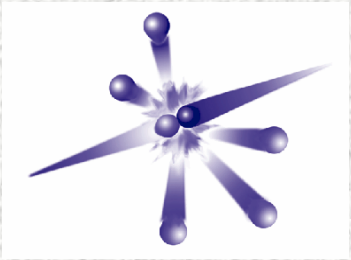
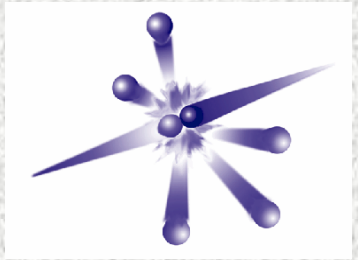


Stanford Linear Accelerator Center



RF Breakdown Studies in Tungsten and Copper Structures

[1]L. Laurent, [1]C. Adolphsen, [1]S. Beebe, [3]S. Döbert, [2]N.C. Luhmann, Jr.,
[1]C. Pearson, [3]A. Rodriguez, [1]G. Scheitrum, [4]D. Swenson, [3]W. Wuensch

[1]Stanford Linear Accelerator Center

[2]University of California, Davis

[3]CERN

[4]Epion Corporation

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Overview

- Review of AAC06 Presentation:

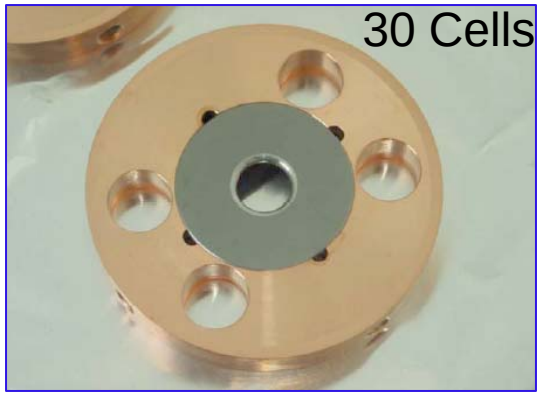
  X-Band Accelerator Experiment:

  CERN Fabricated Structure with Tungsten Iris Inserts

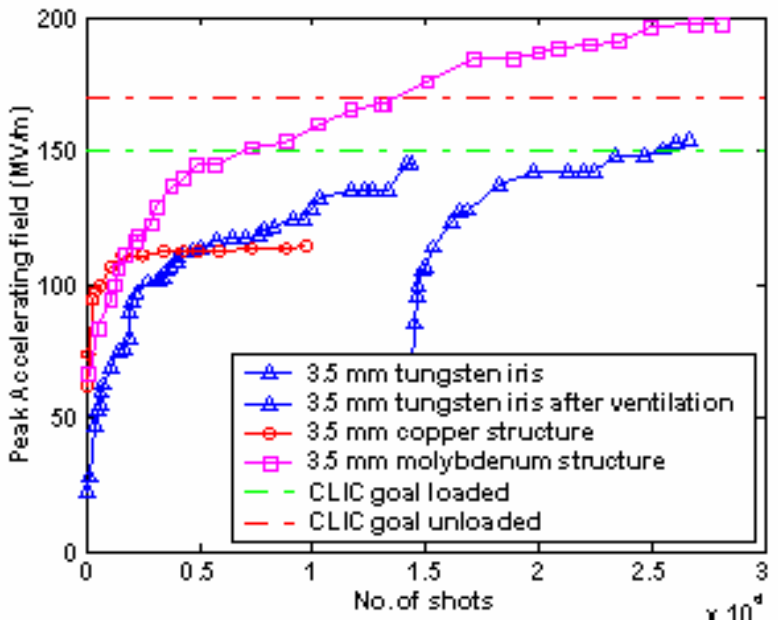
  Tungsten Material Study: Machining, Etching and Polishing Techniques

- Tungsten X-Band Cavity Experiments
- Tungsten GCIB Processing
- Molybdenum Cavity Nose Fabrication

CLIC 30 GHz “30-Cell Clamped” Accelerator Structure using Tungsten/Moly Iris Inserts



Pulse Length=16ns



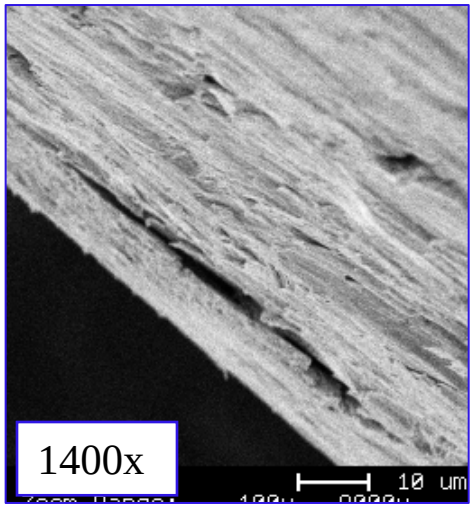
CERN Fabricated X-Band Accelerator with Tungsten Iris Inserts

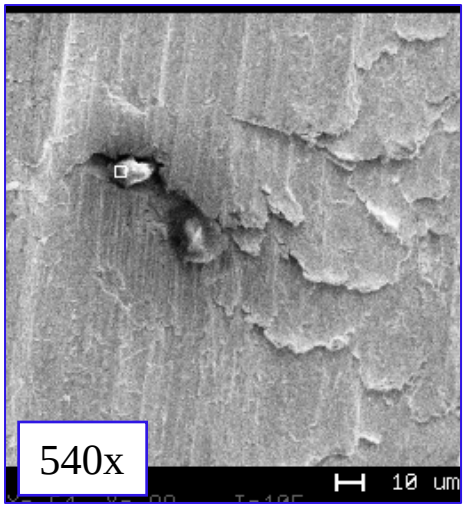
- Tungsten performed much worse than our X-band copper structures:

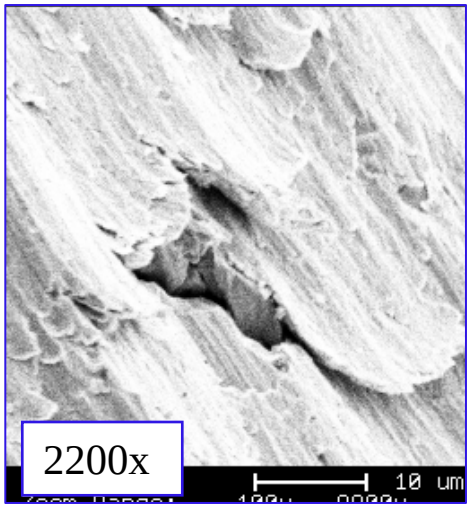
  W-structure: 200ns, 63 MV/m (10-20 bds/hr)
  Cu-structure: 250ns, 100MV/m (<10 bds/hr)

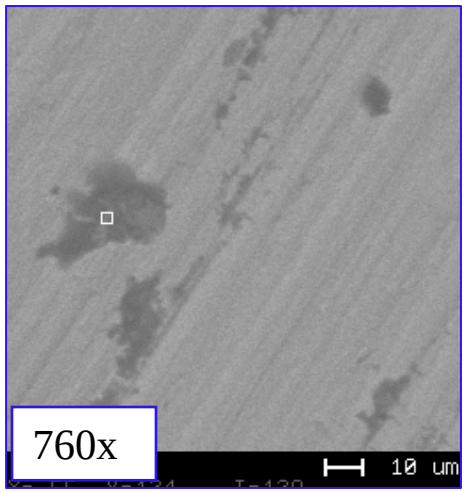
- No significant improvement with continued rf processing.
- Reprocessing was necessary when returning to any given pulse length in order to reach previously achieved power levels.
- SEM analysis on sample tungsten inserts revealed numerous fractures and embedded carbon particles on the surface suggesting the need to find a better fabrication process.

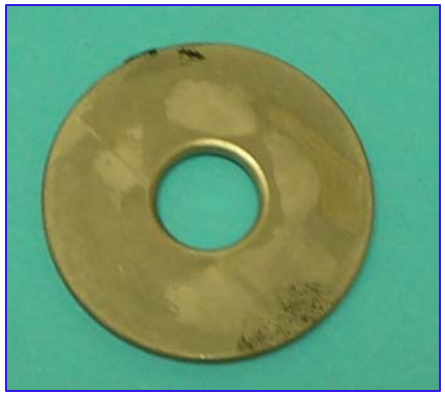
SEM Images of a Tungsten Iris Insert

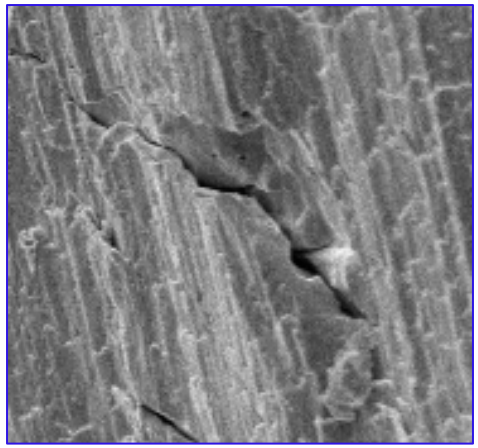












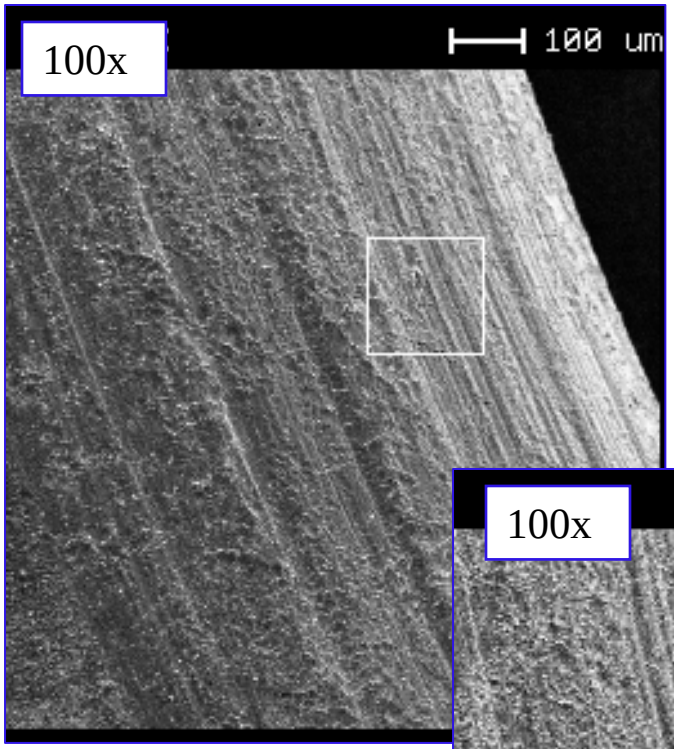
Photograph of Six Tungsten Iris Inserts Taken After RF Processing

A-Side: Iris Facing Toward Input

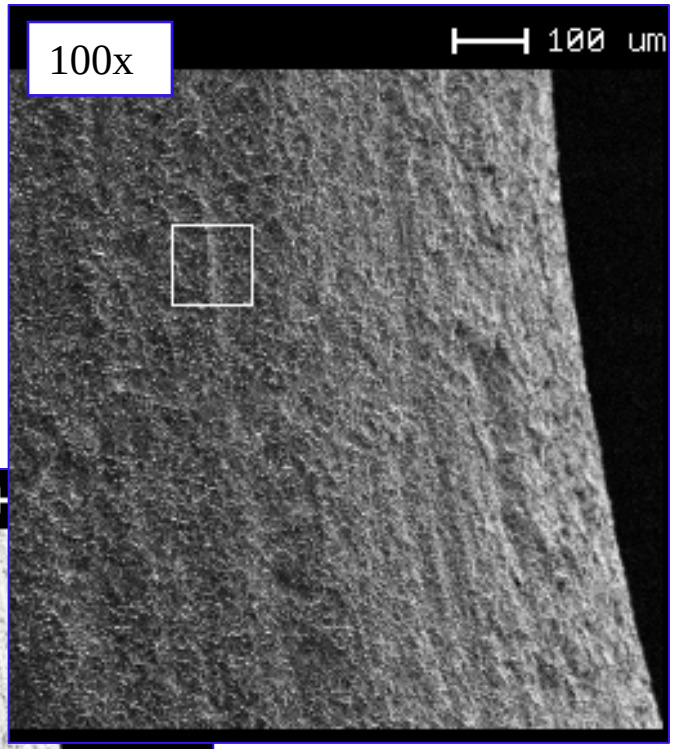
Iris 1 Iris 2 Iris 3

Iris 15 Iris 25 Iris 32

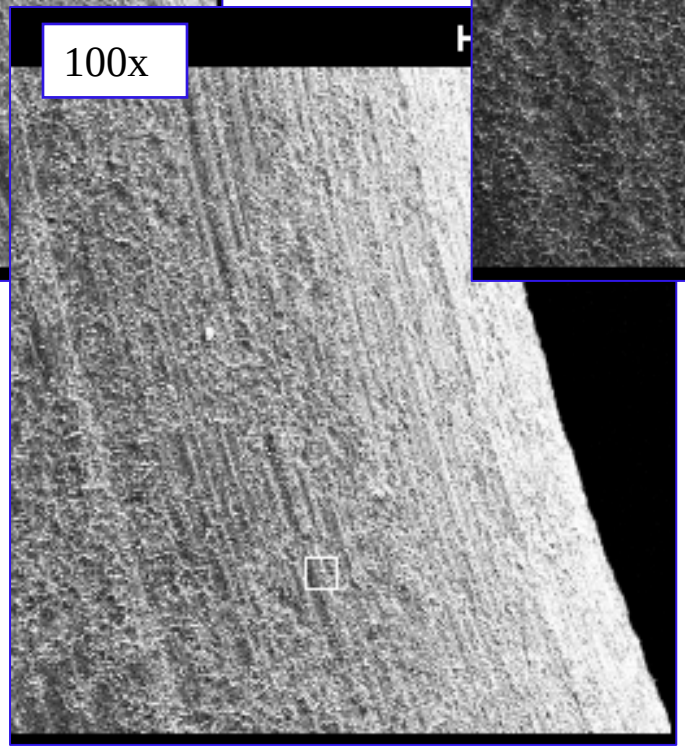
Iris 1



Iris 2

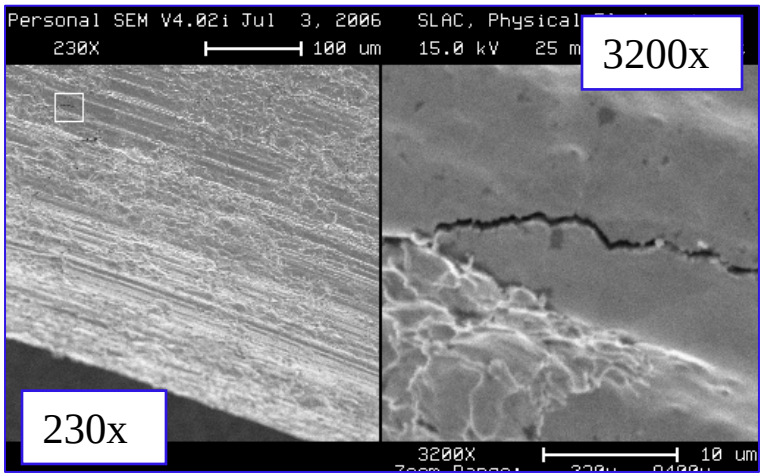


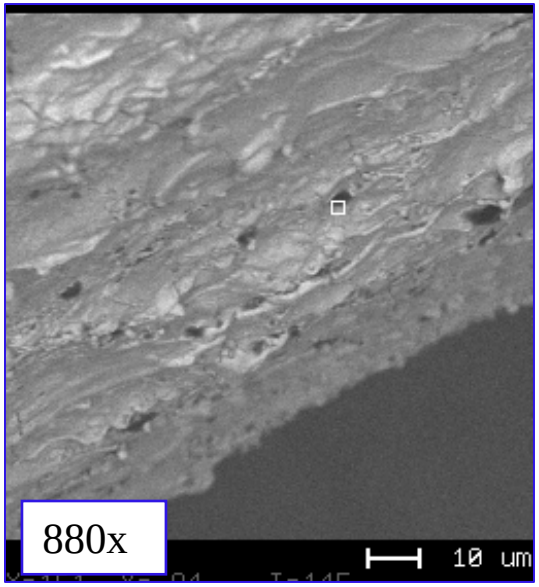
Iris 3



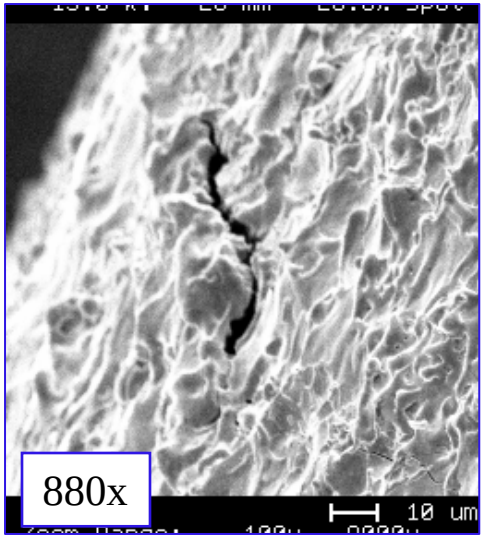
Tungsten Iris Inserts After RF Processing

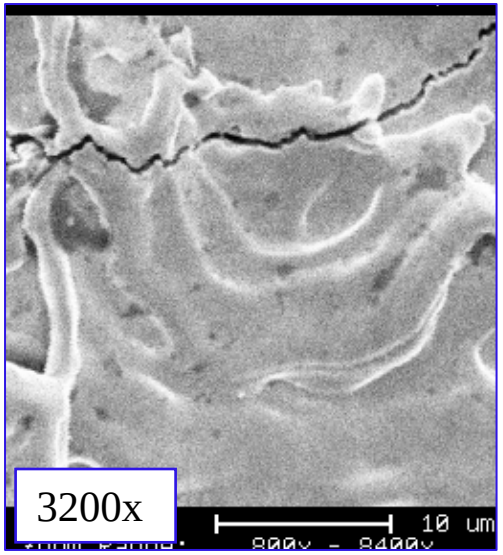
Tungsten Iris 1



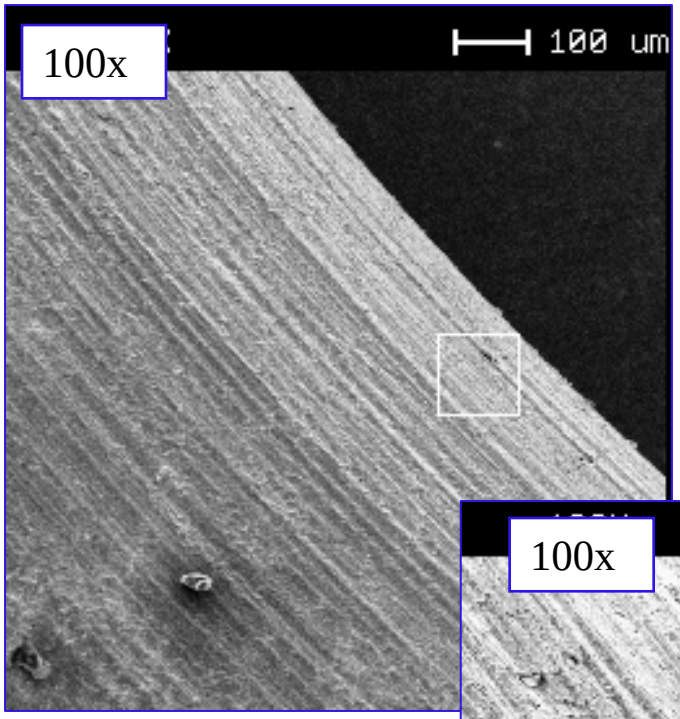


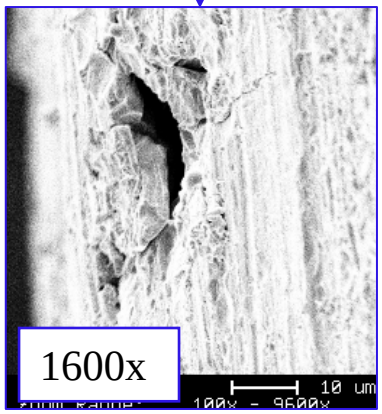
Tungsten Iris 2



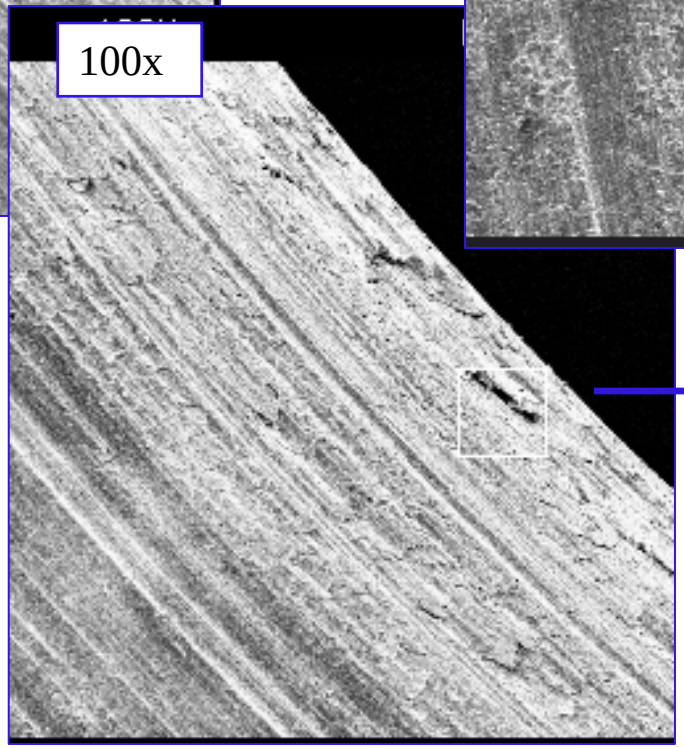


Iris 15

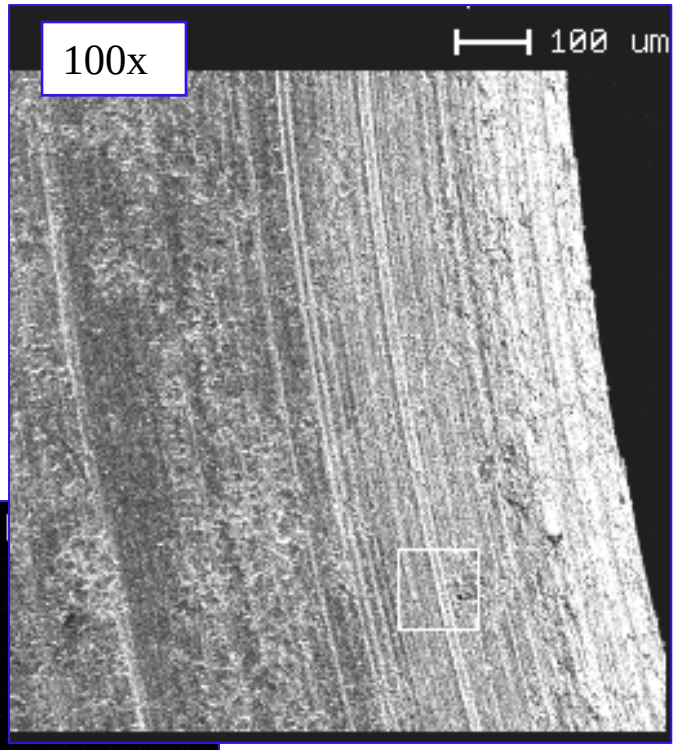


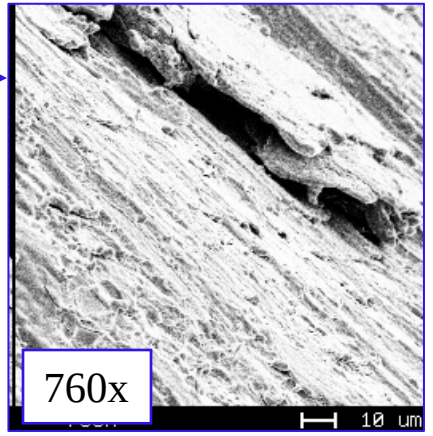


Iris 32



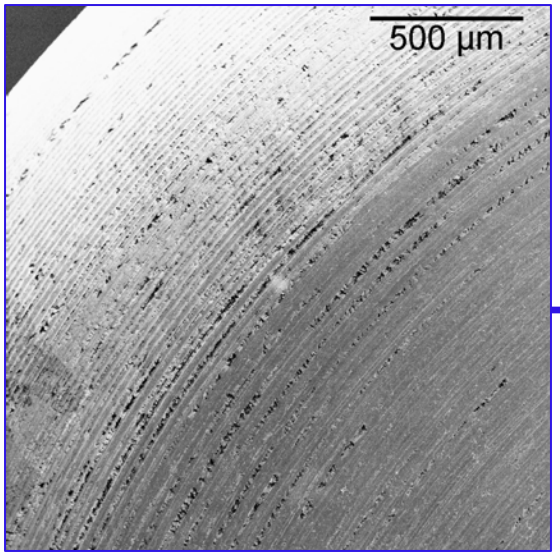
Iris 25



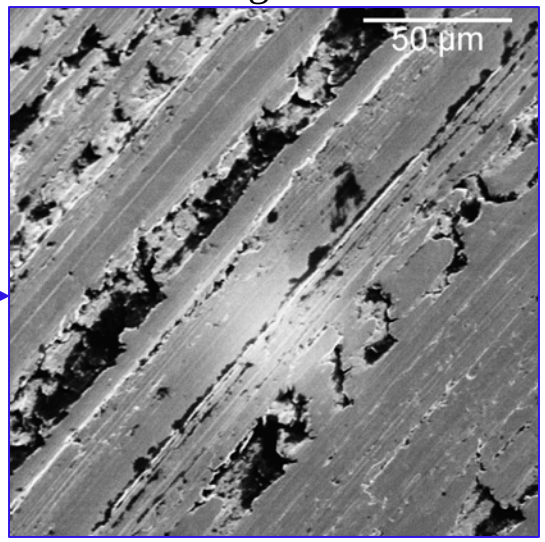


TMat

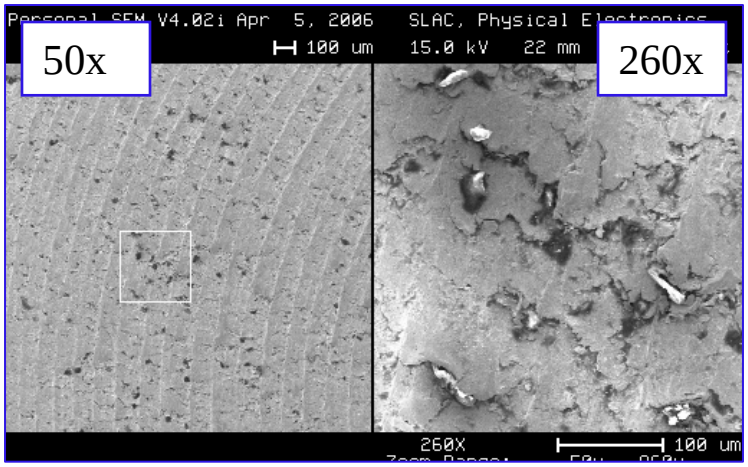
Tungsten Material Study



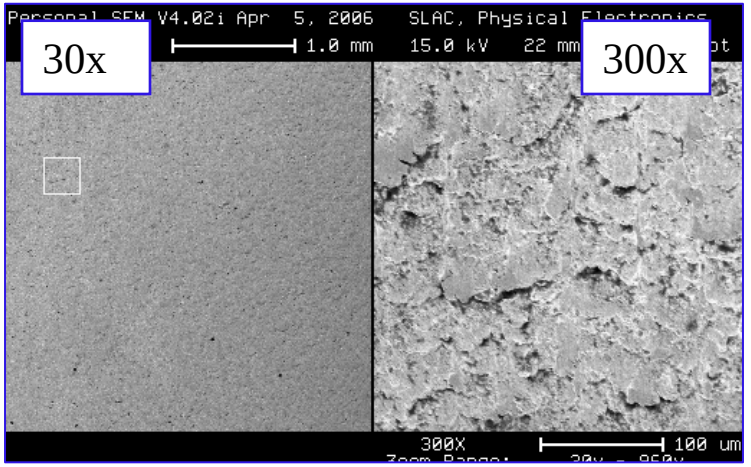
Cutting Tool 1



Cutting Tool 2

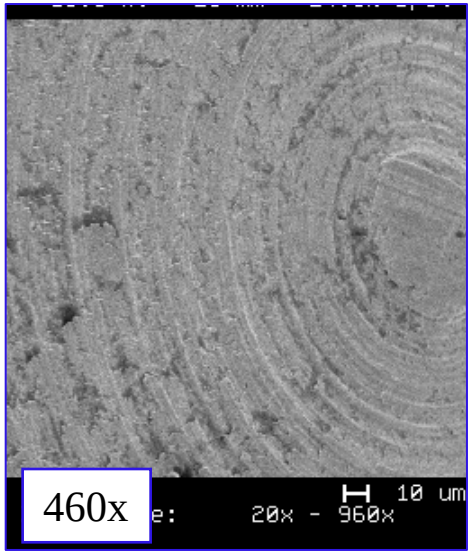


Cutting Tool 3

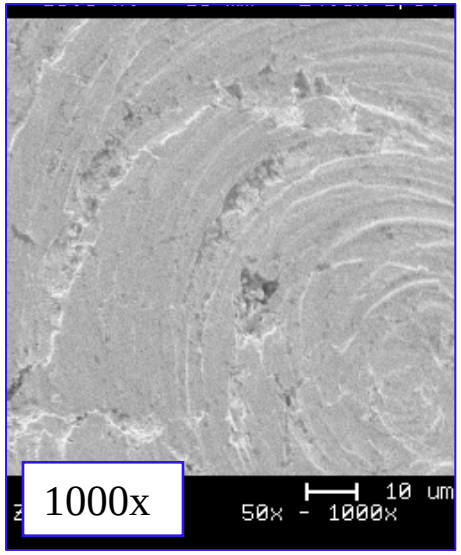


Tungsten Rods Machined at SLAC using Different Cutting Tools

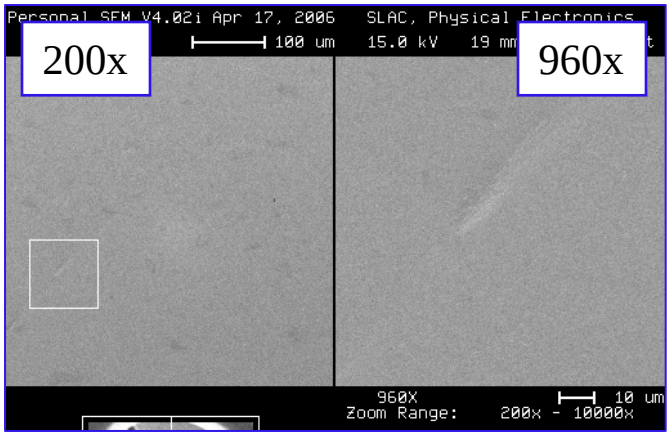
Machined by Philip-Elmet



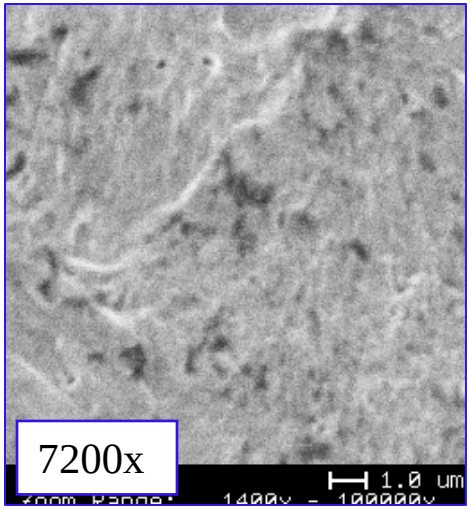
Turned and Polished
by Philip-Elmet



Tungsten Rod Machined at Philip-Elmet and Hand Polished using a Lathe at SLAC

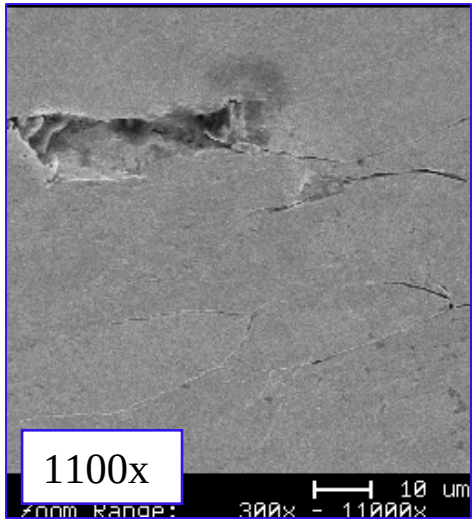


After Electropolishing

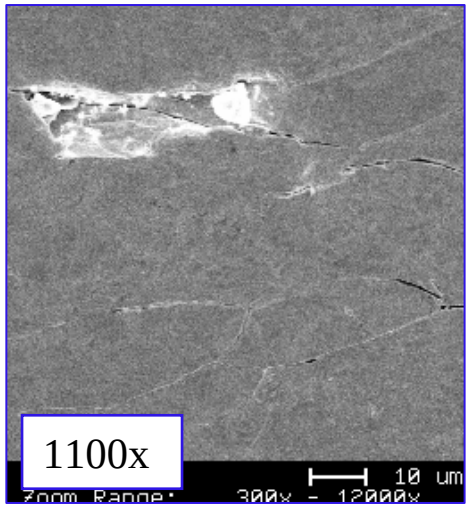


Tungsten Rod After Wet Hydrogen Firing at ~1000°C for Two Hours

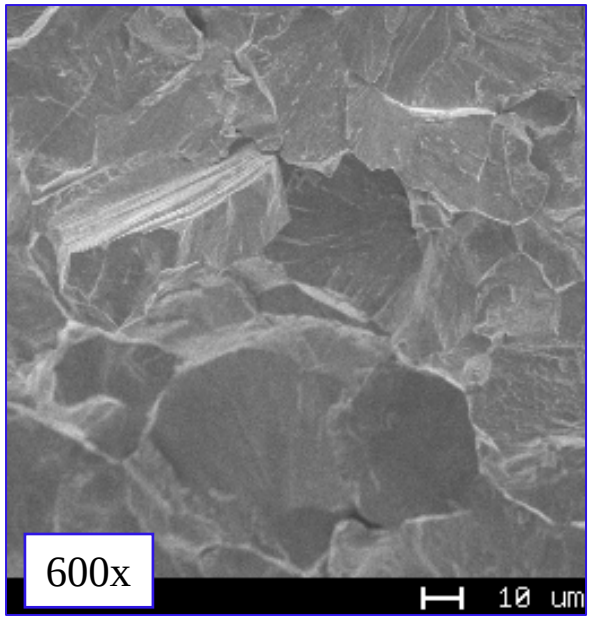
Before →



After →



Bulk Material Purity Test: Cracked Tungsten Rod



Cu

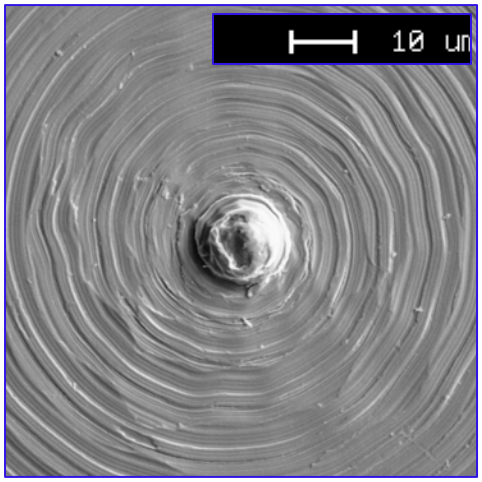
Surface Topography of Copper Compared to Tungsten (Magnification: 1000x)

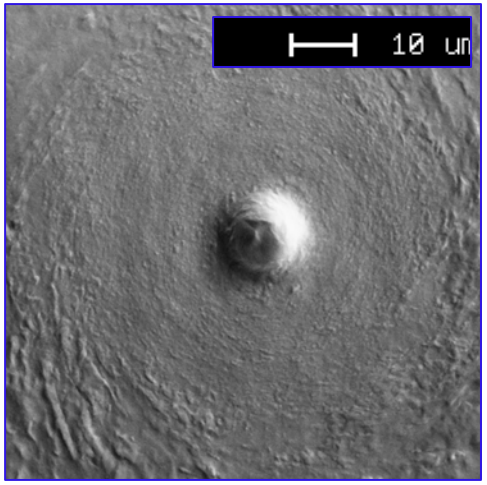
Before Etch

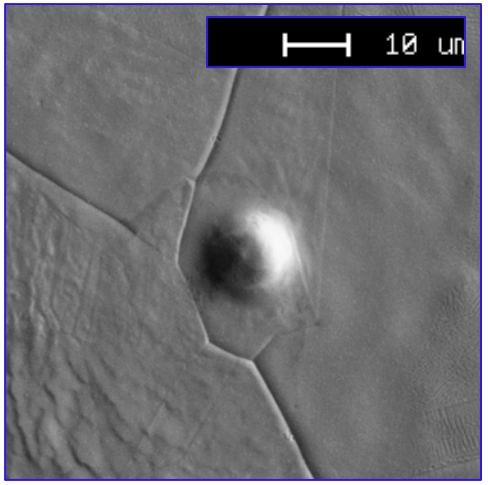
After Chemical Etch

After Heat Cycle

Copper



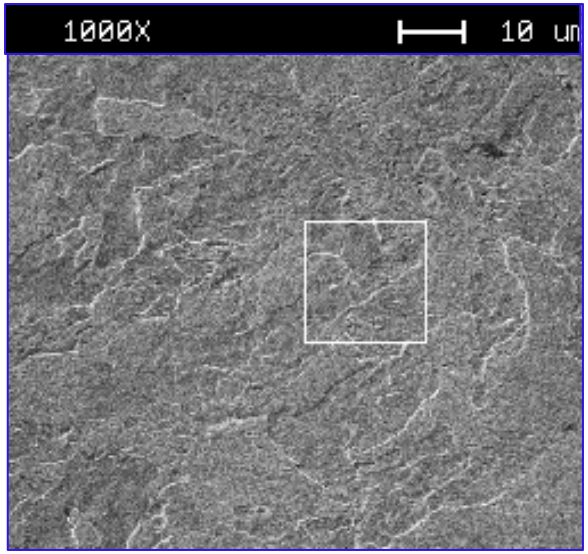


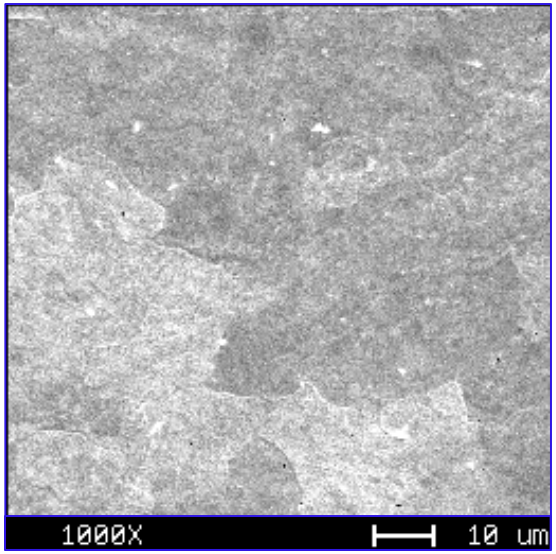


After Hand Polishing and Electropolishing

After Heat Cycle

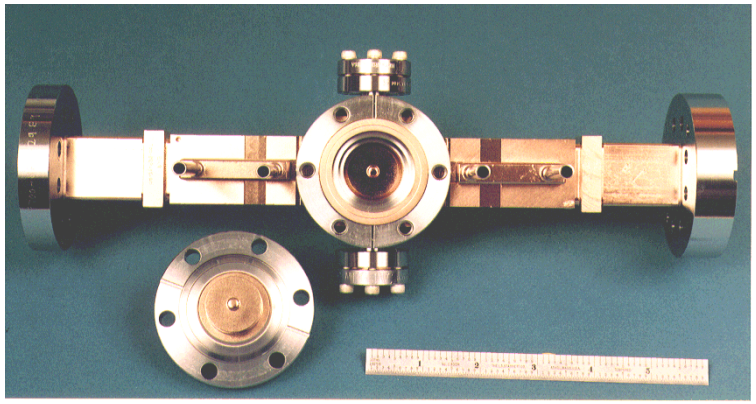
Tungsten





Cav

X-Band Cavity Material Breakdown Study

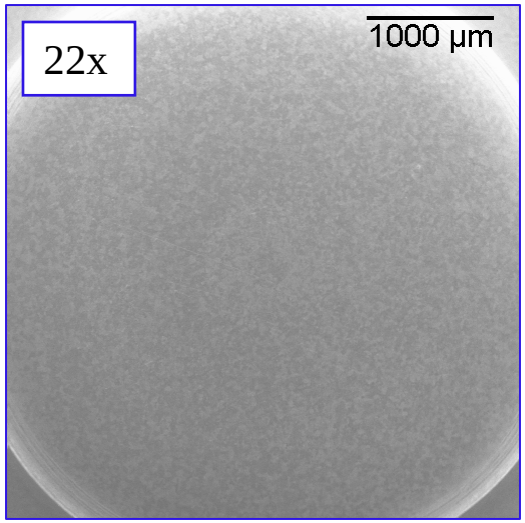


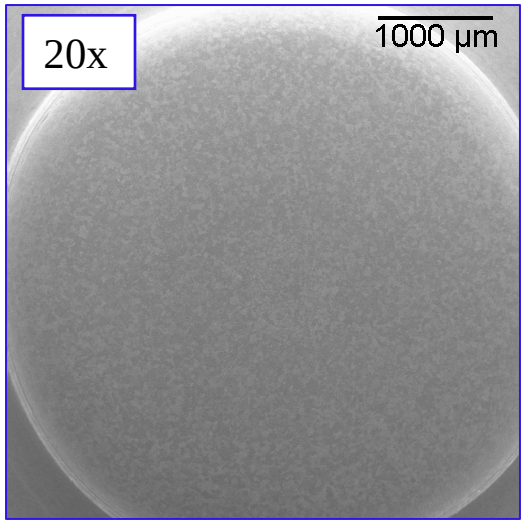
Program History

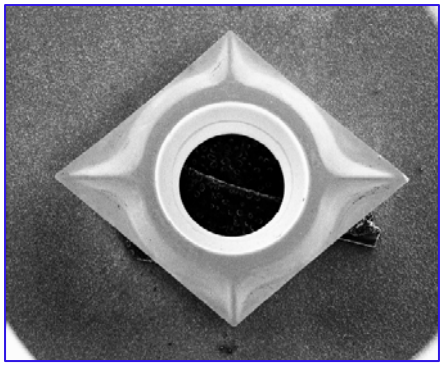
1996	Development of a TM_{010} Cavity
1997	Testing of Coatings and Surface Finish
	Development of a TM_{020} Cavity
1998	Micro-particle Contamination
	Grain Boundaries
1999	Pulse Length Studies
	Various Vacuum Conditions
2000	Hi Q and Lo Q Cavity Experiments
2001	Materials Study
	Short Pulse Processing

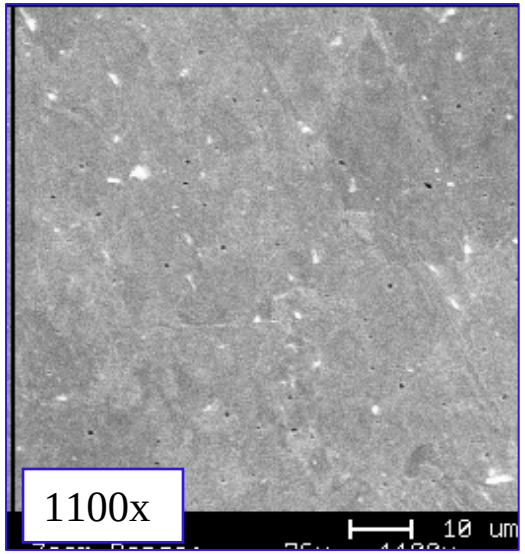
Cavity Nose with Tungsten Insert

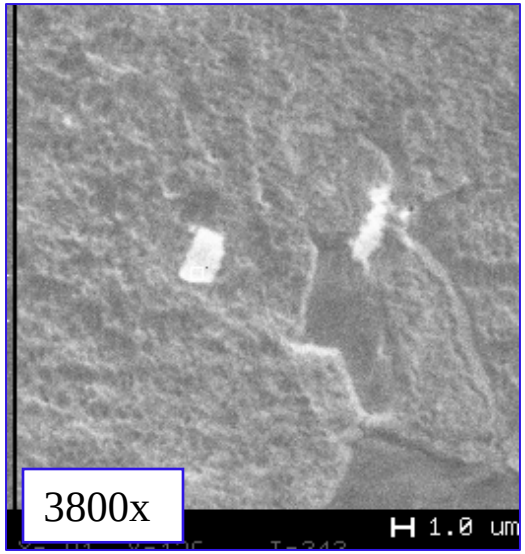
Tungsten Cavity Nose Pair prior to RF Processing

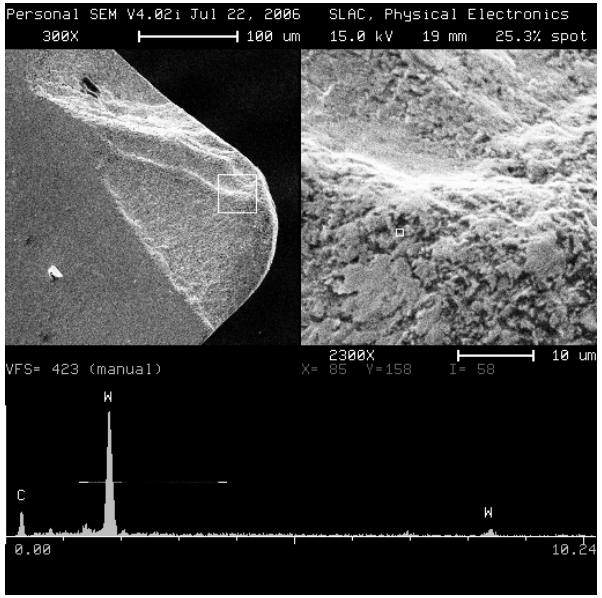


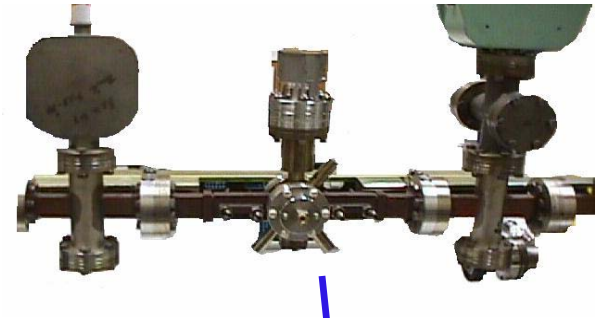


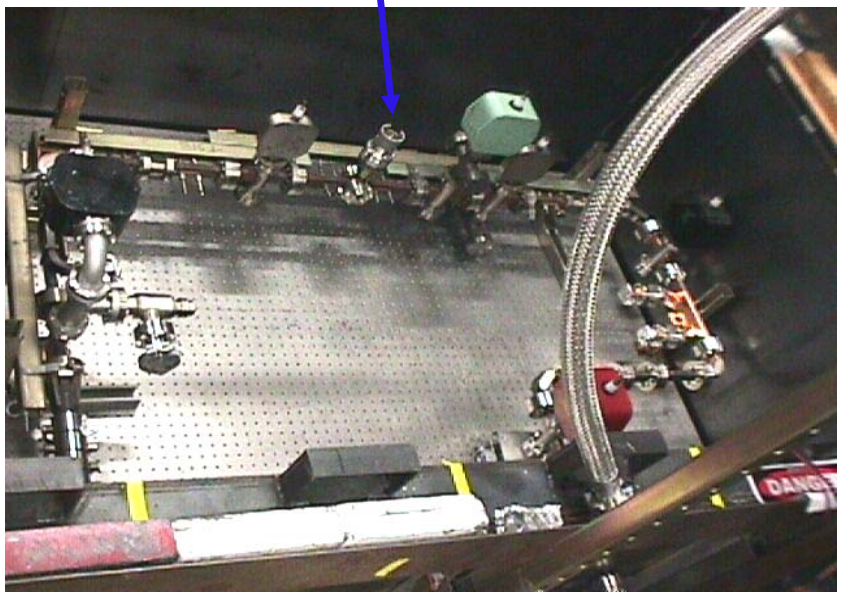




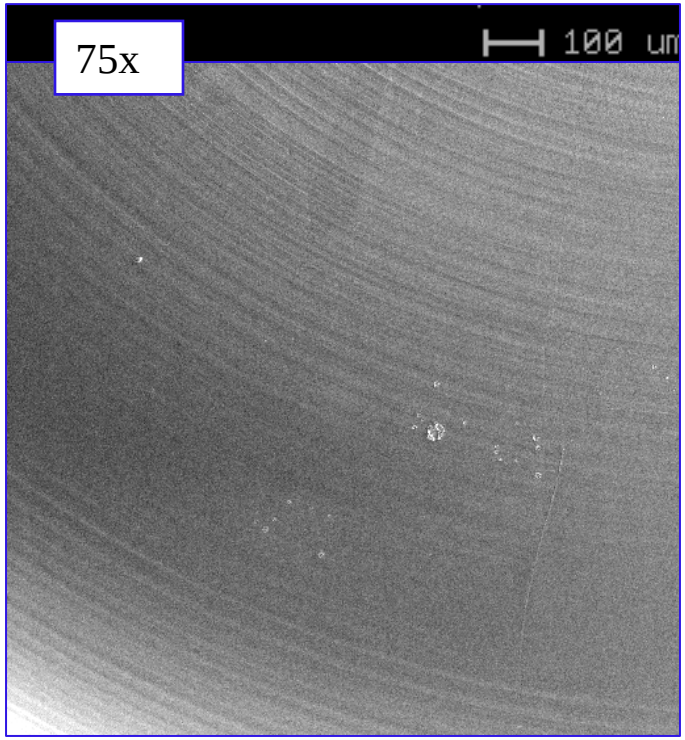




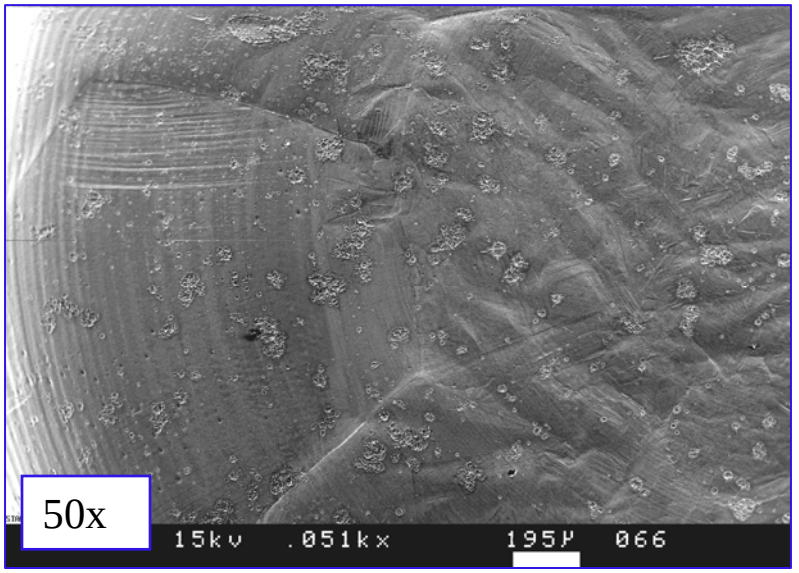




Copper Cavity Noses



350 MV/m

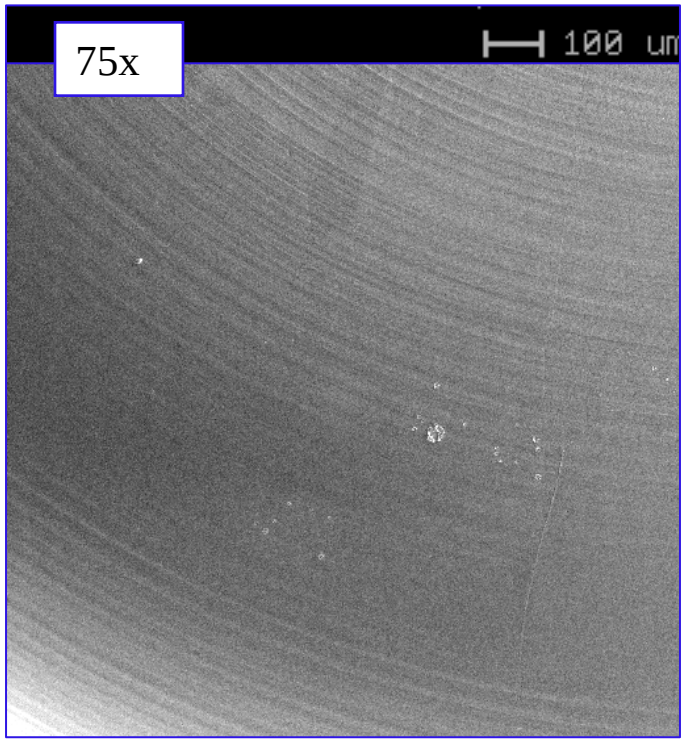


500 MV/m

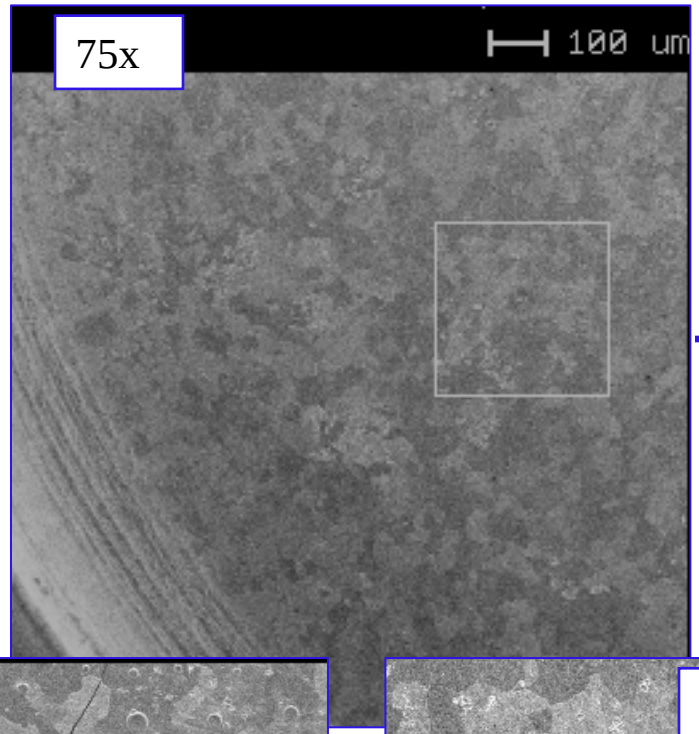
SEM photograph showing a section of the cavity nose surface area after rf processing with a pulse length of 150ns up to field levels of 350MV/m and 500MV/m.

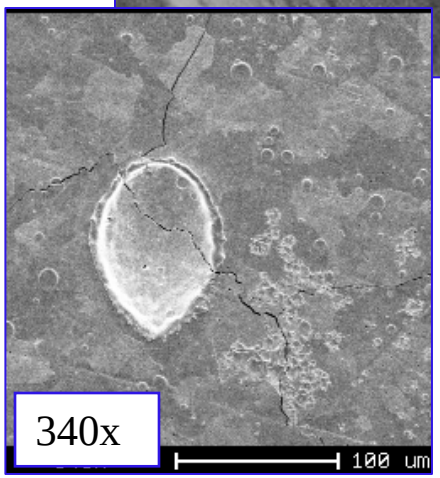
After RF Processing to 350 MV/m (Pulse length=150ns)

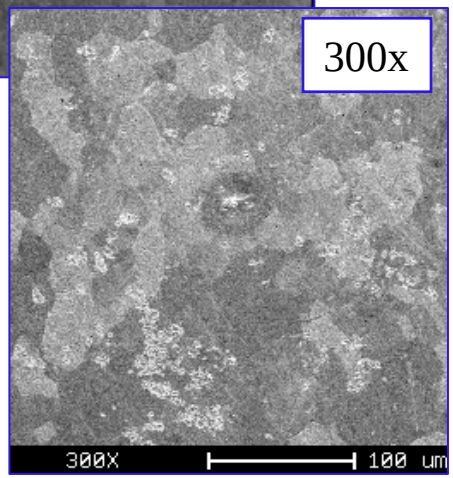
Copper



Tungsten

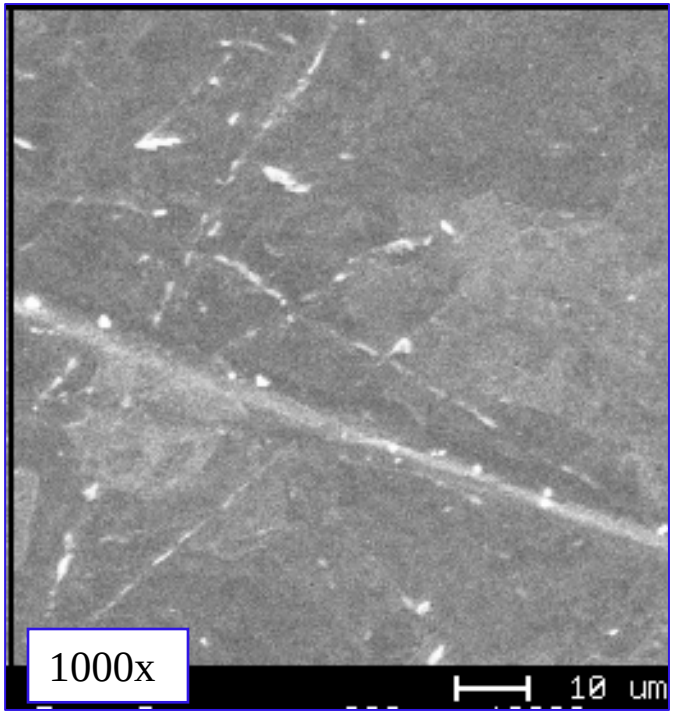




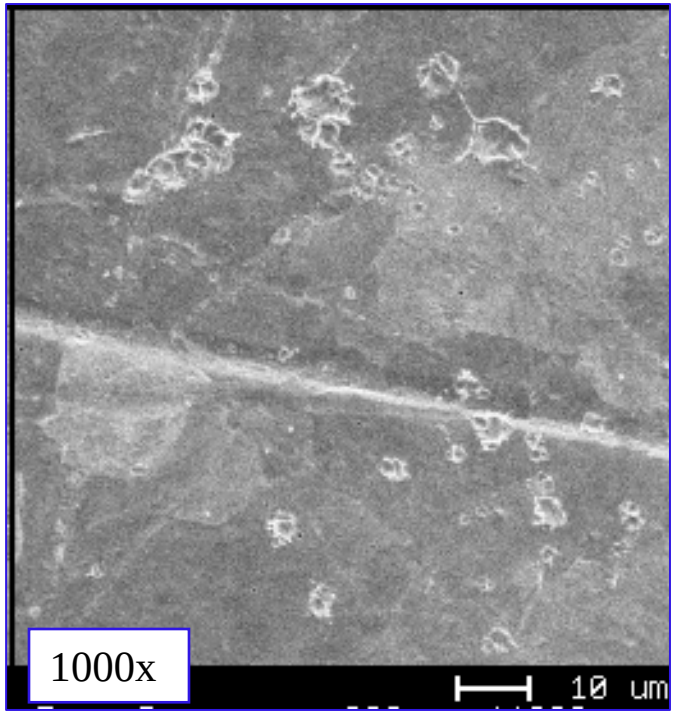


Tungsten: Before and After RF Processing to 350 MV/m

(Pulse length=150ns)



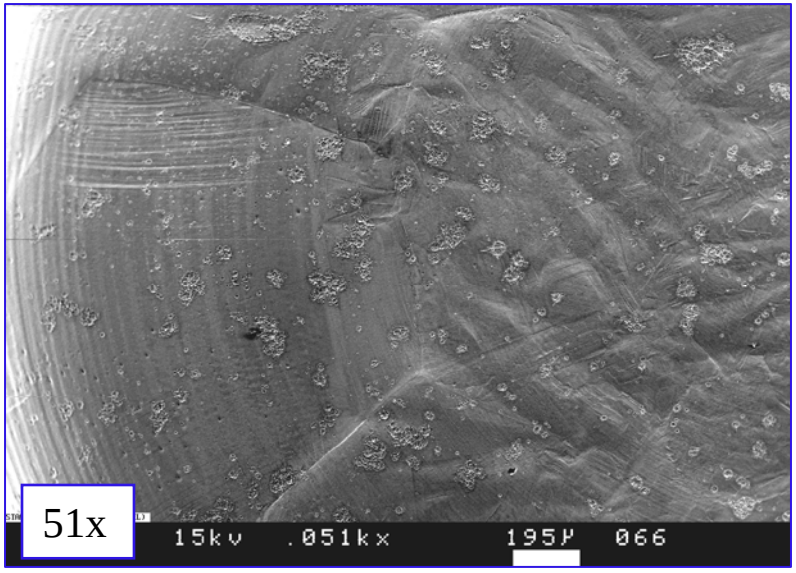
Before



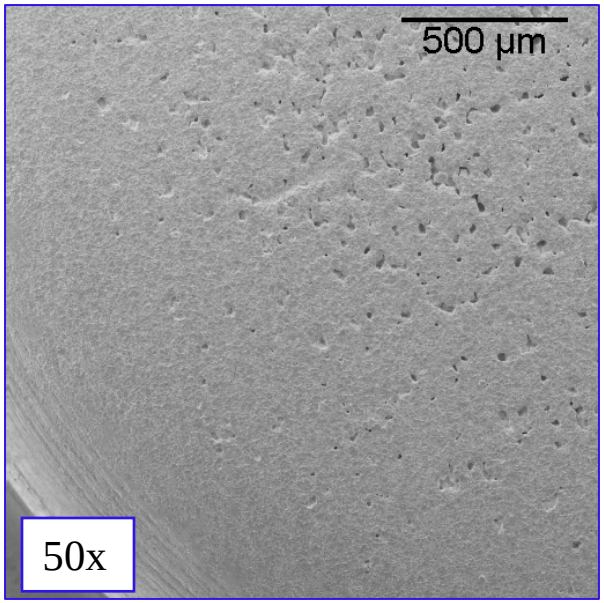
After

Tungsten Insert Before RF Processing

Tungsten Insert After RF Processing to 419 MV/m
(Pulse Length: 150ns)

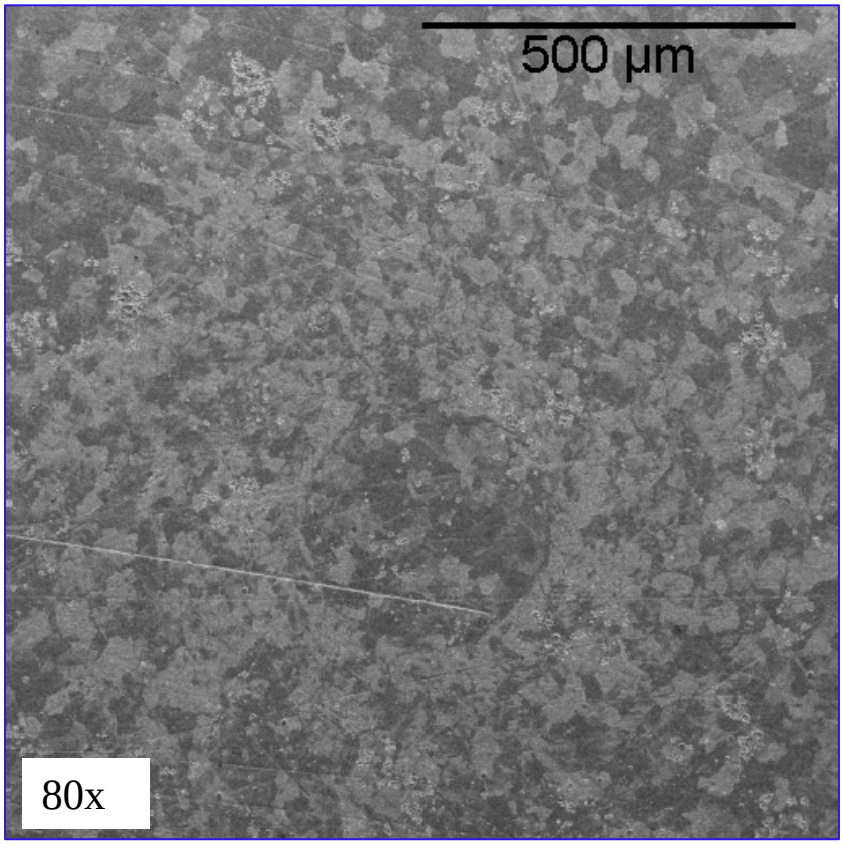


Copper Surface: 500 MV/m

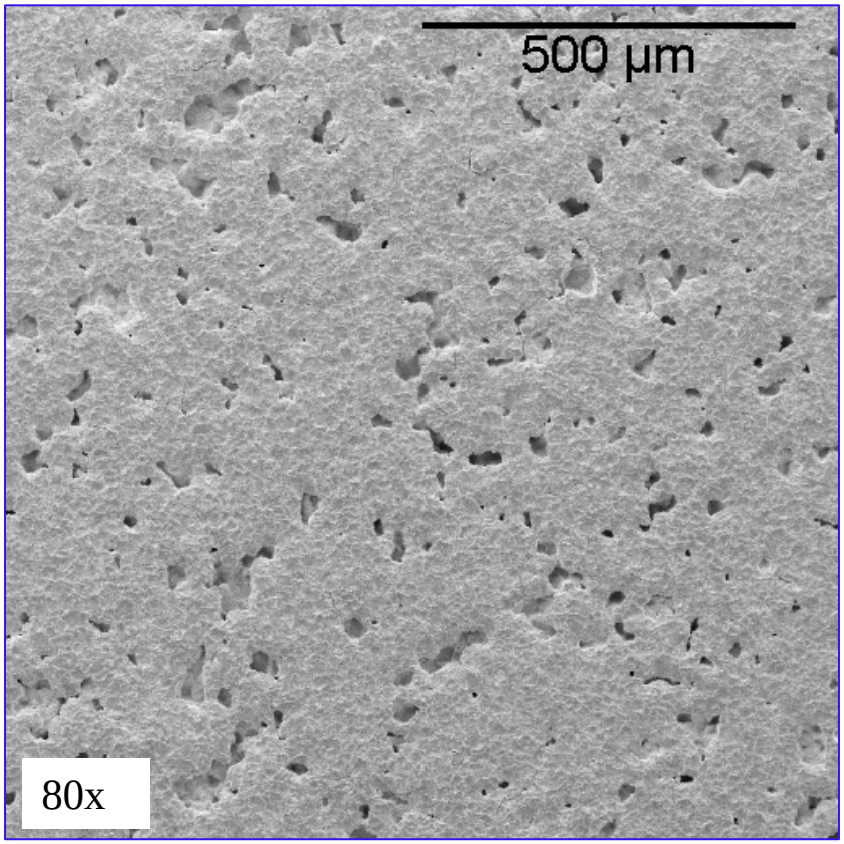


Tungsten Surface: 419 MV/m

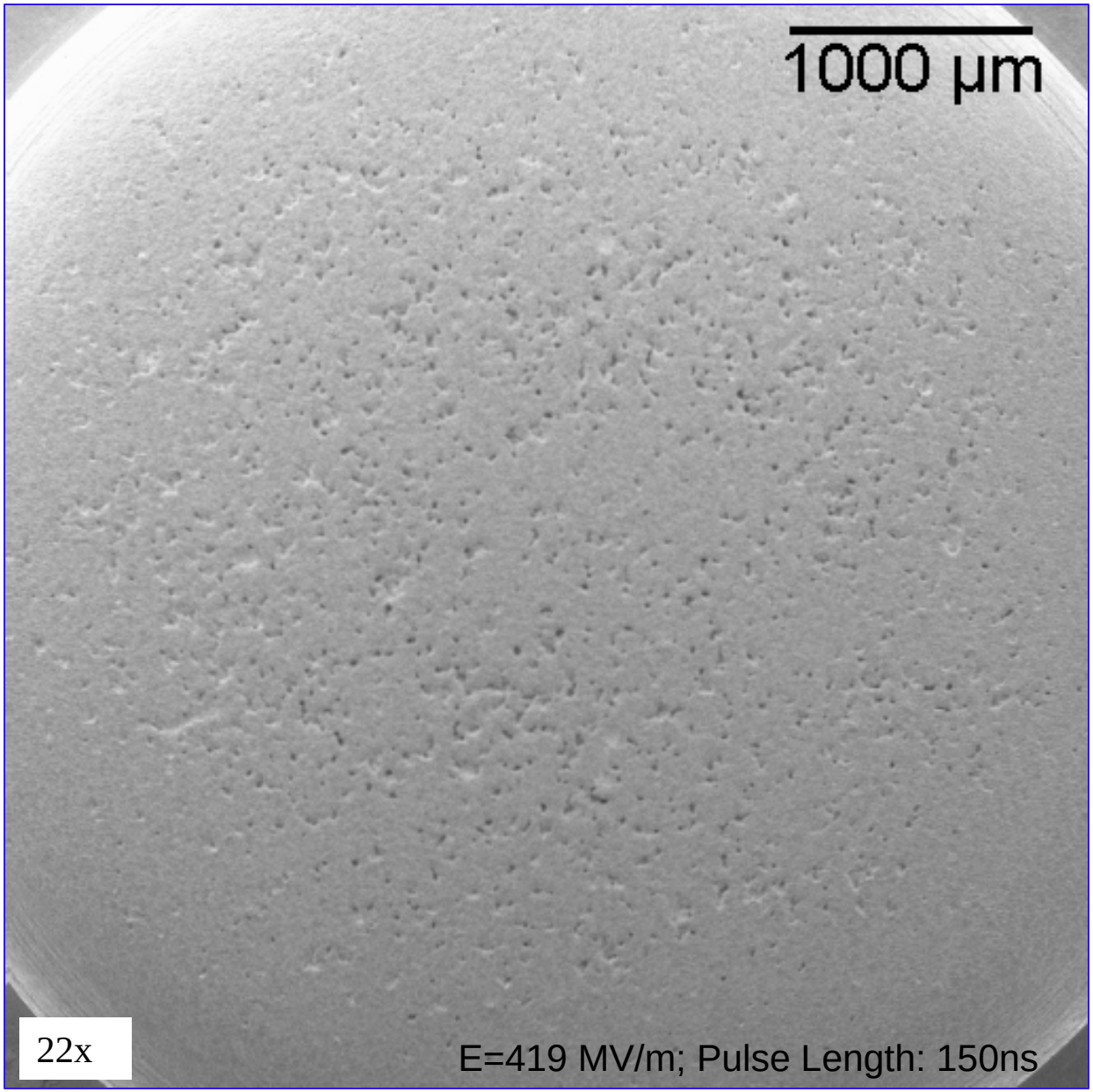
Tungsten Cavity Nose: Surface at 350 MV/m and 419 MV/m

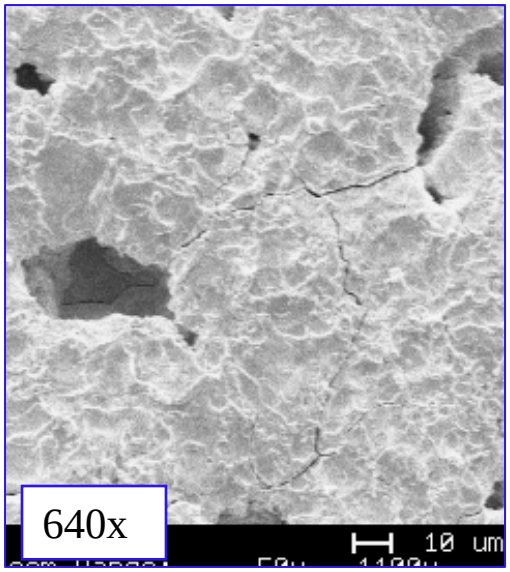


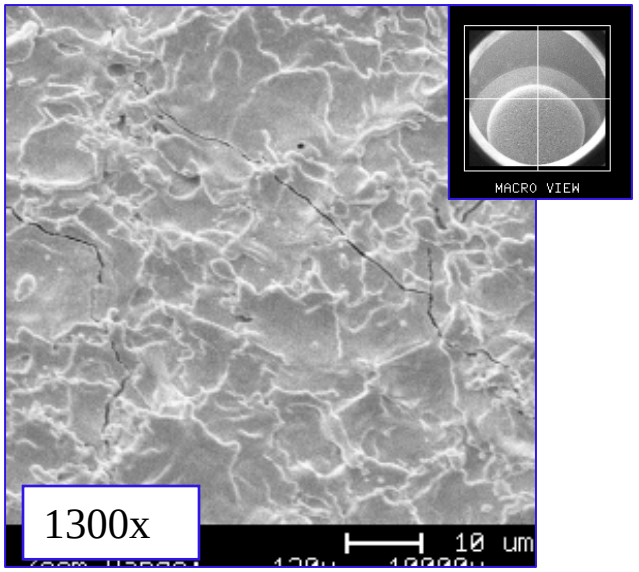
E=350 MV/m; Pulse Length: 150ns

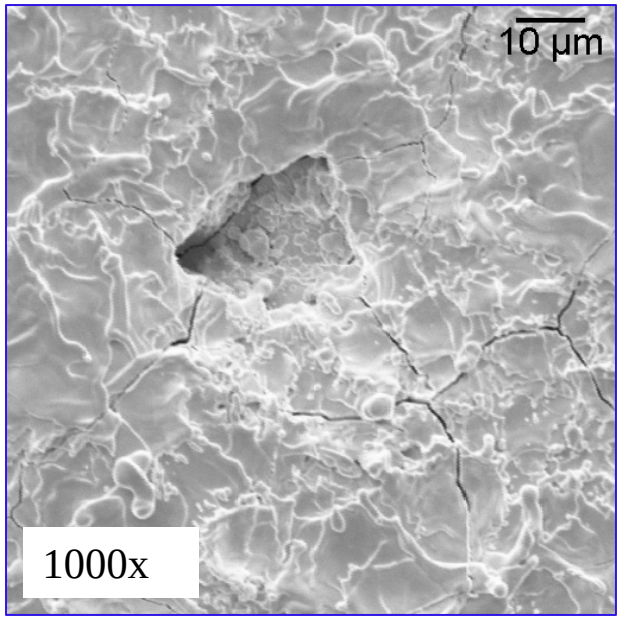


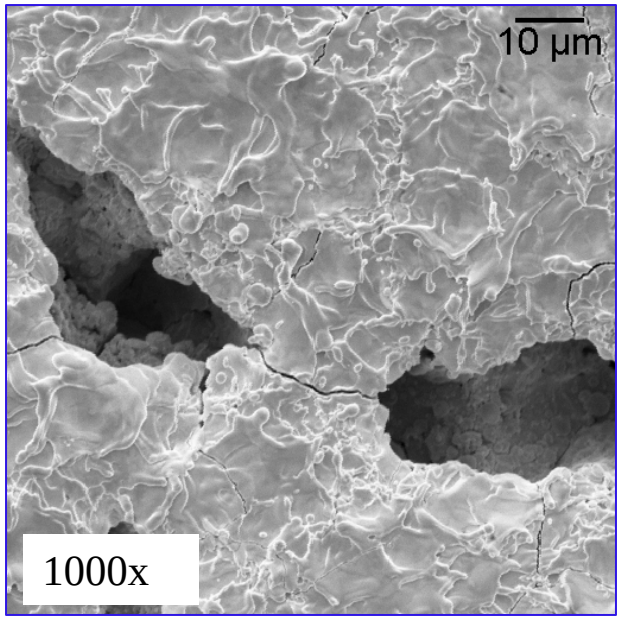
E=419 MV/m; Pulse Length: 150ns


1000 µm
22x
E=419 MV/m; Pulse Length: 150ns





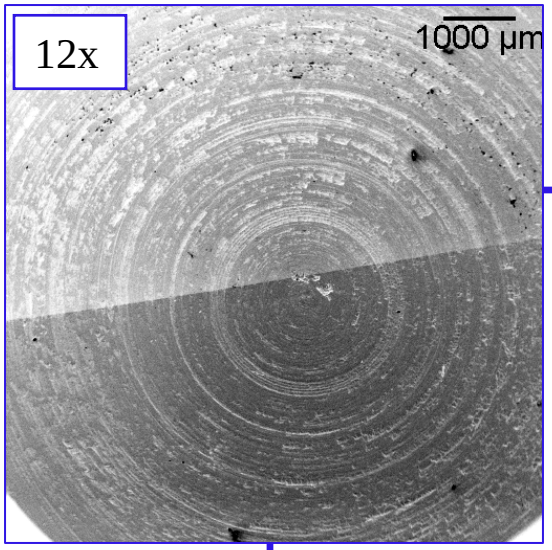


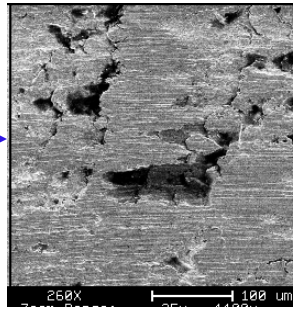


Tungsten Nose: E=419 MV/m; Pulse Length: 150ns

GCB

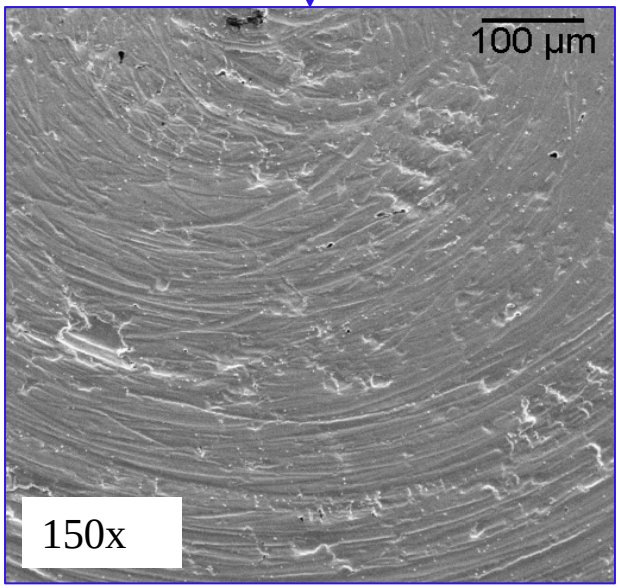
GCIB Processing: Tungsten



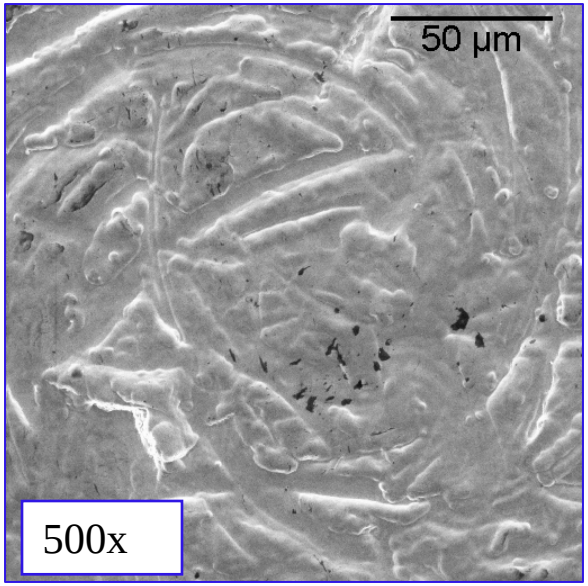


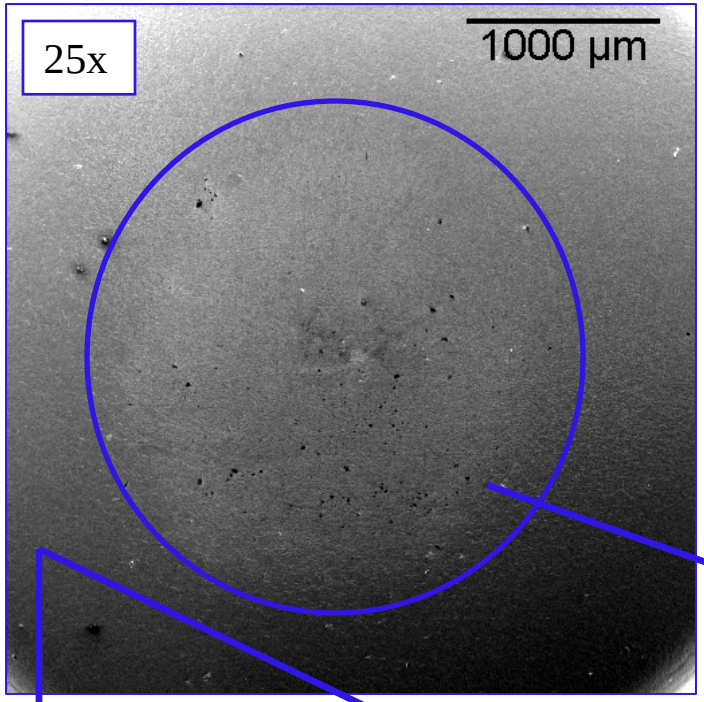
Masked Area

GCIB: 1 Hr



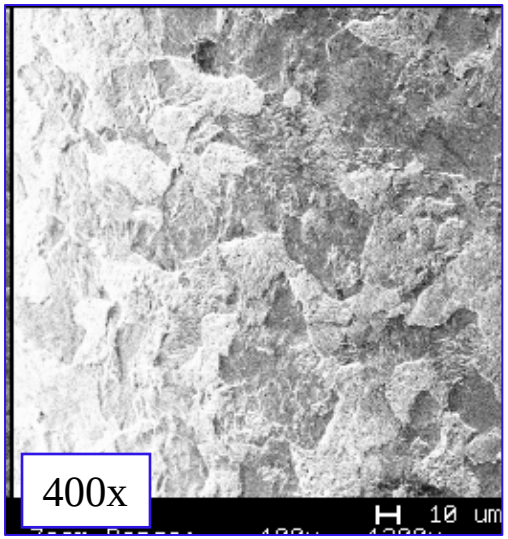
GCIB: 2 Days



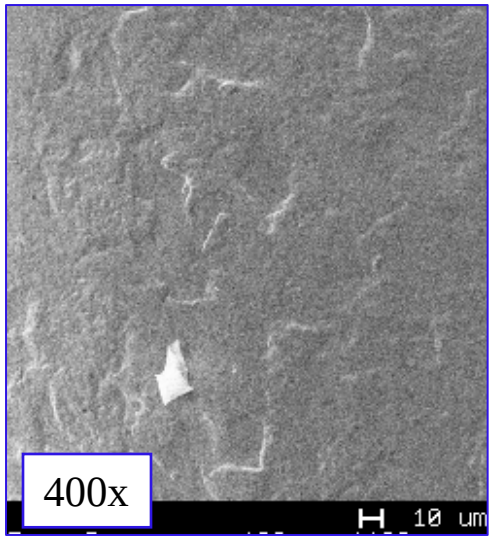


GCIB Processing: Tungsten
Grazing Incident: 1.5 days
Perpendicular: 0.5 days

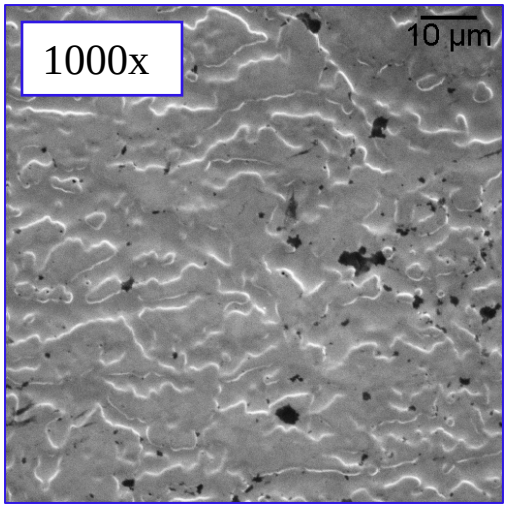
Before GCIB



After GCIB

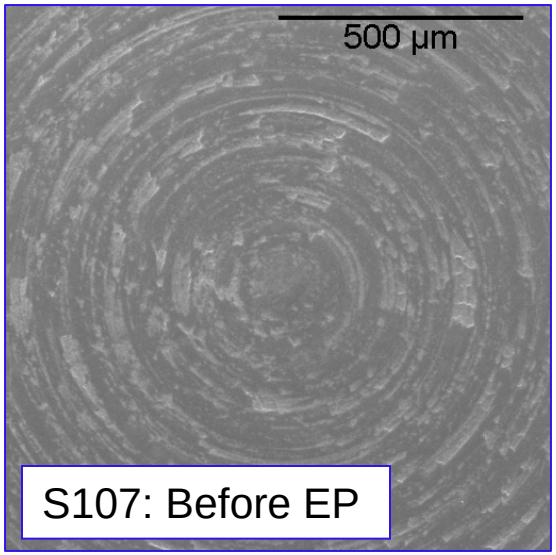


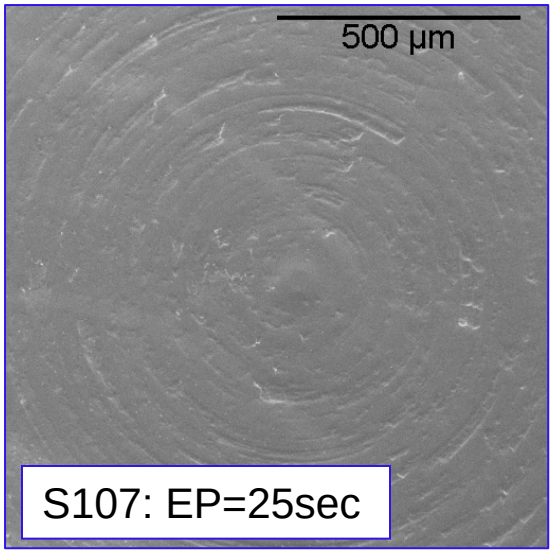
After GCIB

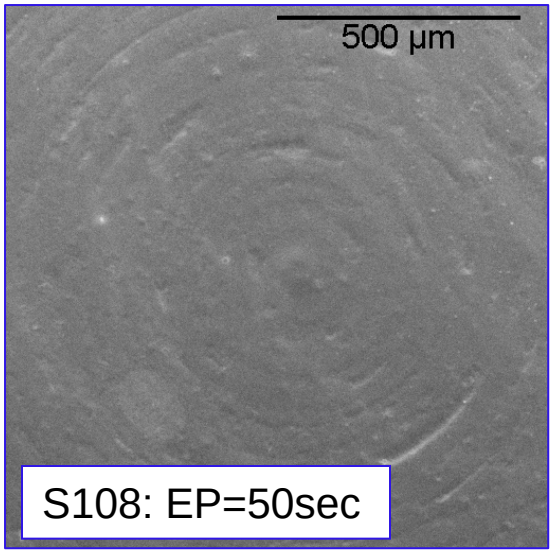


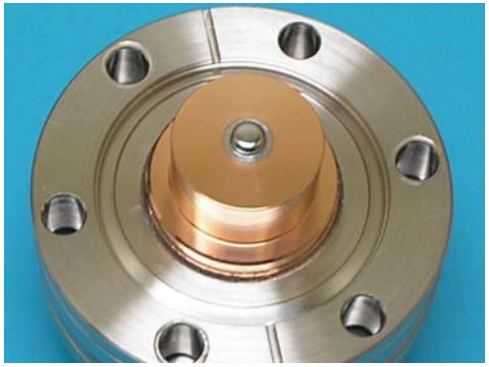
Mo

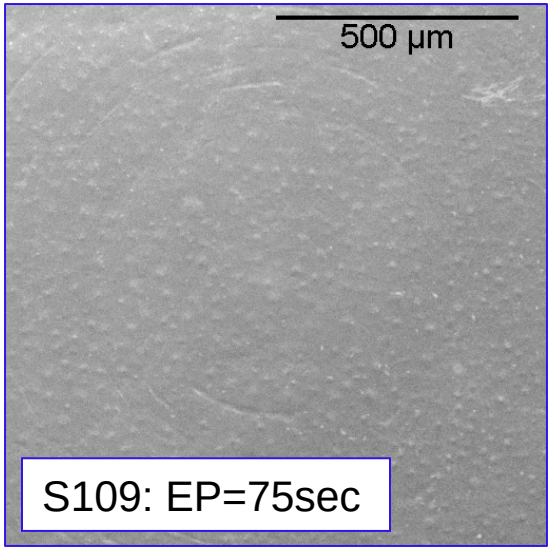
SEM Images of Four Moly Cavity Noses Before and After Electropolishing from 25 to 100 seconds (All images were taken at 80x magnification).

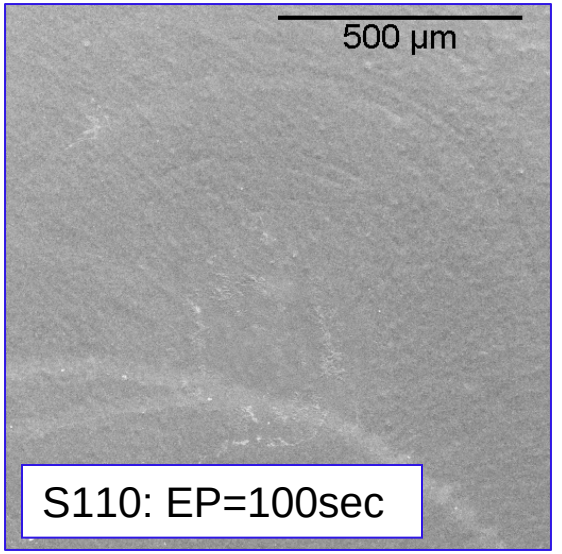




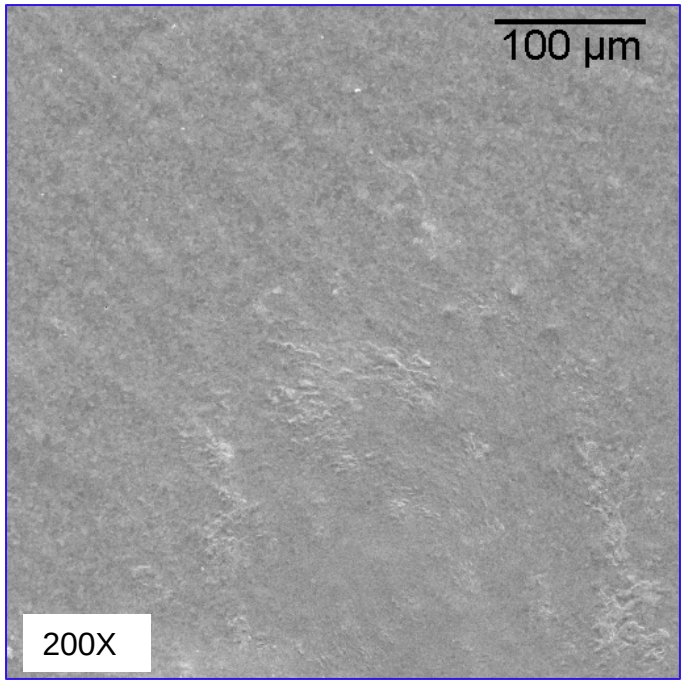


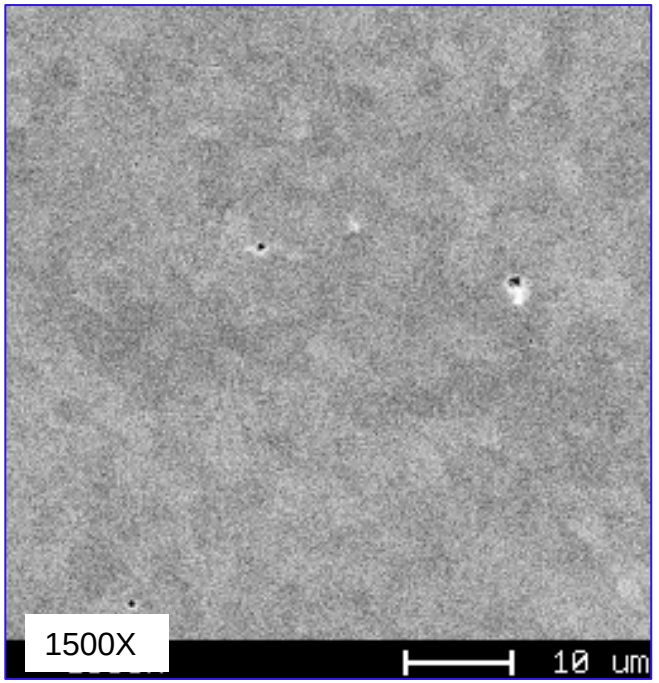






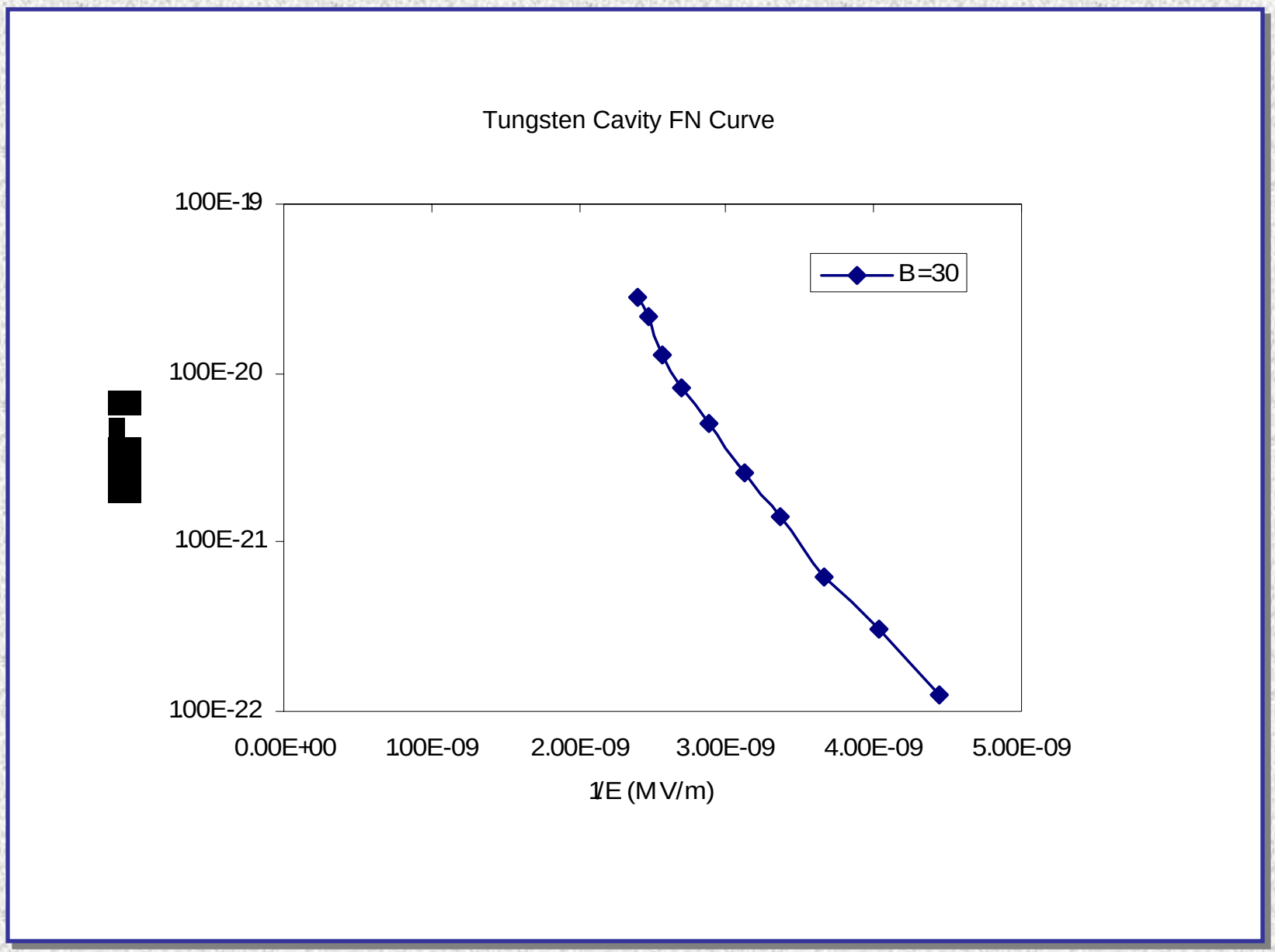
SEM Images of the Moly Cavity Nose S110 at Higher Magnification.





Conclusions

- Eliminating carbon and tears from tungsten surfaces may not end up being the overarching issues when working with tungsten as once was thought.
- Commercial tungsten is fabricated using Powder Metallurgy which may limit tungsten's full capabilities.
- GCIB processing was conducted on both rough and smooth tungsten surfaces. It does not appear that GCIB processing will be effective at a macroscopic level but it may have potential on microscopic features.
- Molybdenum noses have been fabricated and are ready for rf testing. They were also manufactured using powder metallurgy and rf testing these cavity noses may shed more light on the powder metallurgy issues.


Tungsten Cavity FN Curve
100E-19
100E-20
100E-21
100E-22
B=30
0.00E+00
100E-09
2.00E-09
3.00E-09
4.00E-09
5.00E-09
1/E (MV/m)