



UNIVERSITY OF TARTU

MATTER

Characterization of Cu electrodes after vacuum breakdown with AFM and SEM

1st CERN Baltic Conference (CBC 2021)

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POSTDOCTORAL RESEARCHER

30.06.2021

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Introduction

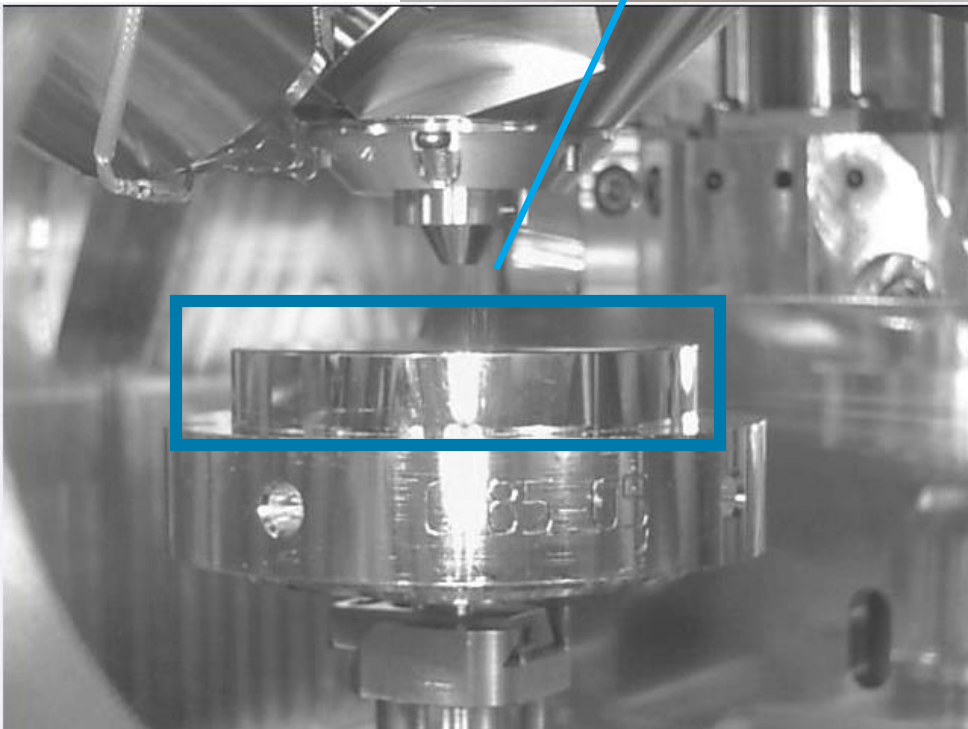
We have received two pairs of Cu electrodes from Helsinki.

Hard Cu

Soft Cu

All electrodes have been plasma treated.

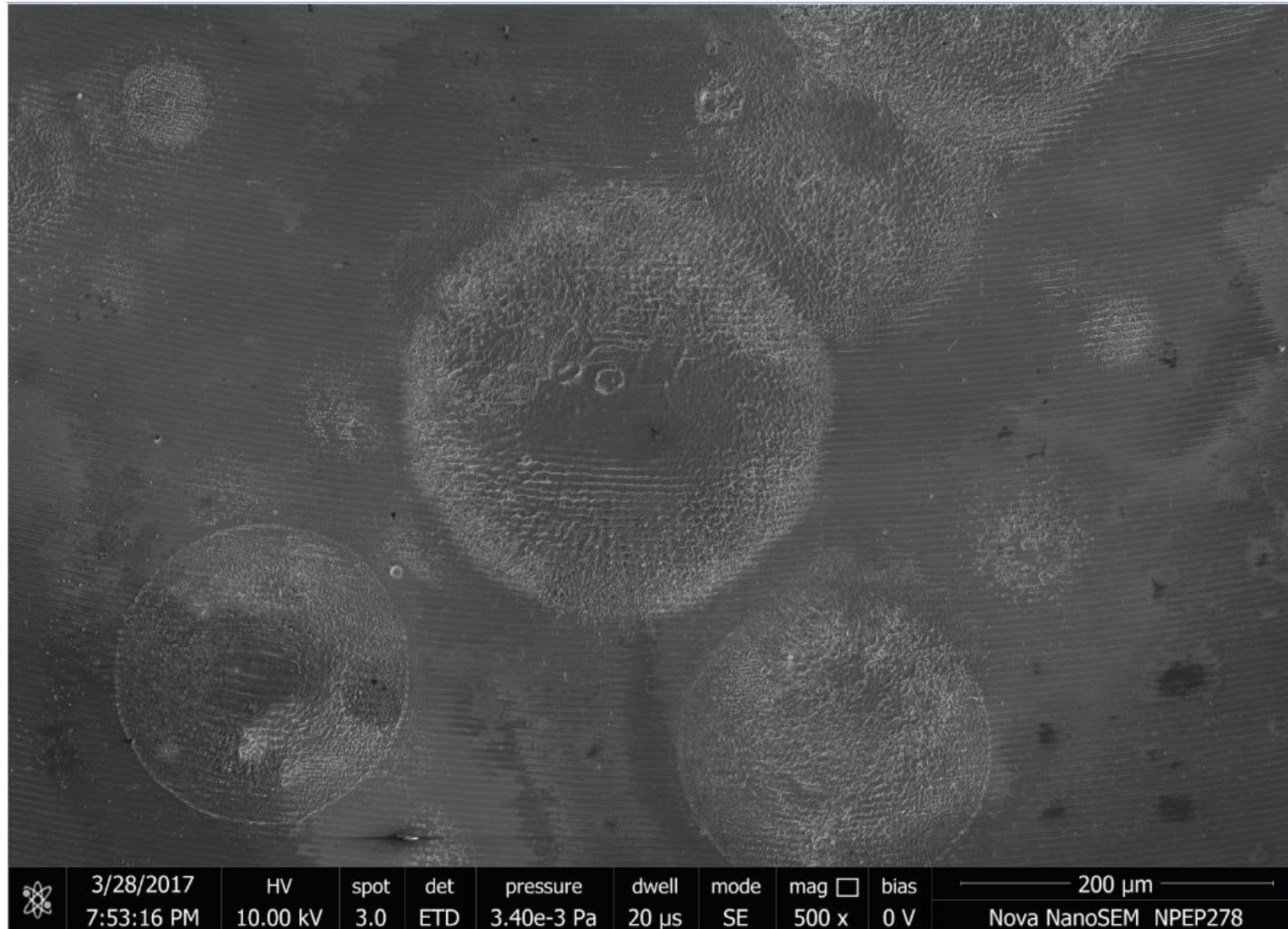
Aim was to characterize with SEM and AFM.





SEM images

Craters

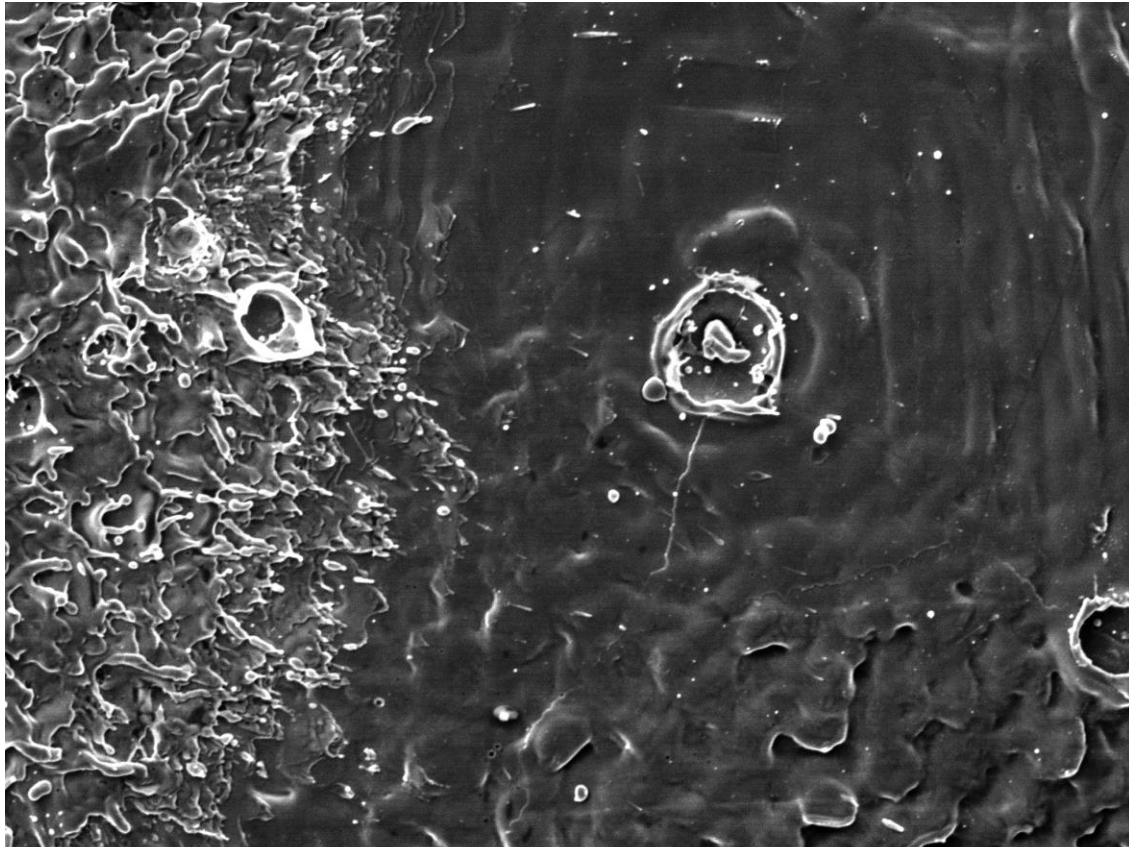


Center structure

A particle like structure in the middle of the crater.

Sometimes a plateau in the middle.

Hard Cu cathode

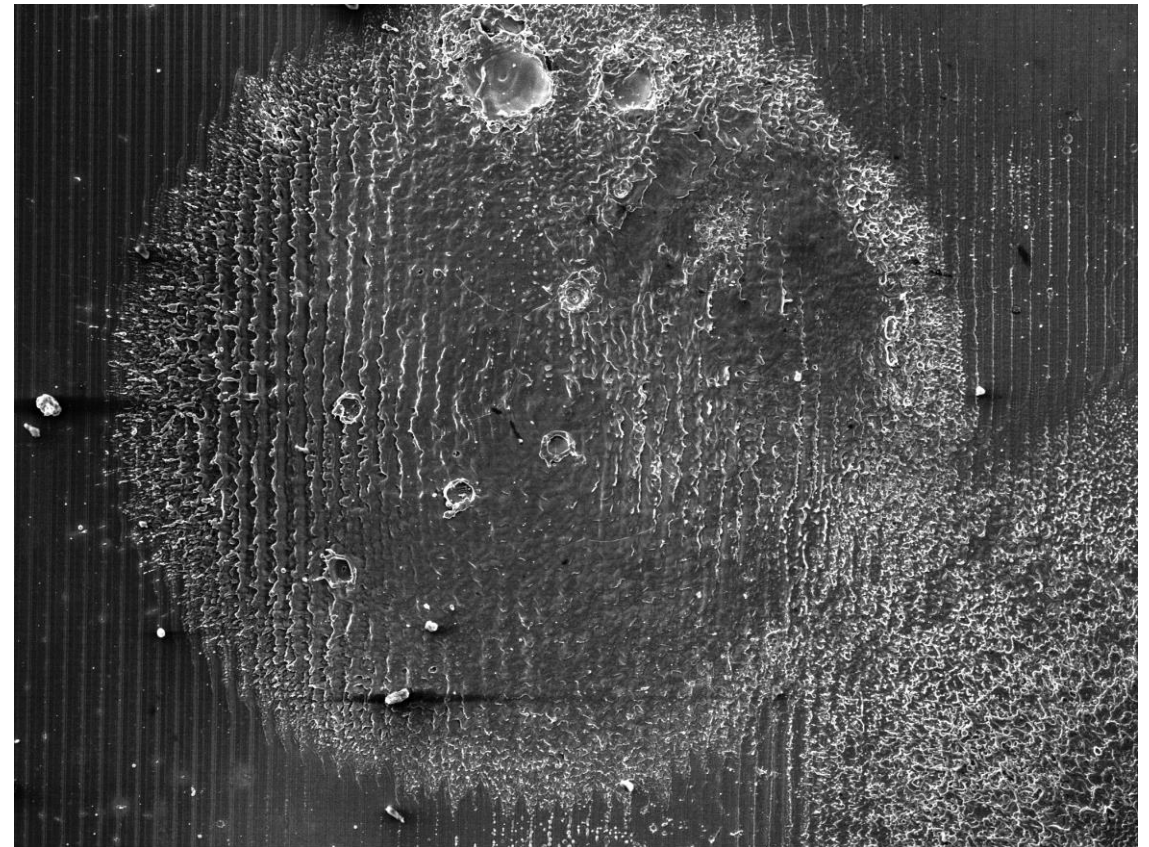


SEM HV: 10.00 kV WD: 22.9890 mm
View field: 84.84 μm Det: SE
Date(m/d/y): 03/07/21 Sergei

20 μm

VEGA\\ TESCAN

Performance in nanospace



SEM HV: 10.00 kV WD: 23.0030 mm
View field: 295.9 μm Det: SE
Date(m/d/y): 03/07/21 Sergei

50 μm

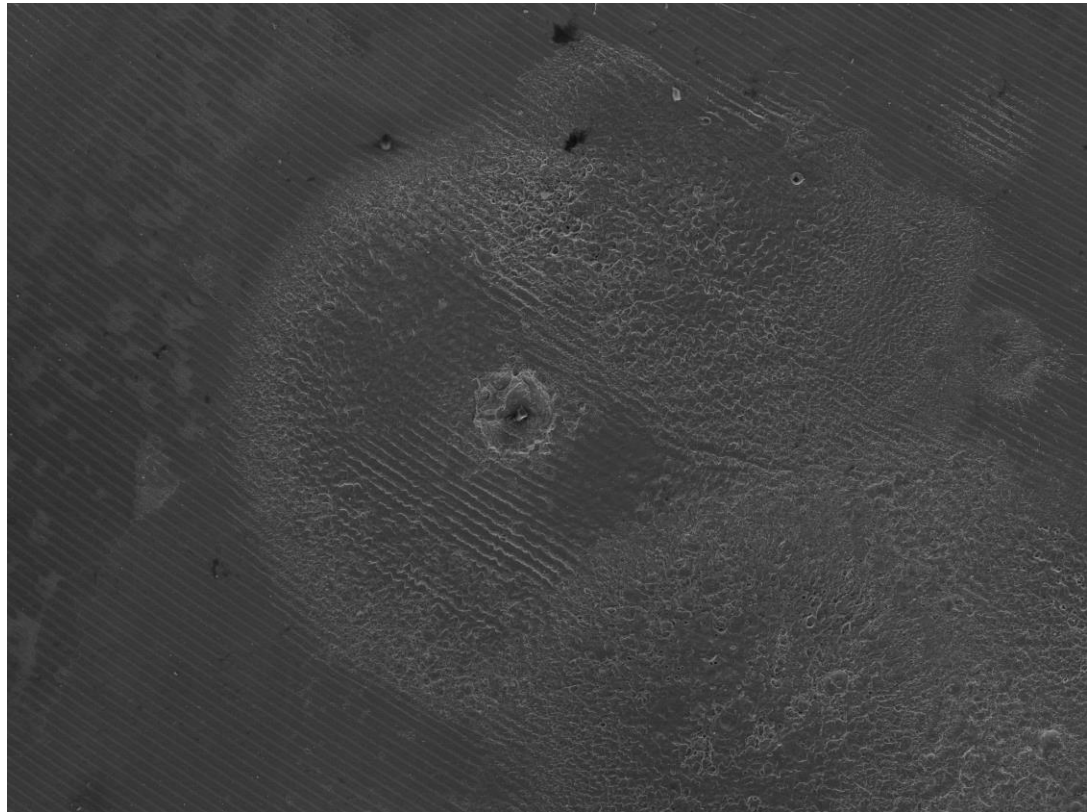
VEGA\\ TESCAN

Performance in nanospace

Protrusions

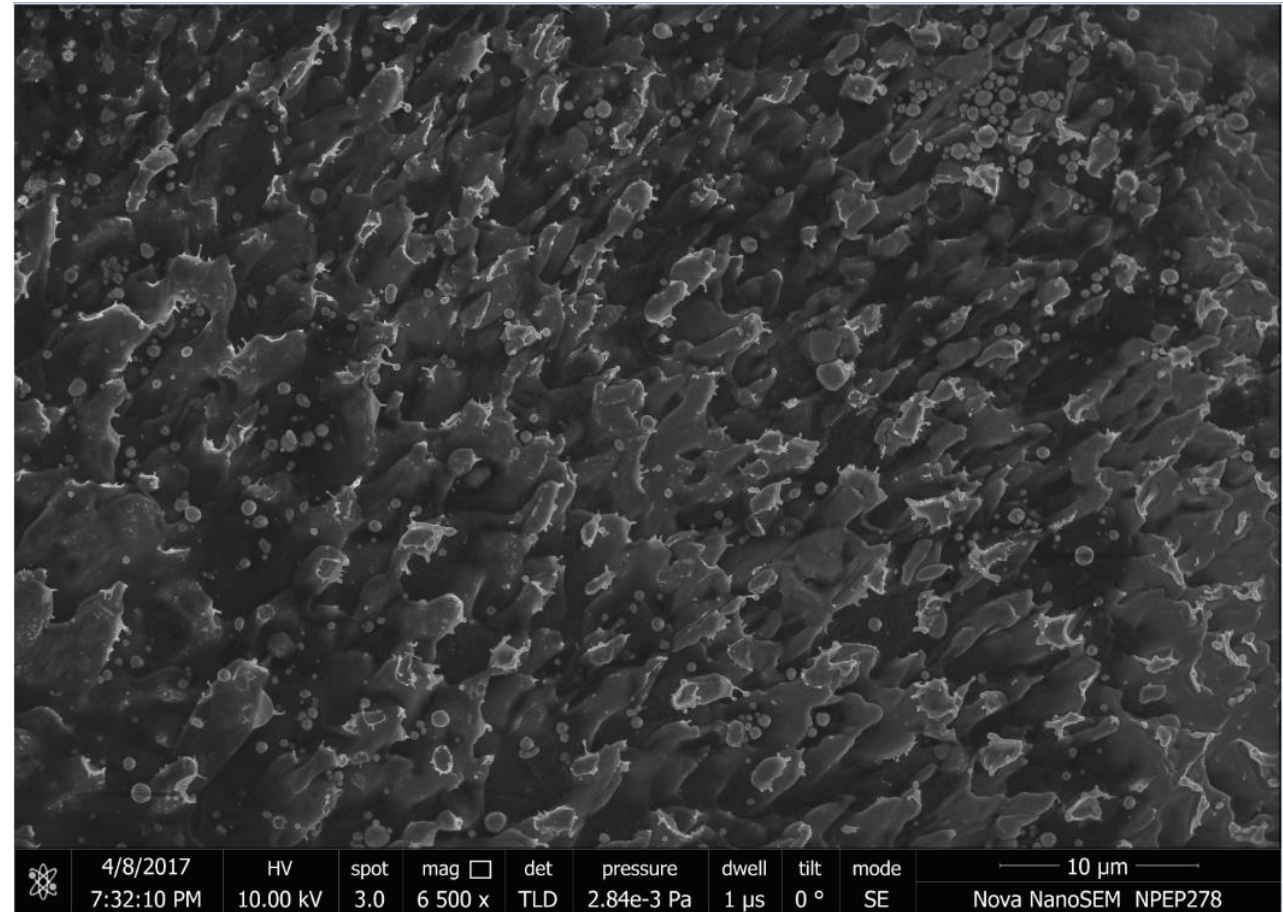
The sides of the crater are filled with various protrusions.

Hard Cu cathode



SEM HV: 10.00 kV WD: 9.2488 mm
View field: 507.8 μm Det: SE
Date(m/d/y): 12/11/20 Sergei
VEGA\\ TESCAN
Performance in nanospace

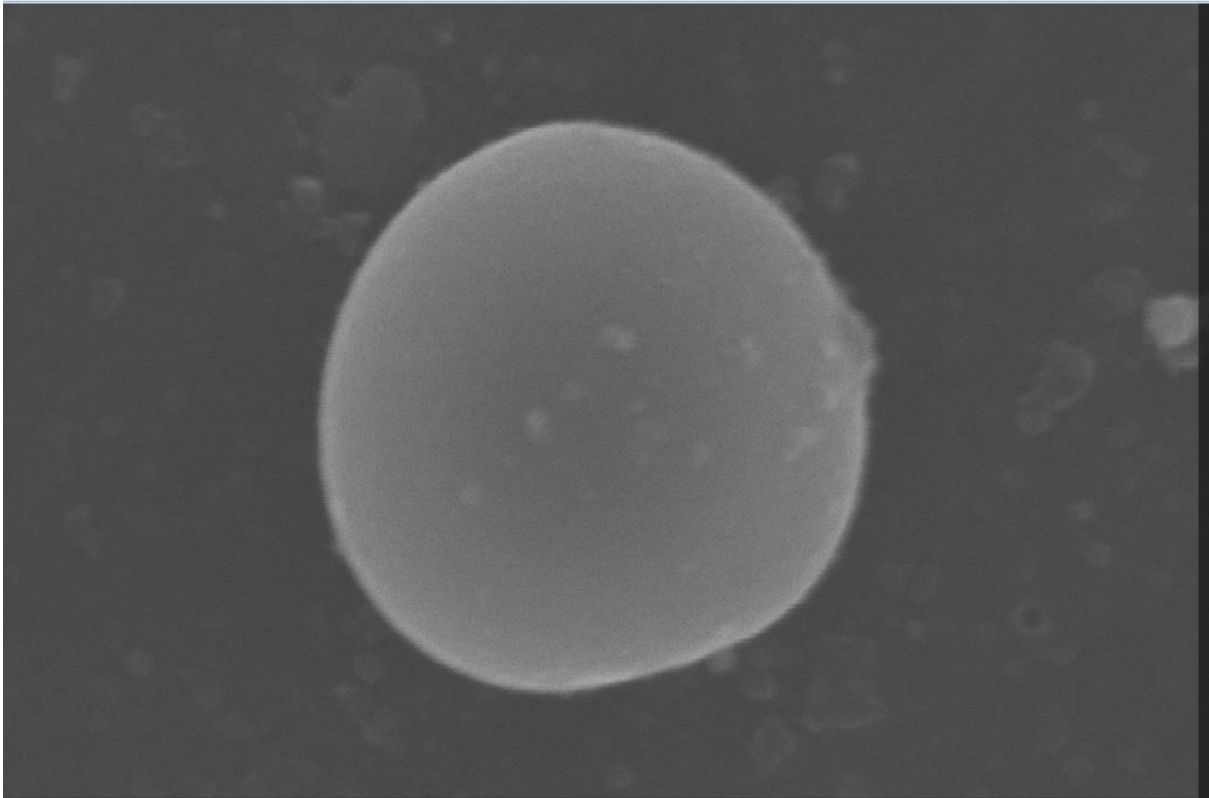
Hard Cu anode



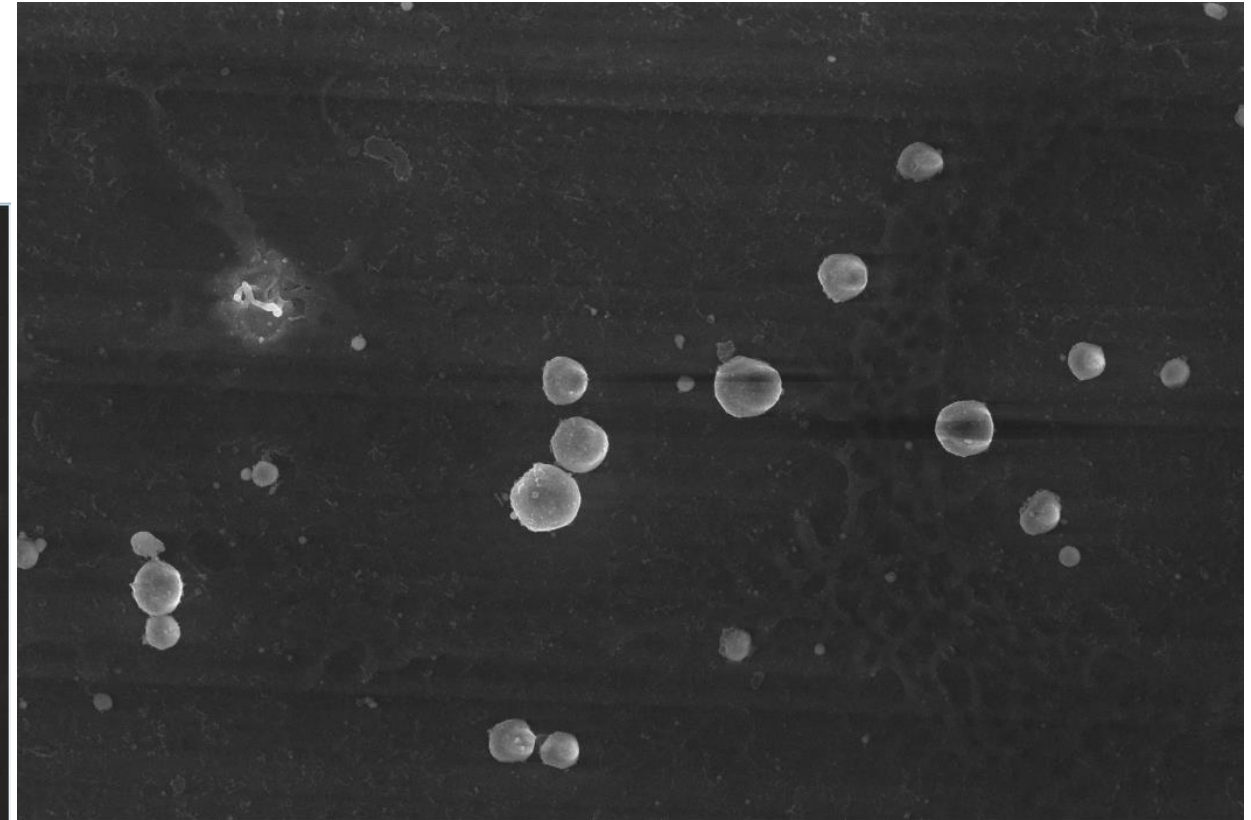
4/8/2017 HV spot mag det pressure dwell tilt mode
7:32:10 PM 10.00 kV 3.0 6 500 x TLD 2.84e-3 Pa 1 μs 0 $^\circ$ SE
10 μm
Nova NanoSEM NPEP278

Particles

Hard Cu cathode



Nova NanoSEM NPEP278	4/8/2017	HV	spot	mag	det	pressure	dwell	tilt	mode	200 nm
	8:12:51 PM	10.00 kV	3.0	350 000 x	TLD	2.48e-3 Pa	6 μs	0 °	SE	



Nova NanoSEM NPEP278	3/28/2017	HV	spot	det	pressure	dwell	mode	mag	bias	4 μm
	9:02:04 PM	10.00 kV	3.0	TLD	2.84e-3 Pa	1 μs	SE	20 000 x	0 V	

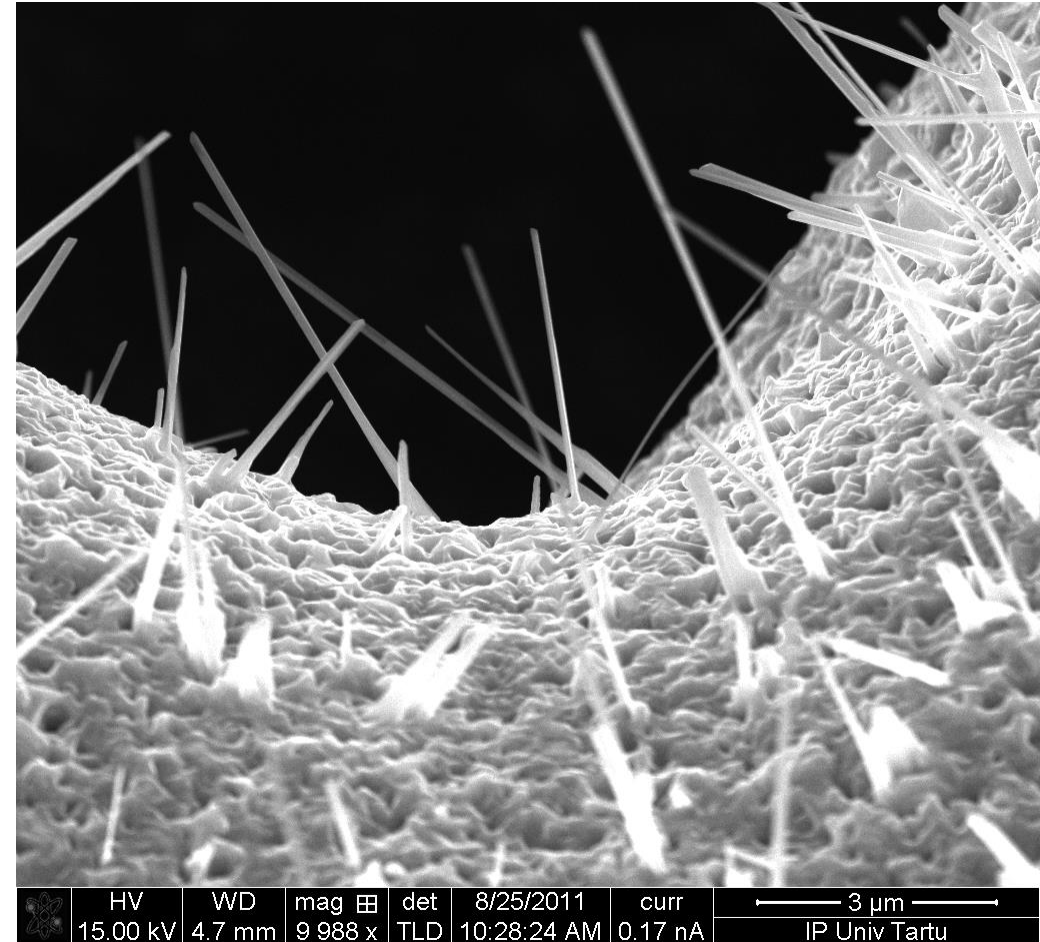
Hard Cu cathode

Growth of CuO nanowires

Another candidate for protrusions:

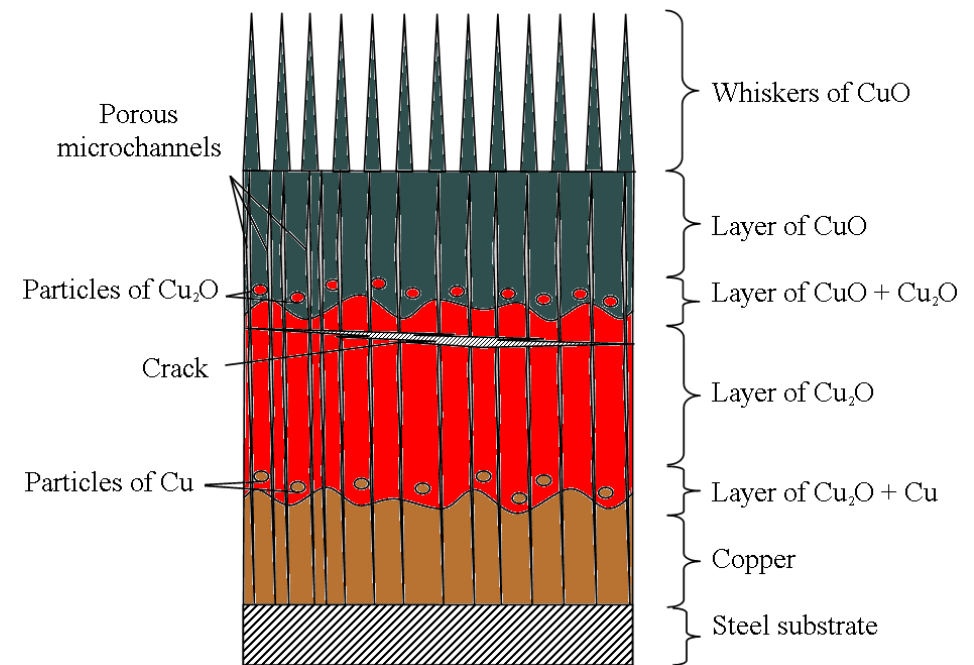
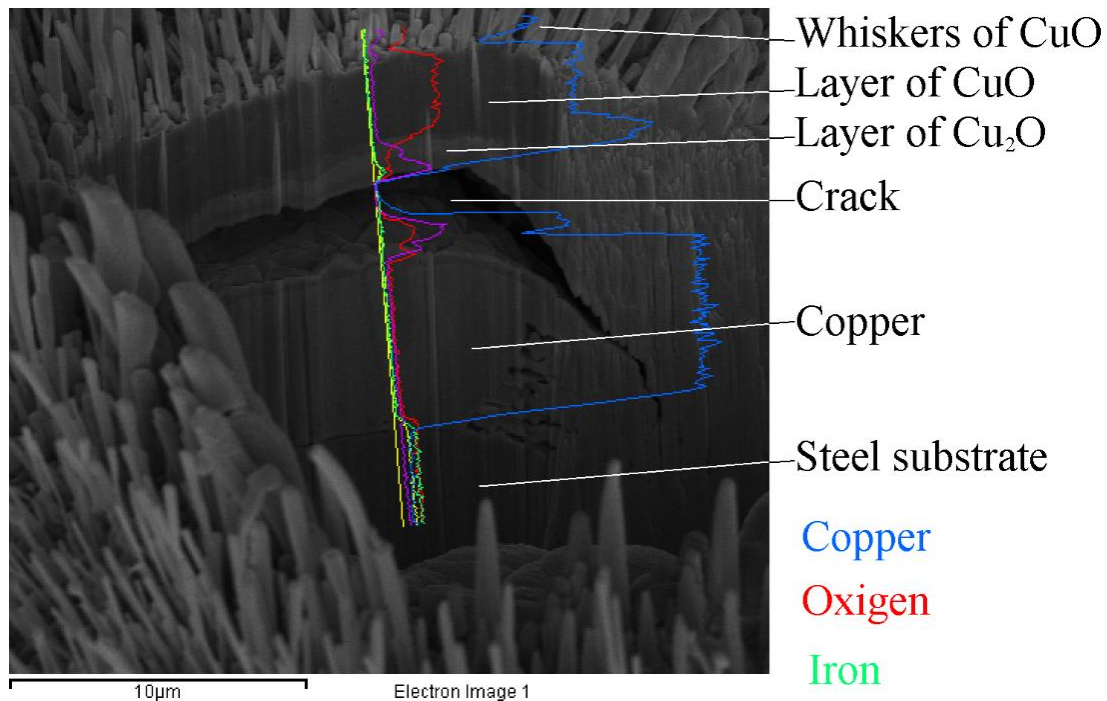
CuO NWs can be synthesized by heating Cu in air. **Nano Lett., Vol. 2, No. 12, 2002**

Temperatures 400°-700° results in NWs.
Higher temperatures produces particles.



Cu sample with CuO nanowires:

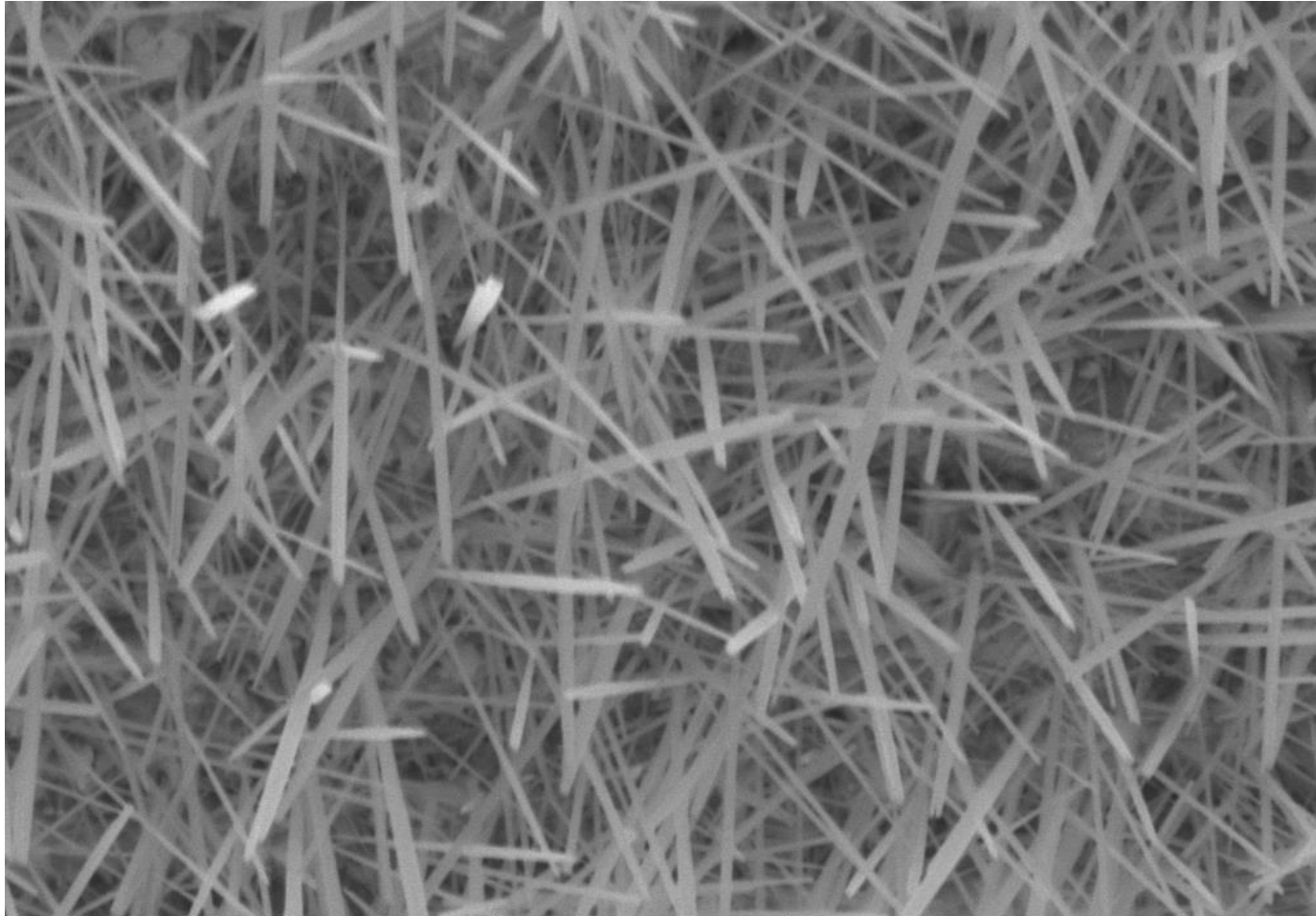
inner structure after heat-treatment
Cut by FIB, analysed by EDX (NSFL, IPUT)






Dorogov, et. al, *Appl. Surf. Sci.* **246**, 423 (2015).

SEM tungsten filament

Tungsten Oxide NWs grown on burnt tungsten filament used in SEM



	HV 10.00 kV	WD 4.0 mm	mag  15 004 x	det ETD	10/10/2011 12:45:08 PM	curr 0.17 nA	 2 μ m
IP Univ Tartu							



Estimating the amount of molecules in CLIC

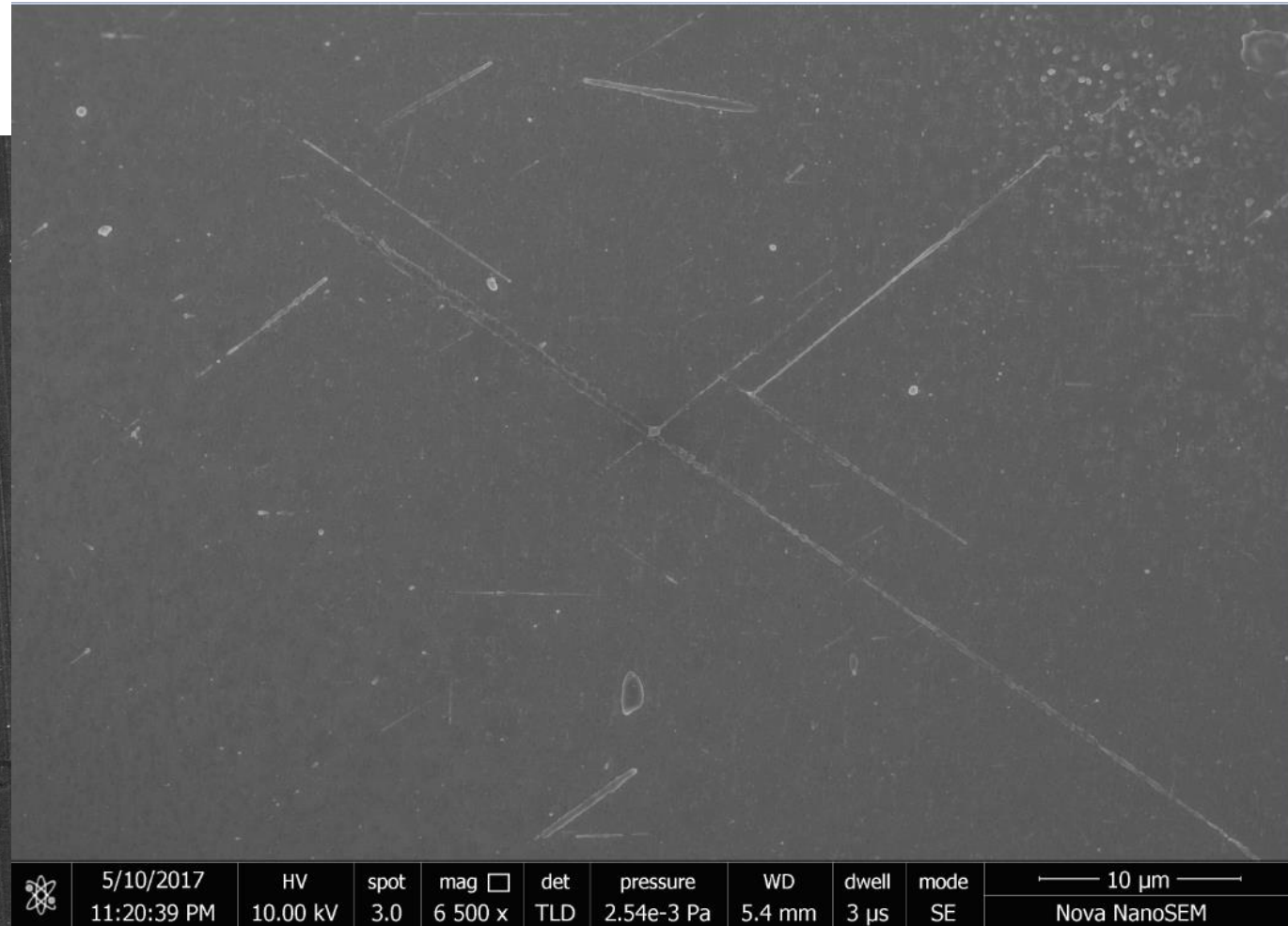
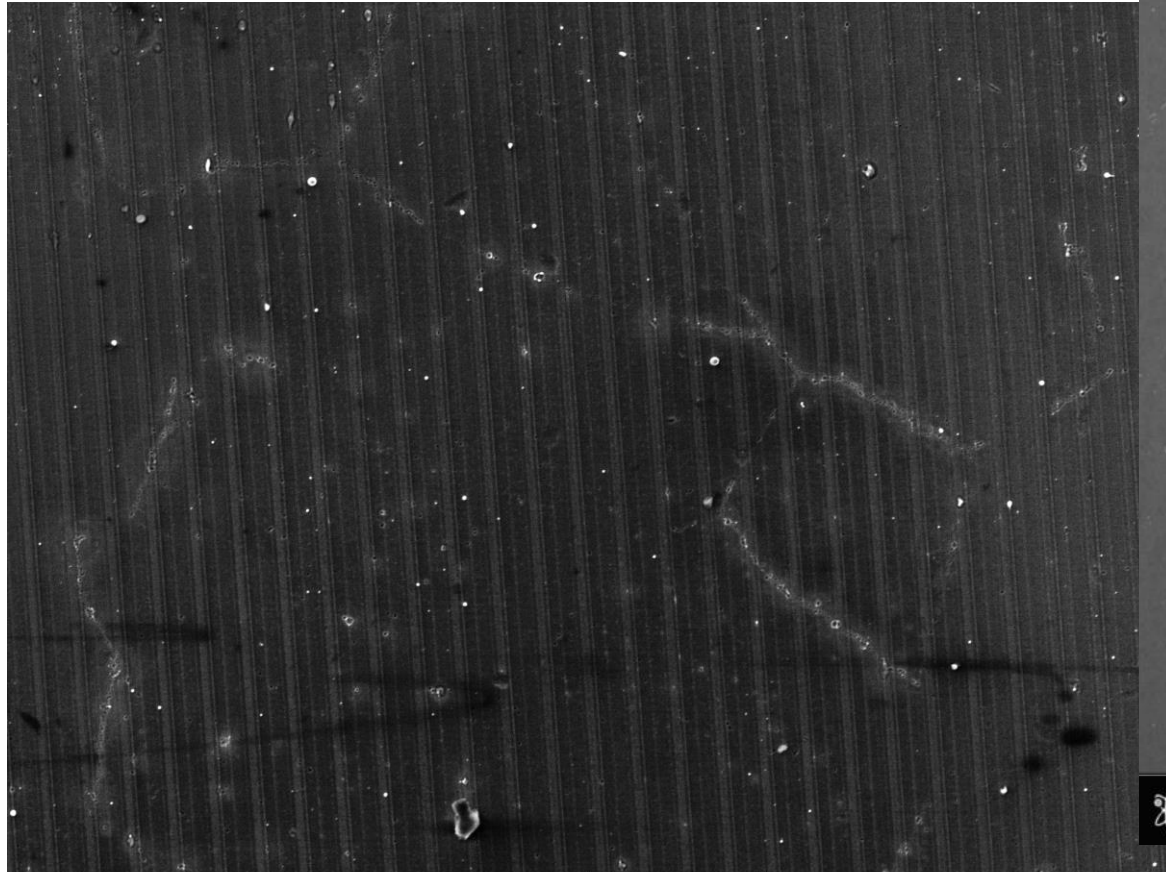
$$T = 293K$$

$$P = 10^{-9} \text{mbar}$$


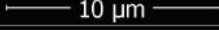
$$\frac{n}{V} = \frac{P}{R \cdot T} = 2^{14} \frac{\text{molecules}}{\text{m}^3}$$

Lines

Soft Cu cathode



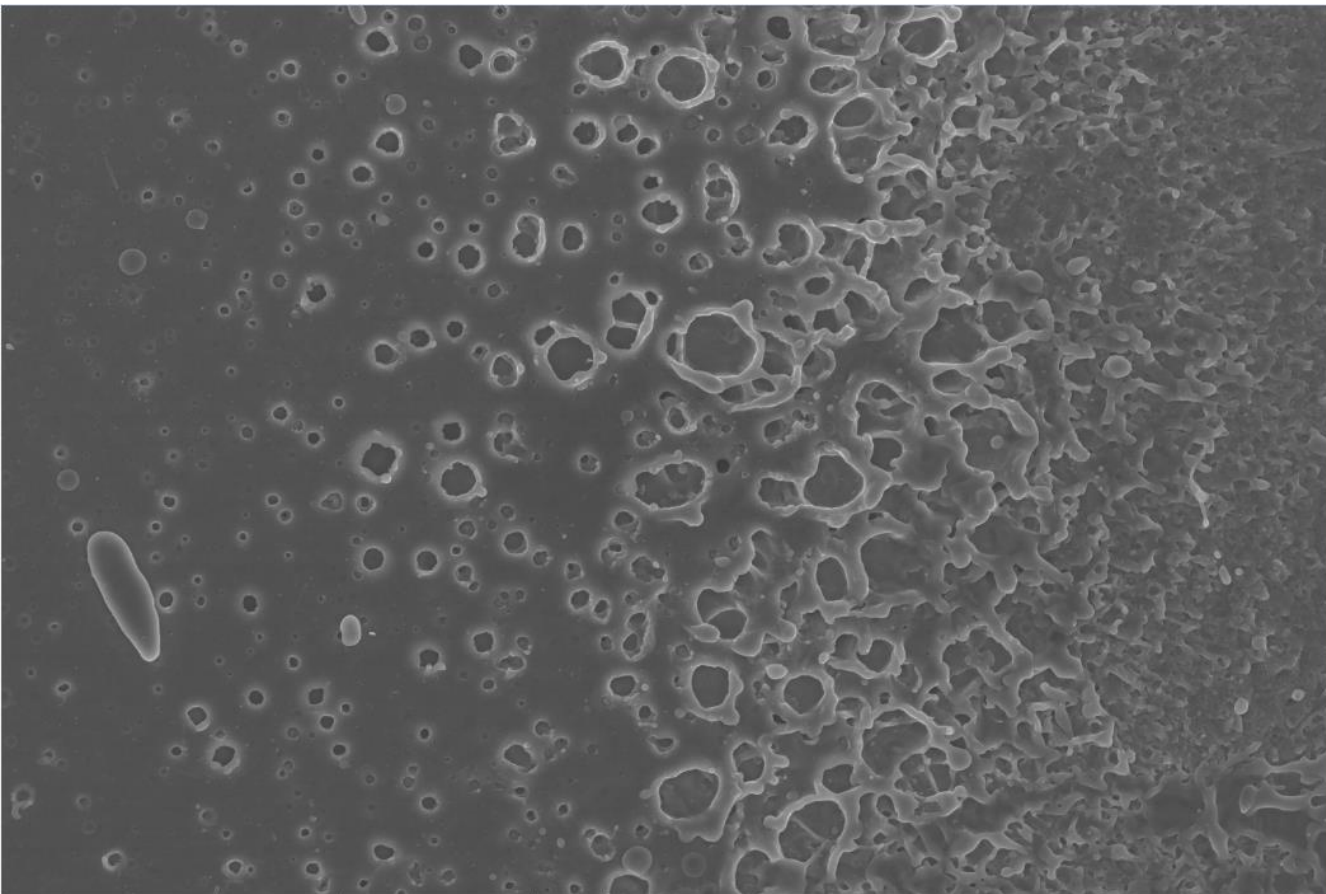
SEM HV: 10.00 kV WD: 23.0810 mm VEGA\\ TESCAN
View field: 136.9 μ m Det: SE 20 μ m
Date(m/d/y): 03/07/21 Sergei Performance in nanospace

	5/10/2017 11:20:39 PM	HV 10.00 kV	spot 3.0	mag <input type="checkbox"/> 6 500 x	det TLD	pressure 2.54e-3 Pa	WD 5.4 mm	dwell 3 μ s	mode SE	 10 μ m Nova NanoSEM
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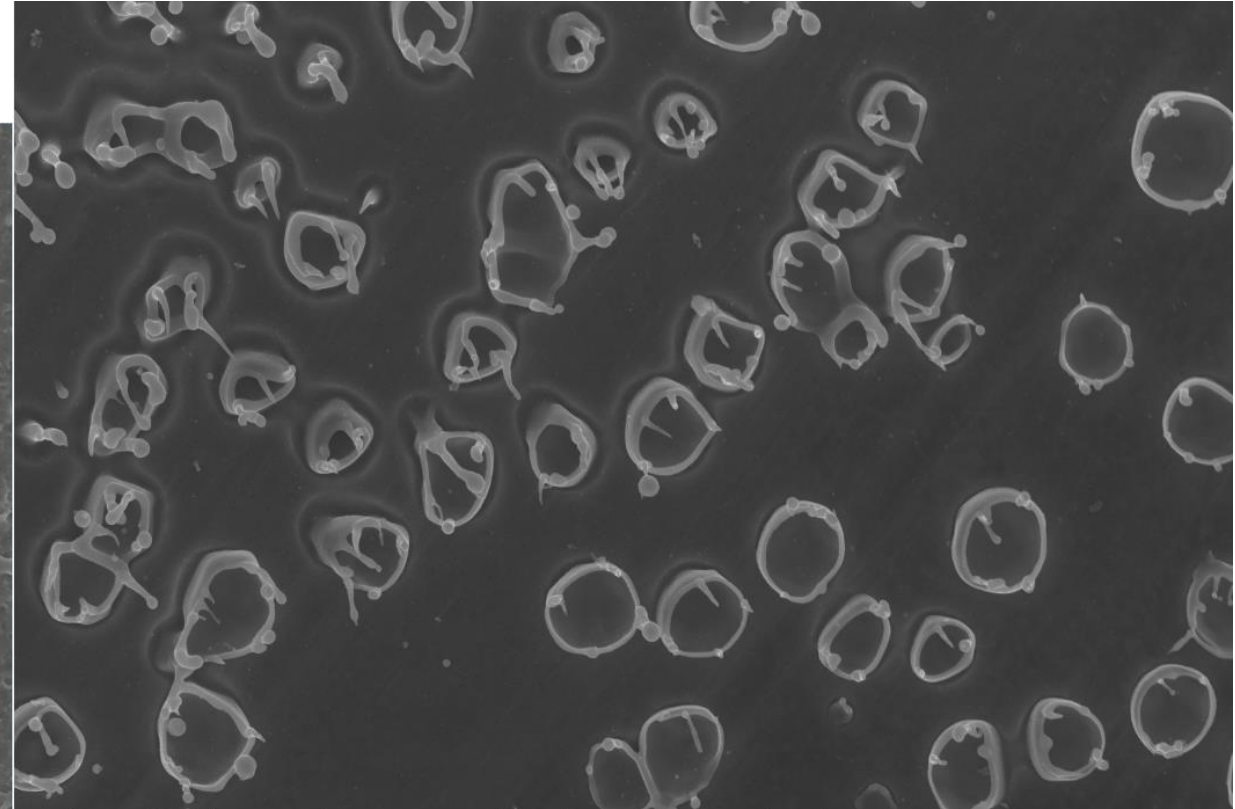
Hard Cu cathode

Rings on anode

Soft Cu



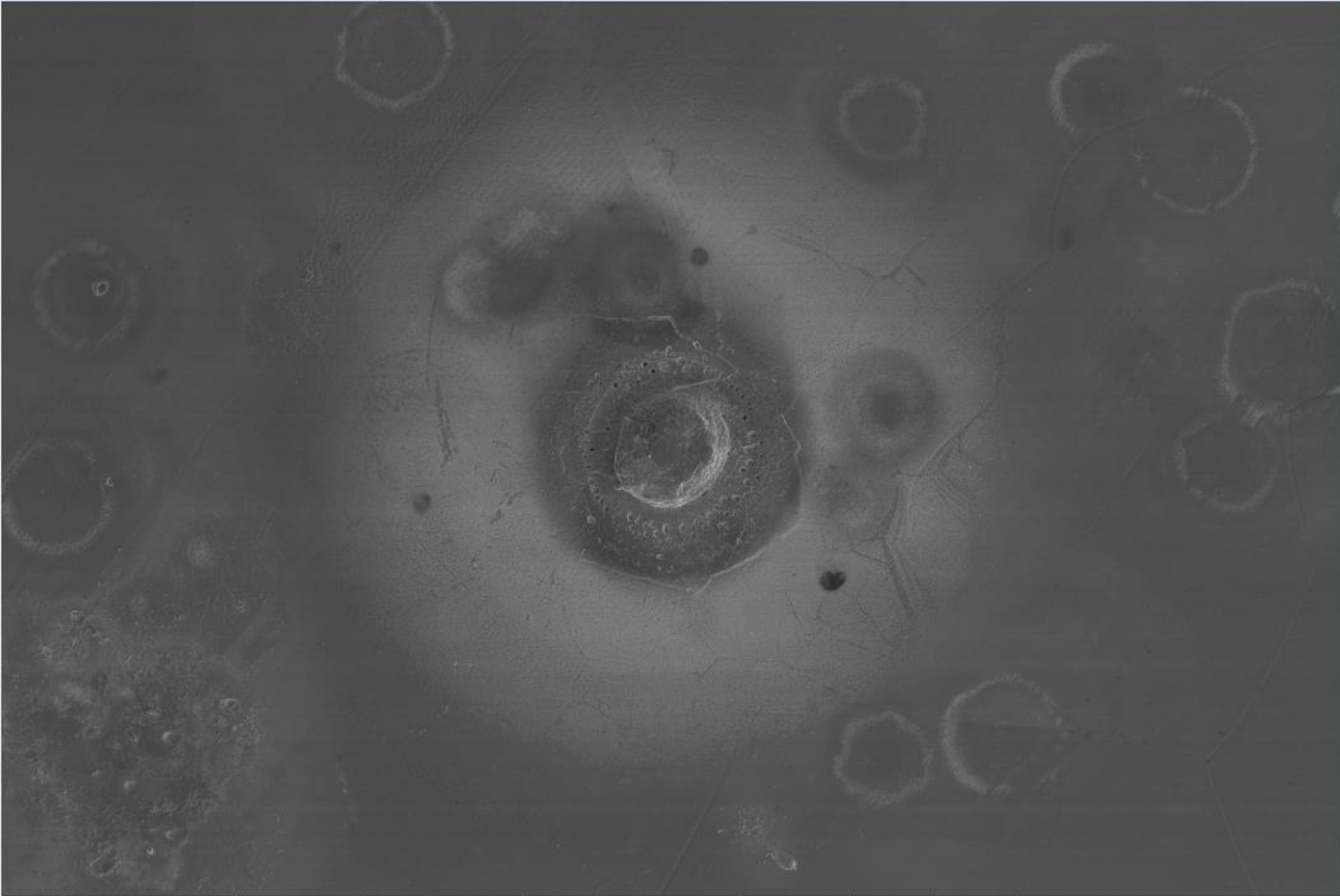
5/13/2017	HV	spot	mag	det	pressure	WD	dwell	5 μ m
9:30:38 PM	10.00 kV	3.0	15 000 x	TLD	2.59e-3 Pa	5.4 mm	20 μ s	Nova NanoSEM




4/8/2017	HV	spot	mag	det	pressure	dwell	tilt	mode	3 μ m
8:05:31 PM	10.00 kV	3.0	25 000 x	TLD	2.48e-3 Pa	10 μ s	0 $^{\circ}$	SE	Nova NanoSEM NPEP278

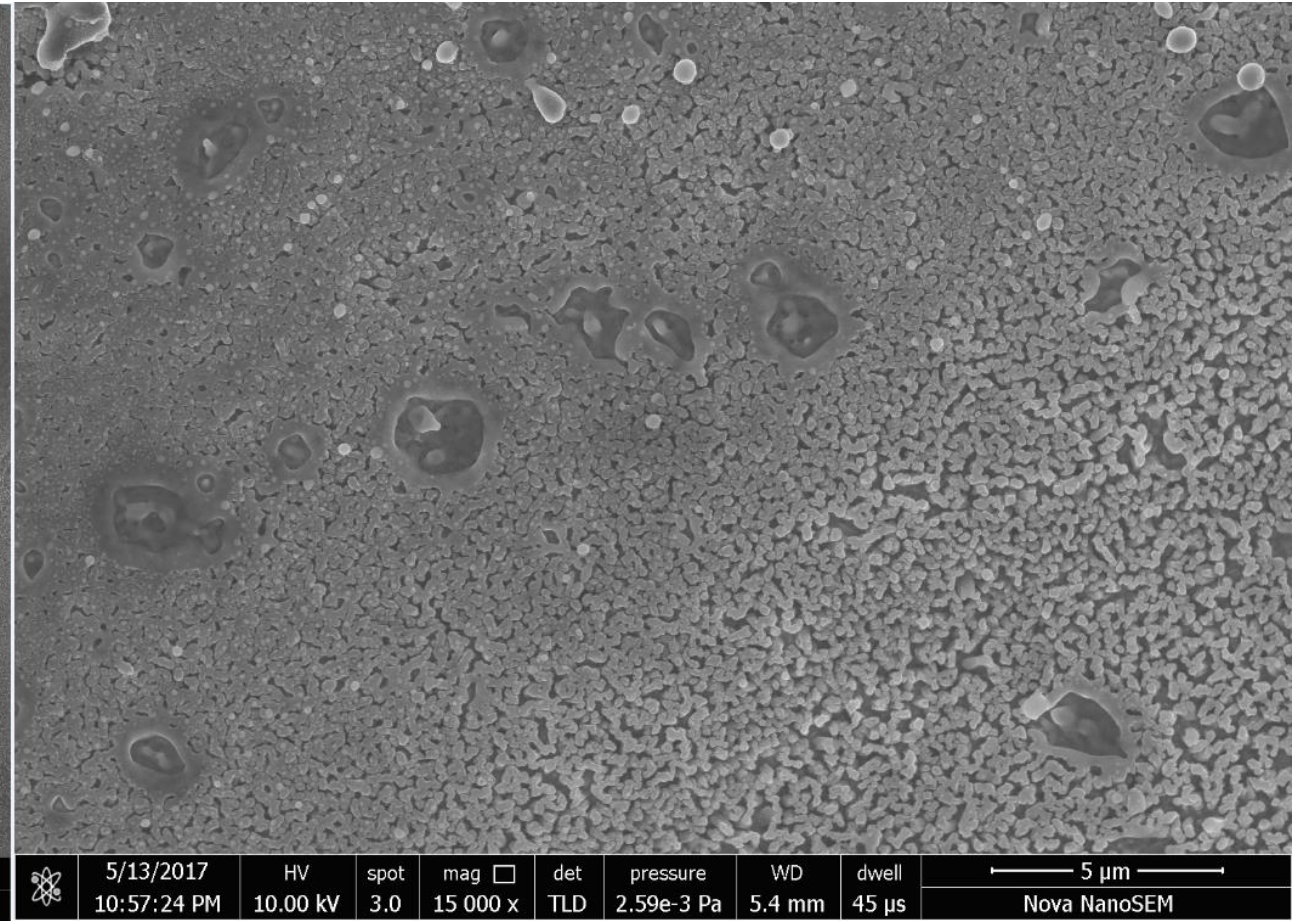
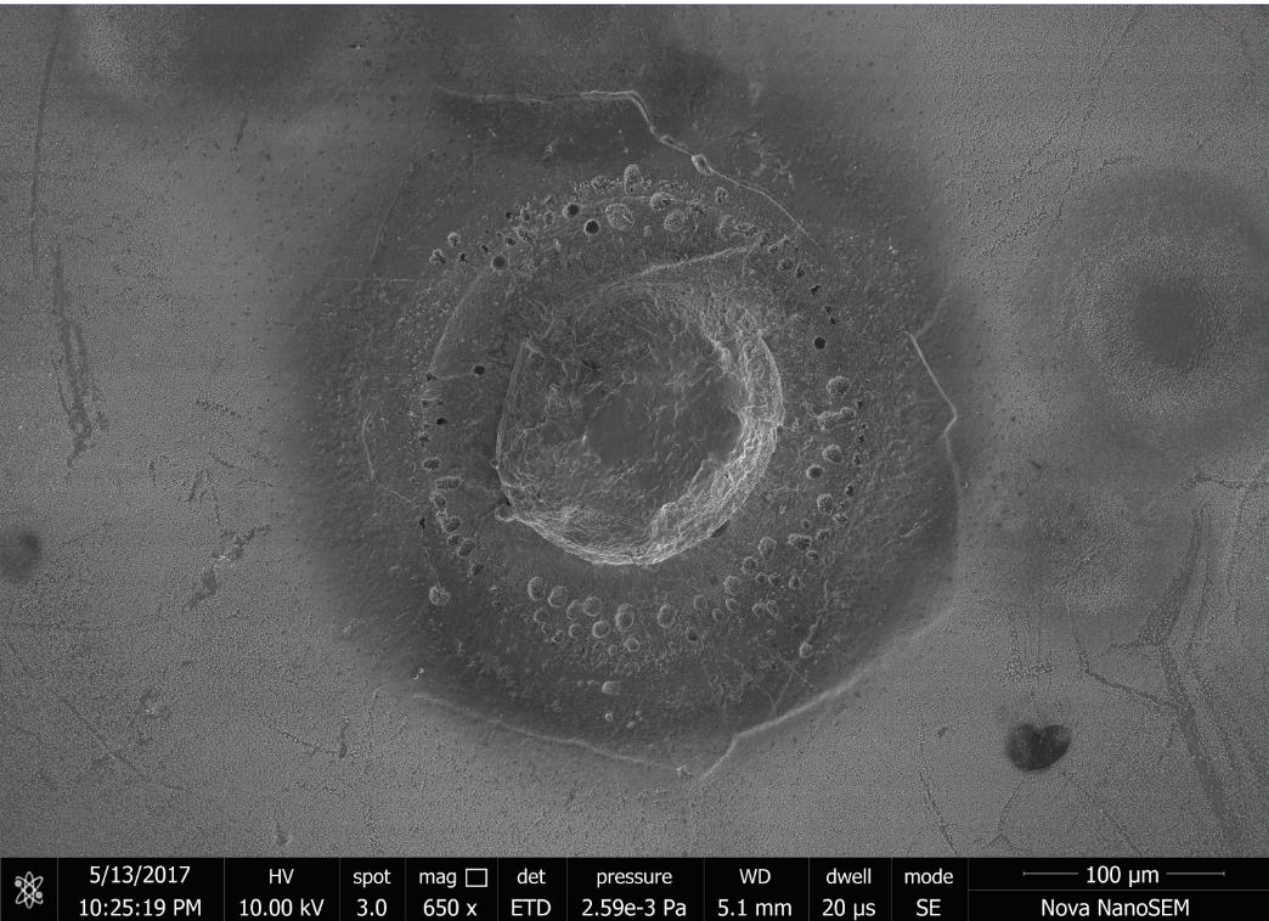
Hard Cu

Soft Cu anode 1

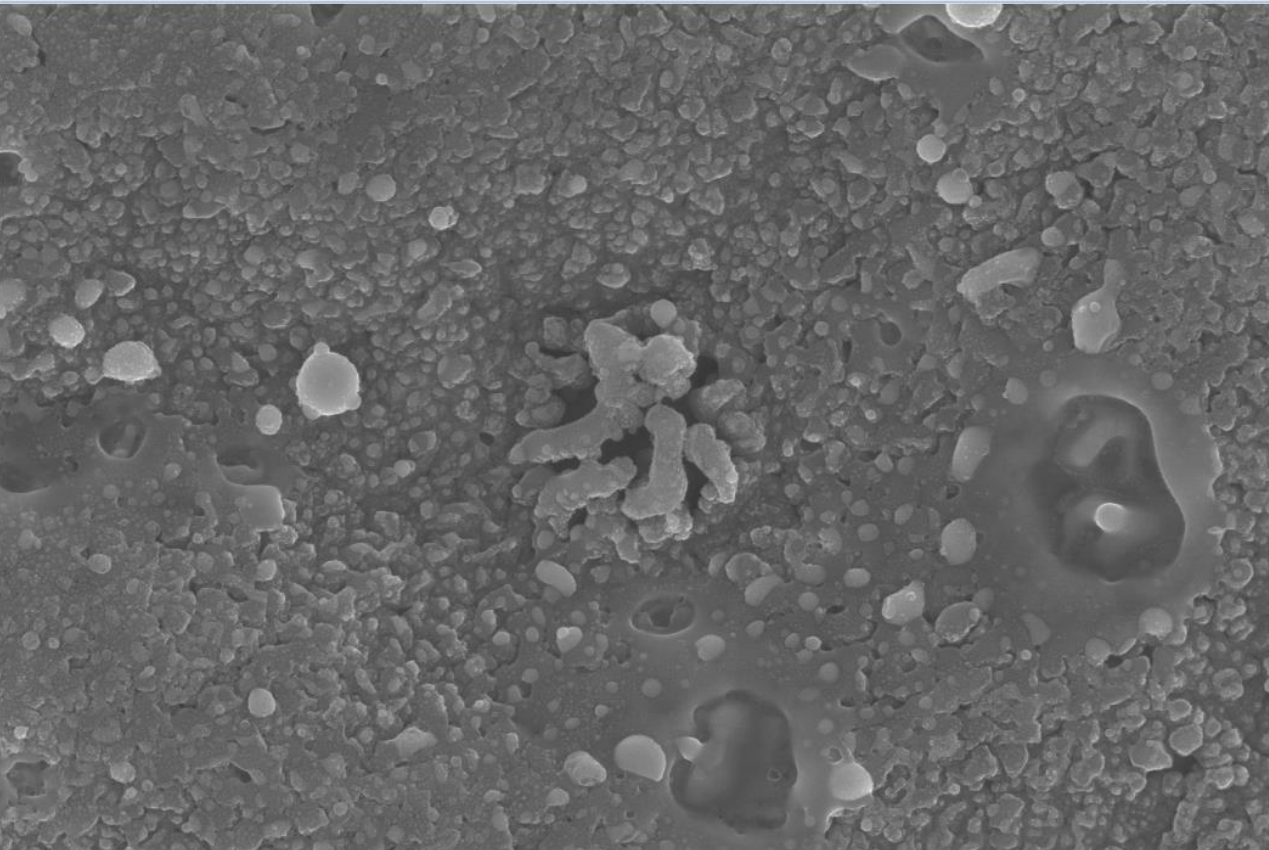


	5/13/2017	HV	spot	mag	det	pressure	WD	dwell	mode	300 μ m
	10:14:08 PM	10.00 kV	3.0	250 x	ETD	2.59e-3 Pa	5.1 mm	20 μ s	SE	

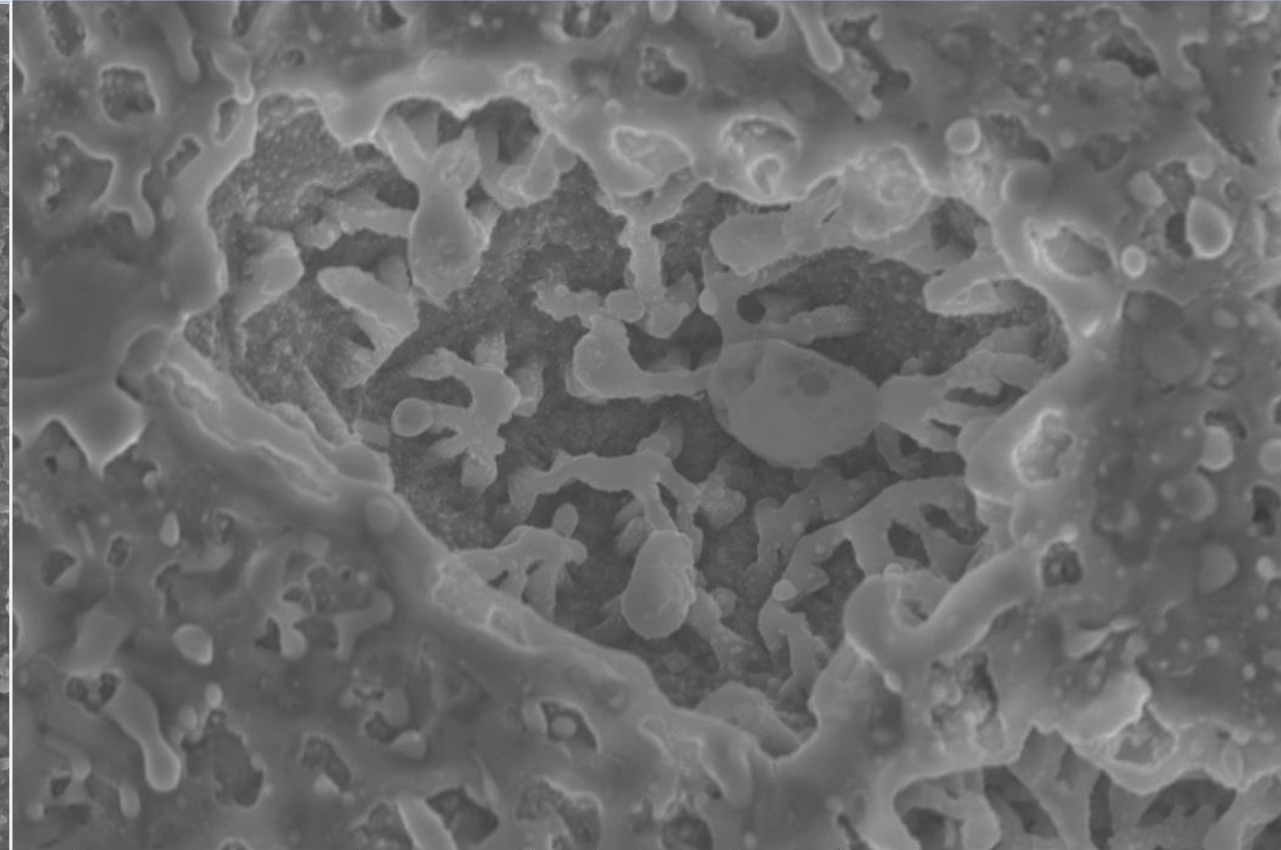
Soft Cu anode 2



Soft Cu anode 3



5/13/2017 11:10:21 PM	HV 10.00 kV	spot 3.0	mag <input type="checkbox"/> 50 000 x	det TLD	pressure 2.59e-3 Pa	WD 5.4 mm	dwell 45 μ s	2 μ m	Nova NanoSEM
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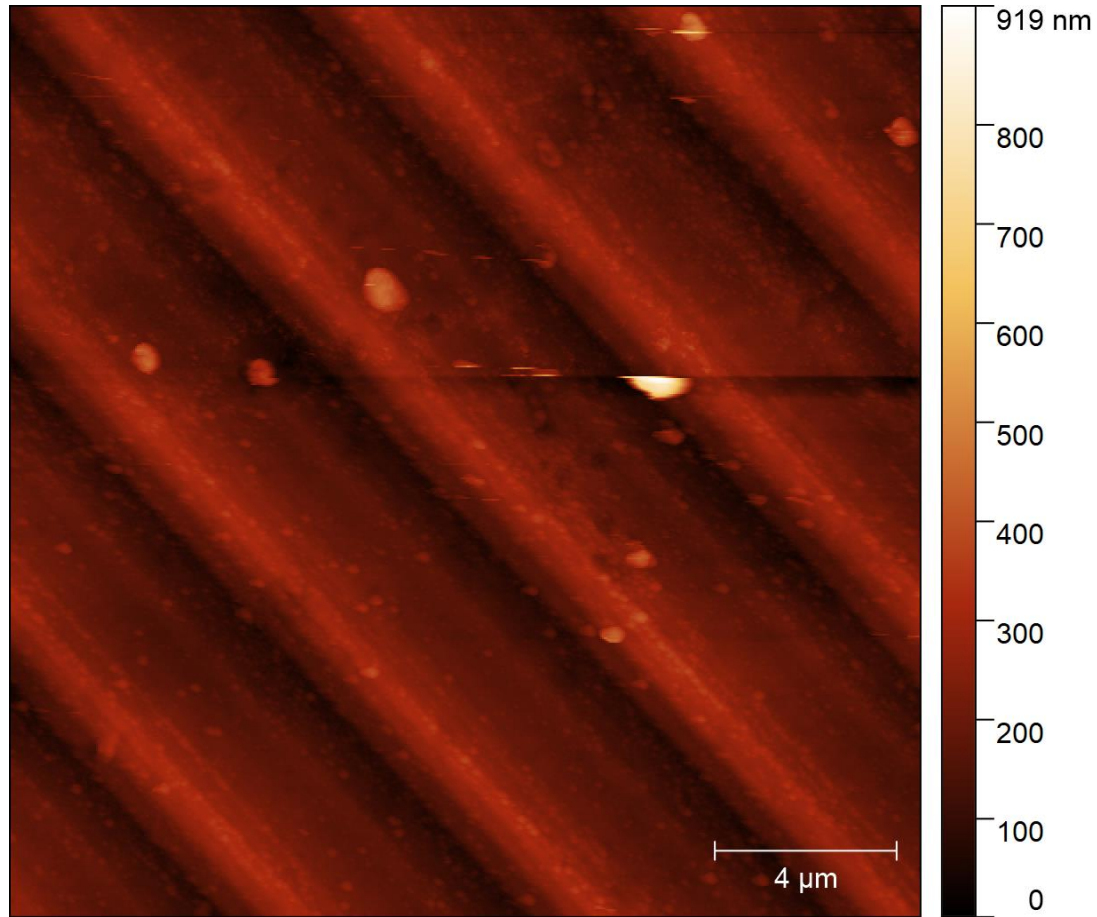


5/13/2017 11:18:17 PM	HV 10.00 kV	spot 3.0	mag <input type="checkbox"/> 25 000 x	det TLD	pressure 2.59e-3 Pa	WD 5.4 mm	dwell 45 μ s	4 μ m	Nova NanoSEM
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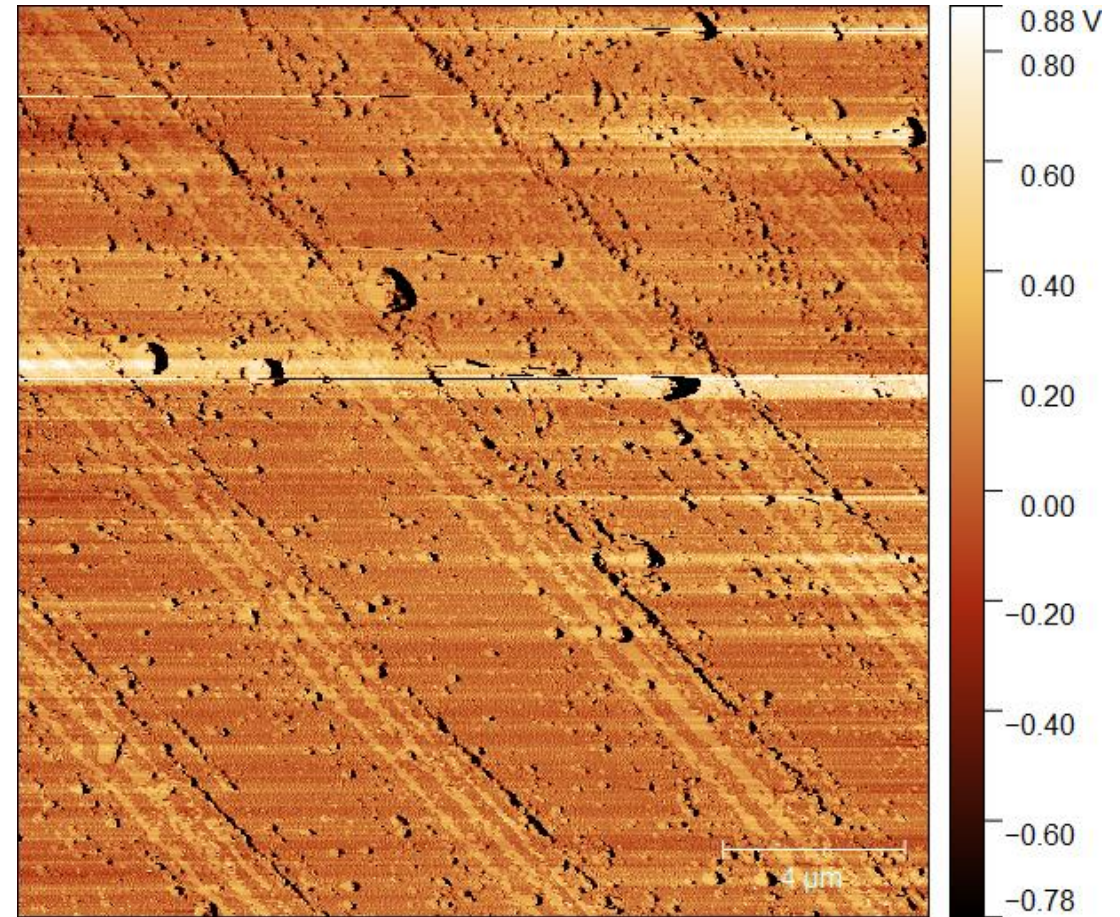


AFM images (only hard Cu cathode)

Plain surface topography & surface potential

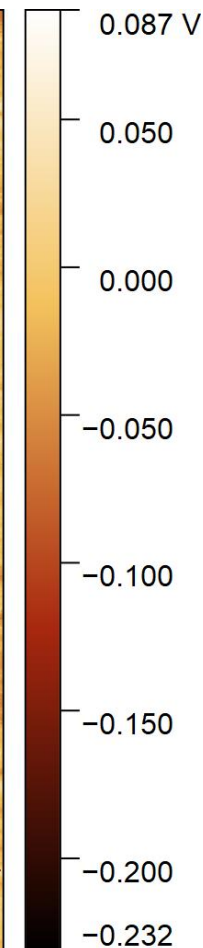
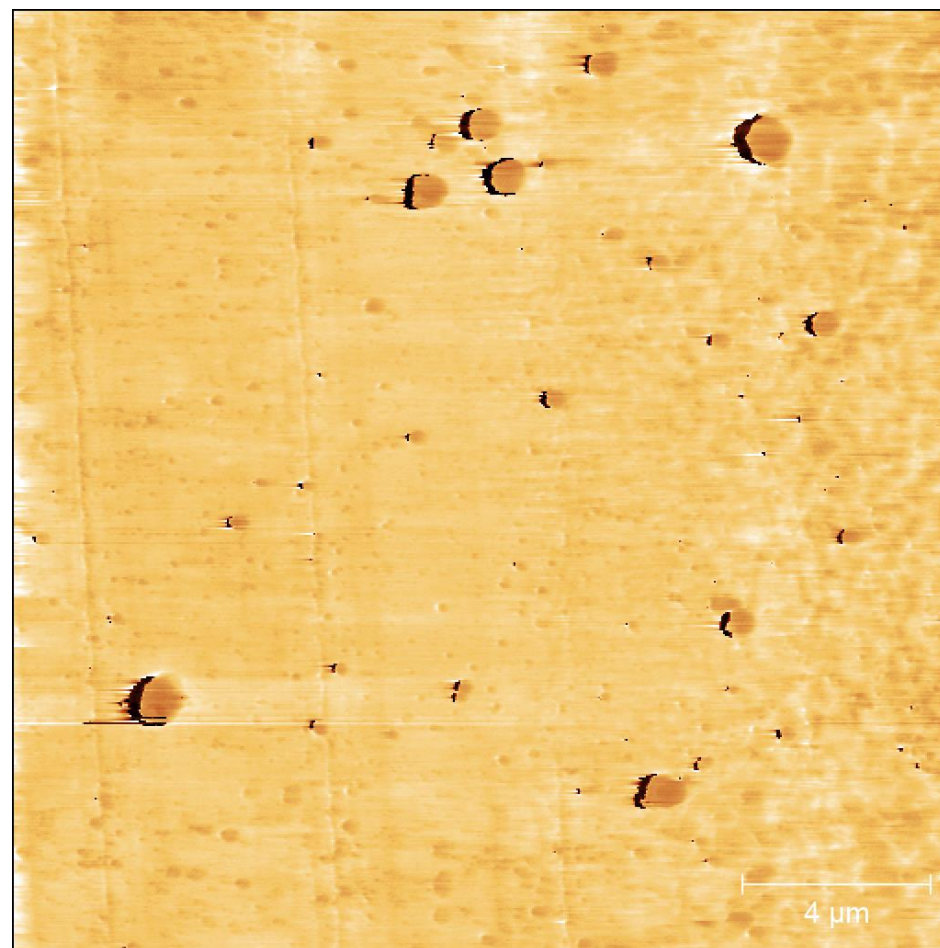
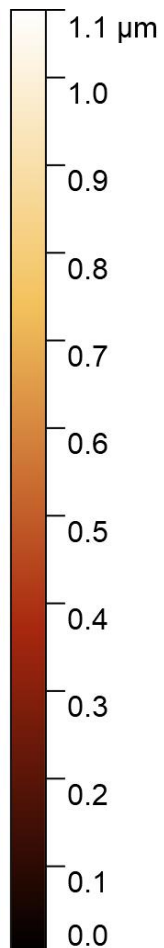
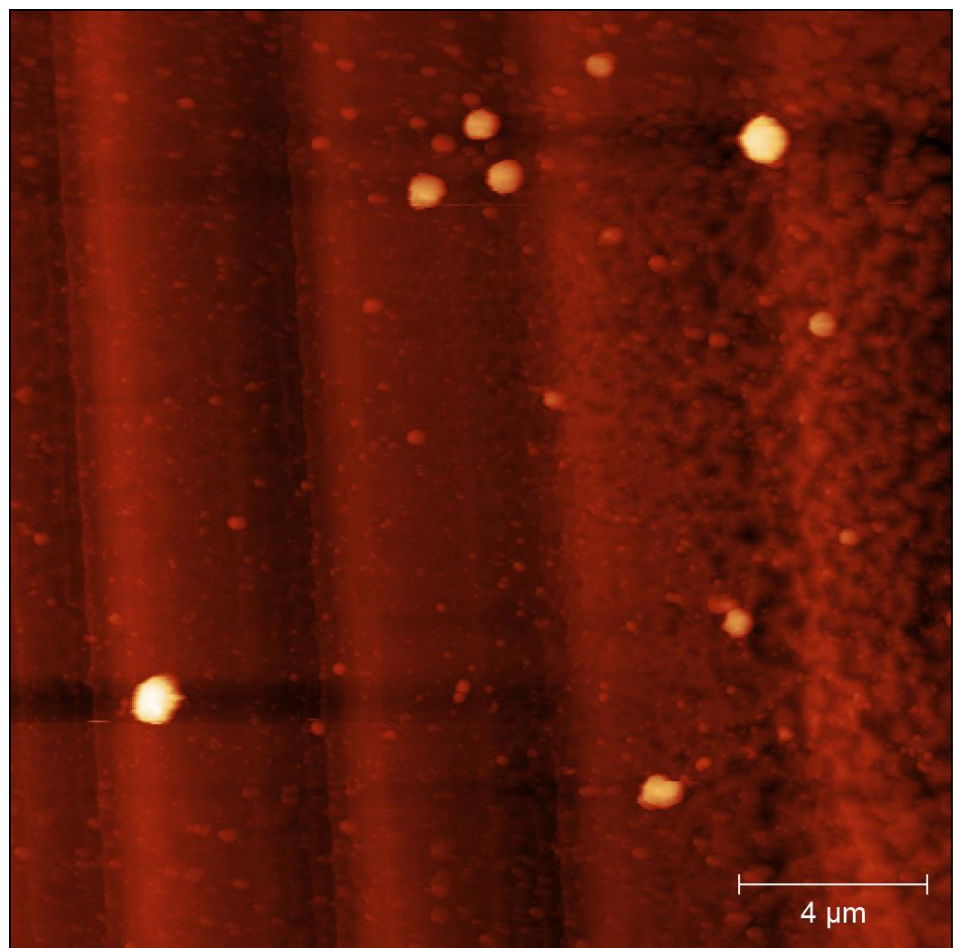


Topography



Potential image

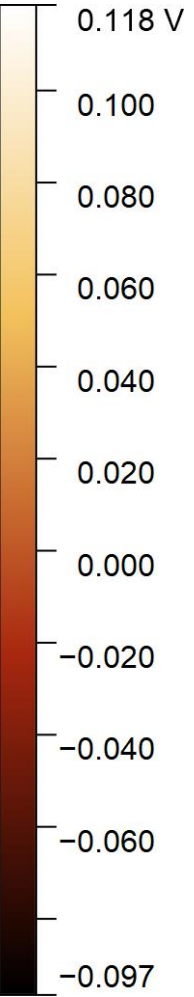
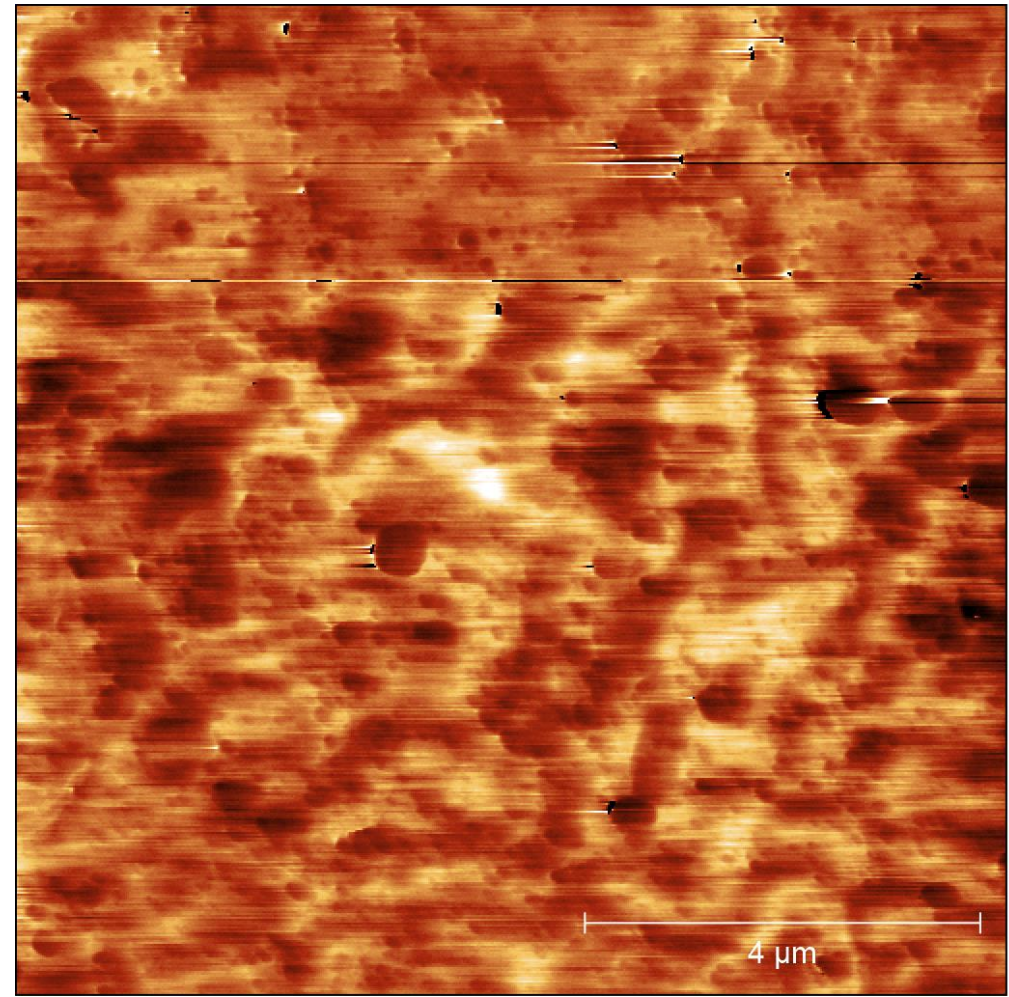
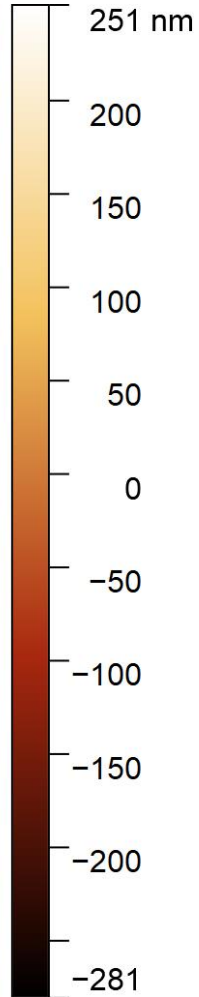
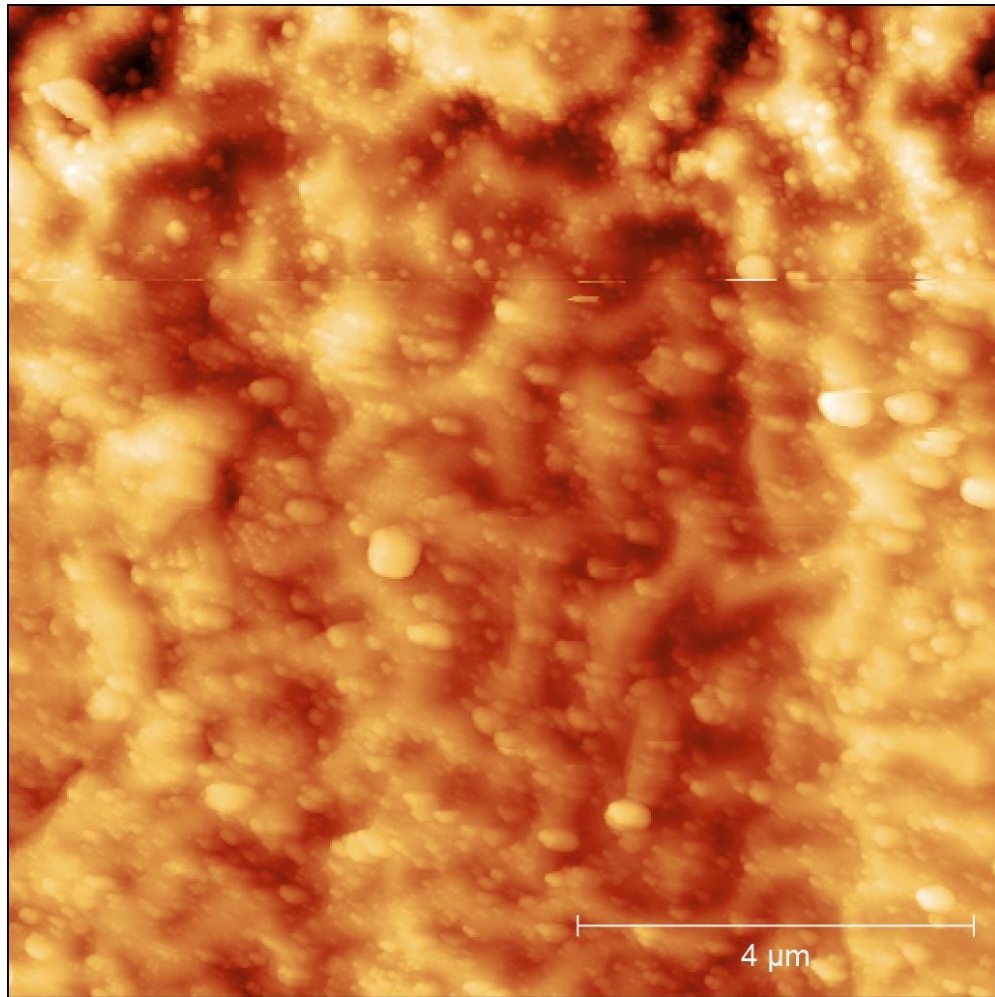
Crater edge topography & potential



Topography

Potential image

Crater topo vs potential

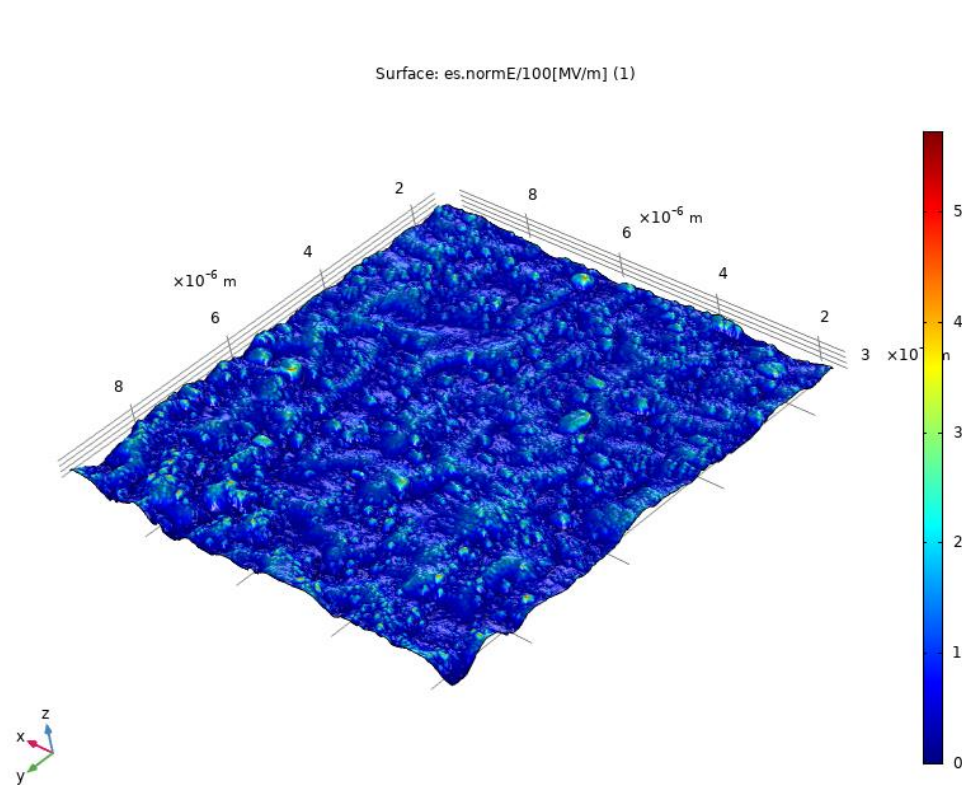
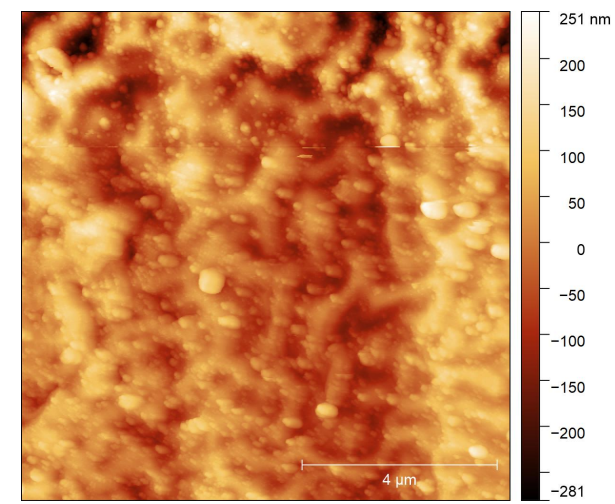


Topography

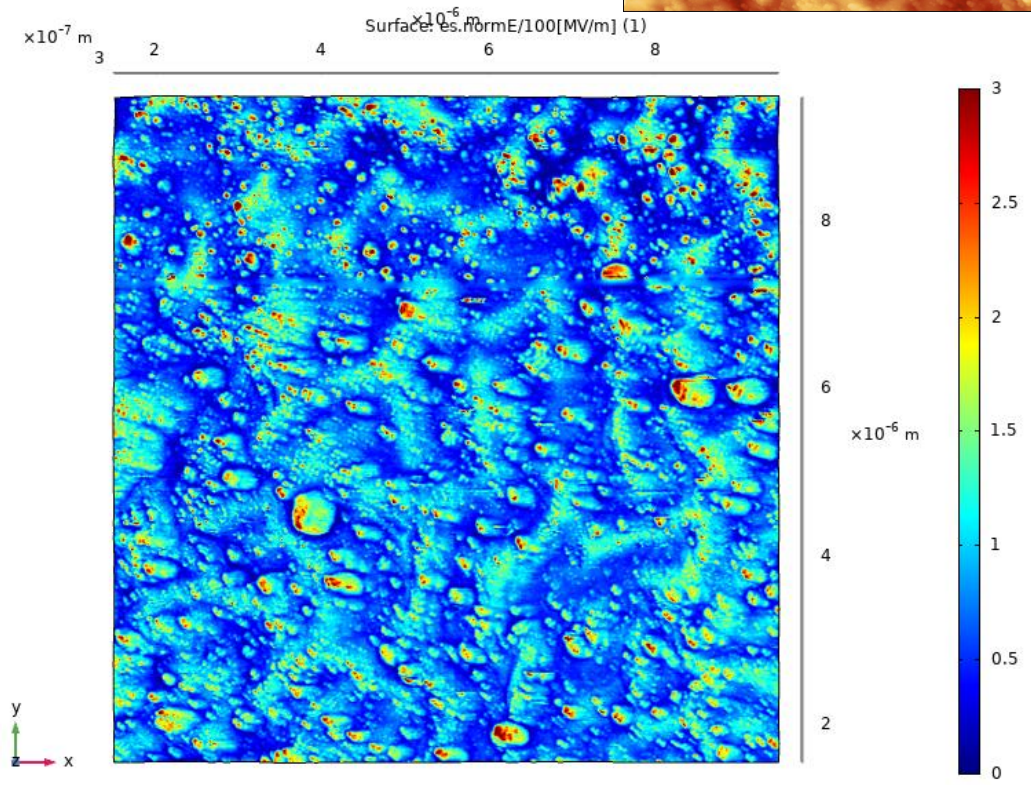
Potential image

Field enhancement image

Field enhancement up to 5 times due to topology.



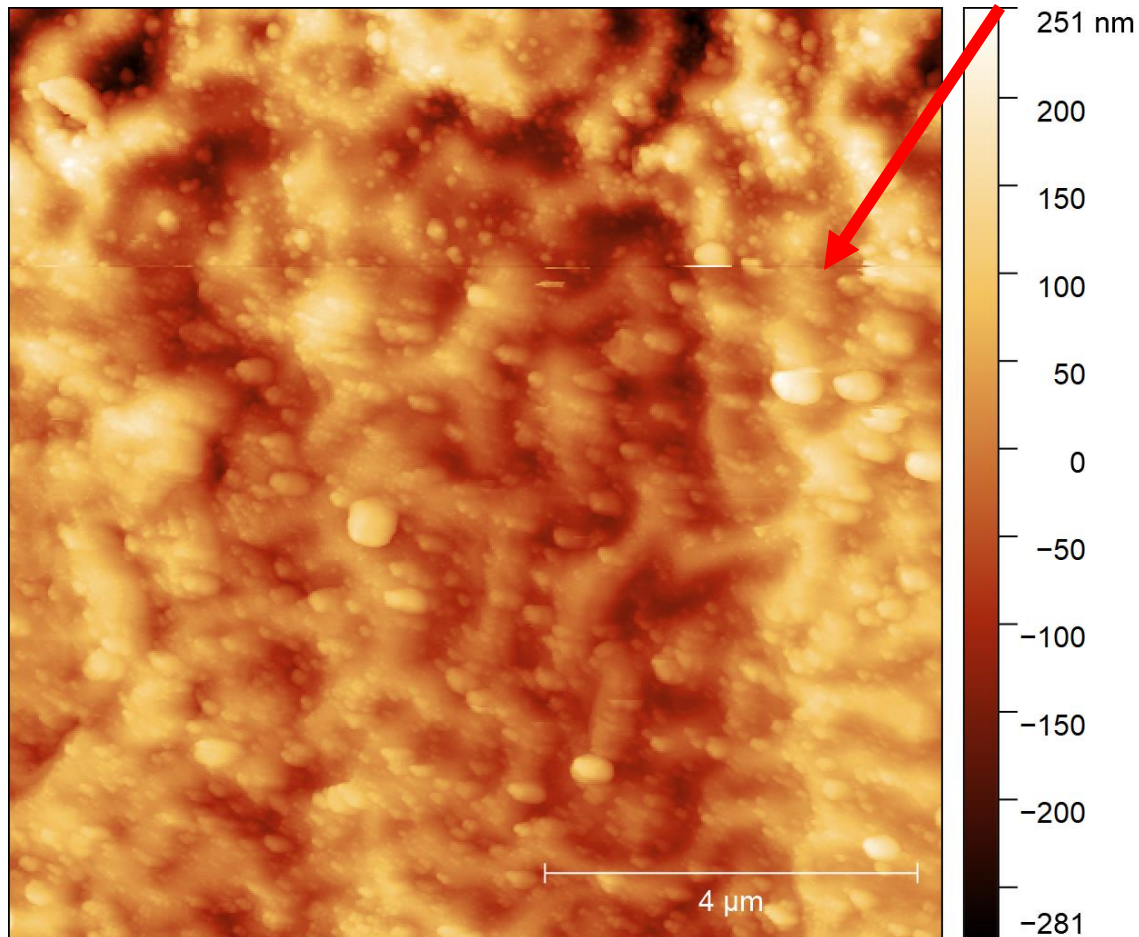
Field enhancement modeling



Field enhancement capped at 3

Mapping large craters

Mapping of the most interesting part is almost impossible.



¾ of image with dull tip

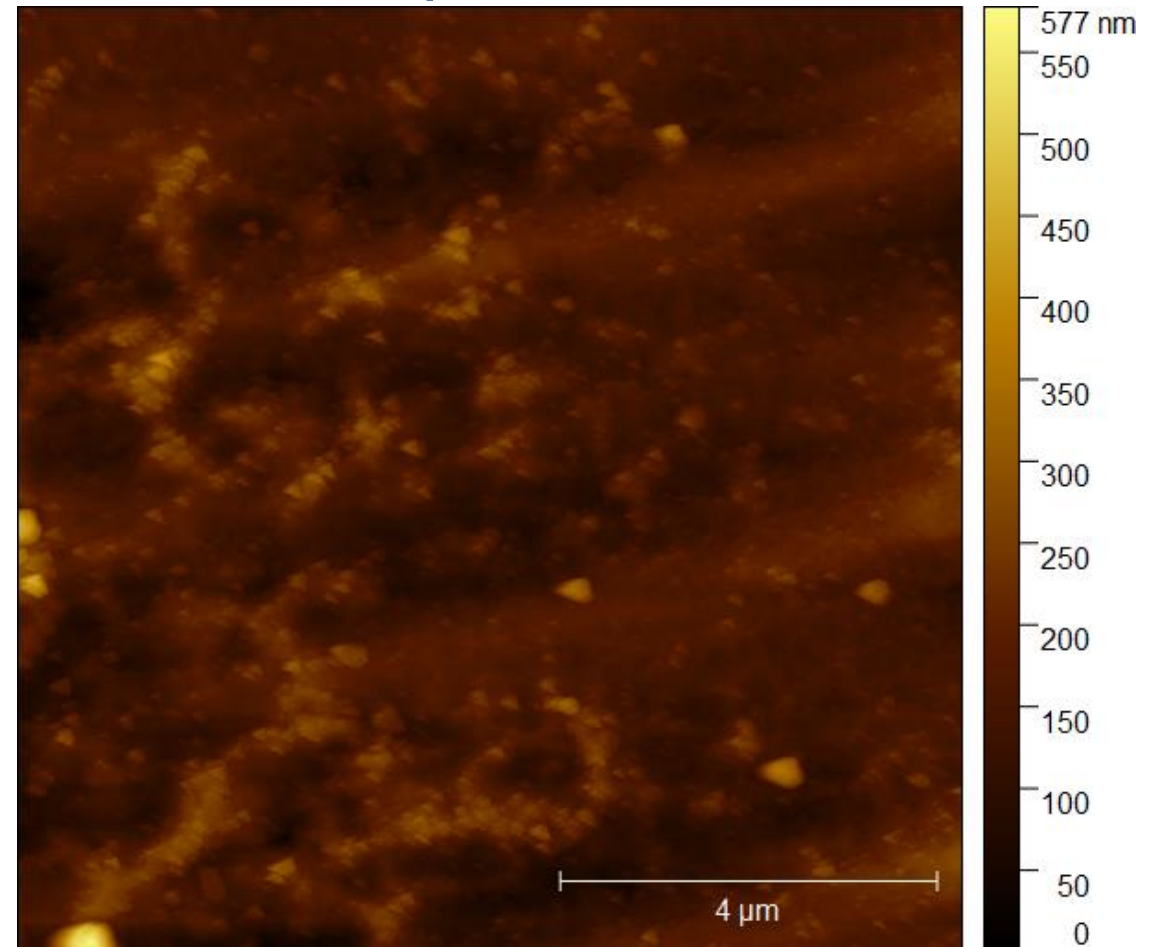


Image of crater with artefacts



Conclusions & plans

The surface topology in craters is very rough, forming a lot of interesting structures.

The field enhancement of the protrusions can be at least up to 5.

Plans:

Also analyse Cu electrodes without plasma treatment.



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Haridus- ja Teadusministeerium
Estonian Ministry of Education and Research



Thank You!