Preliminary Results for Steady State Implantation of He^+ and D^+ in Carbon Velvet and W – Coated Carbon Velvet

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HAPL Meeting-PPPL

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Fusion Technology Institute

University of Wisconsin-Madison

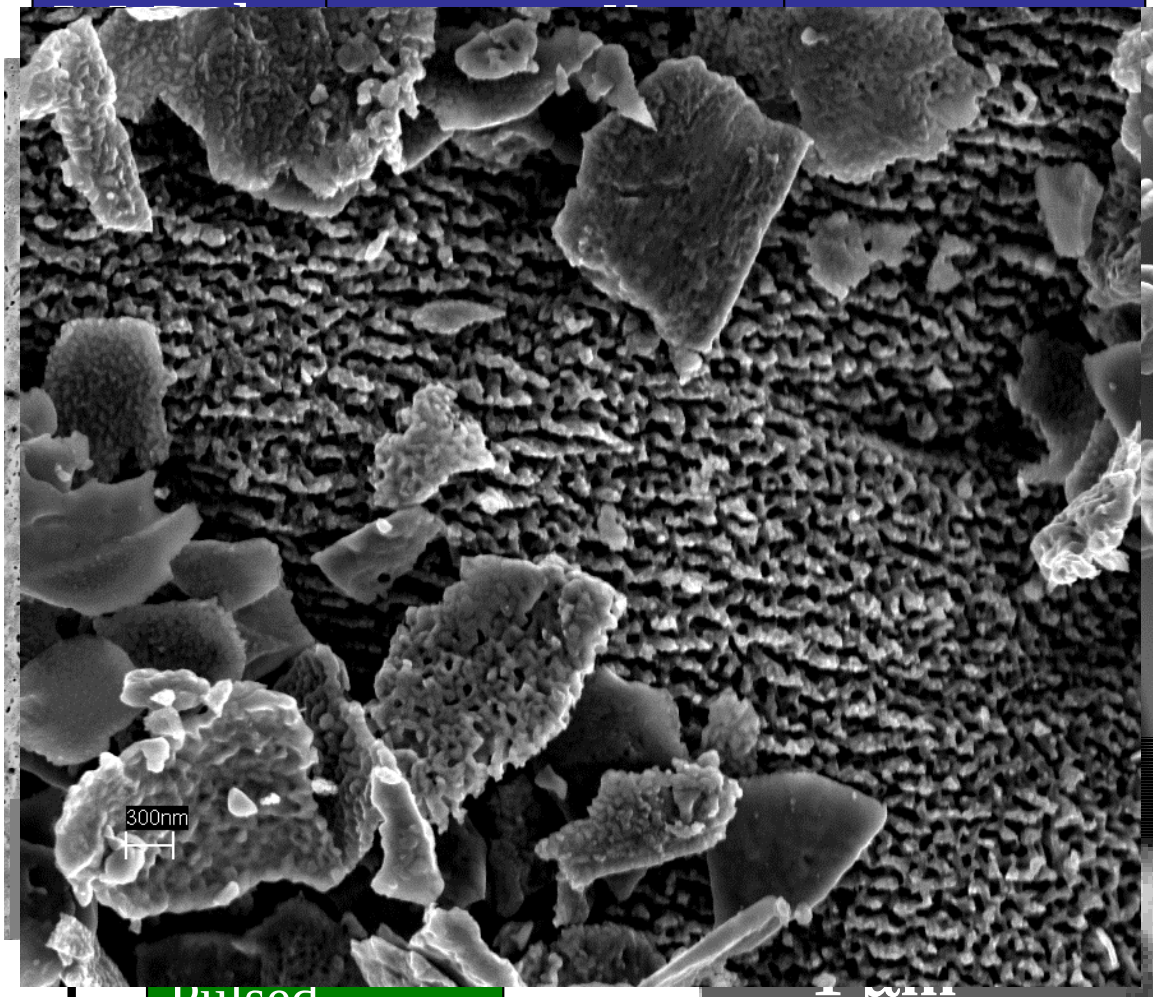
THE UNIVERSITY of WISCONSIN MADISON

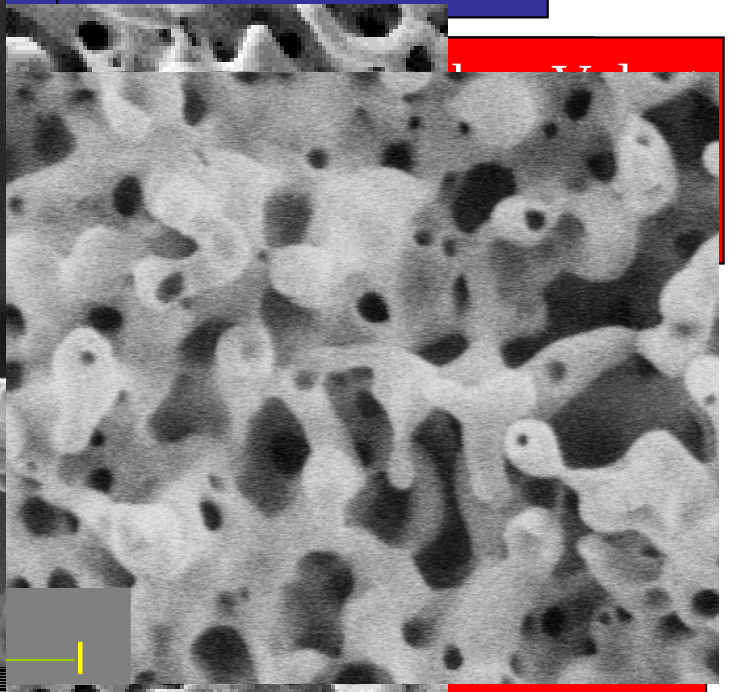
Progress Since Last Meeting

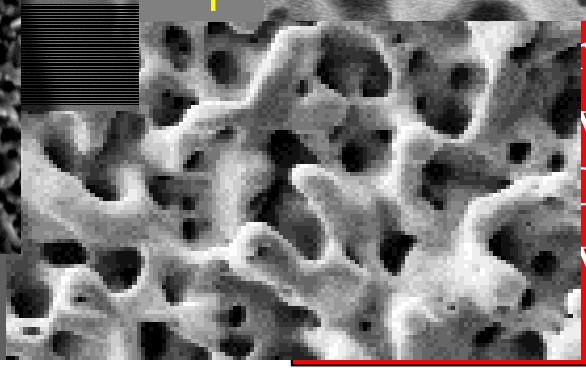
- Carbon – carbon velvet (CCV) and tungsten coated carbon velvet (W/CCV) samples acquired from Tim Knowles at ESLI Laboratories
- A molybdenum irradiation holster was manufactured to ensure repeatability between each of the carbon velvet irradiations.
- SRIM Calculations were performed to estimate the range of He^+ and D^+ for the carbon and tungsten coated specimens
- CCV specimens were irradiated to $1x10^{19}$ ions/cm^2 using both helium and deuterium ions at 1150 ºC
- A W/CCV specimen was irradiated to $1x10^{19}$ He^+/cm^2 at 1150 ºC
- SEM analysis has been performed to evaluate the surface morphology changes on the carbon velvet specimens from irradiations

The Campaign to Assess Ability of Multiple Materials to Operate in HAPL Environment is Proceeding

Carbon Velvet



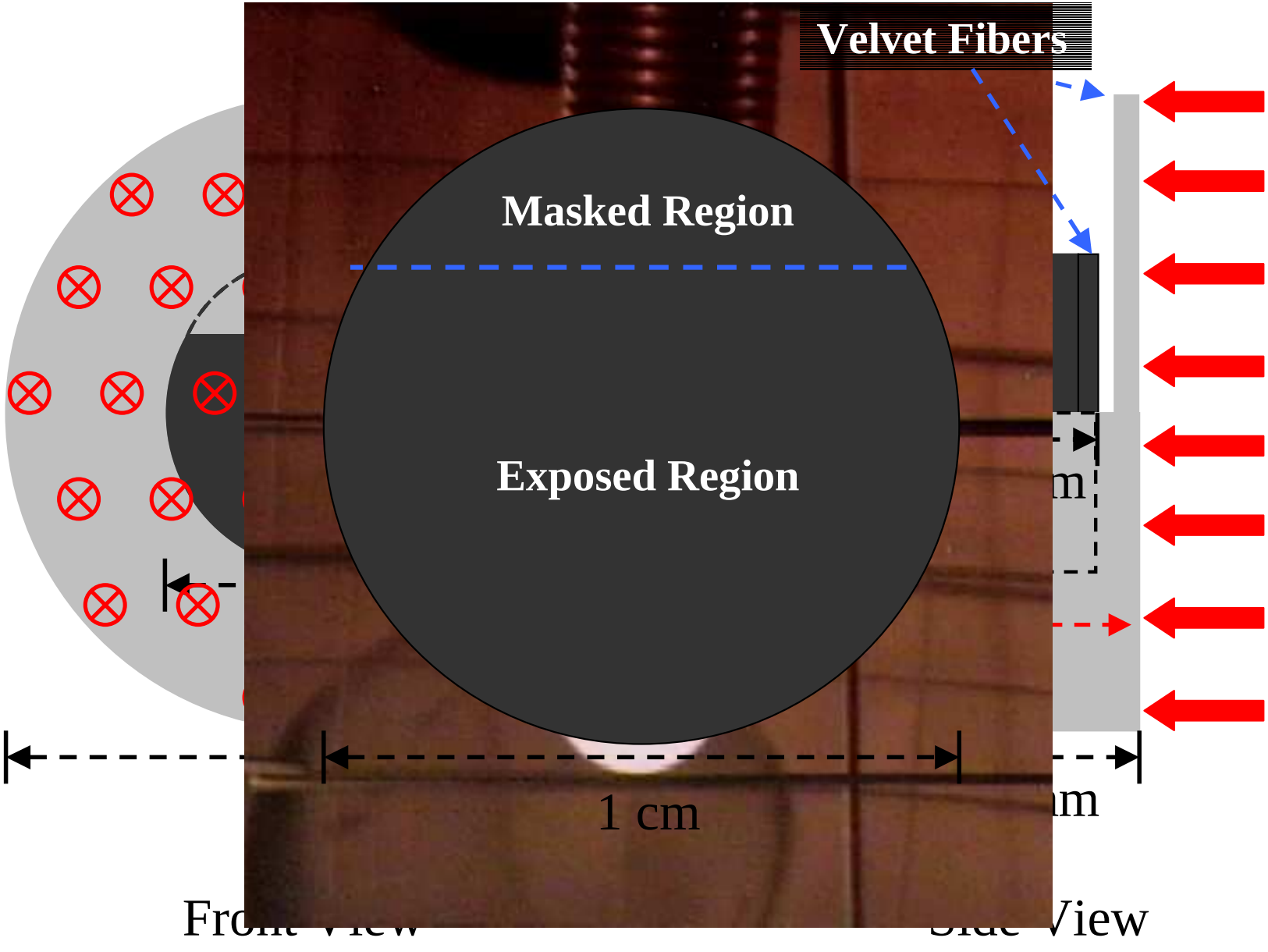




rbon-
vet and
Carbon-
vet

Pulsed
Irradiation

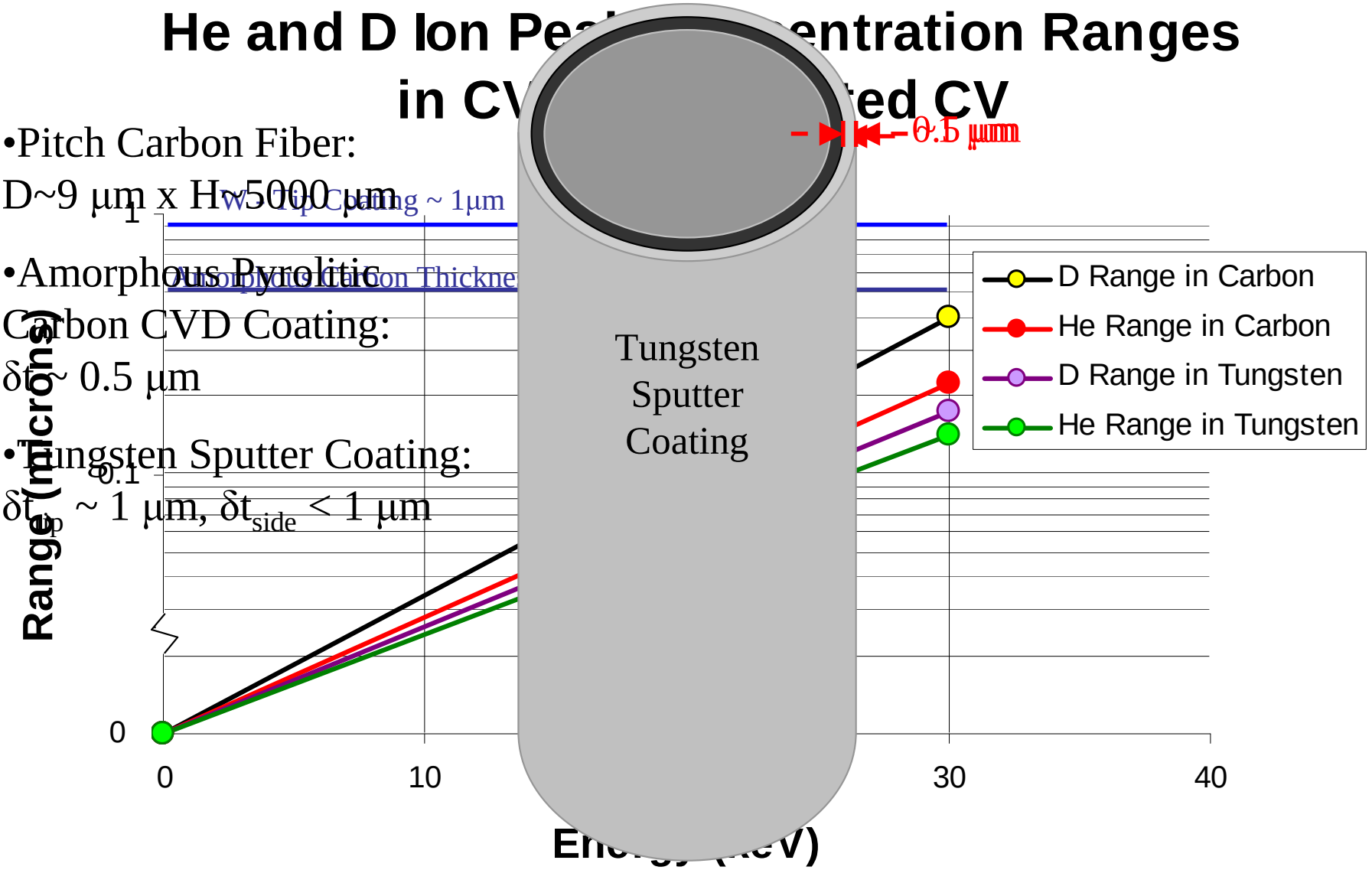
Experiment Setup Using Molybdenum Irradiation Holster



SRIM Calculations Estimate the Range of 30 kV He^+ and D^+ in CCV and W/CCV

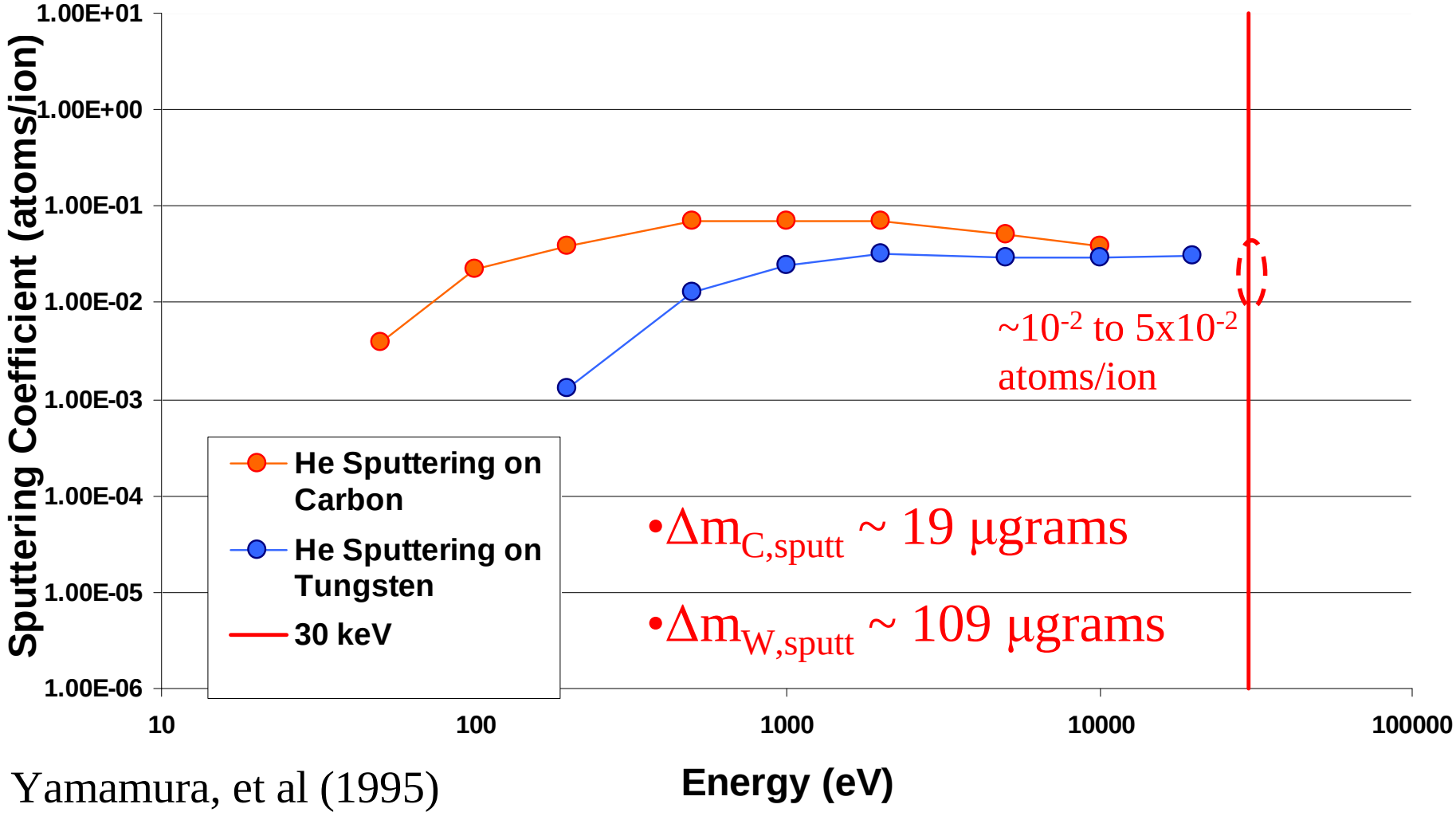
He and D Ion Pea entration Ranges in CV ted CV

- Pitch Carbon Fiber: D~9 μm x H~5000 μm
- Amorphous Pyrolitic Carbon CVD Coating: $\delta t \sim 0.5$ μm
- Tungsten Sputter Coating: $\delta t_{top} \sim 1$ μm, $\delta t_{side} < 1$ μm



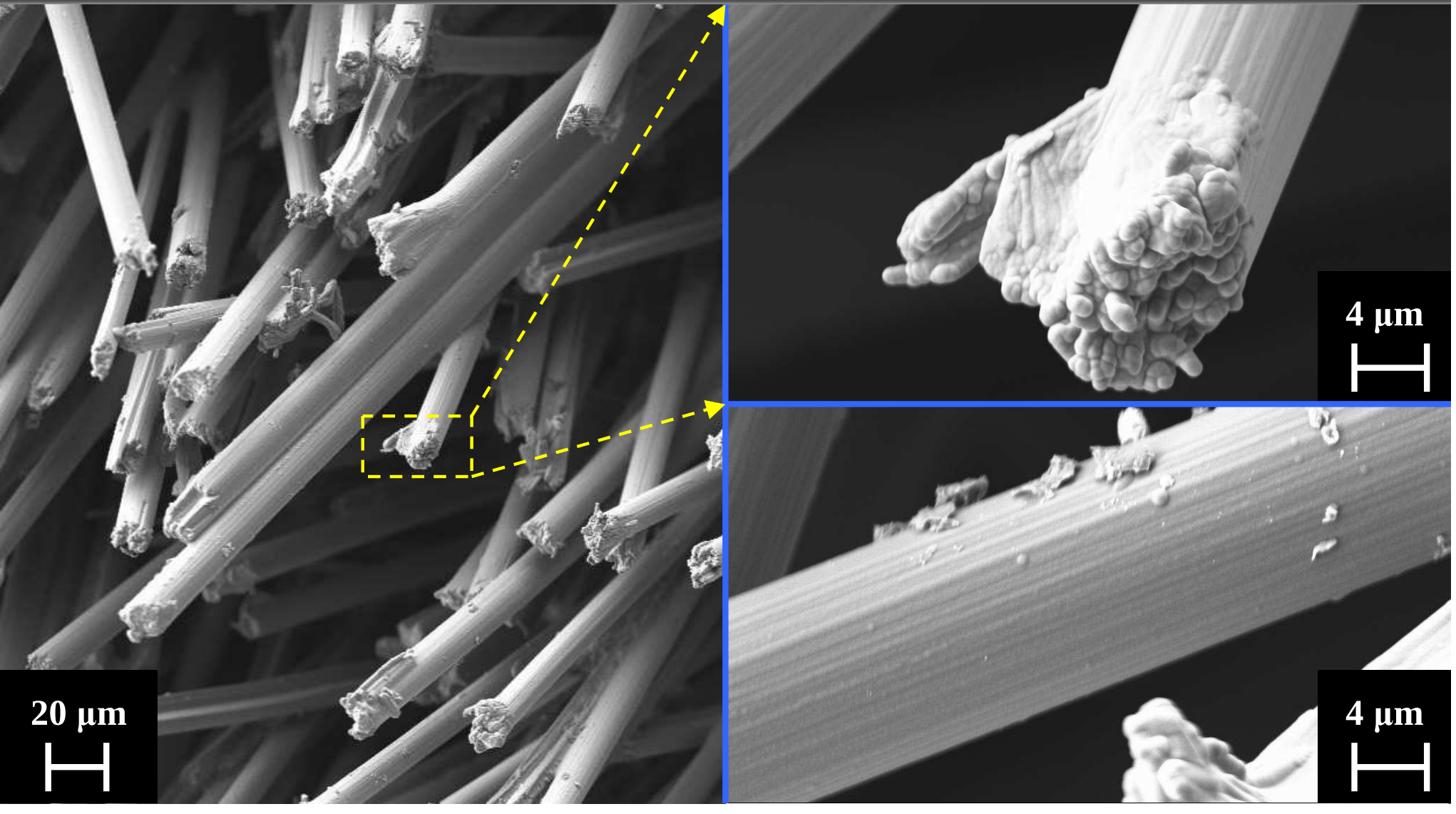
At 30 keV He^+ Has a Similar Sputtering Yields on Carbon and Tungsten

Helium Sputtering Coefficients



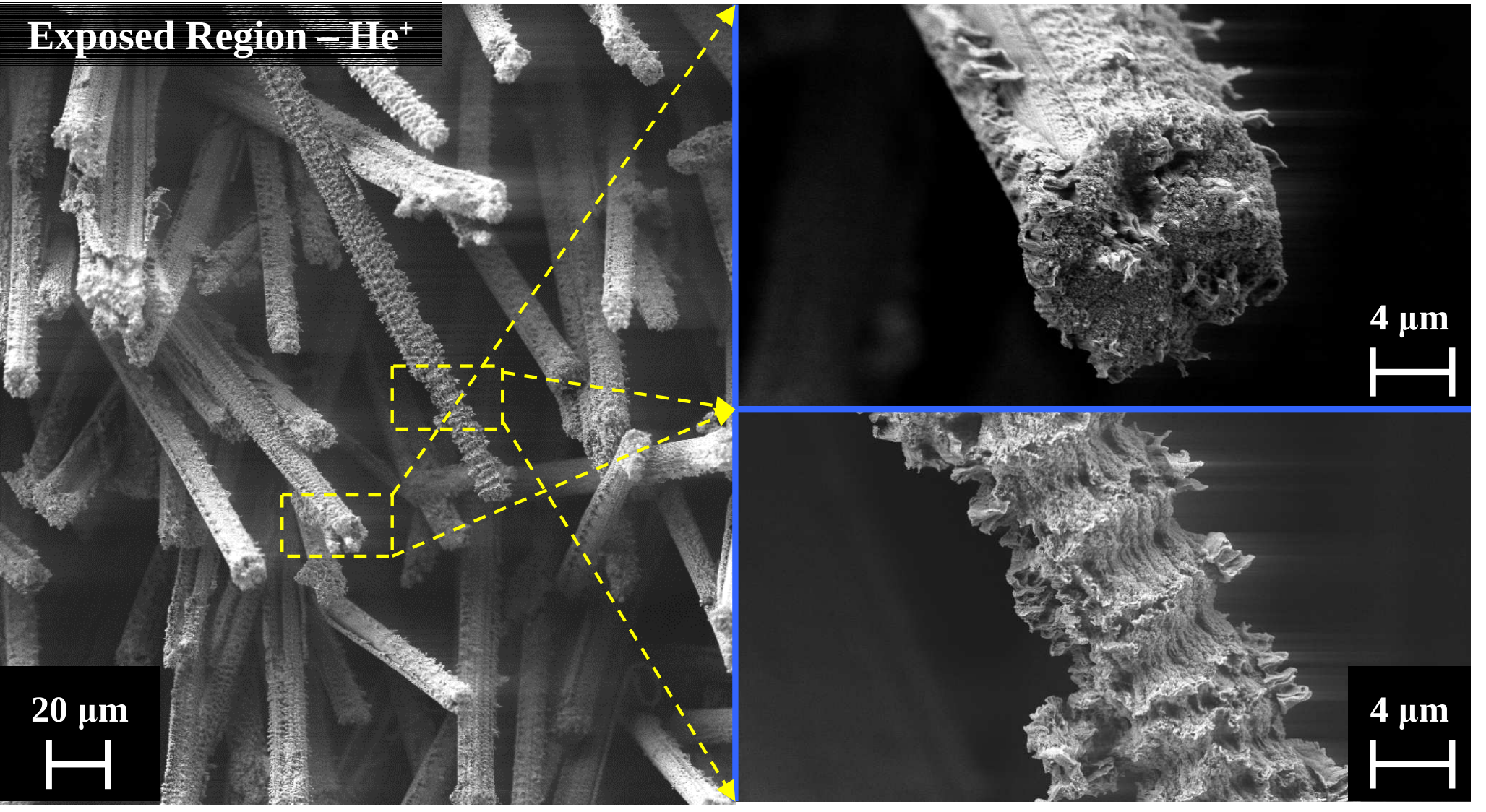
Yamamura, et al (1995)

Objective: Assess Viability of Carbon Velvet as HAPL's First Wall Armor



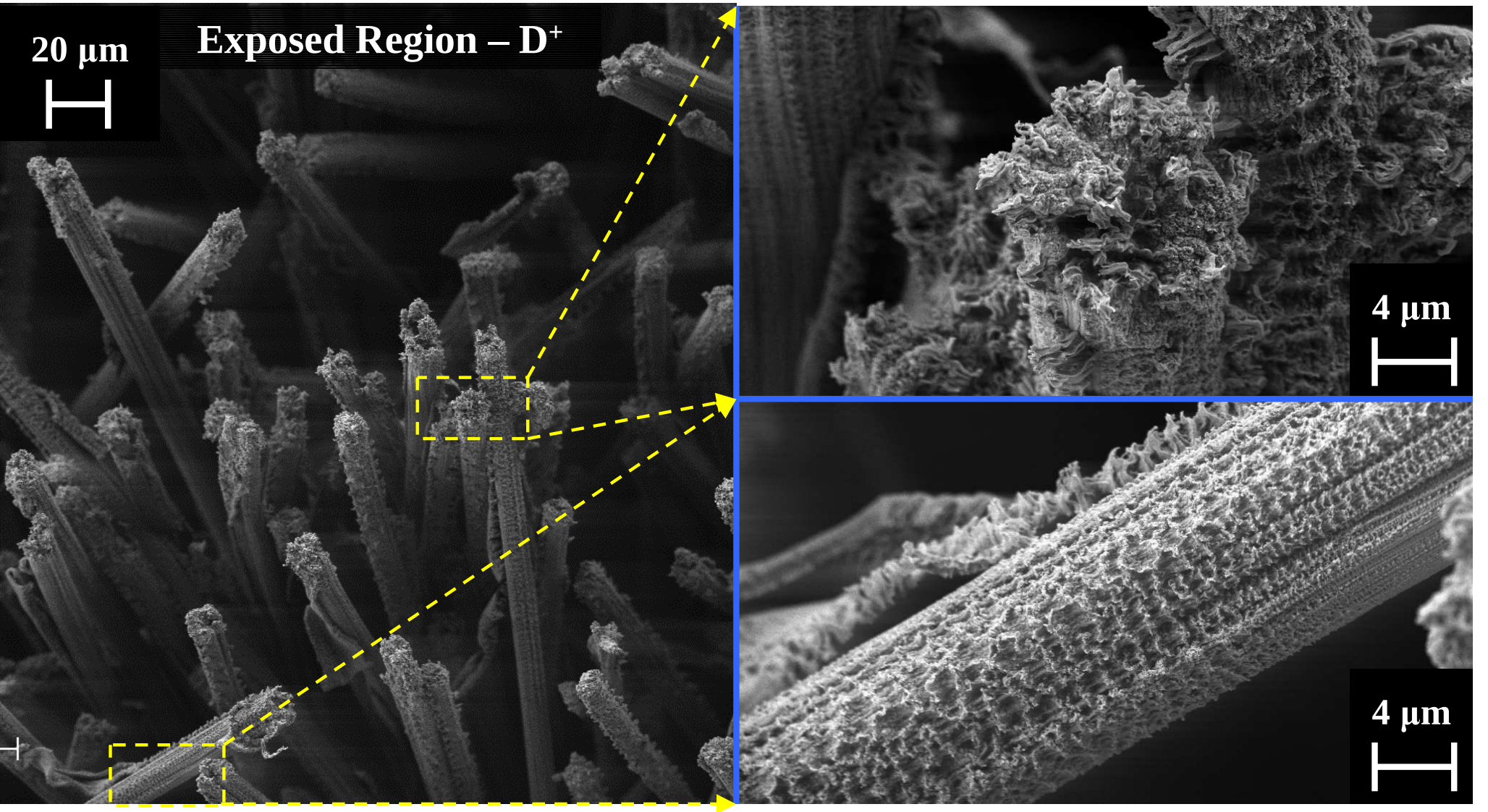
Unirradiated CCV

Irradiation of CCV to 10^{19} He^+/cm^2 Results in Surface Roughness and Shaft Corrugation



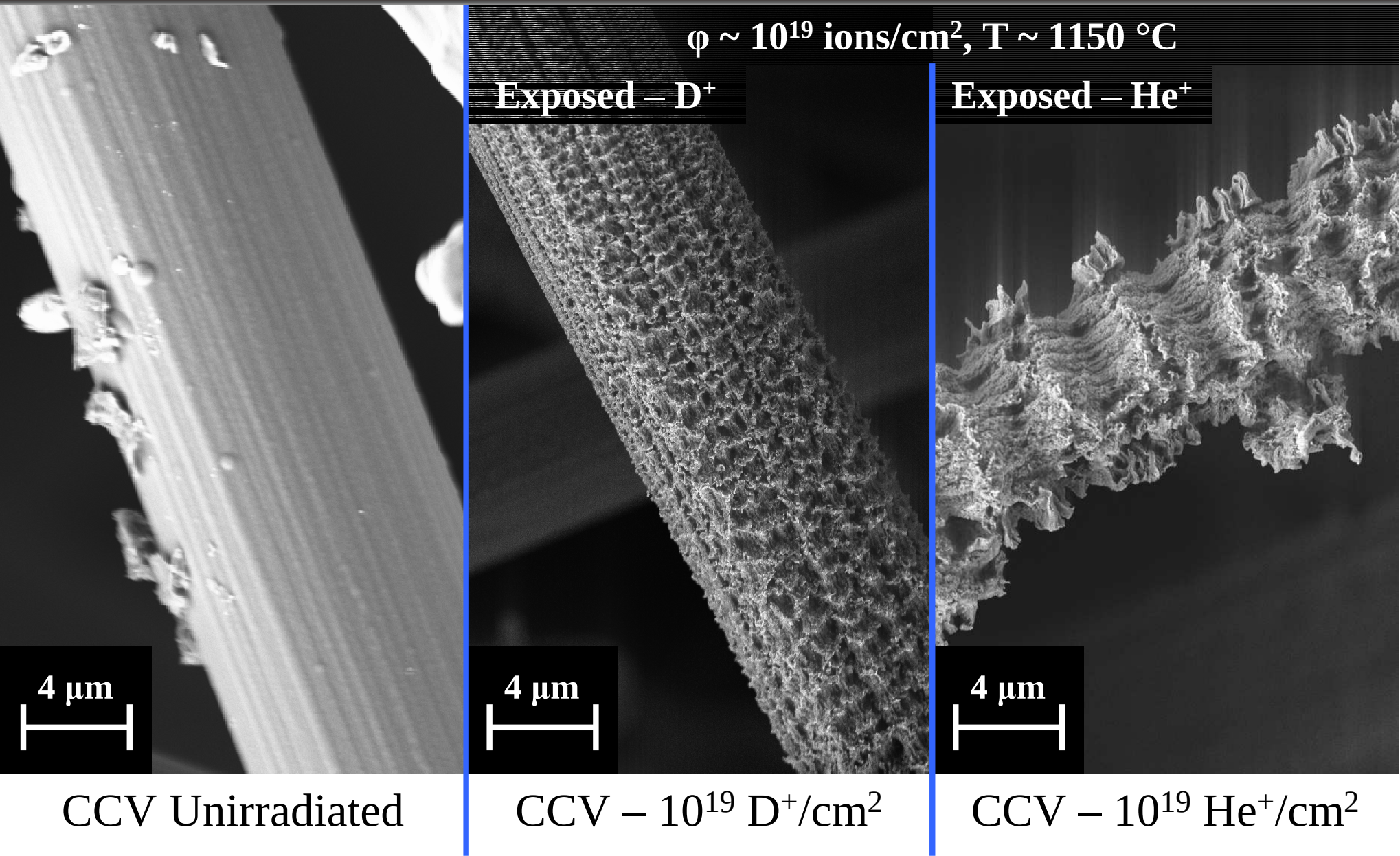
T ~ 1150 °C, φ ~ 10^{19} He^+/cm^2, V ~ 30 kV

Irradiation of CCV to 10^{19} D^+/cm^2 also Results in Surface Roughness



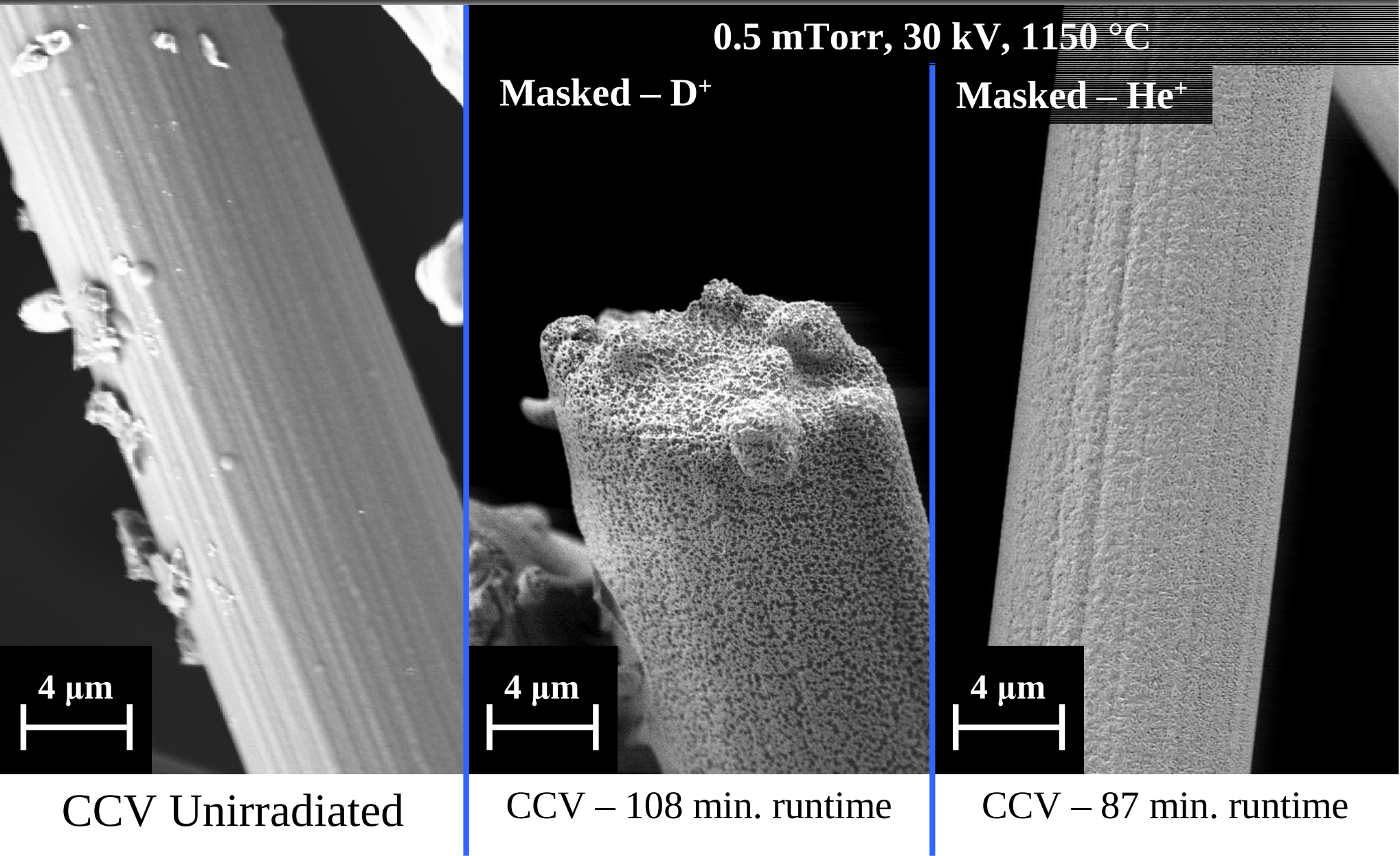
T ~ 1150 °C, φ ~ 10^{19} D^+/cm^2, V ~ 30 kV

CCV Exposure to He^+ Fluxes Shows an Increase in Fiber Surface Roughening Compared to D^+ Fluxes



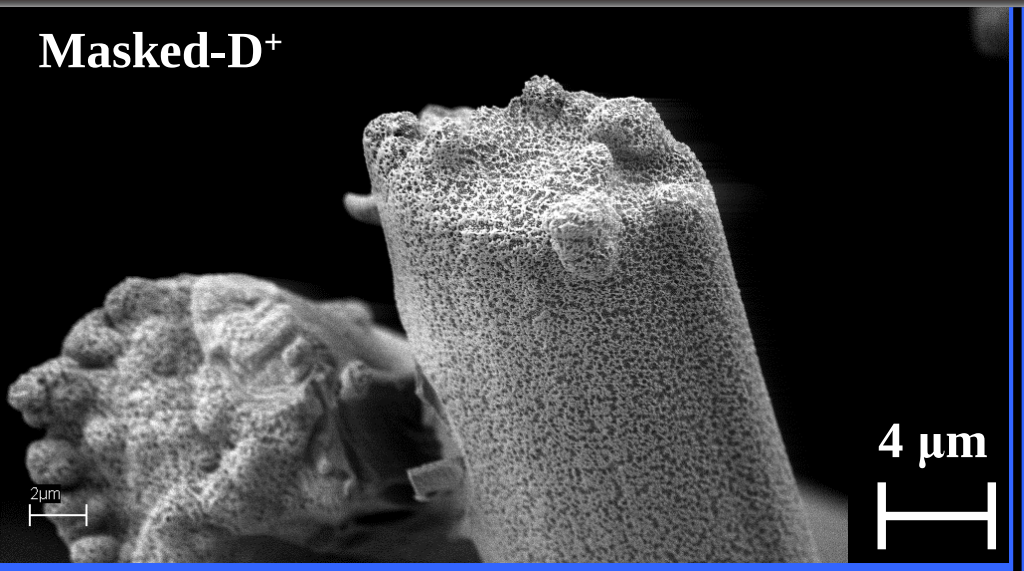
CCV Unirradiated | CCV – 10^{19} D^+/cm^2 | CCV – 10^{19} He^+/cm^2

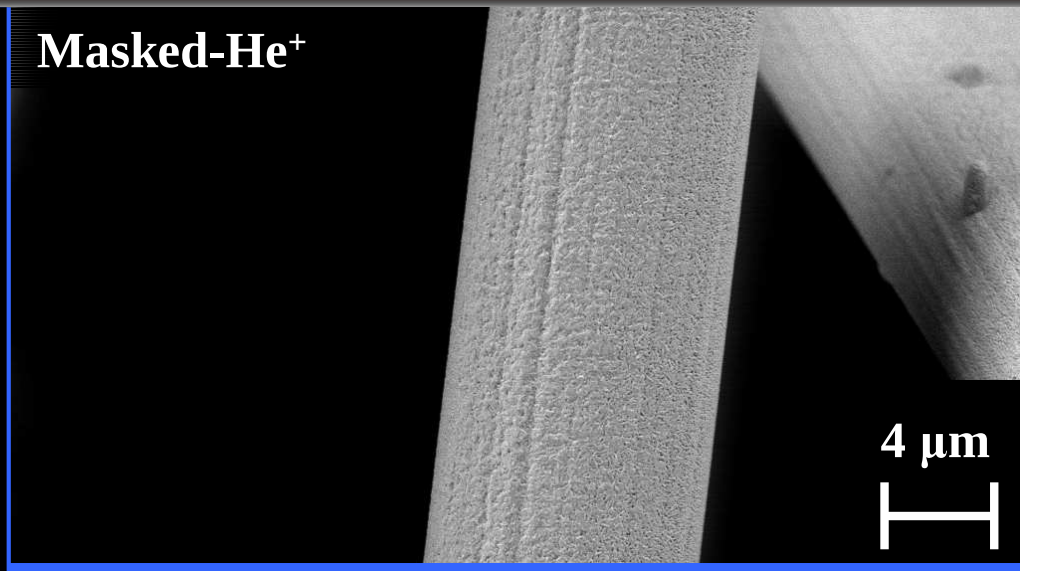
Similar Surface Modification Occurs in the Masked Region of CCV Samples Exposed to He^+ and D^+ Fluxes

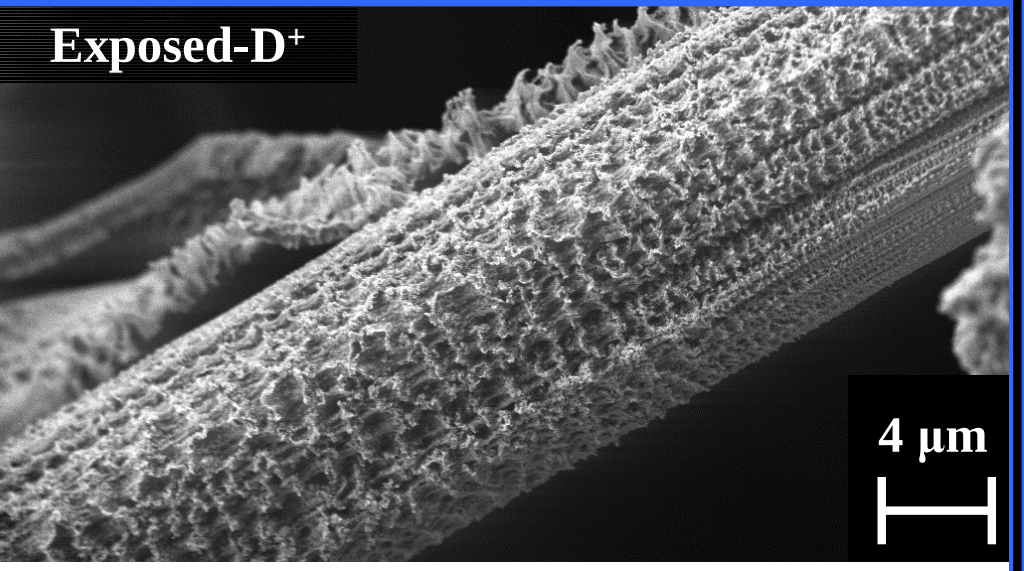


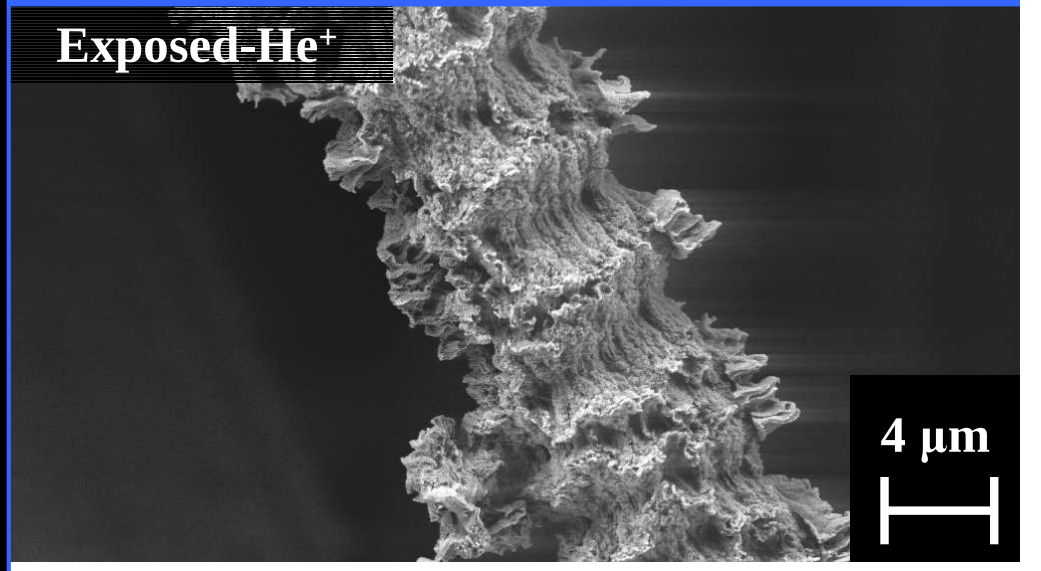
CCV Unirradiated | CCV – 108 min. runtime | CCV – 87 min. runtime

Drastic Differences in CCV Surface Morphology Are Evident Between the Exposed and Masked Regions





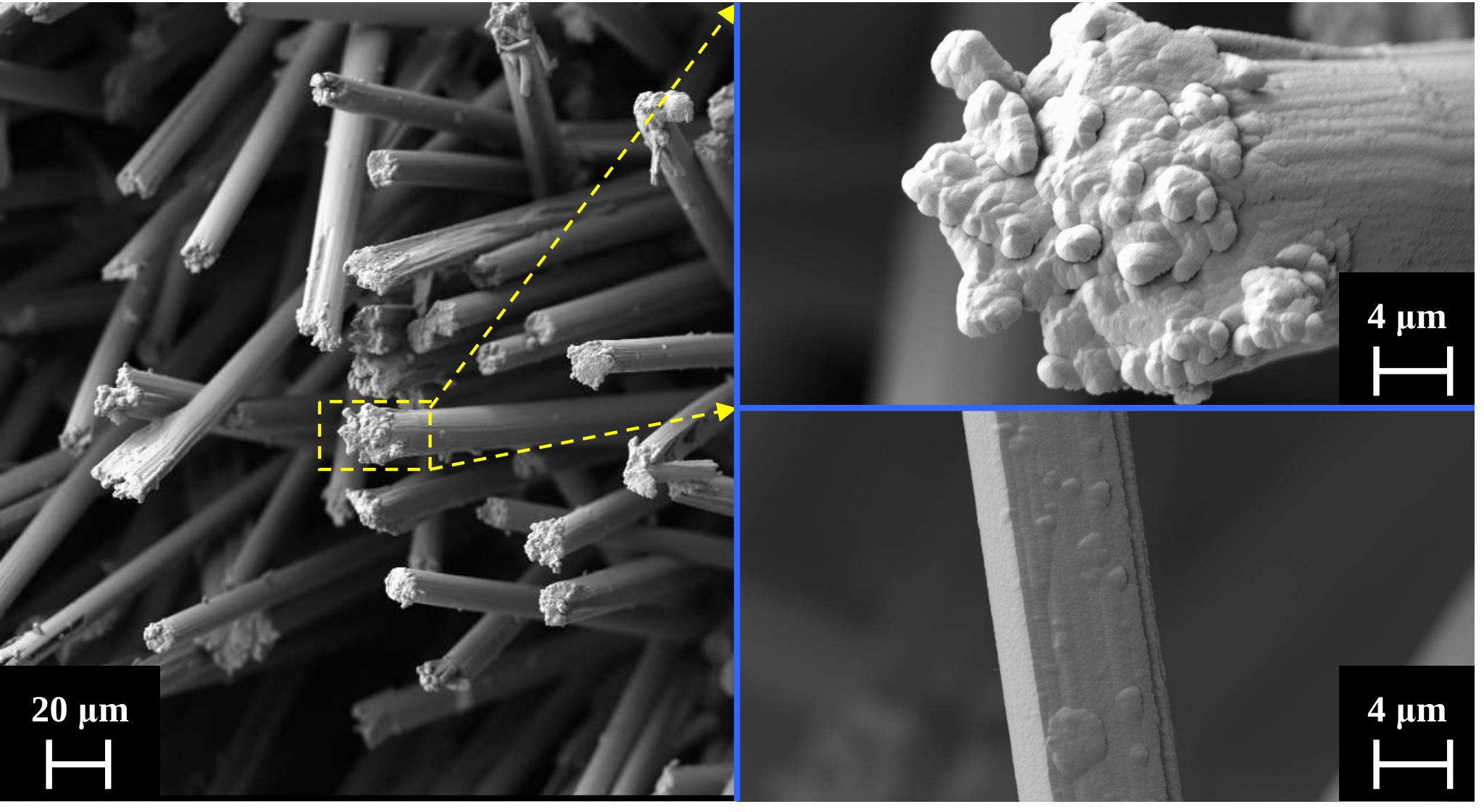




CCV – Irradiated to 10^{19} D^+/cm^2 @ 1150 °C

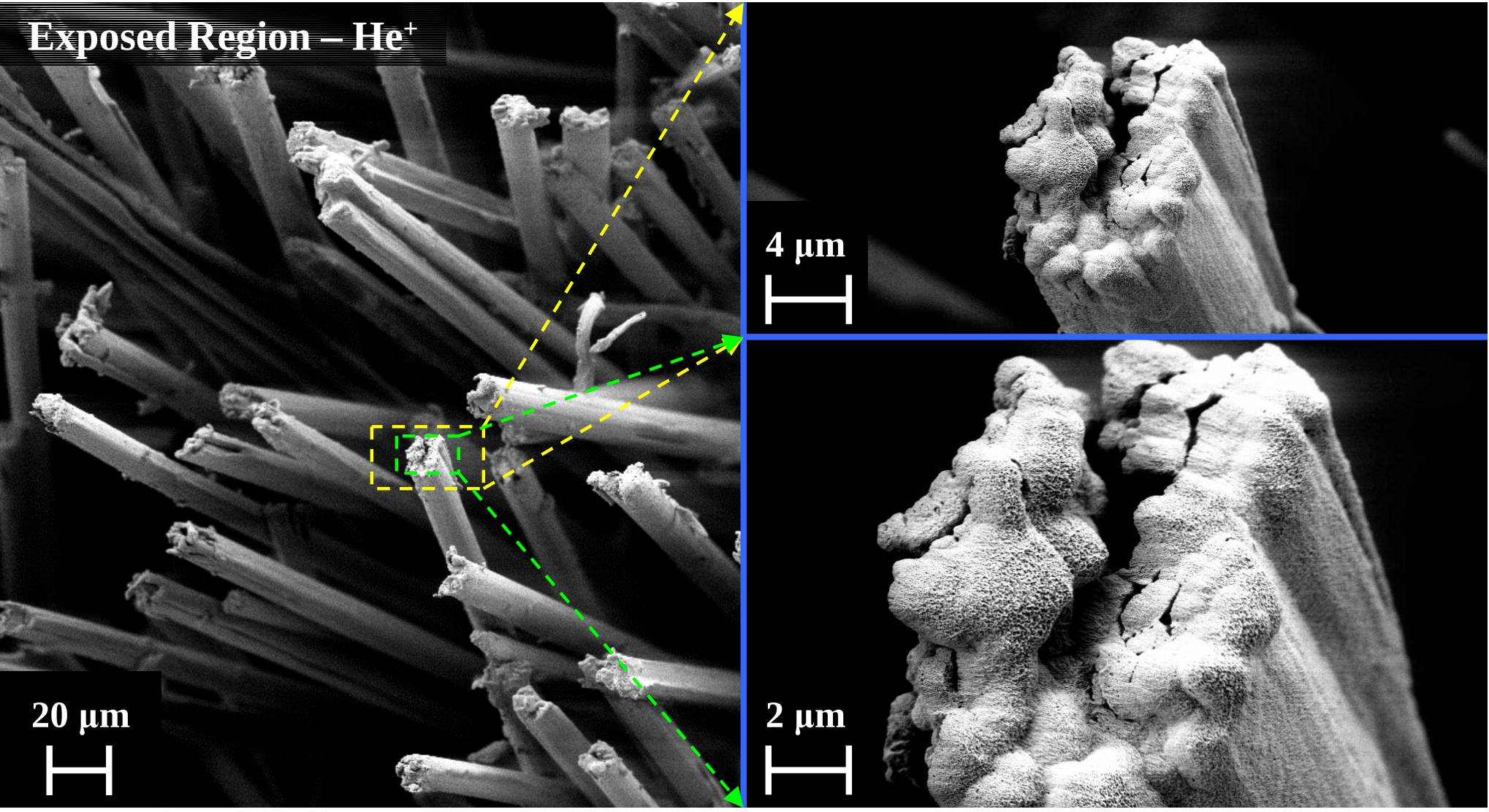
CCV – Irradiated to 10^{19} He^+/cm^2 @ 1150 °C

Objective: Assess Viability of Tungsten Coated Carbon Velvet as HAPL's First Wall Armor



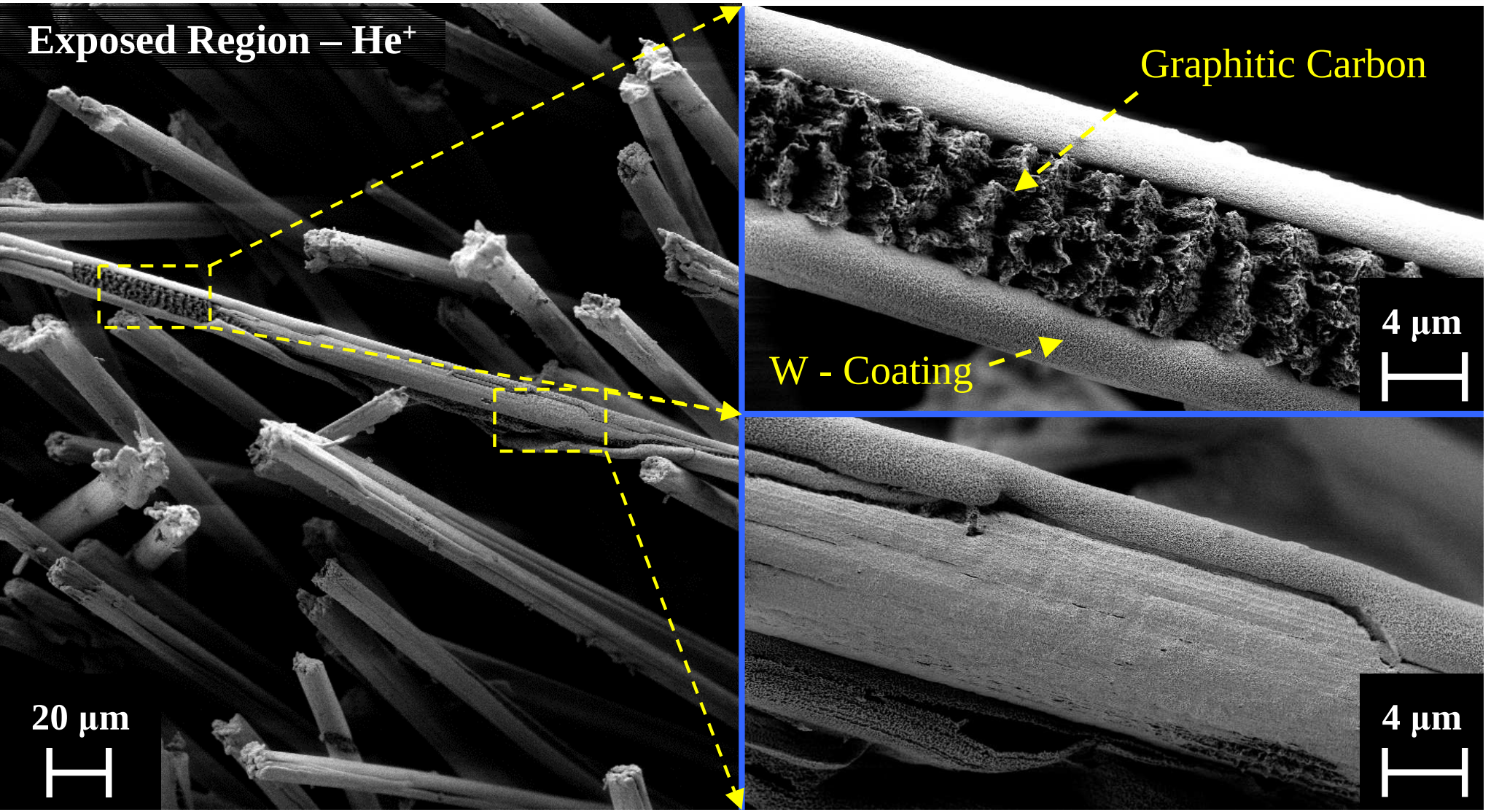
Unirradiated Tungsten – coated Carbon Velvet

SEM Analysis Illustrates Increased Surface Roughening on W-Coating after Irradiation of W/CCV to 10^{19} He^+/cm^2



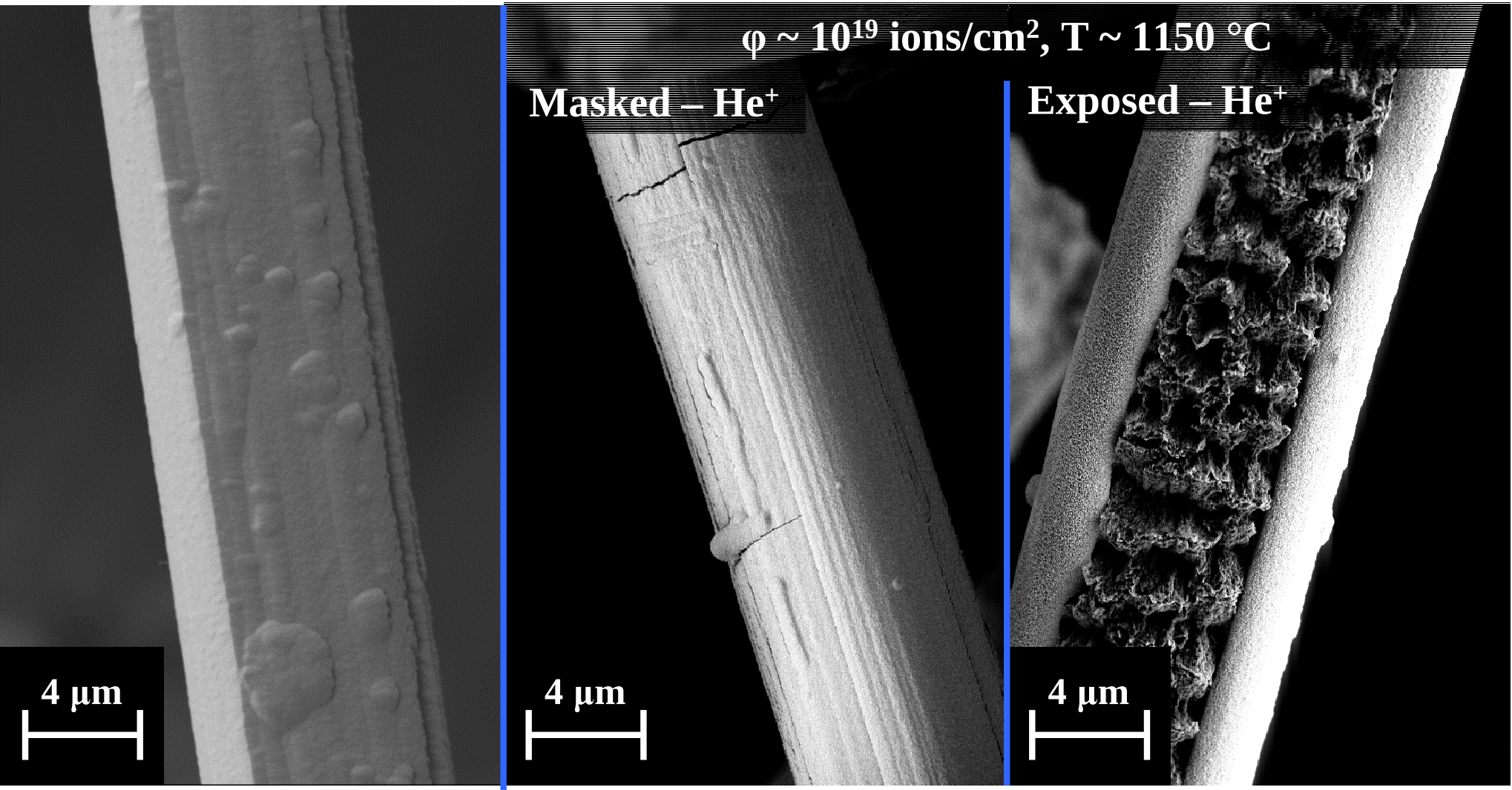
T ~ 1150 °C, φ ~ 10^{19} He^+/cm^2, V ~ 30 kV

After Irradiation of W/CCV to 10^{19} He^+/cm^2 Rupturing of the W-Coating is Also Observed



T ~ 1150 °C, φ ~ 10^{19} He^+/cm^2, V ~ 30 kV

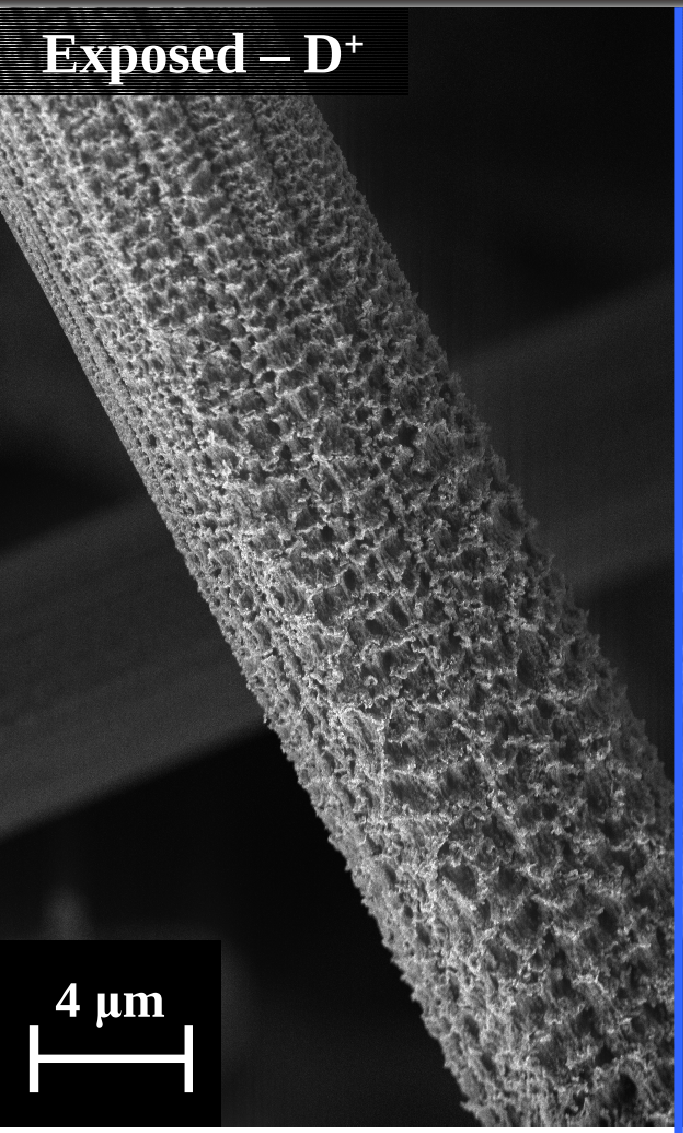
Masked W/CCV Experiences W-Coating Cracks But Not Increased Surface Roughness



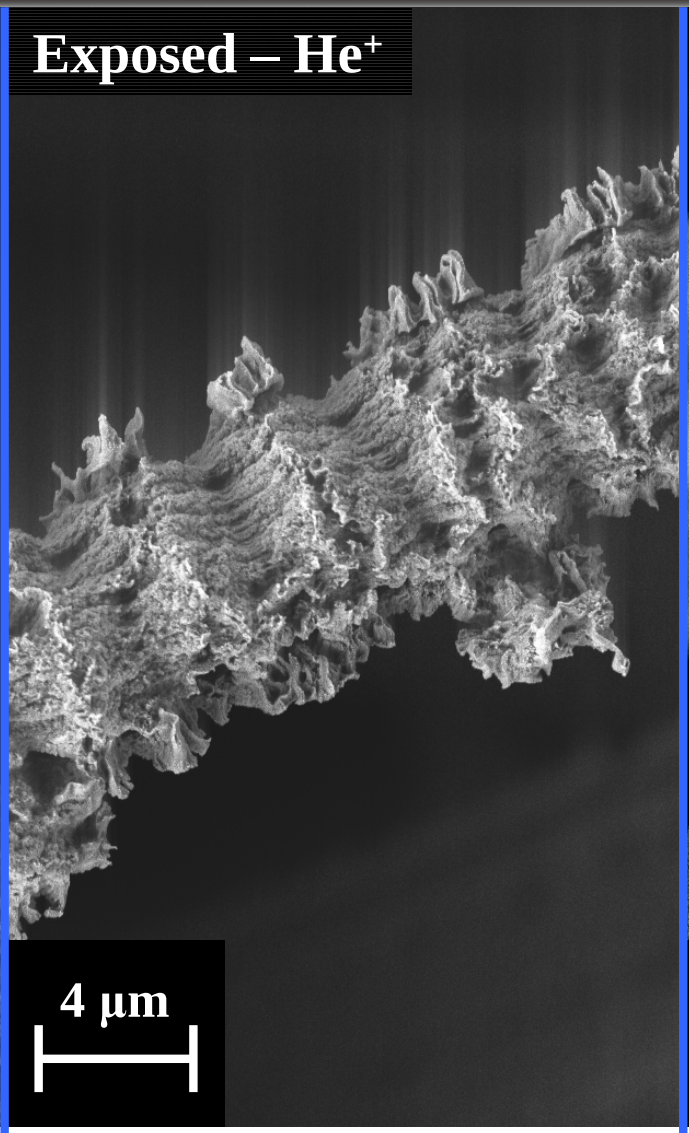
W/CCV Unirradiated

W/CCV – 10^{19} He^+/cm^2, 105 min. runtime

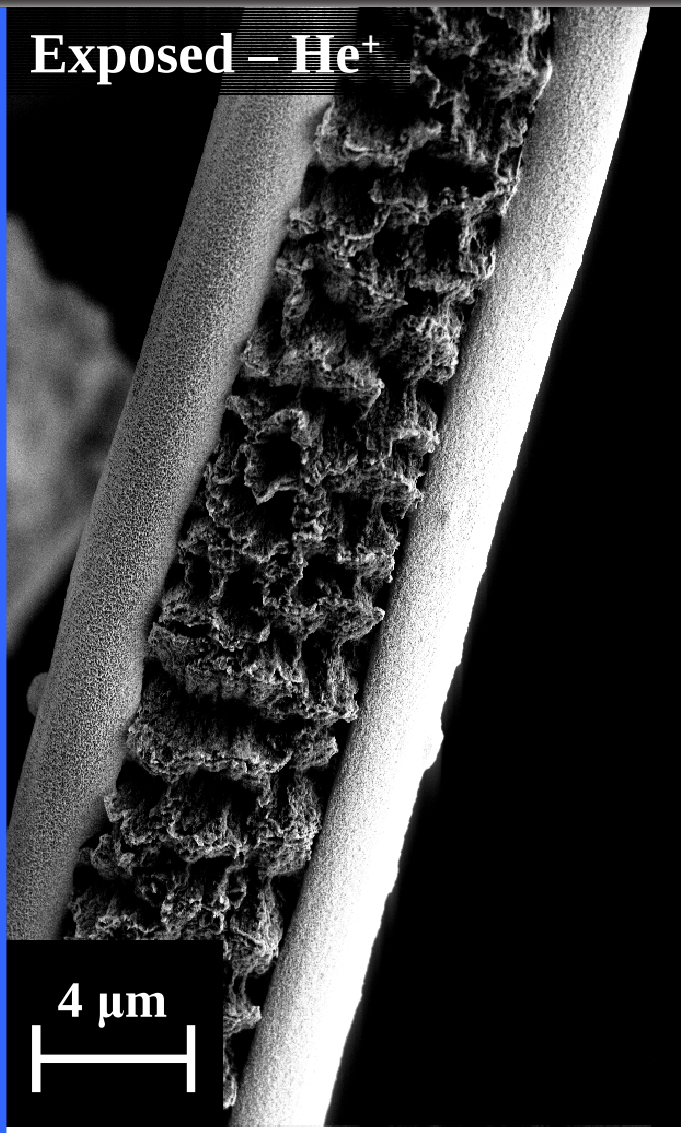
Velvet Specimens Exposed to He^+ Appear to Sustain an Exaggerated Surface Corrugation Effect



CCV – 10^{19} D^+/cm^2 @ 1150 °C

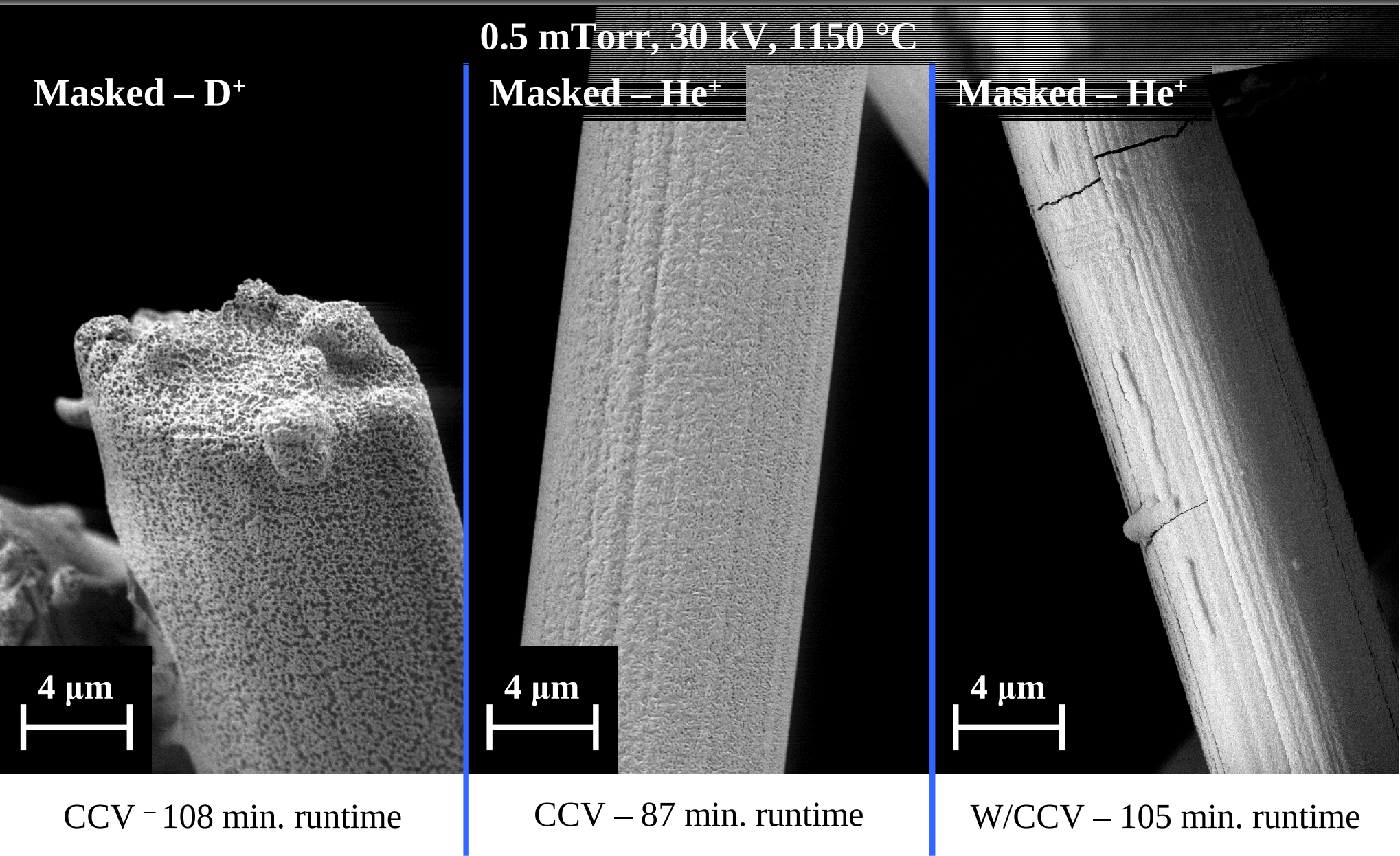


CCV – 10^{19} He^+/cm^2 @ 1150 °C



W/CCV–10^{19} He^+/cm^2@1150°C

Velvet Fibers in the Masked Regions Experience Surface Pitting and W-Coating Cracks

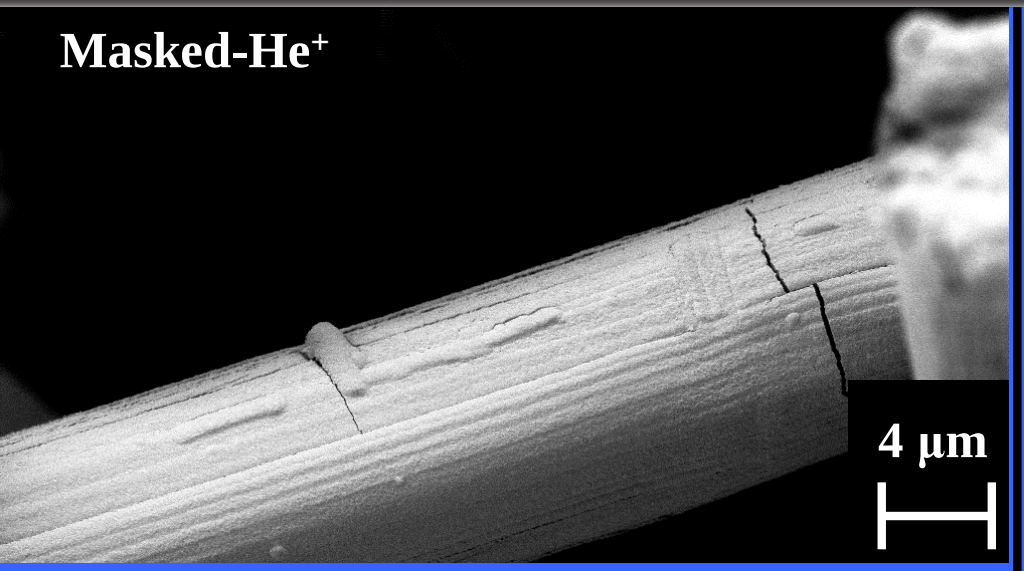


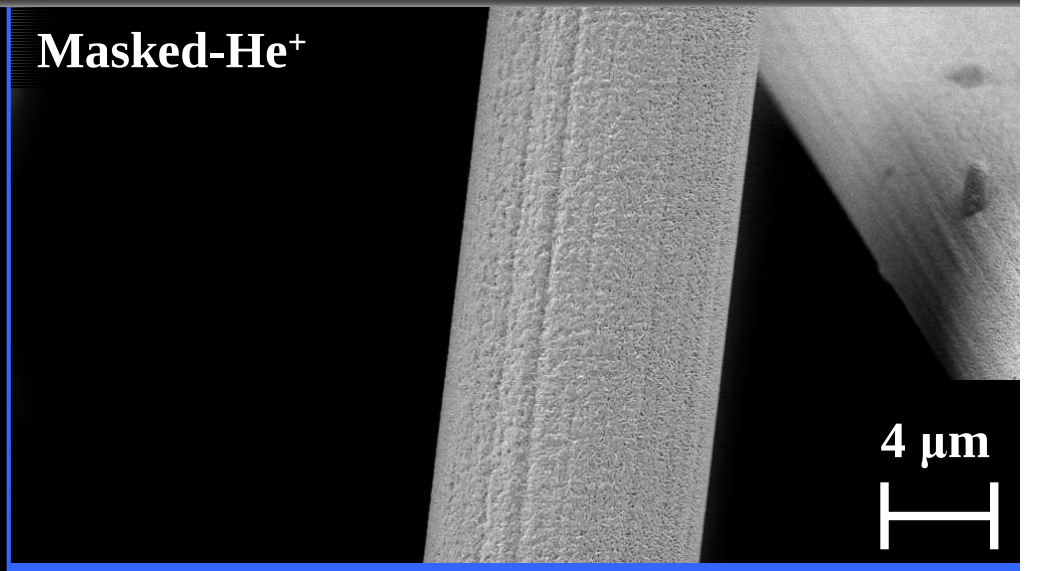
CCV – 108 min. runtime

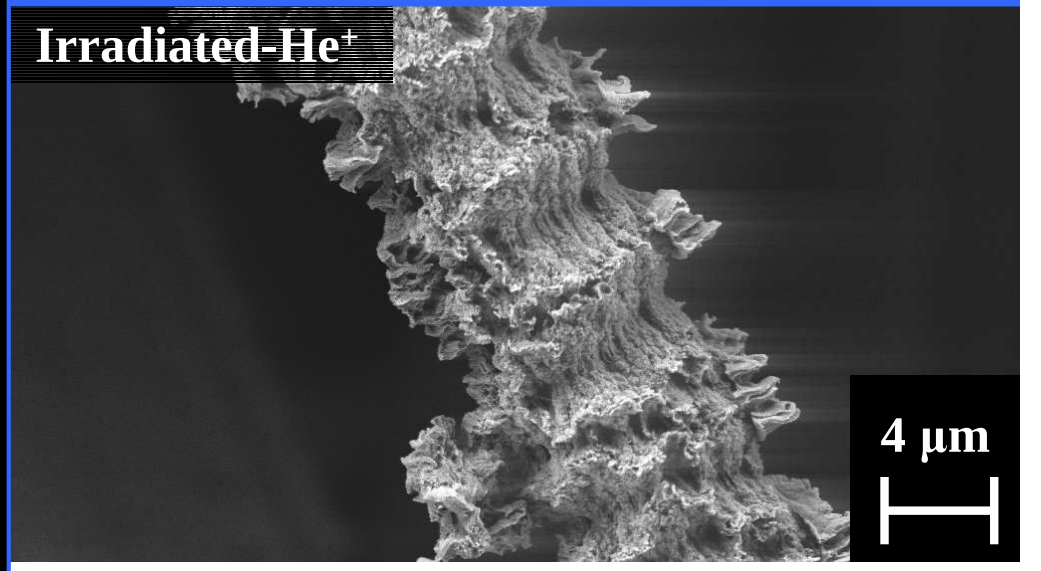
CCV – 87 min. runtime

W/CCV – 105 min. runtime

Fibers in the Exposed Regions Sustain More Drastic Morphology Changes than in the Masked Regions







W/CCV – Irradiated to 10^{19} He^+/cm^2 @ 1150 °C

CCV – Irradiated to 10^{19} D^+/cm^2 @ 1150 °C

All Carbon Velvet Samples Experience Measurable Mass Loss After Irradiation

$1x10^{19}$ ions/cm^2	Pre - Irradiation Mass (mg)	Post-Irradiation Mass (mg)	Irradiation Mass Loss (mg)
CCV (D^+)			
CCV (He^+)			
W/CCV (He^+)			

Preliminary Observations @ 1150 °C

- Both He^+ and D^+ irradiation of carbon-carbon velvet specimens causes fiber shaft corrugation, though He^+ irradiated samples have a more pronounced effect
- Some W-coated carbon fiber shafts incur rupturing, in addition to increased W surface roughness after He^+ irradiation
- Both He^+ and D^+ irradiation resulted in measurable mass loss in each of the carbon velvet specimens
- Masked sections of all carbon velvet specimens exposed to high temperature and high voltage, sustained less damage (quantitiative), as well as a qualitatively different surface structure than exposed sections

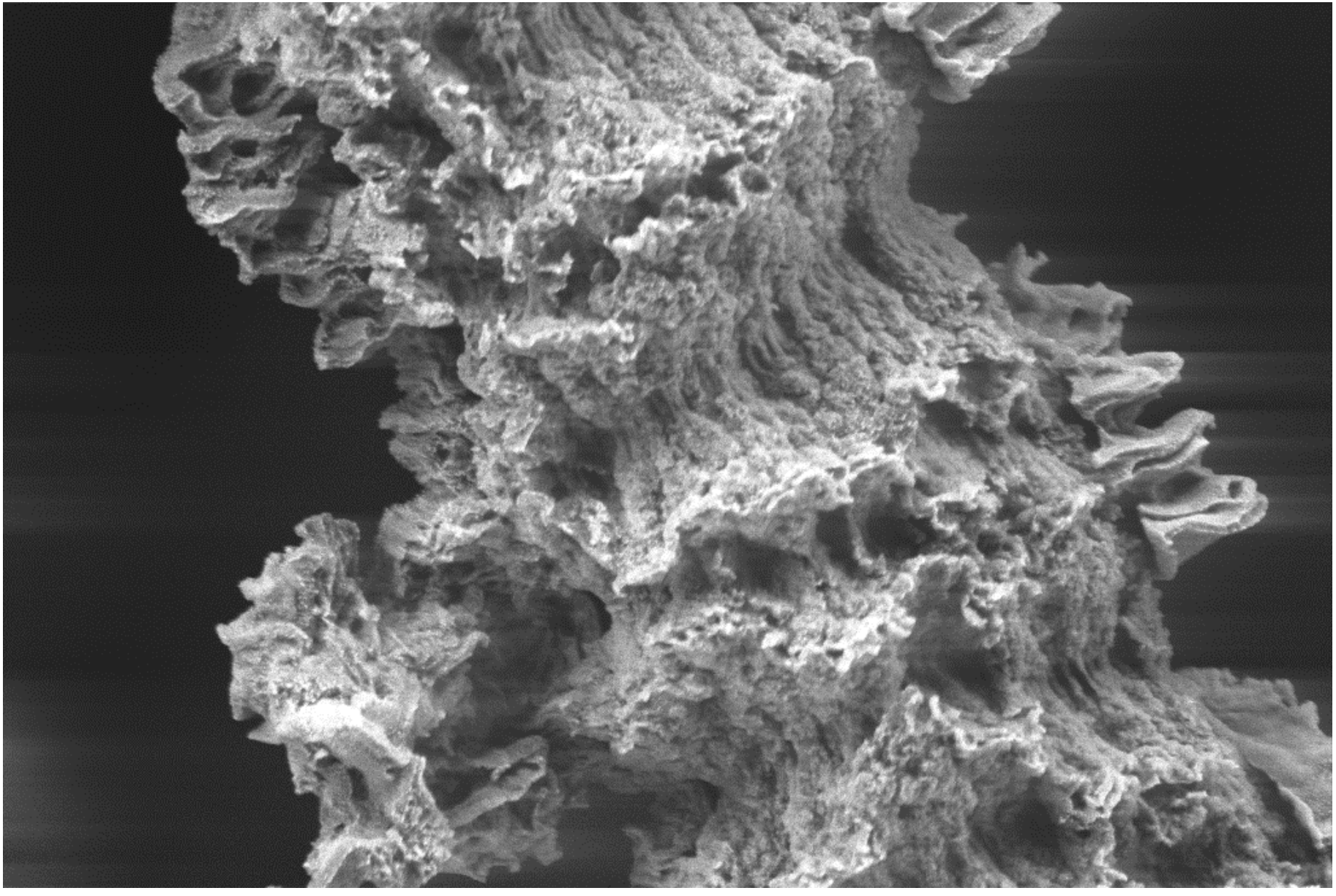
Possible Future Work

- Damage investigations for CCV and W/CCV held at high temperature without ion fluxes
- Damage investigations for CCV and W/CCV held at high temperature and high voltage without ion fluxes
- Irradiation of W-coated carbon velvet specimen using D^+

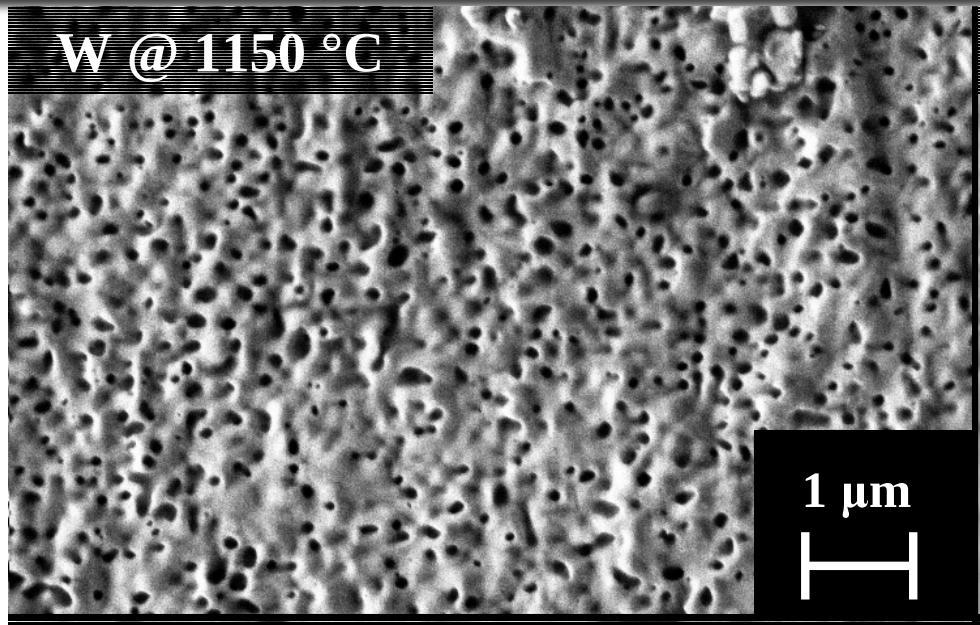
Possible Future Work, Cont.

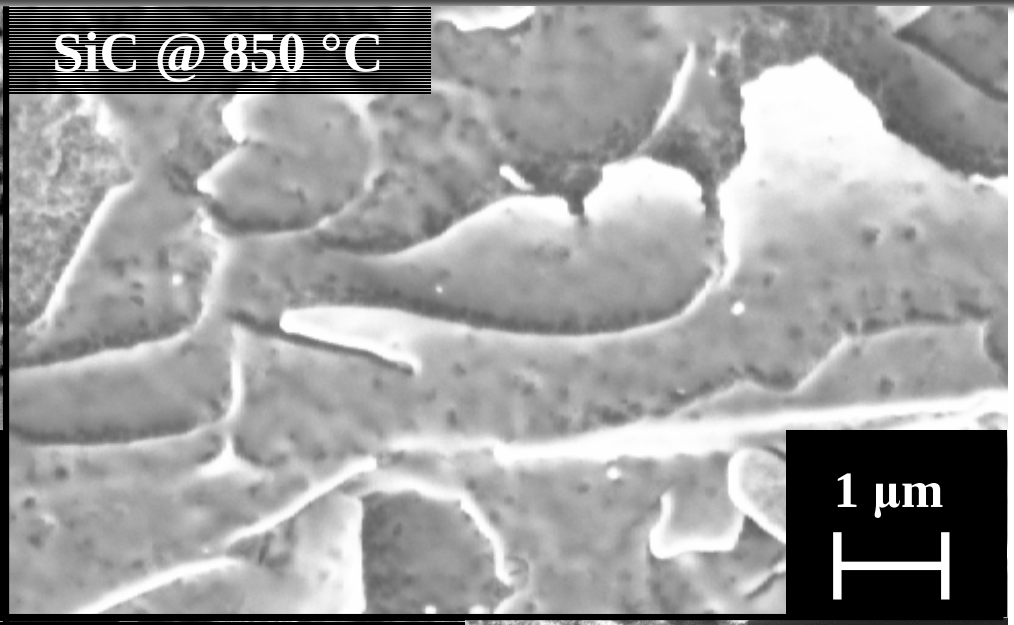
- Investigation of other carbon velvet source material (pan fibers, glassy carbon, etc.)
- Energy Dispersive Spectrometer (EDS) post-irradiation chemical analysis to determine surface composition
- FIB analysis of individual fibers on all examined samples

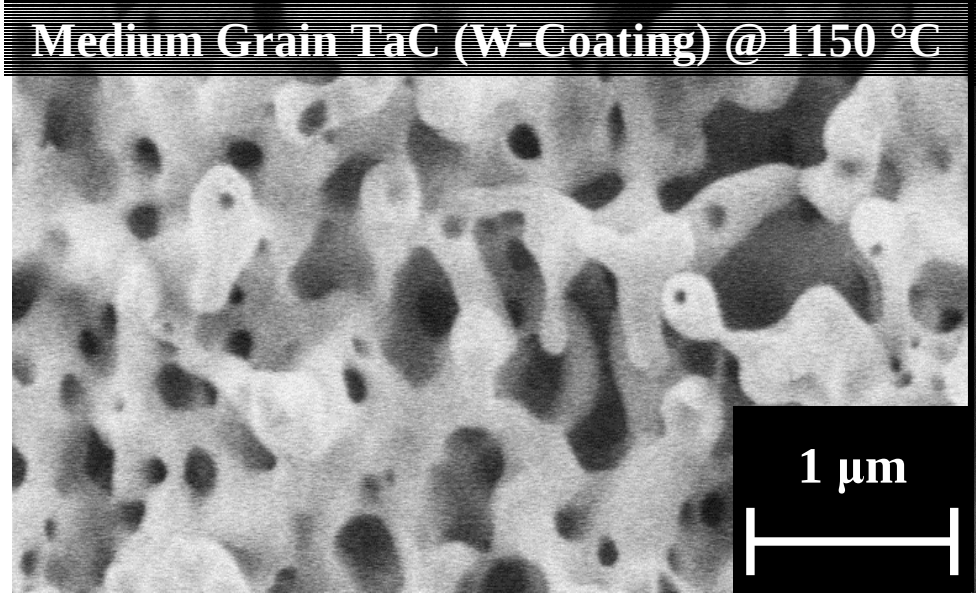
Questions?

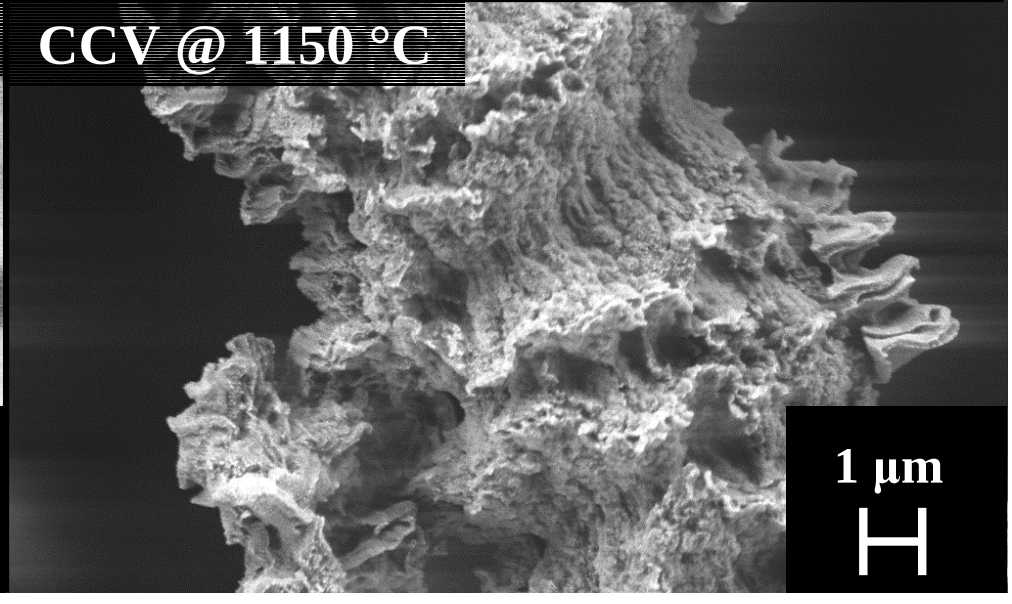


Surface Damage Comparison of W, TaC Foam, SiC, and CCV Samples at $1x10^{19}$ He^{+}/cm^{2}

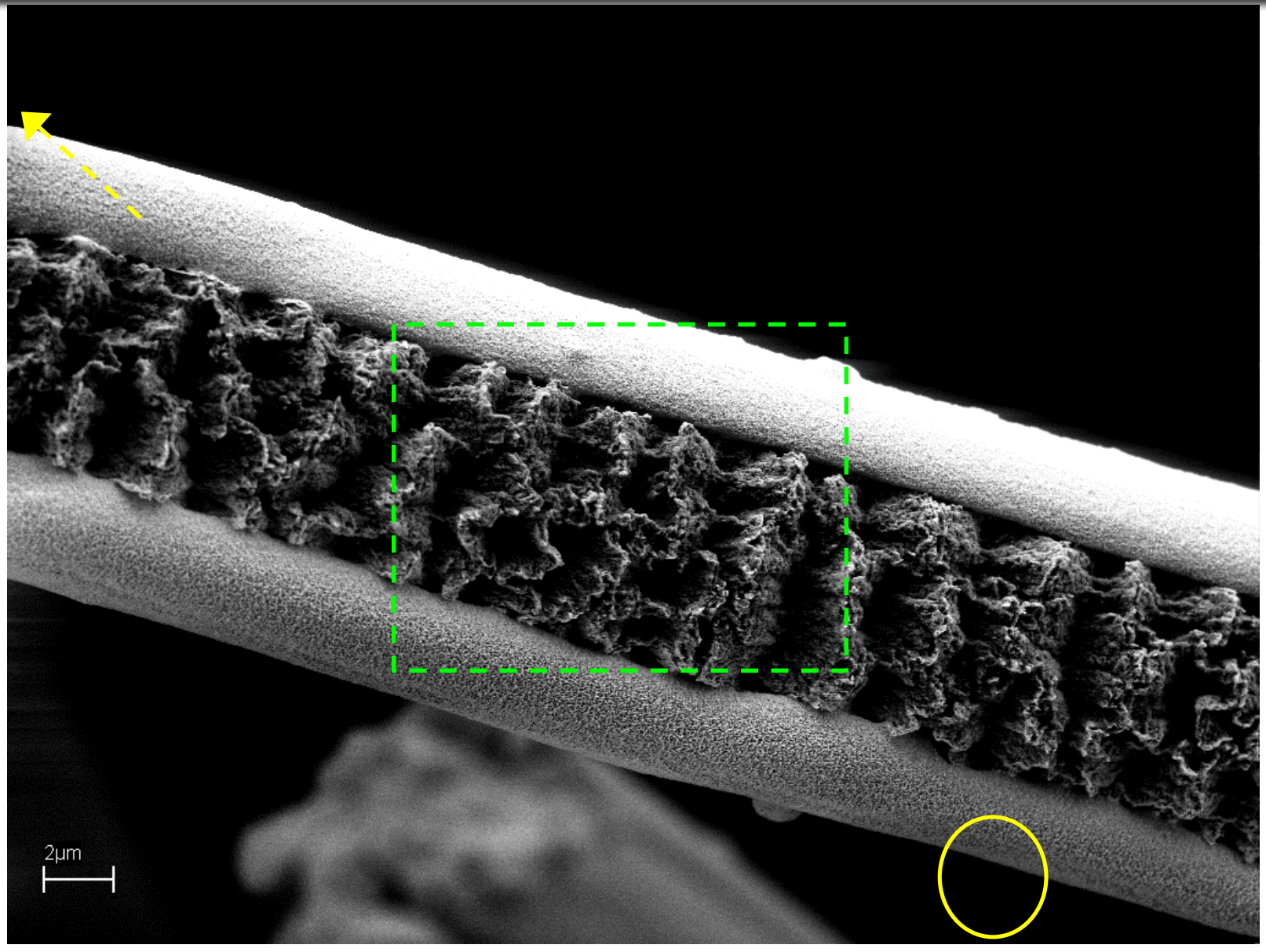




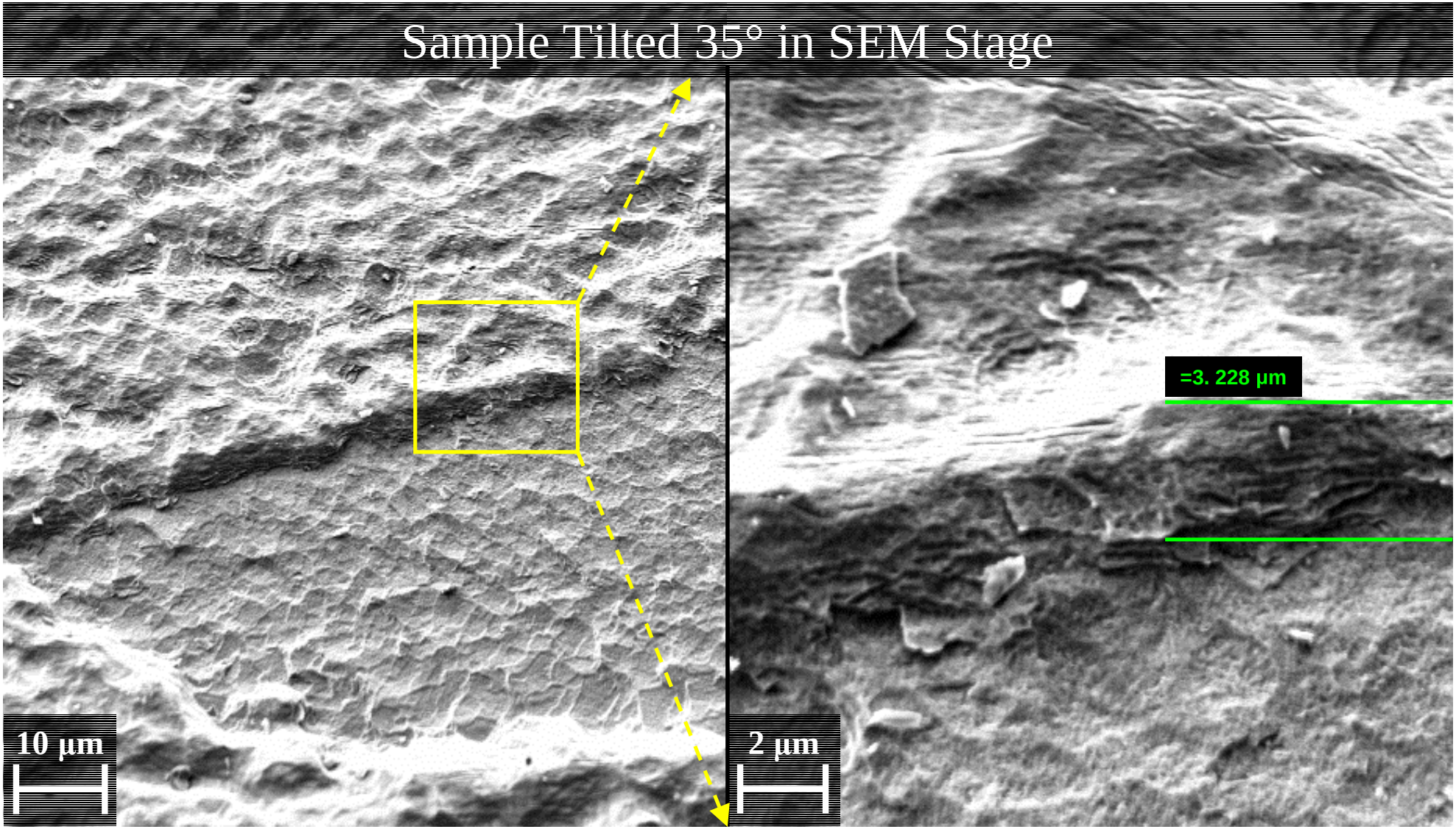




W-Coating Rupturing Occurs on Different Fibers Over the Sample



Irradiated Zone of *Masked* SiC Sample Illustrates the Effects of Repeated Flaking

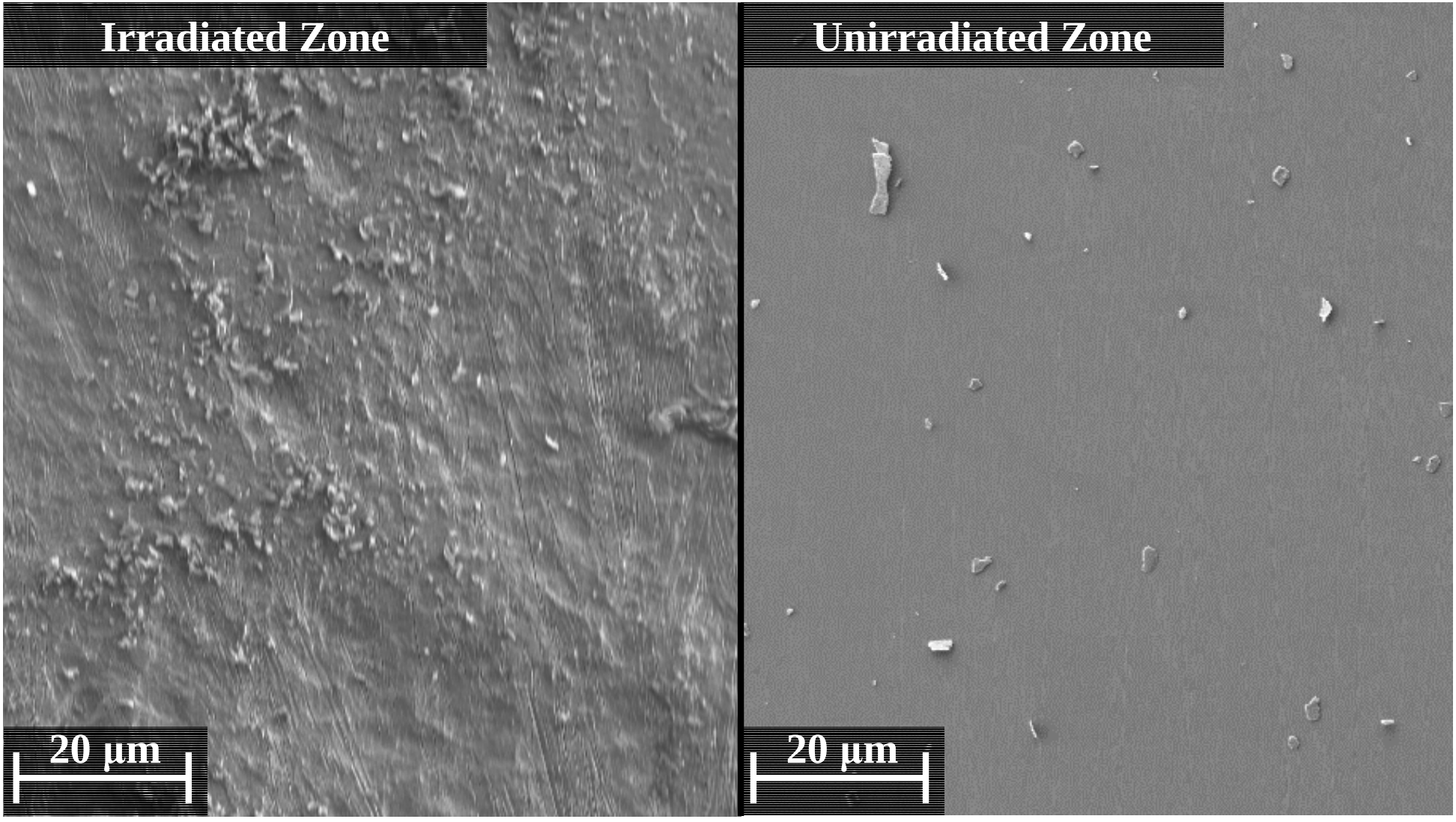


30 kV, 5.5 mA, 950°C, ~1.5x10^{19} He^{+}/cm^{2}, 147 minute runtime

Some Interesting Numbers

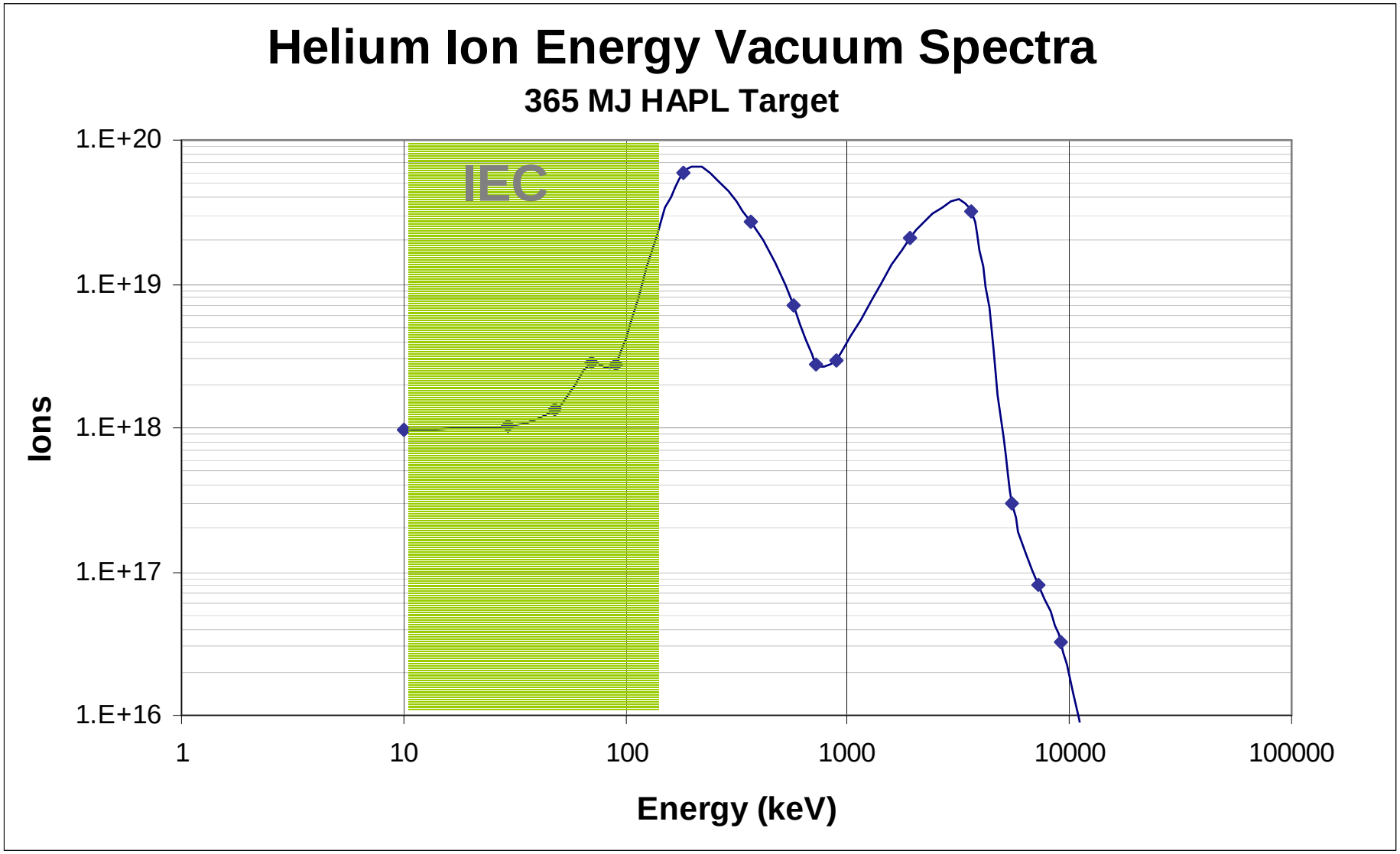
- HAPL total He dose (5 Hz, 10.5 m radius) is ≈ 6 x 10^{12}/cm^2 per pulse (3 x 10^{13}/cm^2s ave.)
- IEC steady state He flux @ 6 mA ≈ 10^{14}/cm^2s
- IEC pulsed instantaneous He flux (10 Hz, 1 ms, 60 mA) ≈ 10^{13}/cm^2 per pulse--->(≈ 10^{16}/cm^2s)

Masked SiC Sample Surface Roughening is Due to Irradiation Not Temperature Exposure

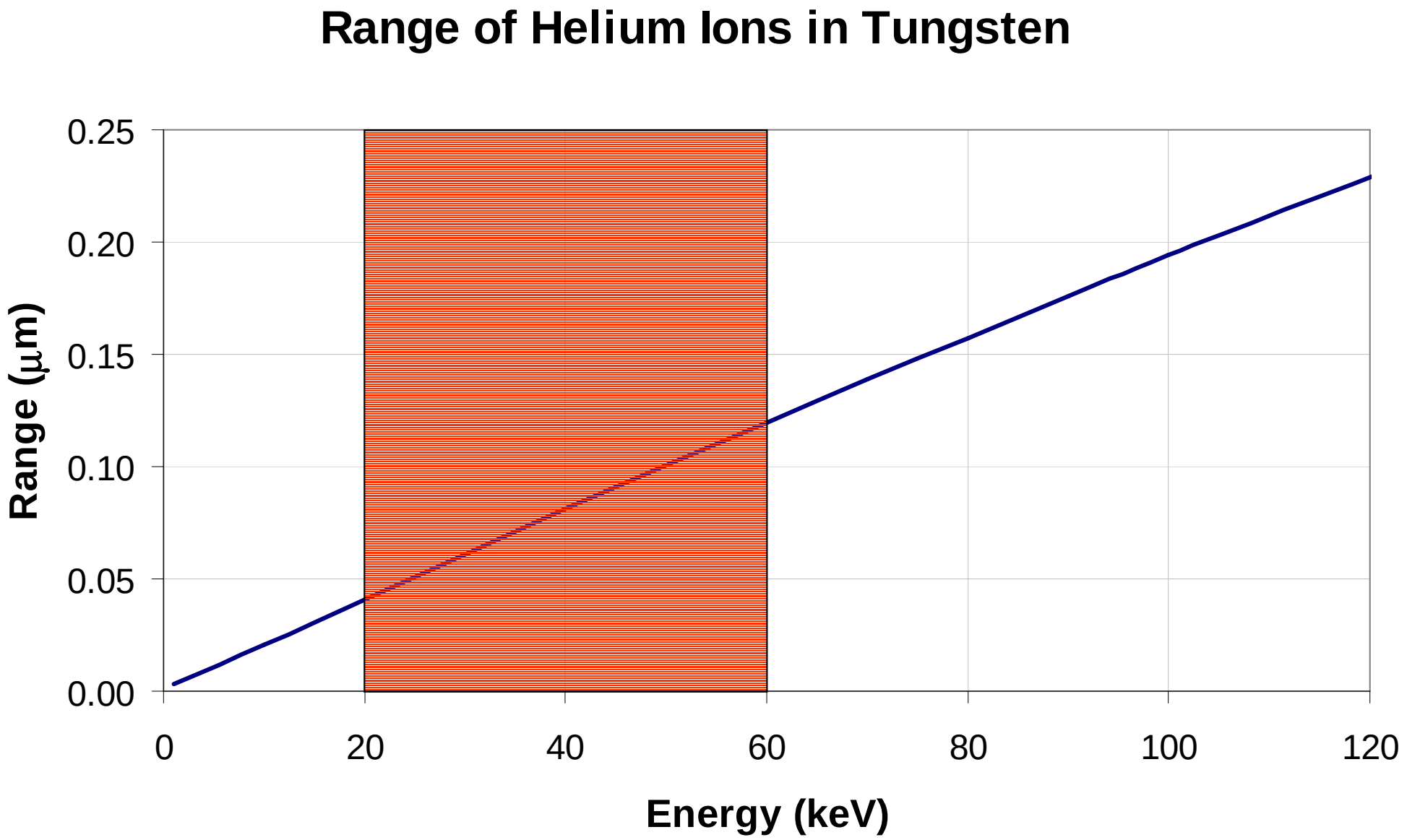


30 kV, 5.5 mA, 950°C, ~1.5x10^{19} He^{+}/cm^{2}, 147 minute runtime

The IEC Voltage Capability Covers Nearly 25% of the Ions at the First Wall



Implantation Covered a Small Range of the Helium Energy Spectrum



IEC Ion Implantation Process