Facility update: Sandia National Laboratories / CA

SAND2018-12287PE

Overview

- Medium-flux RF plasma source (DPE)
- Hydrogen permeation measurements
- High temperature thermal desorption
- Spectroscopic ellipsometry

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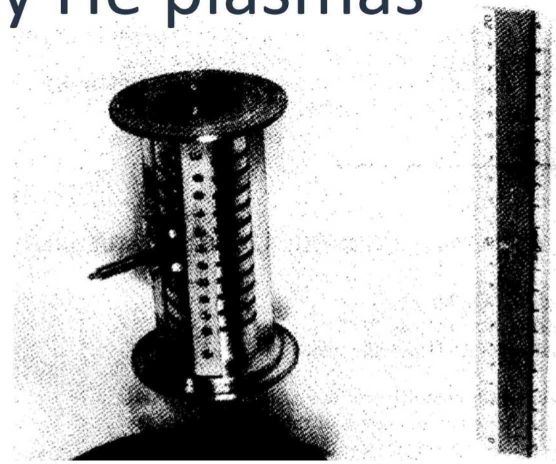
Above: Pre-exposure of PHENIX sample with He plasma

FY17 research focus: Gas-driven D permeation through W surfaces modified by He plasmas



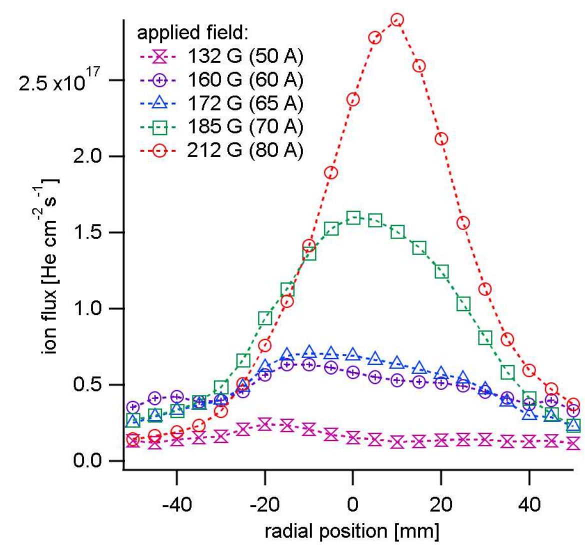
Helical Lisitano coil RF guide
[1] G. Lisitano et al. *Appl. Phys. Lett.* (1970)

<u>RF plasma device</u>:

- Axial magnetic field: 185 G
- Lisitano coil with helical cuts machined into each end, based on “short wave” design in Ref. [1].
- Input RF power ~250 W, RF frequency 420 Mz (non-resonant absorption)

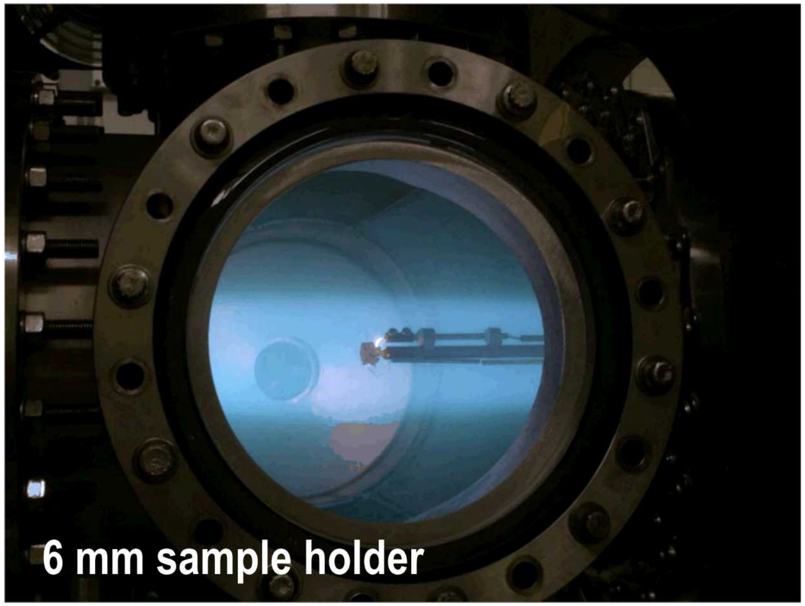
<u>PHENIX exposure conditions</u>:

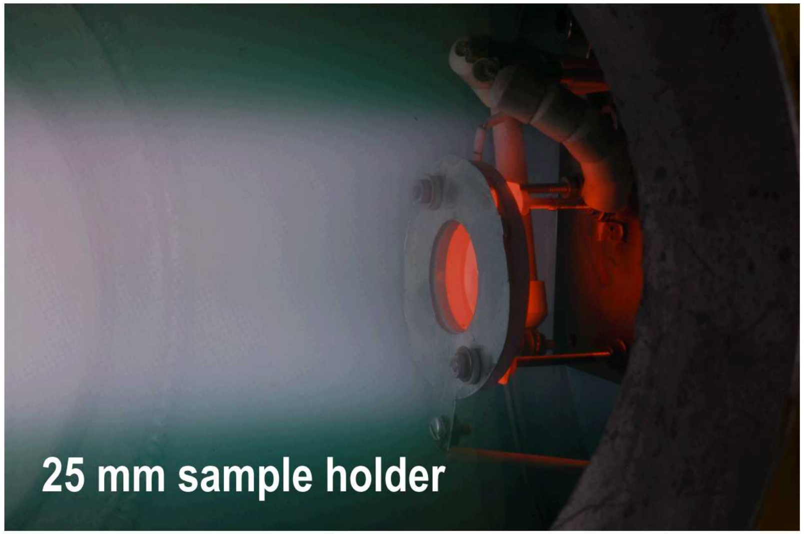
n_{pl}	7×10^{10} cm^{-3}
T_{e}	11.5 eV
E_{ion}	50 eV
Γ_{ion}	1.5×10^{21} m^{-2} s^{-1}
F_{ion}	2.7×10^{25} m^{-2}
T_{sample}	910 °C



Ion flux profiles measured with a Langmuir probe assembly

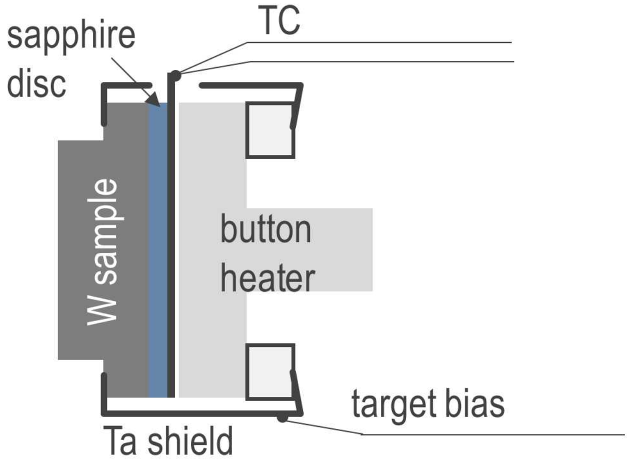
Medium-flux RF plasma source capable of accommodating a variety of target configurations





Sample temperature control:

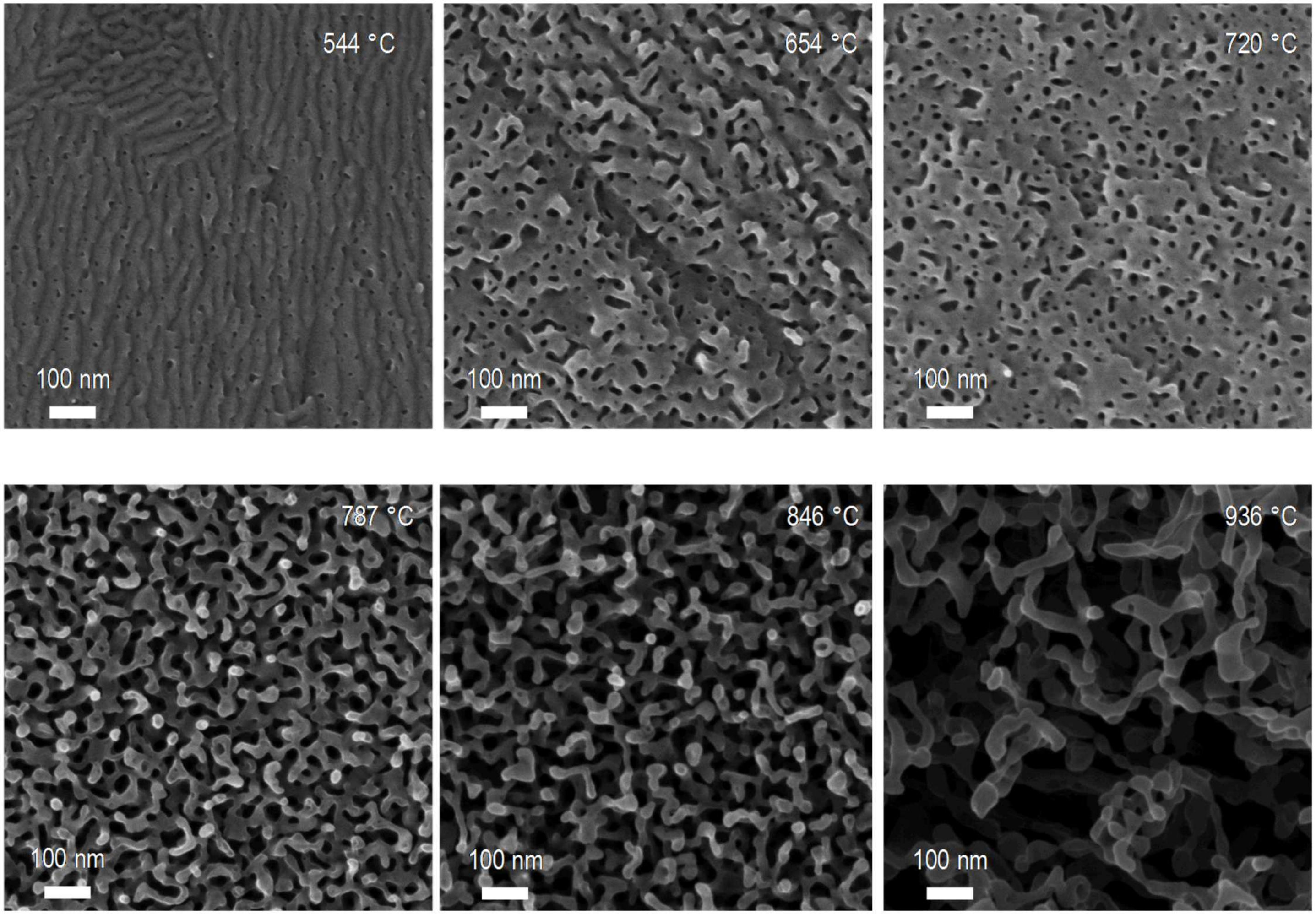
- Heat load from the plasma is small
- Small resistive heater elements



Two sample configurations for PHENIX studies:

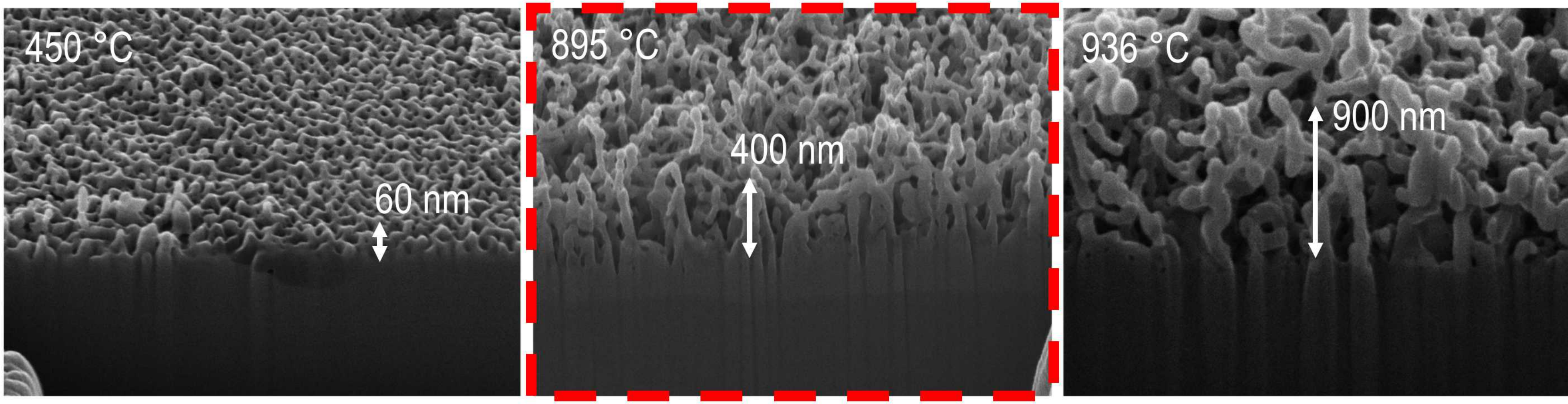
- 25 mm foils used for pre-exposure of PHENIX gas-driven permeation samples
- 6 mm buttons suitable for high-temperature TDS / microscopy

W nanostructure growth at different temperatures

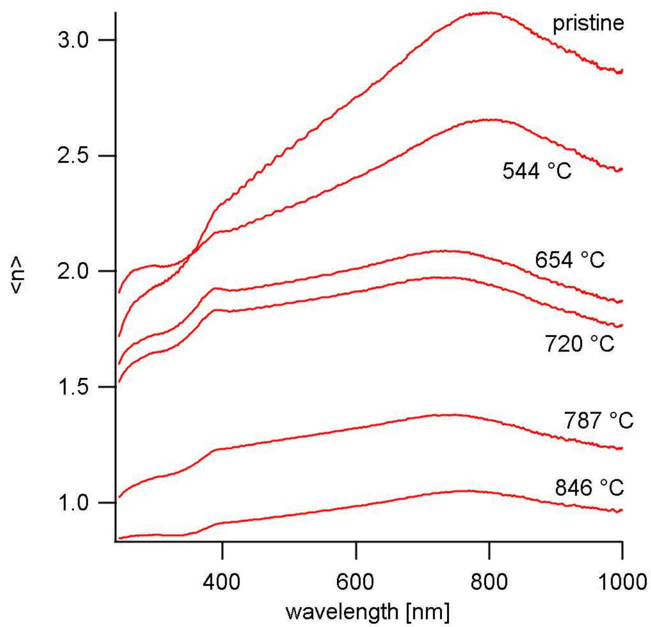


Above: Helium ion microscope images of ITER-grade W samples exposed to medium flux He plasmas.
Exposure conditions: Γ_{ion} = 1.5×10^{21} m^{-2} s^{-1}; F = 2.7×10^{25} m^{-2}; E_{ion} = 50 eV

Plasma exposure for PHENIX permeation samples produced a nanostructure layer 400 nm thick.

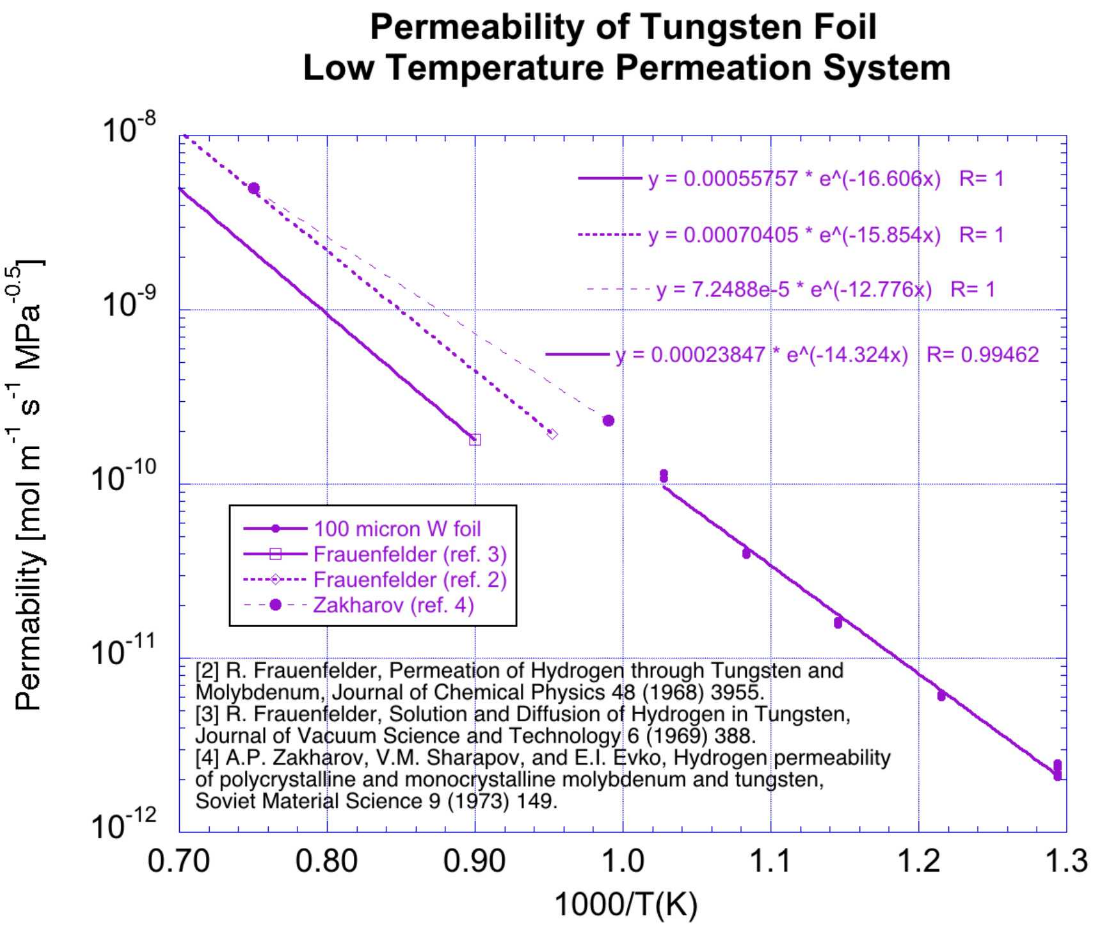


PHENIX permeation sample conditions



- W nanostructure thickness assessed through atomic force microscopy (early stage growth) and focused ion beam profiling / HIM (later stages.)
- Thickness of nanostructure layer is ~400 nm.
- As nanostructure grows, optical properties of the surface change and can be quantified by spectroscopic ellipsometry.
- Once correlated with the HIM images, ellipsometry provides a convenient means of assessing the condition of the surface

Permeation experiments done using tungsten foil



- Permeability aligns well with other studies at higher temperatures.
- W foil coated with Pd to inhibit oxidation.
- Further analysis on the the effect of oxide formation is planned.

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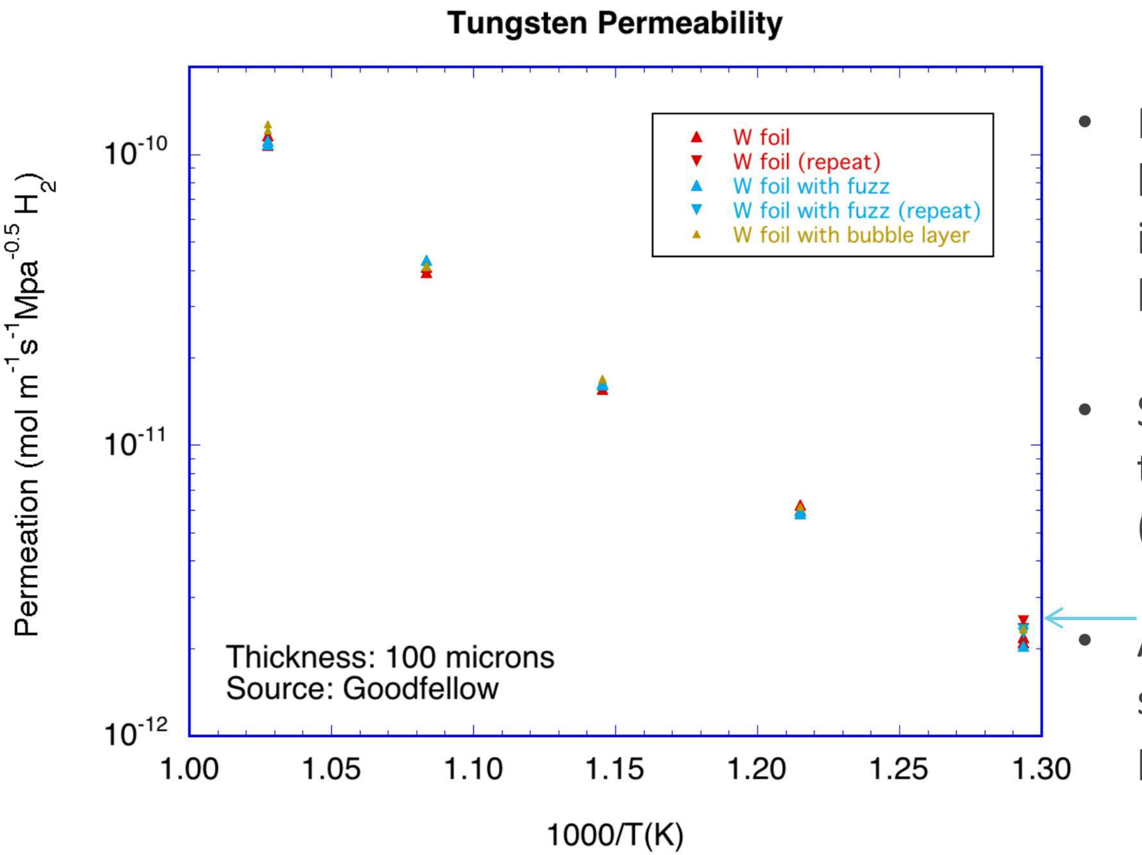
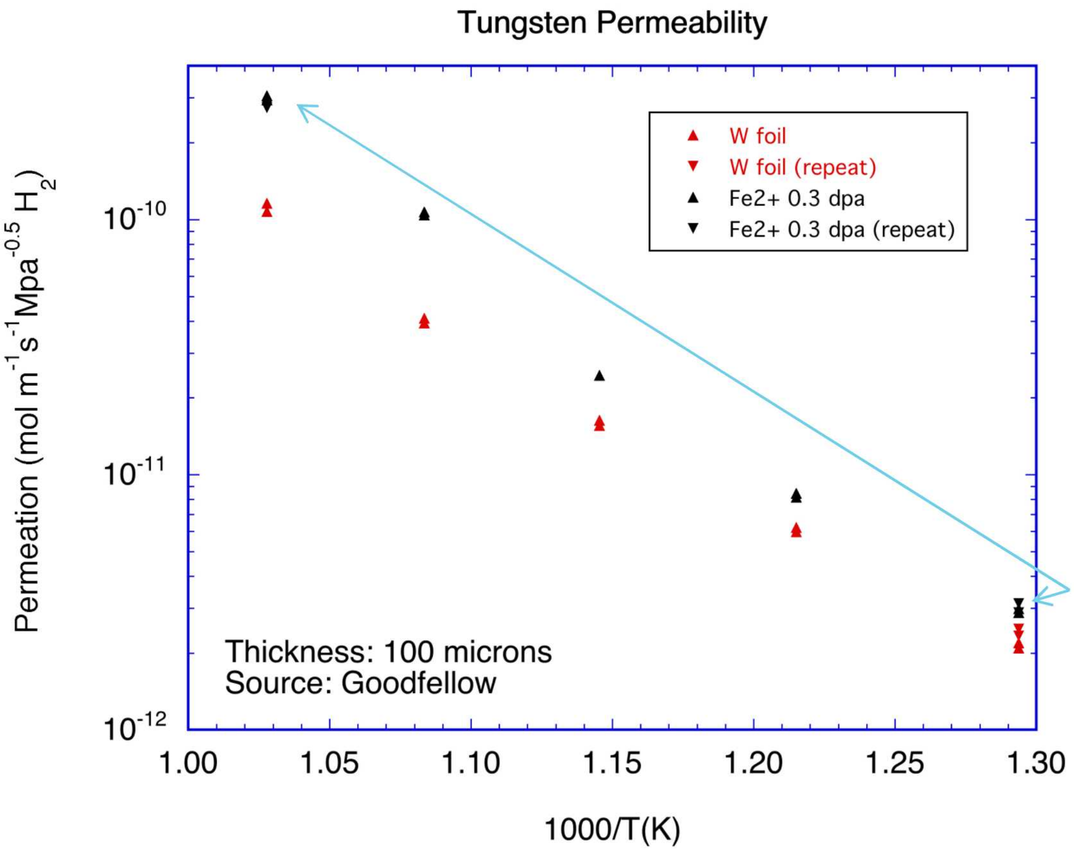
Comparison of permeation for W foil exposed to low energy helium plasmas



- No large changes seen between foils with He-induced fuzz (900 °C) or bubble layer (500 °C).
- Samples run with same temperature history (500,550,600,650,700 °C).
- A repeat run at 500 °C shows somewhat higher permeation.

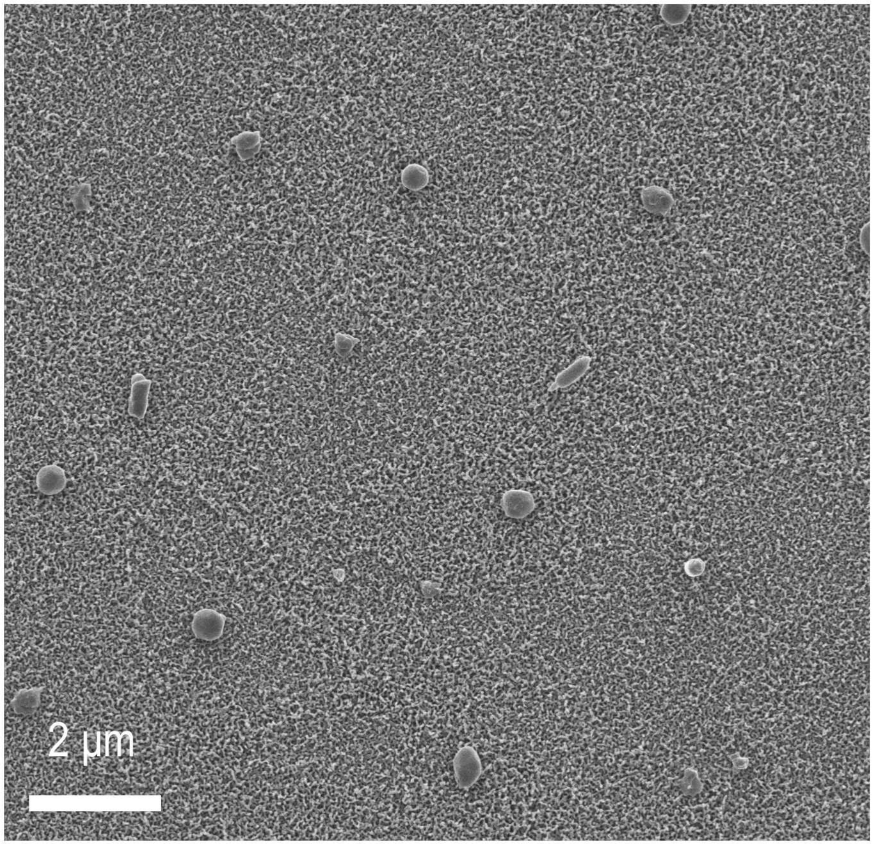
Recent permeation data for 6 MeV Fe^{2+} damaged tungsten foil (0.3 dpa) shows no evidence of reduced permeability

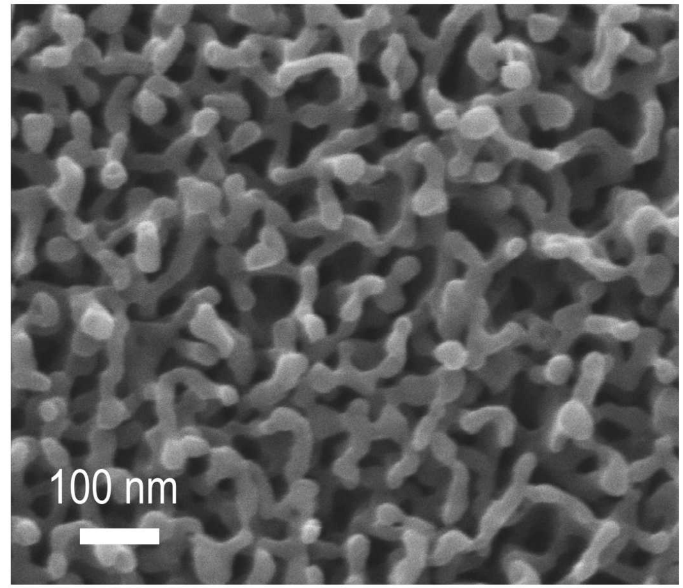


- This sample shows higher permeability, but…
  - Transients and post examination indicated potential leak
  - High mass 3 also observed
- Both samples run with same temperature history (500,550,600,650,700 °C).
- Repeat measurements at 500 & 700 °C show similar permeation for the 0.3 dpa sample.

High energy damaged measurements should be repeated

Post-test helium ion microscopy confirms nanostructure not degraded after prolonged heating during permeation experiment





- Helium microscopy reveals small particles present following permeation run.
- Preliminary Auger electron spectroscopy indicates that these particles contain Cu (along with typical O and C)
- Likely originates from the Cu gaskets used for sealing