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

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HAPL Meeting-NRL

October 30th, 2007

Fusion Technology Institute

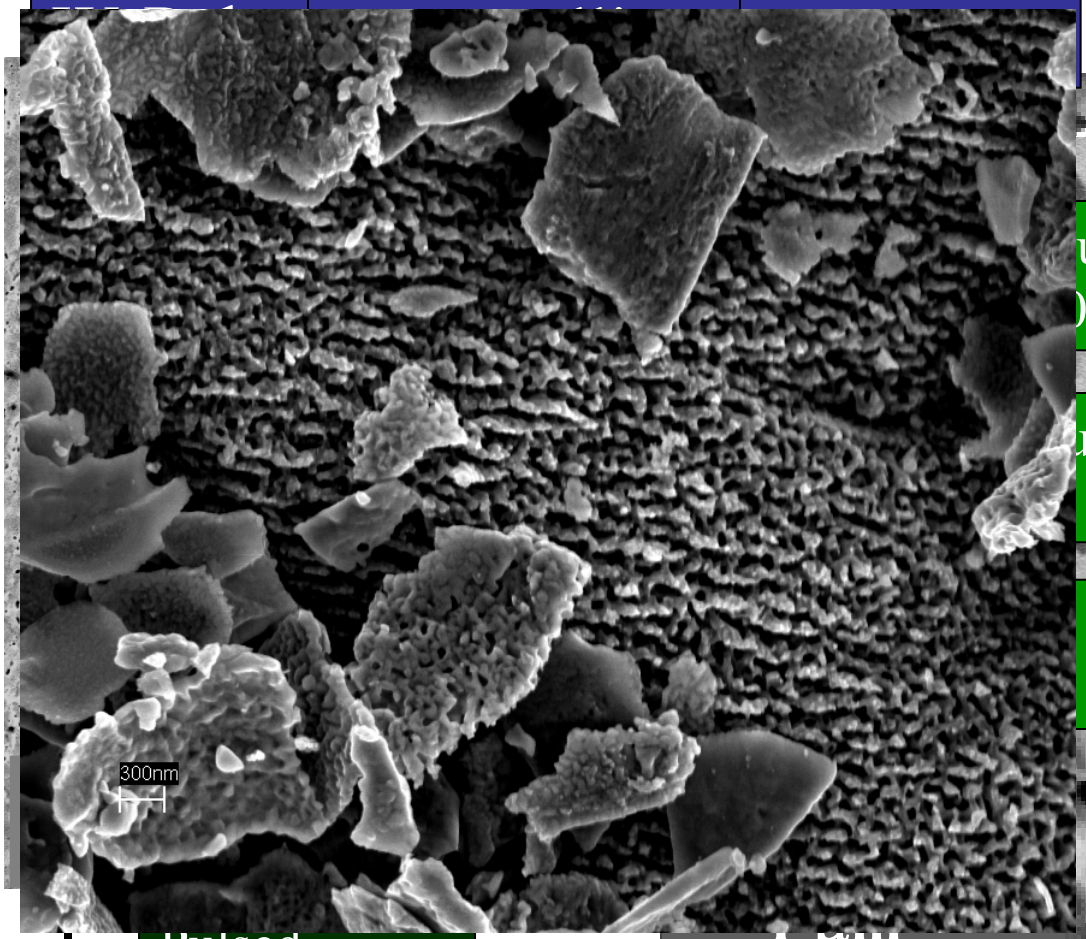
University of Wisconsin-Madison

THE UNIVERSITY of WISCONSIN MADISON

Progress Since Last Meeting

- The majority of the summer's research was spent improving the accuracy and precision of fluence and temperature measurements for irradiation experiments
- Carbon – carbon velvet (CCV) and tungsten-coated carbon-carbon velvet (W/CCV) samples were irradiated in the UW-IEC apparatus ***HELIOS***
- A CCV specimen was irradiated to $5x10^{18}$ He^+/cm^2 at 1150 ºC
- W/CCV specimens were irradiated at 1150 ºC to $1x10^{19}$ D^+/cm^2 and to $5x10^{18}$ ions/cm^2 using He^+ and D^+
- SEM analysis has been performed to evaluate the surface morphology changes on the carbon-carbon velvet specimens from irradiations

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



CVD Si

Carbon Velvet

uence
° C

He^+ Fluence Effect – 750-950 ° C

Masked Sample

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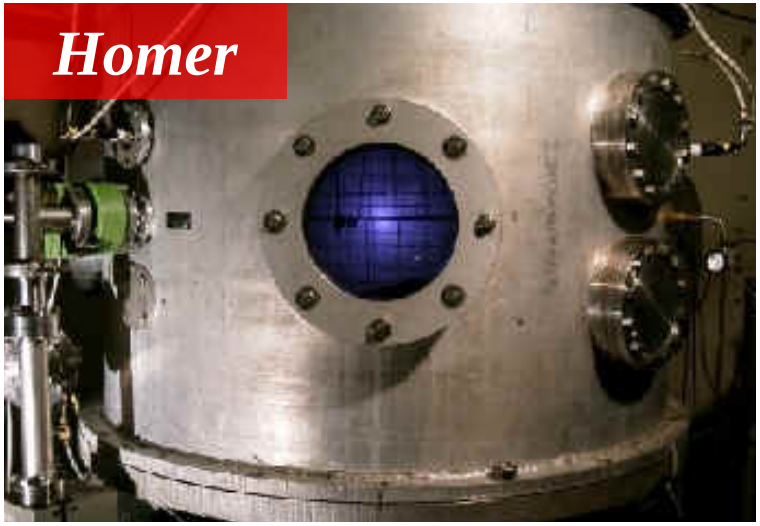
Progress since 12/06

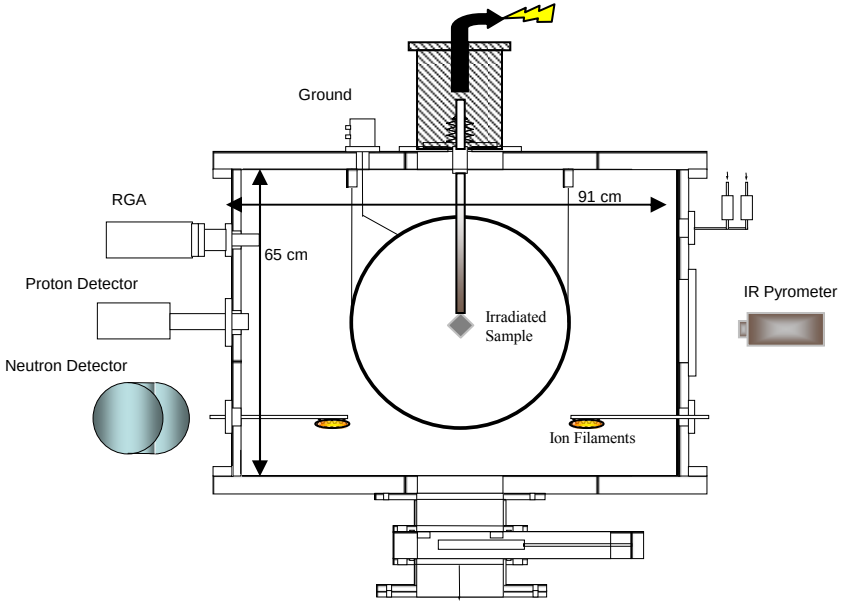
Completed Experiments

Pulsed Irradiation

UW Materials Irradiation Apparatus

Homer





HELIOS

•P

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•N

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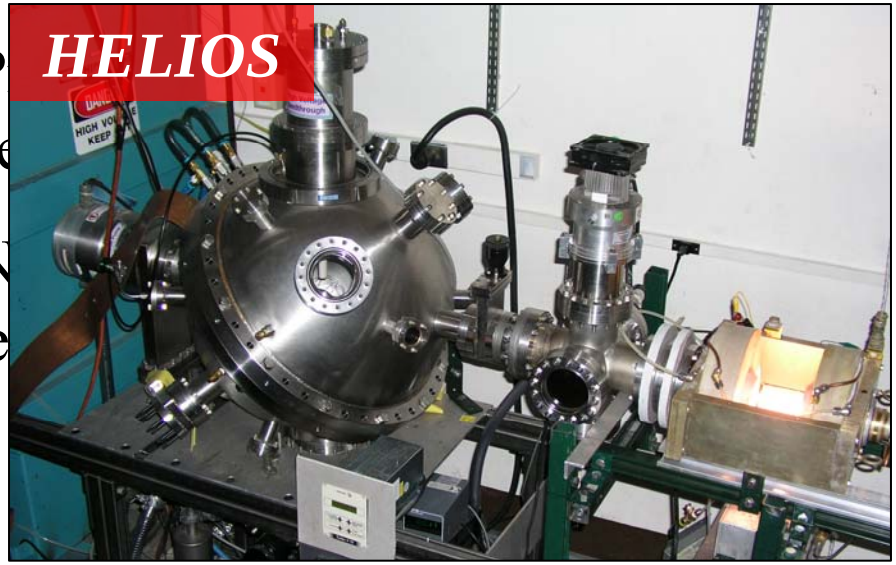
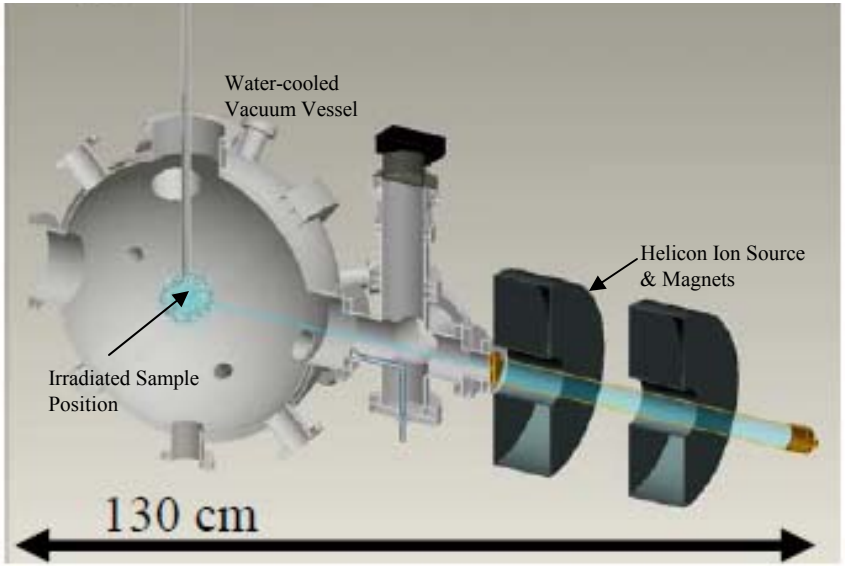
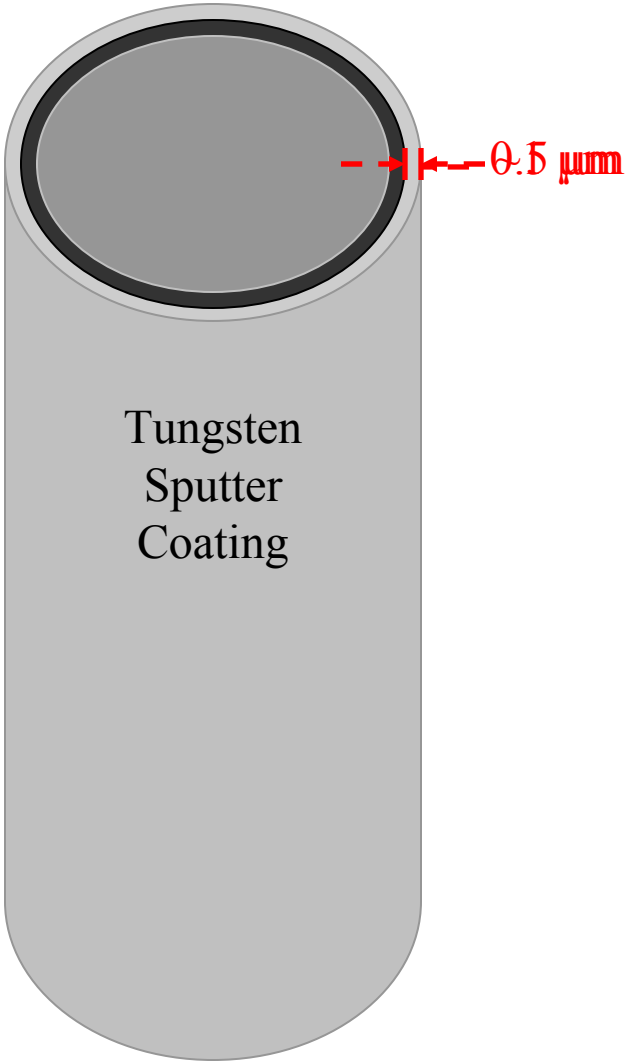


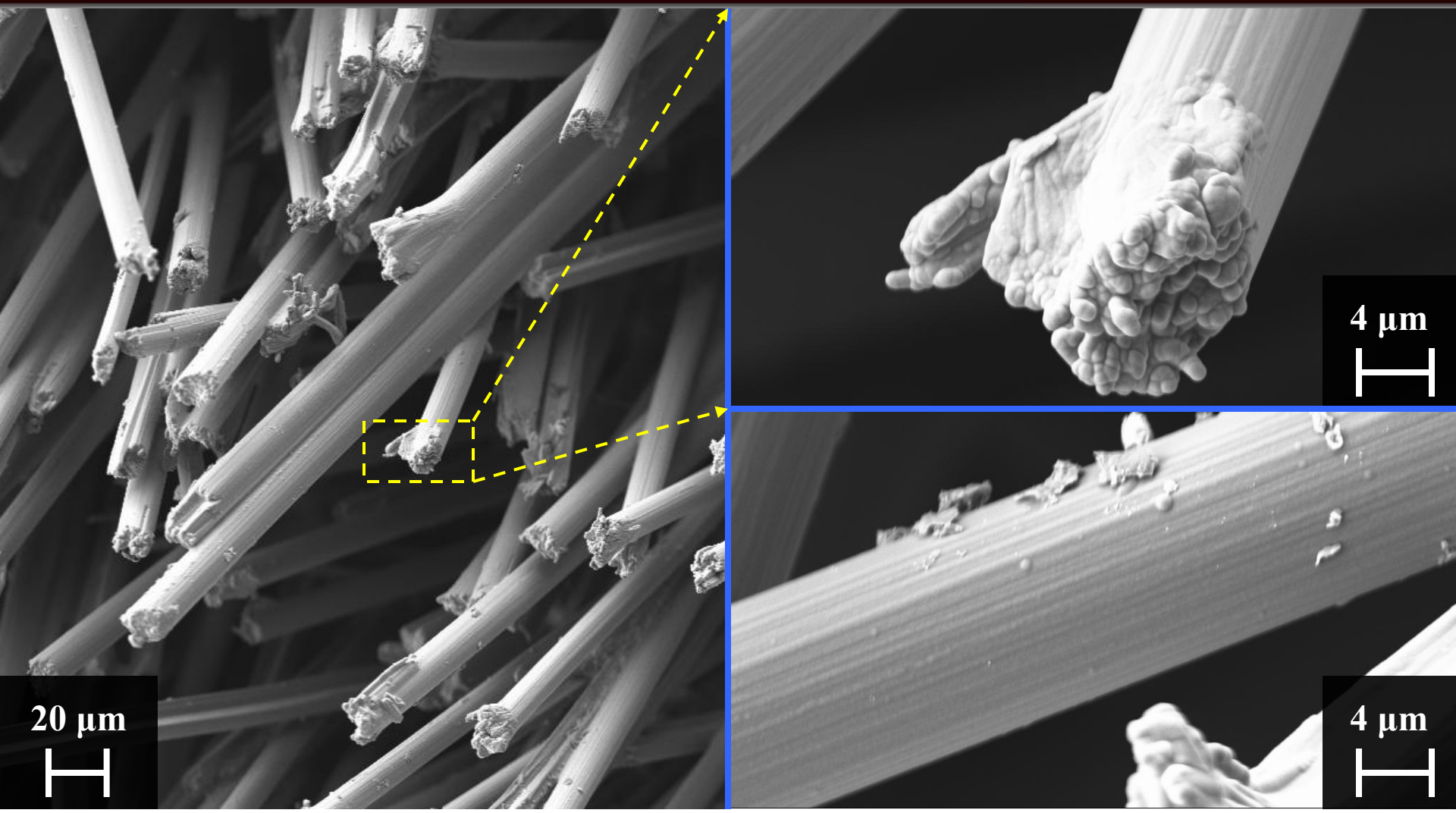


Fiber Composition of CCV and W/CCV

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



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

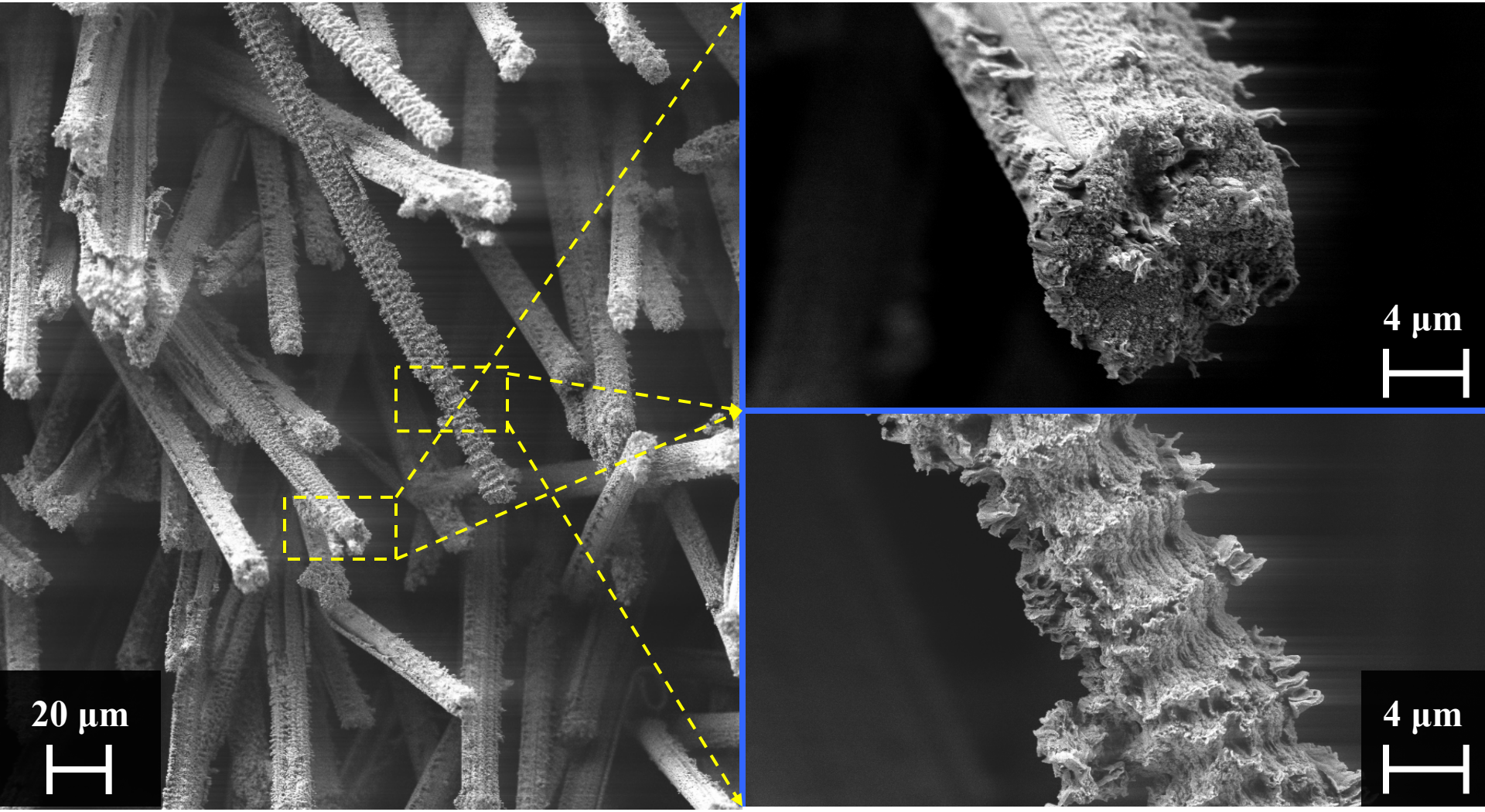


Unirradiated CCV

CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

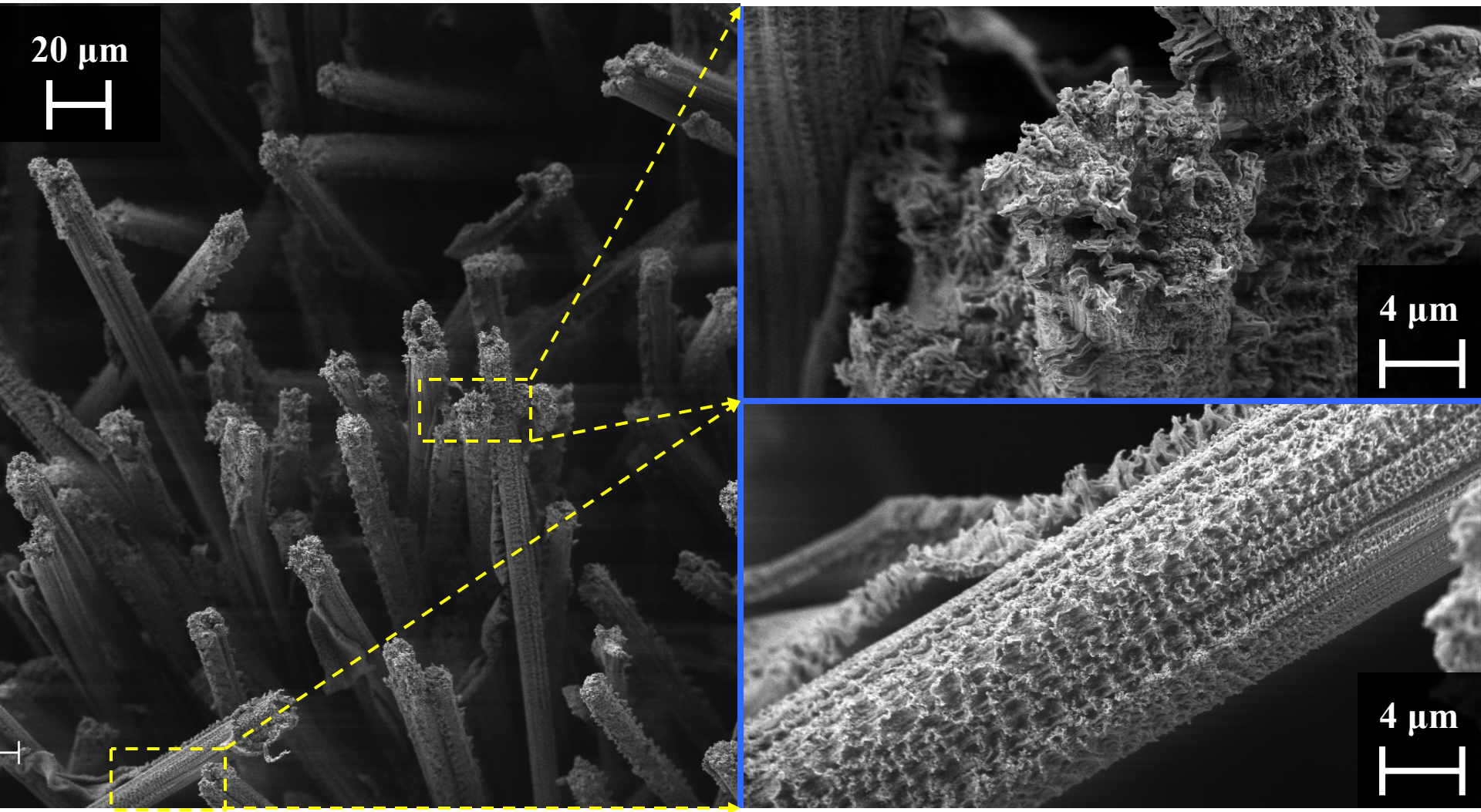
	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+	CCV	CCV
D^+	No data at this time	CCV

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



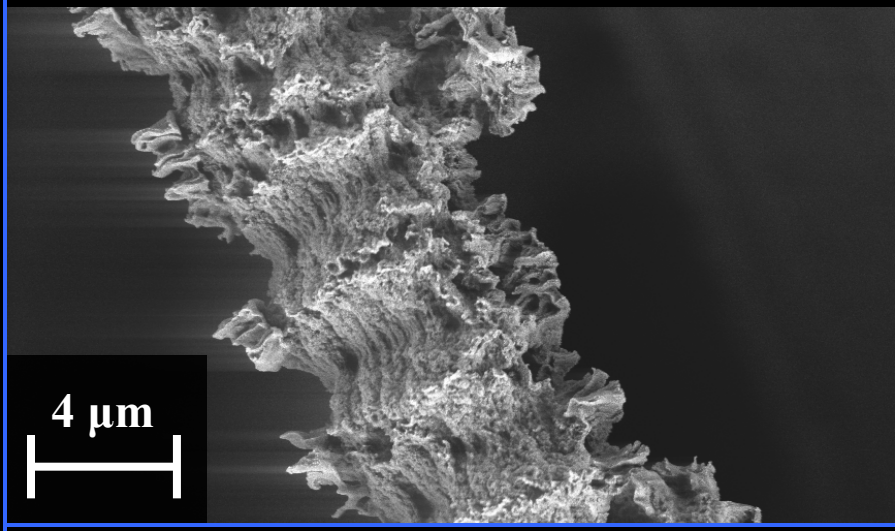
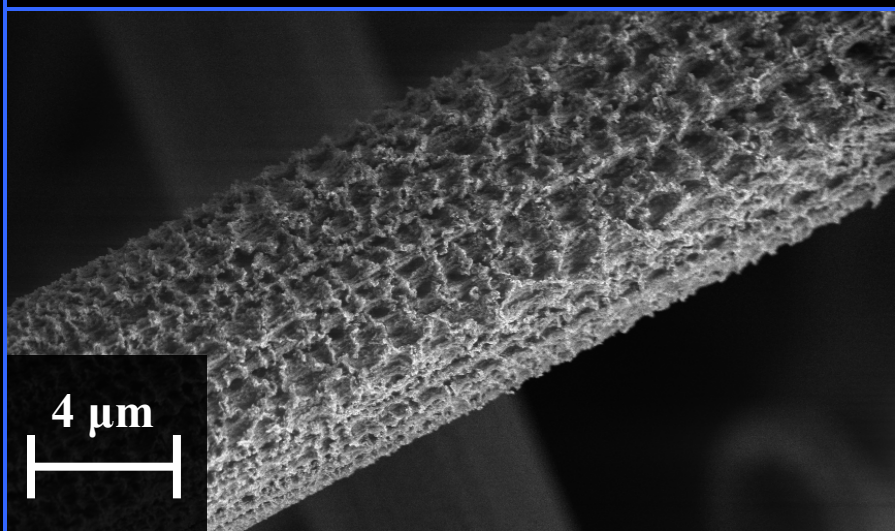
T ~ 1150 °C, φ ~ 10^{19} He^{+}/cm^{2}, V ~ 30 kV

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

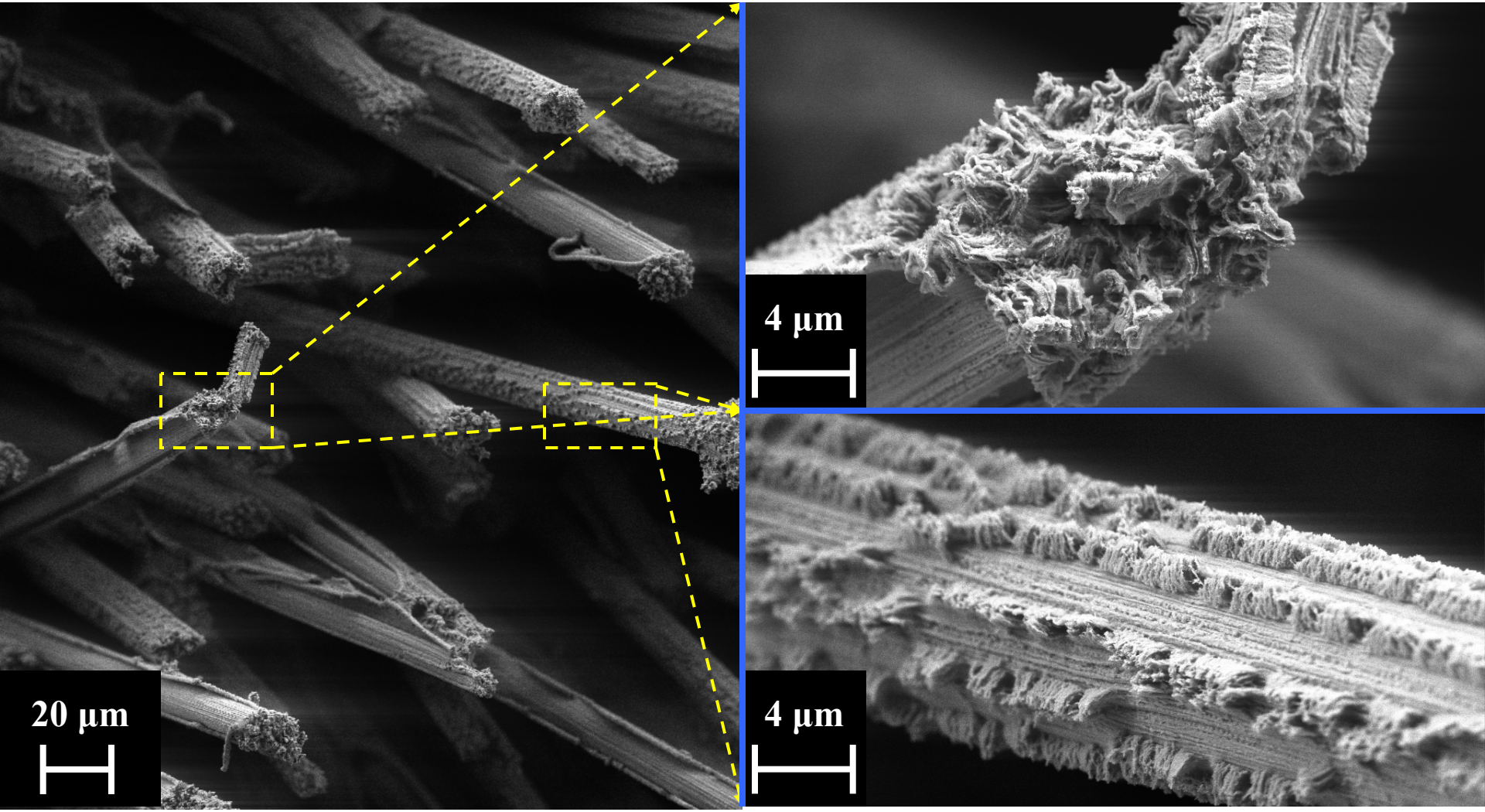


T ~ 1150 °C, φ ~ 10^{19} D^+/cm^2, V ~ 30 kV

CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

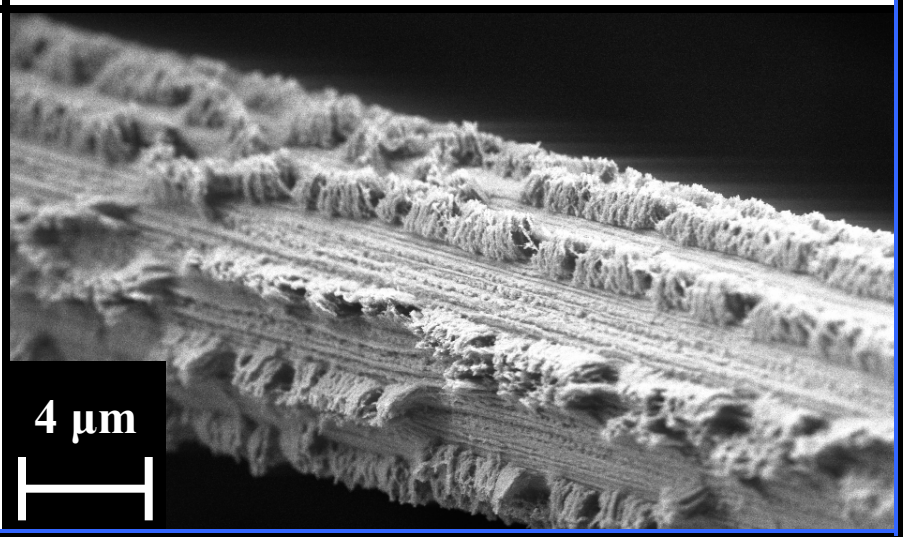
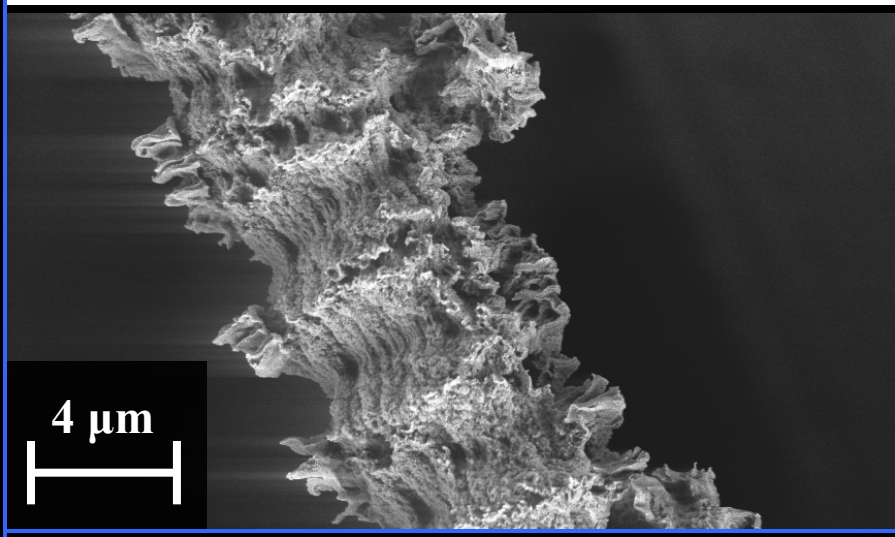
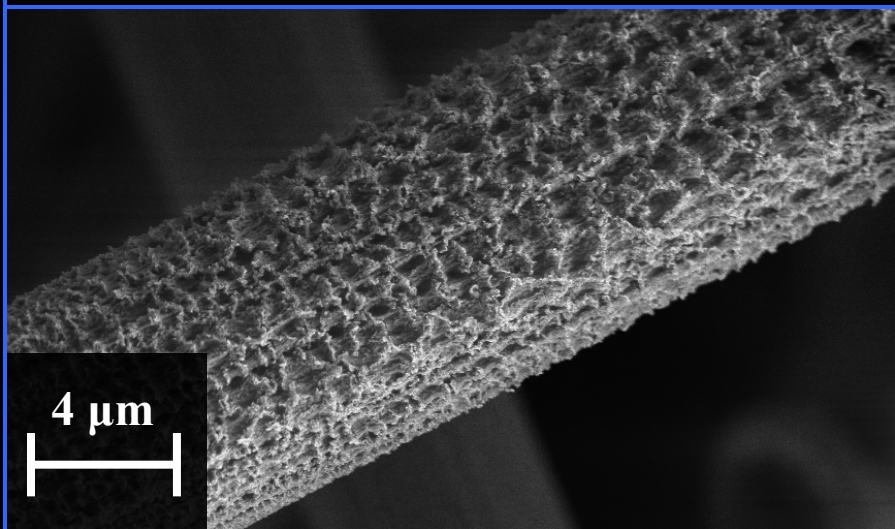
	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+	CCV	
D^+	No data at this time	

Irradiation of CCV to $5x10^{18}$ He^+/cm^2 Results in Erosion of Pyrolitic Carbon Coating and Shaft Striation



T ~ 1150 °C, φ ~ $5x10^{18}$ He^+/cm^2, V ~ 30 kV

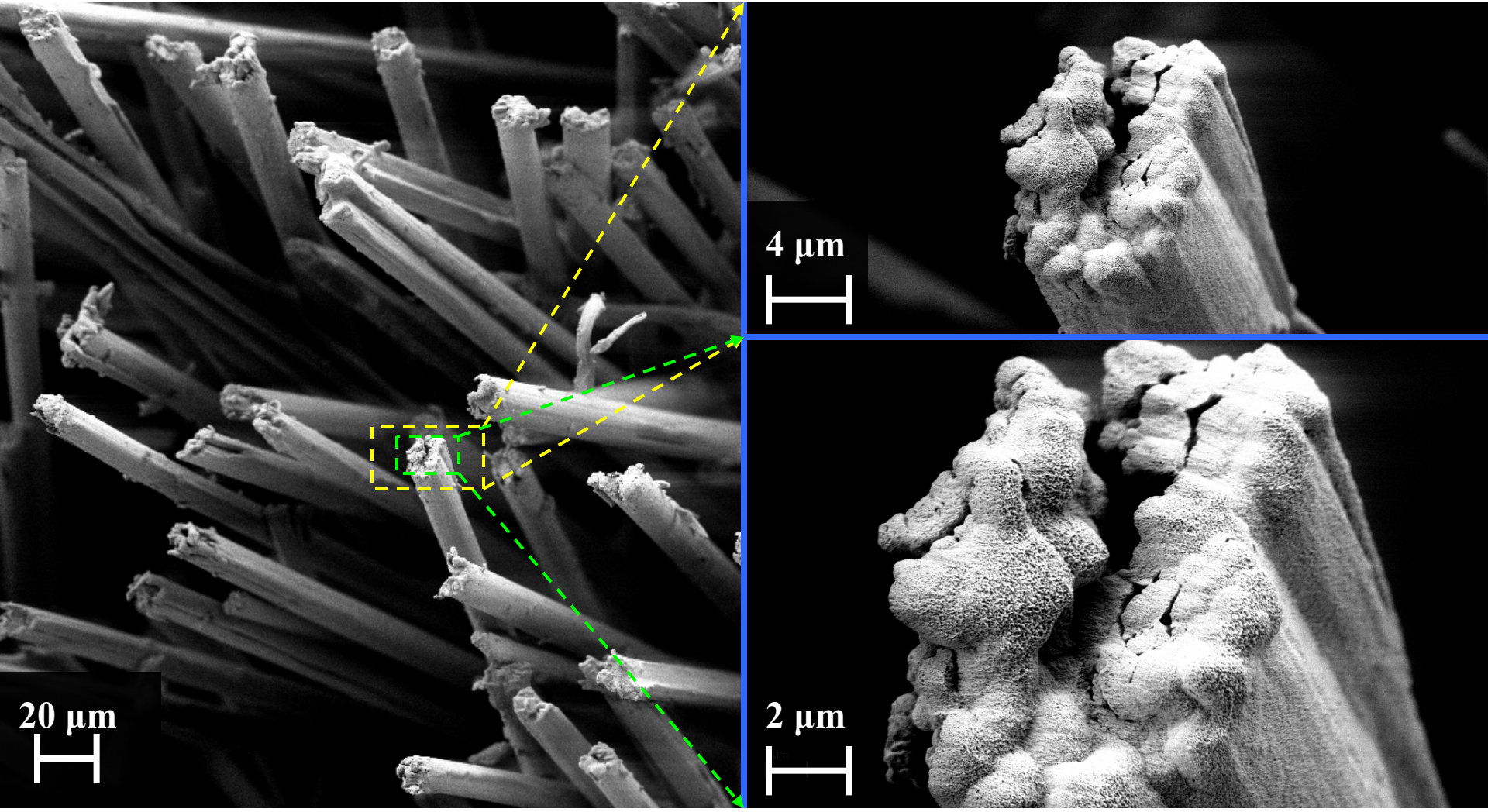
CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+		
D^+	No data at this time	

W/CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

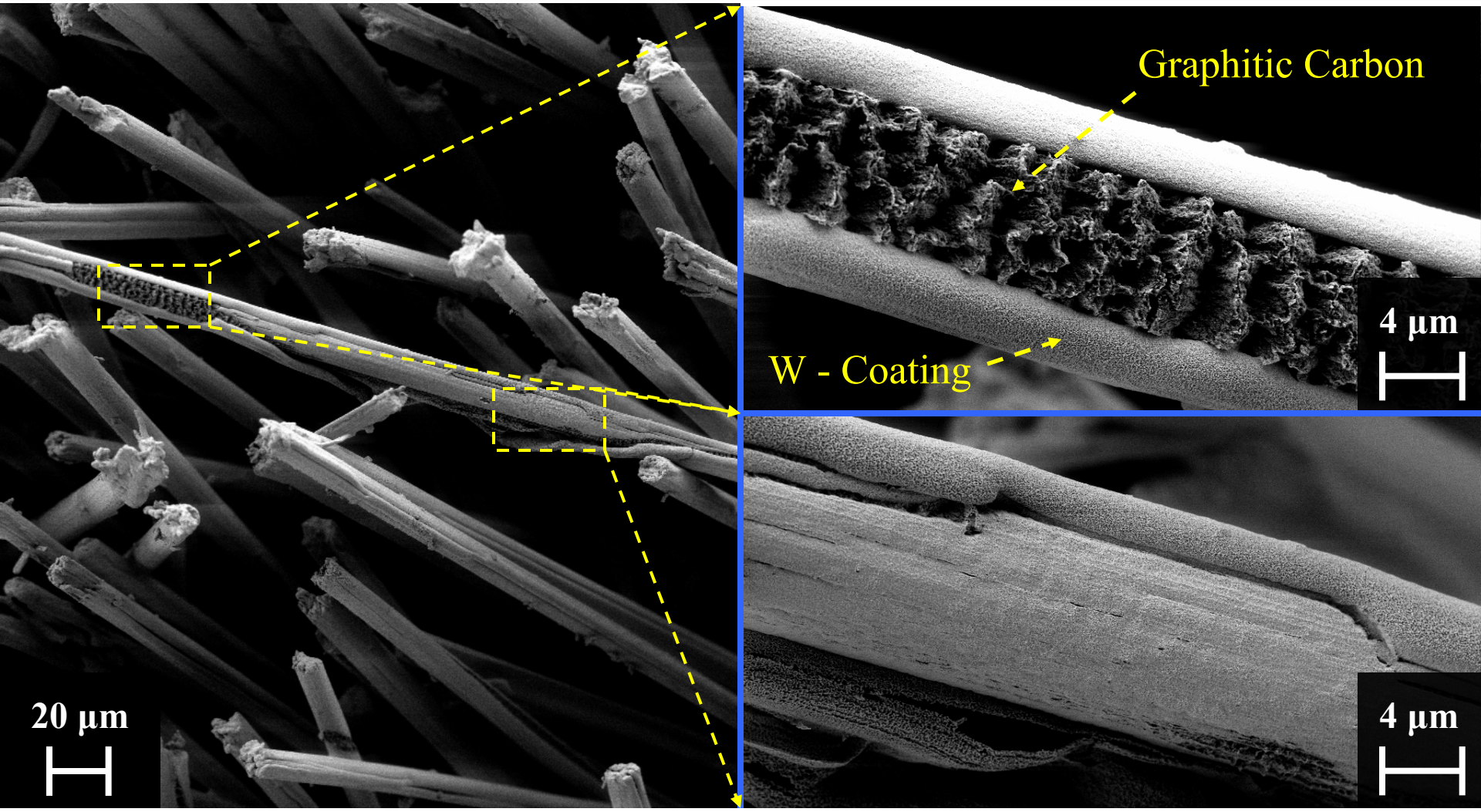
	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+	W/CCV	W/CCV
D^+	W/CCV	W/CCV

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



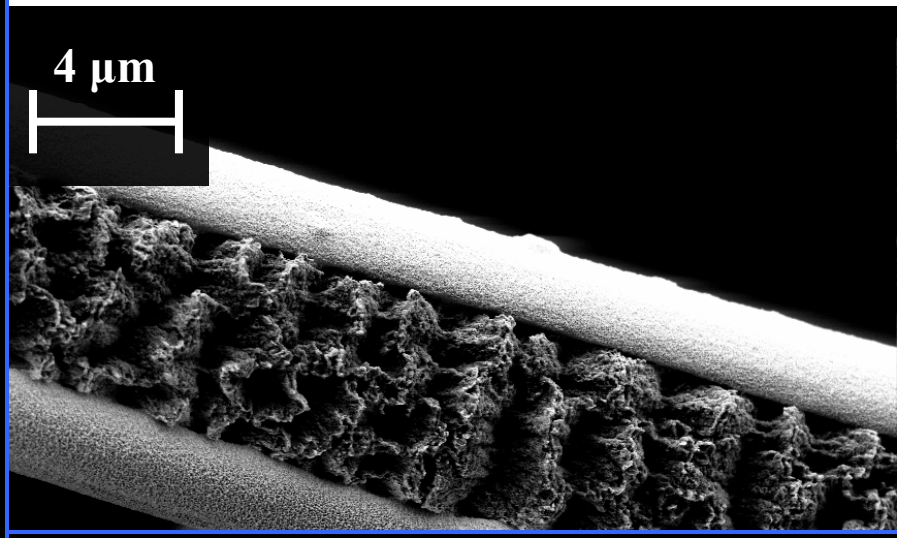
T ~ 1150 °C, φ ~ 10^{19} He^{+}/cm^{2}, V ~ 30 kV

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

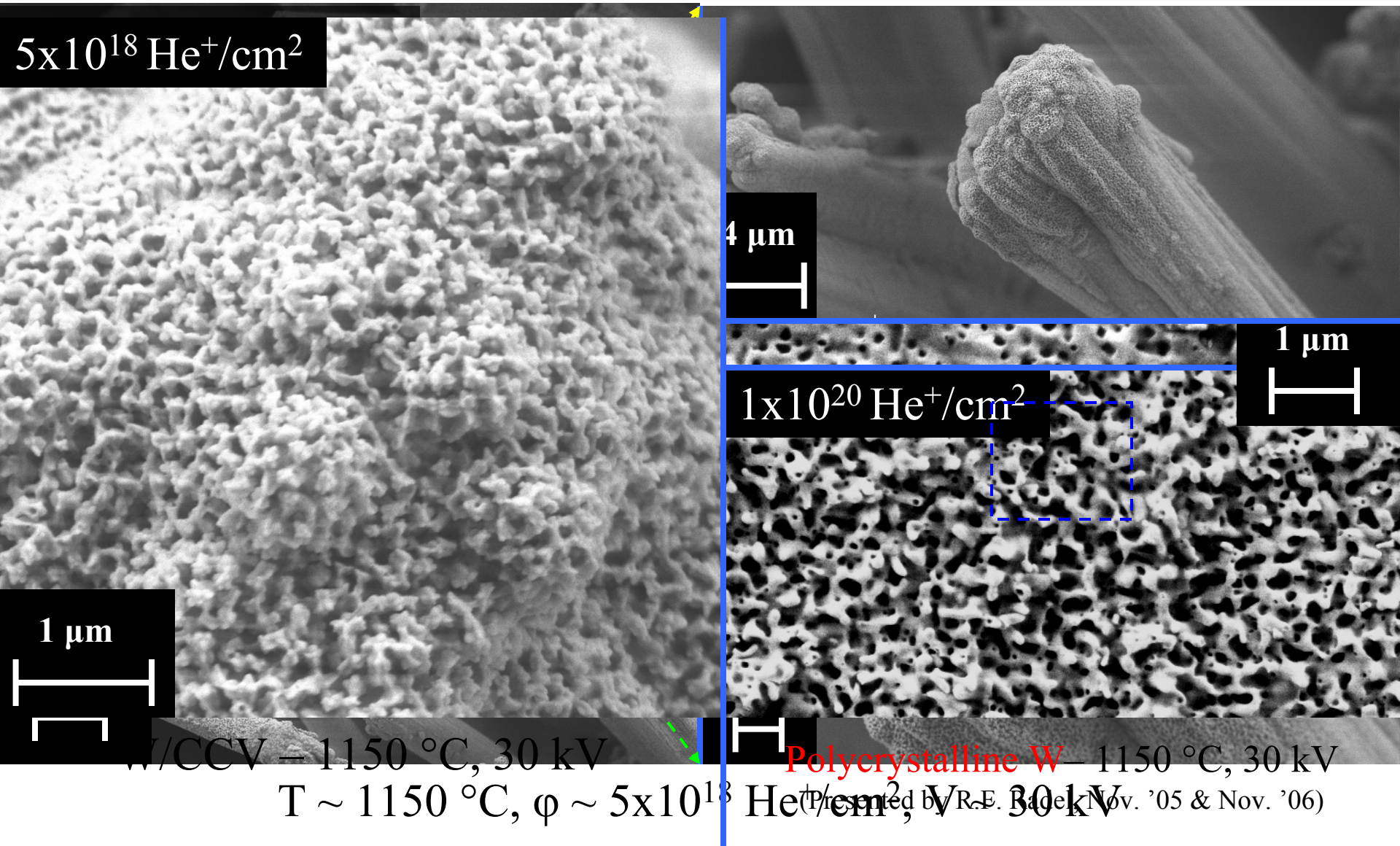


T ~ 1150 °C, φ ~ 10^{19} He^+/cm^2, V ~ 30 kV

W/CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

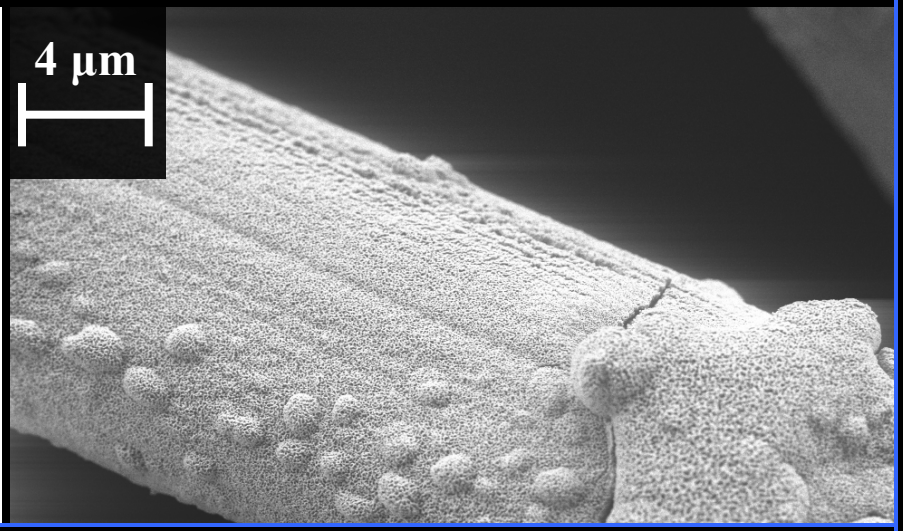
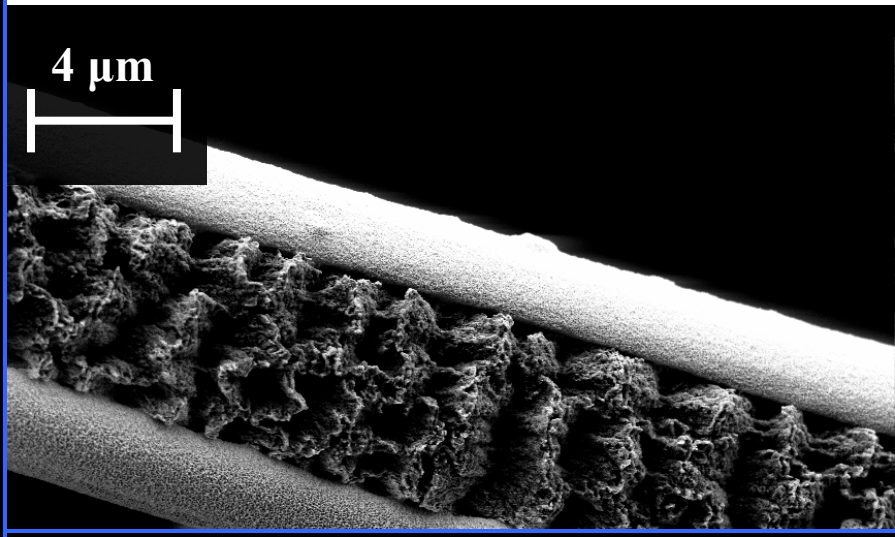
	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+	W/CCV	
D^+	W/CCV	W/CCV

Irradiation of W/CCV and Polycrystalline W Exhibit Similar Responses to He+ Implantation

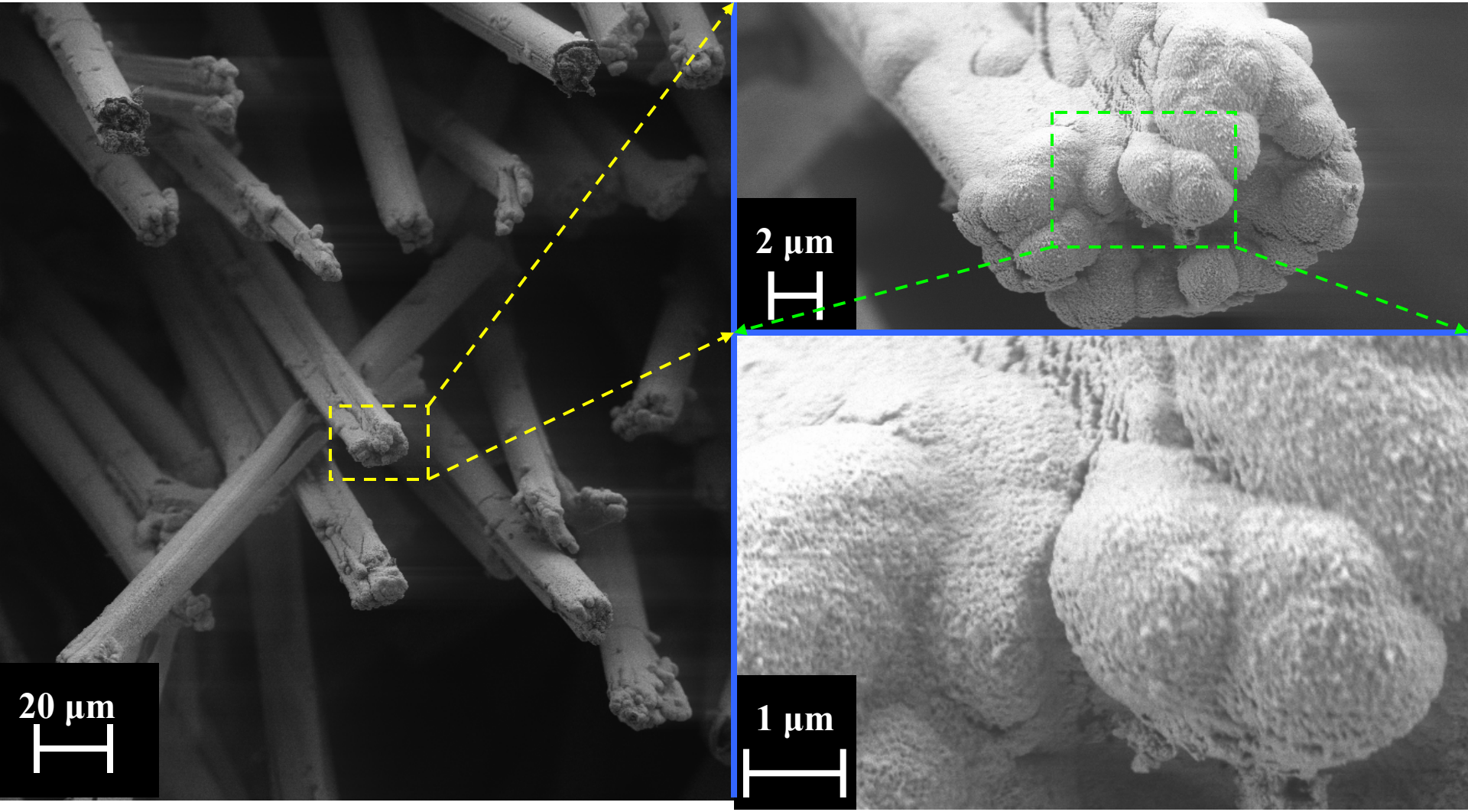


(Presented by R.E. Nygren, Nov. '05 & Nov. '06)

W/CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

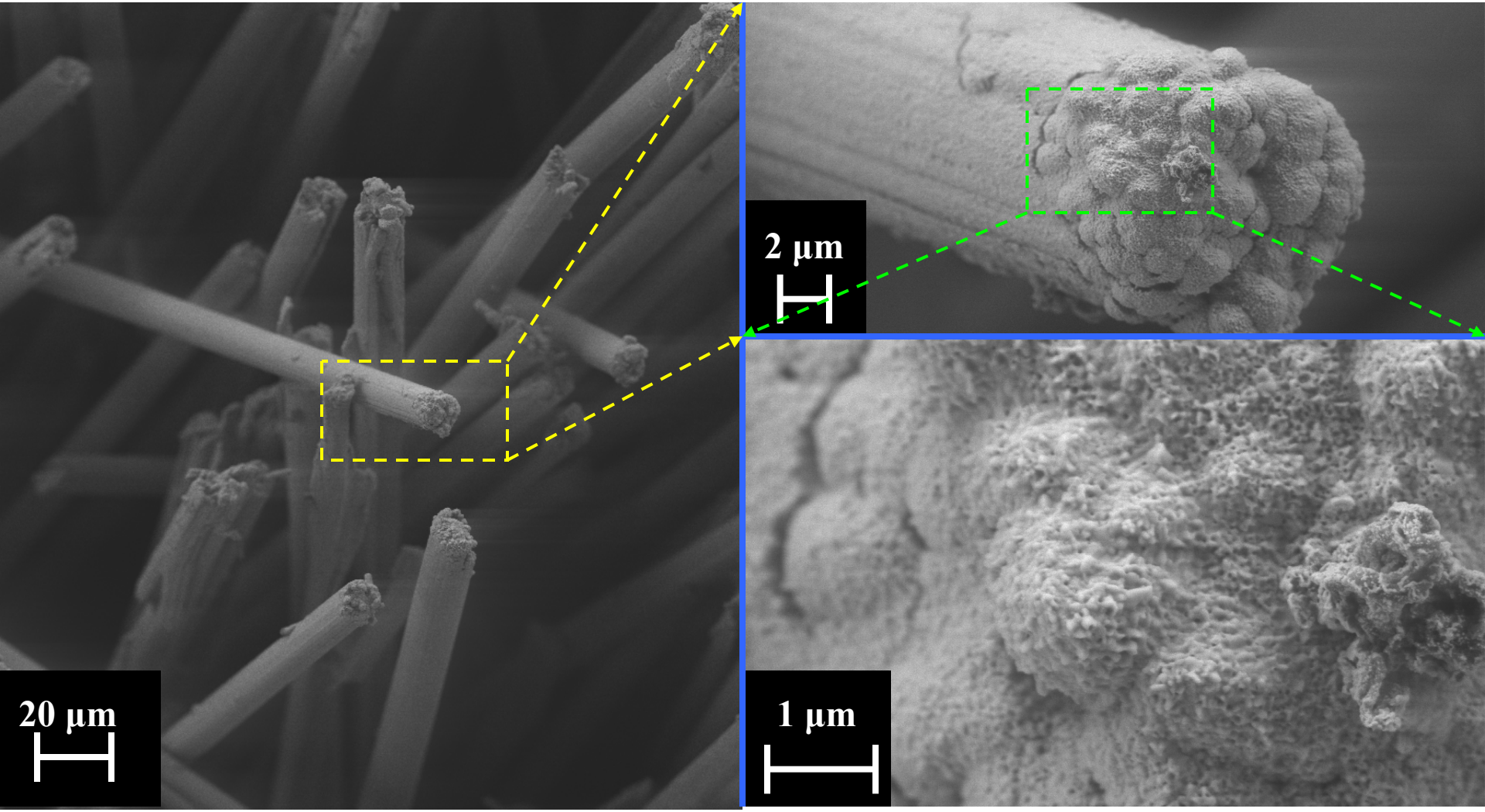
	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+		
D^+	W/CCV	W/CCV

Modest Surface Roughening Occurs on W-Coating after Irradiation of W/CCV to $5x10^{18}$ D^+/cm^2



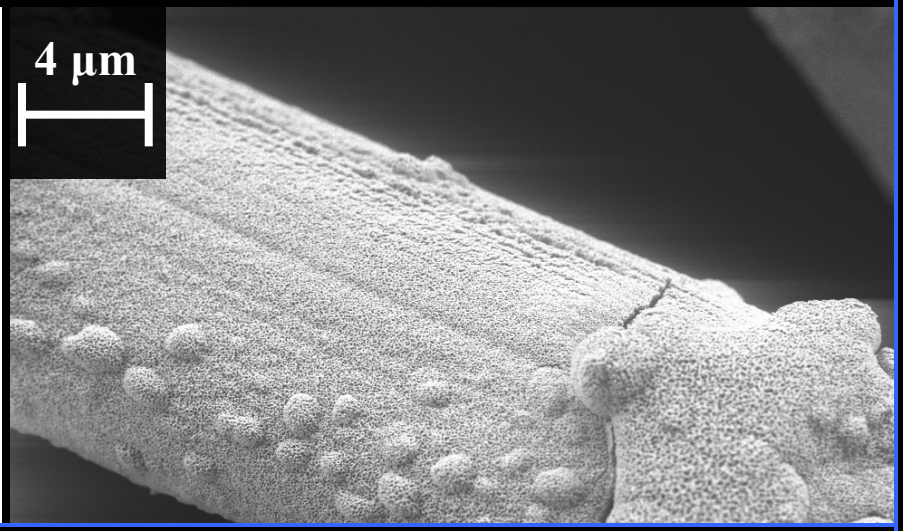
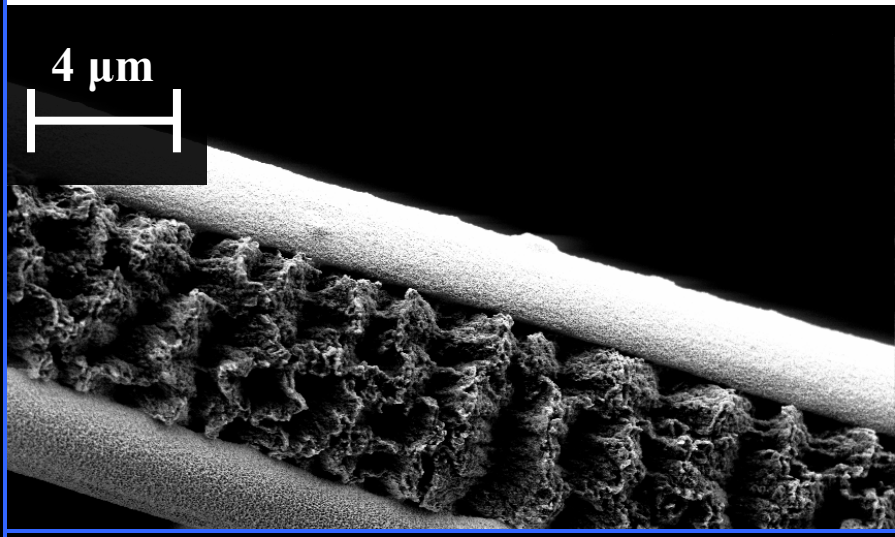
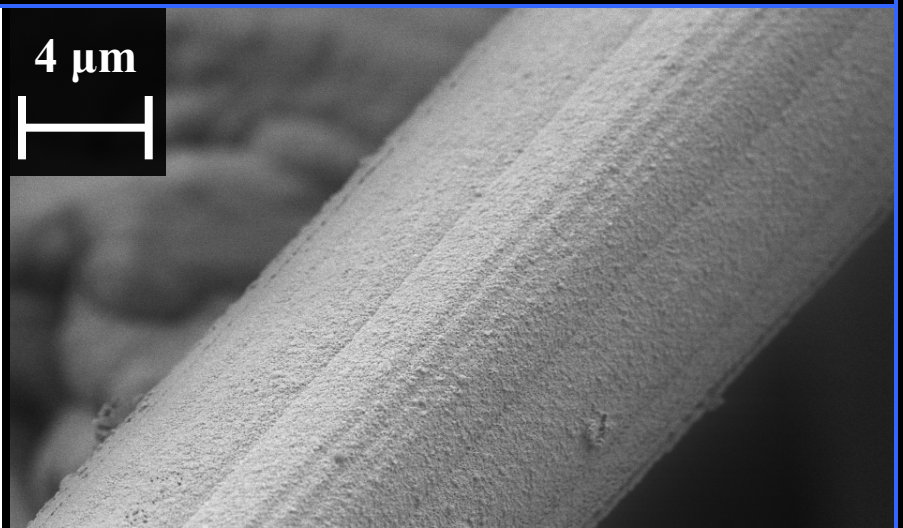
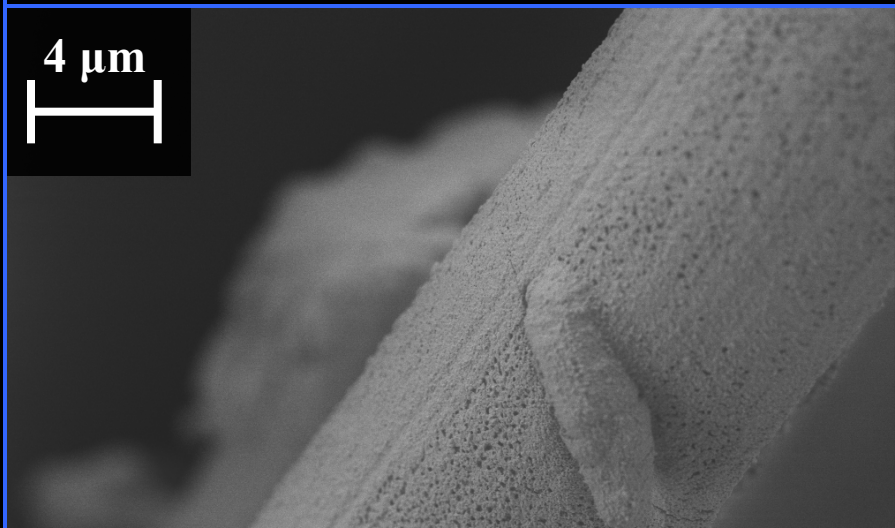
T ~ 1150 °C, φ ~ $5x10^{18}$ D^+/cm^2, V ~ 30 kV

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



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

W/CCV Steady-State Implantation Summary @ 1150 ºC, 30 kV

	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+		
D^+		

CCV & *W/CCV* Steady-State Implantation Summary @ 1150 ºC, 30 kV

	$5x10^{18}$ ions/cm^2	10^{19} ions/cm^2
He^+	**CCV** / **W/CCV**	**CCV** / **W/CCV**
D^+	**No Data** / **W/CCV**	**CCV** / **W/CCV**

Tentative Conclusions @ 1150 °C

- He^+ and D^+ irradiation of CCV results in significant fiber shaft roughening and erosion and appears to remove the pyrolitic carbon coating on individual fibers
- He^+ irradiated CCV samples consistently sustain more damage than the CCV specimen irradiated with D^+
- W/CCV specimens undergo extensive W-coating rupturing during He^+ and D^+ irradiation
- W-coated CCV samples sustain less surface roughening than uncoated CCV after D^+ irradiation
- He^+ irradiated W/CCV samples exhibit similar surface morphology changes to that of polycrystalline W

Conclusion:

- We are not optimistic that CCV or W/CCV will survive the required length of time in the unprotected reference HAPL chamber (300 FPD)

Possible Future Work

- Investigate the possibility of irradiating tungsten with high energy carbon ions
- Examine the effect of He^+ and D^+ implantation on tungsten-carbide armor
- Search for a 1^{st} wall armor with morphology change threshold greater than 10^{18} He^+/cm^2

Questions?