Cone-Wall Chamber Liner

Large Surface Area, Grazing Incidence
Thermal, Sputtering, Sizing

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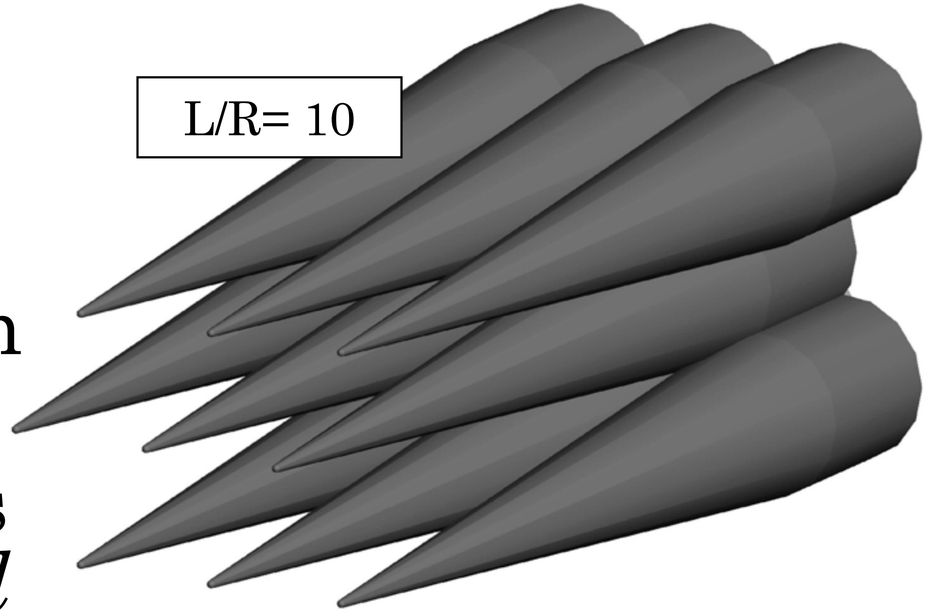
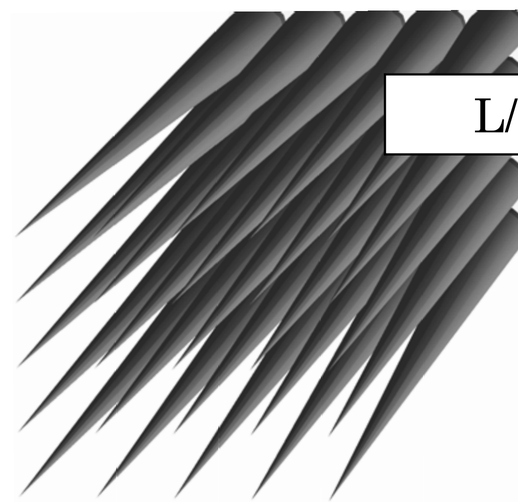
Cone-Wall Chamber Liner

Smooth tungsten is known to damage quickly under helium implantation, severely limiting lifetime in HAPL chamber.

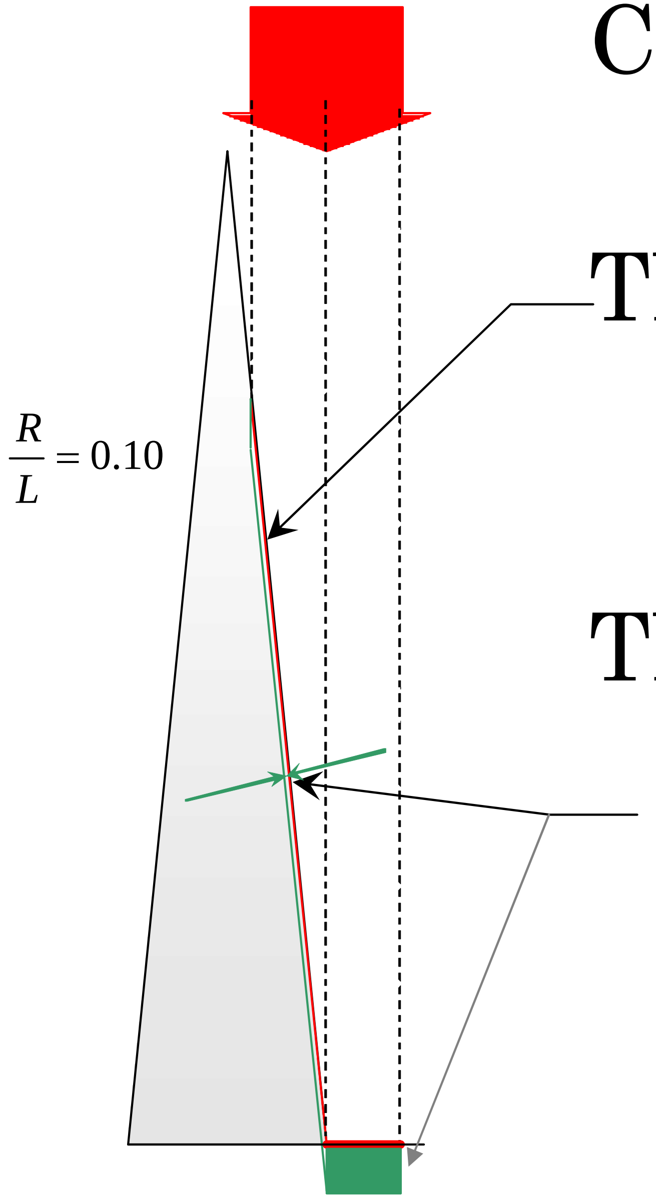
The engineered Cone-Wall is designed to *reduce the local flux and the depth of helium implantation.*

Sputter erosion is slow because sputtered ions redep onto neighboring cones



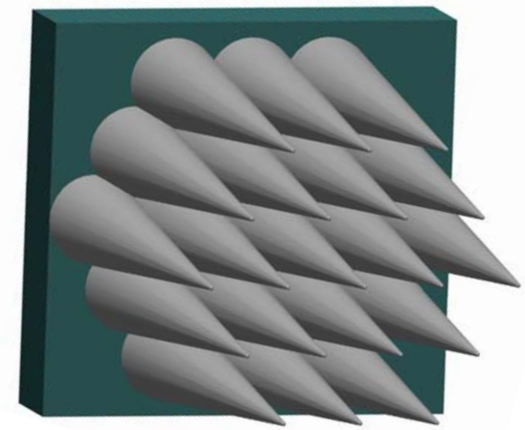


Flux, Fluence, and Range are Reduced



- Cone-Wall area enhancement = side-length / radius = L/R
- The flat wall flux and fluence is spread over this larger area, hence reduced by R/L
- The ion implantation range beneath the surface is also reduced roughly by the same factor (SRIM2008)

Thermal Overview



Steady-State

With a time averaged heat flux of 1 MW/m^2 conducting through a 3-mm thick W Cone-Wall, the T drop is <10 K. The areal mass of such a Cone-Wall is the same as a 1-mm W smooth wall, (independent of aspect ratio).

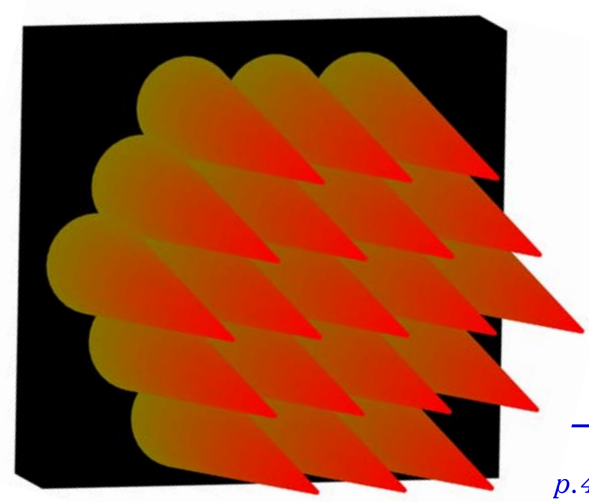
Large cones (> 1 cm length) would result in correspondingly higher steady-state chamber temperature.

Pulsed

Radiant threats to the chamber wall generate T transients that can fatigue flat surfaces. A Cone-Wall with aspect ratio L/R= 10 experiences 10x lower flux.

Cone tips cannot be arbitrarily sharp however.

Thin tips <1 μm radius overheat during 0.2 μs pulse heating in RHEPP.



Scattering Overview

SRIM 2008.03 Modeling: Vary Energy and Incidence Angle

As energy decreases …

- Sputtering increases
- Backscatter increases
- Range decreases

As angle increases (i.e. more grazing) …

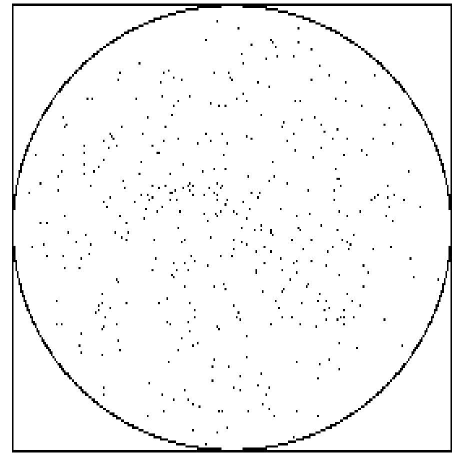
- Sputtering increases
- Backscatter increases
- Range decreases

Energy (keV):	3450	700	30
Ion Angle (deg): 0			
Sputter Yield (atoms/ion):	0	0.0007	0.032
Backscatter Fraction (ions/ion):	0.0010	0.0037	0.152
Ion Average Depth (um):	5.03	1.0	0.0796
Ion Angle (deg): 85			
Sputter Yield (atoms/ion):	0.029	0.165	0.708
Backscatter Fraction (ions/ion):	0.2434	0.475	0.694
Ion Average Depth (um):	0.6844	0.2667	0.0551
Ion Angle (deg): 89.5			
Sputter Yield (atoms/ion):	0.316	0.482	0.489
Backscatter Fraction (ions/ion):	0.732	0.786	0.829
Ion Average Depth (um):	0.5637	0.2439	0.0548

SRIM Sputter & Backscatter

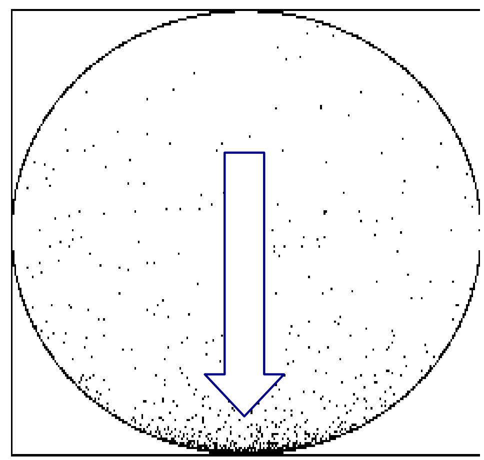
700-kV $^4He^+$ @87deg on W

Sputter yield Y= 0.208 appears Lambertian (isotropic)



Polar plot of local SPUTTER distribution

Backscatter B = 0.585 has a strong forward component ("reflecting" downward into cone-wall)



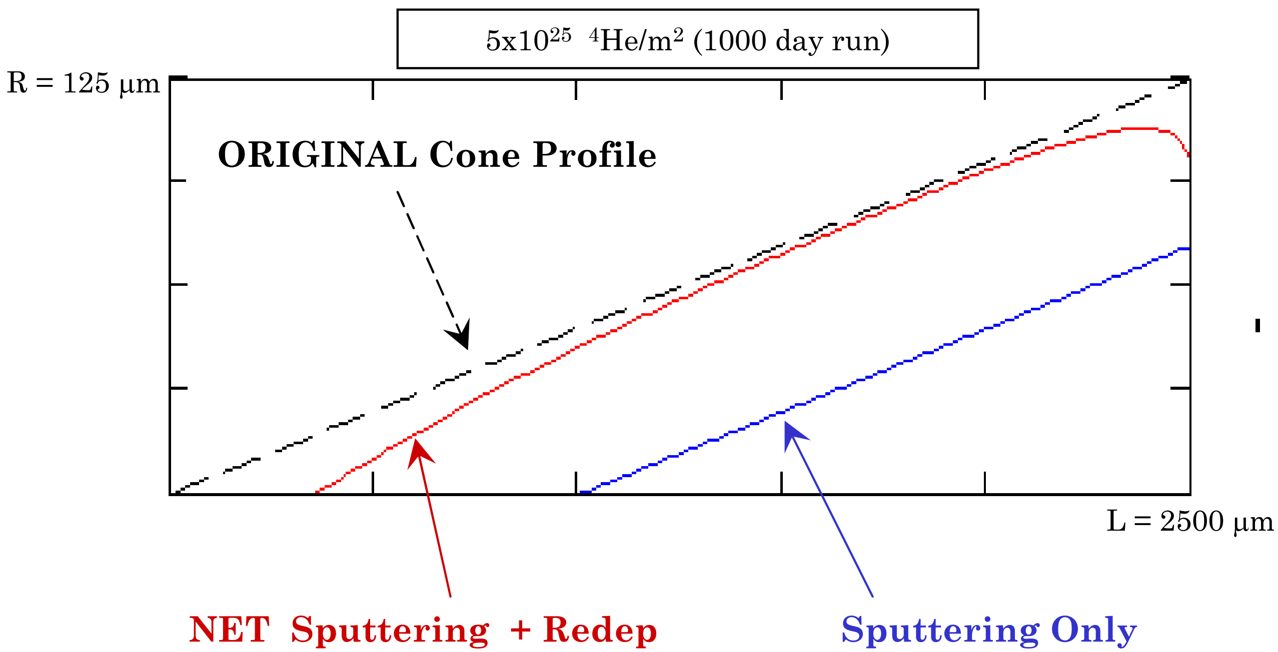
Polar plot of local BACKSCATTER distribution

Net Sputter + Redep (Preliminary)

Sputtered atoms are assumed to have a cosine (Lambertian) distribution and redep on neighboring cones.

Backscatter ions are ignored in this calculation for simplicity (but are surely important to understand Cone-Wall evolution)

Some ions sputter out of the local Cone-Wall, presumably cross the chamber, and reenter the Cone-Wall elsewhere. Such “backflow” into the chamber is much lower (>10x lower) than the backscatter from a smooth W wall.



Modeling performed by M.H. Douglas on ESLI W cone wall assuming local Lambertian yield distribution convoluted with a angle-dependent penetration probability.

This model ignores redep from chamber or from the flat base between (non-intersecting) cones.

Cone-Wall Sizing

Cone-Wall geometry is defined by

- Length **L**, aspect ratio **L/R**, and tip radius **r**
- **Large L/R** reduces local fluence, local T transient, and local implantation depth (range) by the factor R/L
- **Large L** increases mass and lifetime, but also increases average interior wall T
- Modest **r** ~ micron avoids excessive surface transient

Optimum geometry will need to balance the concerns

1. Thermal-mechanical stress life
2. He implantation life
3. Sputter life

Suitable geometry seems likely to be in the range:

L ~ 1-3 mm; L/R ~ 3-30; r ~ 1-3 μm

Conclusions

Cone-Wall offers

- Enhanced area for reduced local flux, shallower implant, lower stress
- Reduced He implantation depth in the thermally active zone
- Reduced sputter backflow into chamber
- Possibly slow(!) sputter erosion with redep between neighbors

Issue

- SRIM predicts significant forward "backscatter" into cone wall. Does this enhance damage at the base or does it allow shallower implant depth as energy is dissipated through multiple grazing collisions?

RECOMMENDATIONS

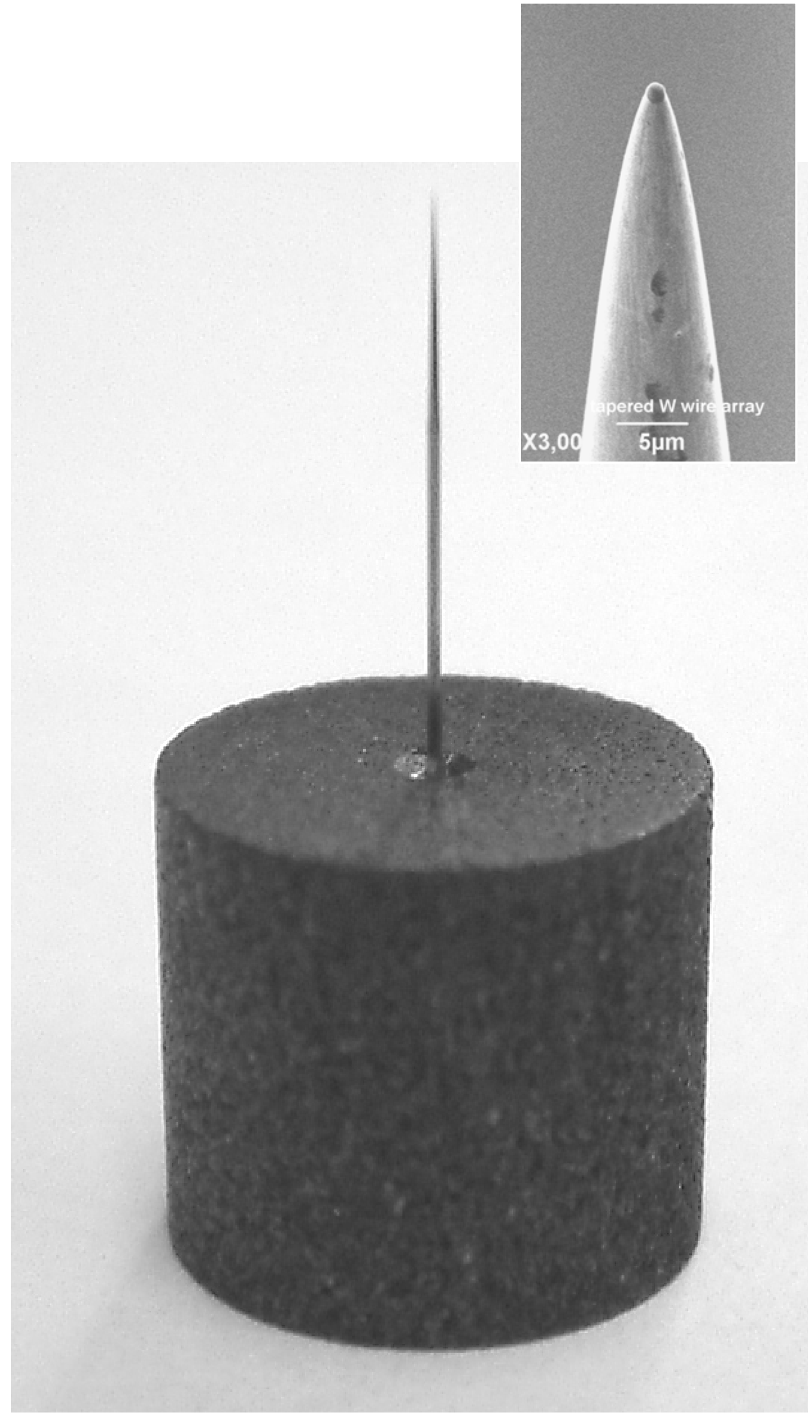
1. Single needle characterization in Pulsed and SS modes
2. Needle cluster redep and backscatter (reflection) characterization
3. Modeling of He diffusion in shallow implant pulsed mode

W Needle Test Articles

Prepared for SNL (T. Renk) and UWisc (S. Zenobia)

2008 HAPL (CTI PO#429698)

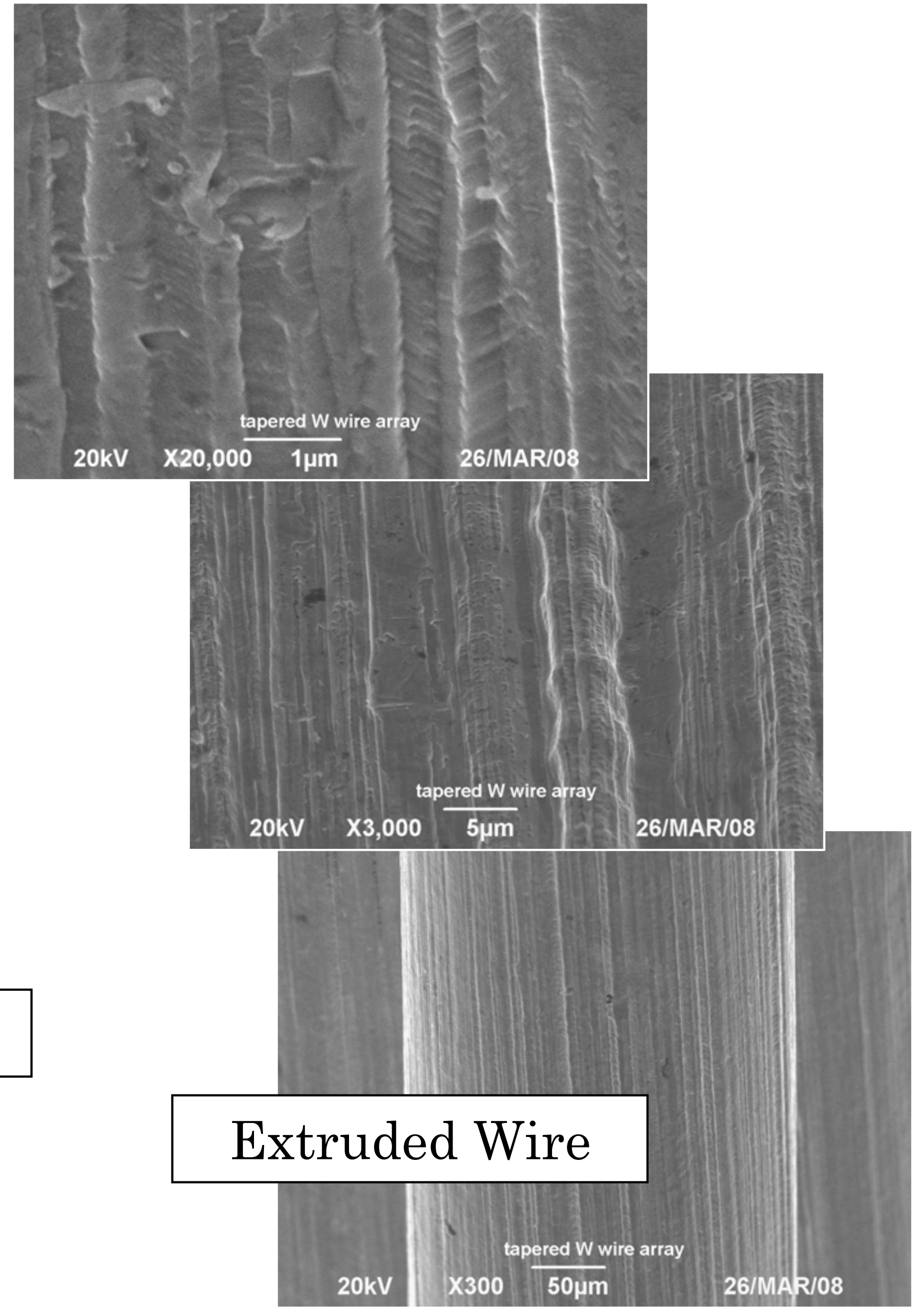
Needle Test Articles



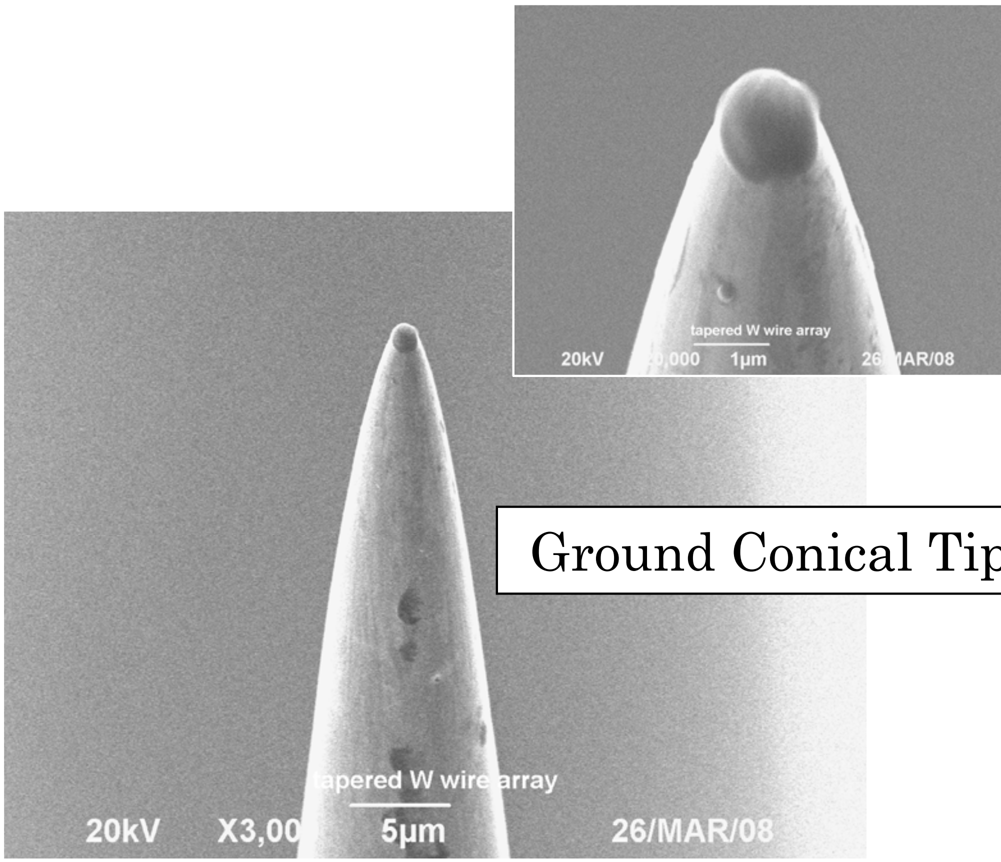
Conical tip	
Length	3.25 mm
Tip diameter	1 um
Full angle	0.1 rad
Needle orientation	±0.03 rad
Graphite base	
Diameter	10 mm
Height	9 mm
Conical aperture	~1.5 mm, 45 deg
Hole diameter	0.27 mm
Hold length	9 mm (clearance)
W Needle (kinked for friction fit)	
Purity	99.9% W
Length	19 mm
Diameter	0.25 mm

W Needle Surface

Heat-treated W wire
Ground surface
Grain structure revealed by etching



Extruded Wire



Ground Conical Tip

W Needle Clusters

For investigating Cone-Wall sputter evolution

Recommended for 2009