# Conical Fiber Chamber Liner

## Concept Illustration
## SRIM Calculations
## W and C Needles
## Test Venues

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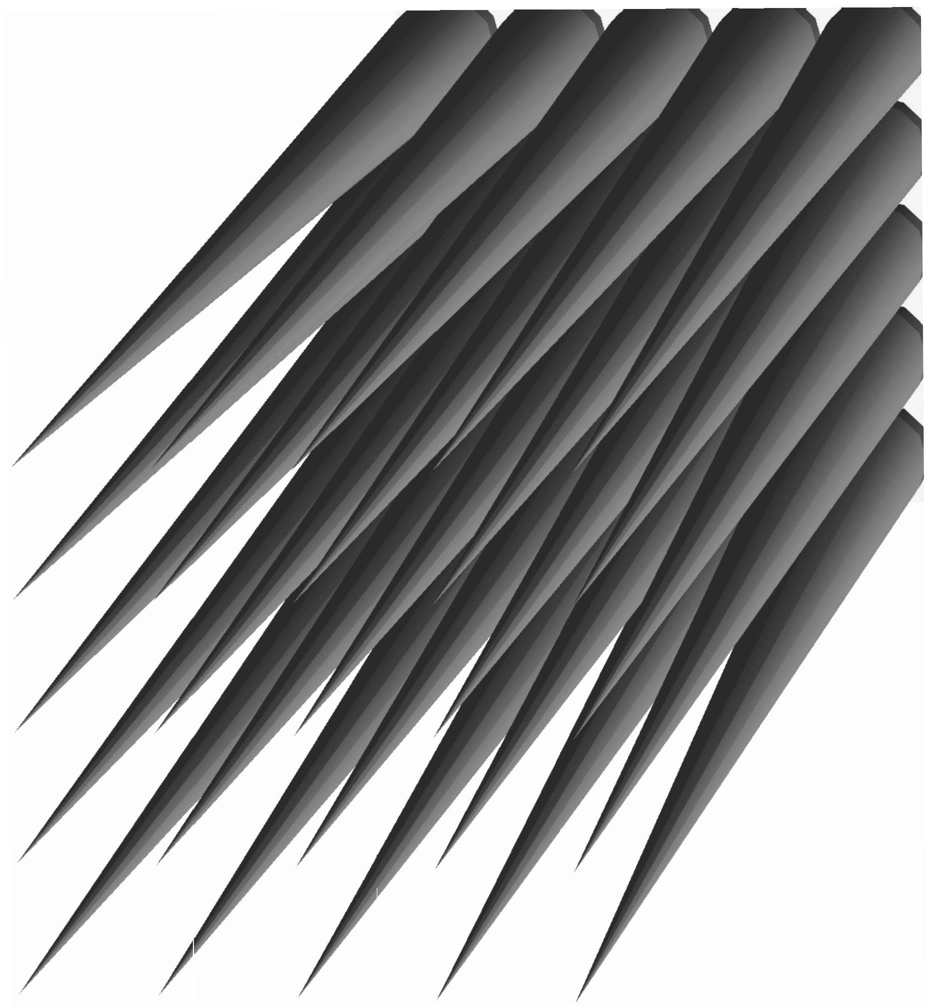
# Cone-Wall Chamber Liner

- He implantation on the LFE chamber wall will eventually blister and exfoliate smooth surfaces. For longer lifetime, we consider rough chamber liners that have large surface area to reduce local fluence and thereby increase lifetime.
- Velvet liners investigated by HAPL show improved survivability of sloping surfaces and sharp tips. Blunt tips and horizontal fibers damage faster.
- The cone-wall is a highly ordered velvet consisting of closely-packed parallel needles with sharp tips and strictly conical surfaces. Benefits are…
  - Large surface area enhancements are achievable. Local surface fluence is thus reduced, typically 10-100x.
  - LFE radiation emanating from the target impinges at grazing incidence on the cones, resulting in shallower implantation, higher backscatter, and higher sputter yield

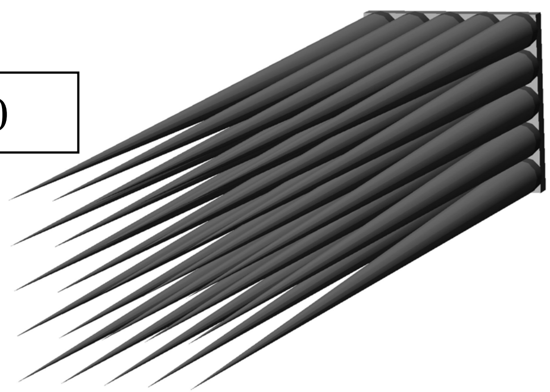


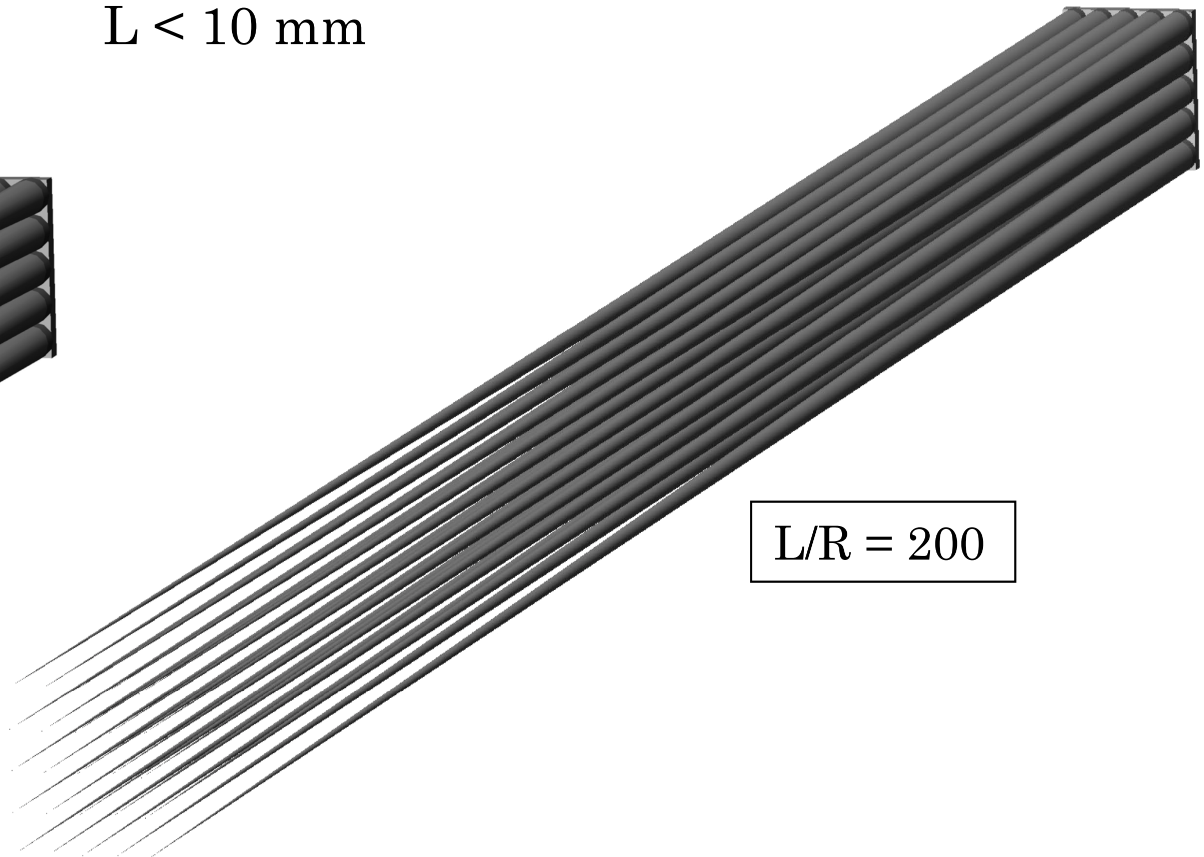
# Scale Considerations

Design variables are length L (~mm) and aspect ratio L/R (dimensionless)

| | | |
|---|---|---|
| Surface area enhancement | $\alpha =$ L/R | (for L/R >>1) |
| Incidence graze angle | $\theta$ = R/L = 1/$\alpha$ | (measured from cone) |
| LFE radiation is collimated | ~ 1 mrad | (1 mm source at 10 m) |
| Low fluence favors | $\alpha > 10$ | |
| Low sputtering favors | $\alpha < 100$ | (see SRIM below) |
| Thermal resistance favors | L < 10 mm | |

L/R= 50





L/R = 200

# Thermal Response

Thermal resistance of L = 3 mm cone-wall is low, resulting in <10 K temperature drop. 10x thicker wall may offer lifetime benefits offsetting increased thermal resistance.

Average transient surface T rise is reduced by the factor $1/\alpha = L/R \sim 0.03$, greatly reducing surface thermal fatigue.

Emissivity and absorptivity of the cone-wall is high (>90%), facilitating radiative heat transfer.

# Grazing Incidence Effects

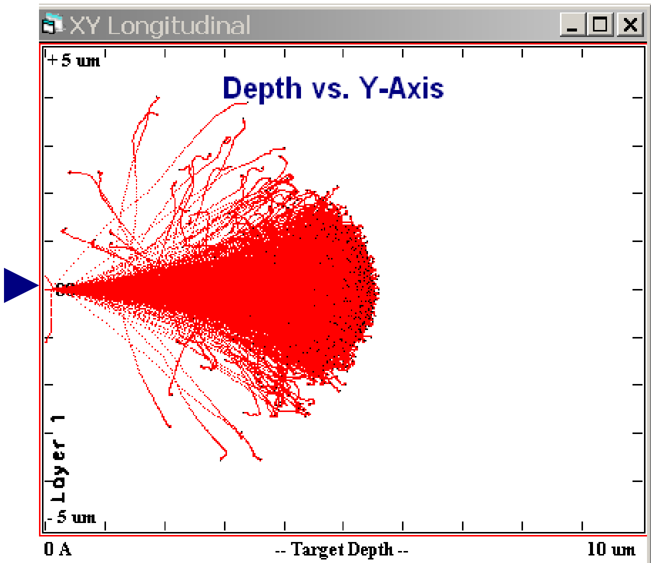
SRIM calcs for 3.45 MeV He on W

At normal incidence…

He ion range ~5.0 µm

0.0 backscatter

0.0 sputter yield

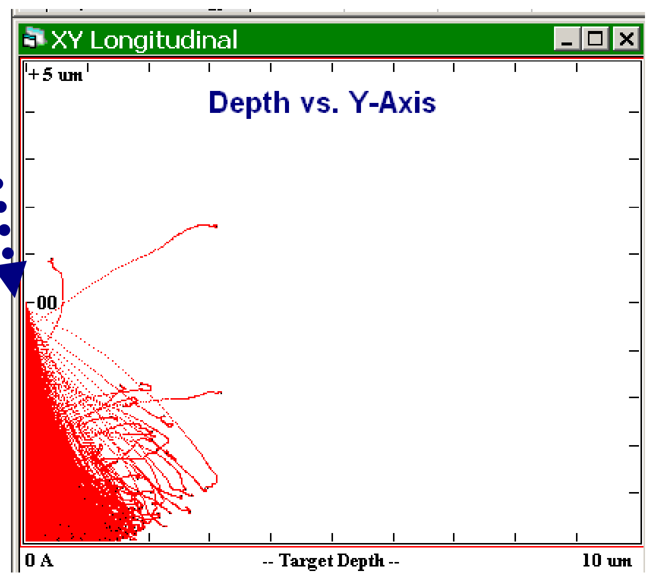



At 10 mrad incidence…

He ion range ~0.6 µm

>0.7 backscatter

>0.3 sputter yield



# Table of Yield, Backscatter, Range

SRIM 2008.03 Modeling:

Vary Energy and incidence Angle

| 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 |

As energy decreases …

- Sputtering increases
- Backscatter increases
- Range decreases

# Sputter Erosion Behavior (Speculation)

Sputtered cone atoms will redep primarily on neighboring cones; comparatively little will sputter across the chamber.

Cone shapes will gradually evolve. Tips will likely recede and become less sharp. The base of the cones may densify.

Very sharp cones ($\theta < 10$ mrad) cause high backscatter (hence multiple scatterings for each He), *and* high sputter yield, resulting in faster deformation of the cones.

Optimum life for cone-wall is likely to occur for aspect ratio in the range L/R = 10-100

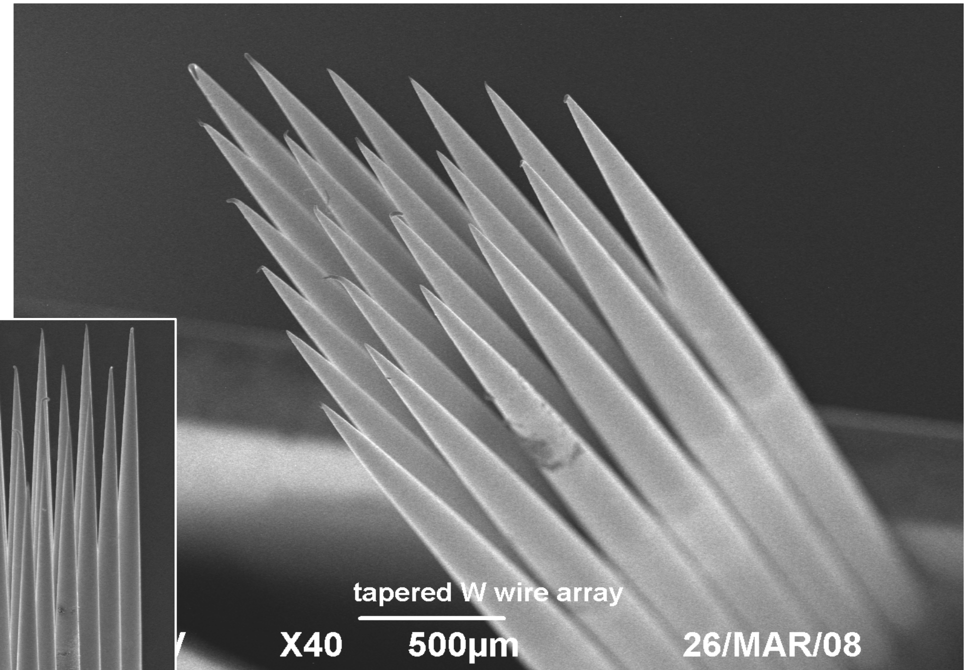
# W Needle Array

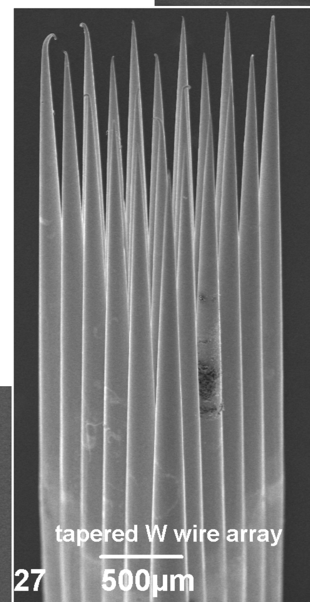
Candidate material

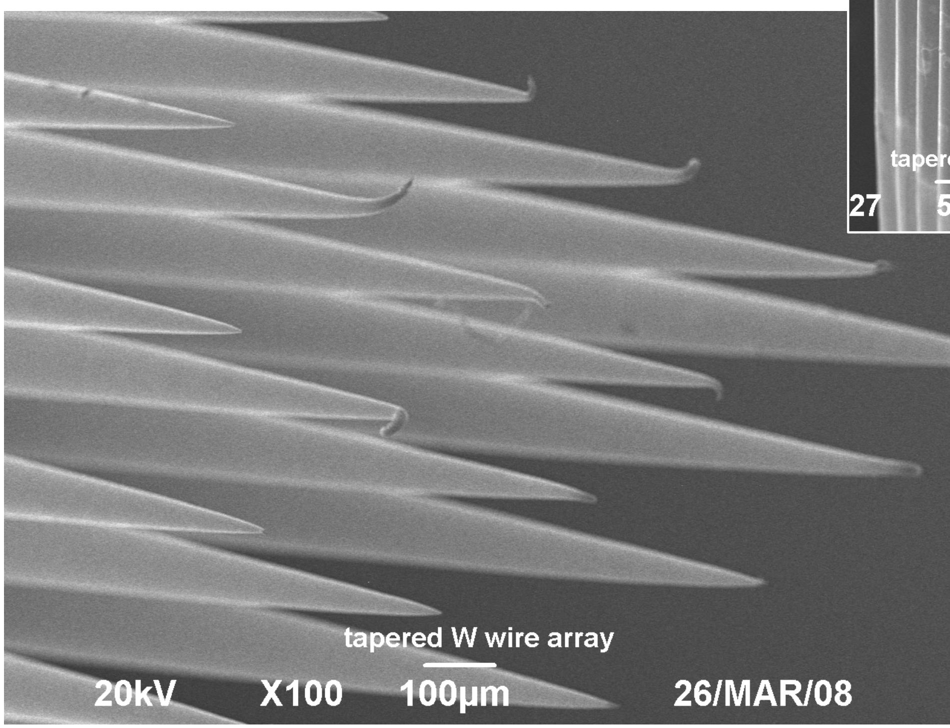
L = 3.8 mm

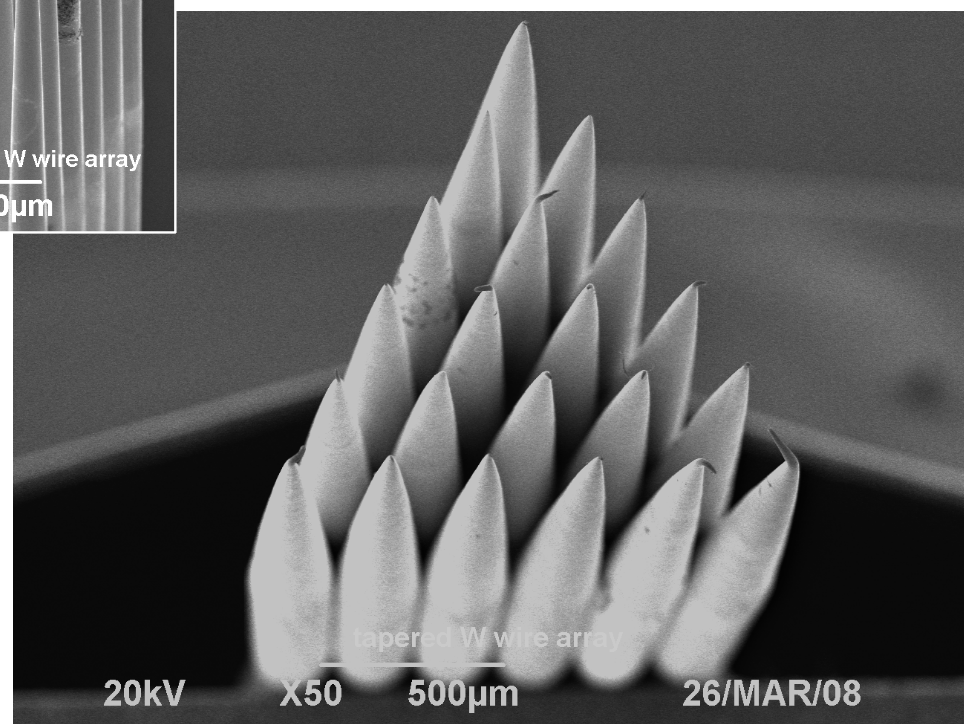
R = 125 μm

$\alpha$ = 30



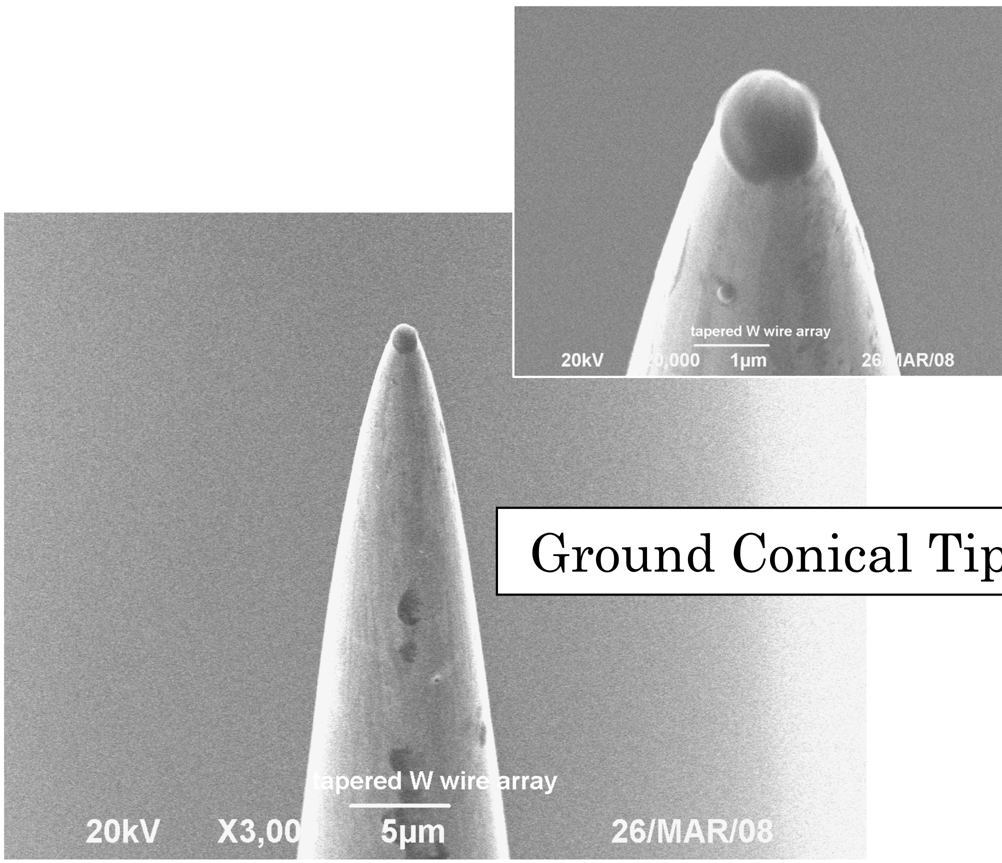



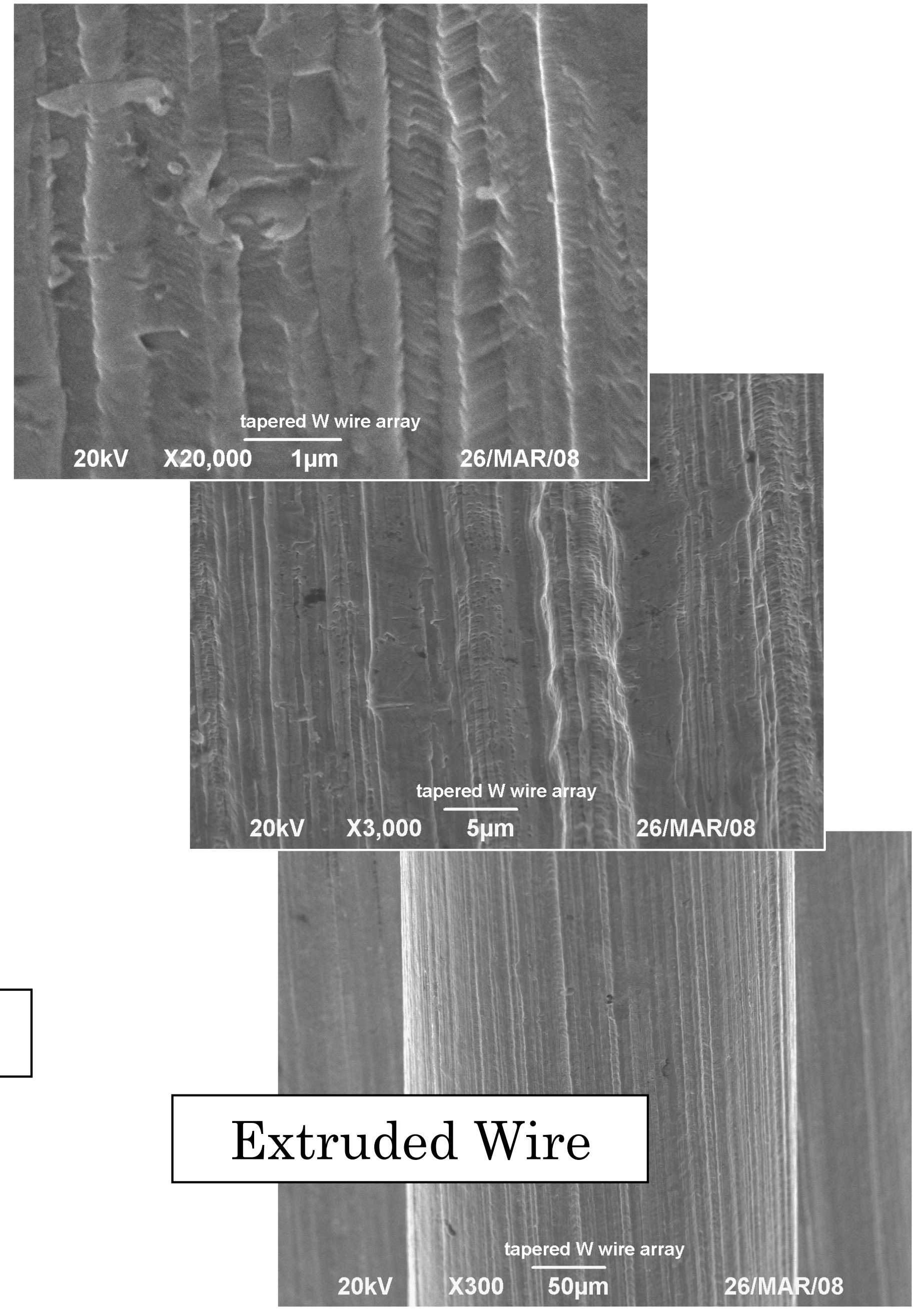



# W Needle Surface

Heat-treated W wire
Ground surface
No grain structure revealed




Ground Conical Tip

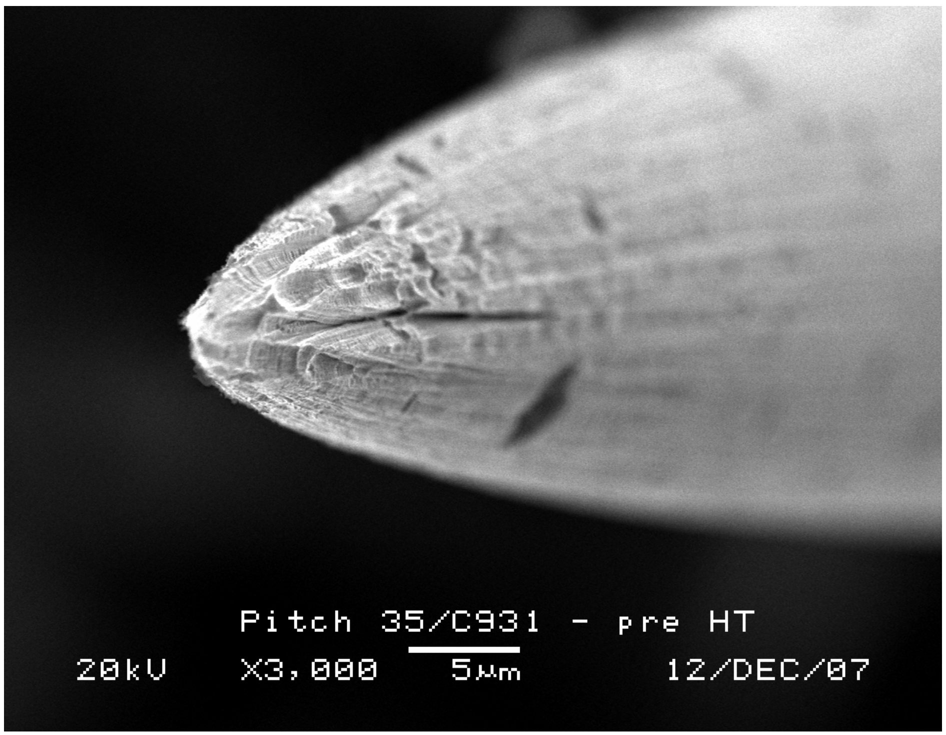


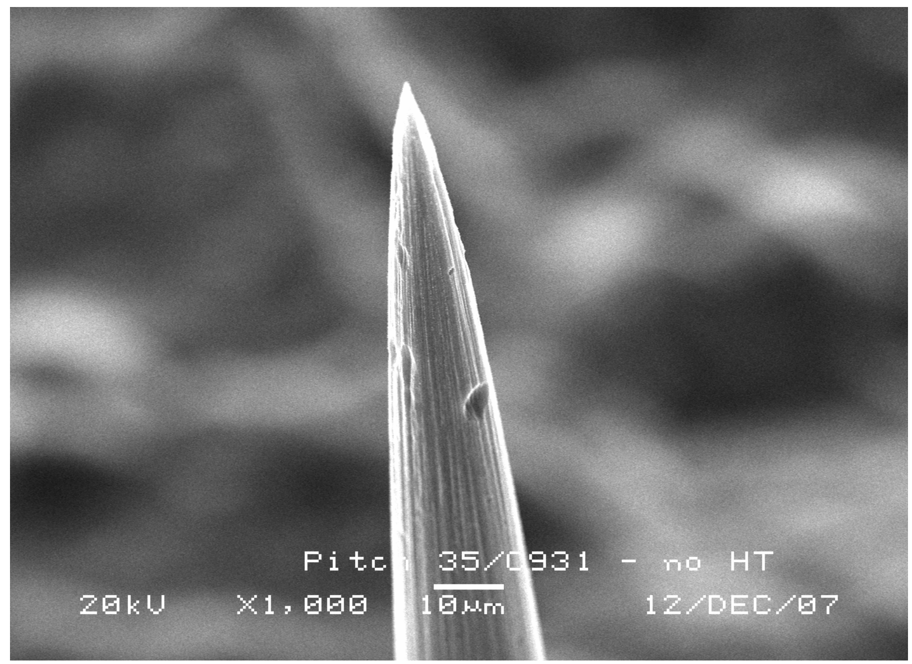

Extruded Wire

# Carbon Needle Option

ESLI fabricates carbon fiber velvets, etched to sharp tips, approximately conical for L = 1 mm, R = 17 μm

ESLI 35-μm mesophase pitch fiber tapered to submicron radius tip



# Test Objectives 2008

Investigate discrete W needles having L/R ~ 30

Options: C needles; Needle Clusters; Different Angles; other W types

Observe erosion and damage of discrete vertical needles…

| | |
|---|---|
| Mass loss | Microbalance |
| Dulling of tip | SEM |
| Shaft erosion | SEM |
| Blistering | SEM, FIB |

Compare with modeling results (*e.g.* SRIM)

He Implantation Test Facilities

| | |
|---|---|
| SNL/RHEPP | pulsed 0.7 MeV; incidence ~ 0.2 rad |
| UW/HELIOS | high fluence 30 keV, collimated (TBD) |

# Conclusions

Benefits of mini-cone chamber wall liner

- Surface area enhancement $\alpha$ =10-100, all accessible by line of sight, reduces flux and fluence correspondingly
  - ➢ Reduced blistering/exfoliation
  - ➢ Reduced transient T excursion
- Radiation arrives at grazing incidence
  - ➢ Potentially less damage by high energy ion implantation
  - ➢ Shallow implantation, high backscatter, high sputter
  - ➢ Potentially high rate of deformation as cone atoms migrate downward

Issues

- Wear, redep deformation
- Tip fragility and repair
- Manufacturability

Tests planned in coming months

- He bombardment of discrete vertical W, and possibly C, cones