Effects of Pulsed He^+ Irradiation on Tungsten Surfaces

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Progress Since Last Meeting

- Pulsed helium source was used to irradiate tungsten samples at 1150 °C to $1x10^{19}$, $6x10^{18}$, and $1x10^{18}$ He^{+}/cm^{2}
- FIB and SEM analysis has been performed to evaluate pulsed surface damage relative to previous experiments
- SiC samples have been received from ORNL
- Paper was submitted to *Journal of Nuclear Materials:*
  - R.F. Radel and G.L. Kulcinski. "Implantation of He^{+} in Candidate Fusion First Wall Materials" (presented at ICFRM-12 conference)

The Campaign to Assess Ability of W Coatings to Operate in HAPL Environment is Proceeding

Polycrystalline

- He^+& D^+ Fluence Effect – 800-1200 ° C
- Temperature and Voltage Effects
- Simultaneous He^+ & D^+
- Helium Retention
- W-Re Alloy
- Pulsed Irradiation

Metallic Foams

- Large, medium, & small grain size W on TaC – (He^+) 800-1200 °C
- Large, medium, & small grain size W on TaC – (D^+) 800 °C
- Medium grain size W on HfC (He^+ & D^+) – 800-1200 °C

Single Crystal

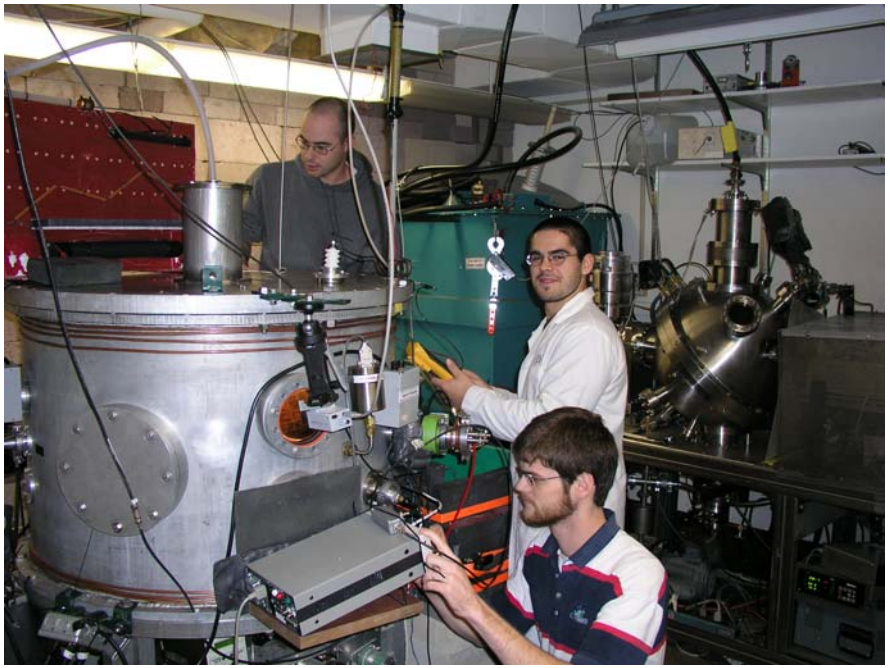
- He^+& D^+ Fluence Effect – 800 ° C
- Simultaneous He^+ & D^+
- Helium Retention

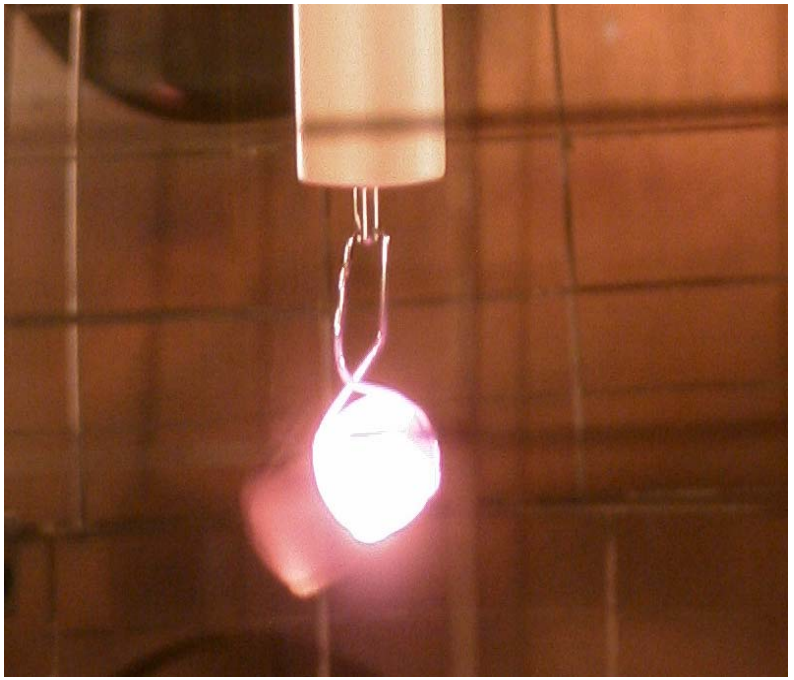
Completed

In progress

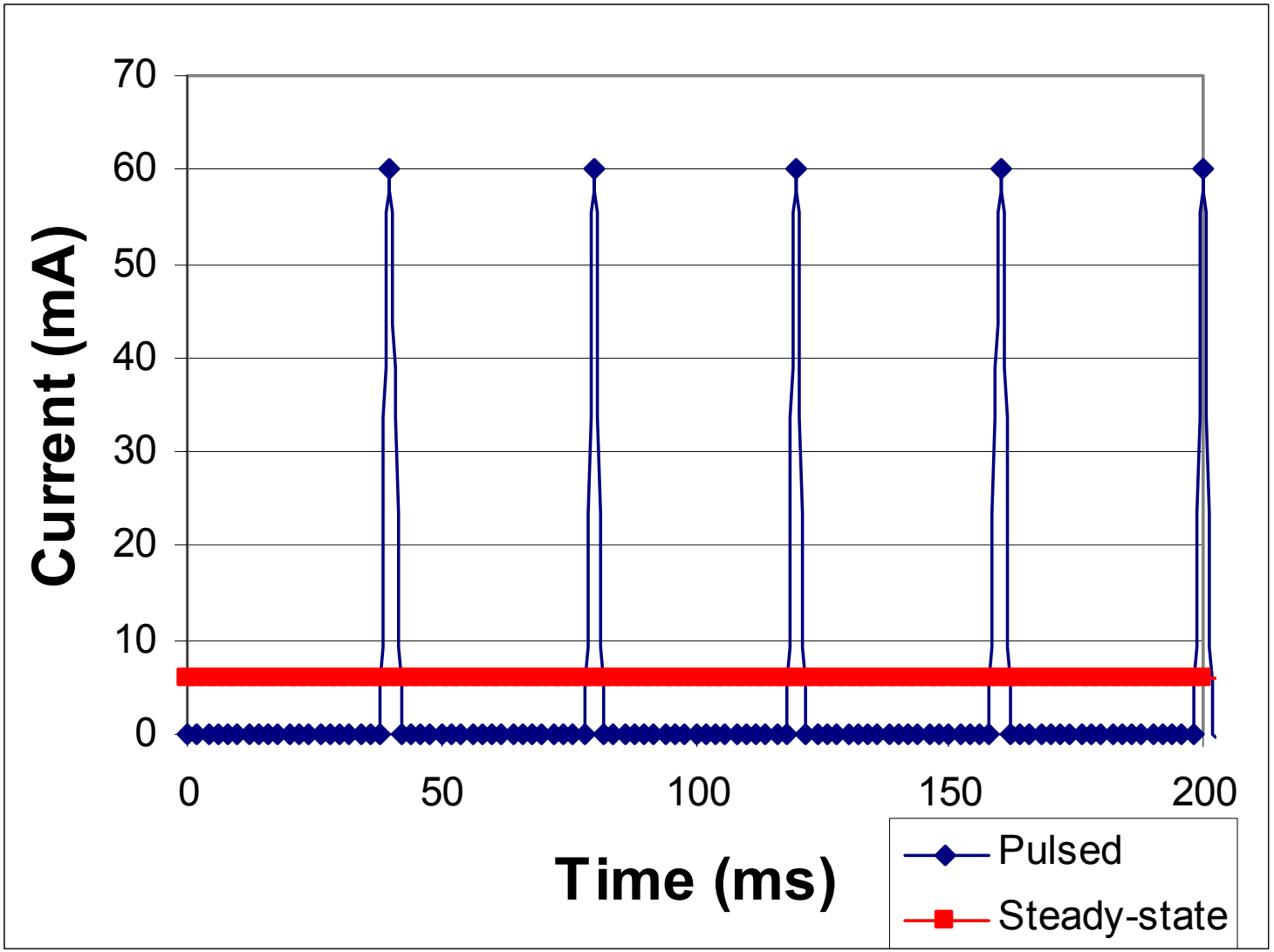
New Design Allows Pulsed IEC Operation

- Currently able to pulse up to 110 kV
- Operation has been performed with pulses as short as 100 μs
- Capable of running D_2 and He fuel gas

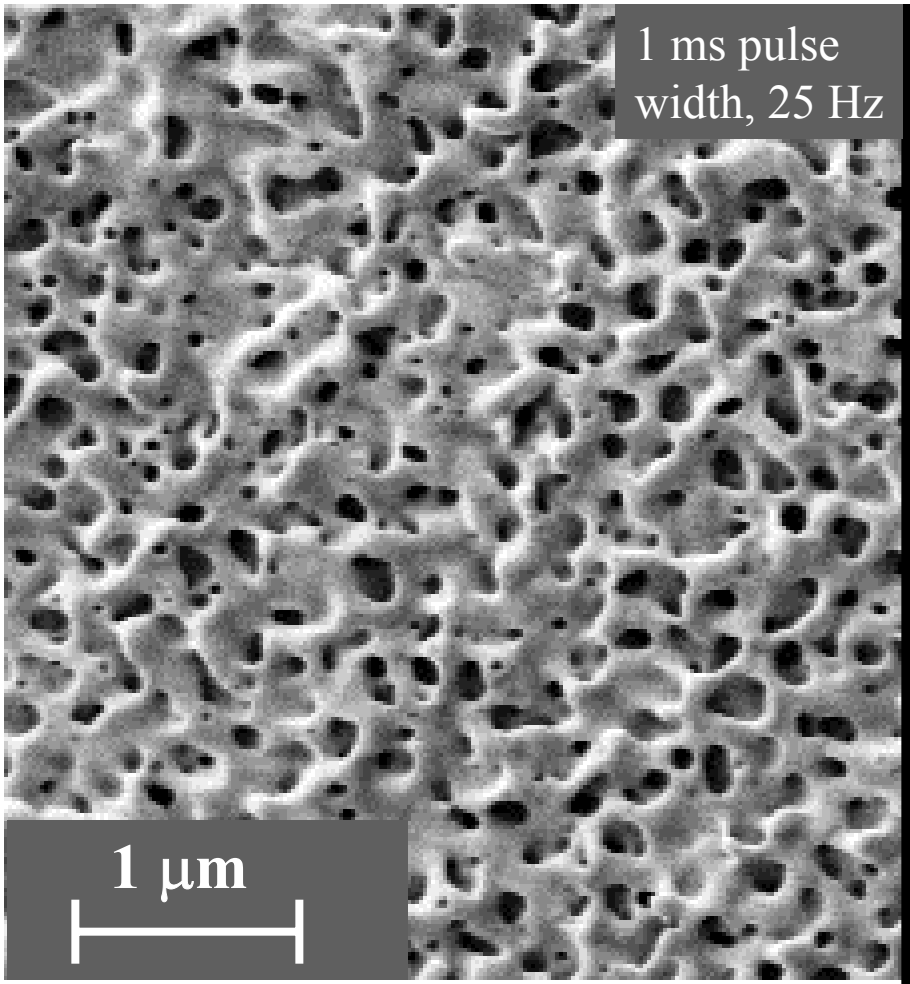




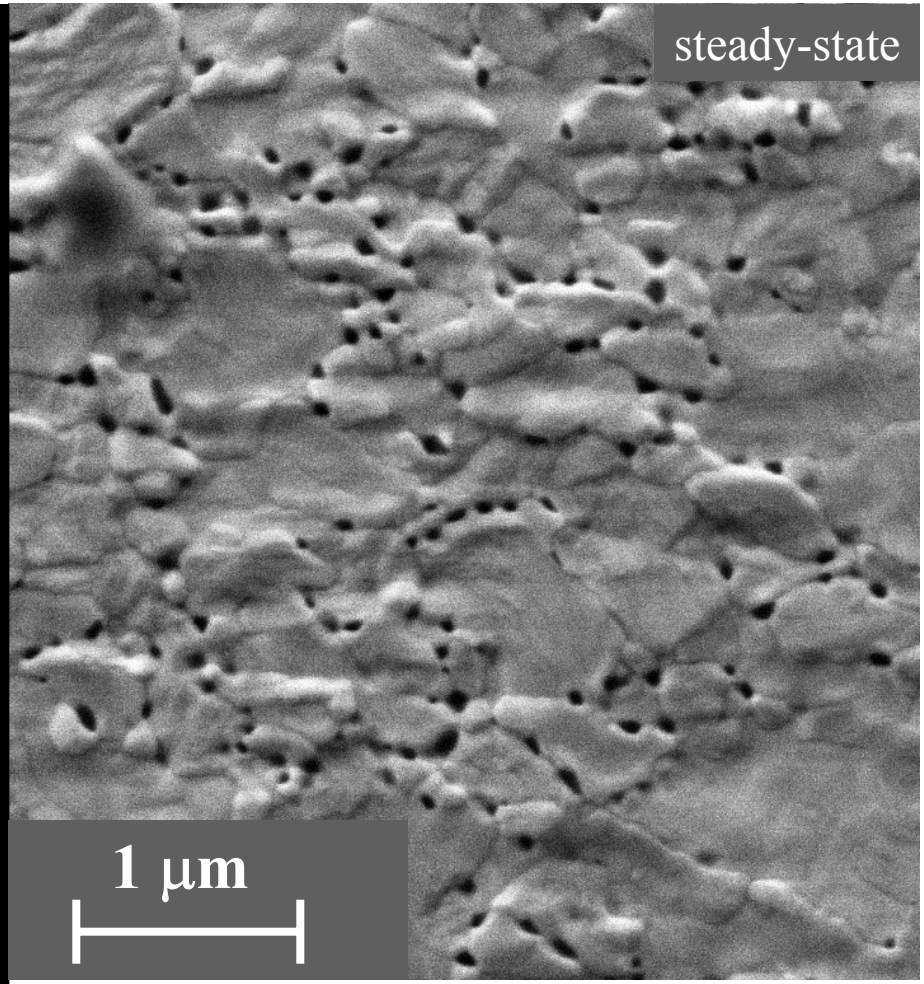
Pulsed IEC Irradiation Better Simulates HAPL Flux



Pulsed Irradiation Caused Increased Damage to Tungsten Surface at 10^{18} He^+/cm^2

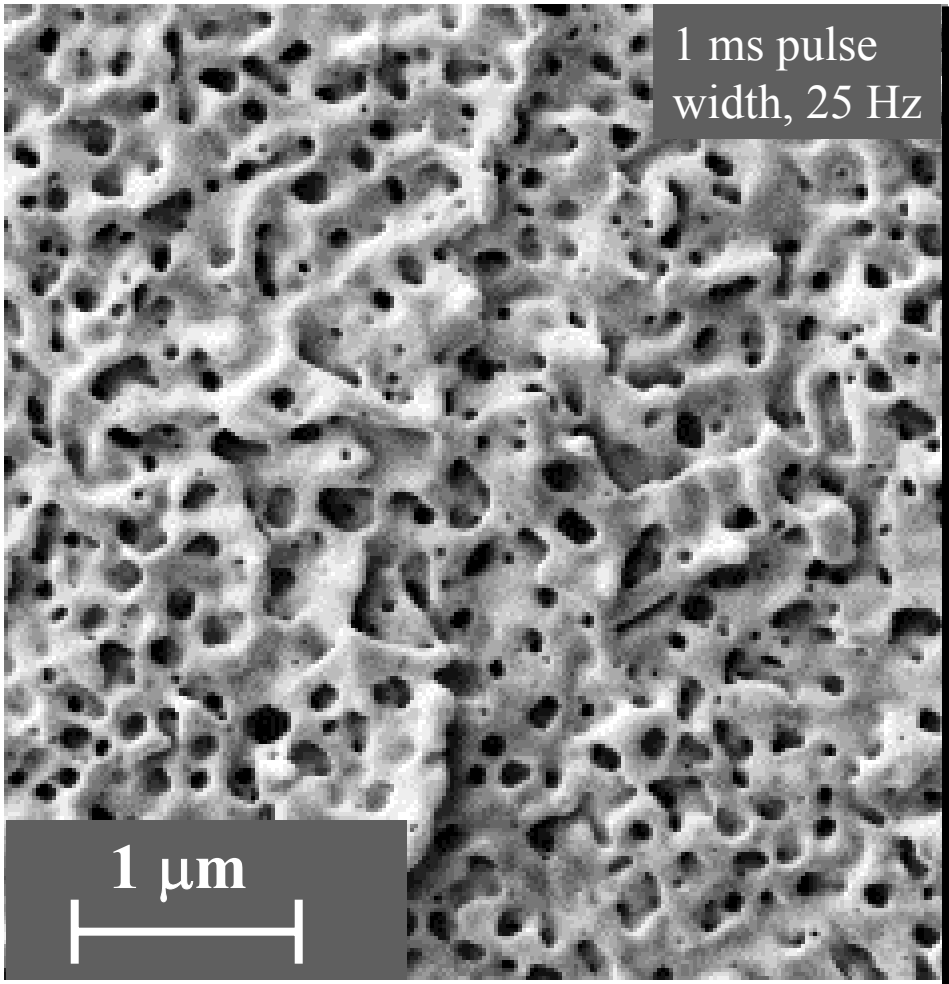


40 kV, 60 mA Pulsed (1170±20 °C baseline)
12 minute runtime

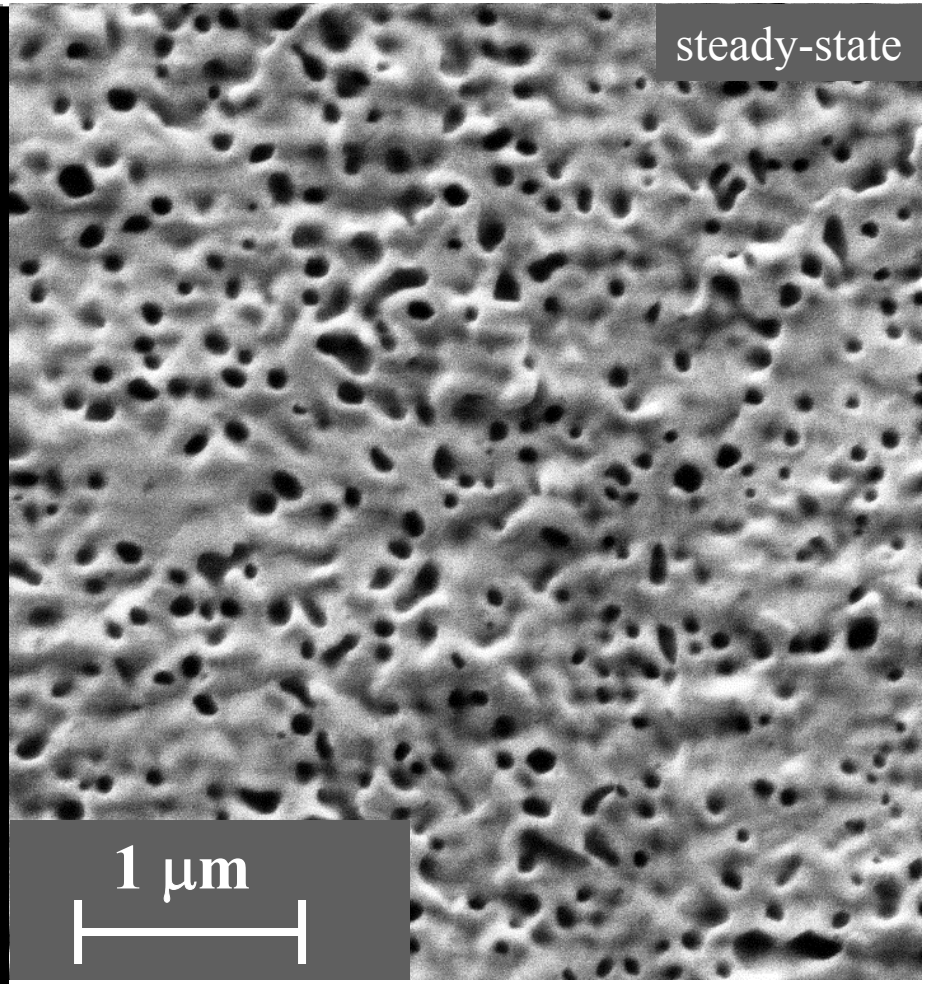


30 kV, 6 mA Steady-State (1150±20 °C)
3 minute runtime

Pulsed Irradiation Caused Increased Damage to Tungsten Surface at 6×10^{18} He^{+}/cm^{2}

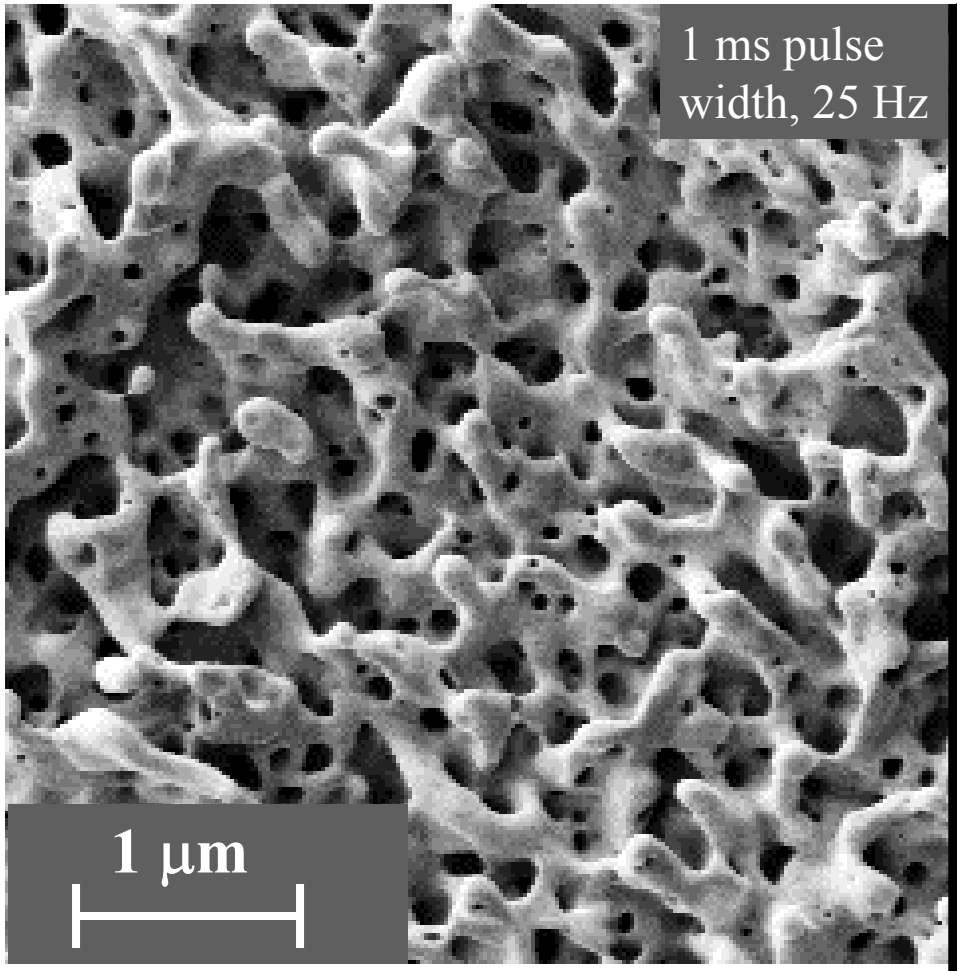


40 kV, 60 mA Pulsed (1170±20 °C baseline)
72 minute runtime

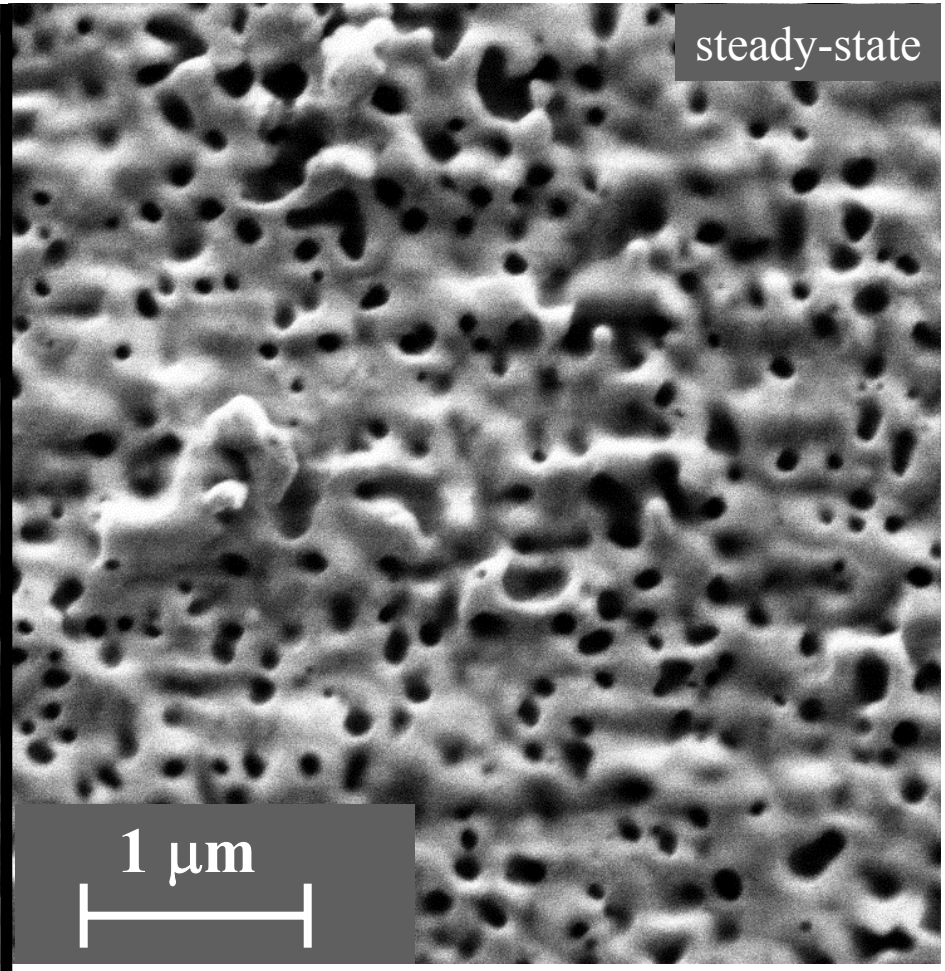


30 kV, 6 mA Steady-State (1130±20 °C)
18 minute runtime

Pulsed Irradiation Created Coral-Like Tungsten Features at 10^{19} He^{+}/cm^{2}

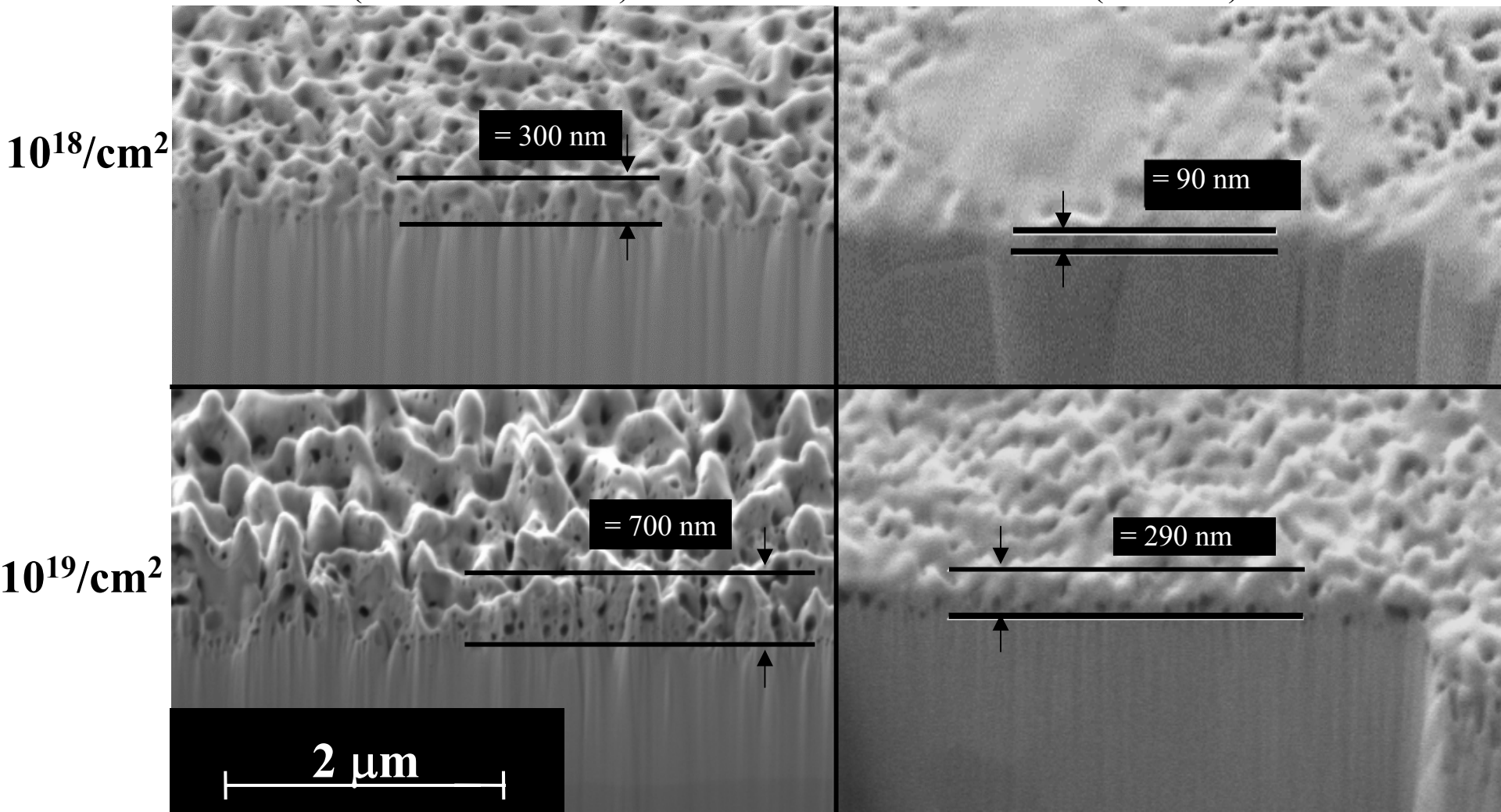


40 kV, 60 mA Pulsed (1140±20 °C baseline)
2 hour runtime



30 kV, 6 mA Steady-State (1150±20 °C)
30 minute runtime

FIB Analysis Reveals Increased Porous Layer in Pulsed Samples



Mass Loss was Measured for Pulsed Tungsten Samples

- There has been no observable mass loss at fluences below $10^{19}/cm^2$ for steady-state irradiation at 1150 °C
- Measured mass loss and corresponding thickness loss for pulsed irradiation is shown below:

	$1x10^{19}$	**$6x10^{18}$**	**$1x10^{18}$**
Mass Loss (2 g sample)	4.2±0.1 mg	3.6±0.1 mg	0.5 ± 0.1 mg
Thickness Loss	1.1±0.03 μm	0.93±0.03 μm	0.13±0.03 μm

1 ms pulse width, 25 Hz, 1150 °C

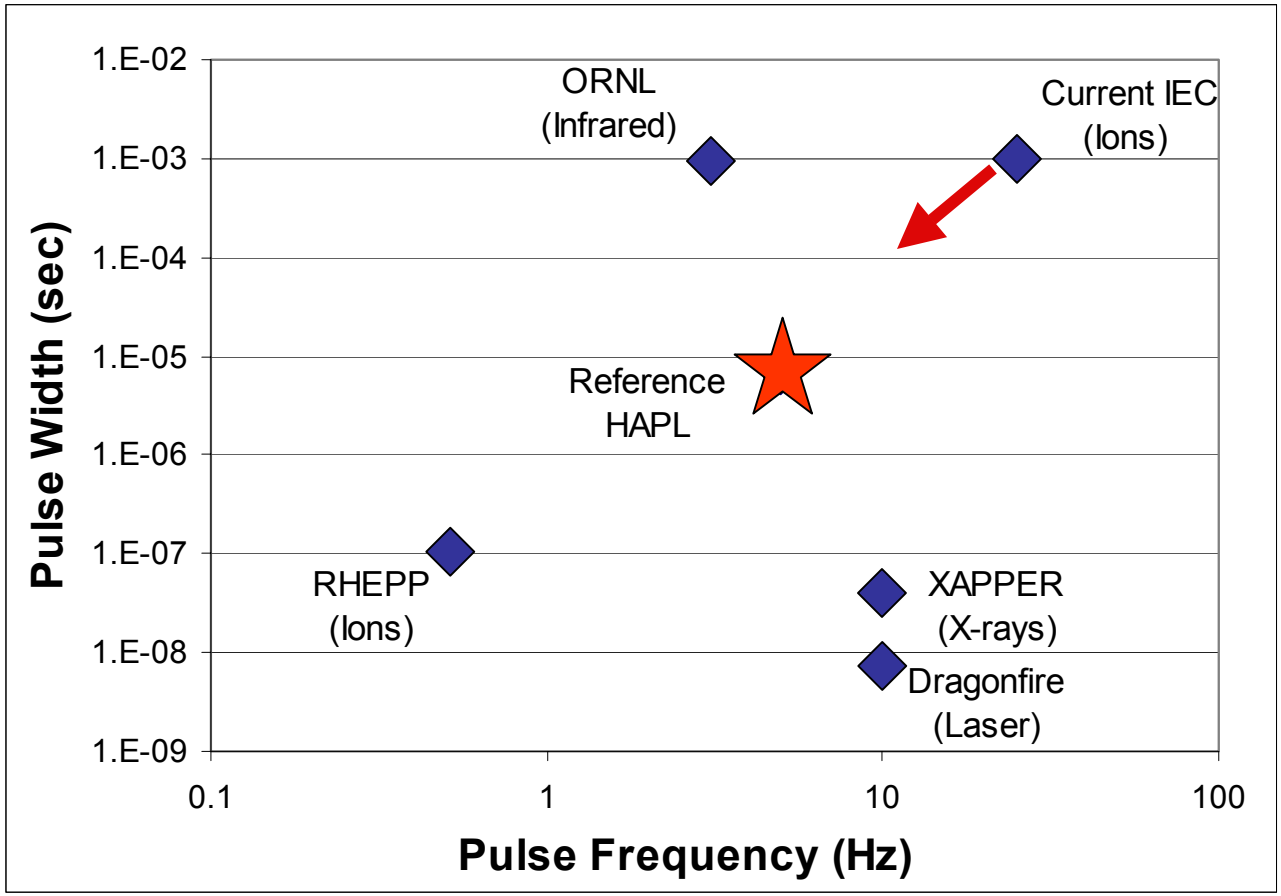
- Reference HAPL W armor could lose 200 μm/FPY (~300 kg/FPY) due to low energy He irradiation alone

Conclusions

- Switching from steady-state to pulsed irradiation at 1150 °C resulted in an increased surface roughening over 10^{18} to 10^{19} He^{+}/cm^{2} range
- Porous layer in tungsten was ~3x thicker after pulsed irradiation compared to steady-state
- Mass loss of tungsten armor in Reference HAPL design could be as much as 200 μm/FPY (~300 kg/FPY), which is well beyond calculated physical sputtering values

Future Work

- Expand pulsed operation to pulse widths that are closer to Reference HAPL conditions

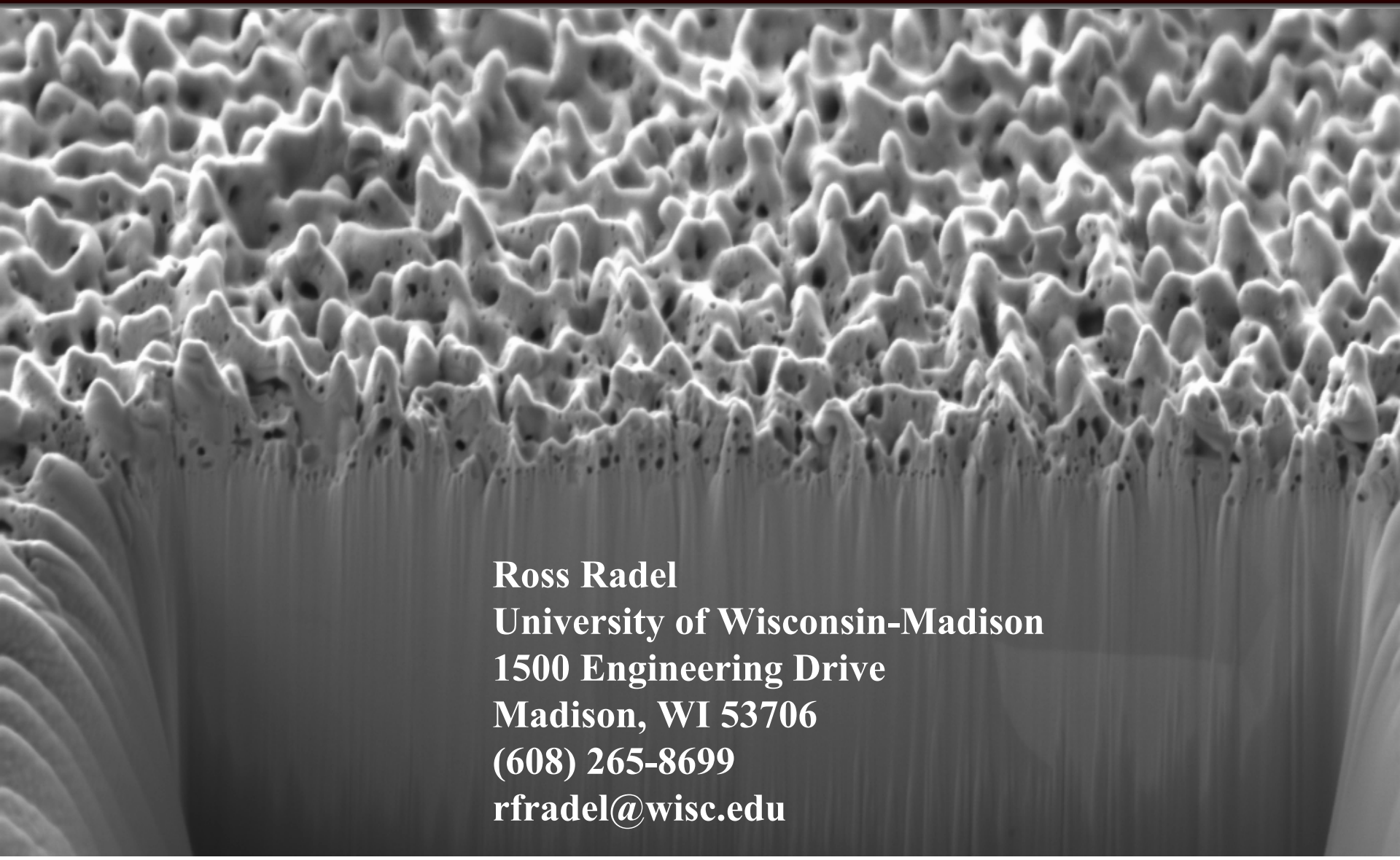


Future Work, cont.

- Begin irradiation of SiC samples

Unirradiated SiC

Questions?



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