EUV Resist Outgassing Testing Based on Contamination of Mo/Si Witness Plates

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Outline

- EUV Resist Outgassing and eXposure (ROX) system
- EUV resist outgassing results with a mass spectrometer
- EUV resist outgassing results due to pumping (not due to EUV exposure)
- Method to measure "sticking coefficient" of outgassed species to help determine which species may contaminate optics
- Witness plate experiments for resist outgassing measurements
  - Challenges with silicon-capped mirrors
  - Chamber cleaning results with glow discharge plasma to reduce amount of contamination due to vacuum chamber
- Proposed test to improve signal-to-noise of witness plate outgassing measurements
- Preliminary results from injection of known resist outgassing species and effect on contamination rate of mirrors during exposure

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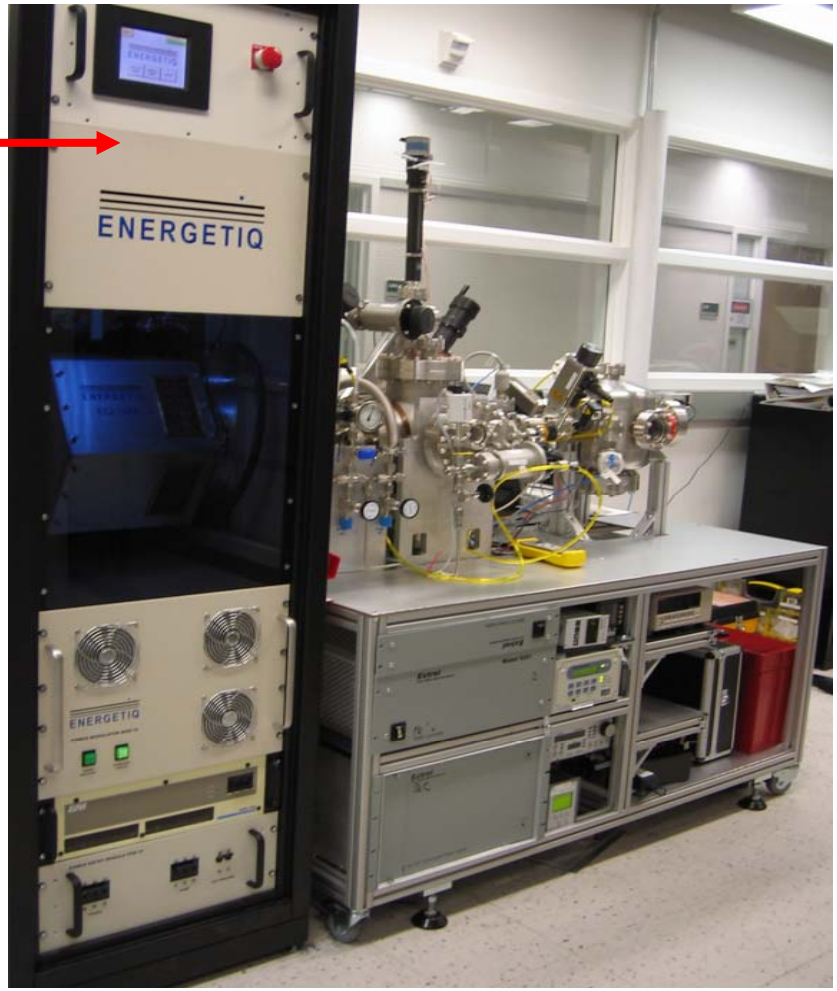
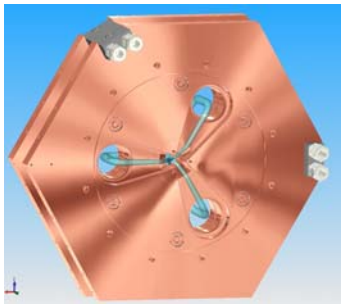
EUV ROX
Extreme Ultra Violet Resist Outgassing and eXposure

EUV ROX System is in Operation (EUV Resist Outgassing and eXposure)

10W electrodeless Xe source from Energetiq

- Based on Z-pinch technology
- Plasma size of ~350 microns





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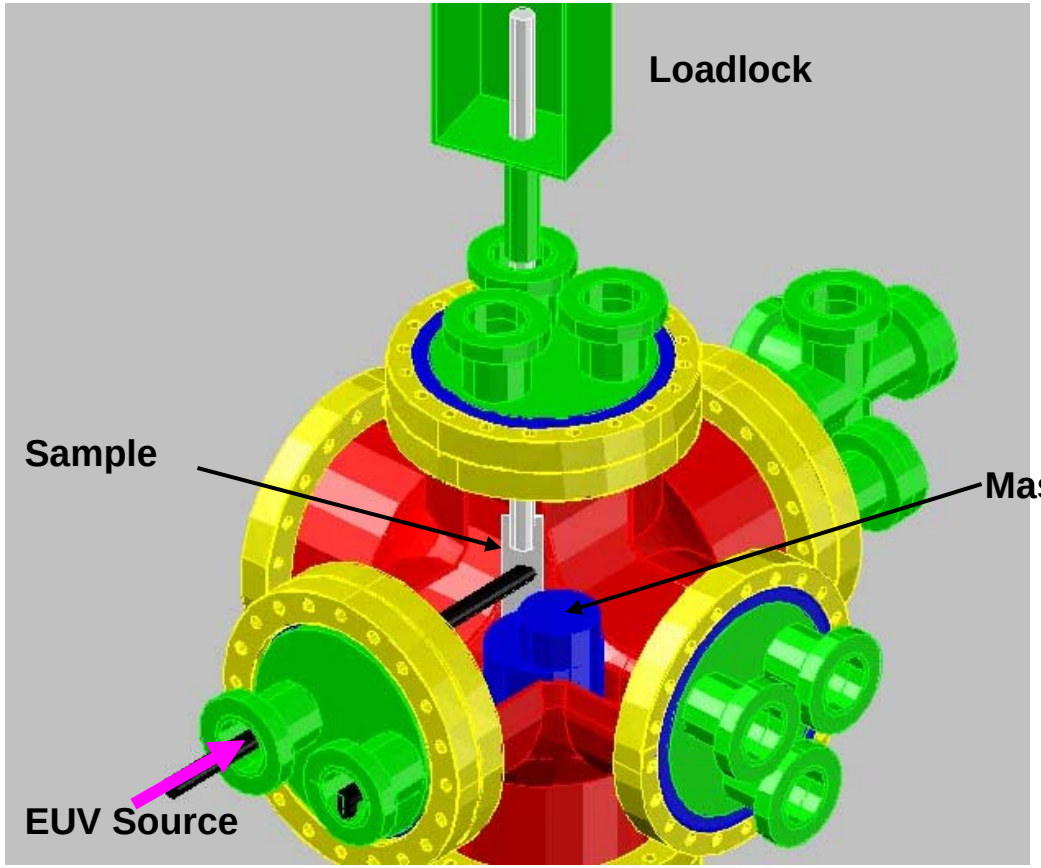
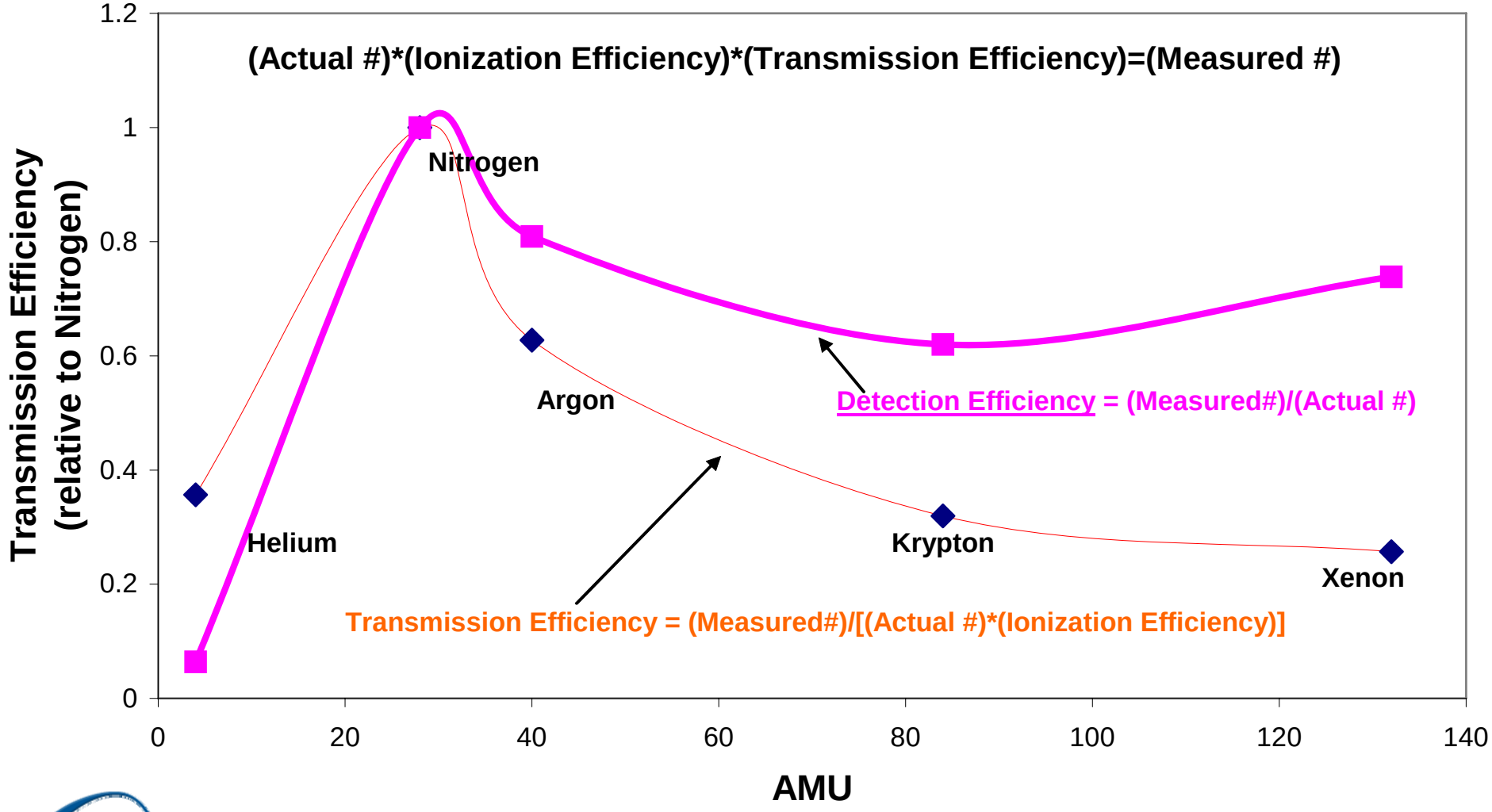
EUV ROX System



Mass Spectrometer Calibration Across the Mass Range

Detection Efficiency is within a factor of 2 for all masses measured (except Helium)



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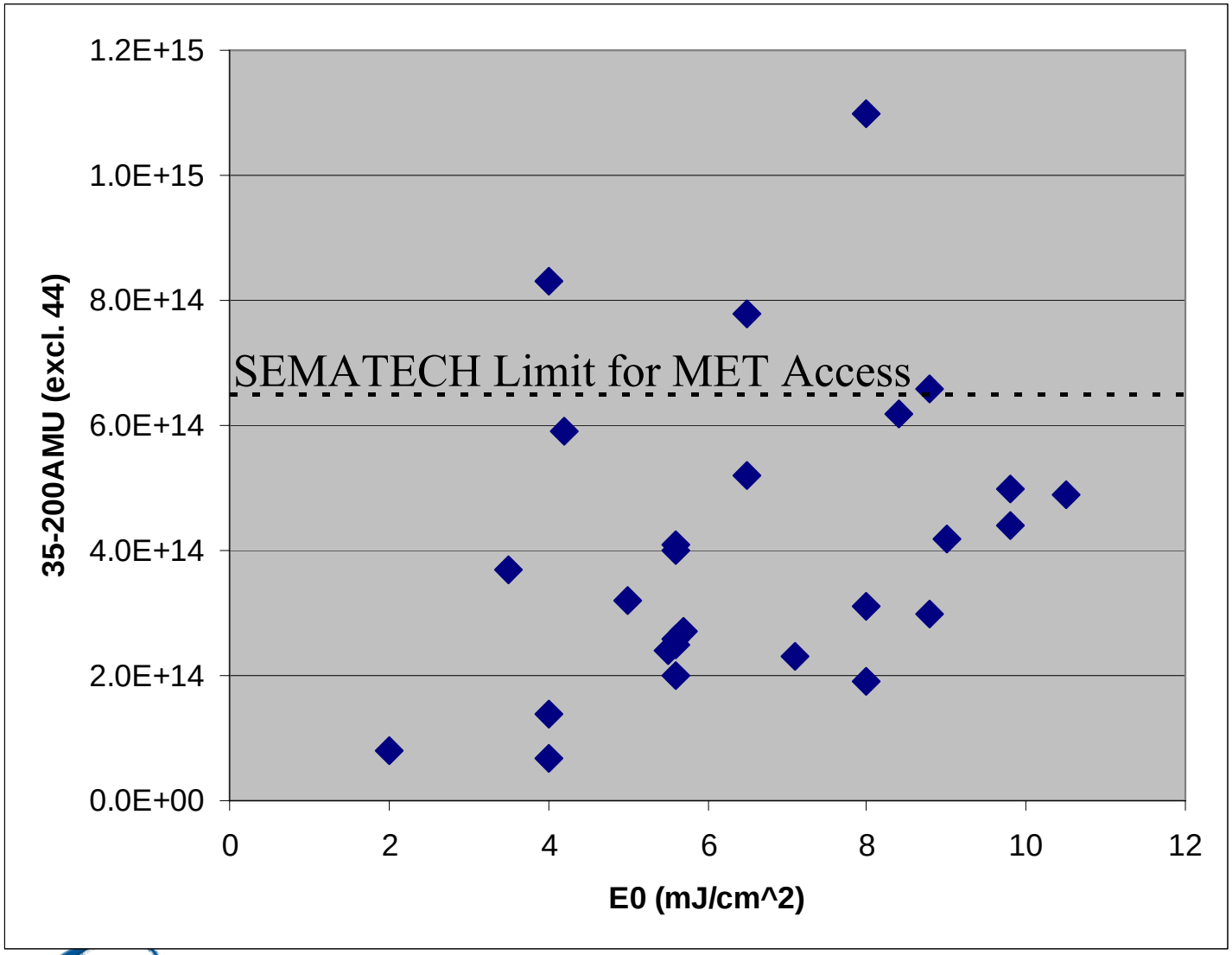
E0 vs. Outgassing – Faster Resists are Better



- Previous measurements showed that lower dose gives lower outgassing for the SAME resist
- This data indicates that as resist formulations are made faster, they are not being done at the expense of outgassing

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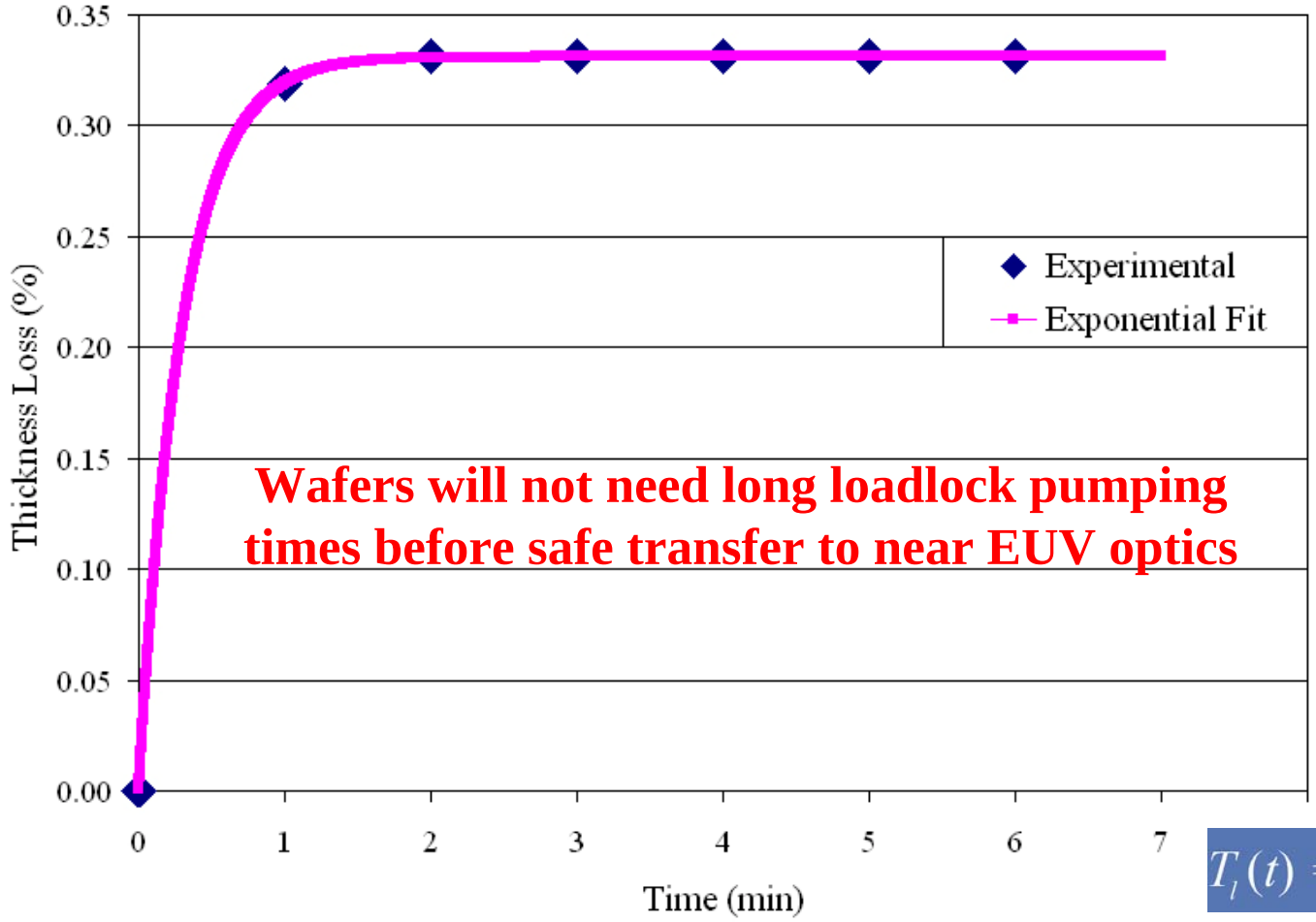
Resist Outgassing Due to Vacuum (not exposure)
How long to pump prior to moving wafer near optics?

Typical quartz crystal microbalance (QCM) outgassing test

PMMA resist

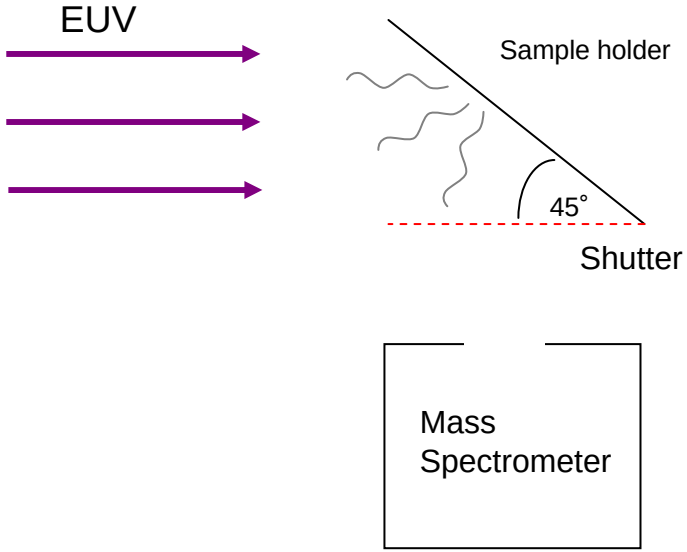


$$T_l(t) = T_{l_{final}}(1 - e^{-t/\tau})$$

Measurement of "Sticking Coefficient" for Outgassed Species

Signal on mass spectrometer comprises both molecules outgassed directly to mass spectrometer and those that bounce off the chamber walls and then enter the mass spectrometer

Measurements of the ratio of each indicate which species do not bounce off vacuum chamber surfaces – and any species that stick to a surface/mirror are of greater concern



Uses a shutter to either pass or block molecules outgassed directly to the mass spectrometer

This measures the likelihood of species to bounce around the chamber and be detected indirectly

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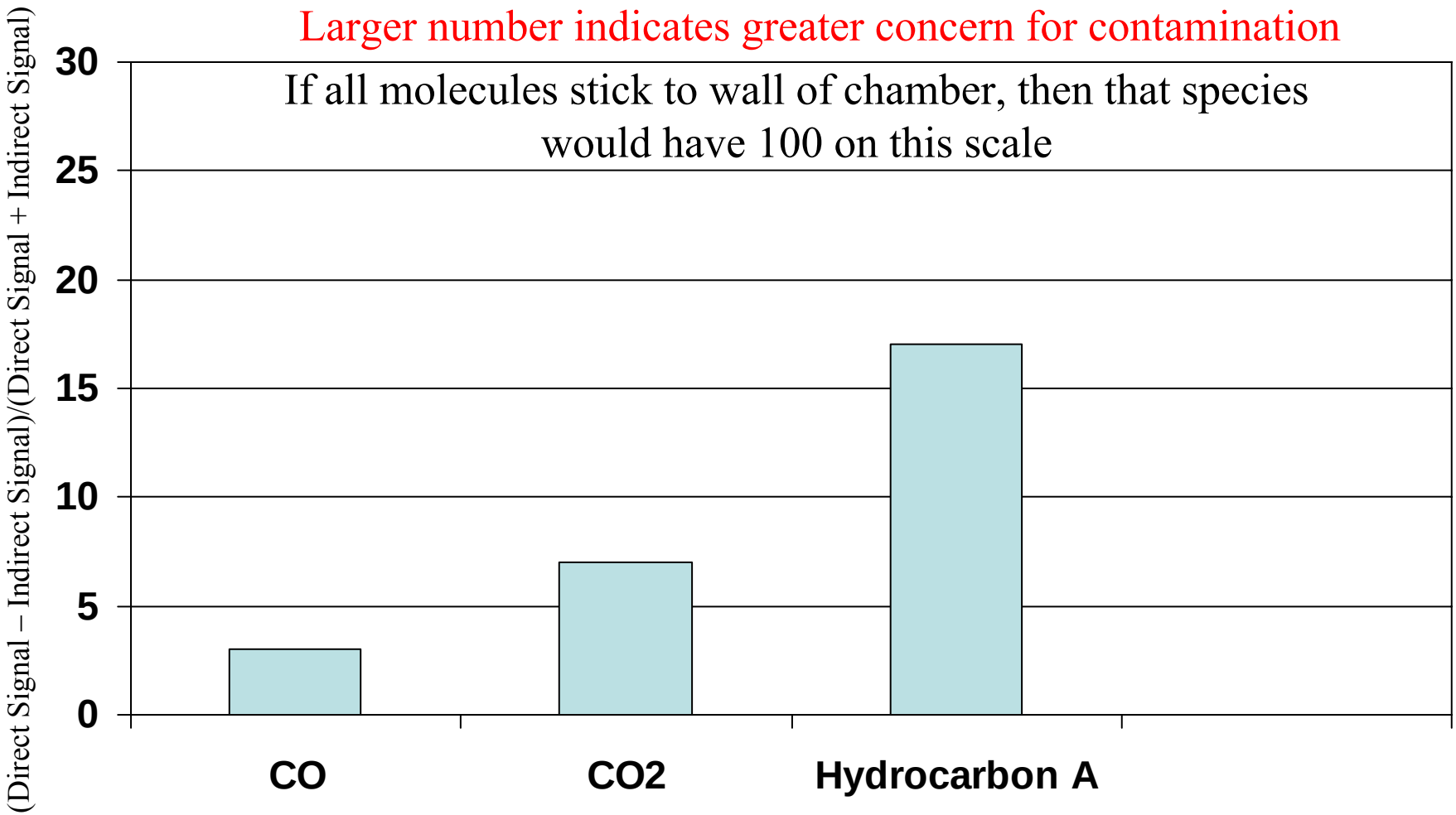
Results for "Sticking Coefficient" for Selected Species



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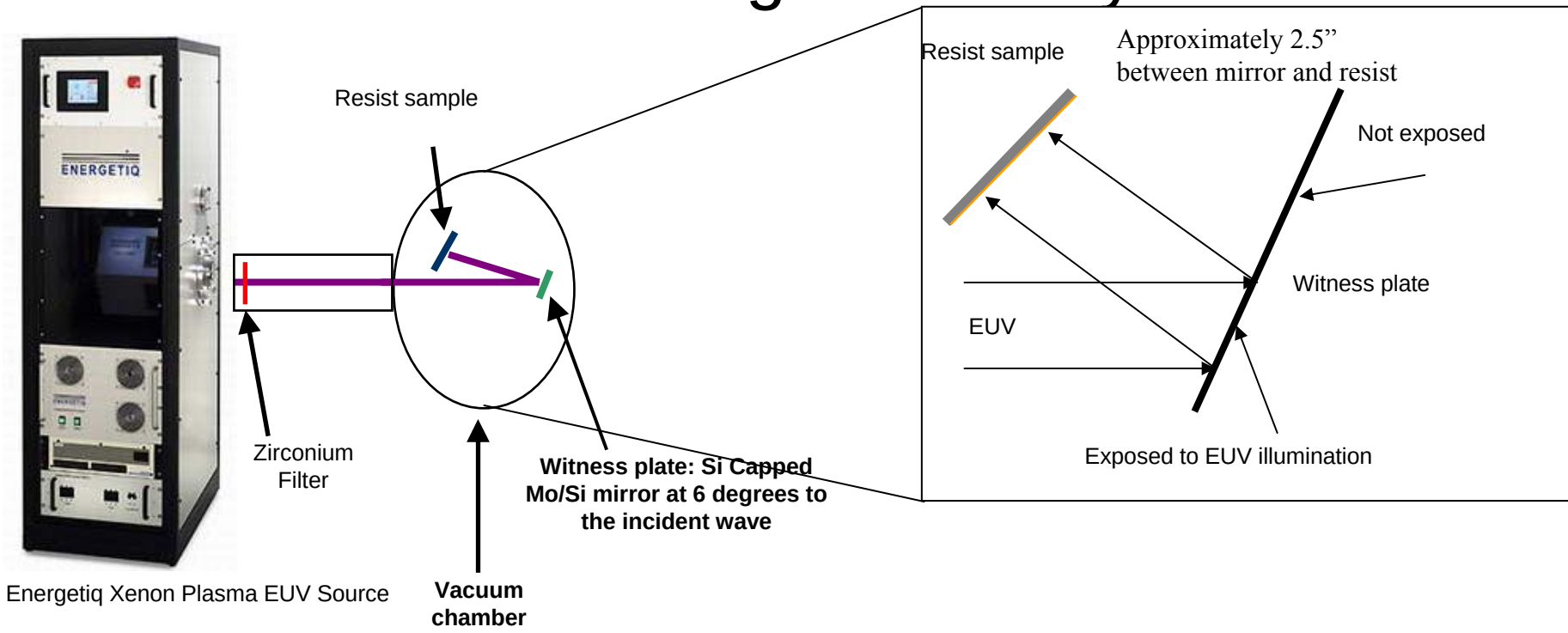
Witness Plate Experimental Configuration for Resist Testing – First Try…



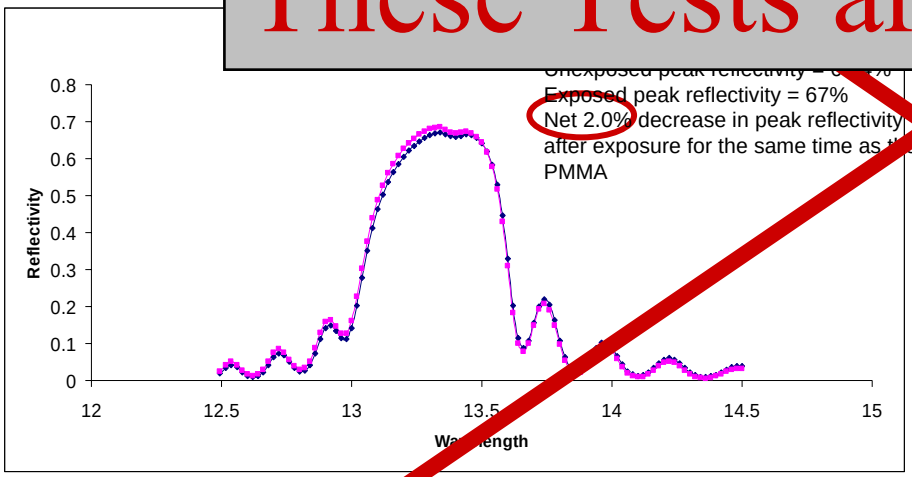
- ASML proposed a test to expose 300 mm wafers worth of resist
  - If reflectivity loss per wafer exposed is ≤ 2%, the resist is safe for use

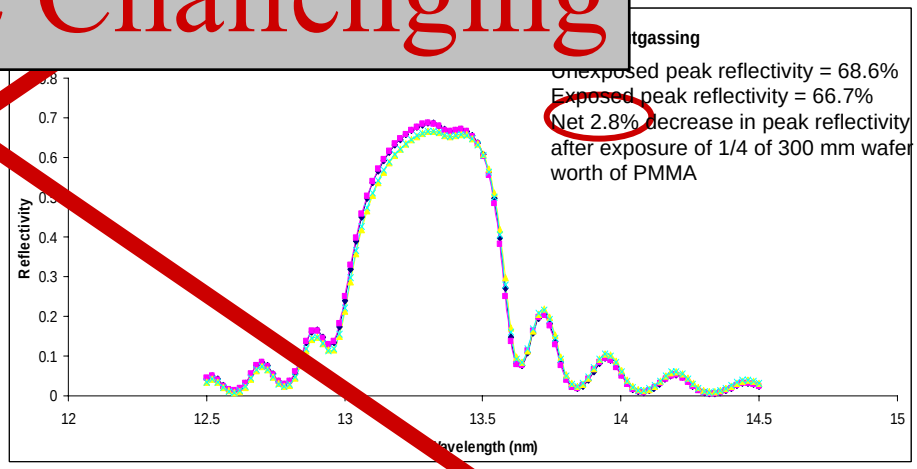
Reflectivity Measurements

Resist	Reflectivity Loss	Control Reflectivity loss	Net reflectivity per 300 mm wafer exposed
PMMA	2.8	2	3.2
High Outgasser (IBM)			
Low Ea (KrF)			
High/Low Ea(KrF)			

GOING

These Tests are Challenging





Net peak reflectivity loss due to ¼ of a 300 mm wafer is 0.8%; therefore, on extrapolating to a full 300 mm wafer PMMA, the peak reflectivity loss is 3.2%

Reflectivity Measurements from Eric Gullikson (CXRO), Steve Grantham (NIST), and Charles Tarrio (NIST)

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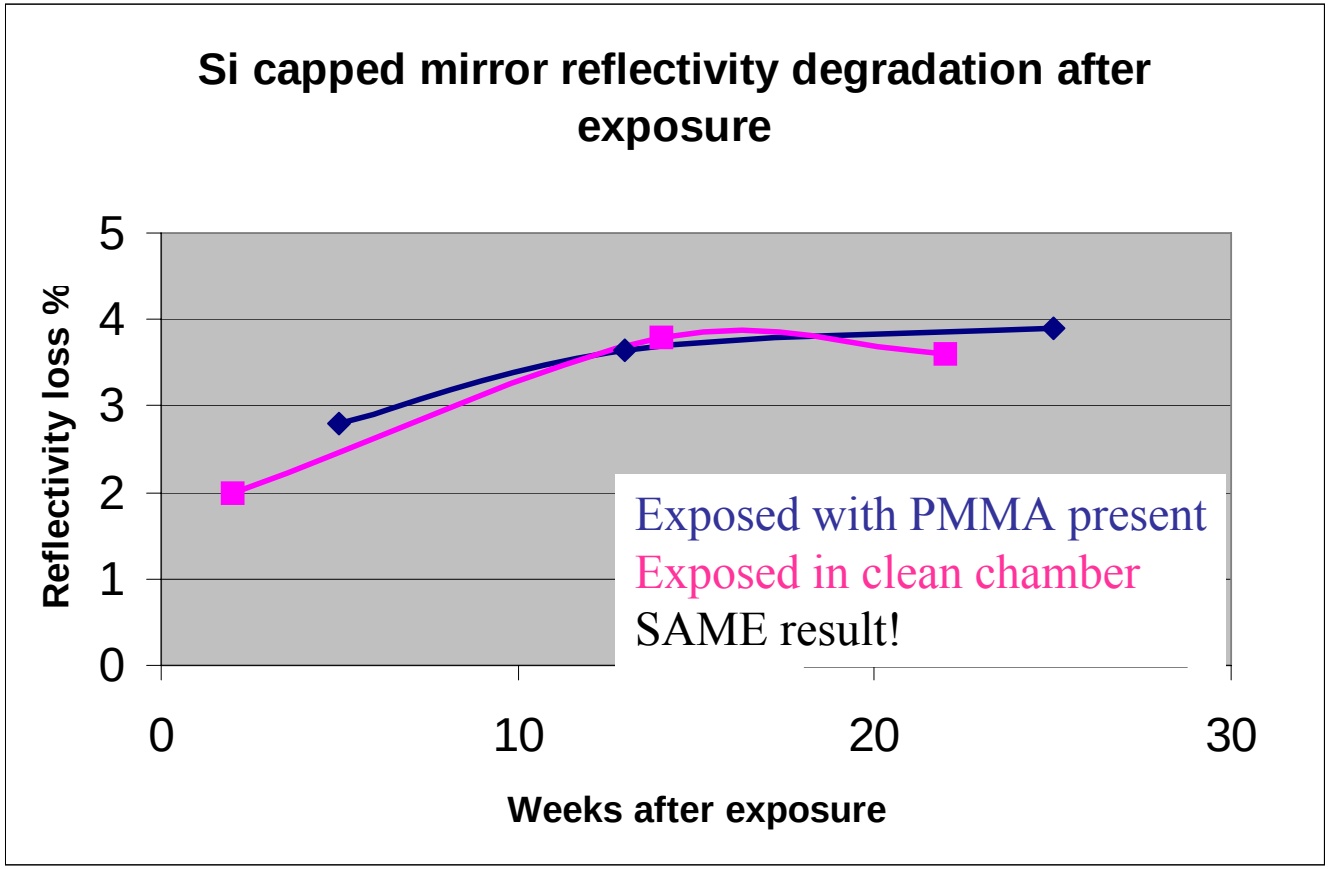
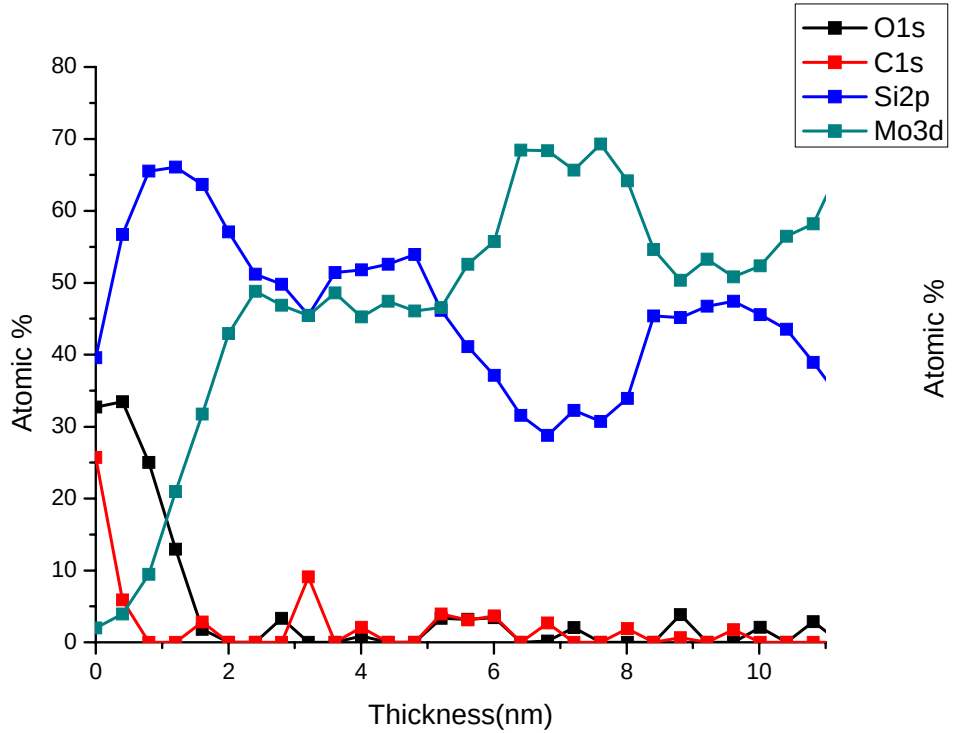
Why Not to Use Silicon-capped Mirrors…



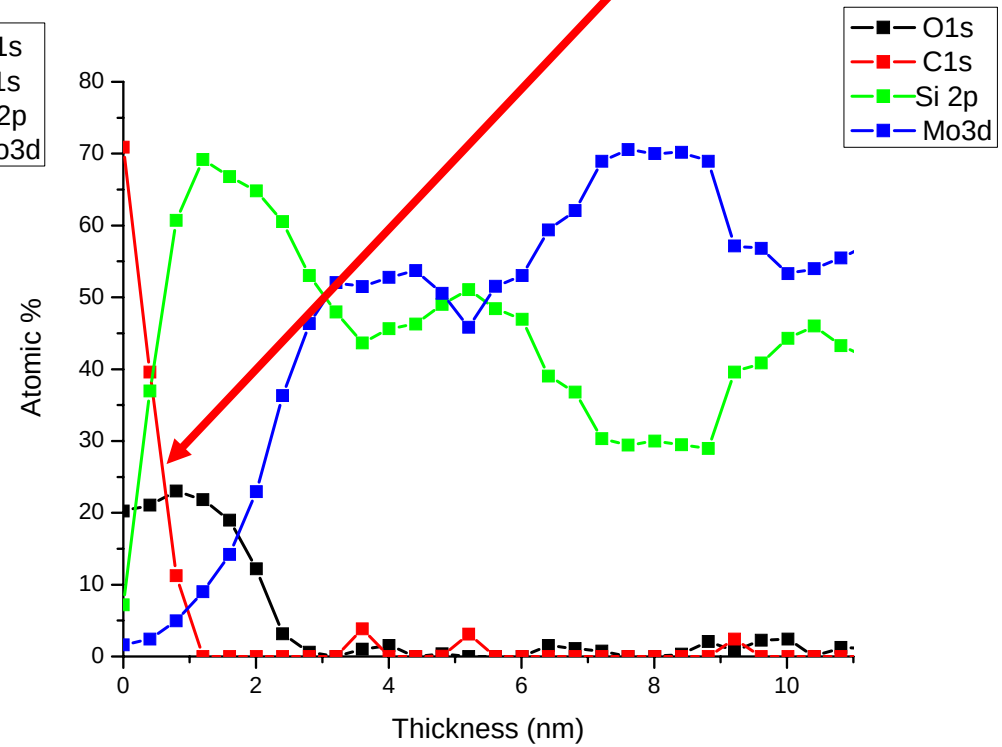
- No difference between resist and control sample
- Need cleaner chamber
- Silicon is a poor choice for capping layer; Ru appears to be better

After Exposure and Reflectivity Loss, XPS Shows Primarily Carbon

Unexposed Witness Plate

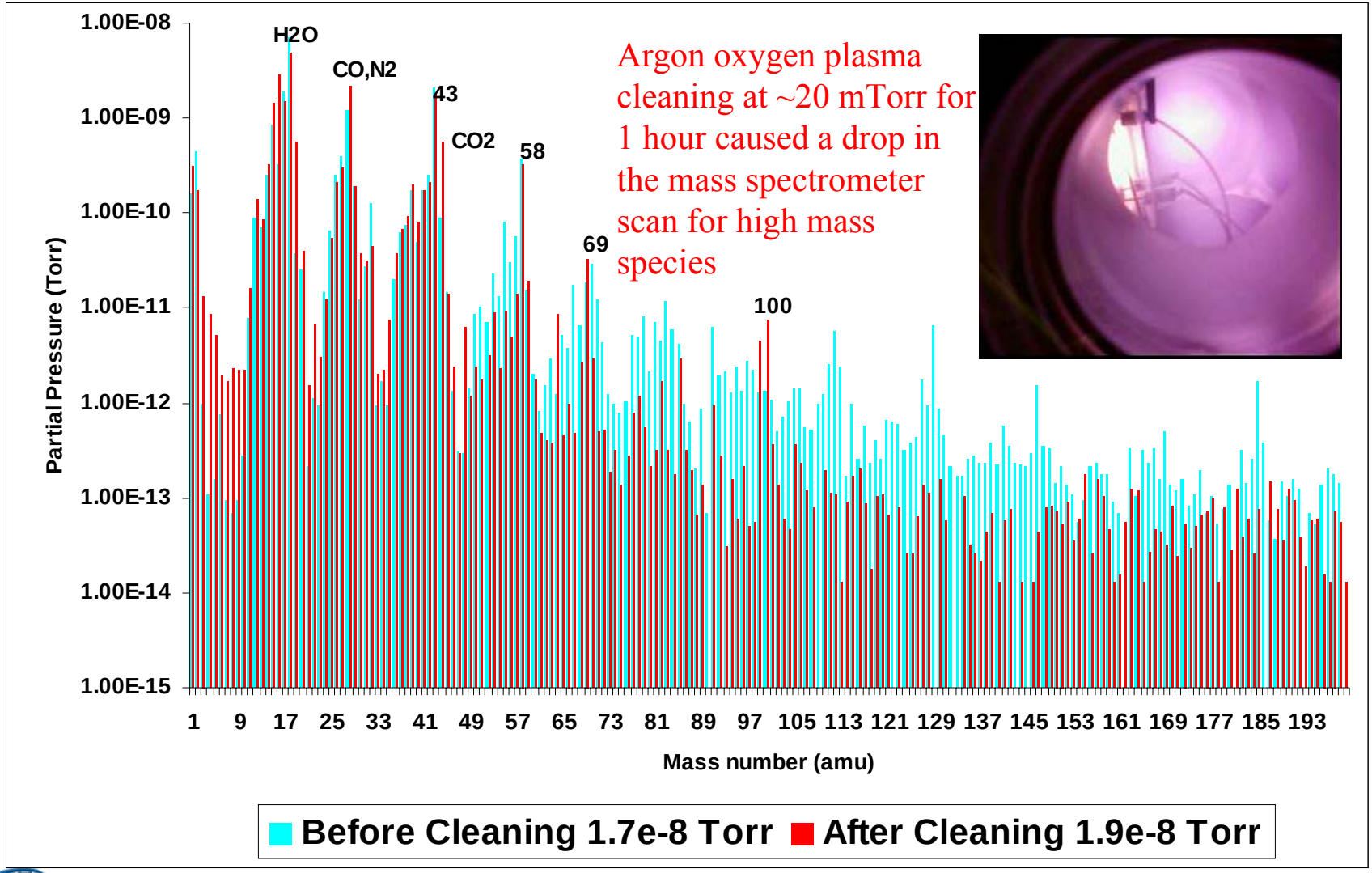


Exposed Witness Plate
Shows primarily an increase in carbon



XPS with sputtering to look at materials through sample thickness

Glow Discharge Plasma Chamber Cleaning



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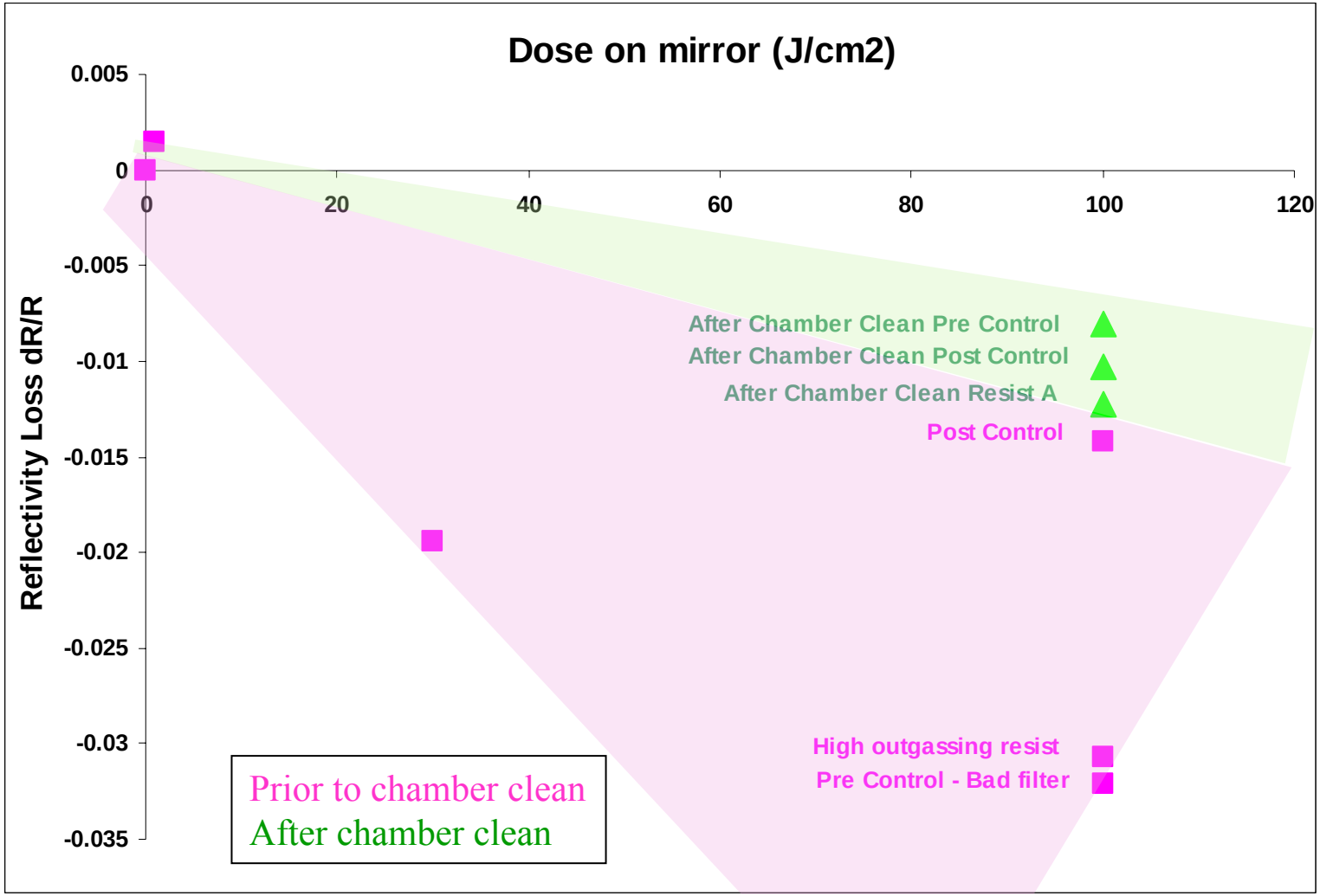
Witness Plate and Control Mirror Results

- Before chamber cleaning, there were large reflectivity losses and a wide spread in results
- After chamber cleaning, the results were improved
- The effect of the resist was subtle compared to chamber effects



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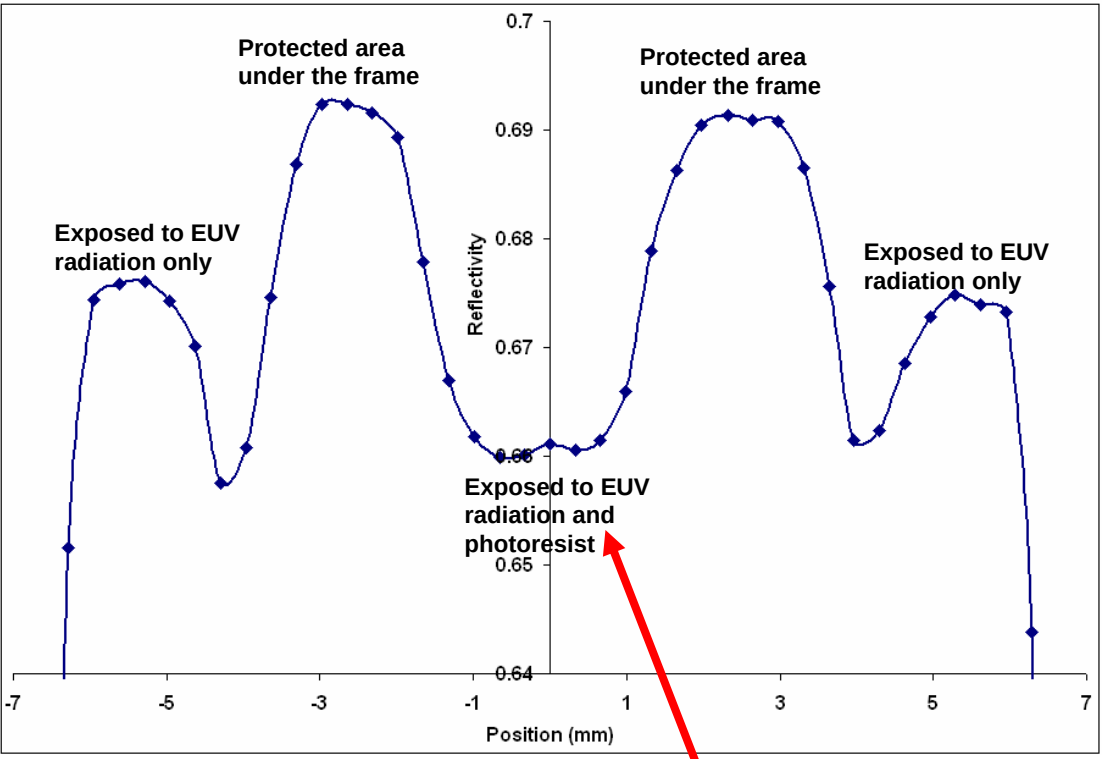
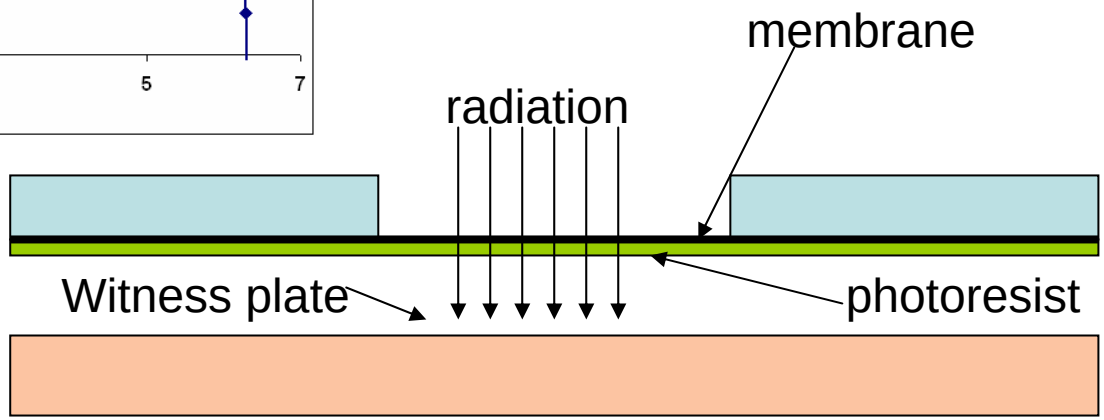
Proposed Faster Witness Plate Test



To get contamination:

1. **A molecule must outgas from resist**
2. **Then hit the mirror**
3. **Then be present on the mirror when photons arrive**
4. **Then interact with photons or electrons to break bonds in the molecule to leave carbon**

This adds up to a low probability and small signals on witness plate tests



Results of first tests show effect of resist on mirror contamination
More resists to follow

Contamination Studies of Injected Species

- We have directly injected a few species known to be outgassed by resist at high concentrations of approximately $1x10^{-5}$ Torr
- Then, we exposed a mirror to 100 J/cm^2 in this high hydrocarbon environment
- We have seen typical results of approximately 1% reflectivity loss
  - This is the same as for the "clean" $1x10^{-8}$ Torr chamber

We have yet to identify any of the outgassed species from resist that contribute significantly to optics contamination!

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Conclusions

- Outgassing with a mass spectrometer works routinely
  - However, without an understanding of which species are likely to contaminate optics, interpretation of the results for each resist is a challenge
    - The "sticking coefficient" measurement or the direct injection of known outgassed species may help with understanding and interpretation of these results
- Resist outgassing in vacuum takes place in a time scale of about one minute, so wafers do not need long loadlock times before insertion into exposure tools
- Witness plate work will provide a more direct understanding of the danger of each resist to the optics
  - However, the current test has a low signal from the resist and a relatively high level of contamination due to the chamber – so it is slow and challenging
- There may be better ways to do witness plate testing with higher signals – like the membrane method proposed here
- The hydrocarbon species injected into the system directly (so far) do not show large contamination

- **Does the resist cause optics contamination at a measurable level?**

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