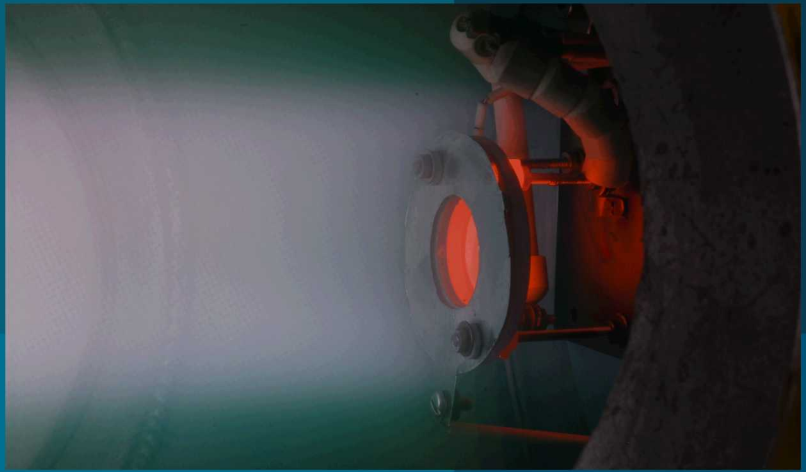
SAND2019-14328C

Fusion Research Facilities at Sandia National Laboratories



PRESENTED BY

Robert D. Kolasinski

Sandia National Laboratories-Livermore, Energy Innovation Dept.

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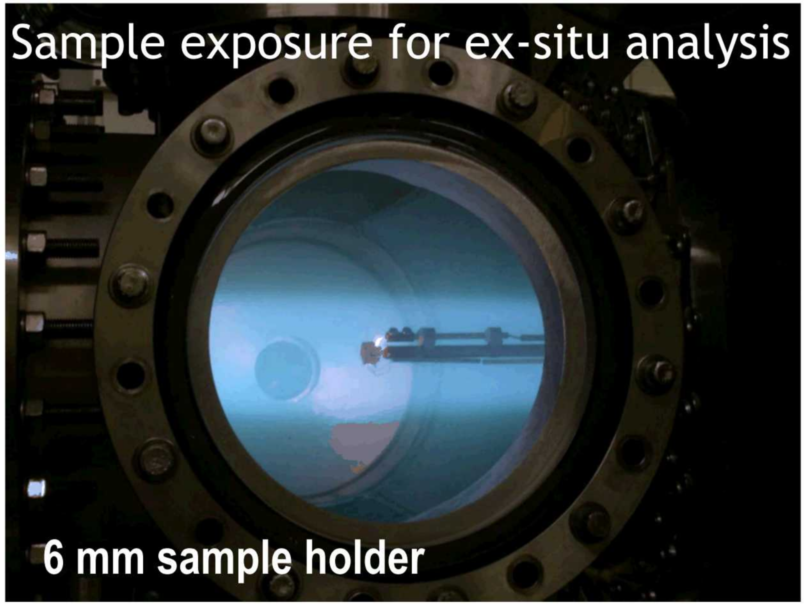
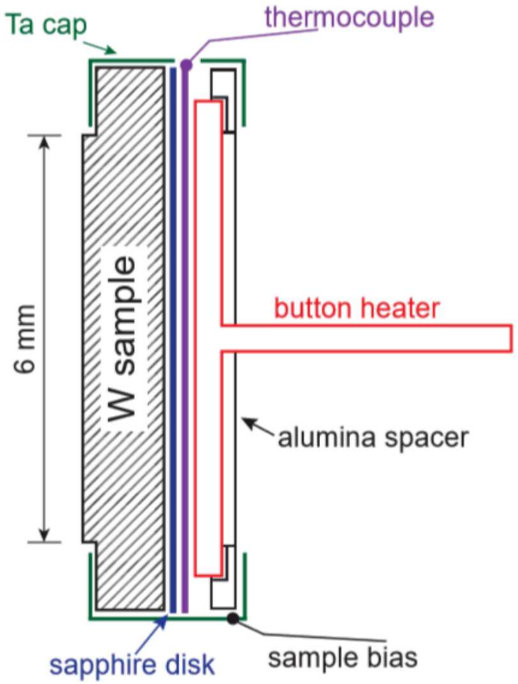
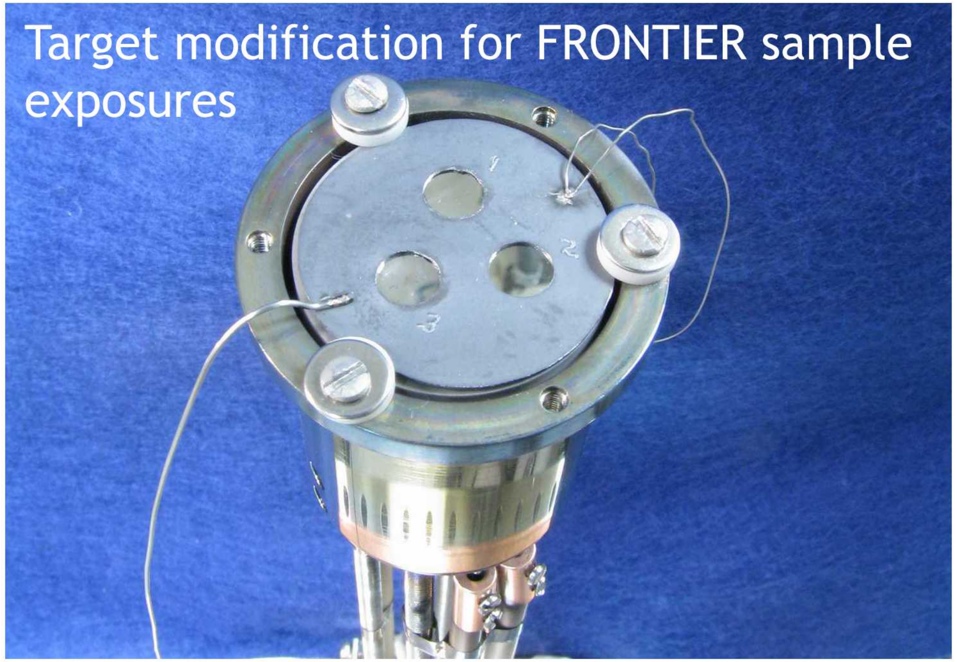
RF source enables exposure of specimens to He^+ and D_2^+ plasmas





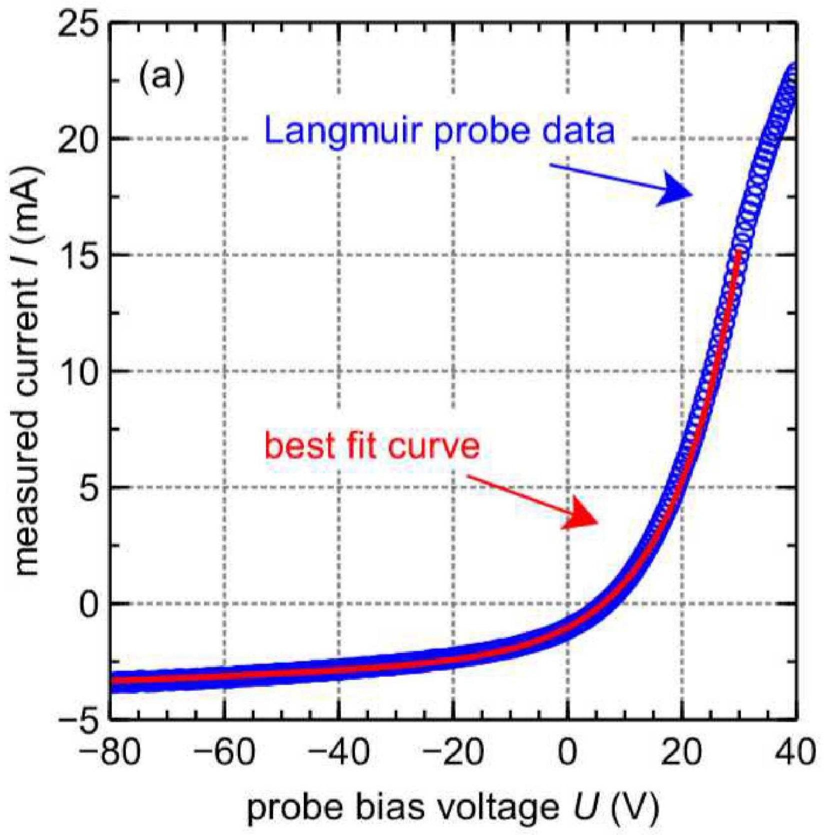


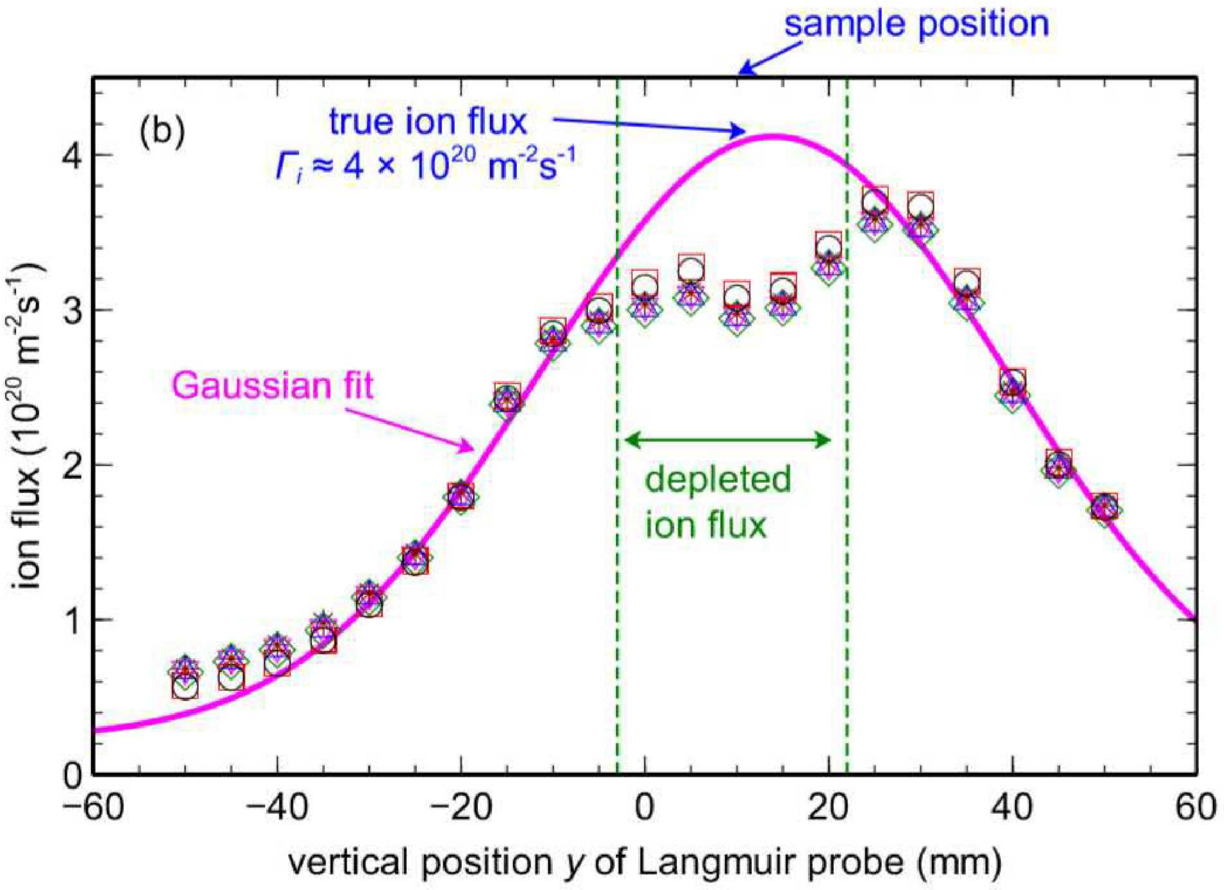
RF linear plasma device:

- 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)

[1] G. Lisitano et al. *Appl. Phys. Lett.* (1970)

Typical exposure conditions for He^+ plasmas





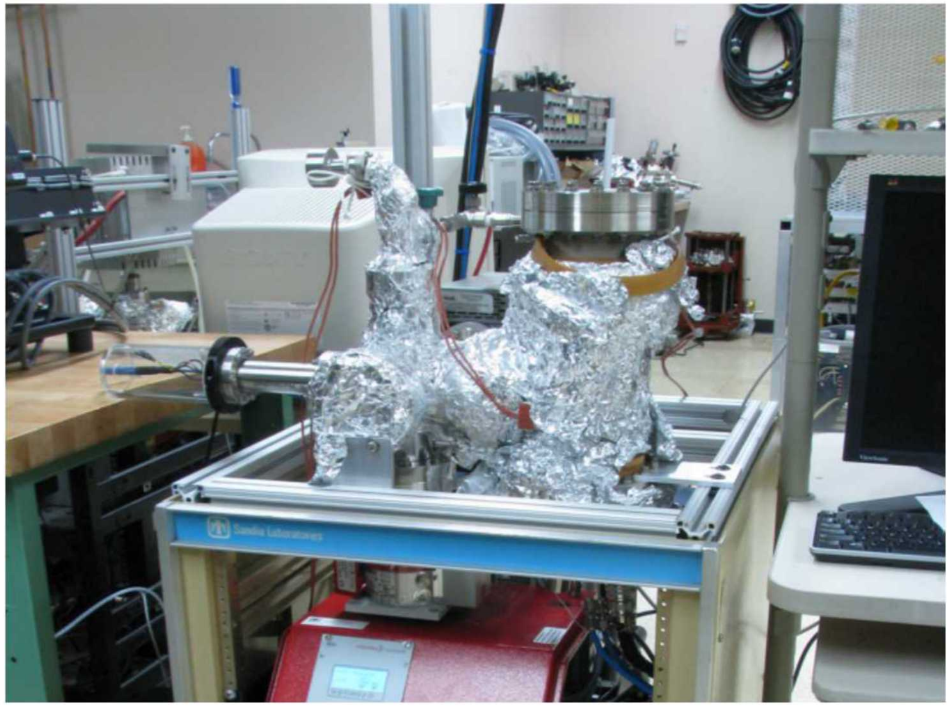
C. –S. Wong, R. Kolasinski, and J. A. Whaley, (in preparation)

<u>Exposure conditions</u>:

n_{pl}	7×10^{10} cm^{-3}	E_{ion}	92 eV
T_e	11.5 eV	Γ_{ion}	1.5×10^{21} m^{-2} s^{-1}
		F_{ion}	2.7×10^{25} m^{-2}

High temperature thermal desorption system enables annealing of small samples up to 1600 °C

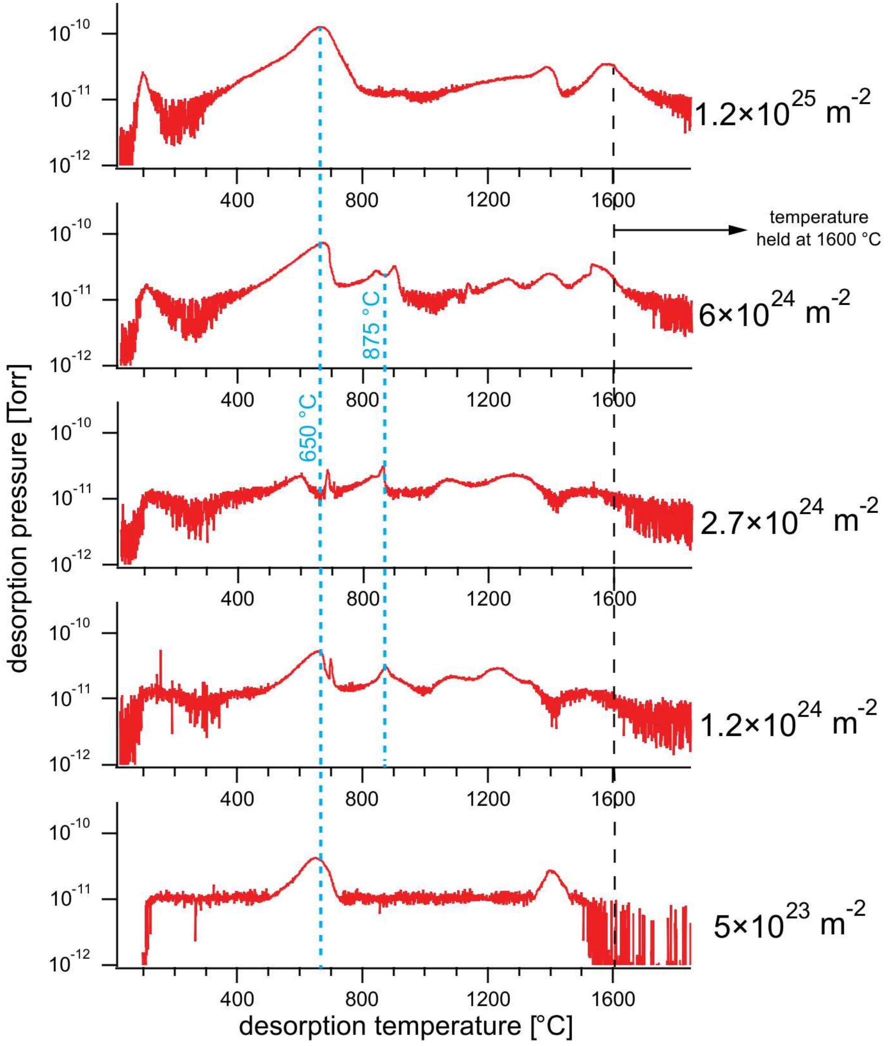
- **High temperature thermal desorption spectrometry**
  - Veeco effusion cell heats specimens up to 1600 ºC at 17.5 ºC/min
  - Released He / D measured using SRS mass spectrometer
  - Lower temperature quartz furnaces (annealing up to 1000 ºC also available.
  - Upgrade to high resolution mass spectrometer planned

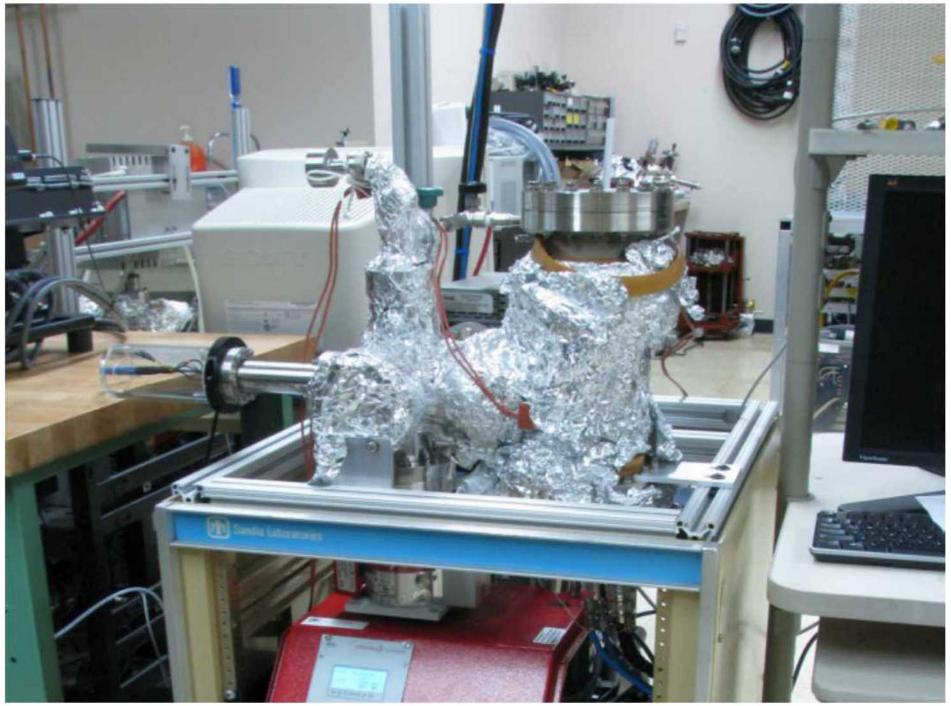


High temperature thermal desorption system

High temperature thermal desorption system enables annealing of small samples up to 1600 °C

He release spectra from plasma exposed W at different fluences





High temperature thermal desorption system

Gas driven permeation instrumentation available for H permeation/diffusion studies

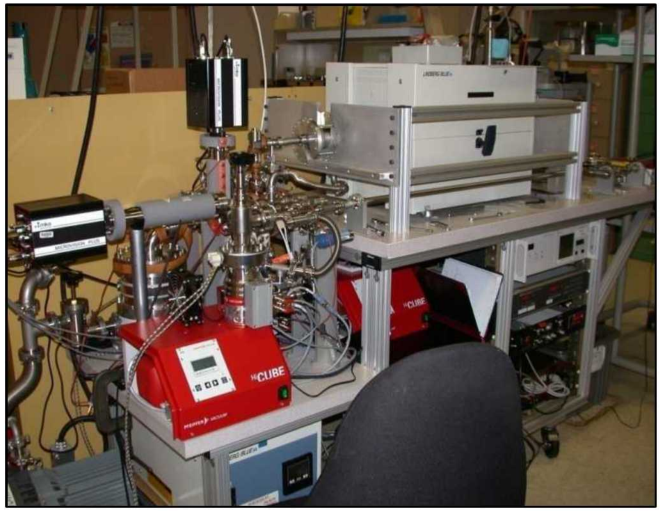
- **Deuterium gas-driven permeation systems presently available:**
  - 1st generation (150 < T < 500 ºC) used stainless steel construction (VCR seals), evacuated quartz outer tube to reduce D_2 bypass, and low flow to prevent surface contamination

Materials studied: stainless steels, steel alloys, welds, aluminum alloys, nickel, tungsten

  - 2nd generation (50 < T < 1150 ºC) uses Al_2O_3 construction and soft, pressure loaded seals for brittle specimens

Materials studied: stainless steels, SiC, tungsten

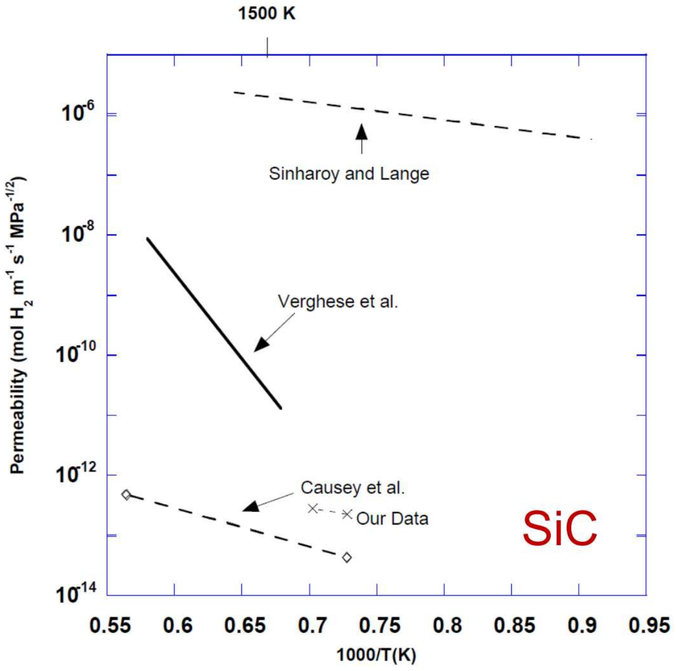
$P_{SiC} < 10^{-12}$ mol H^2 m^{-1} s^{-1} $MPa^{-0.5}$

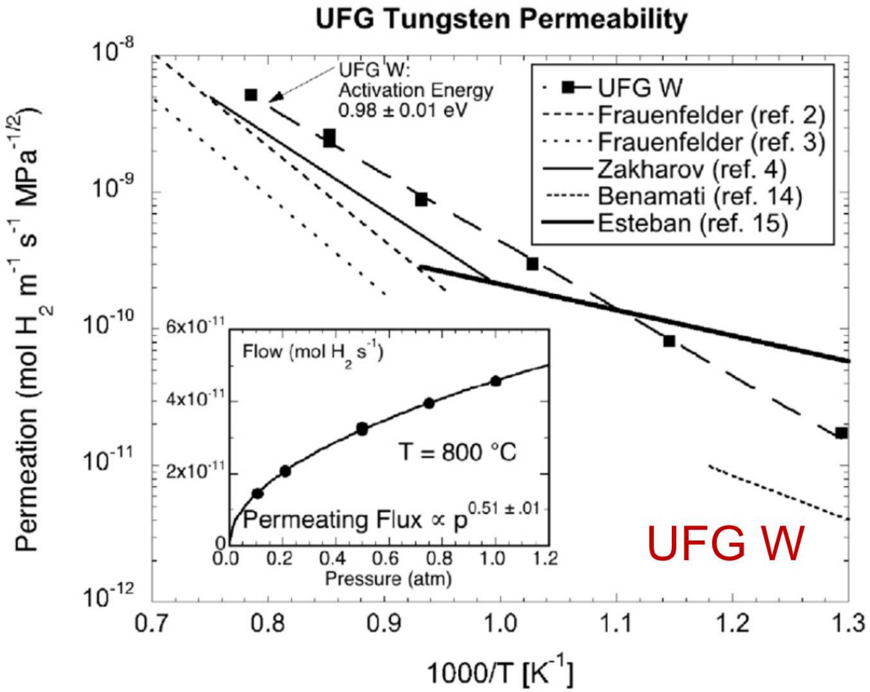


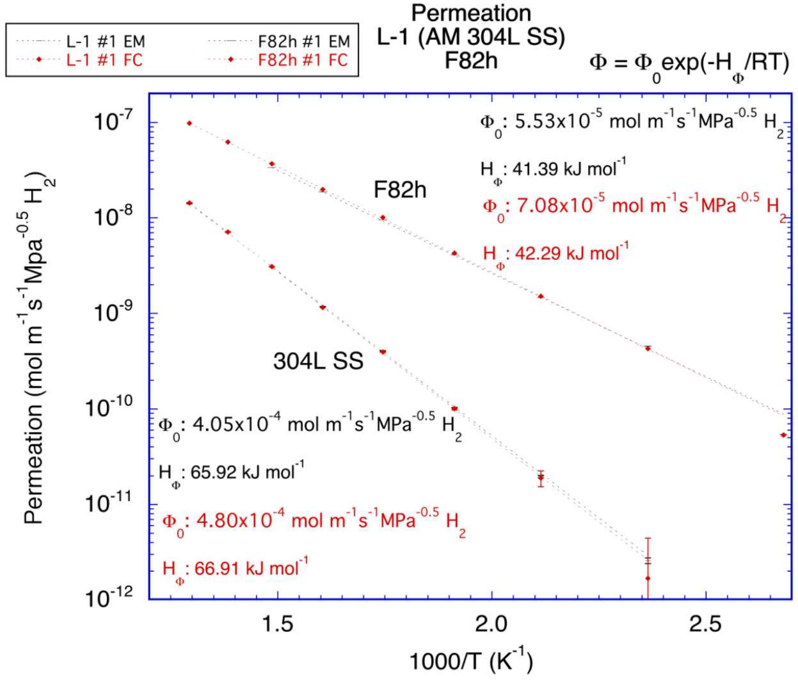
2nd Generation System D_2 permeation system at SNL/CA

Gas driven permeation instrumentation available for H permeation/diffusion studies

Prior work focuses on SiC, W materials, and steels:







304L SS / F82h

Surface analysis capabilities

Low energy ion scattering / direct recoil spectrometry

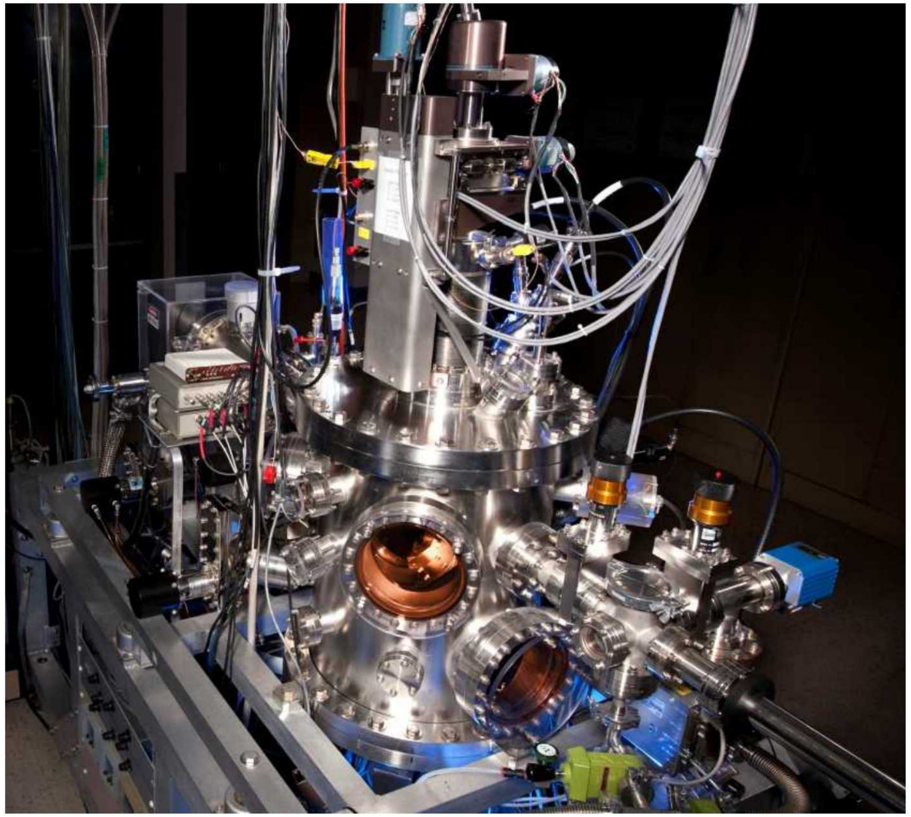
- Provides composition & atomic structure
- Sensitive to chemisorbed H
- Outer-most atomic layer sensitivity

Auger electron spectroscopy

- Precise chemical composition analysis
- Sensitivity to first 5 nm of surface
- Depth profiling, scanning instrument also available

Fourier Transform Infrared Spectrometry

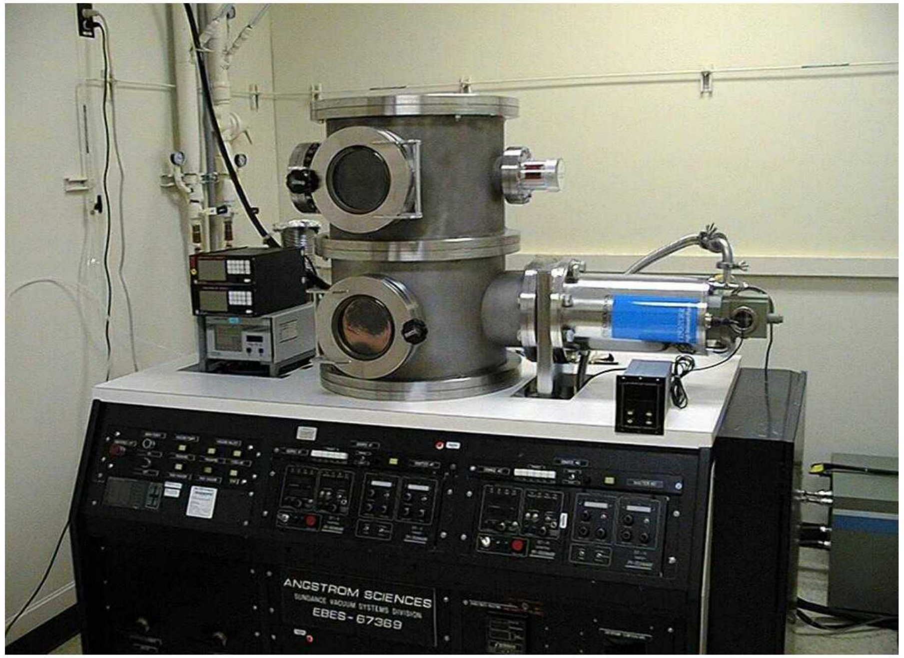
- Vibrational spectroscopy (provides insight into structure & composition)
- Operates at higher pressure (mTorr)



Angle-resolved ion energy spectrometer at Sandia/CA

Gas-driven permeation measurement approach

- **Coating techniques**
  - Dual electron beam evaporator (low vapor pressure materials, e.g., Pd, Ag, Au, Al, Pt)
  - Magnetron sputter deposition (non-magnetic materials), sample pre-sputtering possible
  - Typical film thickness achievable: 50 nm – 1 μm



Dual e-beam evaporator

Microscopy

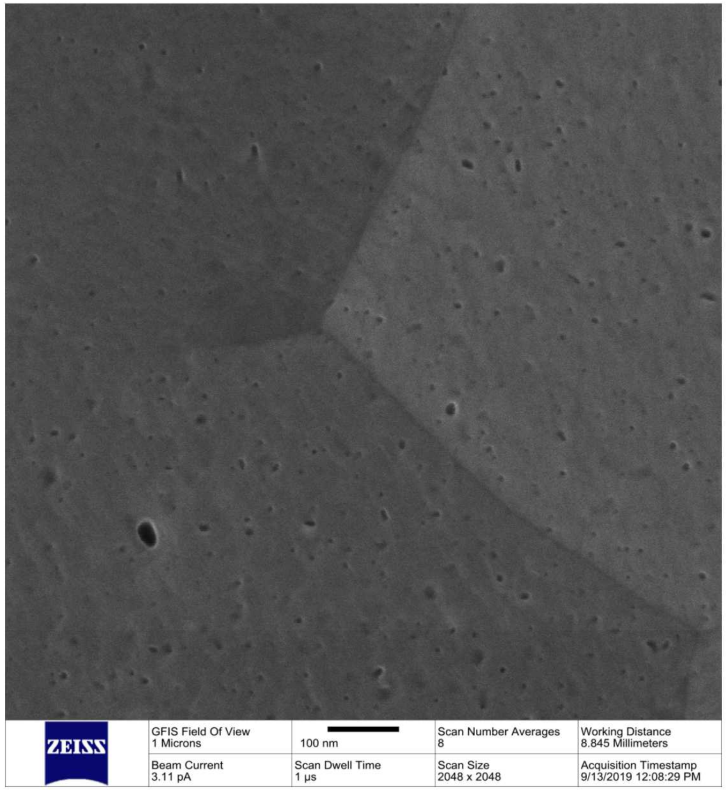


Image of W surface following exposure to He plasma at 700 °C

Capabilities available at Sandia-Livermore:
- SEM/FIB, TEM, EBSD, Scanning Auger

Available through U.C. Berkeley user facility:
- Helium ion microscope / FIB (Zeiss Nano Fab.)

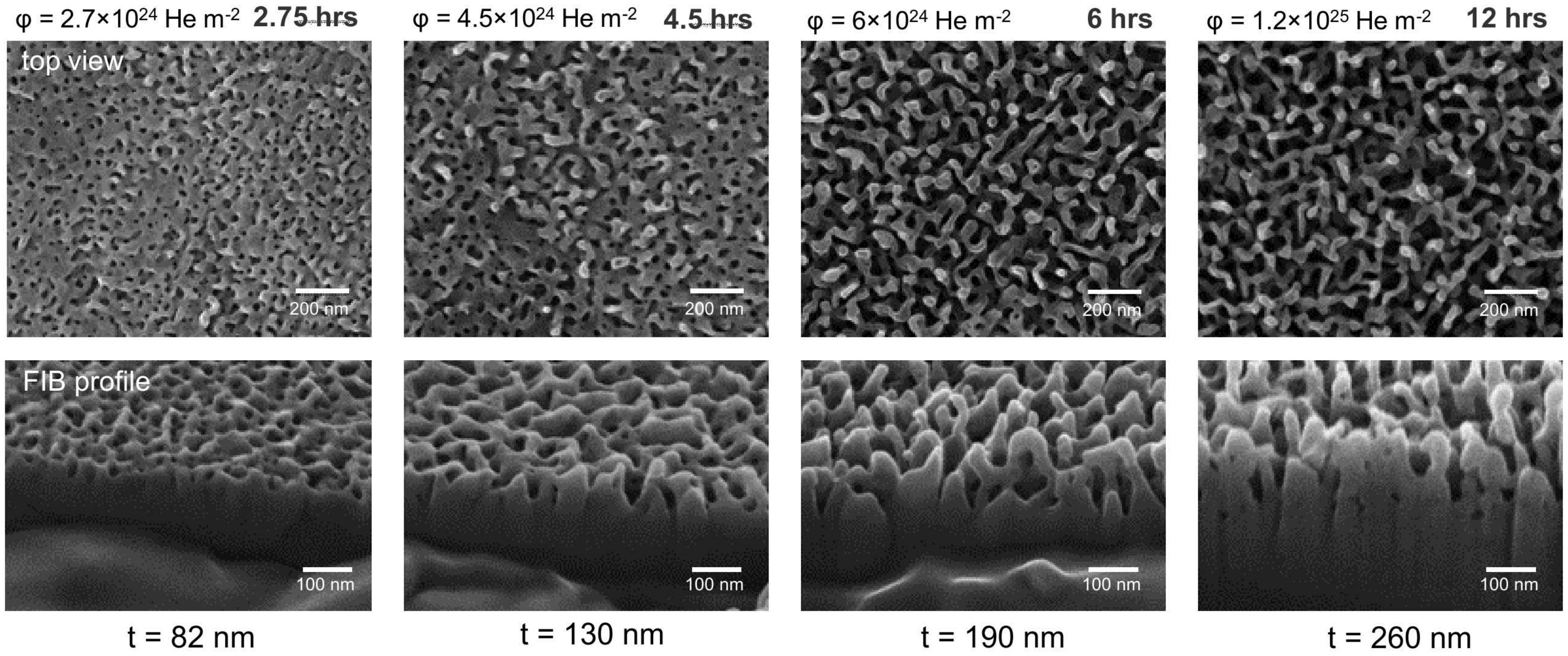


Image sequence (W nanostructure growth)

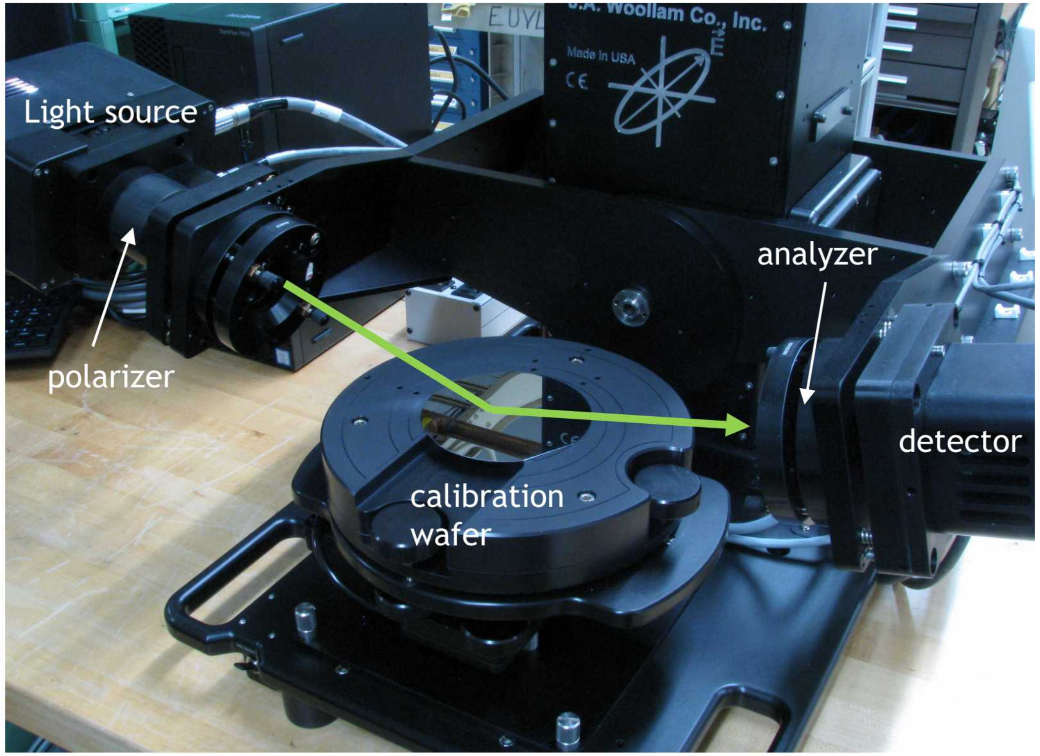
Spectroscopic ellipsometry provides the capability to probe nm-scale changes in the surface

Technique overview:

- Polarized light reflects from a surface
- Polarization change upon reflection (either a phase shift and/or attenuation of s and p waves)
- Changes are strongly sensitive to surface morphology at a nm scale.
- The reflected beam is analyzed using a photodetector / polarizer combination

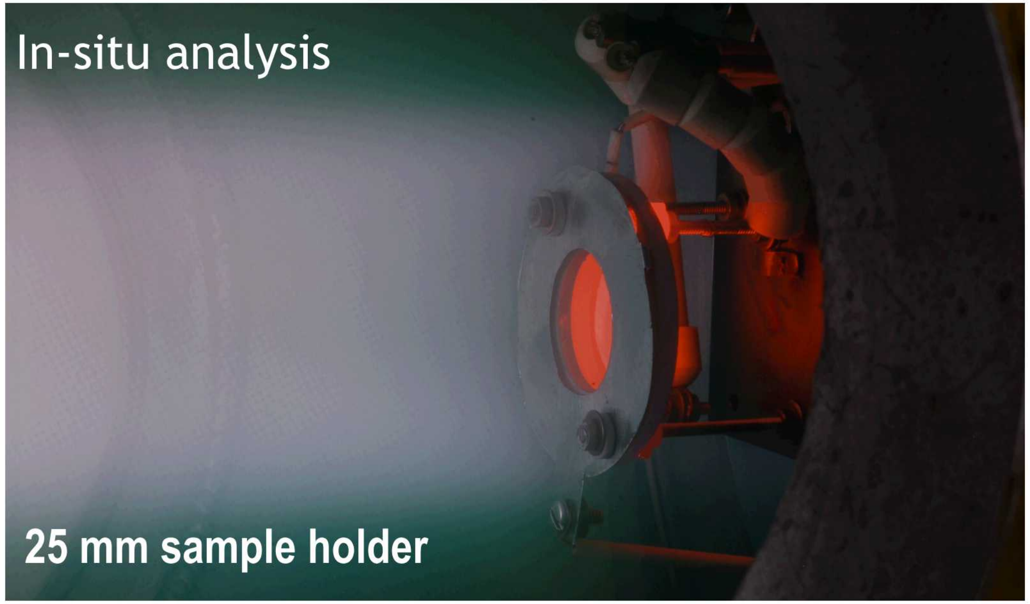
Information provided:

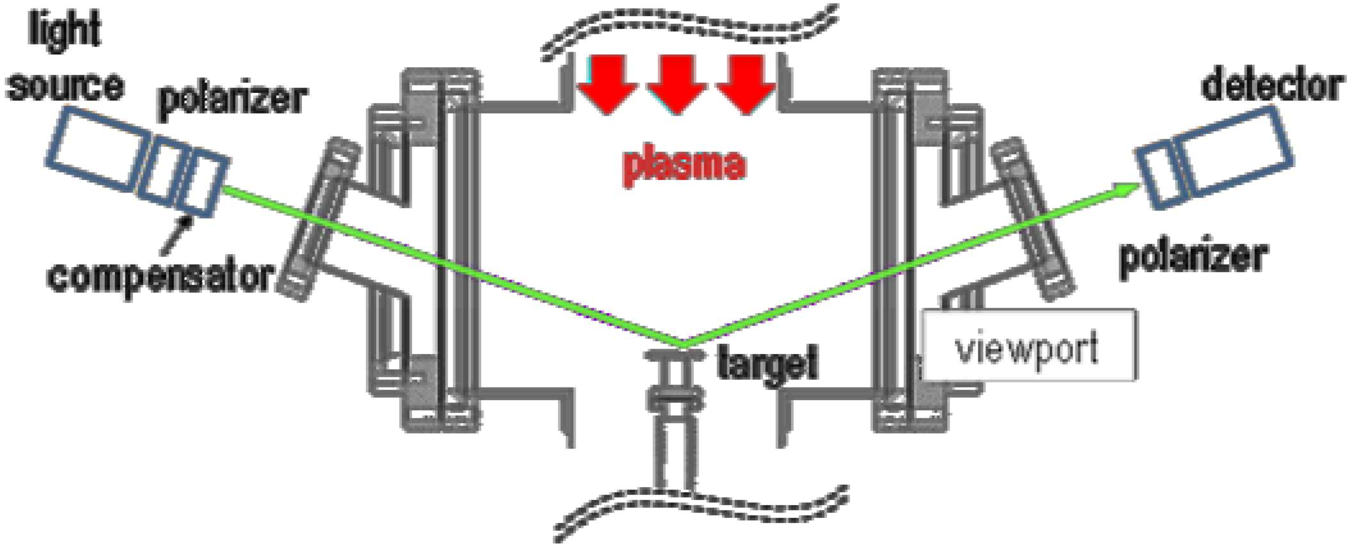
- Frequent use in semiconductor industry for film/oxide thickness
- Optical properties must be calibrated against physical structure



Spectroscopic ellipsometer mounted on variable-angle ex-situ base.

Experimental approach: RF source to expose samples to He plasmas

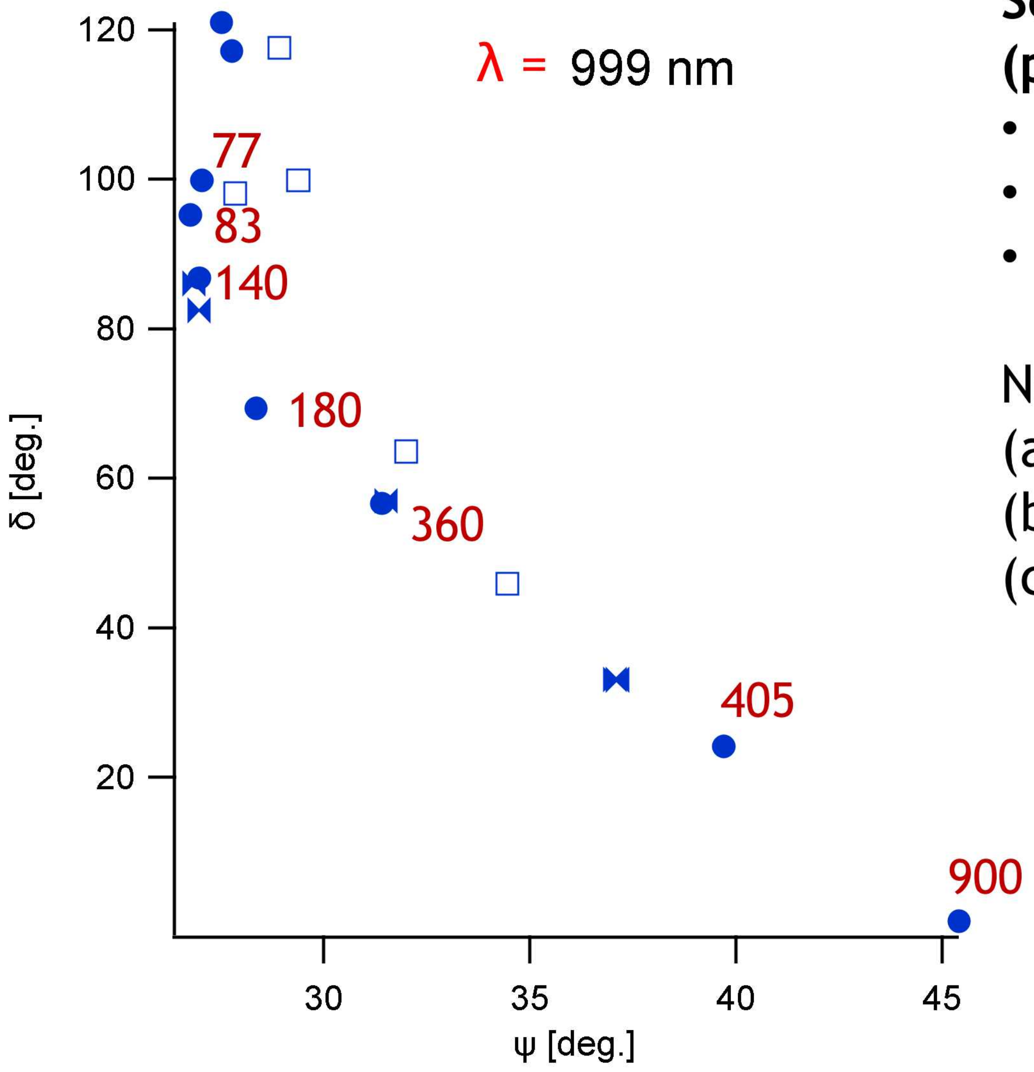




In-situ ellipsometer configuration

- Spectroscopic ellipsometer range: (245 – 1000 nm)
- Gimbals for alignment (70° relative to normal.)
- Calibrated in place using SiO_2 standards
- Strain-free viewports minimize birefringence
- Sample holder mounted to micrometer positioner to account for thermal expansion

Compiling ellipsometry data reveals a distinct trend in (ψ,δ) coordinates



Several data sets were compiled here for analysis (performed at a range of fluences / temperatures):

- Temperature series
- Fluence series
- Other samples from our collaborators

Notes:

(a) The data collapse onto a single curve.
(b) Layer thickness (estimated from HIM) indicated in nm
(c) Sensitivity is highest during initial stages of exposure

Facilities Summary

INFUSE collaborators are welcome for visits at Sandia:

- Areas of specialization:
  - Hydrogen transport / trapping in plasma-facing materials
  - Gas-driven permeation
  - Surface characterization and microscopy
  - Thermal desorption spectroscopy
  - Thin film deposition
  - Ion implantation, low-flux plasma exposure

General considerations:

- Visitor requests at the NNSA laboratories can take longer than at DOE Office of Science facilities (up to 60 days for non-U.S. citizen.)