Implantation of D^+ and He^+ in W-coated Refractory Carbides

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HAPL Meeting-PPPL

October 27th, 2004

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Progress Since the Last Meeting

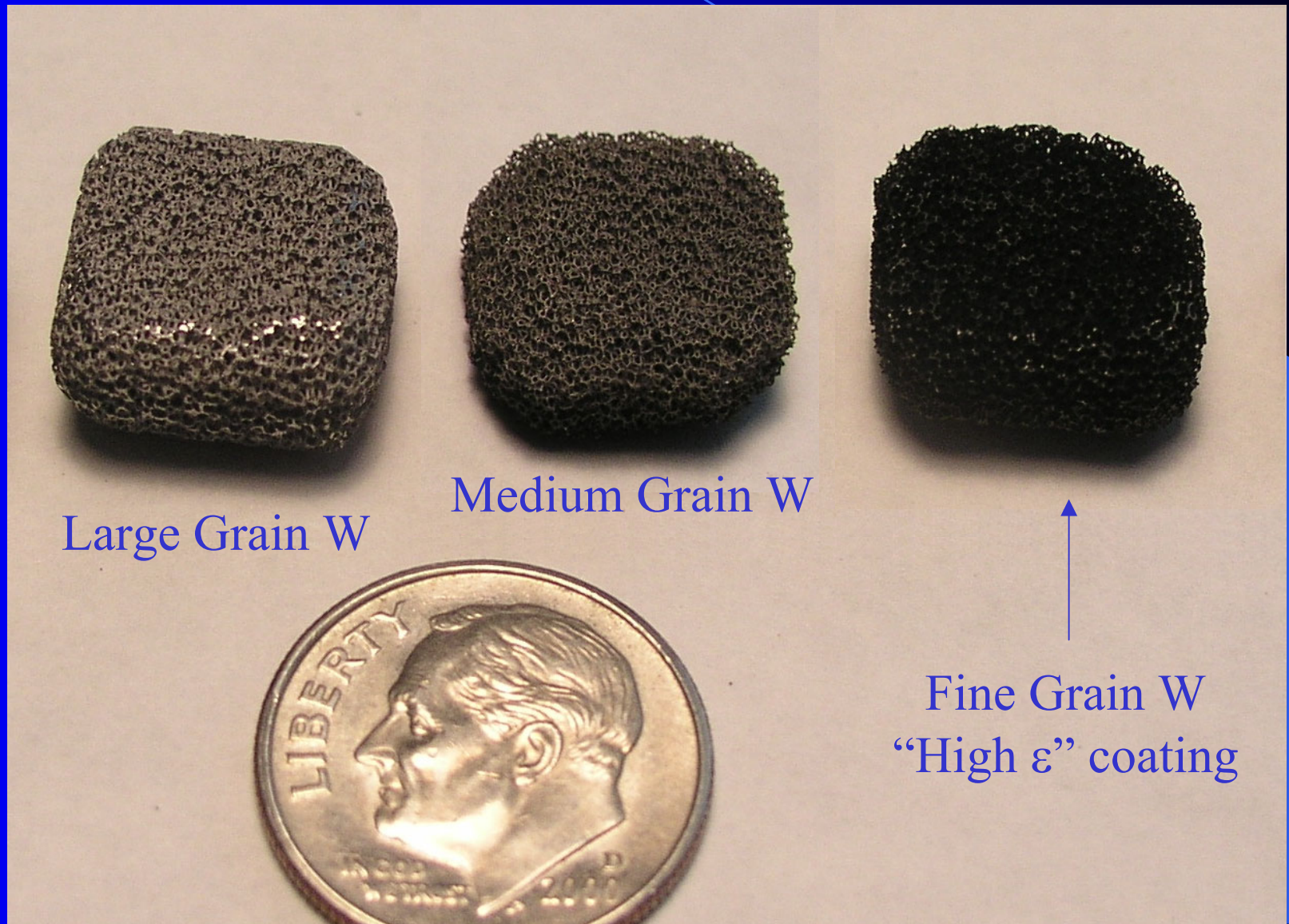
- Paper was submitted to *Journal of Nuclear Materials*:

  B.B. Cipiti and G.L. Kulcinski, Helium and Deuterium Implantation in Tungsten at Elevated Temperatures

- Preliminary work with Single Crystal W samples has been performed
- Evaluation of irradiated foam samples from Ultramet has begun
- Poster was presented at TOFE conference:

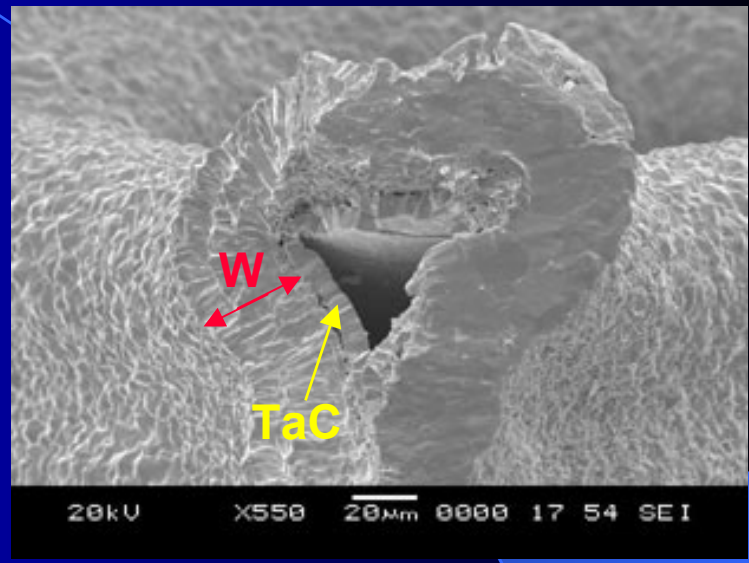
  R.F. Radel and G.L. Kulcinski, "Implantation of D^+ and He^+ in W-coated Refractory Carbides "
- Paper was submitted to *Fusion Science and Technology* for publication

Three Types of Tungsten-Coated TaC Foam Samples were Received From Ultramet

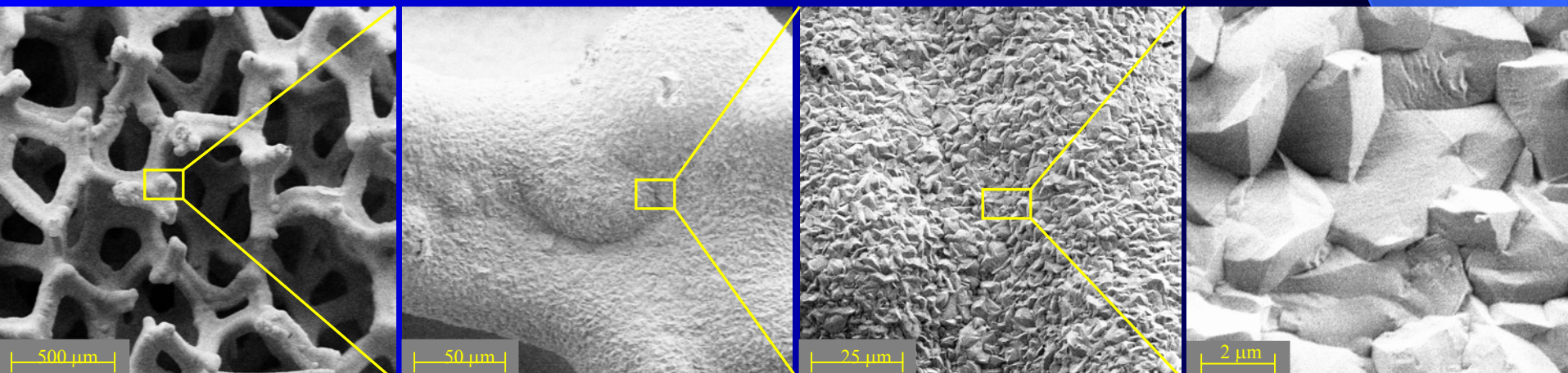


Ultramet TaC Foam Samples- Large Grain W Coating

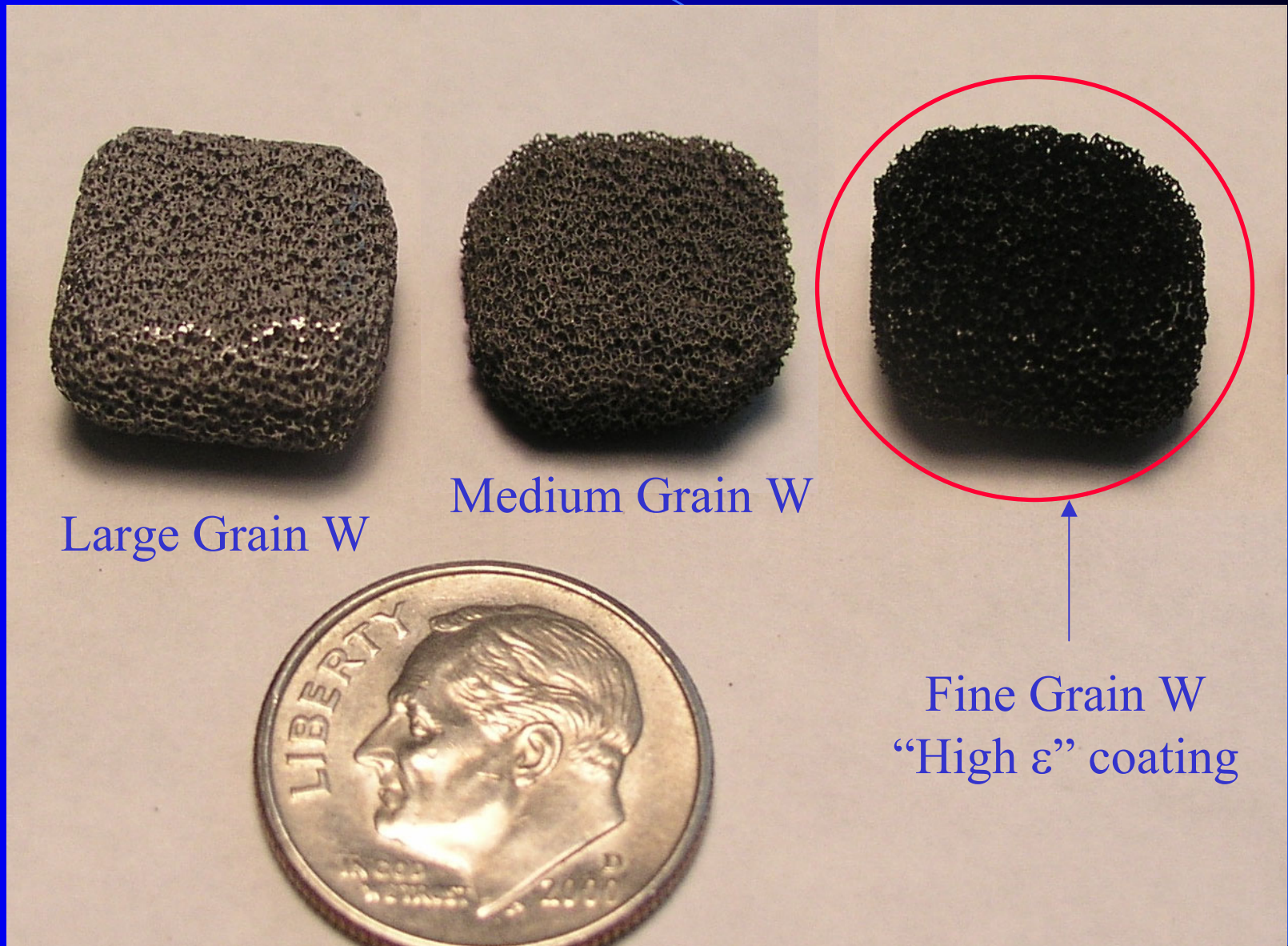
- Skeleton composed of hollow TaC
- CVI technique used to coat W on carbide substrate



(Micrograph Courtesy of Ultramet)

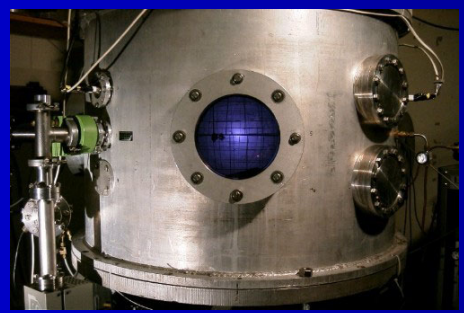


Fine Grain W-Coated TaC Sample Has Extra Layer of "High ε" W Particles over Medium Grain W



Experimental Summary Since Last Meeting

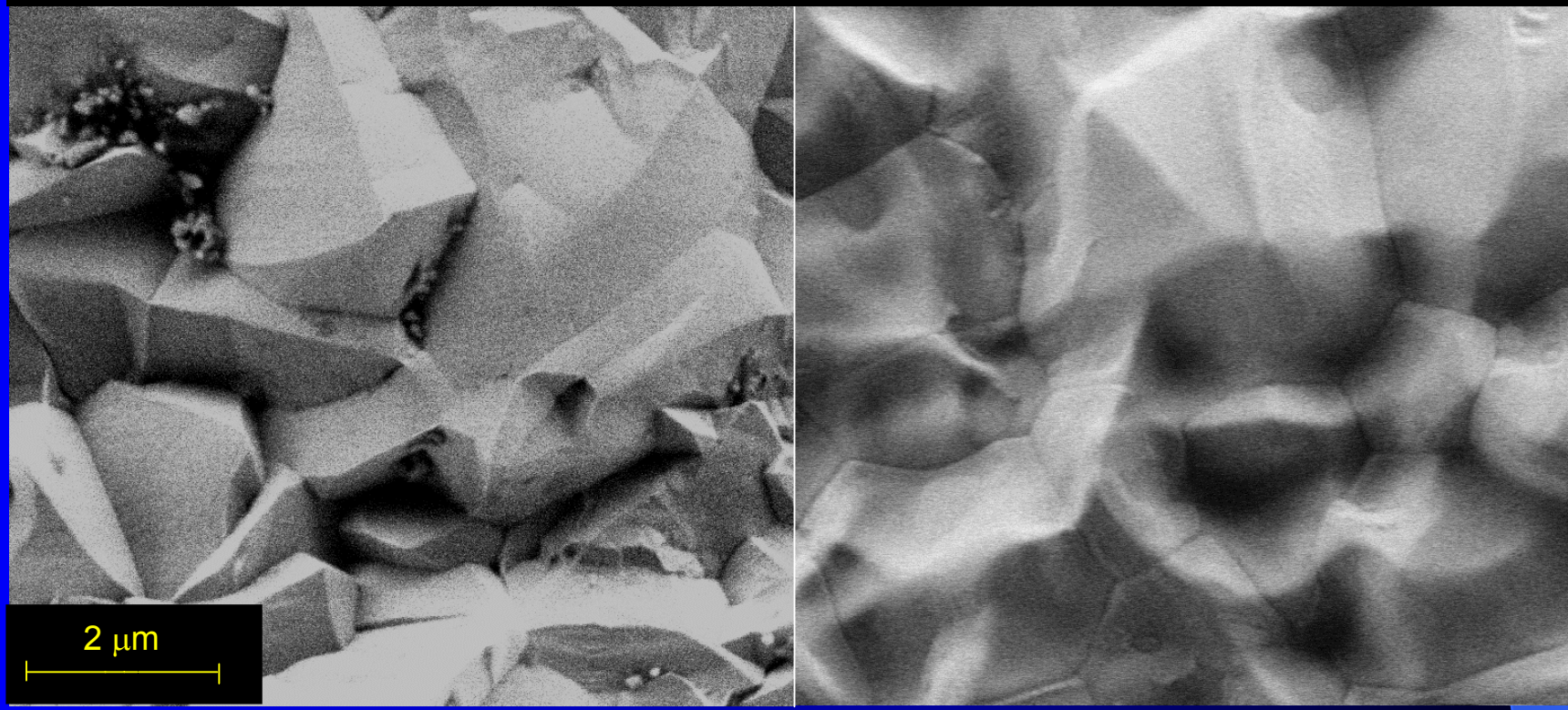
Sample	Ions	Fluence (#/cm^2)	Temp (C)	Energy (kV)
TaC-4	---	---	1200	---
HfC-1	$^4He^+$	$6x10^{17}$	775	30
HfC-4	---	---	1200	---
TaC-ε-4	---	---	1200	---
Single Crystal	$^4He^+$	$4x10^{16}$	830	30

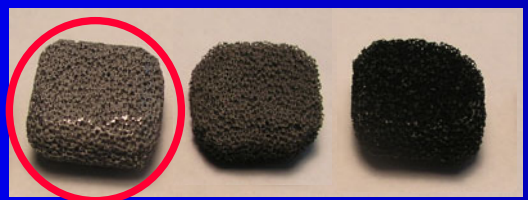


No Pores were Observed in Large Grain W-Coated Foam Samples After D^+ Irradiation to $10^{18}/cm^2$

As Received – Large Grain W

Irradiated at 830 °C





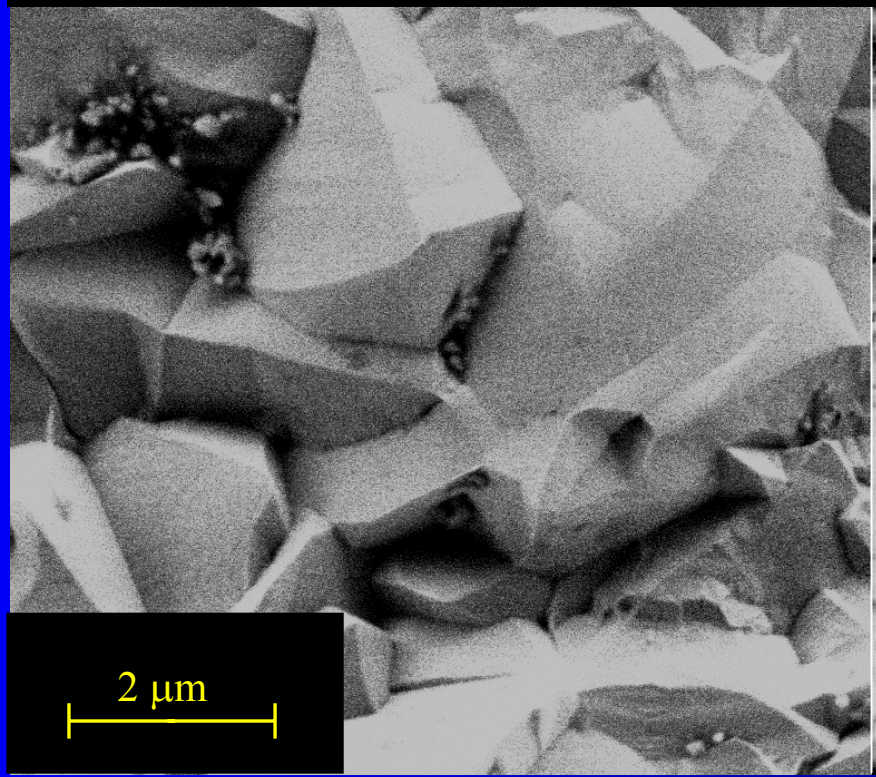
Large Grain W-coated TaC Sample Irradiated at 830 °C with ~10^{18} D^+/cm^2 Fluence

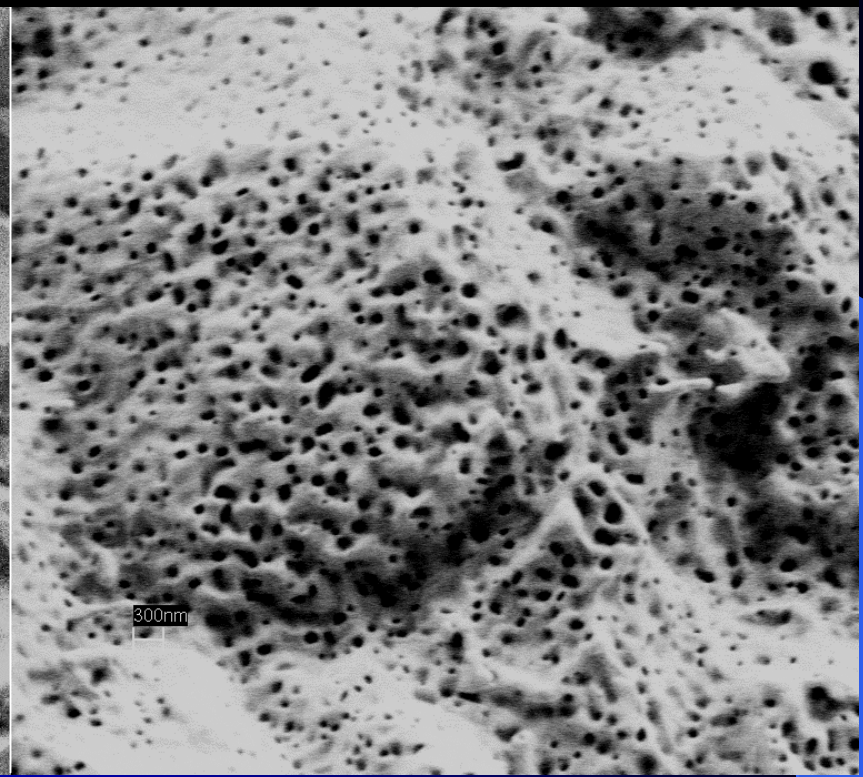
Ref. HAPL Chamber Operation for ~13 hours

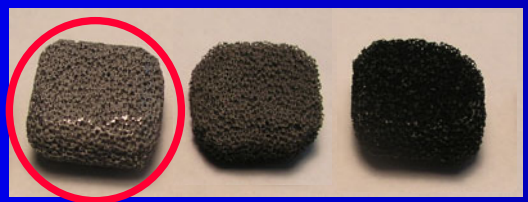
High Temperature He^+ Implantation Resulted in Porous Surface Structure in Large Grain W-coated TaC

As Received – Large Grain W

Irradiated at 800 °C







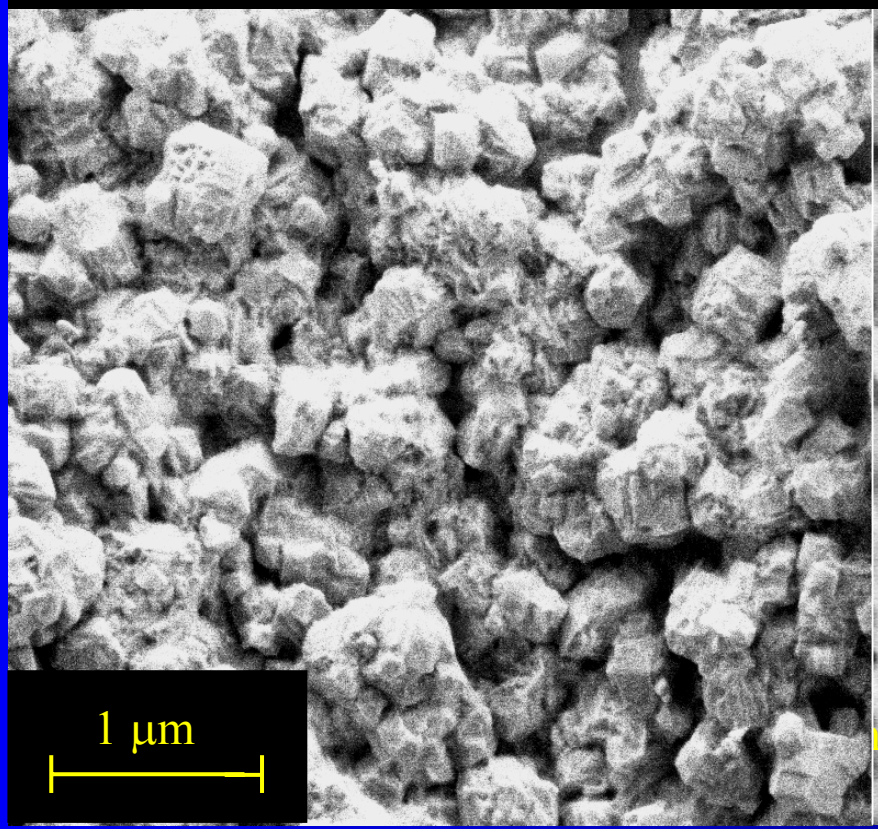
Large Grain W-coated TaC Sample Irradiated at 800 °C with a $6x10^{17}$ He^+/cm^2 Fluence

Ref. HAPL Chamber Operation for ~8 hours

Medium Grain W-Coated TaC Foam Showed a Change in Morphology and Pore Formation

As Received-Medium Grain W

Irradiated at ~800 °C

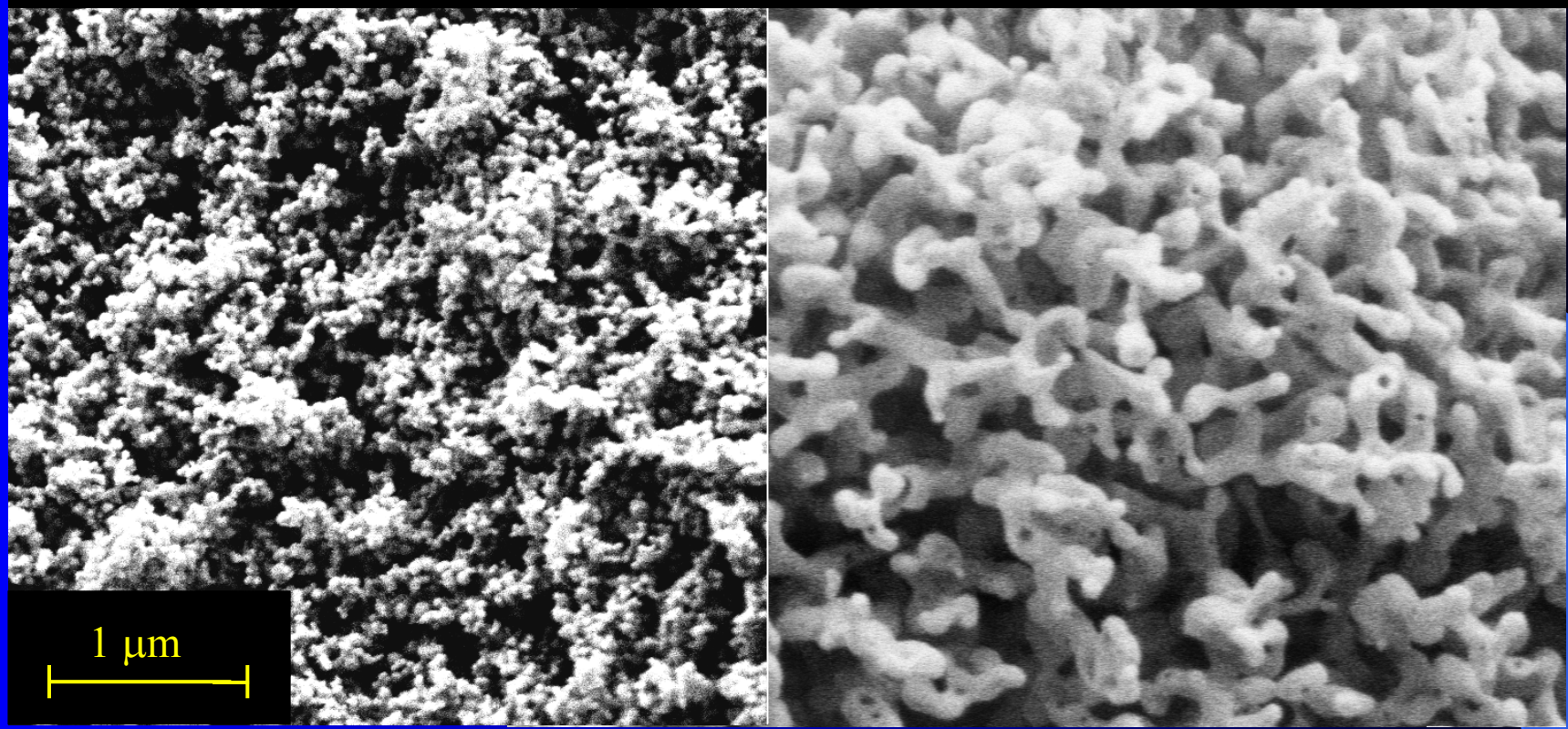


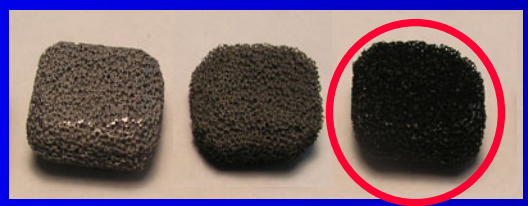
Medium Grain W-coated Sample
Irradiated with a 6×10^{17} He^{+}/cm^{2} Fluence

Ref. HAPL Chamber Operation for ~8 hours

"High ε" Small Grain W Coating Undergoes Dendritic-like Growth Under High Temp He^+ Irradiation

As Received-Small Grain W | **Irradiated at ~800 °C**



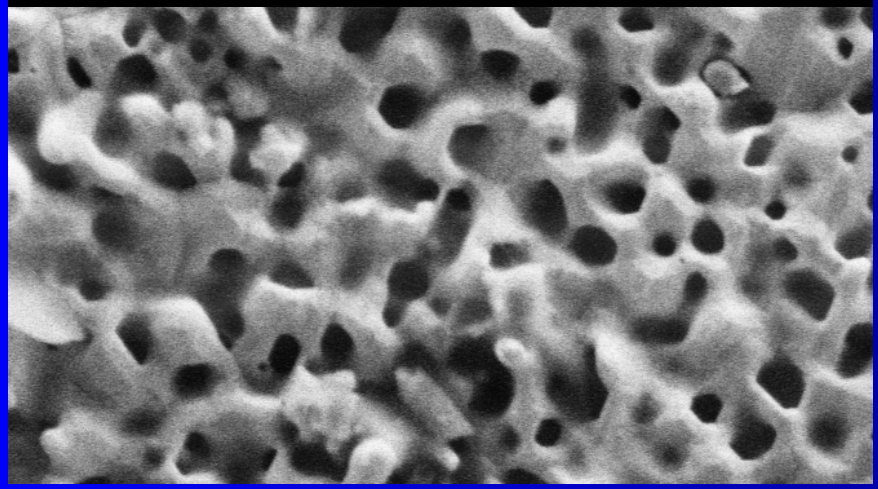


"High ε" Small Grain W Coated Sample Irradiated with a $6x10^{17}$ He^+/cm^2 Fluence

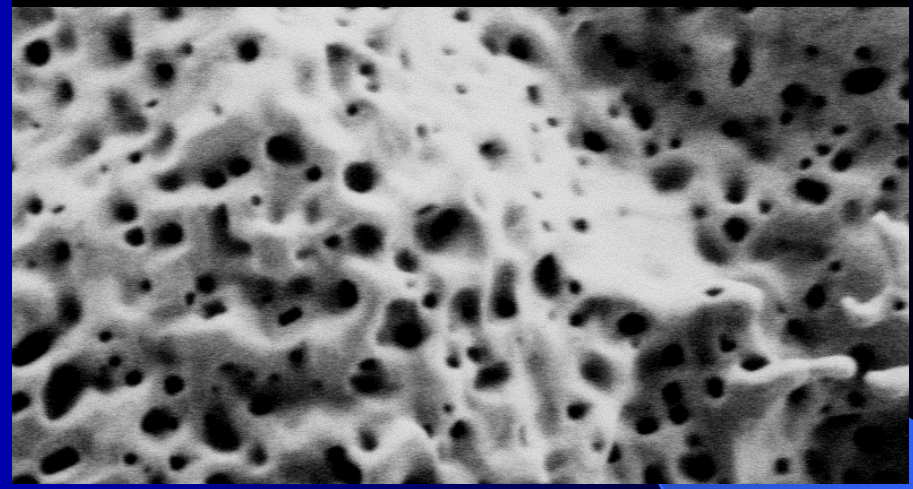
Ref. HAPL Chamber Operation for ~8 hours

Irradiation of W with He at High Temperatures (@ 8h equv HAPL) Greatly Alters Surface Morphology

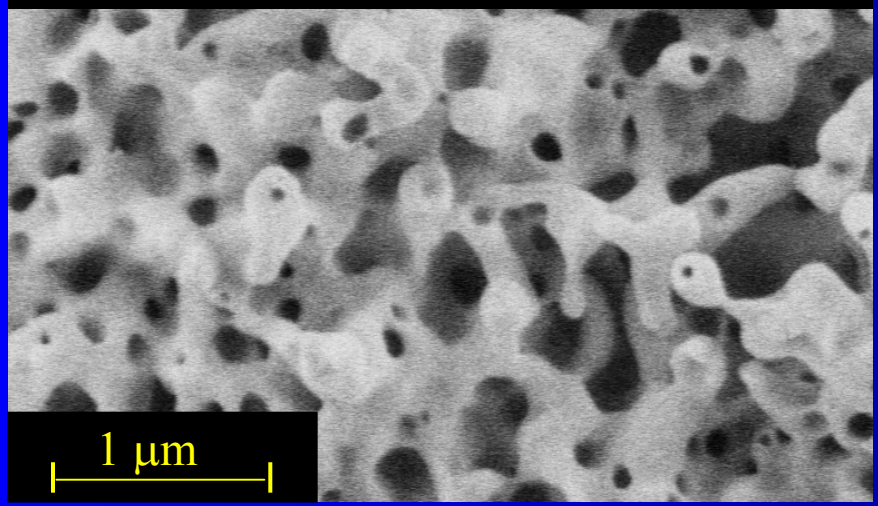
Polycrystalline W - 940 °C



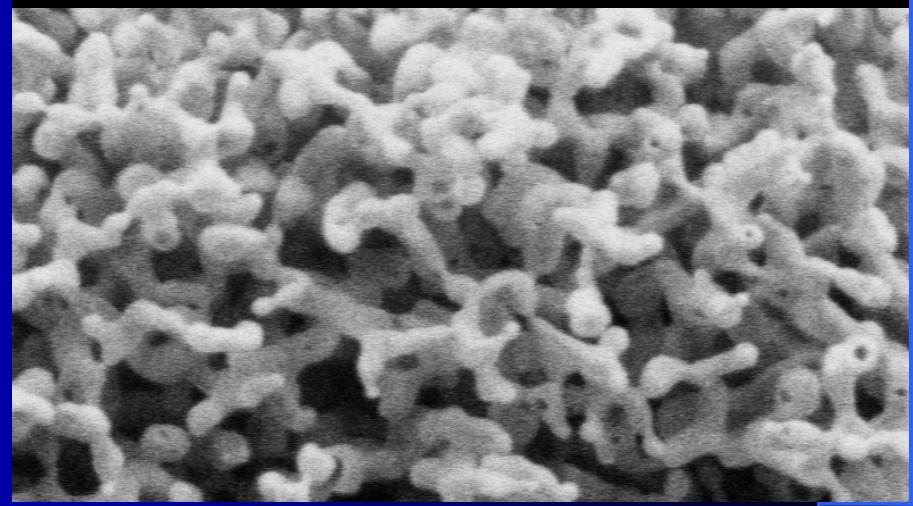
Large Grain W-coated TaC- 800 °C



Med Grain W-coated TaC ~800 °C



Fine Grain W-Coated TaC ~ 800 °C



Implications

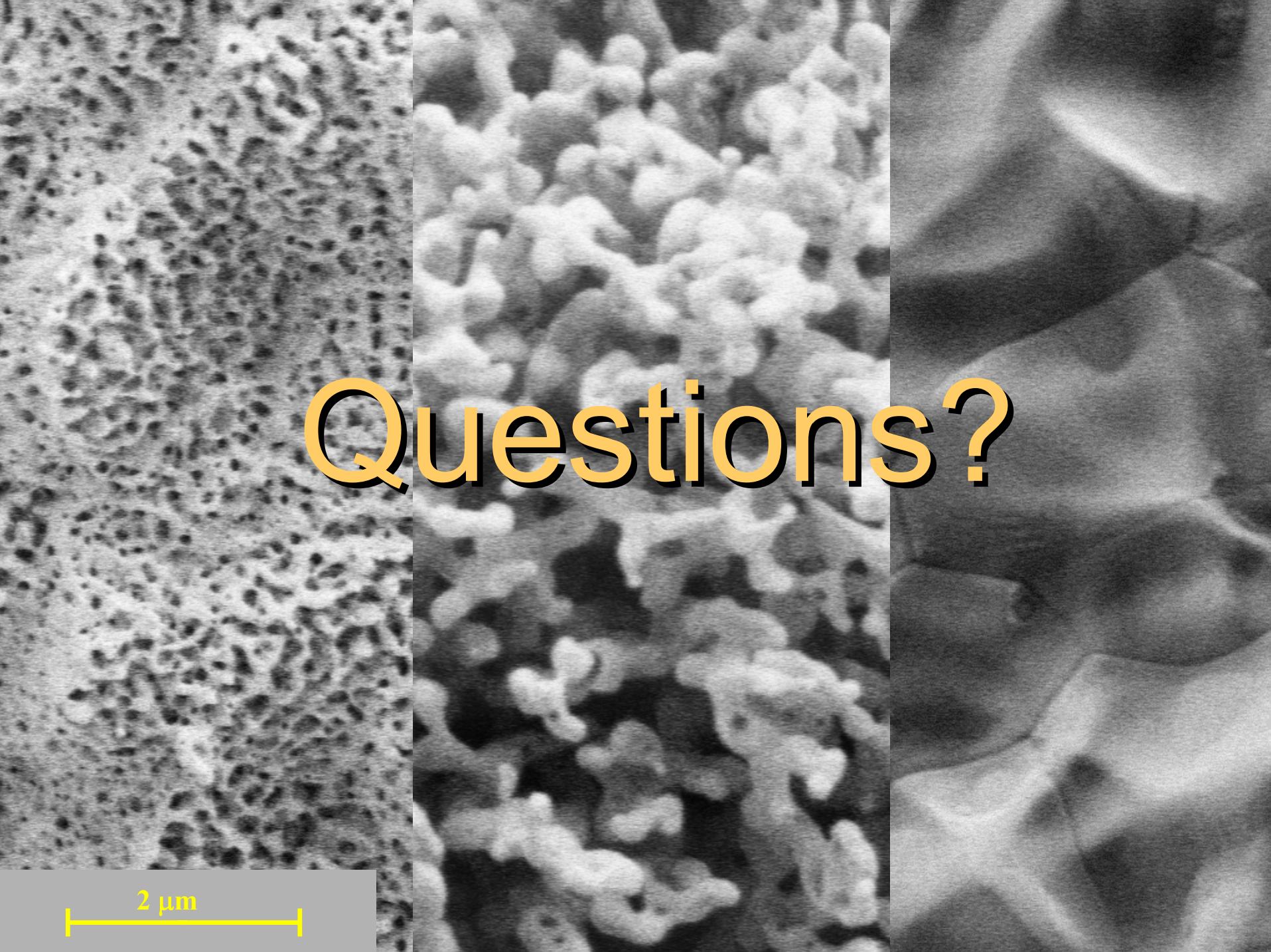
- The high density of small pores could act as:
  - Nucleation sites for cracks under repeated shock loading
  - Sites for initiating the formation of "dust"
  - Release sites for implanted He
- The growth of "dendrites" in high-ε foams during high temperature He bombardment may alter the emissive properties of the coating.

Conclusions

- D^+ implantation at ~10^{18} ions/cm^2 and 830 ˚C on large grain W-coated TaC and HfC foam showed no pore formation or change in morphology.
- When subjected to a 6x10^{17} He^+ fluence at 800 ˚C, both large grain W-coated TaC and HfC samples showed pore formation similar to polycrystalline samples.
- At fluences of 6x10^{17} He^+/cm^2, the medium grain W-coated TaC foam showed significant changes in its surface morphology
- At fluences of 6x10^{17} He^+/cm^2, the fine grain "high ε" W-coated foam showed growth of tungsten dendrites and a reduced pore formation

Future Work

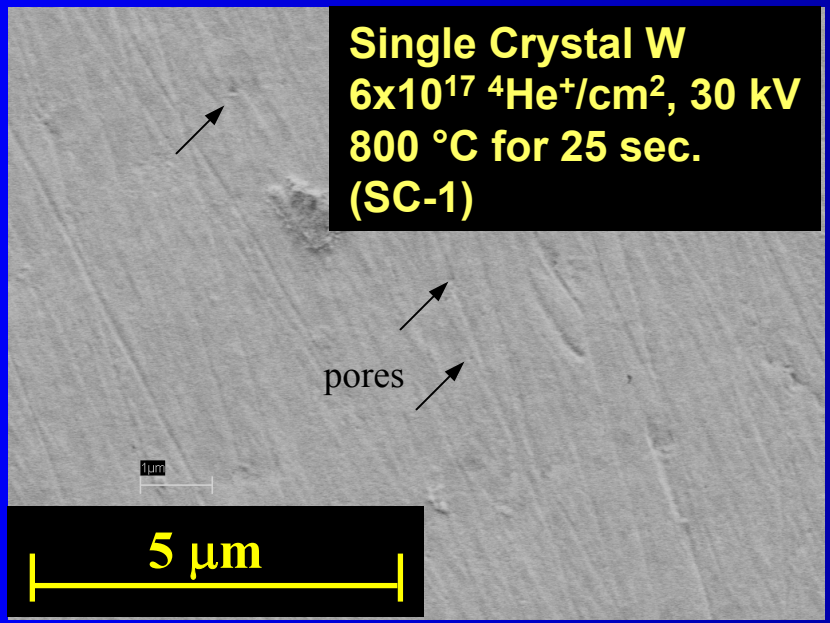
- Fluence and temperature ranges will be expanded in the W-coated foam samples to evaluate foam performance as compared to poly-crystalline samples
- Polycrystalline W-25%Re samples will be used to evaluate the performance of these samples for temperatures ranging from 700 – 1200 ˚C

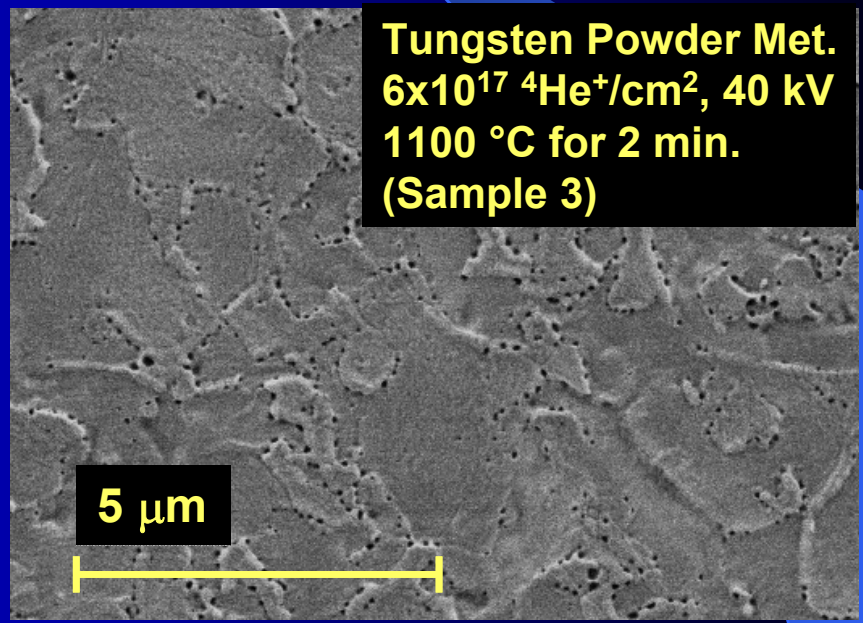

Questions?
2 μm

References

- B.B. CIPITI and G.L. KULCINSKI, "Helium and Deuterium Implantation in Tungsten at Elevated Temperatures," *Journal of Nuclear Materials*, (to be published)
- J.D. SETHIAN, et. al. "Fusion Energy with Lasers, Direct-Drive Targets, and Dry Wall Chambers," *Nuclear Fusion,* **43**, 1963 (2003).
- R.P. ASHLEY et al., "Recent Progress in Steady State Fusion using D-^{3}He," *Fusion Technology,* **44**(2), 564 (September, 2003).
- B.E. WILLIAMS, Private Communication. September, 2004.

Preliminary Data on Single Crystal shows Minimal Pore Formation





IEC Device Provides Uniform Ion Fluence