

NIST witness-plate testing

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Outline

- Requirements
- Process flow
- Witness sample exposure system
- Dose-to-clear
- Metrology
- Results

Resist requirements

- Deposited carbon thickness < 3 nm scaled to 300 mm wafer
- Atomic H cleaning of all deposited carbon
- XPS of cleaned contamination spot to detect: Br, Cl, I, P, S, and Si
- $\Delta R/R \leq 0.23\%$ (NXE3100) as calculated from XPS at% using ASML-provided scaling factors.

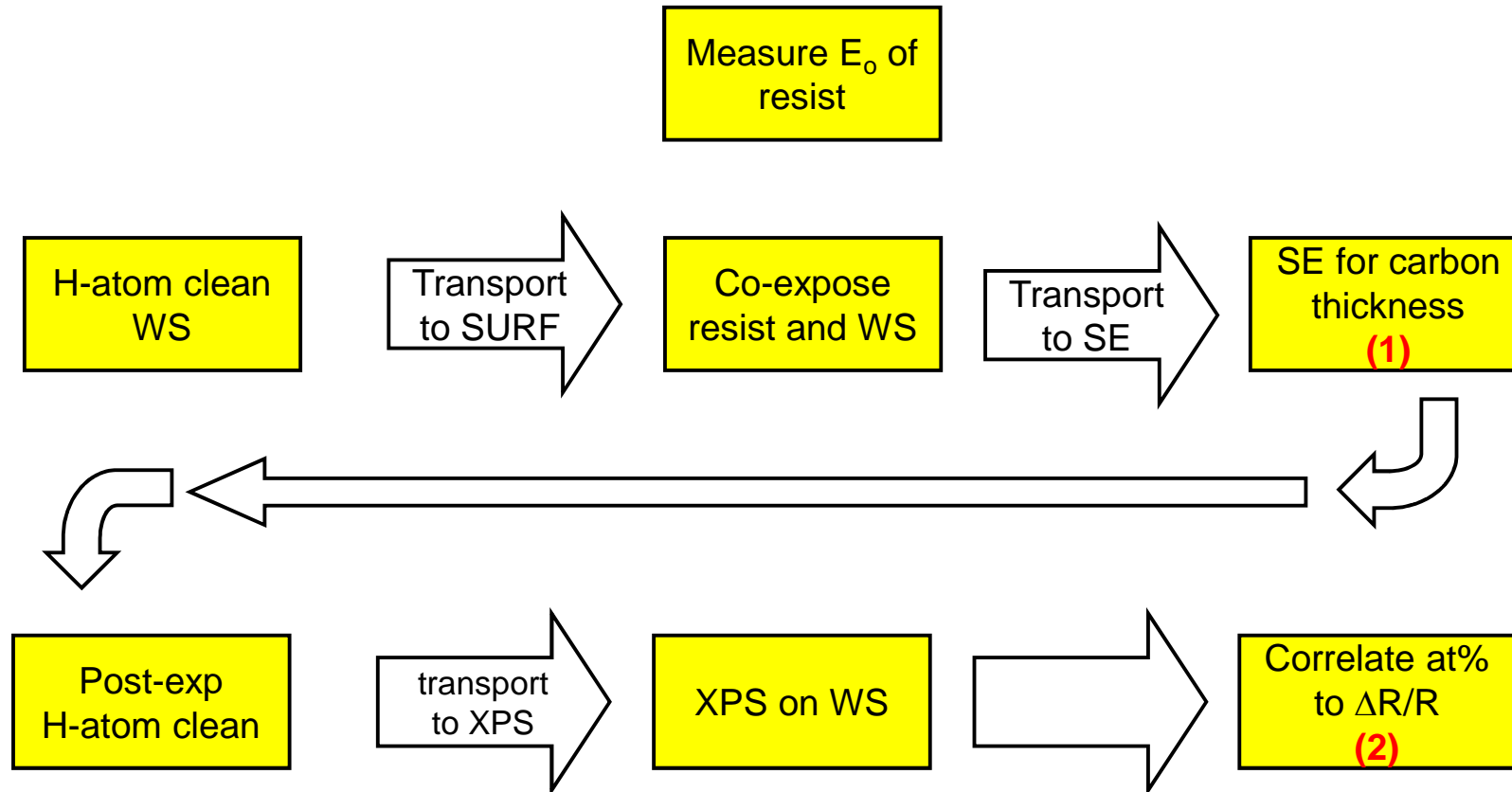
Witness-sample facility requirements

- Sufficient intensity to provide mass limited deposition rates.
- Clean vacuum with base pressure $\sim 10^{-8}$ mbar
- Uniform exposure to well-characterized dose-to-clear
- Spectroscopic ellipsometry with sub-nm sensitivity to measure deposited-carbon thickness
- Filament-based atomic-hydrogen cleaning to clean samples prior to and after exposure
- XPS with sensitivity sufficient to detect non-cleanable residuals present at $\sim 1\%$ atomic concentration

Witness-sample facility (BL-1B)

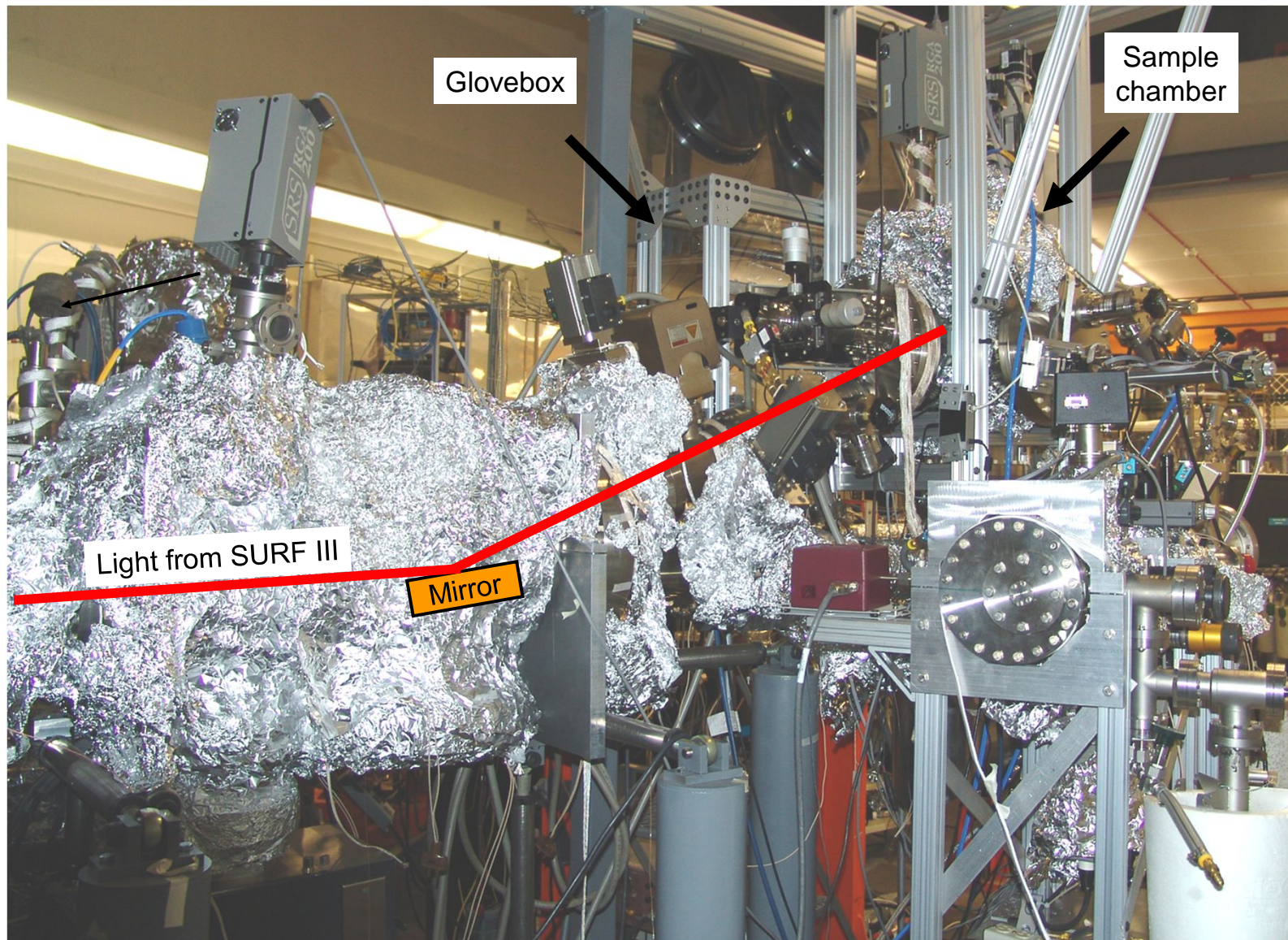
- Intensities up to $50\text{mW}/\text{mm}^2$ are sufficient for mass limited C deposition
- In situ power measurement to ensure accurate resist dose
- Single-wavelength, Null-field Ellipsometric Imaging System (NEIS) monitors deposition in real-time during exposure
- Wafer translation and rotation performed with sufficient oversampling to insure uniform wafer exposure
- Narrow-band 13.5 nm radiation exposes 200 mm wafer in <1 hr
- Integrated glovebox reduces chamber exposure to air during sample exchange.
- Vacuum base pressure $\sim 10^{-9}$ mbar

Test sequence flow chart



- (1) Carbon thickness < 3 nm by Spectroscopic ellipsometry scaled to 300 mm wafer
- (2) Post cleaning $\Delta R/R < 0.23\%$ as determined by XPS at% (NXE 3100)

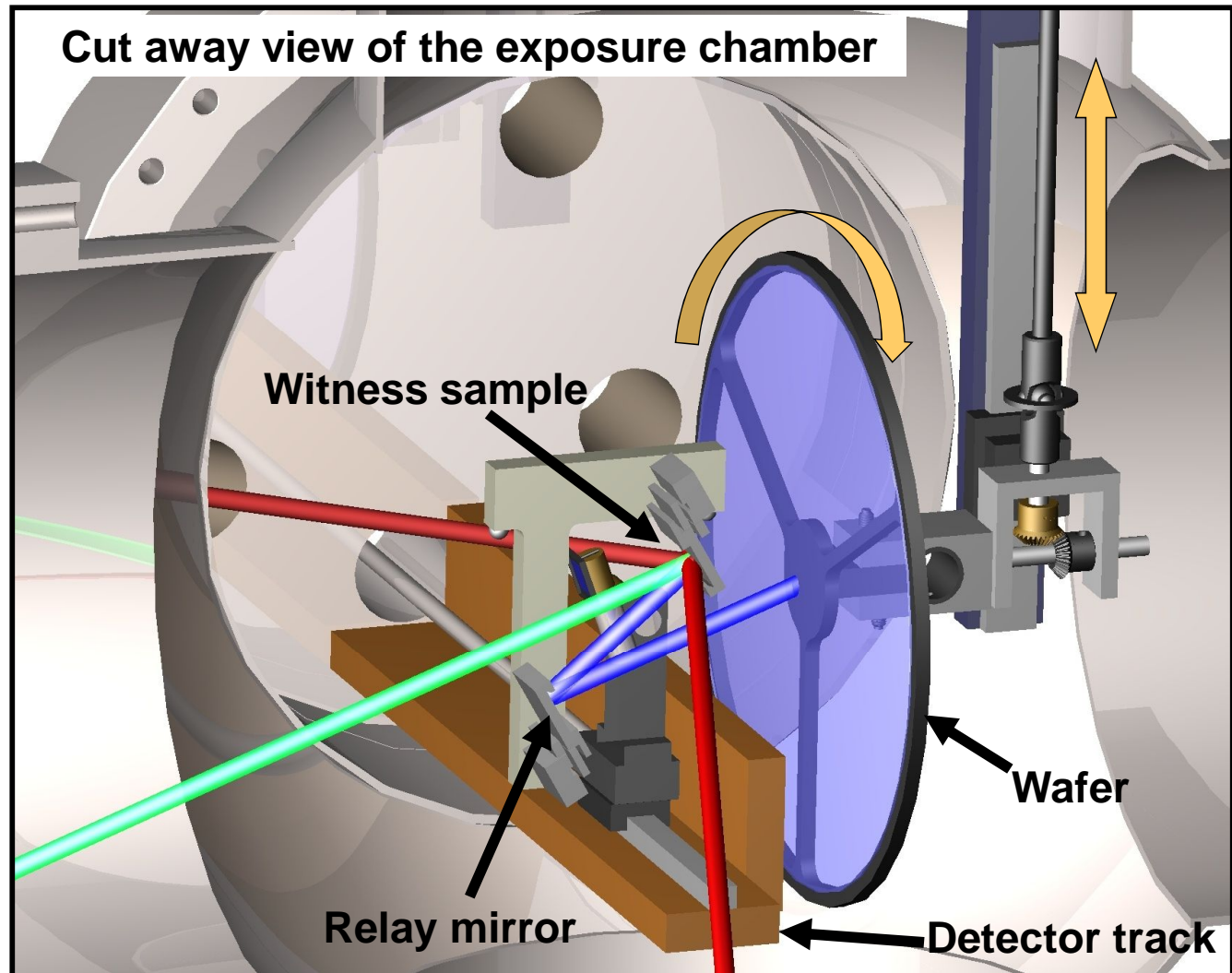
Witness-plate facility (BL-1B)



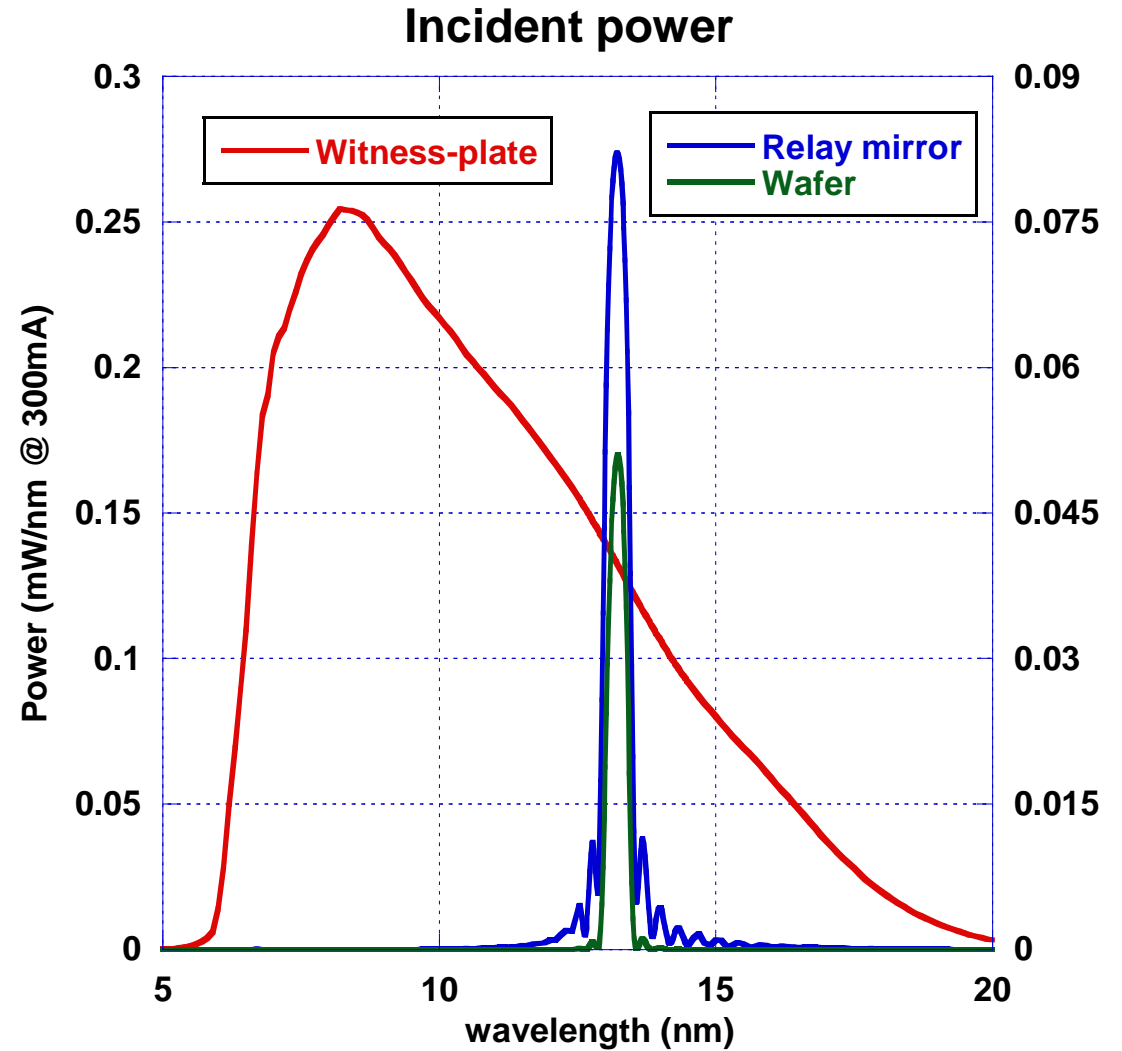
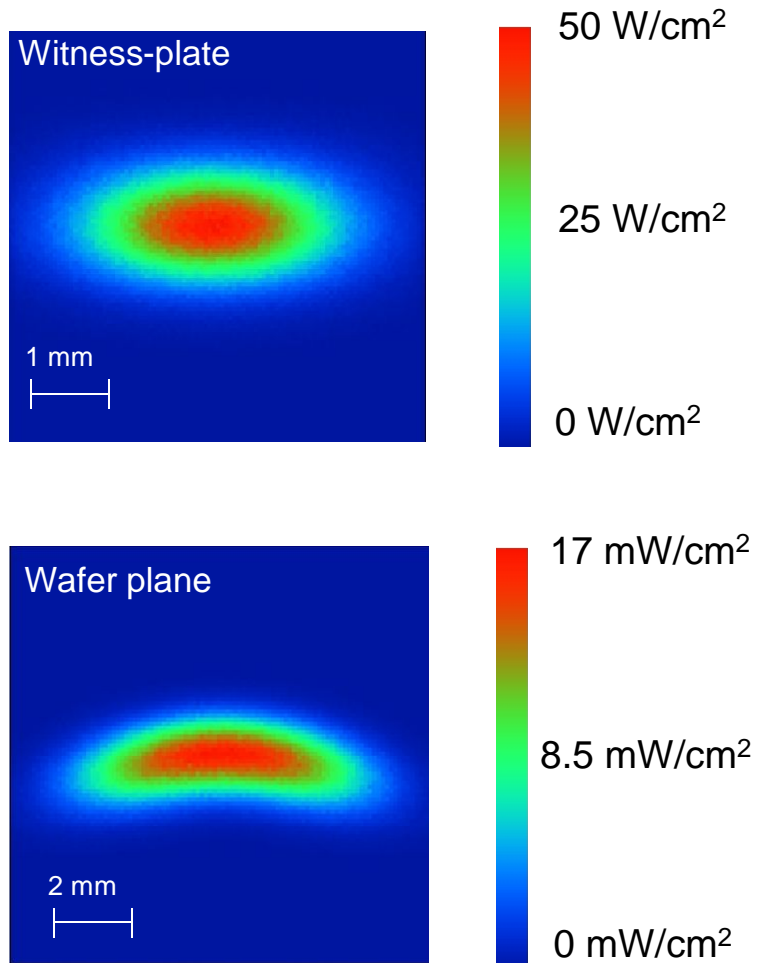
Witness-sample facility (BL-1B)

Witness sample is at intersection of focused EUV beam from synchrotron and NEIS laser beam.

Second mirror of focused beam path relays narrow band EUV to the resist.

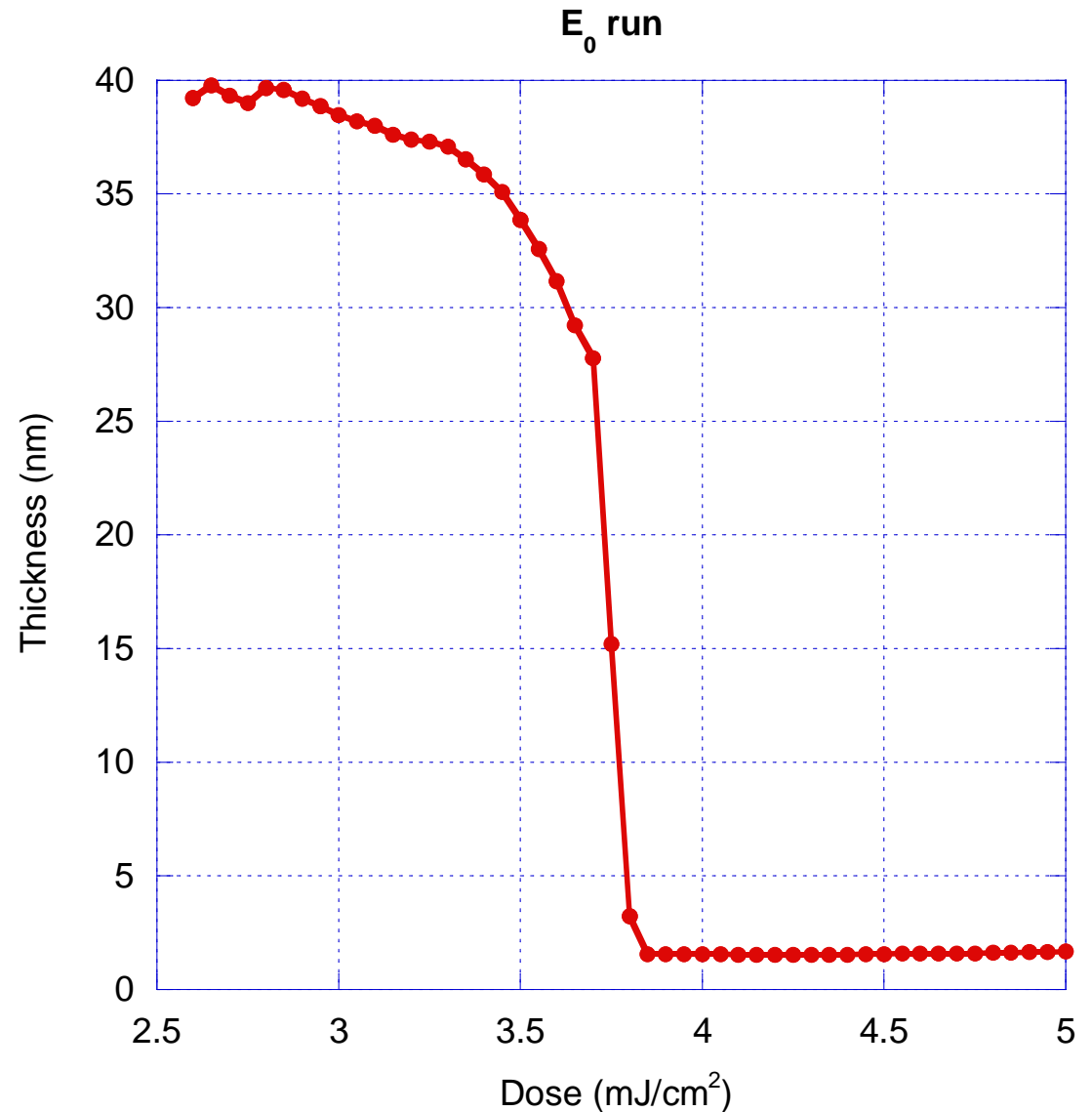


EUV spot and spectra for BL1B witness-plate facility



Dose-to-Clear (E_0) measurement

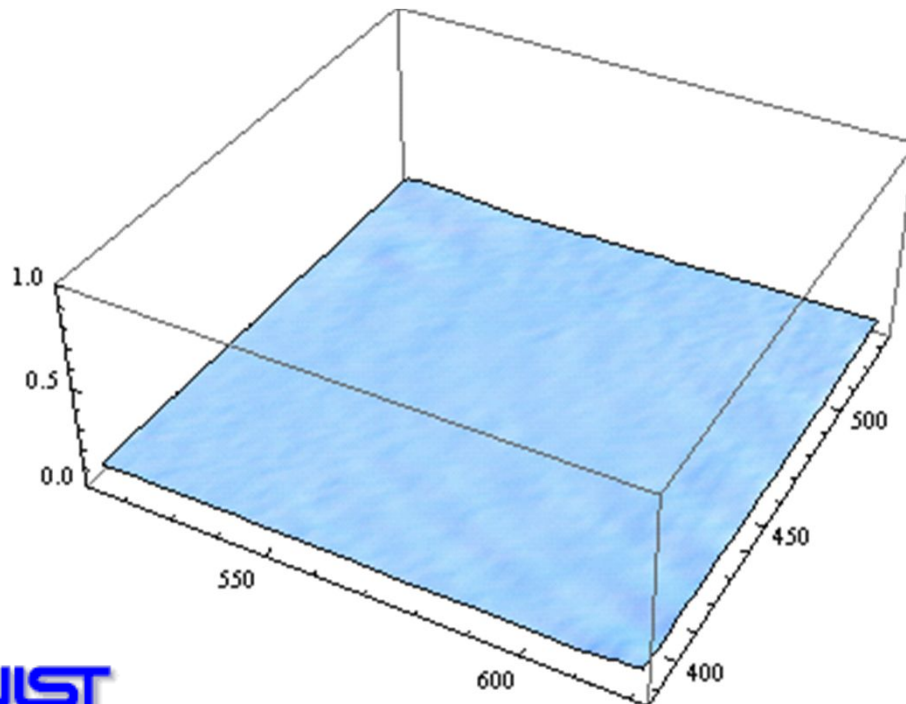
- E_0 measurement necessary for a proper wafer exposure.
- Programmed ramp of dose with turntable action of wafer motion provides simple method for E_0 determination.
- Resist processing and thickness measurement done at NIST Center for Nanoscale Science and Technology (CNST)



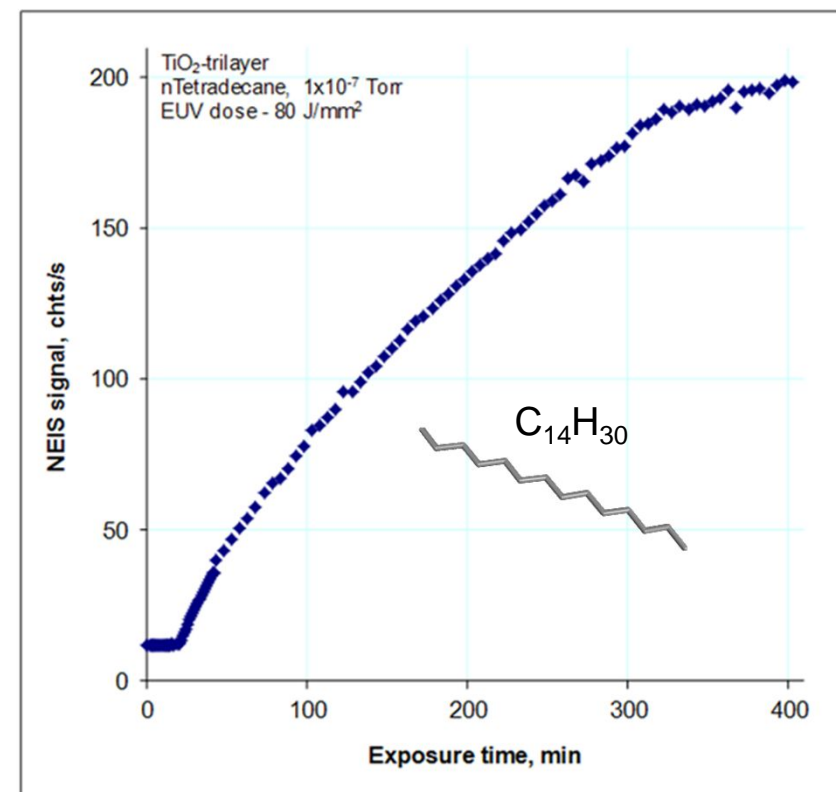
NEIS system provides real-time measurement of carbon contamination

- The null-field ellipsometric imaging system (NEIS) provides a real-time monitor of carbon accumulation on the irradiated sample.
- Can be scaled to absolute thickness with ex situ spectroscopic ellipsometry.
- Sensitive to ~1 monolayer (~0.2 nm) of deposited carbon

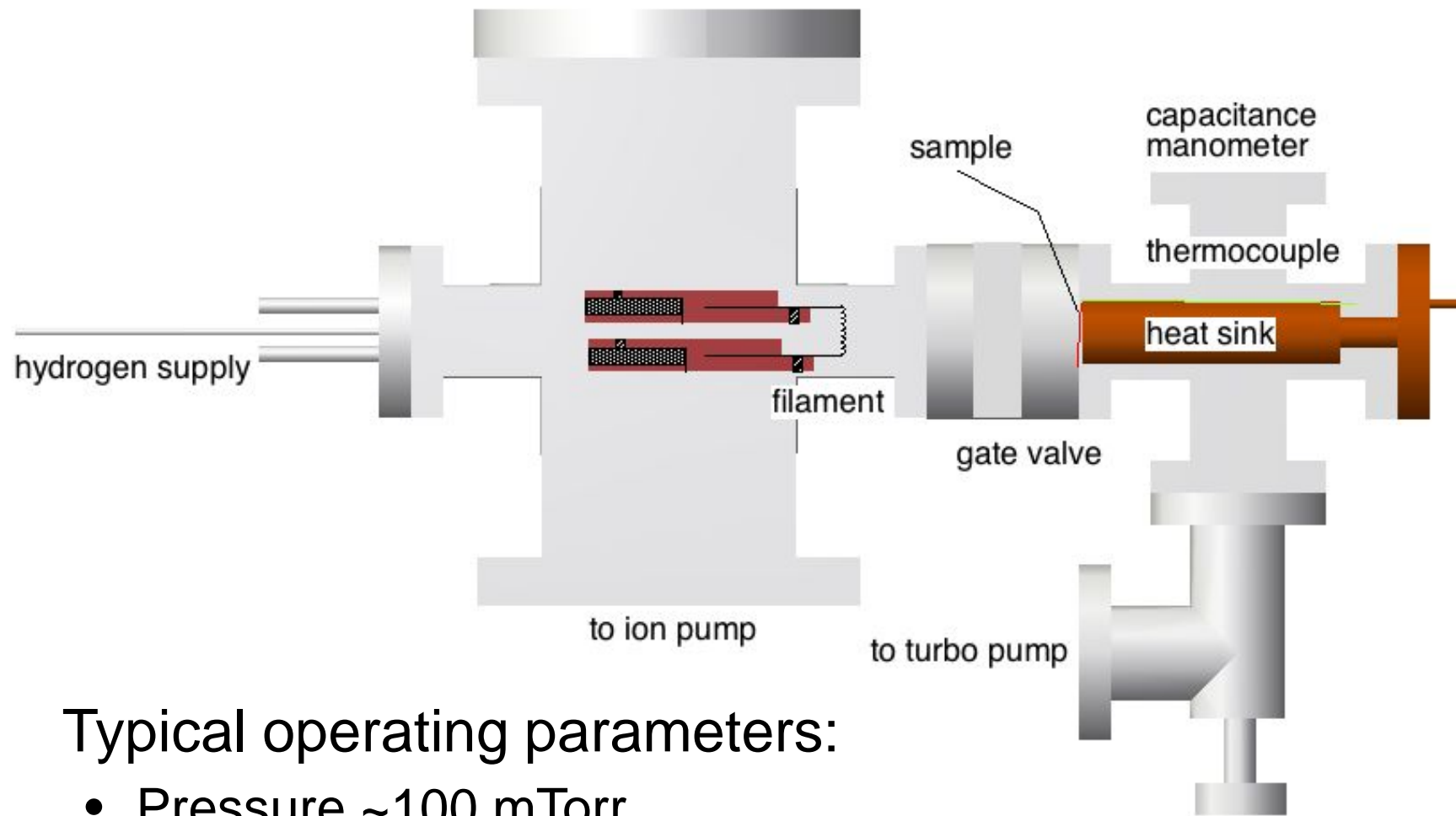
Evolution of exposure spot during EUV irradiation



NEIS signal in center of spot



Atomic hydrogen cleaning system



Typical operating parameters:

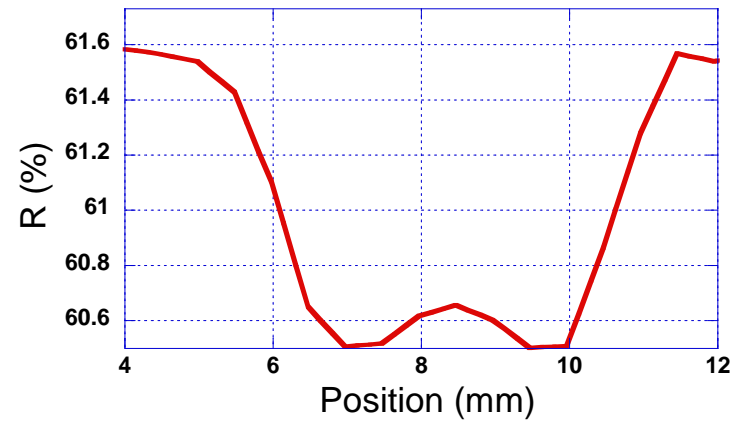
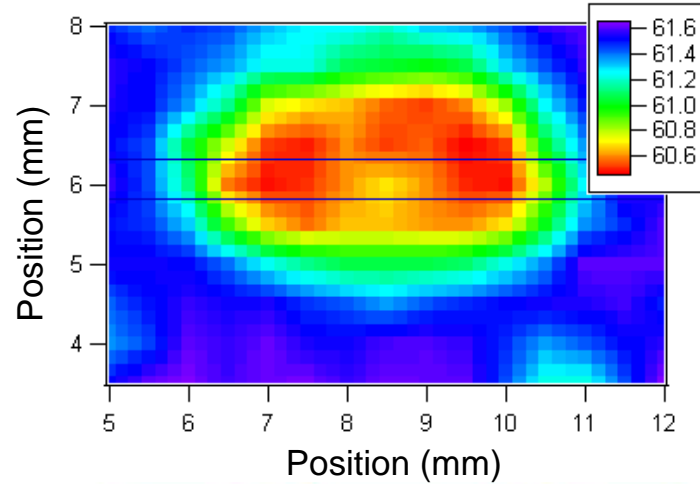
- Pressure ~100 mTorr
- Filament temperature ~2050 °C

Pre- and post- processing facilities for witness-plate testing at NIST

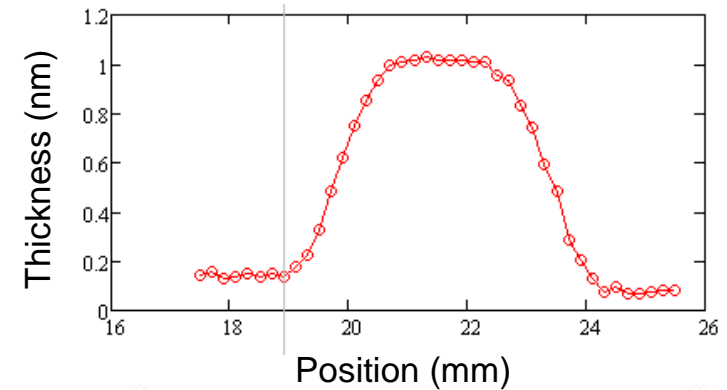
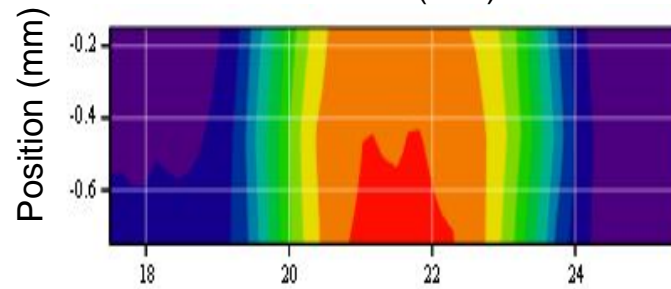
- Atomic hydrogen cleaning facility for pre- and post- exposure cleaning of witness-plates.
- Scanning spectroscopic ellipsometer for evaluation of post-exposure contamination thickness.
- X-ray photoelectron spectroscopy system for post-exposure elemental analysis of contamination from witness-plate test.
- EUV reflectometer available for reflectivity pre- and post- exposure scans of witness plates.

Three types of metrology correlate WS results

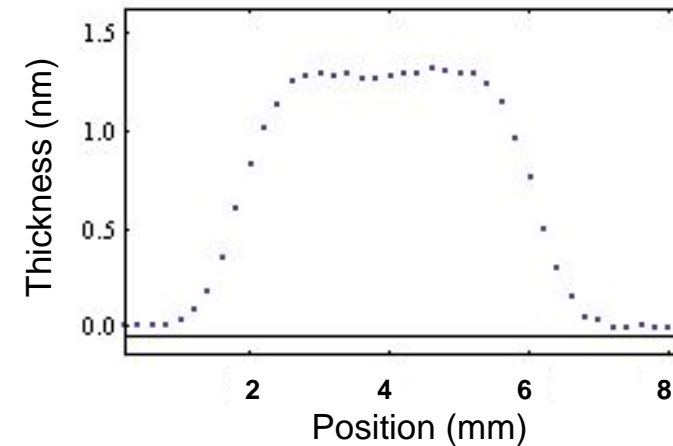
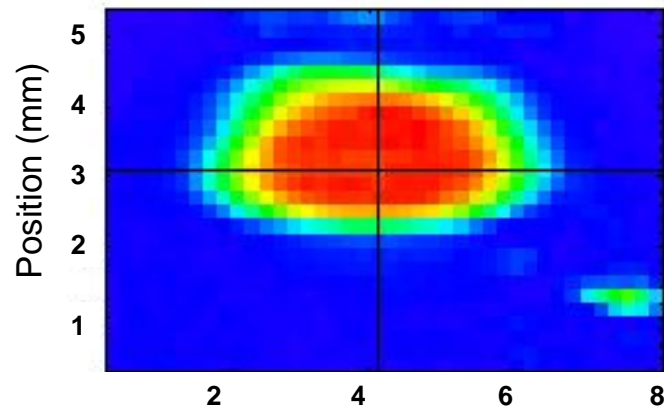
**EUV
Reflectometry**



XPS

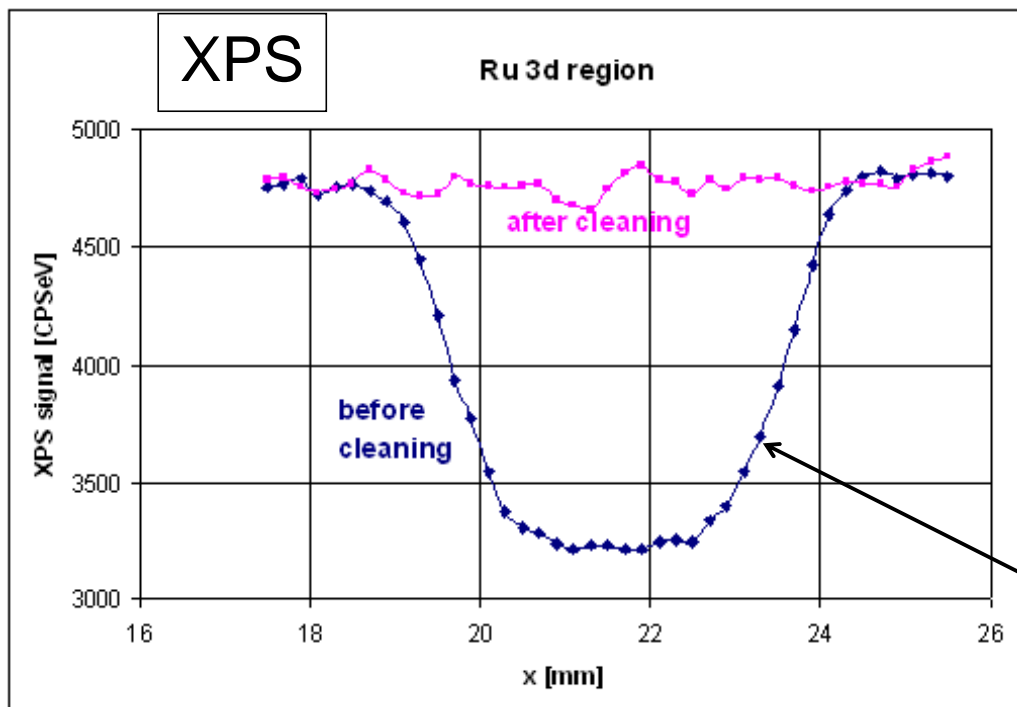


SE

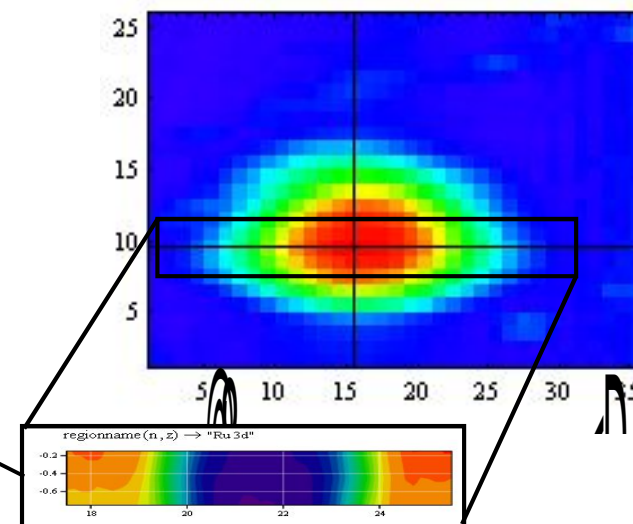


Results before and after AH cleaning

XPS	Elemental composition, at. %						C thickness above bckgr
	Ru3d/C1s	Si 2p	Mo 3d	O 1s	S 2p	Cl 2p	Δt_c , nm
Post-cleaning C spot background	47.2	11.3	2.5	37.9		1.0	-0.1
	46.5	10.9	2.5	39.0		1.1	
Pre-cleaning C spot background	54.9	9.3	3.1	30.5	2.2		0.9
	56.7	9.4	3.3	30.7			



Spectroscopic ellipsometry after EUV exposure & *before* cleaning

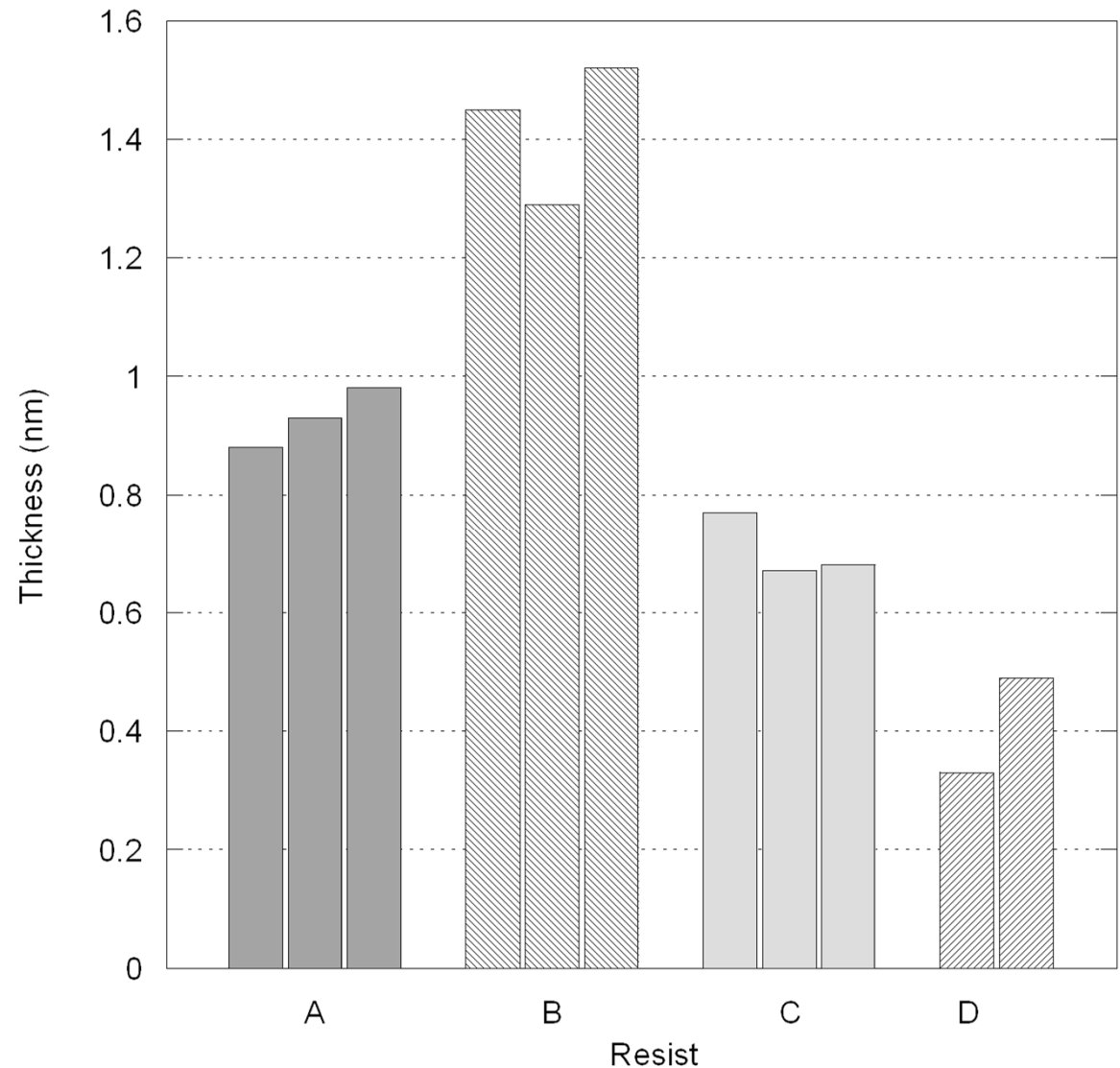


XPS after EUV exposure & *before* cleaning

Witness plate results show acceptable reproducibility

4 resists for qualification tests:

- Repeatability adequate for qualification purposes.
- Rates varied over a factor of three from the least to the most contaminating.
- No elements other than carbon detected above the ~ 1% atomic concentration level.



Summary

- NIST has constructed a witness plate testing facility meeting the requirements for resist outgas testing for the ASML NXE tools.
- *In situ* ellipsometric imaging provides the first real-time measurement of evolution of contaminant across EUV intensity distribution.
- On-site wafer processing, XPS analysis, and spectroscopic ellipsometry measurements
- EUV reflectometry also available on site for possible correlation study
- The NIST facility has begun to provide testing for resist developers.
- Multiple tests on several resists show good repeatability with sufficient process control.