Progress in Analyzing HAPL Tungsten Candidate First Wall Materials

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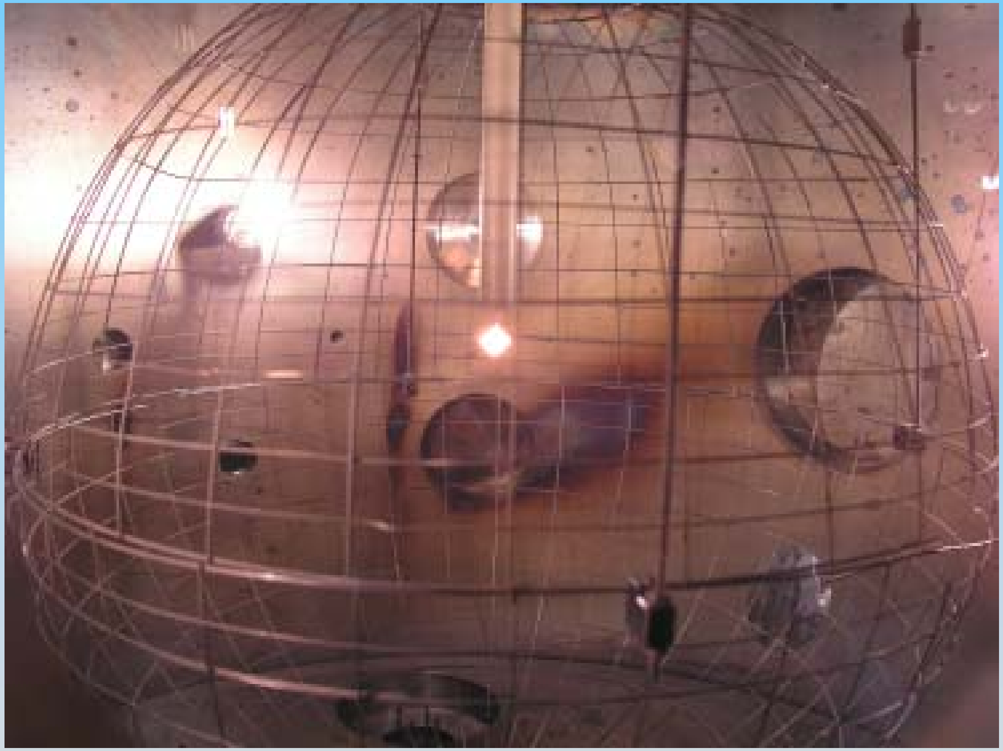
Helium Implantation in Tungsten Using the University of Wisconsin IEC Facility

- **Purpose:** To determine the effect of helium implantation on the surface morphology of tungsten coatings at high temperatures
- **Why:** To see if tungsten can serve as a suitable coating material for the HAPL first wall
- **How:** Use of high voltages to drive helium ions into tungsten cathodes held at high temperatures (800 to 1,200 °C)

UW IEC Chamber has Capability of High-Temperature Implantation at 10-100 kV



D^+, 20 kV, 5 mA
2 mtorr, 1100 °C

Results Since the Last HAPL Meeting

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- Ion implantation fluences were reported about an order of magnitude higher than actual
  - Secondary electron emission was measured and found to be much higher than previously thought
- Single crystal tungsten samples were obtained for future runs
- Experimental measurements reveal porous surface increases emissivity
- Tungsten foam samples were obtained from Ultramet and as-received samples were characterized.
- Initial irradiations have begun (45 kV and ≈1,000 °C)

Secondary Electron Emission Off the Grid Wires is Much Higher than Expected

Helium and Deuterium Fluence Corrections

Helium Fluence Scan (He^+/cm^2)

Previous	$3x10^{17}$	$1x10^{18}$	$2x10^{18}$	$4x10^{18}$	$1x10^{19}$
Updated	**$1x10^{16}$**	**$3x10^{16}$**	**$1x10^{17}$**	**$3x10^{17}$**	**$6x10^{17}$**

Helium Energy (20-80 keV)
& Temperature (730-1160 °C) Scans (He^+/cm^2)

Previous	$5x10^{18}$
Updated	**$3x10^{17}$**

Deuterium Run, 40 kV @ 1200 °C (D^+/cm^2)

Previous	$2x10^{19}$
Updated	**$2x10^{18}$**

Threshold for Pore Formation with 30 keV Helium Occurs at <4x10^{16} He^{+}/cm^{2}

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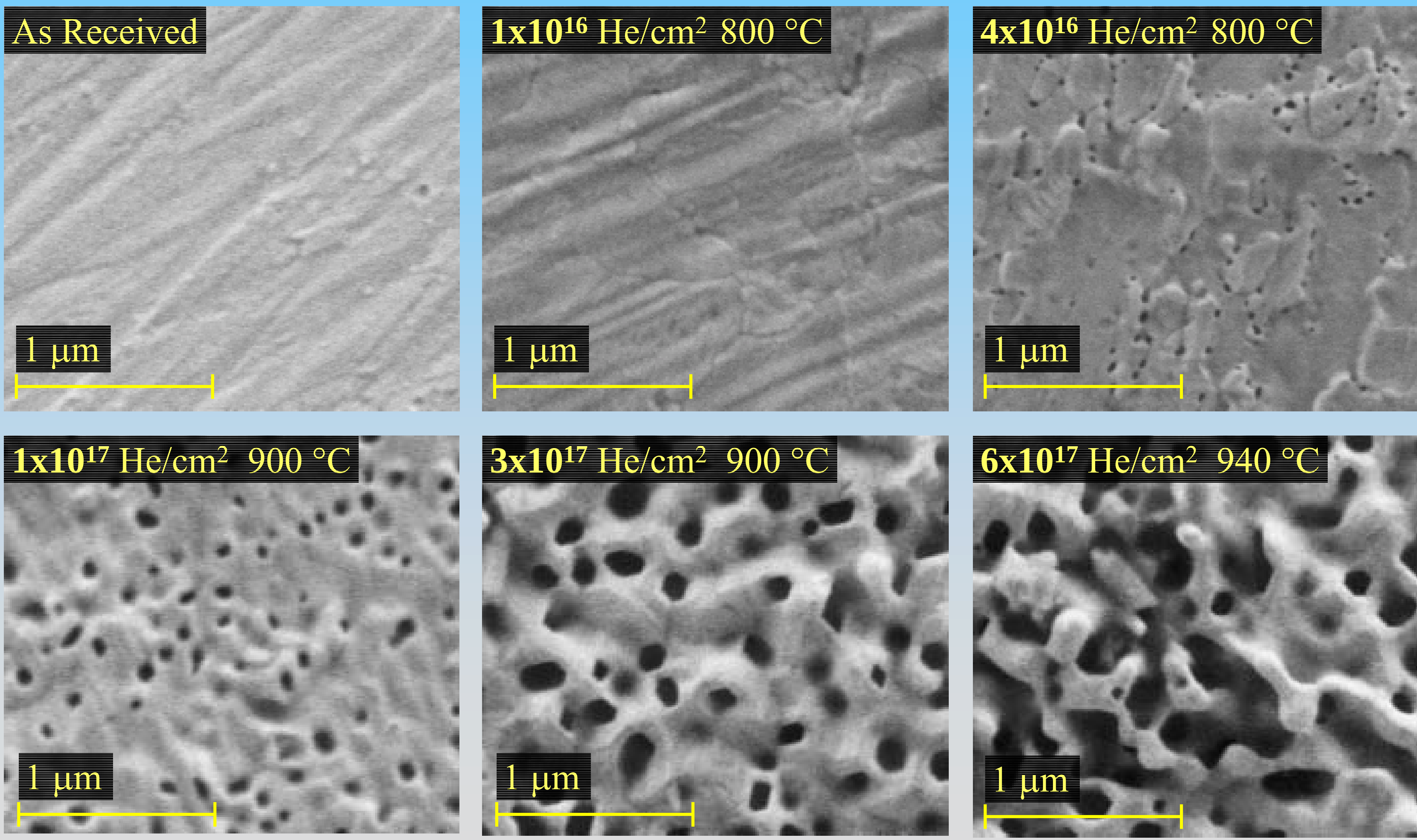

Temperature Scan Was Performed at 3×10^{17} He^+/cm^2 (5×10^{18} Was Reported Before)

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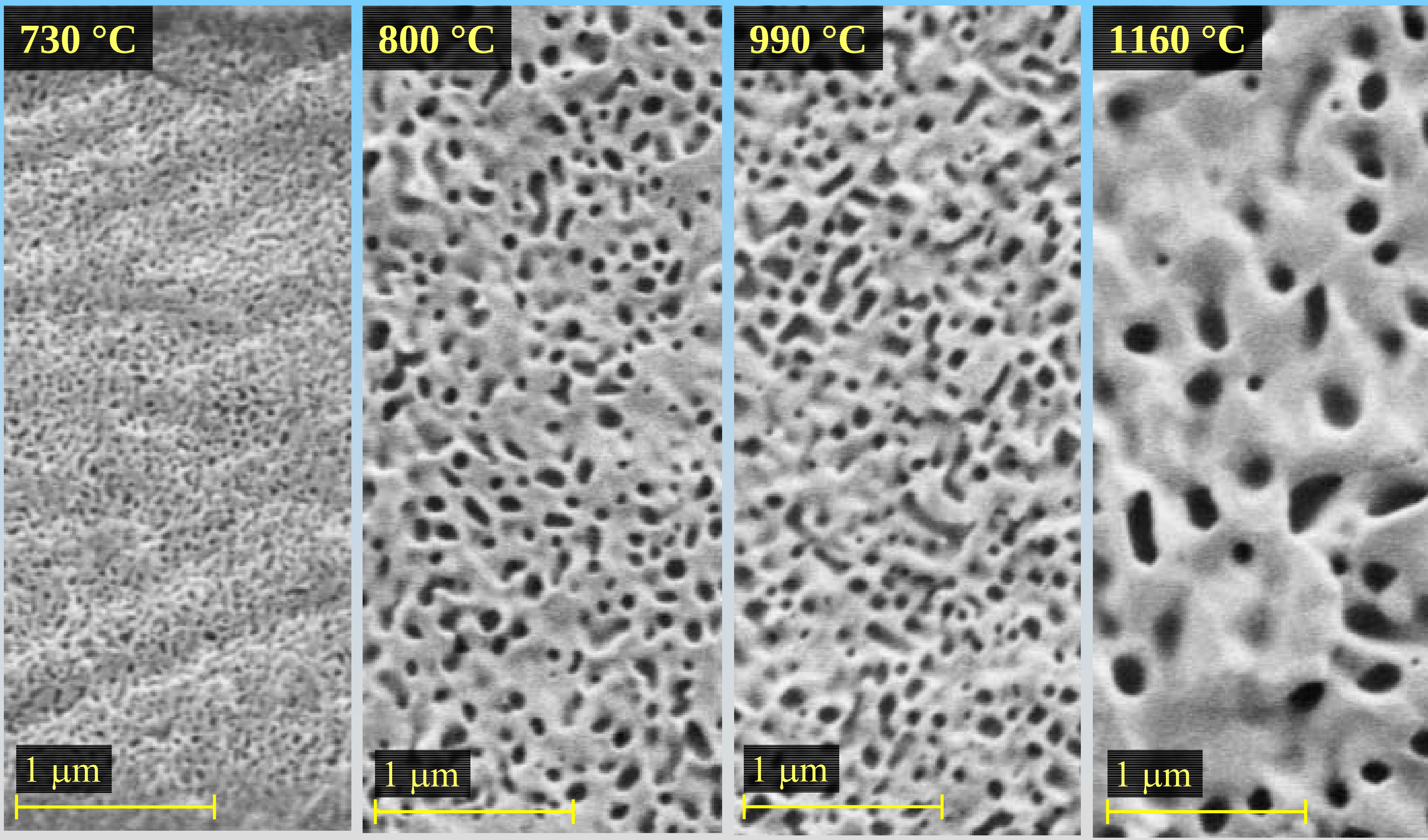
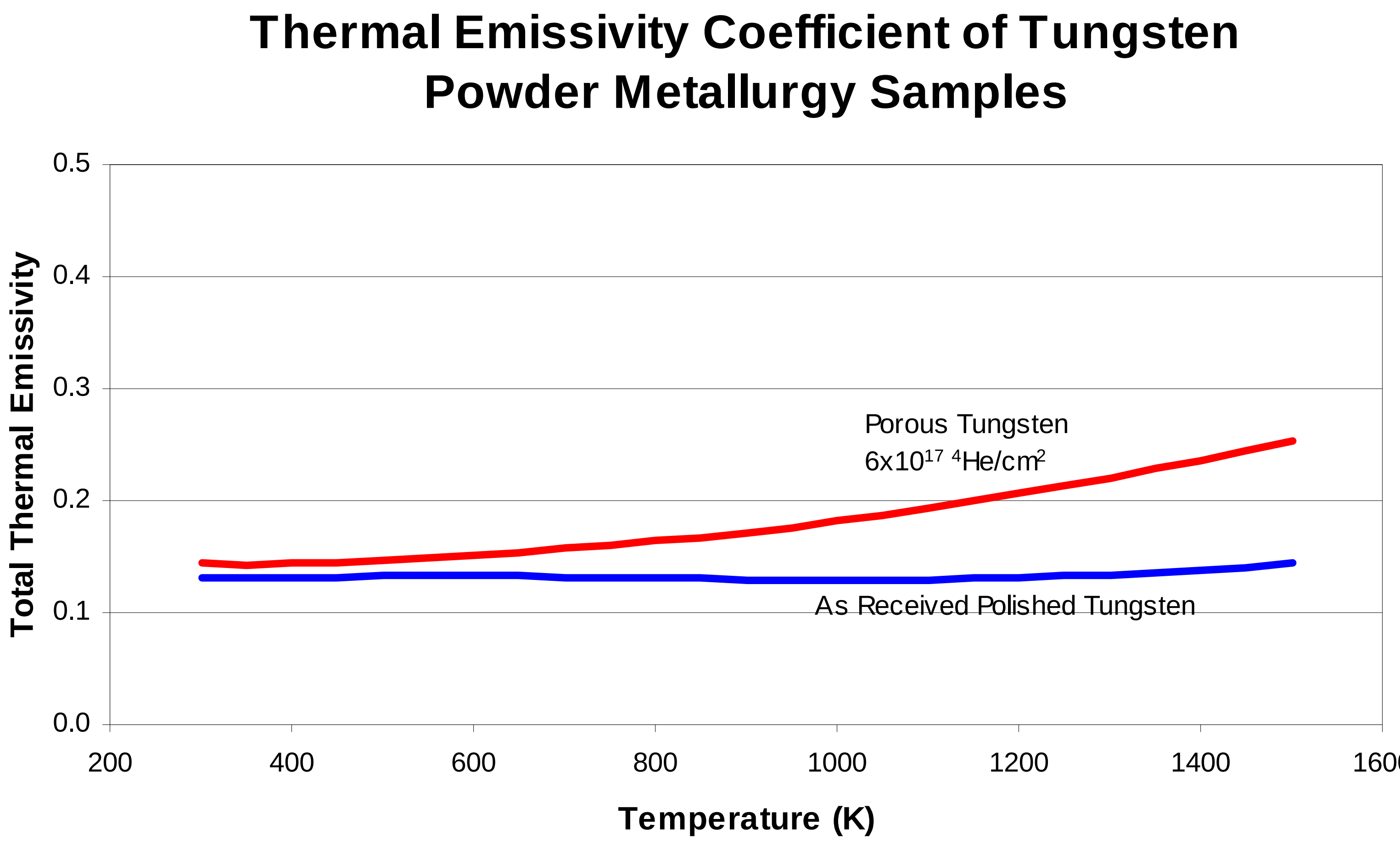


Irradiation of W at High Temperature With Helium Ions Can Improve the Thermal Emissivity

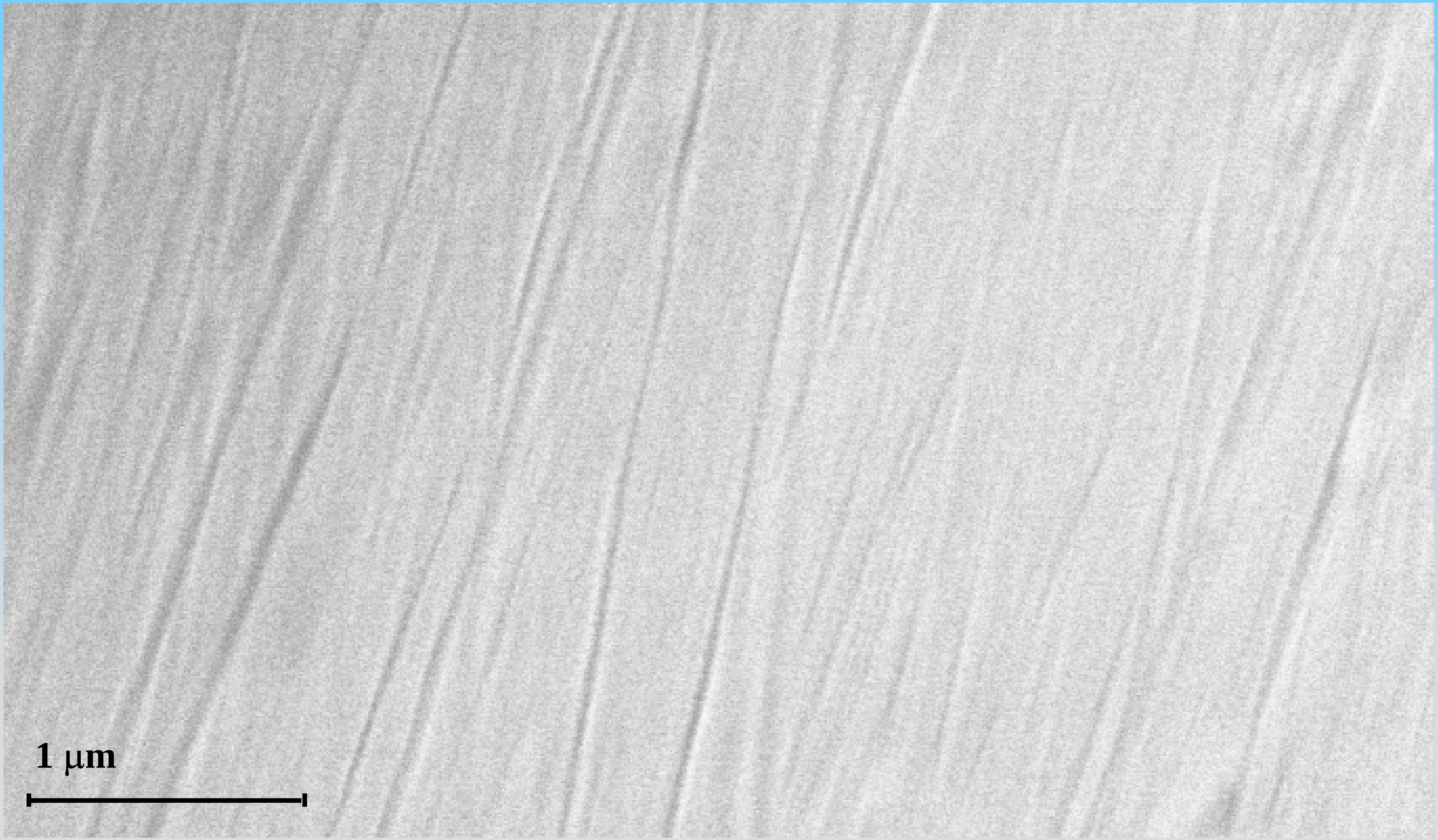


Jaworske and Beach-NASA Glen Research Center

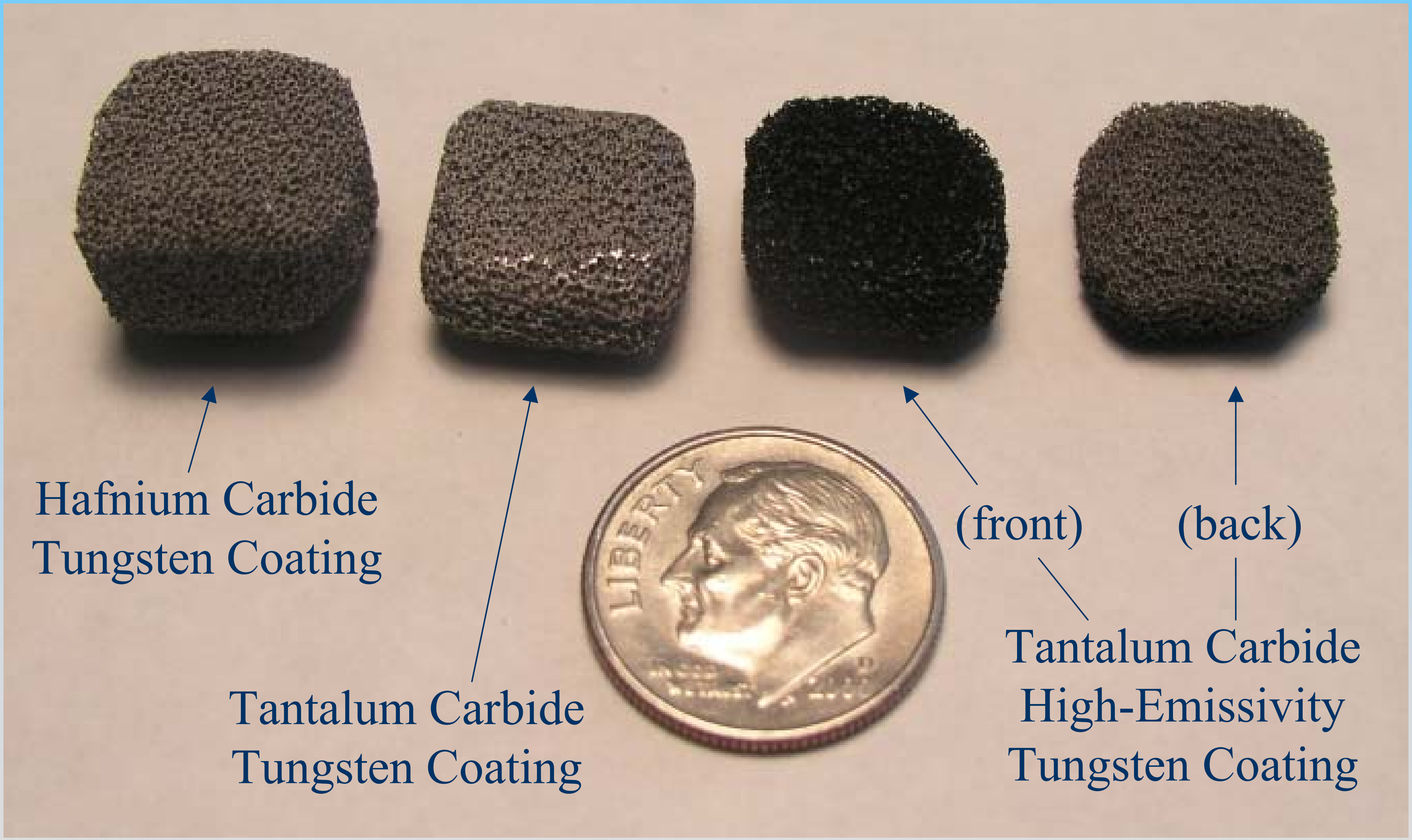
Tungsten Single Crystal Sample

Tungsten Single Crystal will show how much the lack of grain boundaries will affect the helium pore formation
(Obtained from Lance Snead, ORNL)

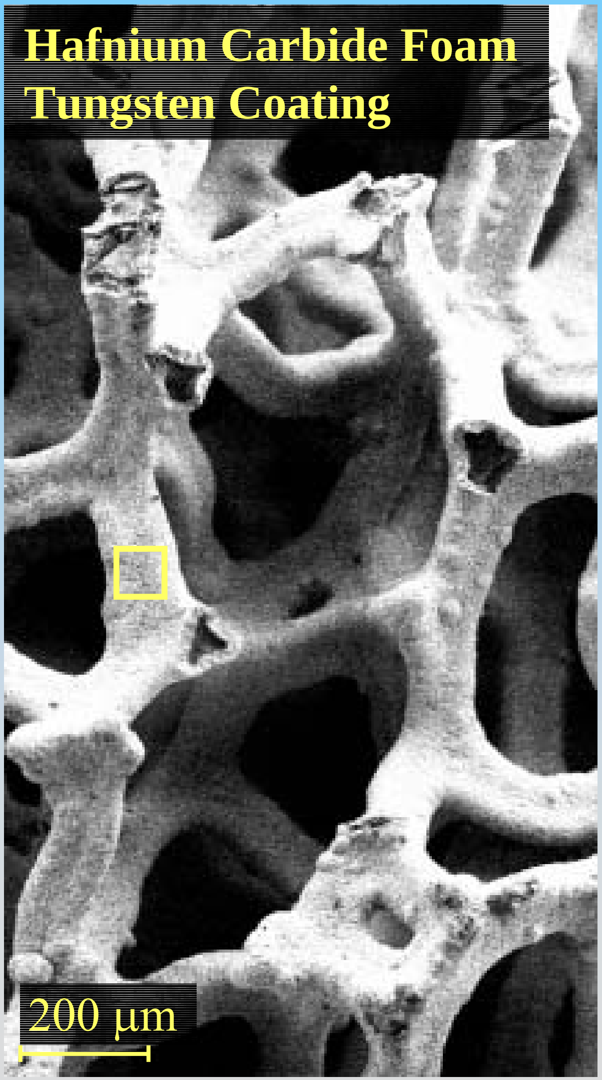
Tungsten Single Crystal Sample

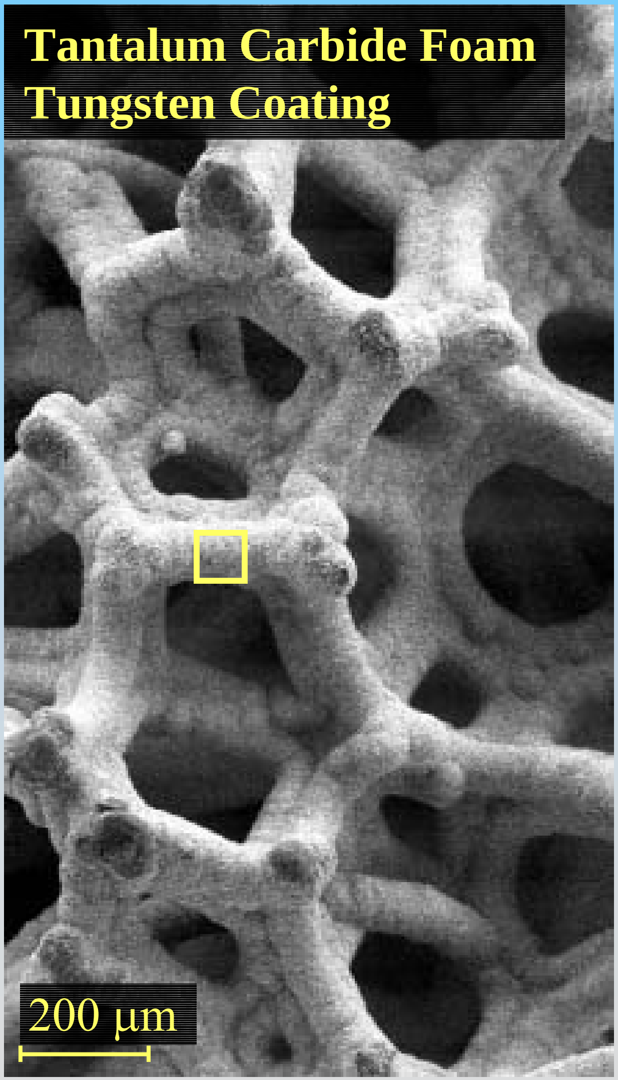


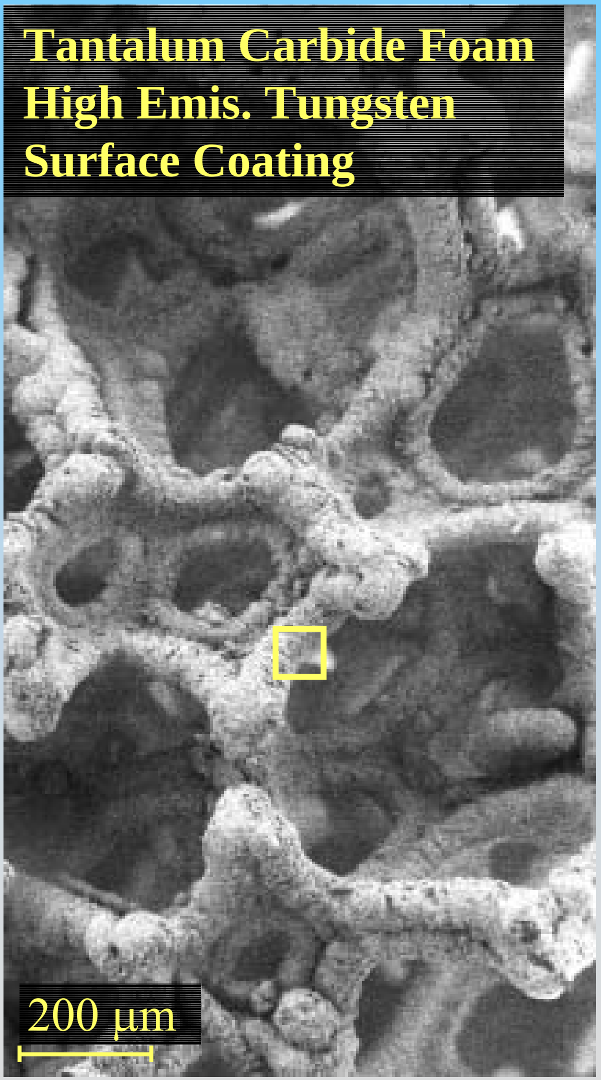
Tungsten-Coated Carbide Foam Samples From Ultramet



As-Received Foam Tungsten-Coated Carbide Samples From Ultramet







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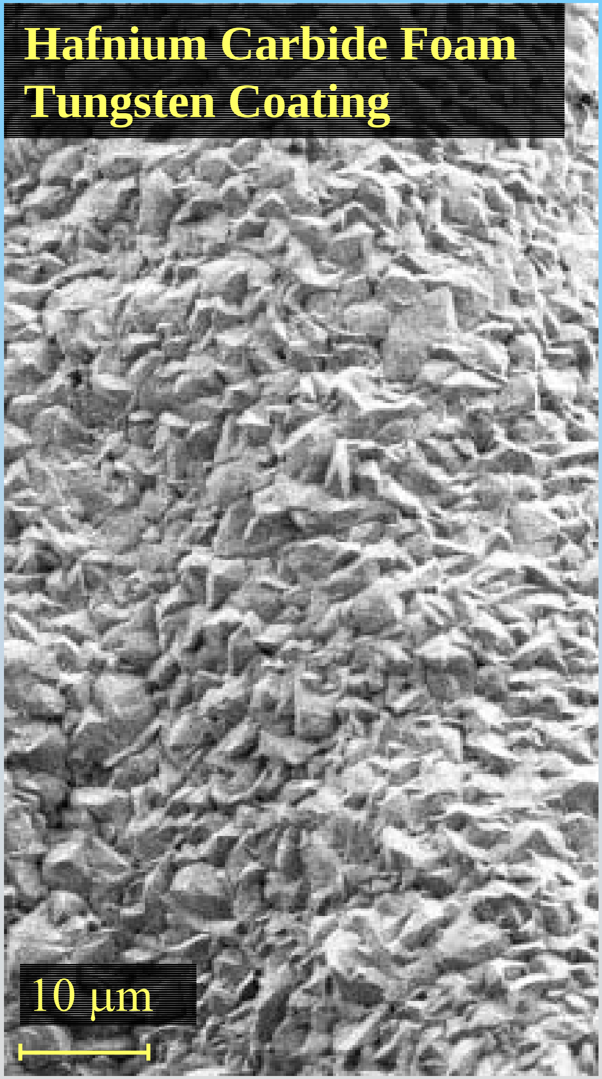
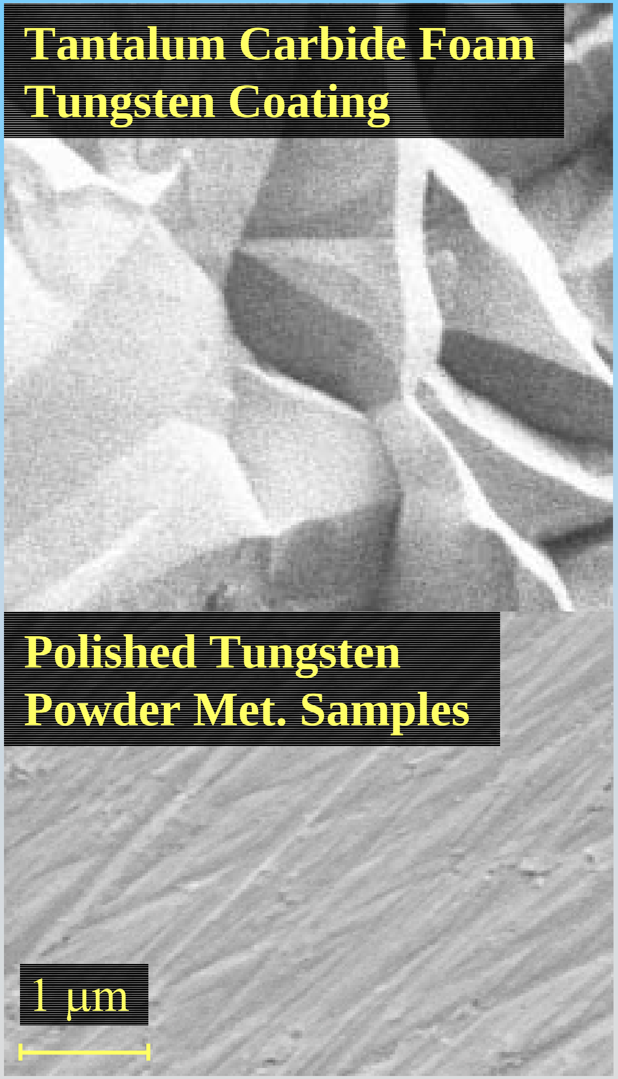
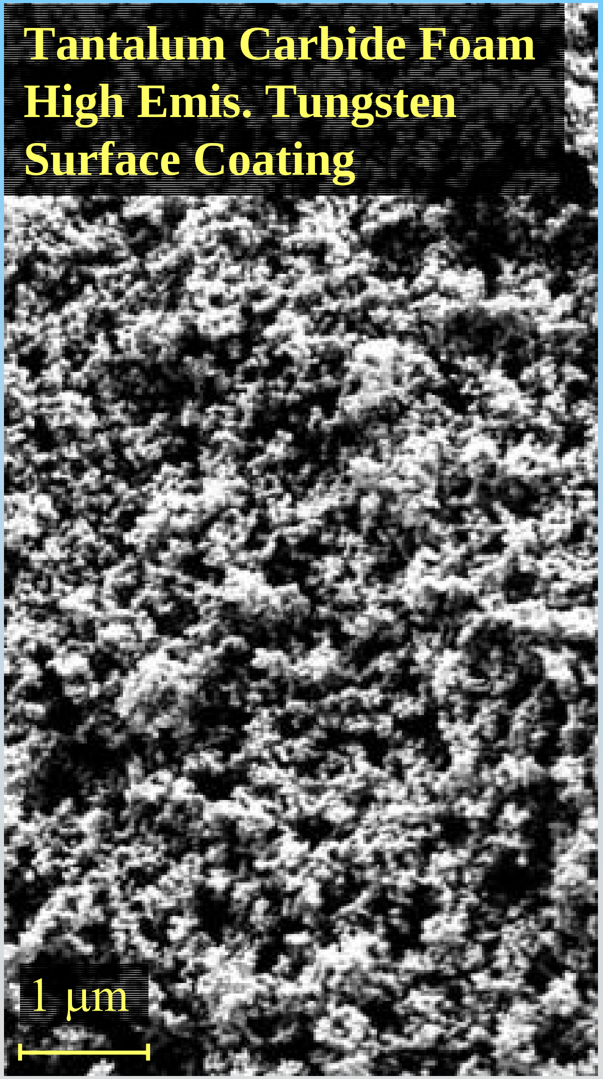
As-Received Foam Surfaces Are Rough

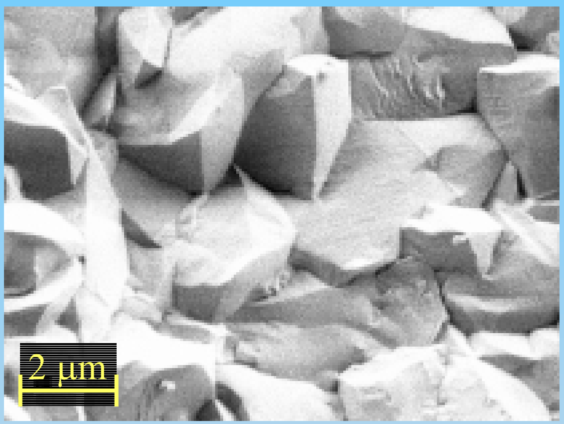


As-Received Foam Surfaces Are Rough

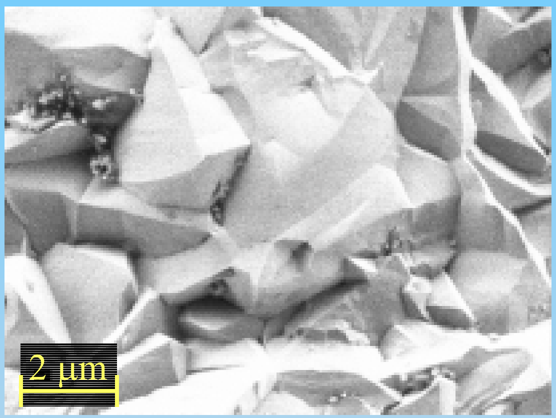




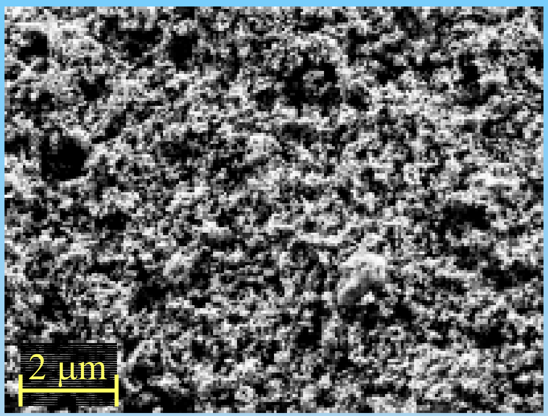
Annealing at 1200 °C for 30 min. has Little Effect on the Foam Surface Morphology



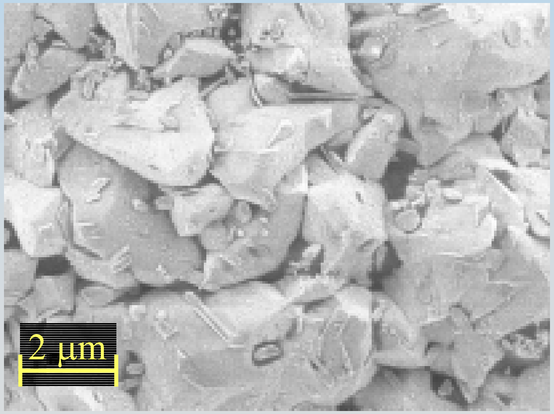
W-Coated HfC
As-Received



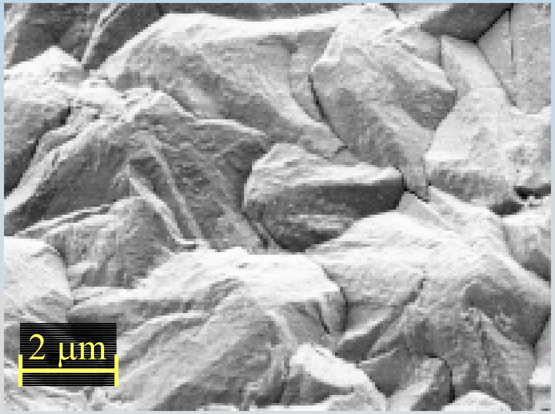
W-Coated TaC
As-Received



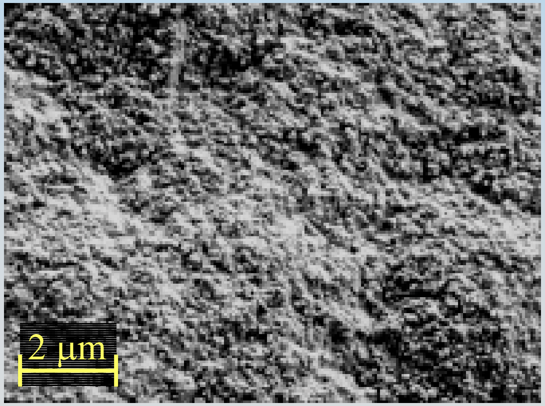
High-ε W-Coated TaC
As Received



W-Coated HfC
Annealed



W-Coated TaC
Annealed



High-ε W-Coated TaC
Annealed

Conclusions

- Incorporation of higher secondary electron emission required a restatement of helium ion fluences to W samples
  - Implication: Pore formation will occur at $<4\text{x}10^{16}$ He^{+}/cm^{2} (30 min. reference HAPL chamber operation)
- Porous W surface can increase thermal emissivity
- As-received morphology of W-coated carbide foam samples have a rough, angular surface
- Annealing of W-coated carbide foam samples to 1,200 °C causes little change to surface morphology
- Initial tests on W-coated carbide foam samples have been conducted up to 45 kV at 1,000 °C

Future Experimental Plans

- Determine the threshold for pore formation in single crystal tungsten (at high temperatures) using helium implantation
- Examine D + He effects on morphology of W surfaces bombarded at 1,000 to 1,200 °C
- Run foam samples in the IEC device
- Design pulsing capability into UW IEC facility