Science & Technology Facilities Council

Water Erosion Experiment Update

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PASI meeting at RAL 9th Sep 2014

Motivation

- ISIS water cooled tungsten targets are clad with tantalum to avoid tungsten corrosion problems that occur when in direct contact with water
- Evidence of tungsten has been found in the TS2 water circuit suggesting that there may have been a failure of the cladding

Several possible reasons for the trace of tungsten in the cooling water are under investigation -

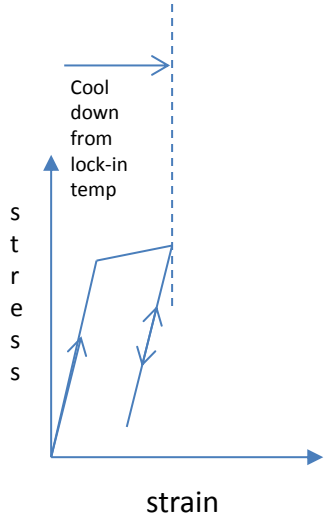
1. Tungsten deposited on the tantalum cladding during the manufacturing process is released into the water

2. Potentially significant plastic deformation of the tantalum during the hipping process

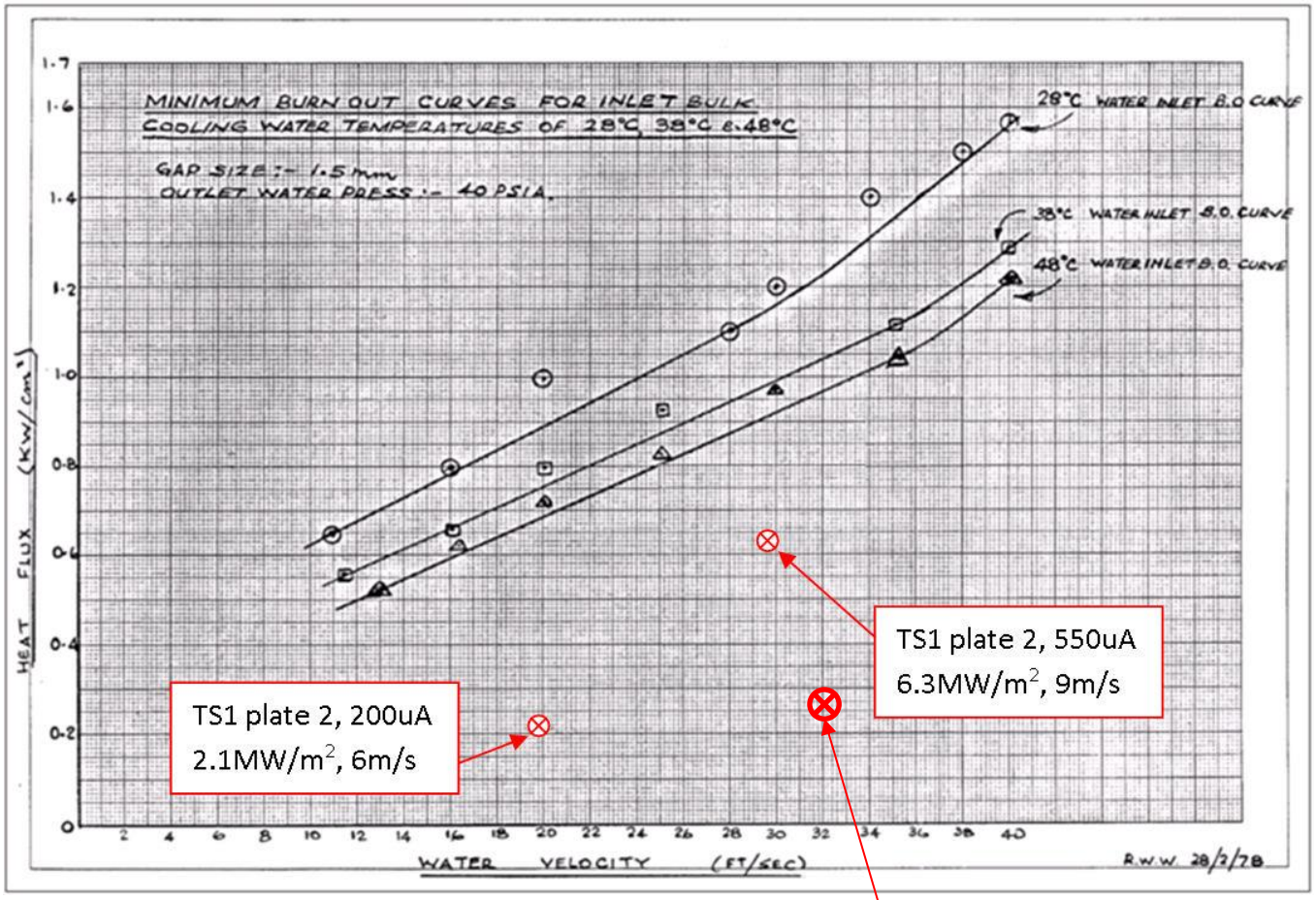
3. Significant beam induced cyclic strain resulting from 25K temperature jump per pulse

4. Water Erosion of tantalum at TS2 water velocity

Tantalum erosion resistance is also of interest for
-upgrades to TS1,
- and for more general interest,
SNS target 2 and ESS backup solution



Risk mitigation 2: Can water velocity be reduced?



Experiment

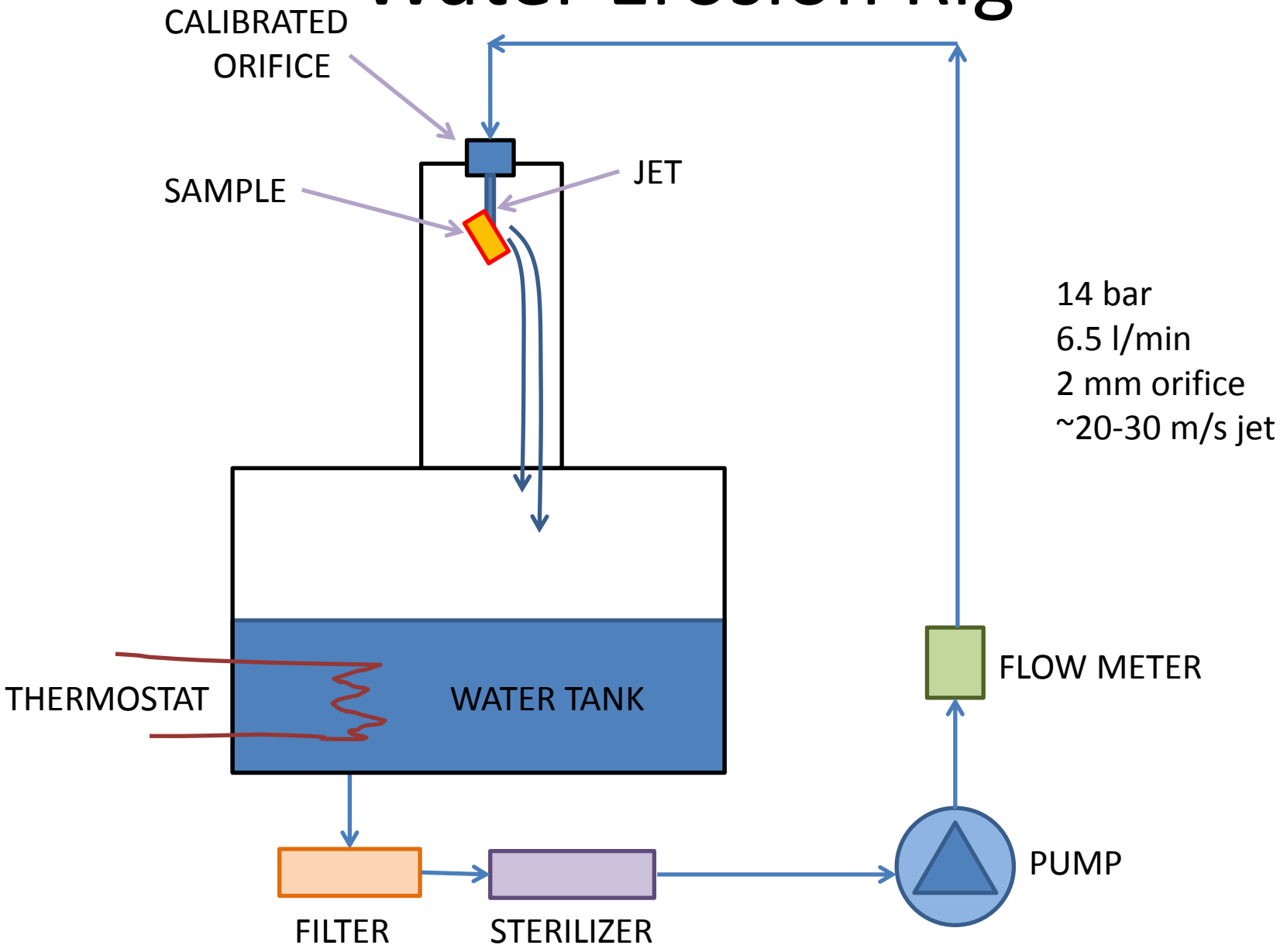
Aim – Investigate the resistance of tantalum cladding and tantalum coatings to erosion by high speed water cooling

Method – Use an impinging water jet to generate accelerated erosion rates

Outputs (the wishful thinking) –

- Erosion rate vs water impingement velocity.
- Erosion rate vs water temperature.
- Erosion rate following acid exposure (simulate hydrogen embrittlement).
- Comparison of erosion resistance of tantalum cladding and coatings.

Water Erosion Rig

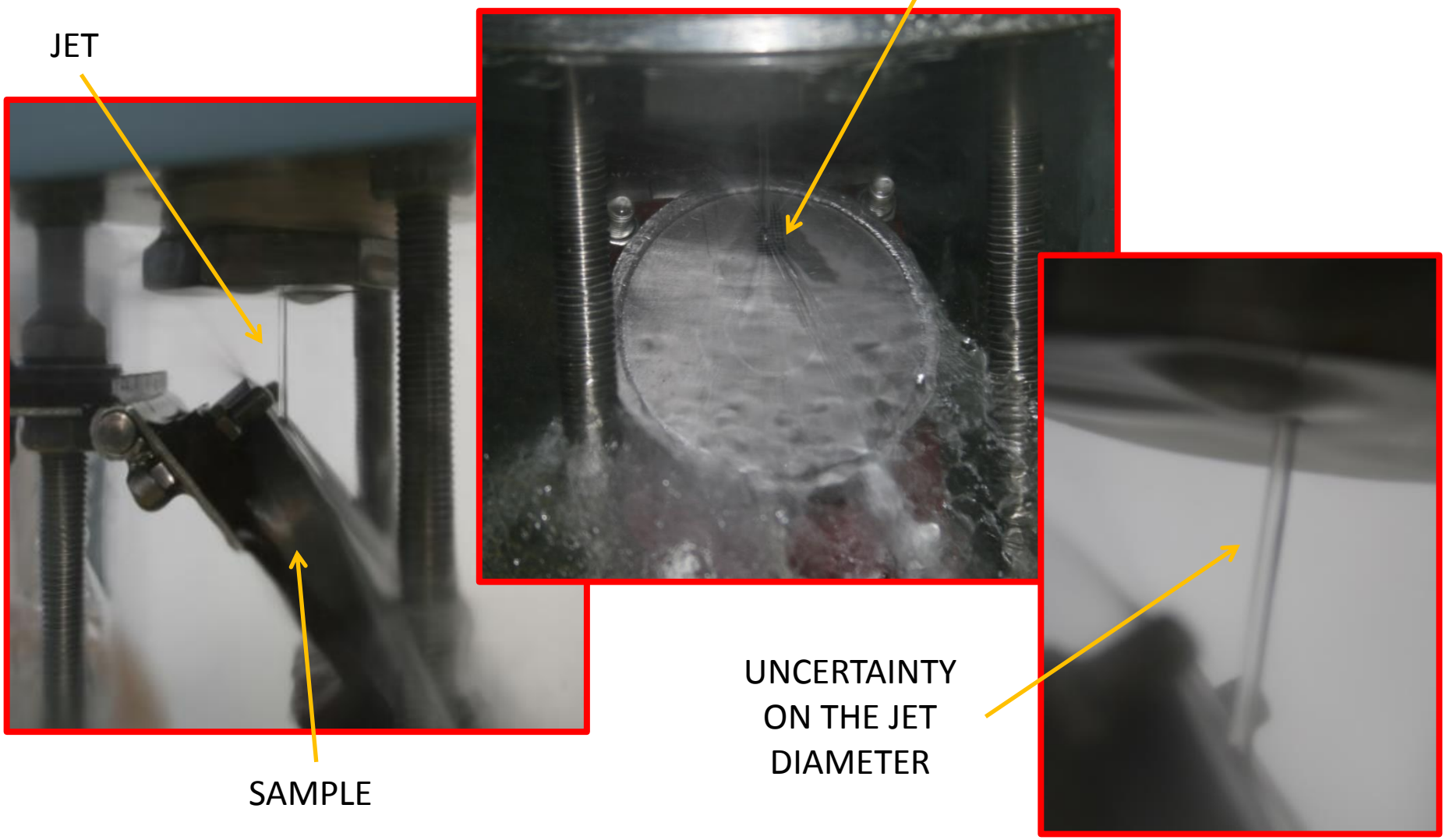


The rig

RIG AND ANCILLARIES

MULTISTAGE VARIABLE SPEED PUMP

The jet and sample

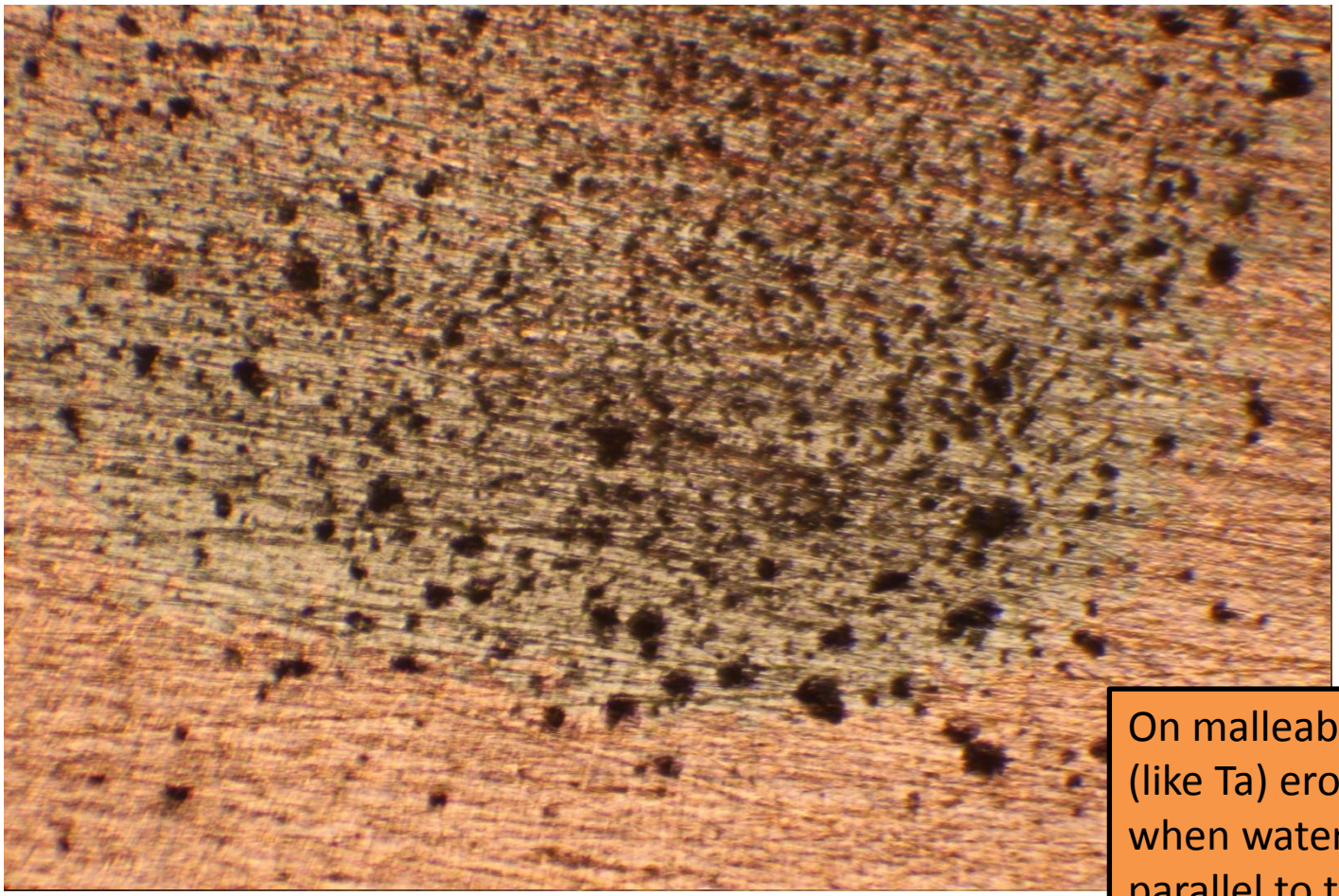


Experimentation and Results on Cu

Erosion of Copper with jet at 30deg angle

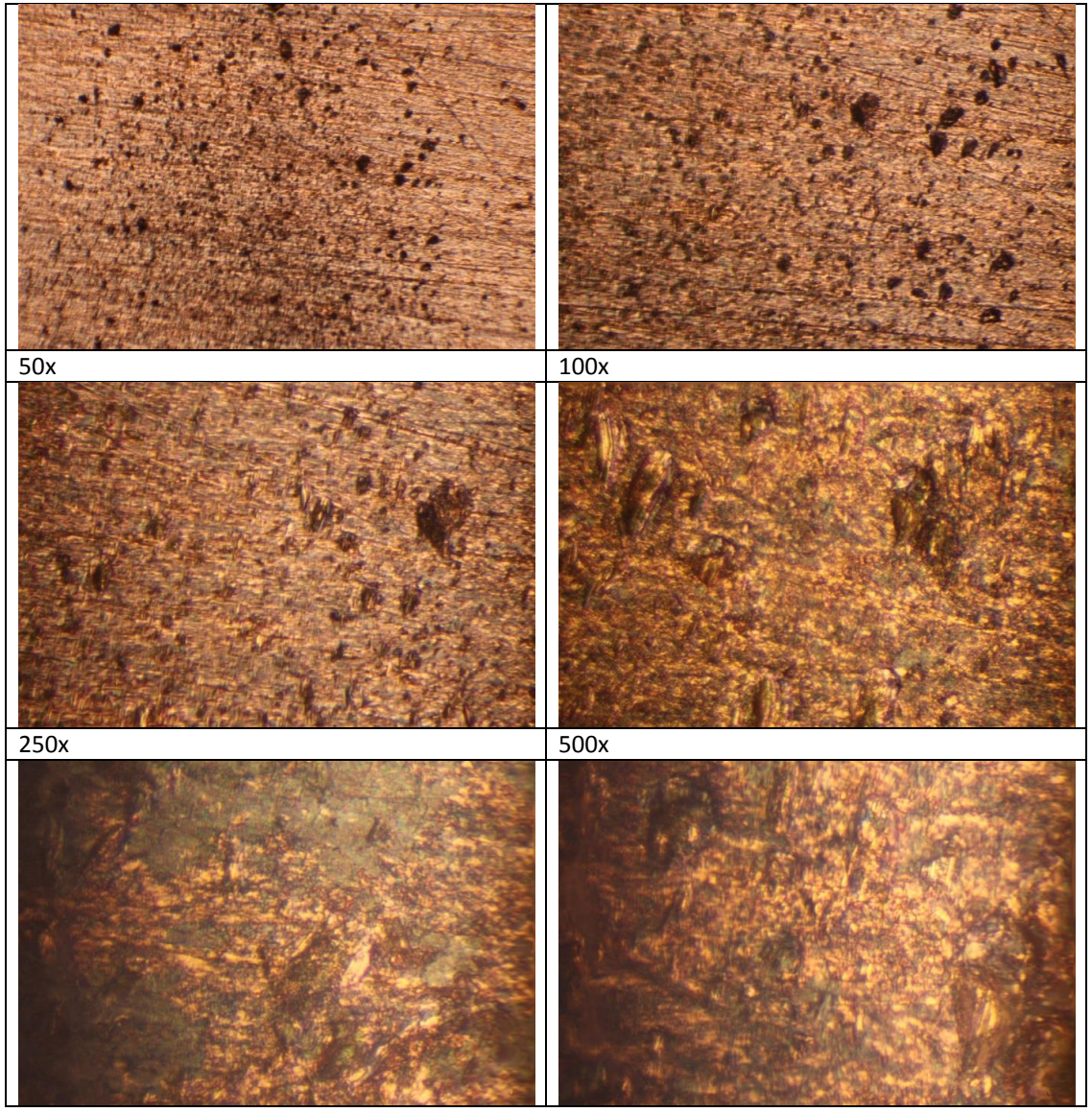
Results on copper ~70hrs :

[illegible] eroded area at 50x Magnification



On malleable materials (like Ta) erosion is higher when water flows is near parallel to the surface

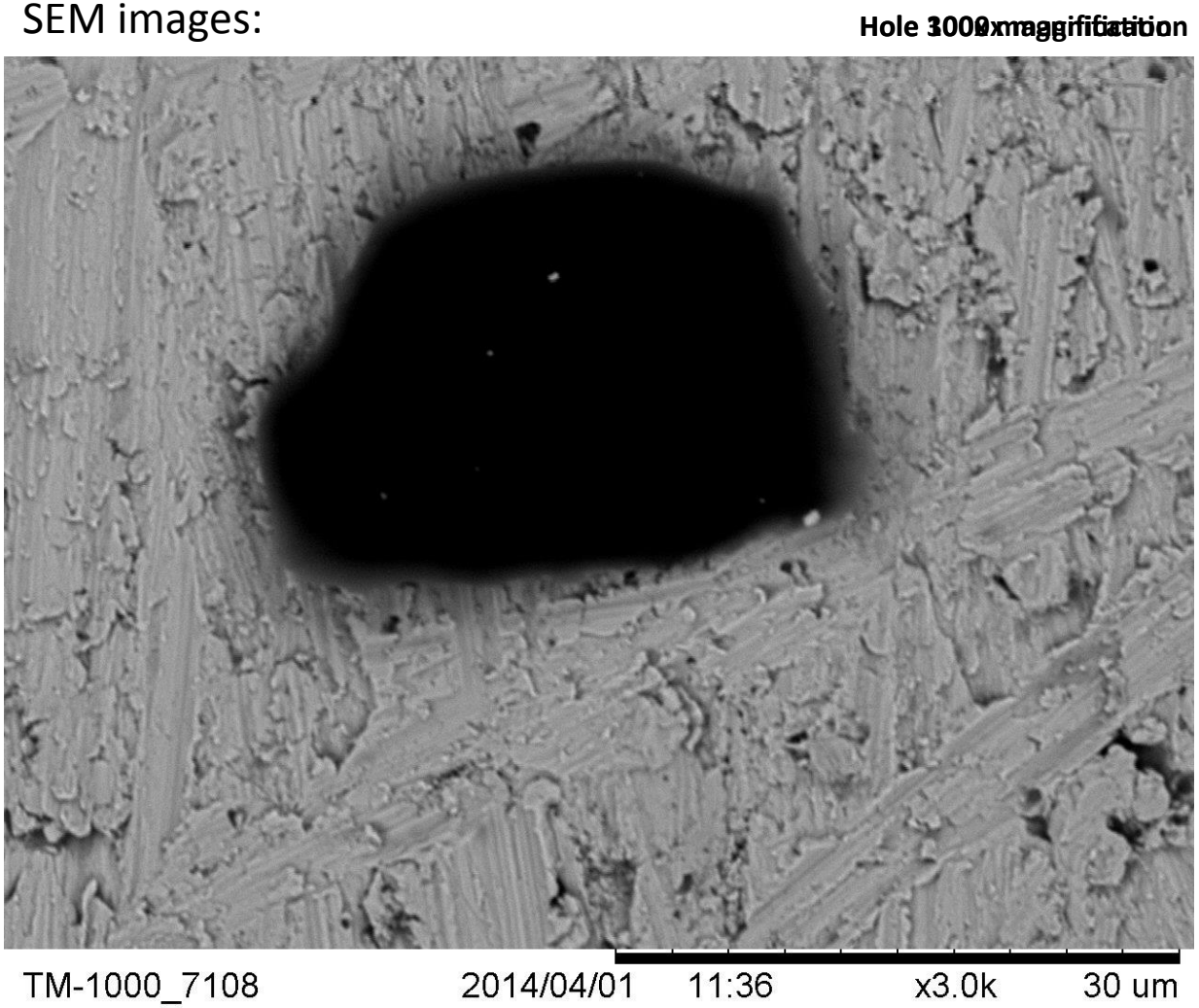
Experimentation and Results on Cu



Tantalum: pits found after several days

Erosion of Tantalum at angled incidence under a discontinuous jet

SEM images:

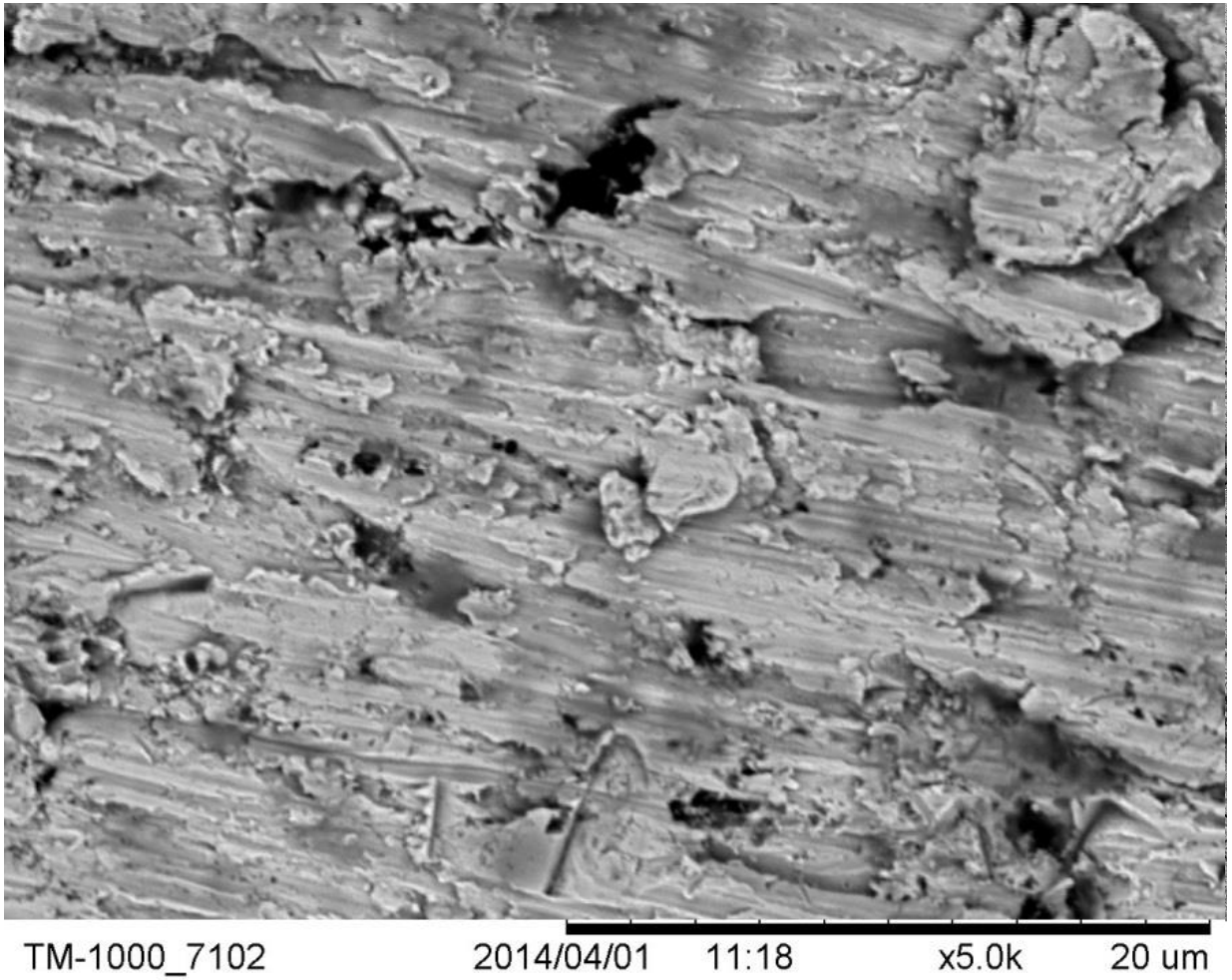


Tantalum surface characterisation

Erosion of Tantalum at angled incidence under a discontinuous jet

SEM images:

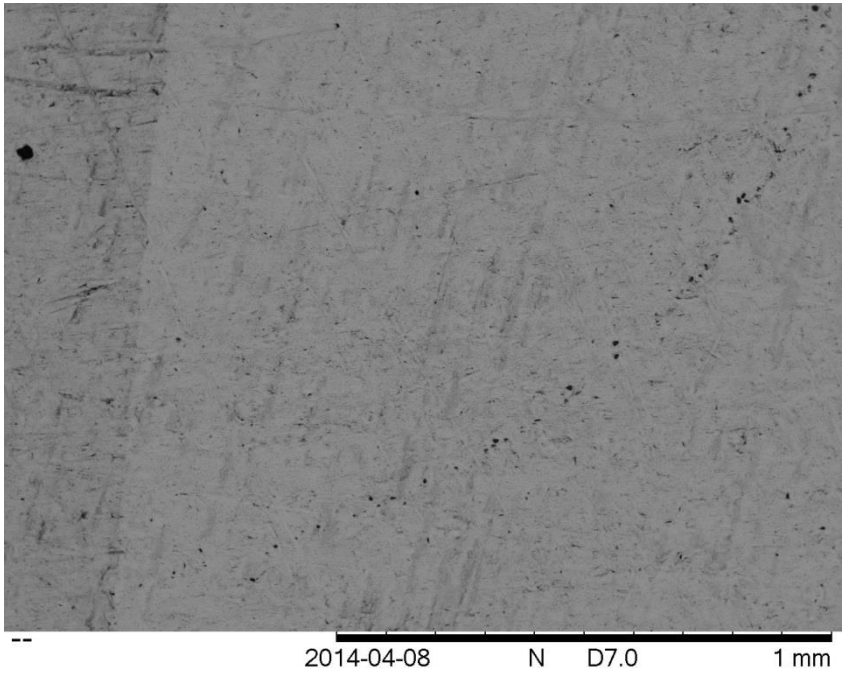
Outside target area 1000x magnification



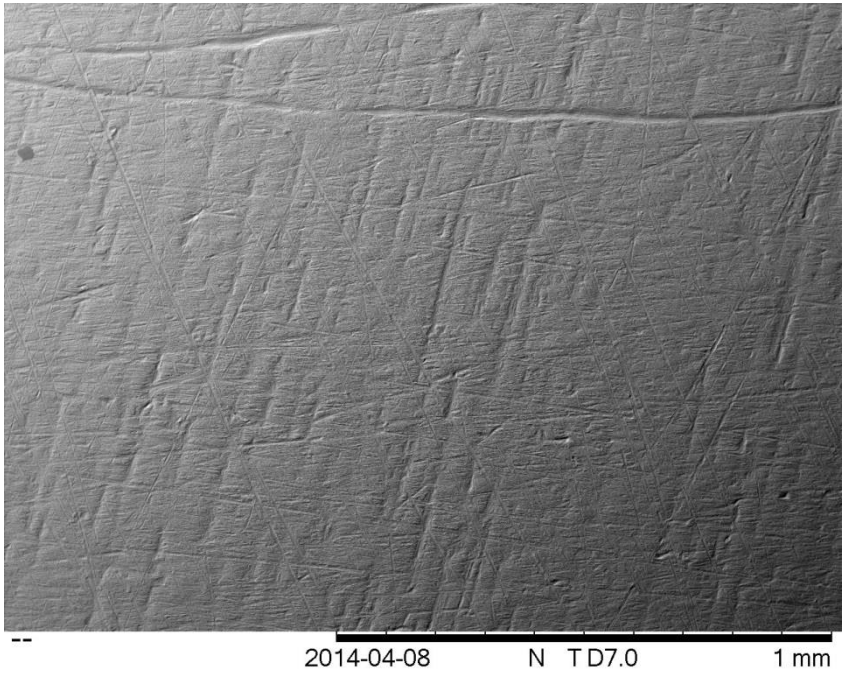
Tantalum surface characterisation

Erosion of Tantalum at angled incidence under a discontinuous jet

SEM images:



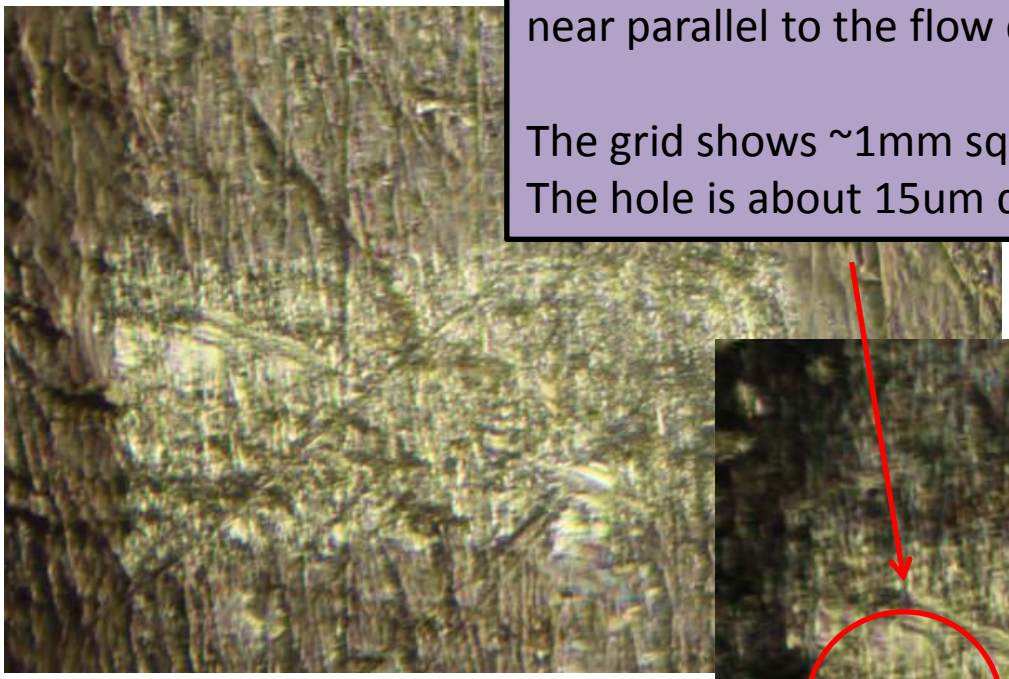
Surface picture 100x magnification (Composite)



Surface picture 100x magnification (Topographical)

Found irrefutable evidence of erosion in Ta

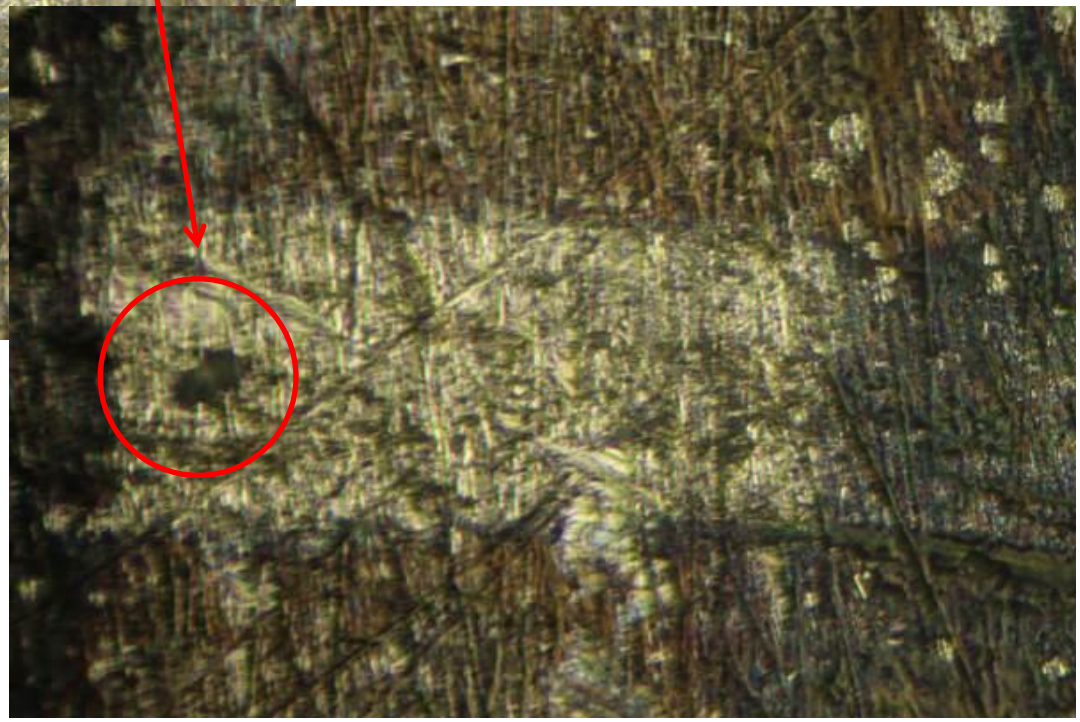
BEFORE



Approx. 1month of operation with water jet speed around 30m/s and sample 30deg from water jet (we think for soft materials near parallel to the flow direction is worst).

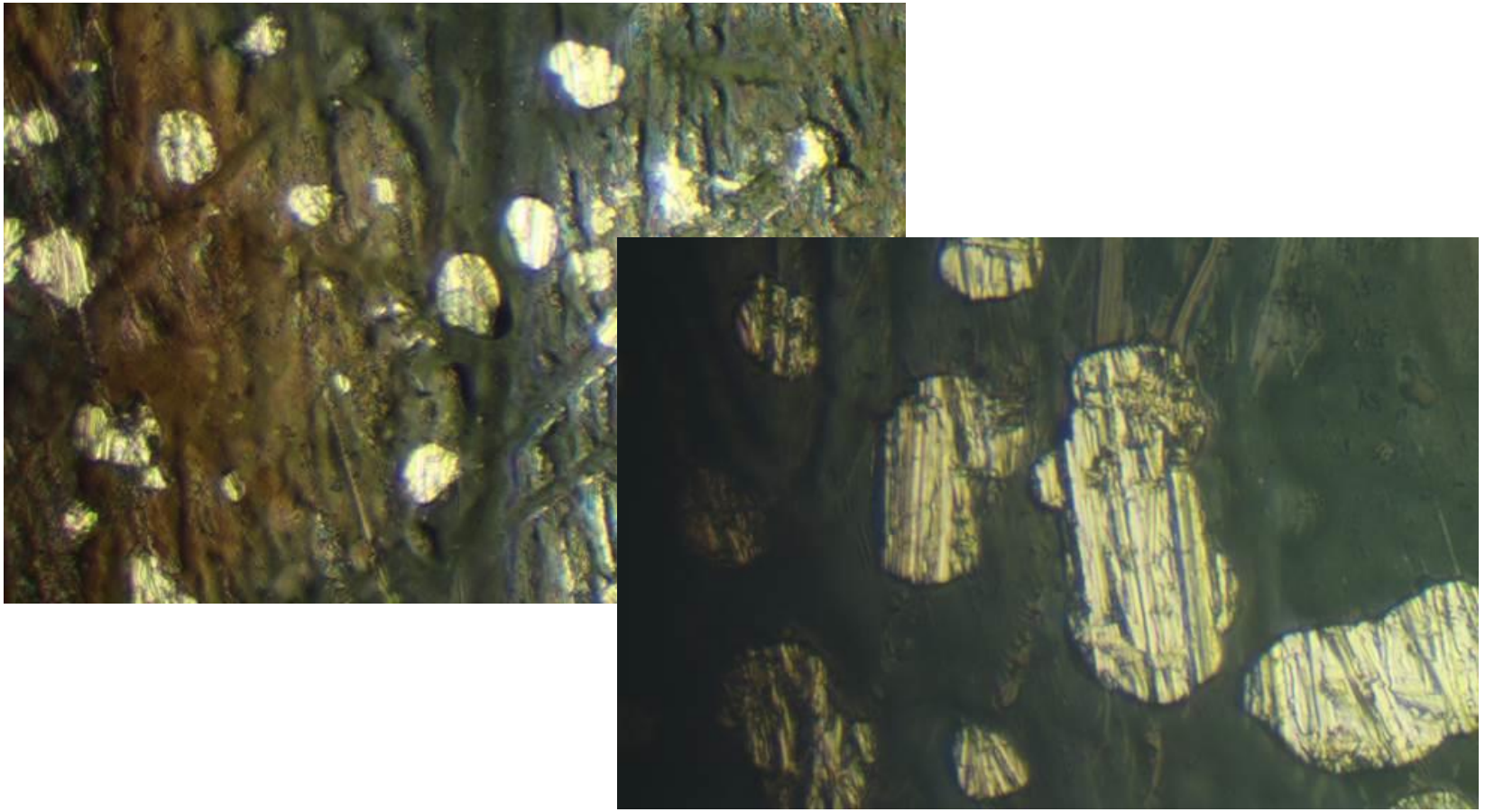
The grid shows ~1mm squares at 200x magnification.
The hole is about 15um deep and 50 wide

AFTER



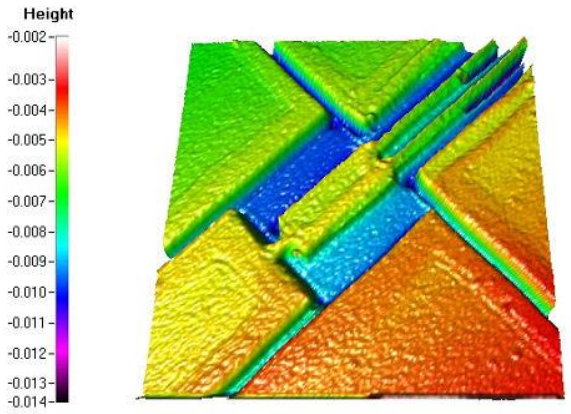
Found evidence of erosion in Ta

Many shiny spots have appeared (most obvious on the black marker)

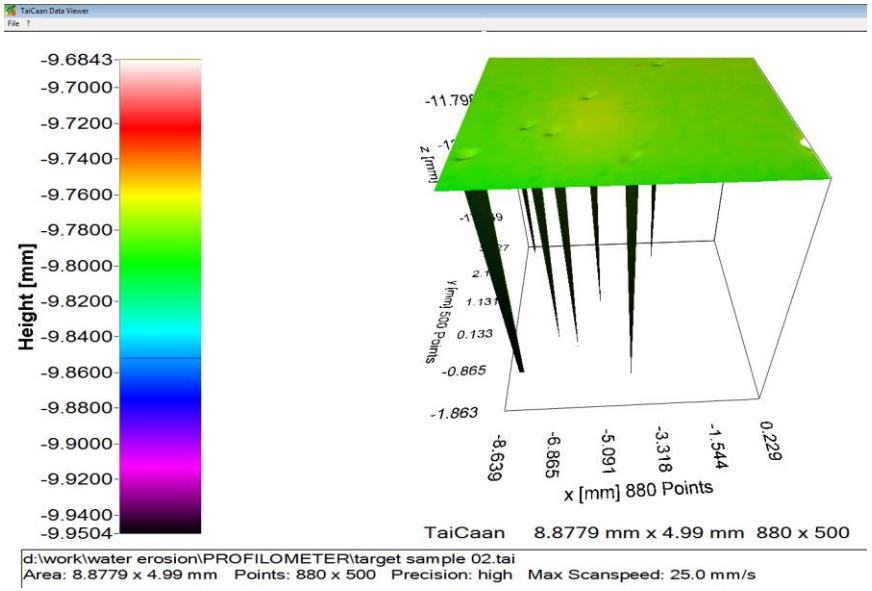


Surface characterisation round 3: the revenge!

Laser profilometer



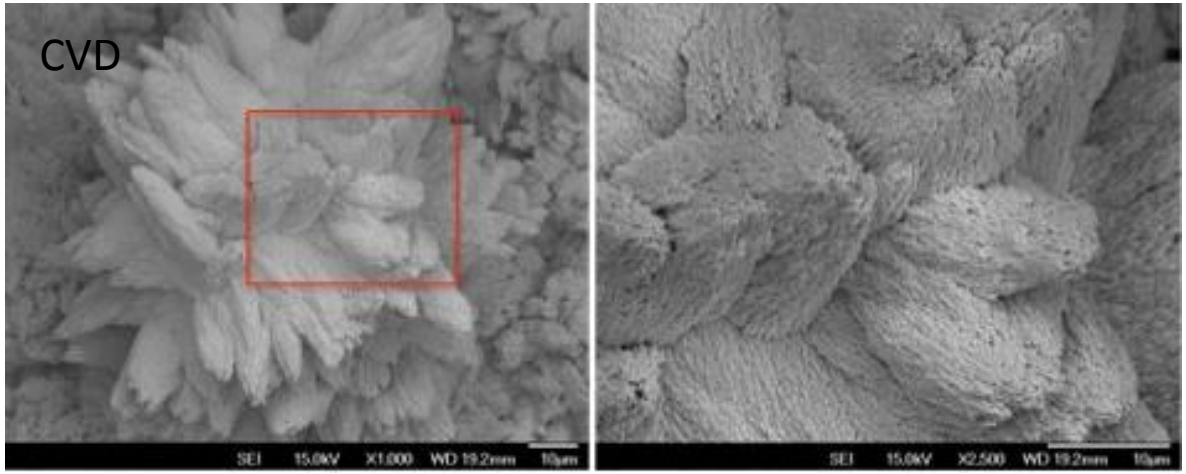
Analysis of the tungsten sample
Shows several pits



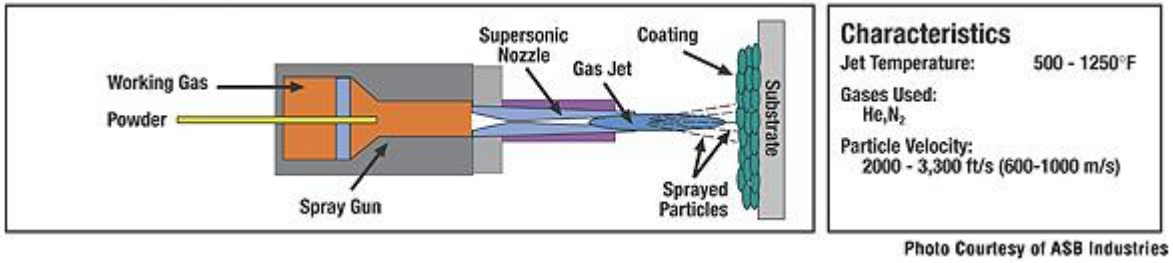
Coating methods to be tested

1. Tantalum Hot isostatic press (HIP)
2. Tantaline – chemical vapour deposition (CVD)
3. Cold Sprayed tantalum
4. SiC - CVD

CVD

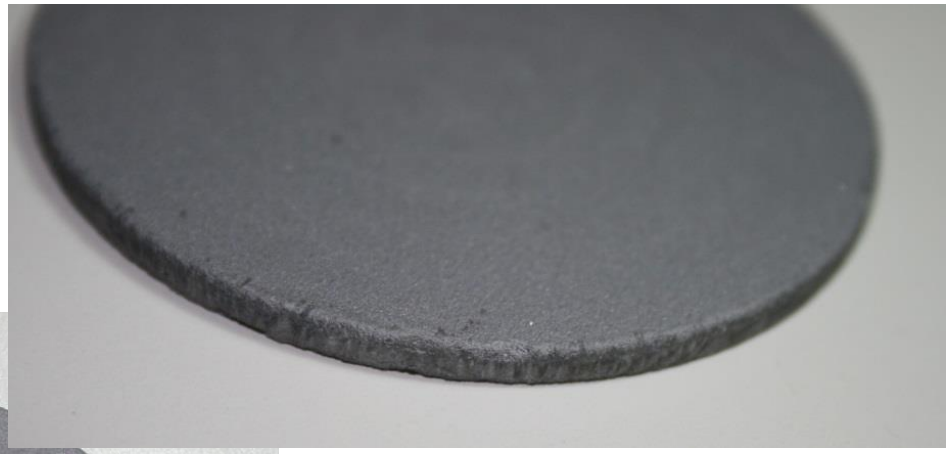


Cold Spray

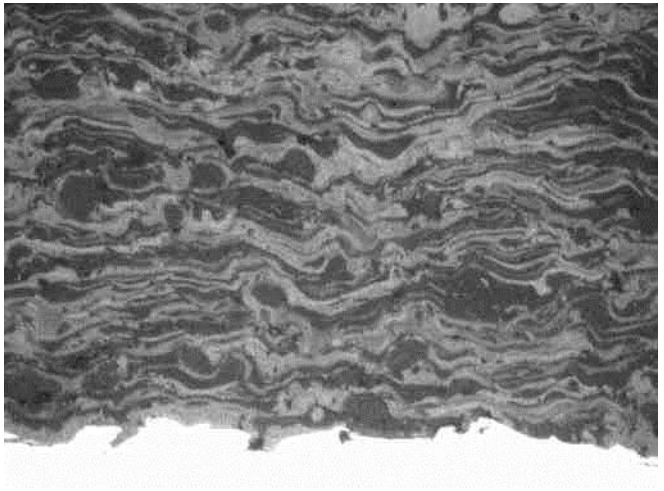


Samples on the waiting list 1

Cold sprayed tantalum

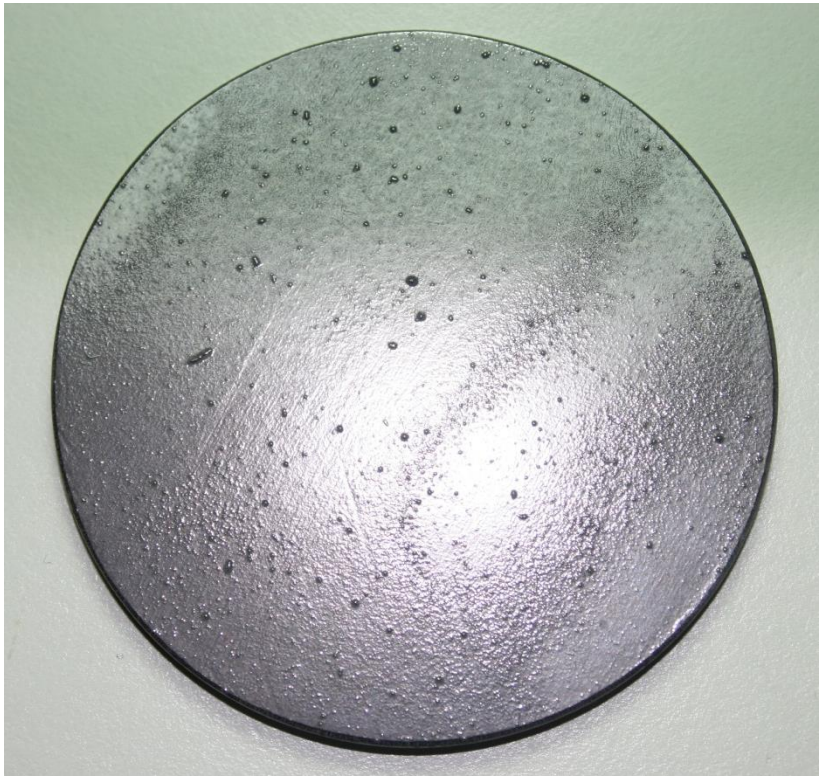


Plastically deformed Ta beads
(this is not a real picture)



Samples on the waiting list 2

Ta Chemical Vapour Deposition CVD – from Tantaline



Samples on the waiting list

SiC Chemical Vapour Deposition CVD

Summary and further work

- Irrefutable evidence of erosion in the hipped tantalum sample has been found after ~1month of operation at ~30m/s
- Erosion is slow (although significant) and so requires accurate surface characterisation which we might have finally achieved!
- It is likely that the erosion picks up after an incubation period
- A better characterisation of the jet is required to determine the velocity of the water (which could be much slower than theoretically calculated)
- Several factors are likely to influence the rate of erosion and could be investigated further: temperature, water chemistry, electrical potential, hydrogen embrittlement, type of coating, etc.
- The Experiments suggest that the erosion is fast enough to have an impact within the life of the target.
- However investigation of the parameters affecting the erosion rate possibly requires an accelerated erosion rate (e.g. via a faster jet, water/air droplets, etc)