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MATTER

Characterization of Cu electrodes after vacuum breakdown with AFM and SEM

9th International Workshop on Mechanisms of Vacuum Arcs (MeVArc 2021)

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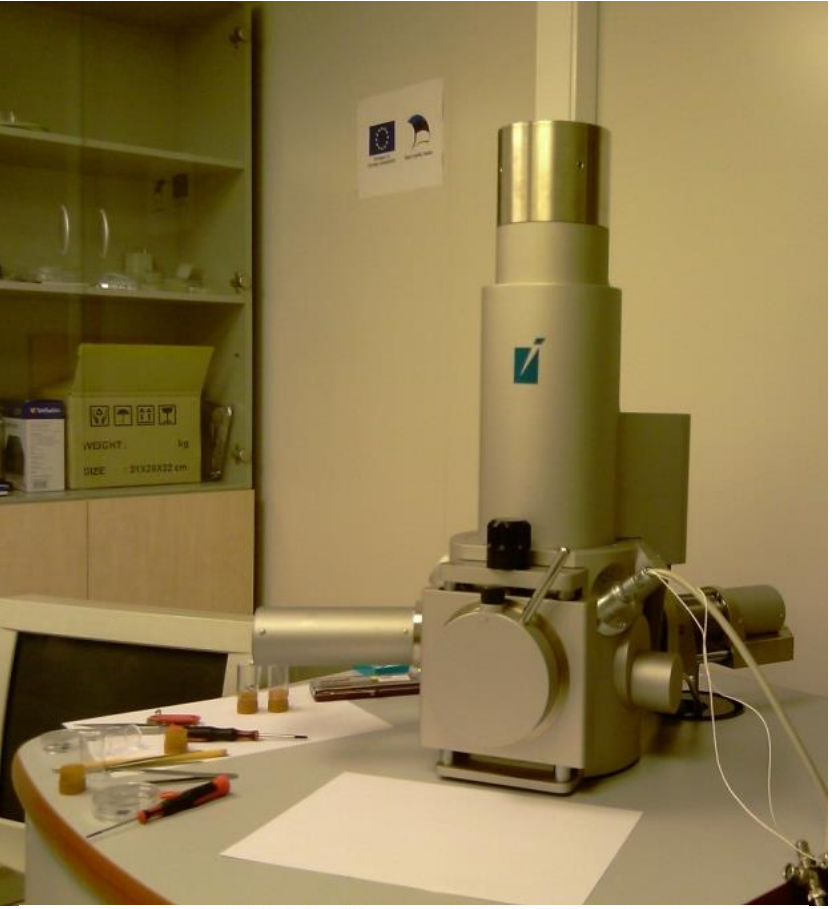
Introduction

We have received a pair of Cu electrodes from Helsinki.

Backside was removed by turning.

Aim was to characterize with SEM and AFM.

All experiments were done on cathode. We haven’t looked at anode yet.



SEM

Vega-II SBU TESCAN

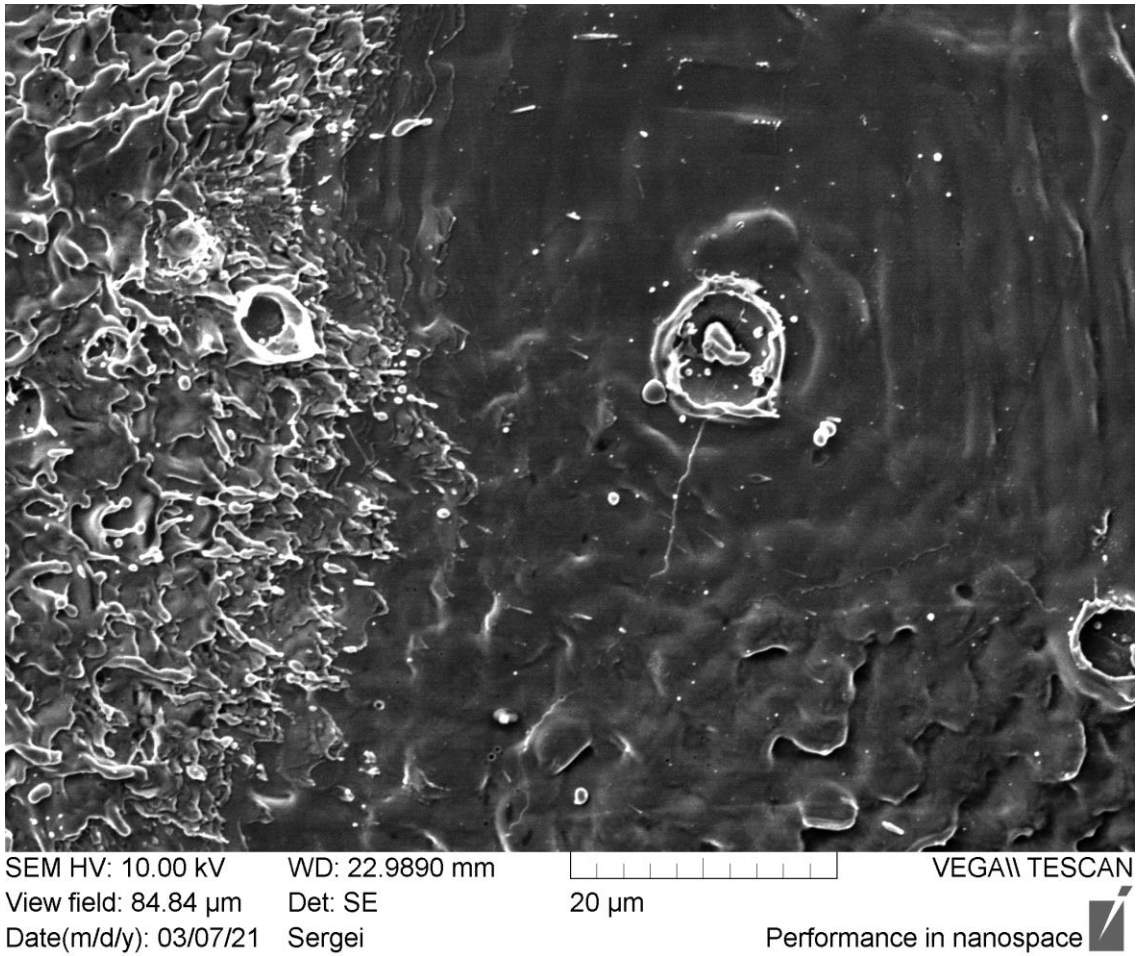
Applied voltage 10 kV.

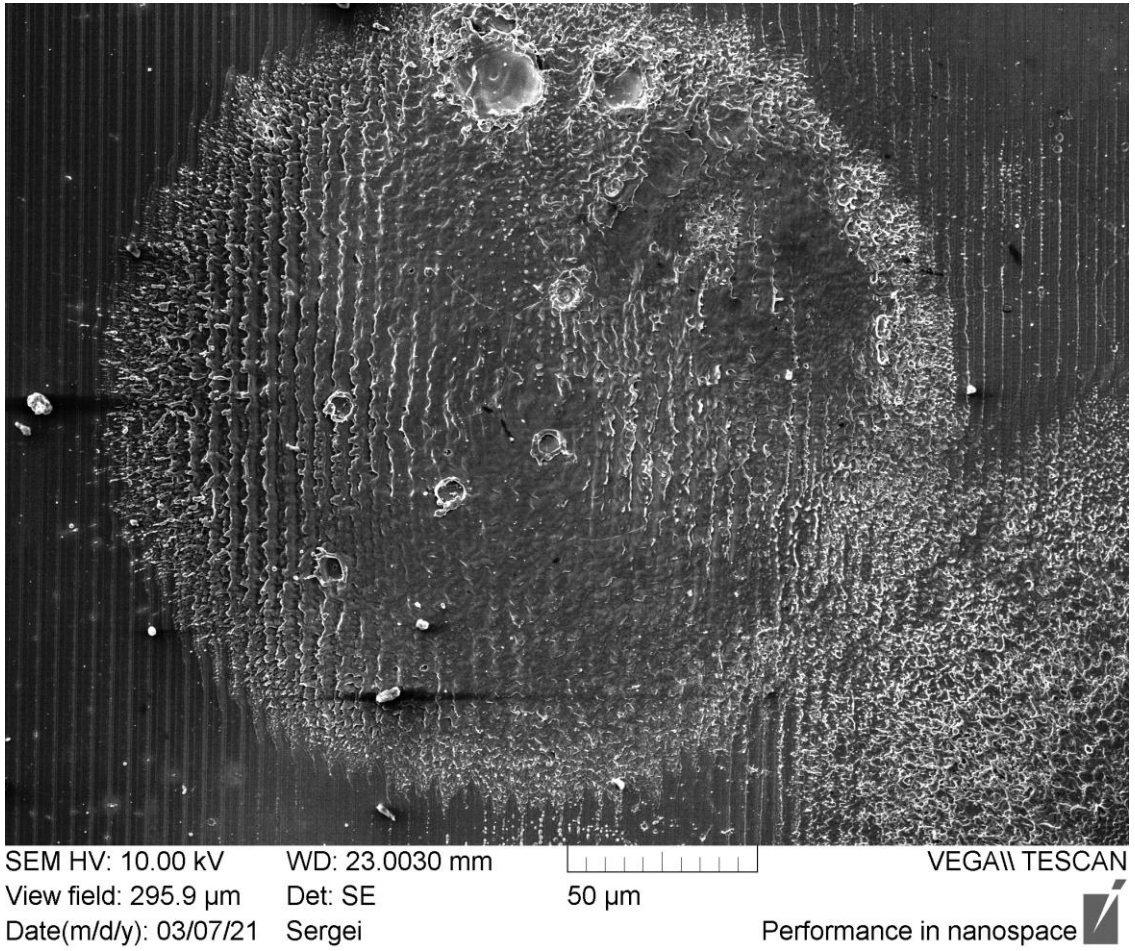
Pressure around $4 \cdot 10^{-4}\ mbar$

Stage can be tilted up to 20 deg.

Center structure

A particle like structure in the middle of the crater (but not always).

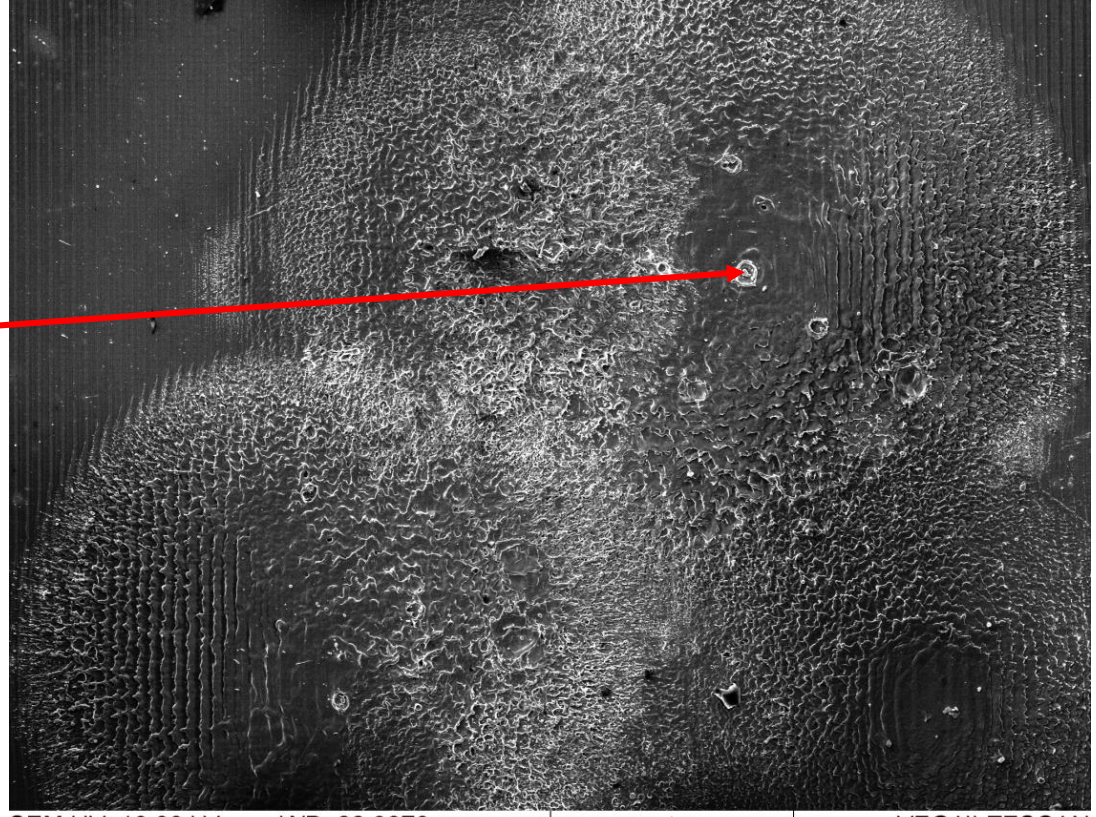


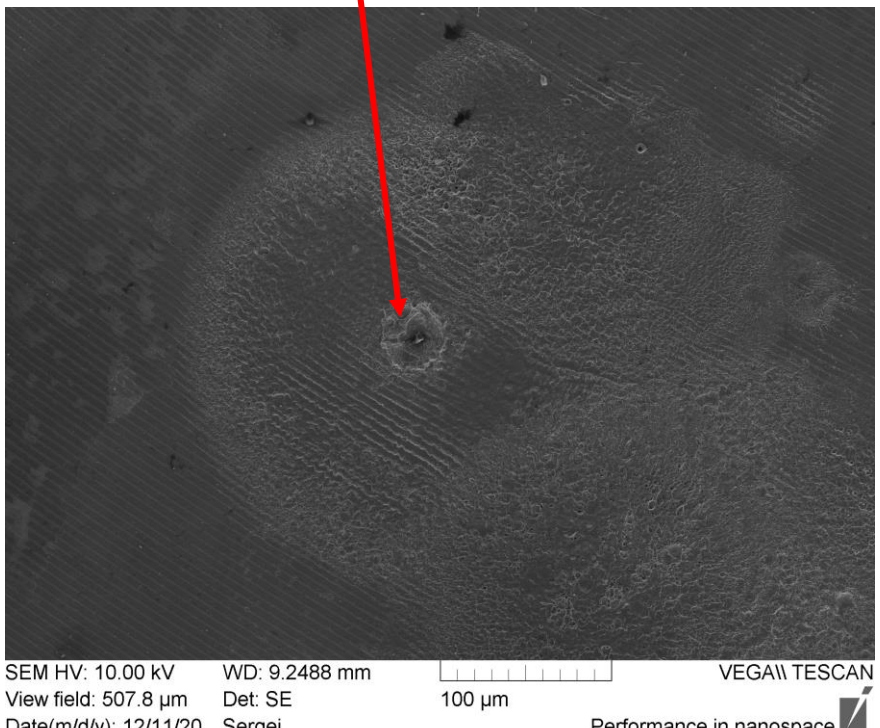


Portrusions

Usually no protrusions in the center area of the crater.

The width of the protrusion-free area can vary.

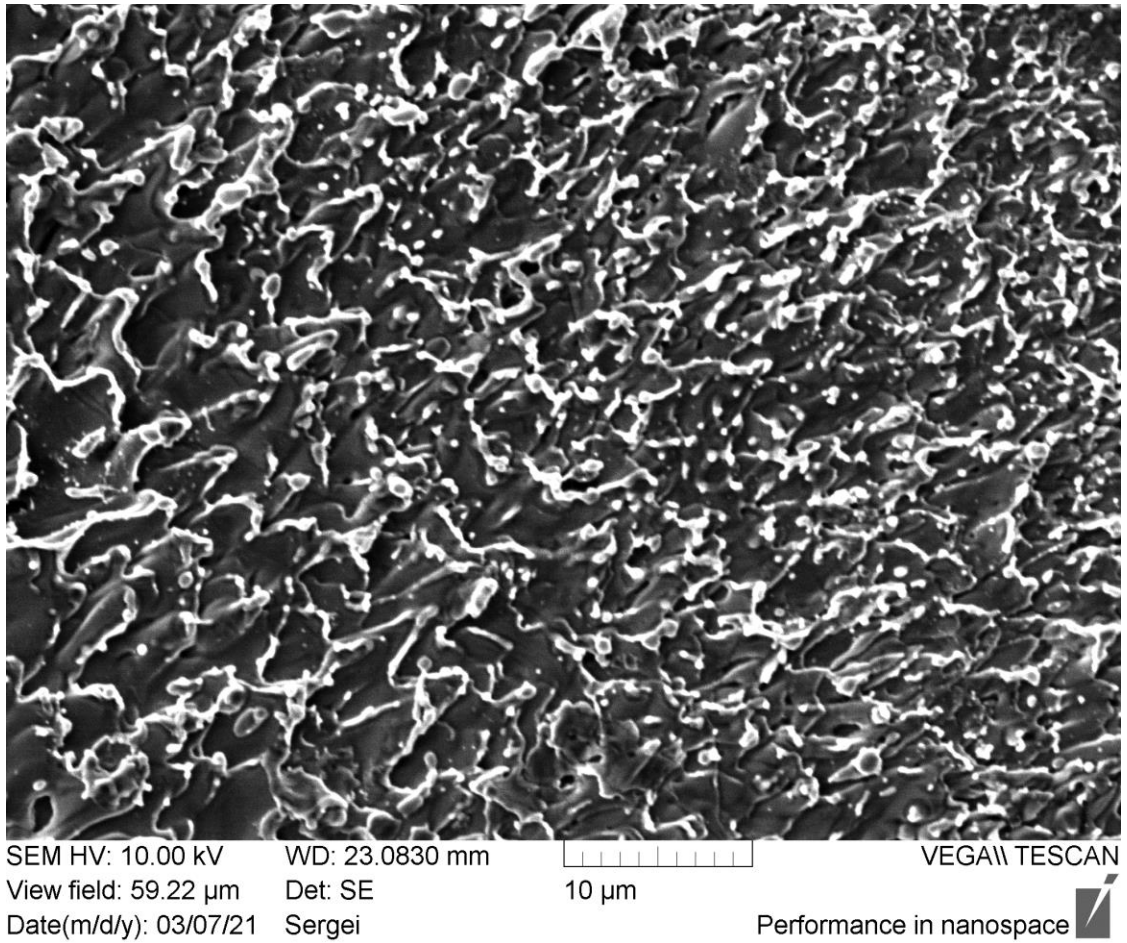


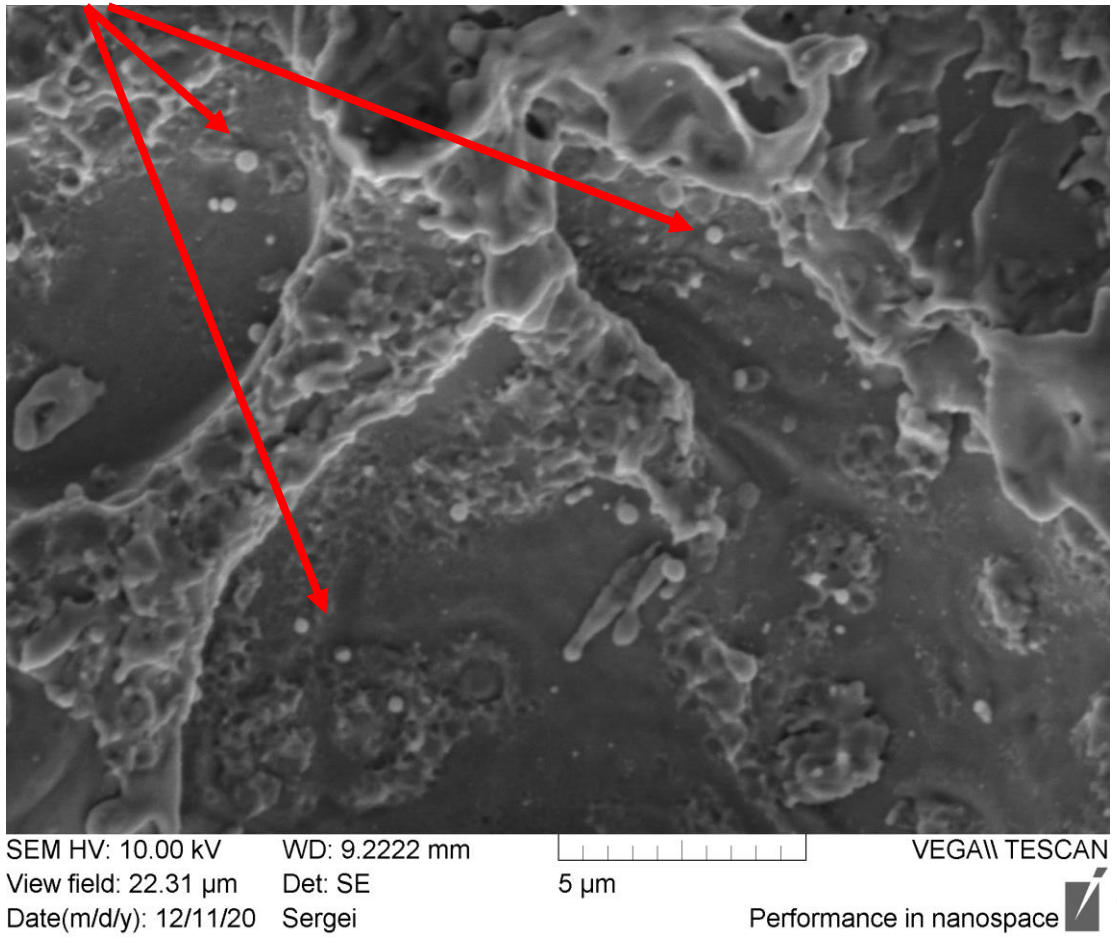


Portrusions and particles

The sides of the crater are filled with various protrusions.

In some cases there are some ball-like particles.





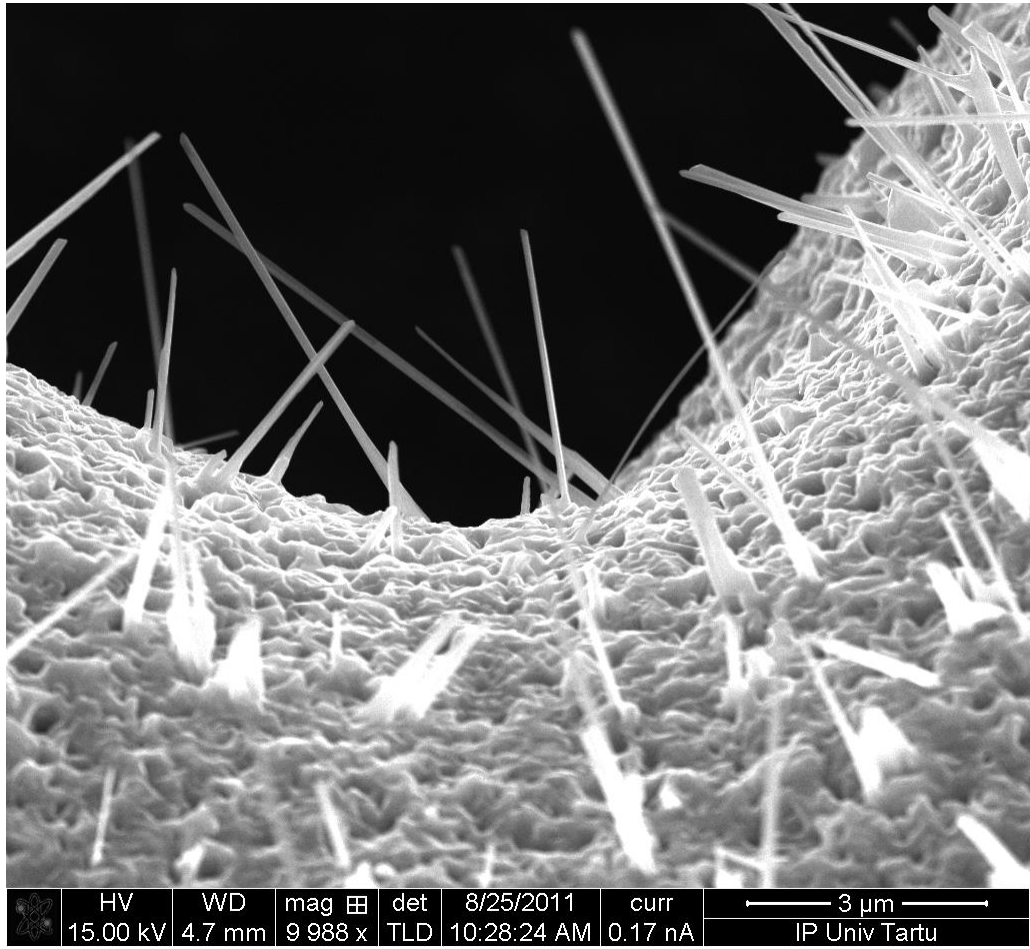
Growth of CuO nanowires

Another candidate for protrusions:

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

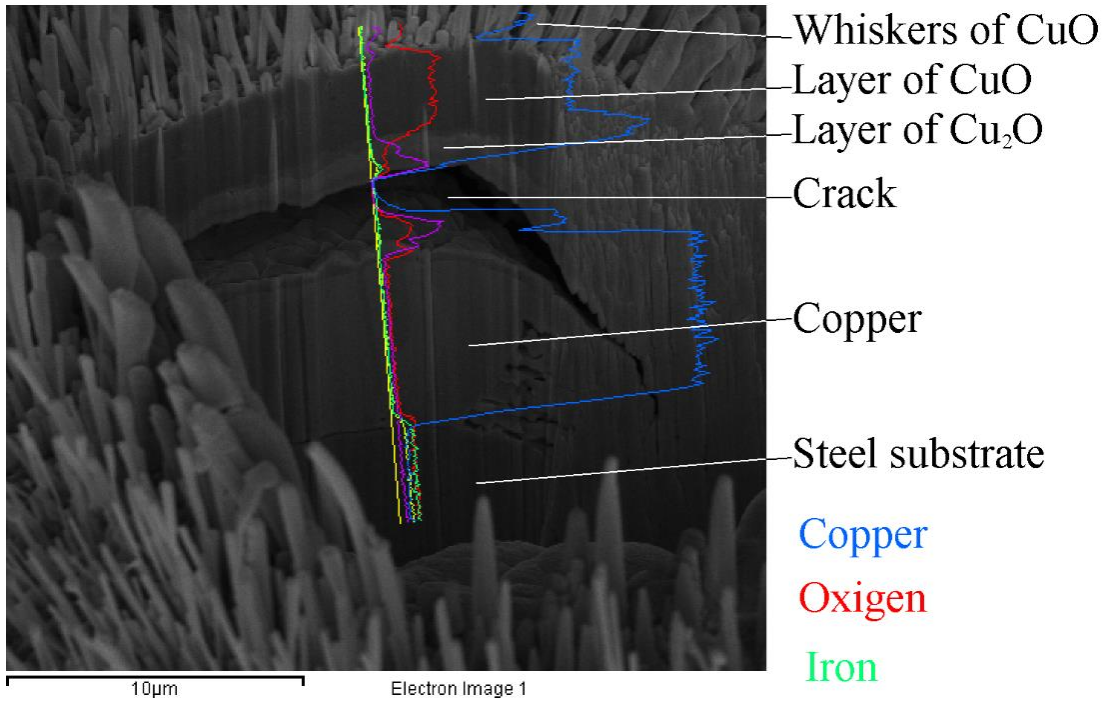
Temperatures 400°-700° results in NWs.

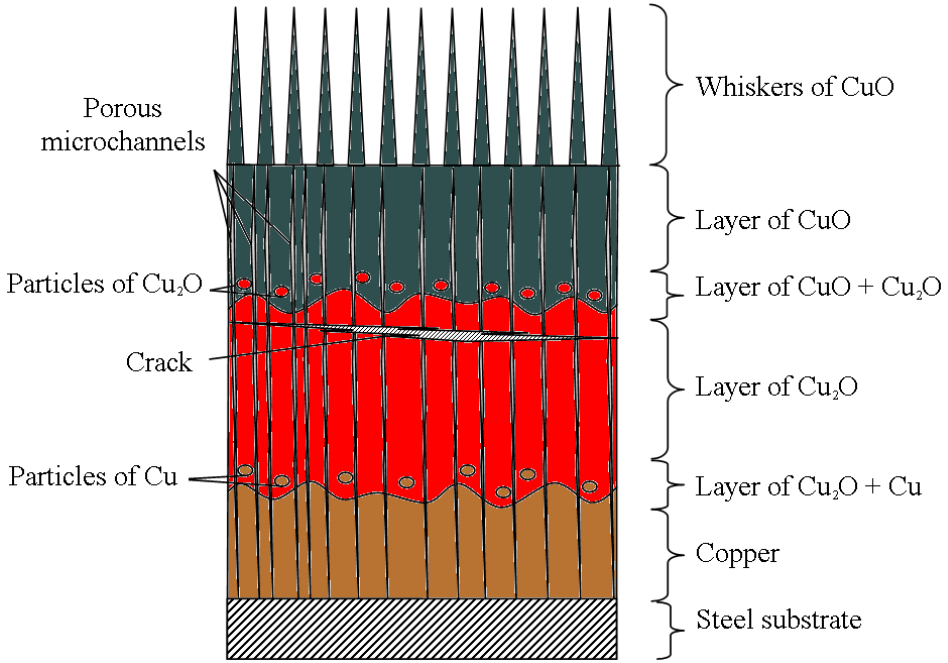
Higher temperatures produces particles.



Cu sample with CuO nanowires:

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

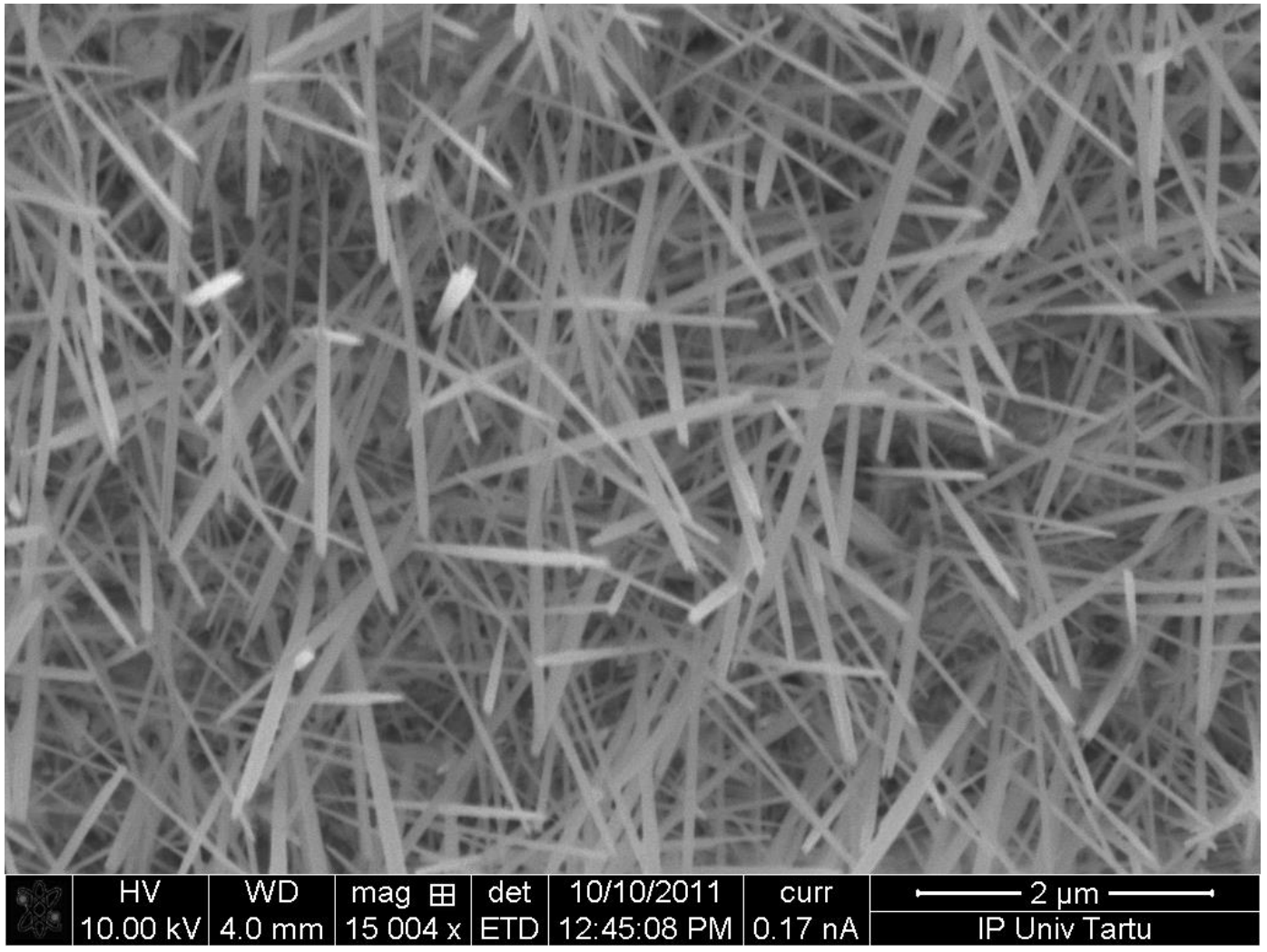




Dorogov, et. al, Appl. Surf. Sci. ***246****, 423 (2015).*

SEM tungsten filament

Tungsten Oxide NWs grown on burnt tungsten filament used in SEM



Estimating the amount of molecules in CLIC

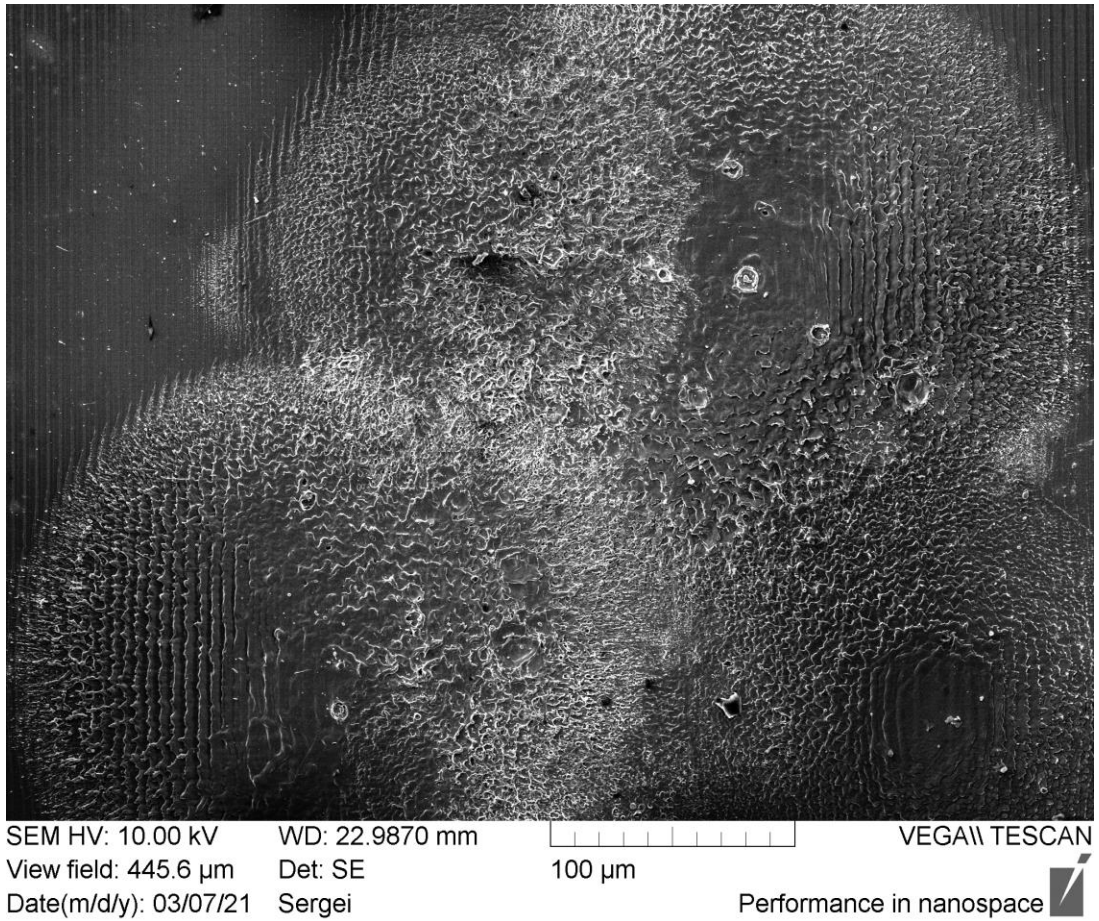
$$T = 293K$$

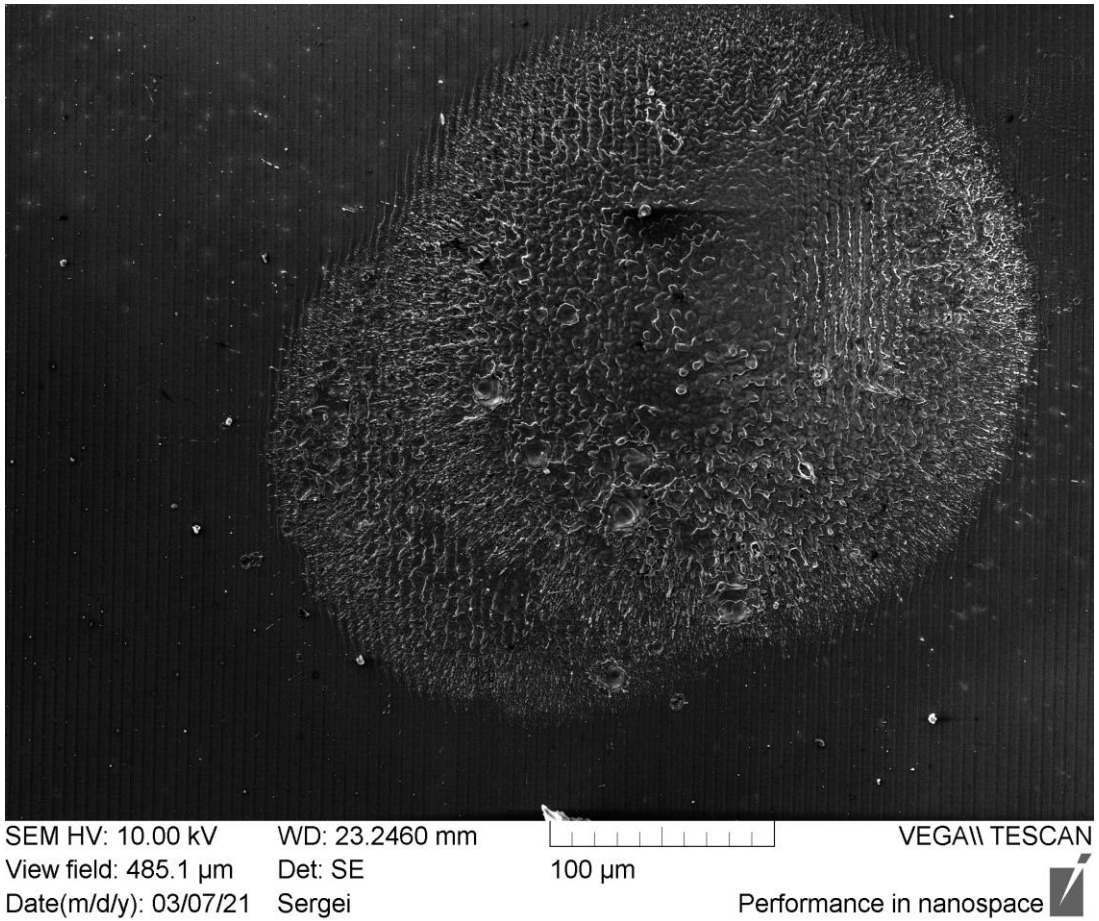
$$P = 10^{-9} mbar$$

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

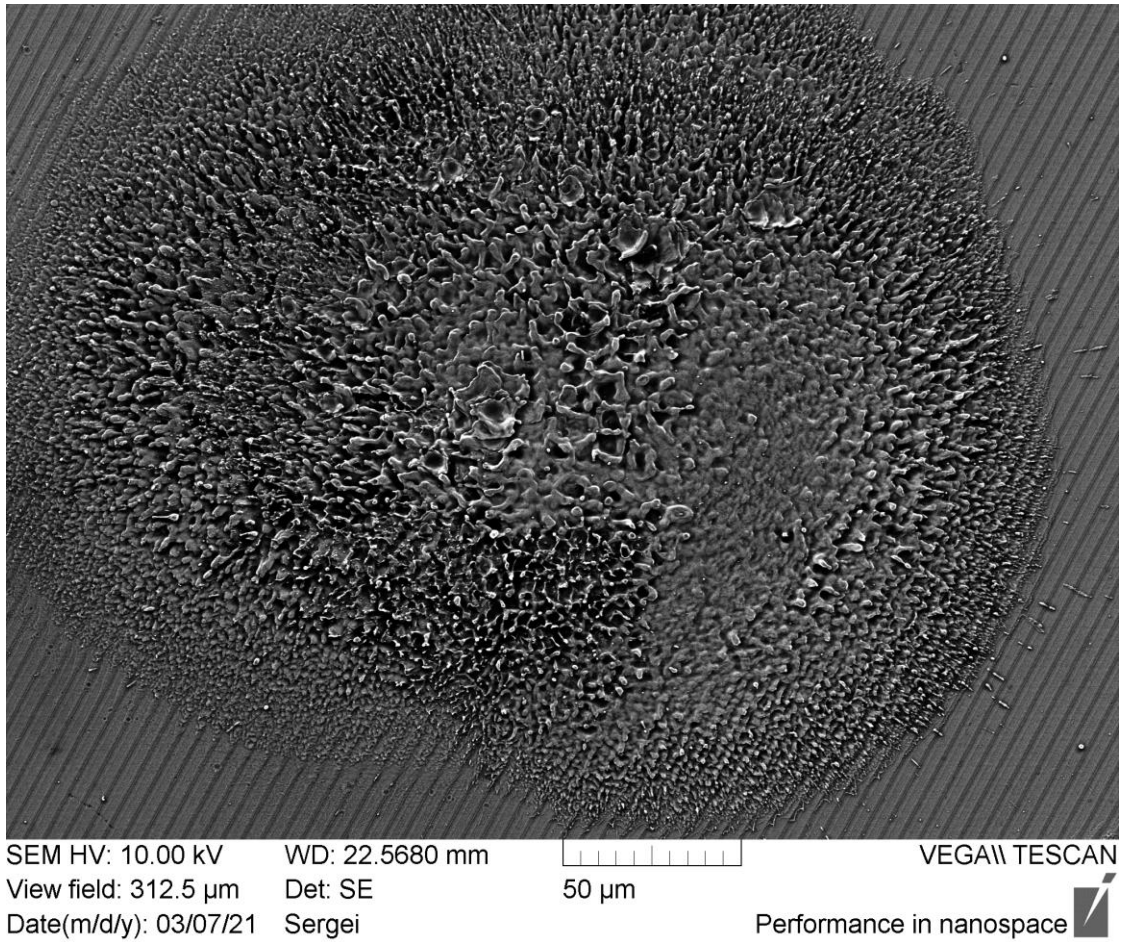
Clustering of craters

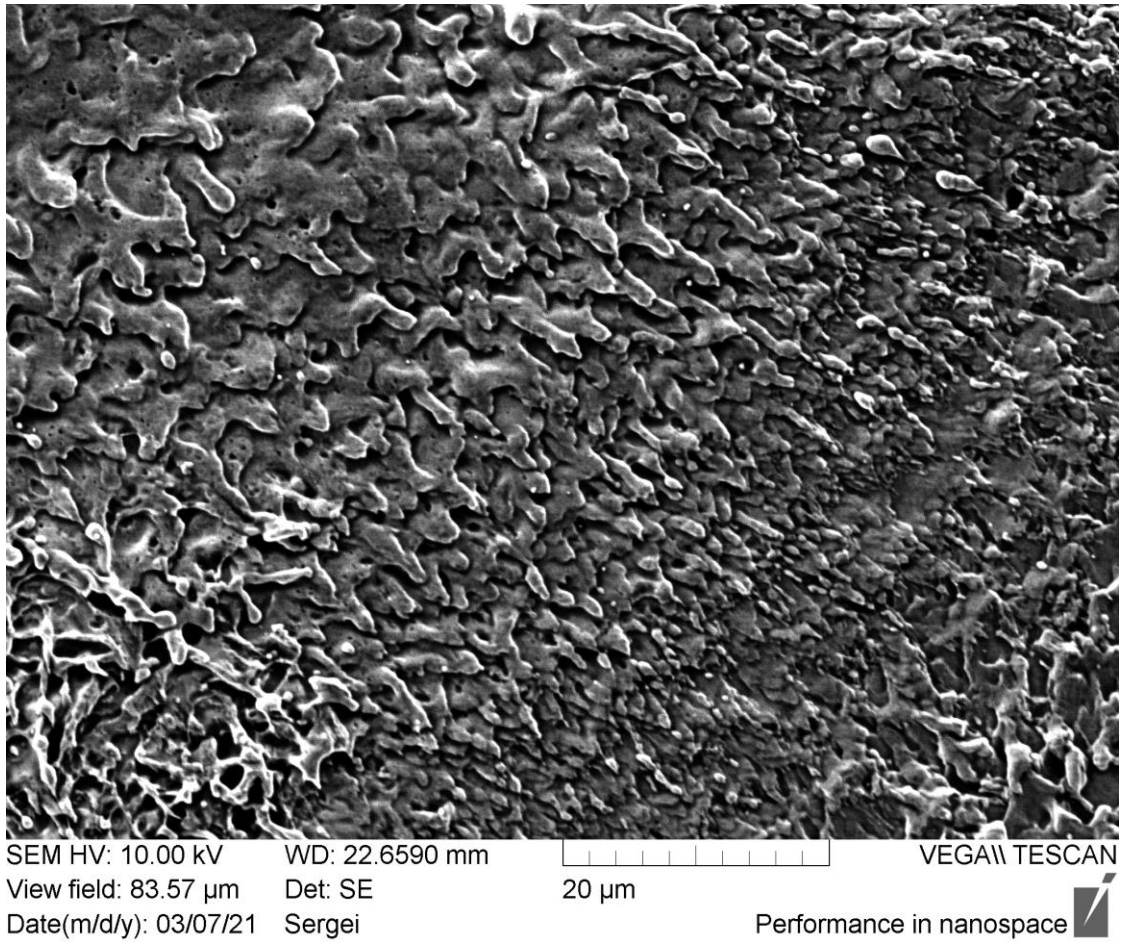
Can protrusions in craters cause next breakdown?





Portrusions at 20° angle

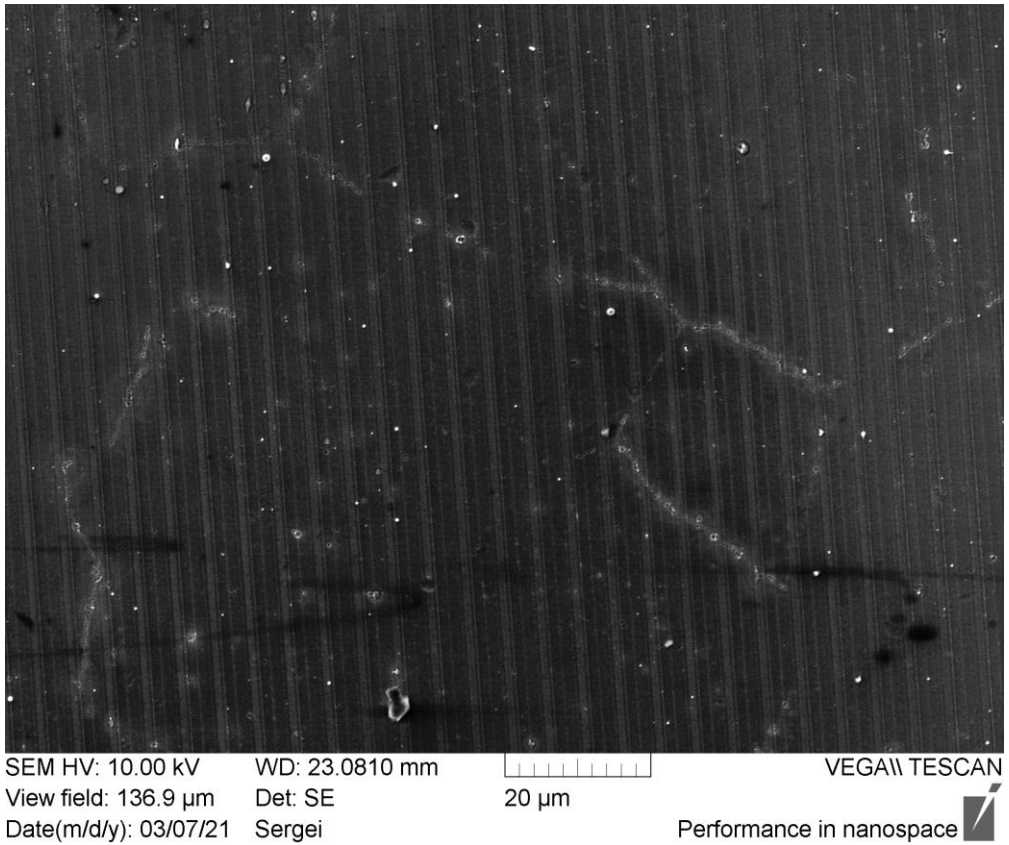


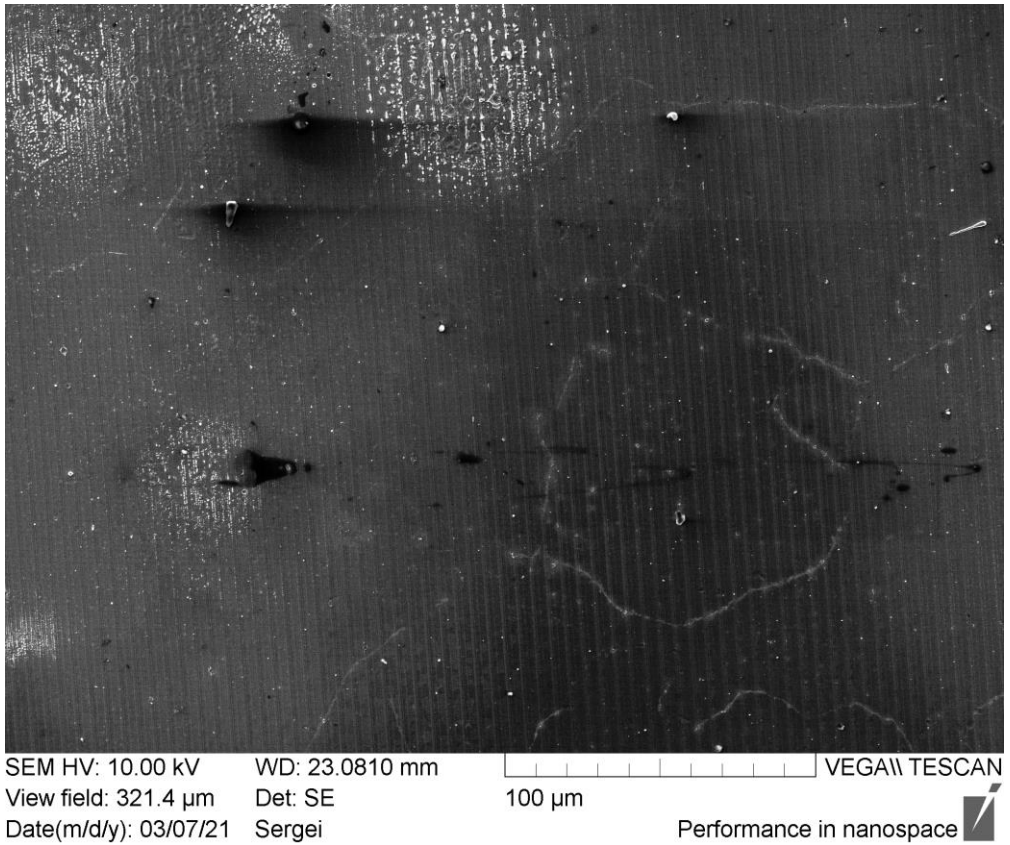


Lines

Lines in some places on the electrode.

They seem to be formed of smaller particles.





AFM

Allows mapping of topology.

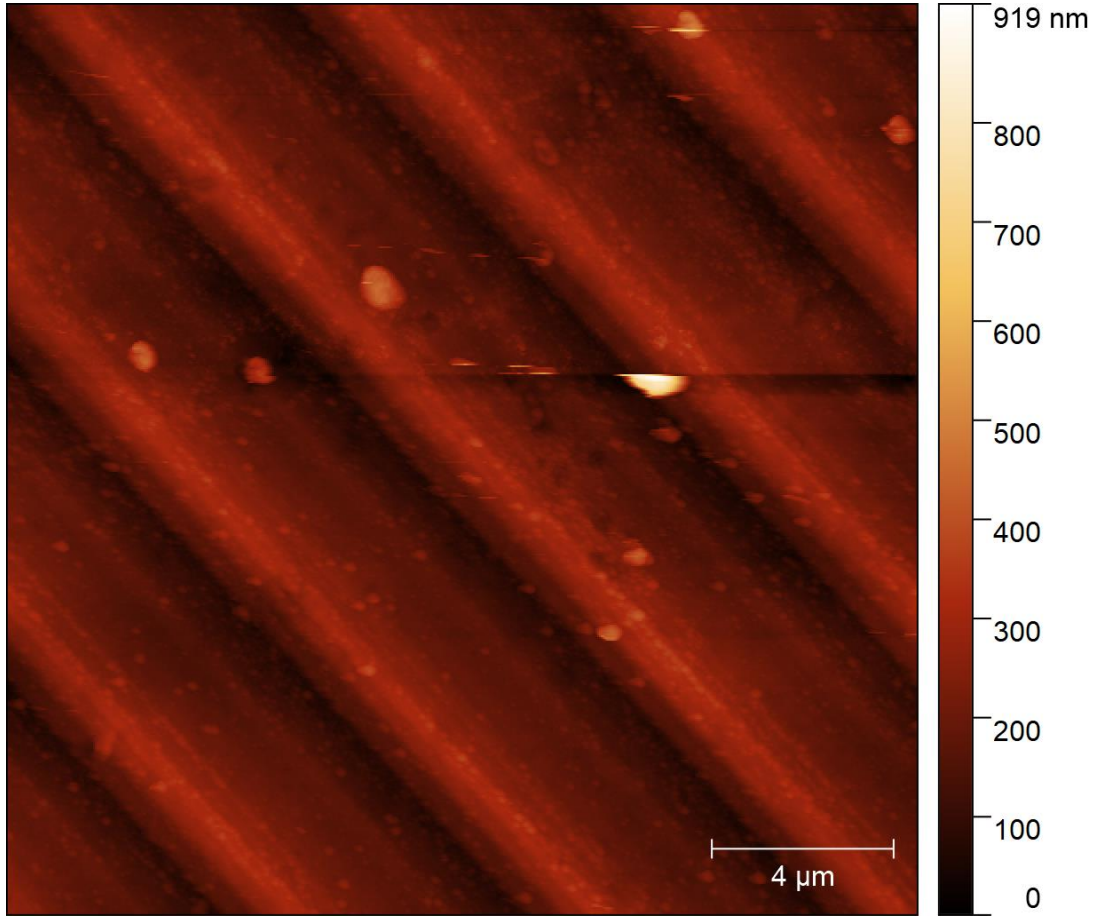
Ambient conditions.

Equipped with kelvin probe – allows mapping of work function on the sample.

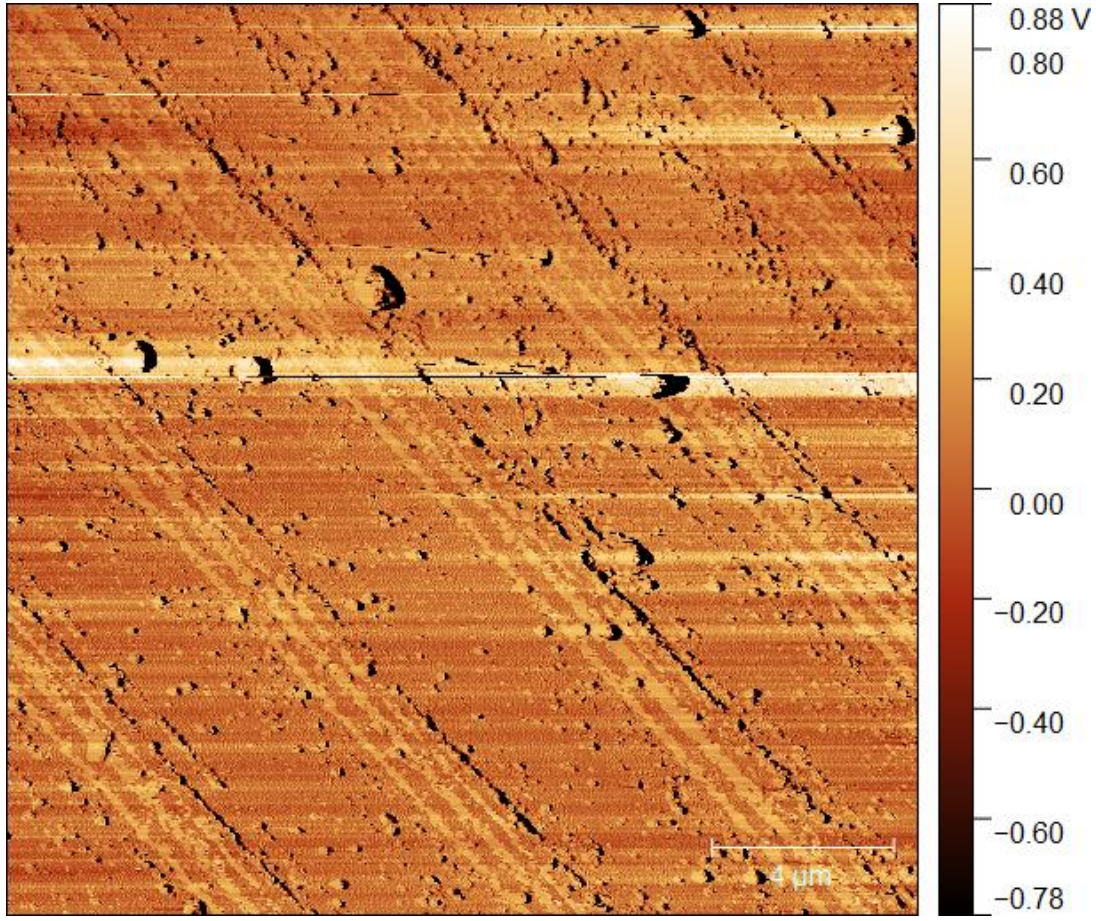
3 types of surfaces were mapped:

- Plain surface
- Crater edge
- Crater

Plain surface topography & surafce potential

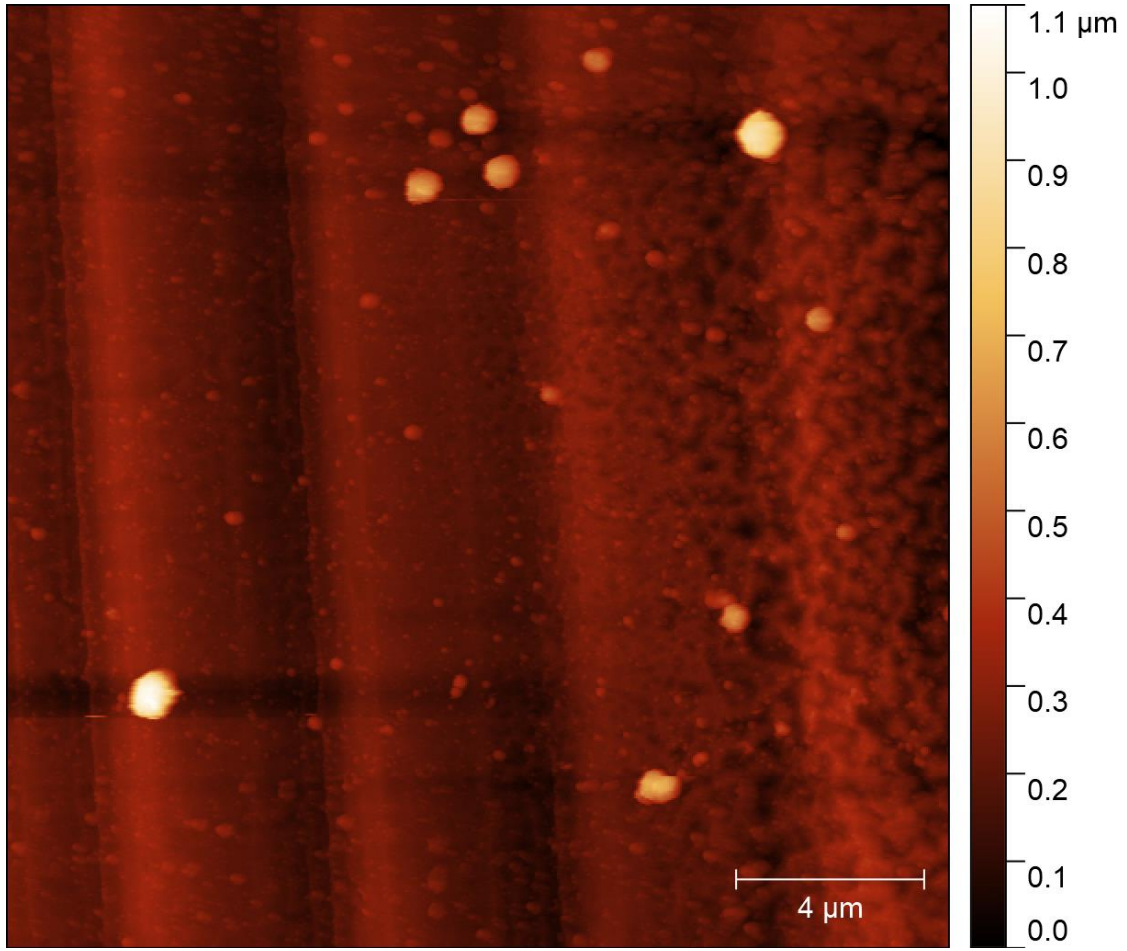


Topography

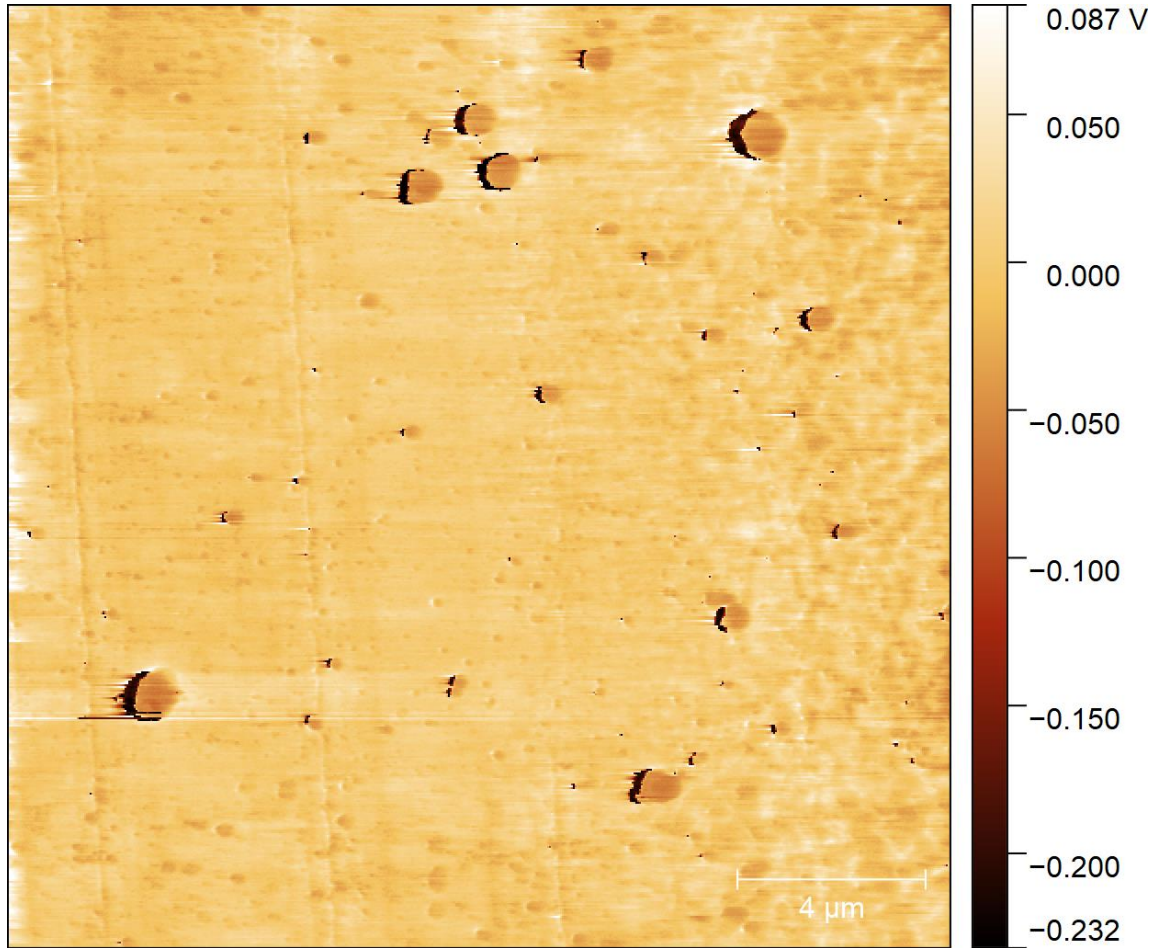


Potential image

Crater edge topography & potential

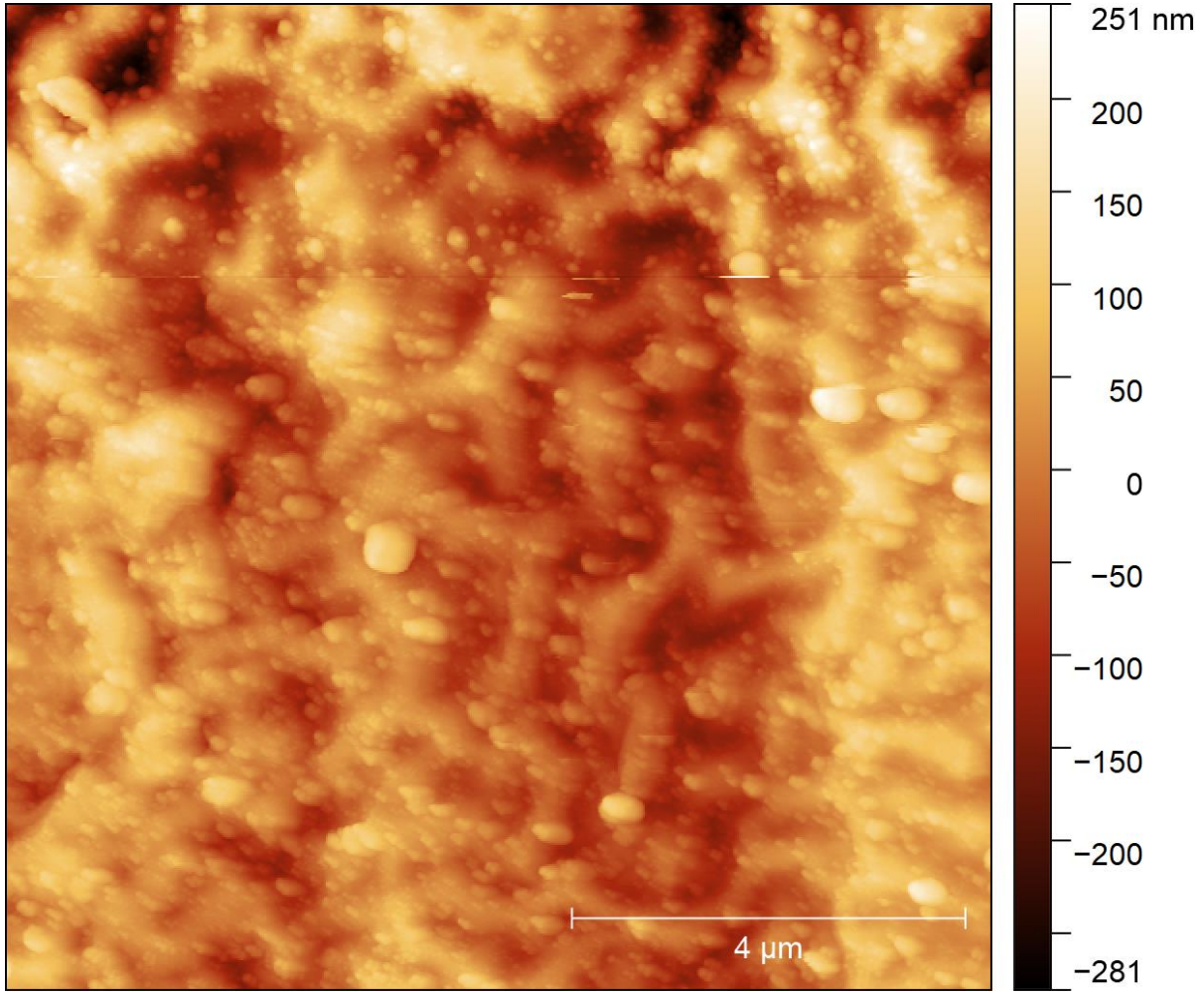


Topography

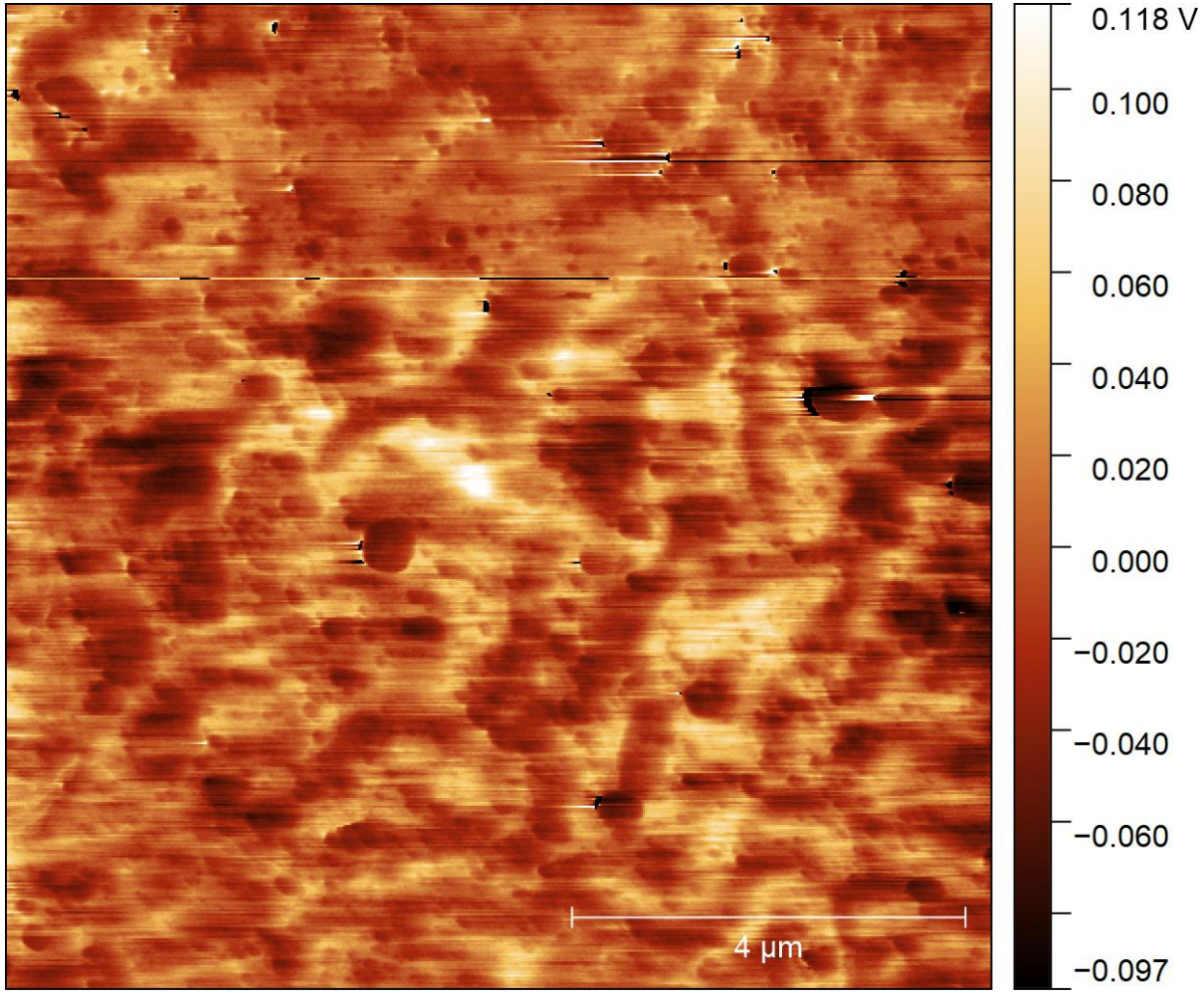


Potential image

Crater topo vs potential



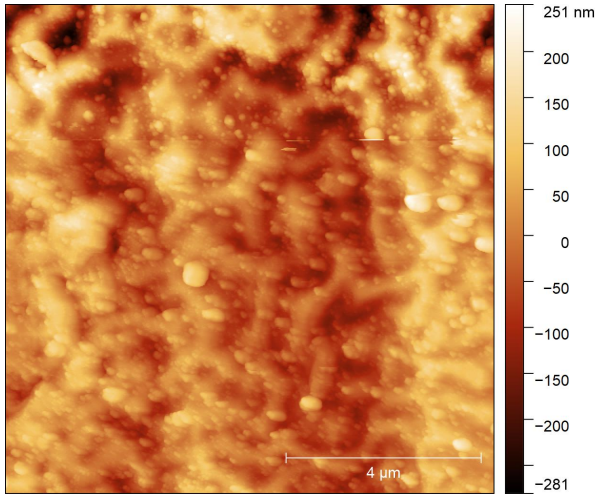
Topography

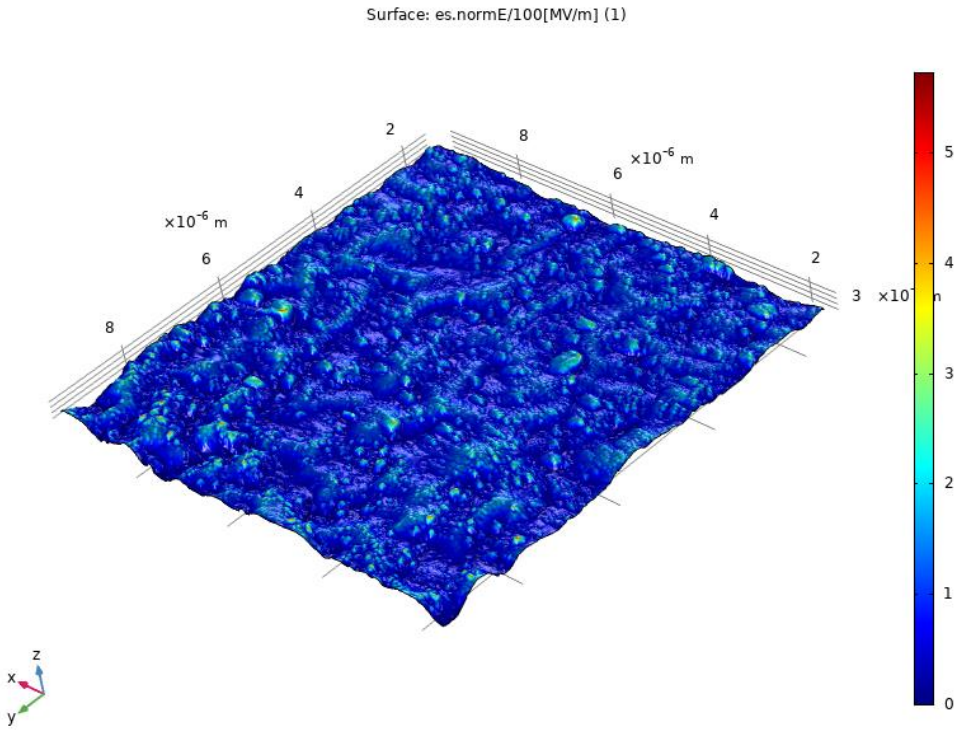


Potential image

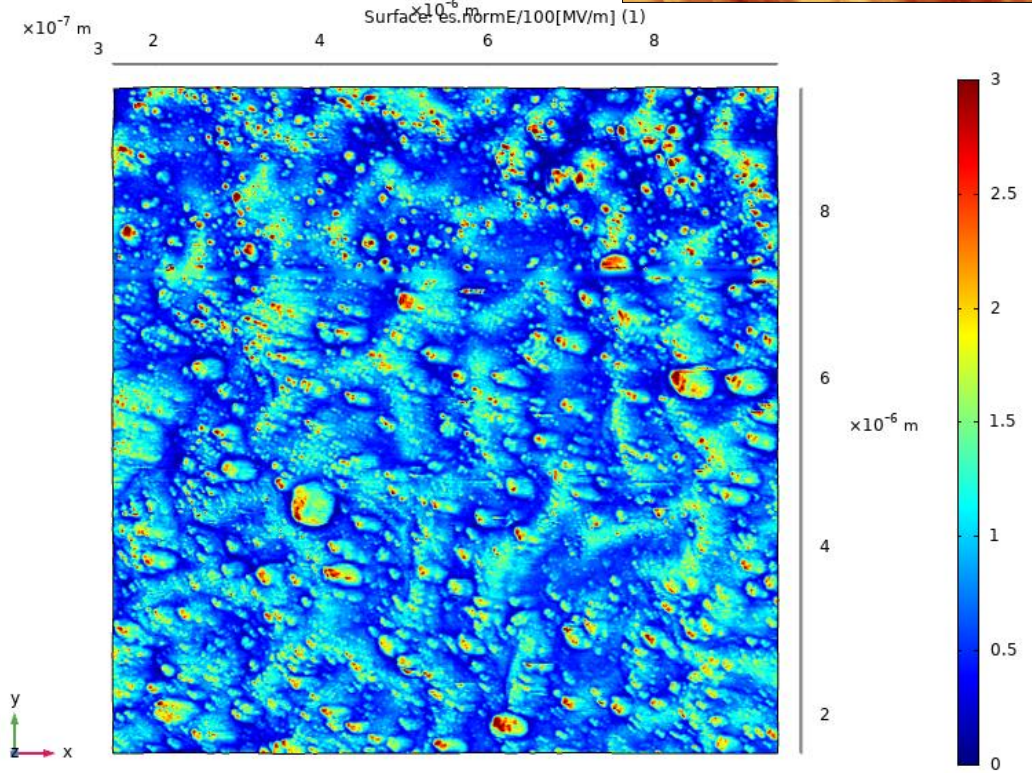
Field enhancement image

Field enhancement up to 5 times due to topology.





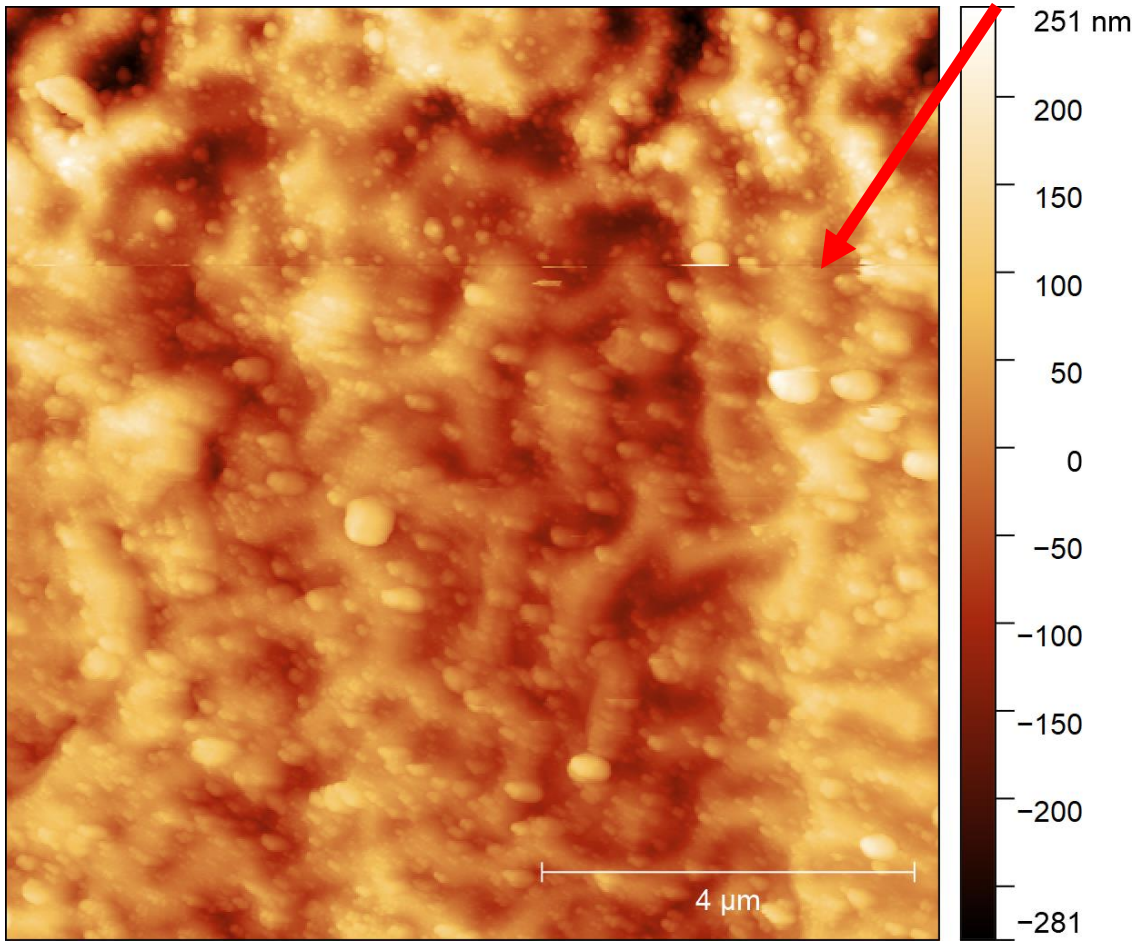
Field enhancement modeling



Field enchancement capped at 3

Mapping large craters

Mapping of the most interesing part is almost impossible.



¾ of image with dull tip

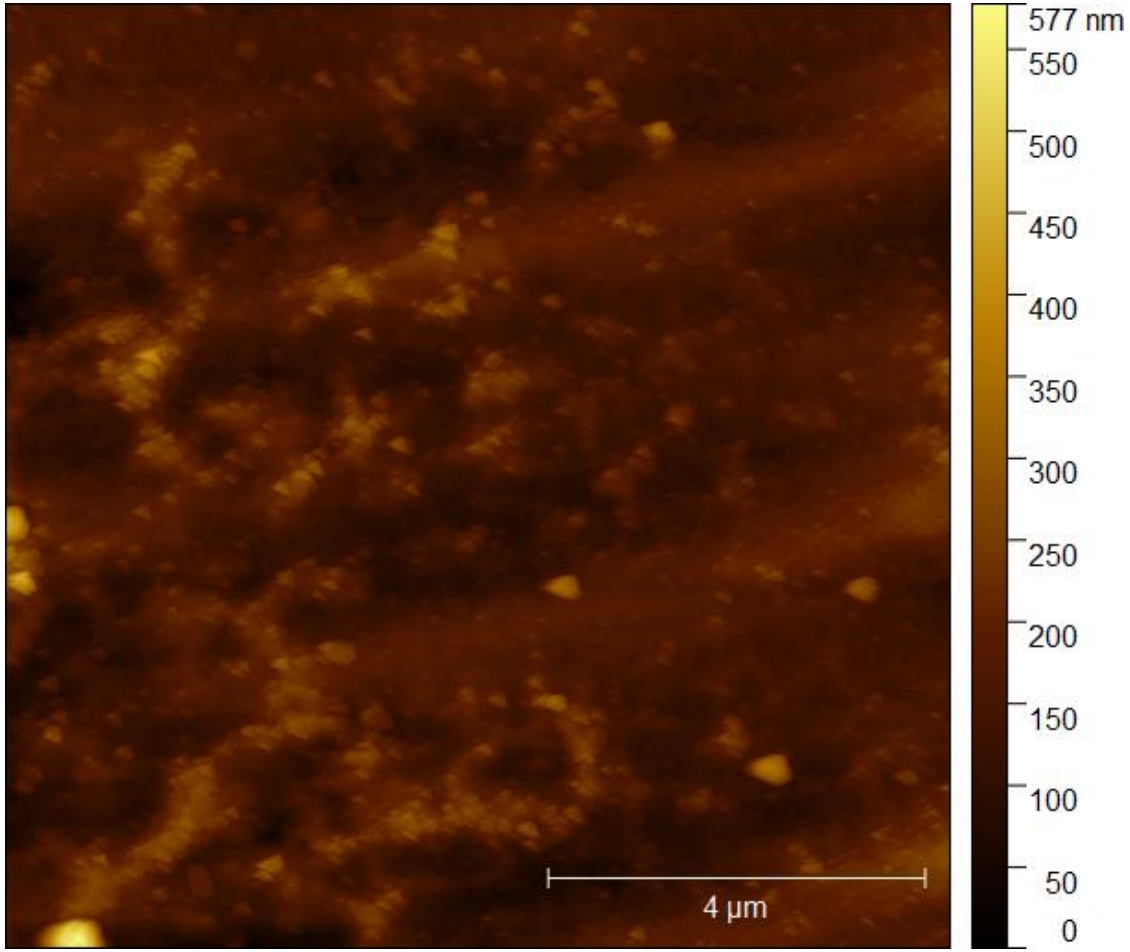


Image of crater with artefacts

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Conclusions & plans

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

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

Not a lot to conclude. There are a lot of hypotheses.

Plans:

Obtaining the topology image of rougher parts of the craters.

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Thank You!

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