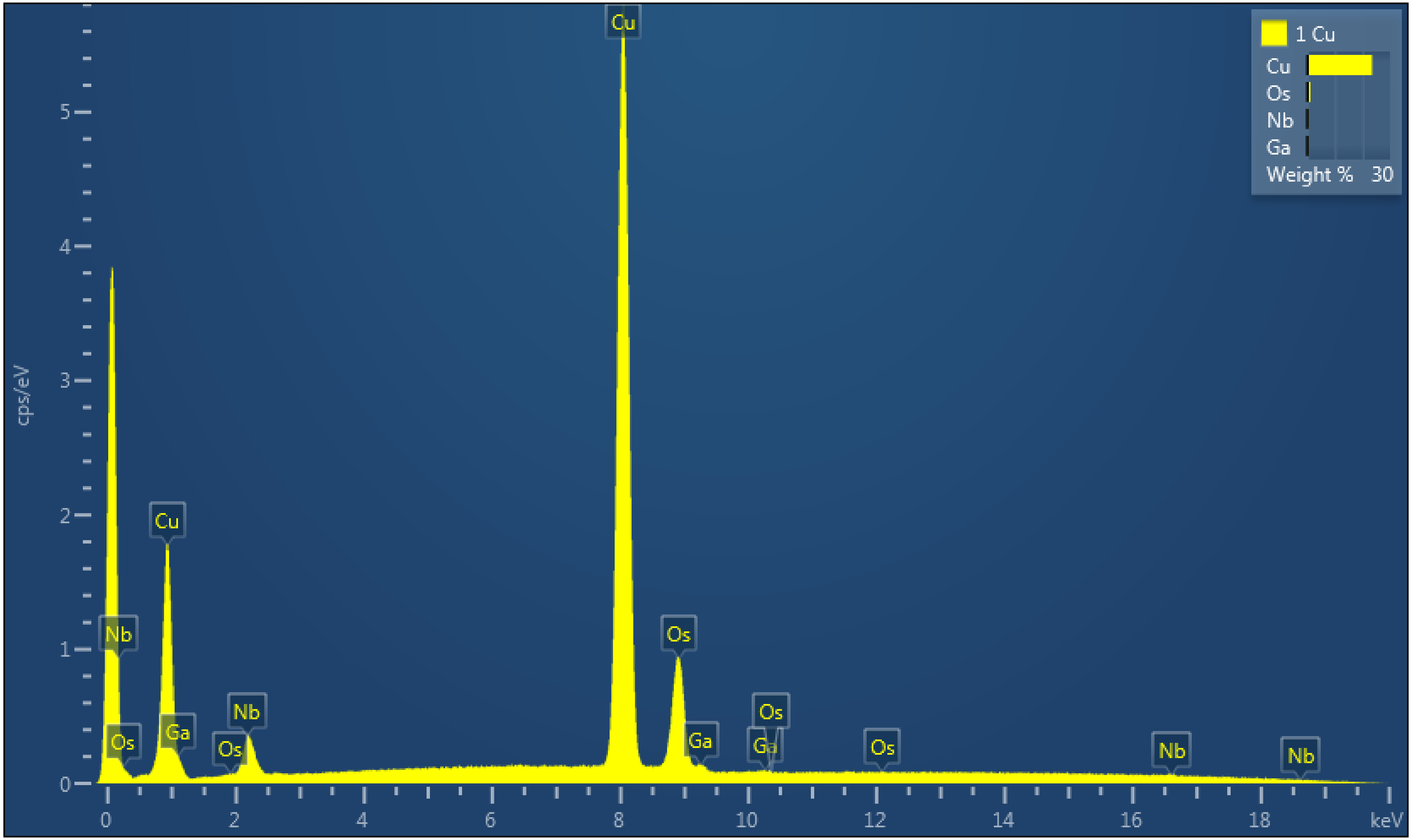


Crack propagation

EDS analysis on defect

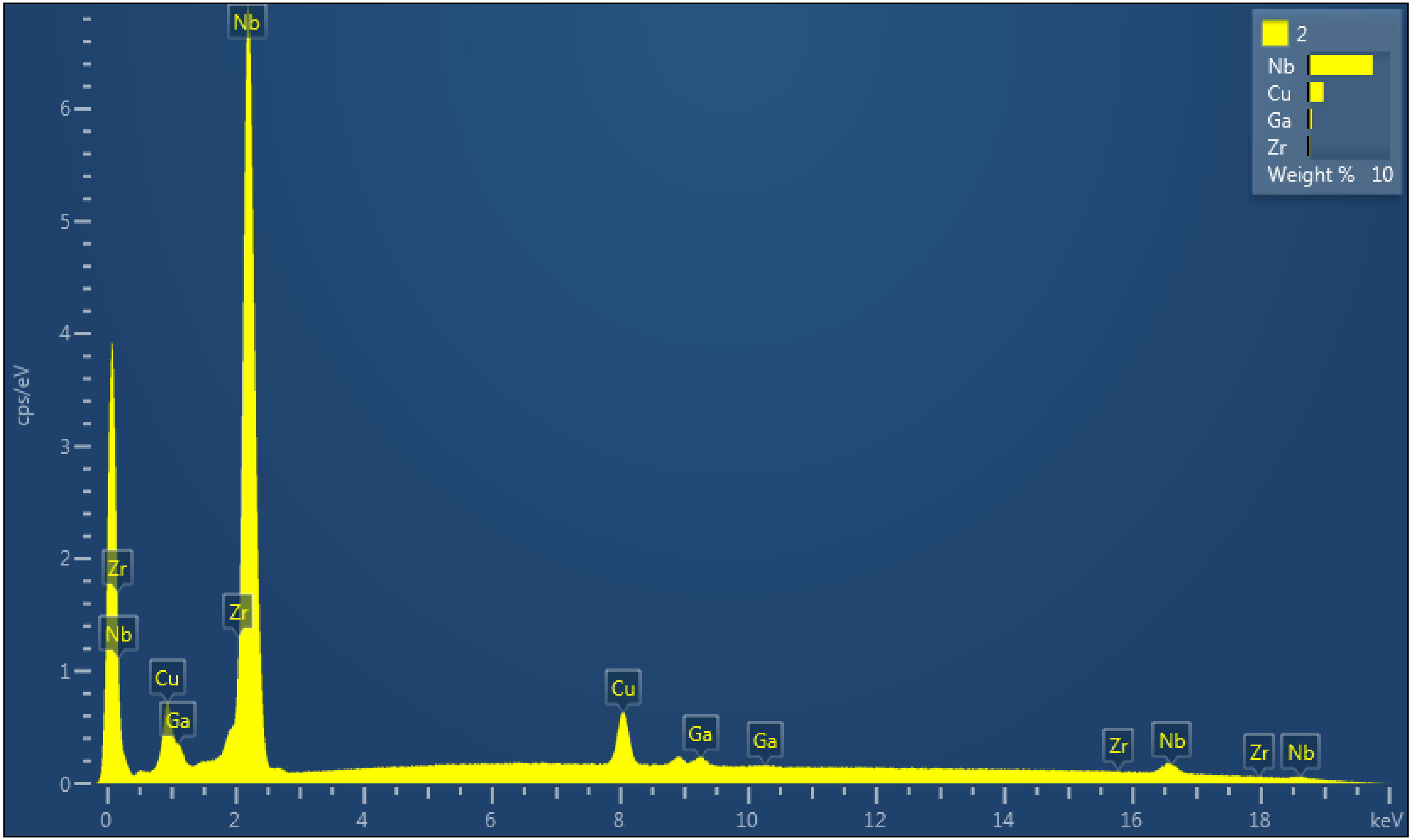


EDS analysis on Cu substrate



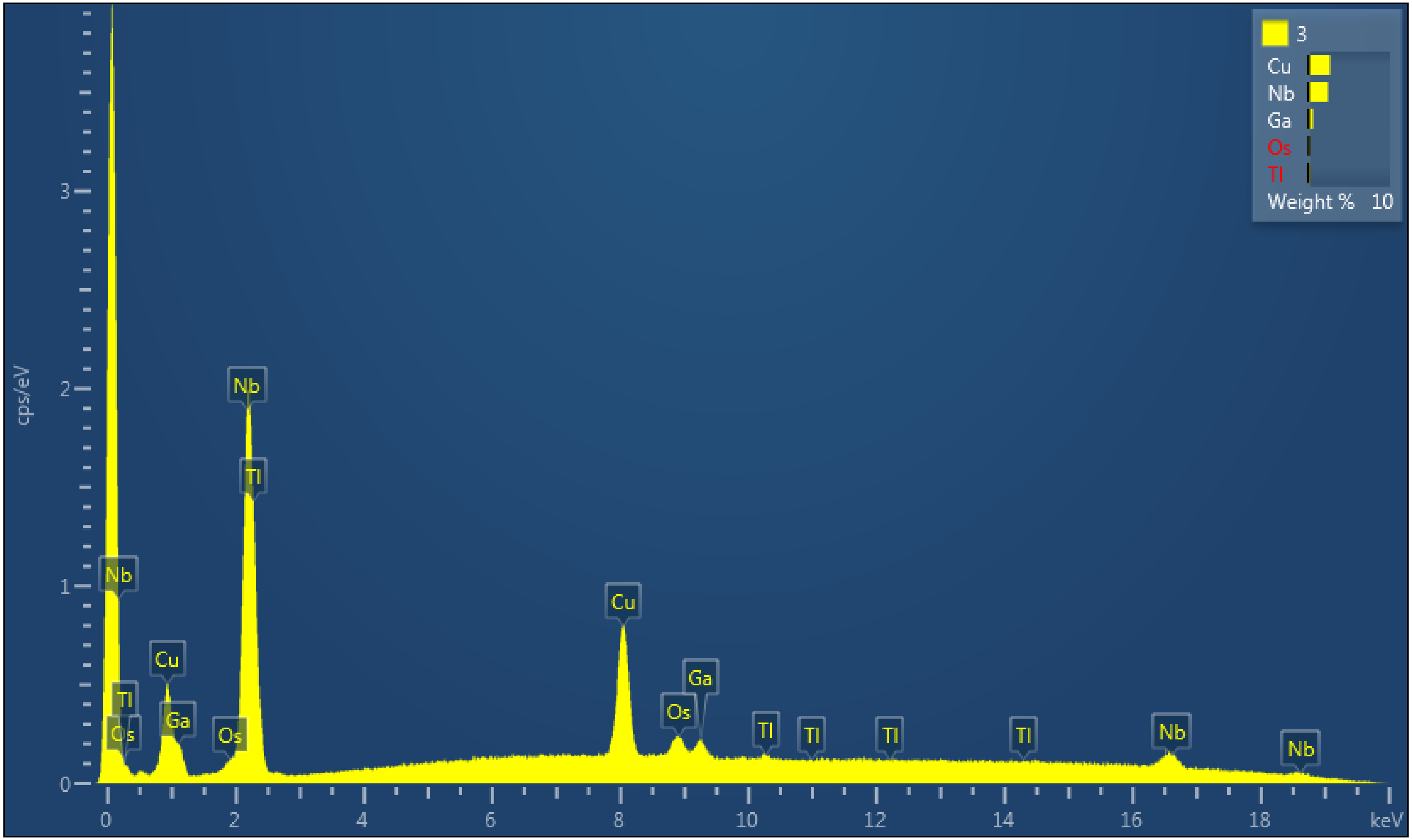
Element	Atomic %
Cu	96.06
Ga	1.30
Nb	1.16
Os	1.48
Total:	100.00

EDS analysis on Nb coating



Element	Atomic %
Cu	23.73
Ga	5.57
Zr	2.04
Nb	68.66
Total:	100.00

EDS analysis on interface



Element	Atomic %
Cu	65.79
Ga	13.20
Nb	21.02
Total:	100.00

Hypothesis

1- Impurity like Os from Cu during extraction can trap H then NbH_2 forms

2- Impurity of a sputtering or carrier gas

3- forming of micro cell Nb cathode, Cu anode then residual hydrogen evolution in grain boundary of Nb, despite the efforts to eliminate the hydrogen sources and the use of nonevaporable getters, hydrogen reduction was unfortunately not effective

4-Inter-grain defects can be also generated by impurities trapped in the film and surface roughness and in turn may cause intrinsic defects

Acknowledgment

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Thanks