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Challenges in development and construction of metrology, calibration, and resist testing tools for the implementation of EUV lithography

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The EUV Technology Team

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About EUV Technology

- Pioneered the development of stand alone EUV Metrology Tools (in 1999)
- EUV Refelectometer Model No. LPR1016-FS1515 was selected by the R&D Magazine as the 100 Most Technologically Significant New Products of the year 2005.
- Two key products;
  - EUV Reflectometer
  - EUV Resist Outgassing tool

Challenges in developing tools

- Low volume
- Specifications are still evolving.
- Custom designs
- Particle issues
  - Detecting >60 nm particles.
  - No data for most of the 3rd party products.

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EUV Reflectometer

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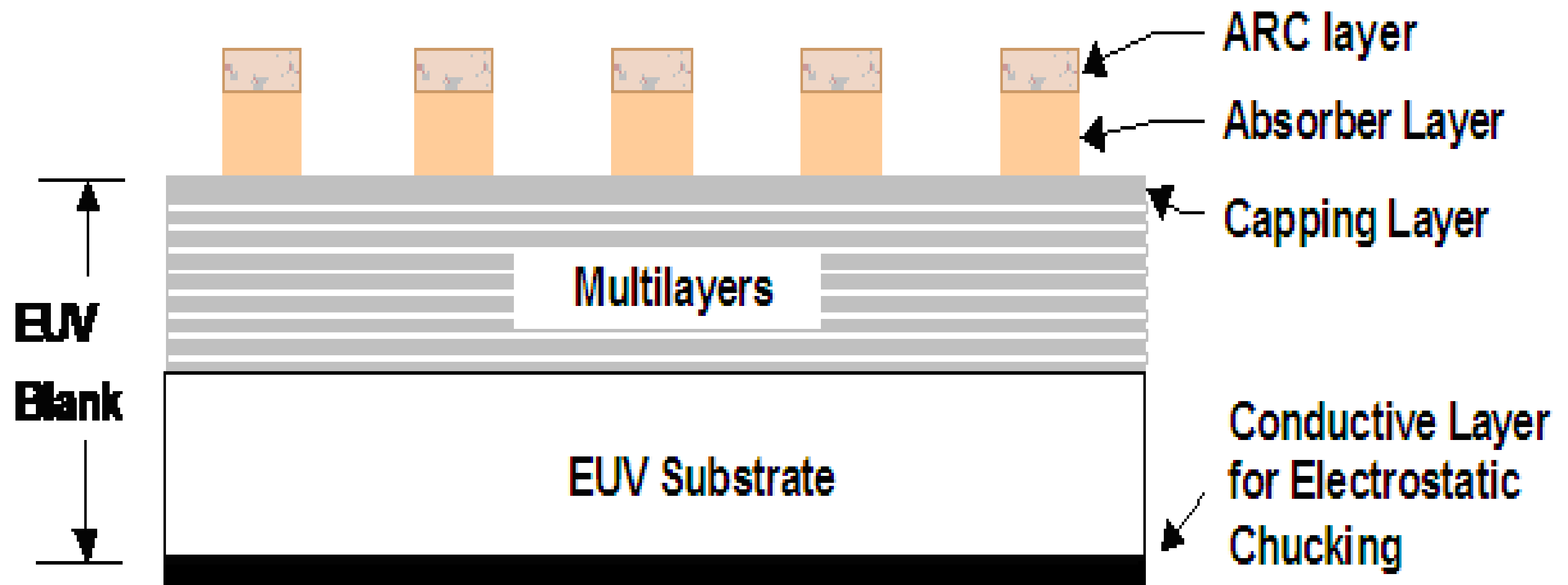
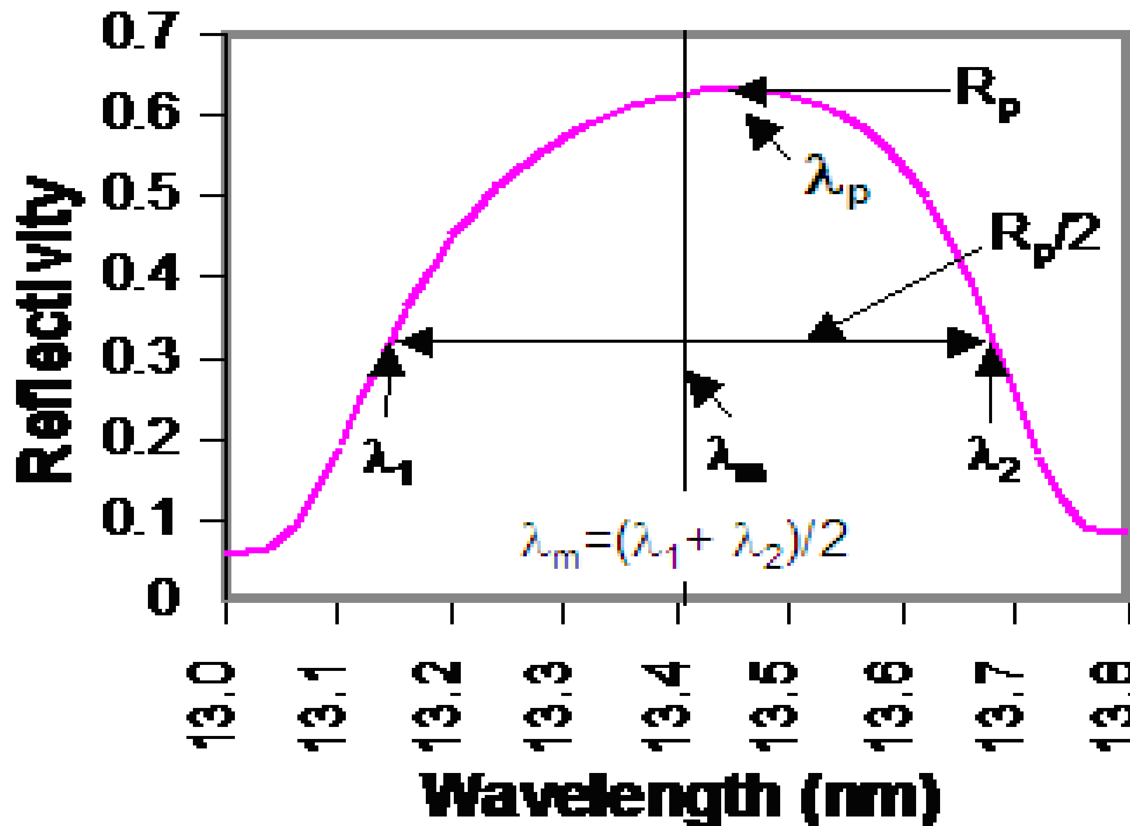
Cross section schematic of an EUVL Mask: 5 layers



Definition of peak EUV reflectivity (R_p) and median wavelength (λ_m).



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Side view of the tool

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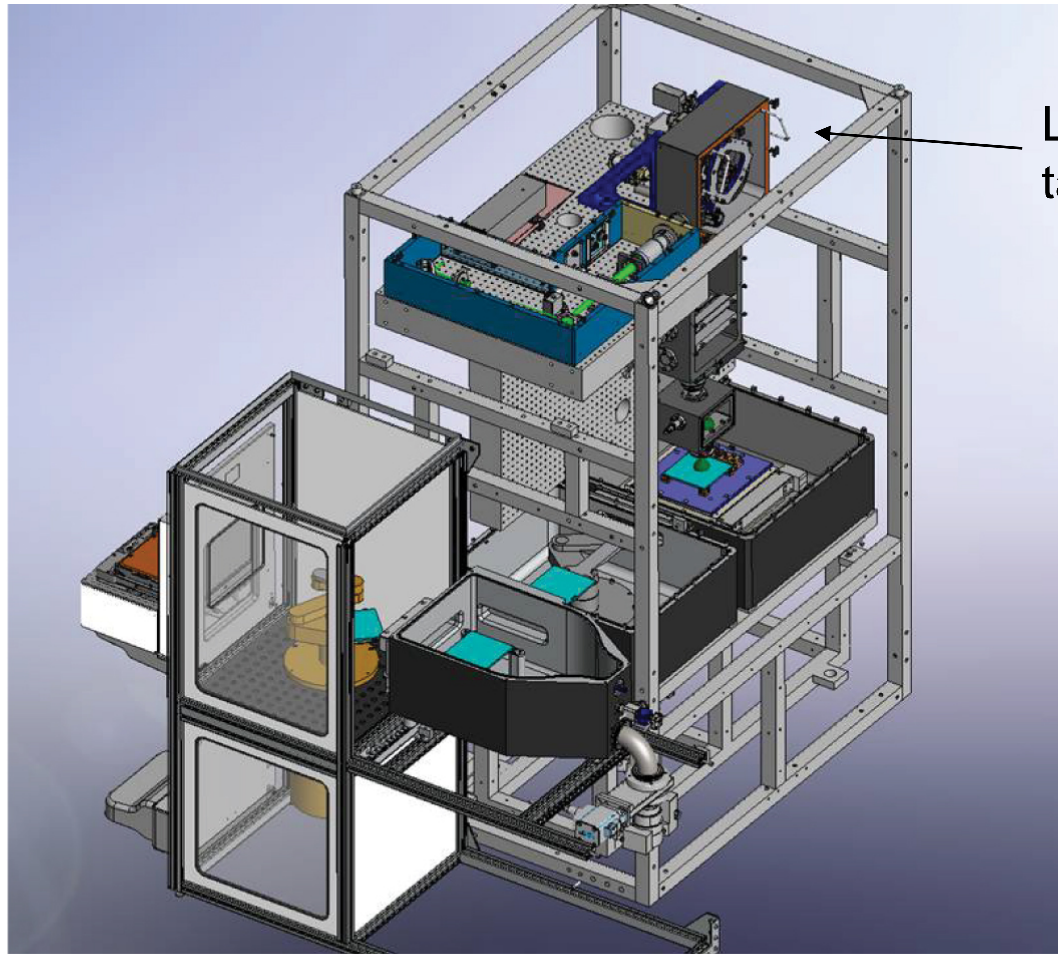
EUV Reflectometer



LPP source. Cu target 5 to 20 nm

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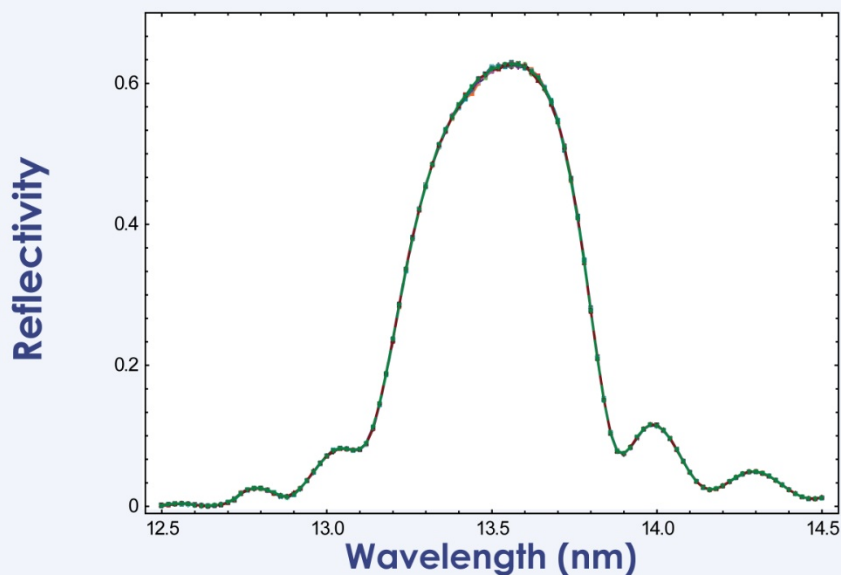
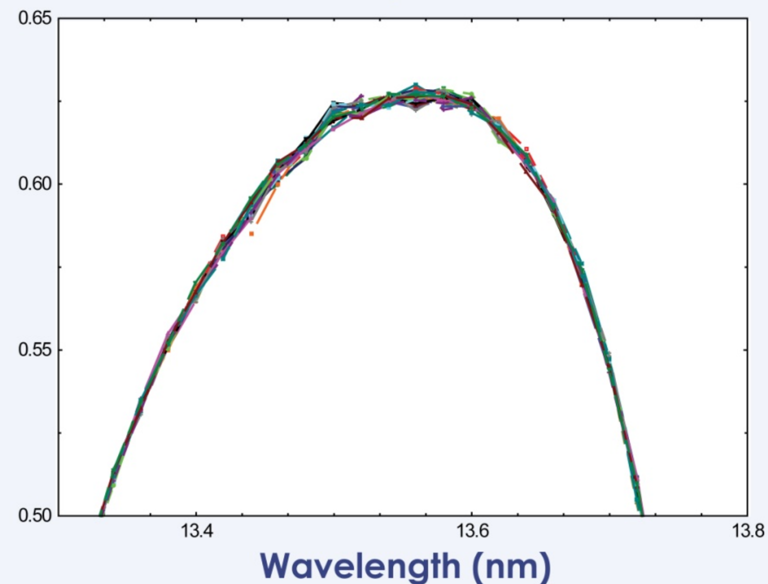
Misconceptions and facts

- Misconceptions
  - Reflectivity parameters are difficult to measure with required accuracy
- Facts
  - Reflectivity measurements are very easy to perform
  - Takes about 30 seconds per measurement
  - Currently, we can measure R with 3σ of 0.05% and lambda 3σ of 0.0005nm

These values far exceed HVM requirements

25 Consecutive Scans at Center of Reference Sample





(a) Twenty reflectivity measurements at the center of a Mo-Si multilayer to illustrate the repeatability (precision) of our Reflectometer. This multilayer was also measured at ALS, BL 6.3.2.
(b) X and Y axes magnified to show the actual 25 curves.

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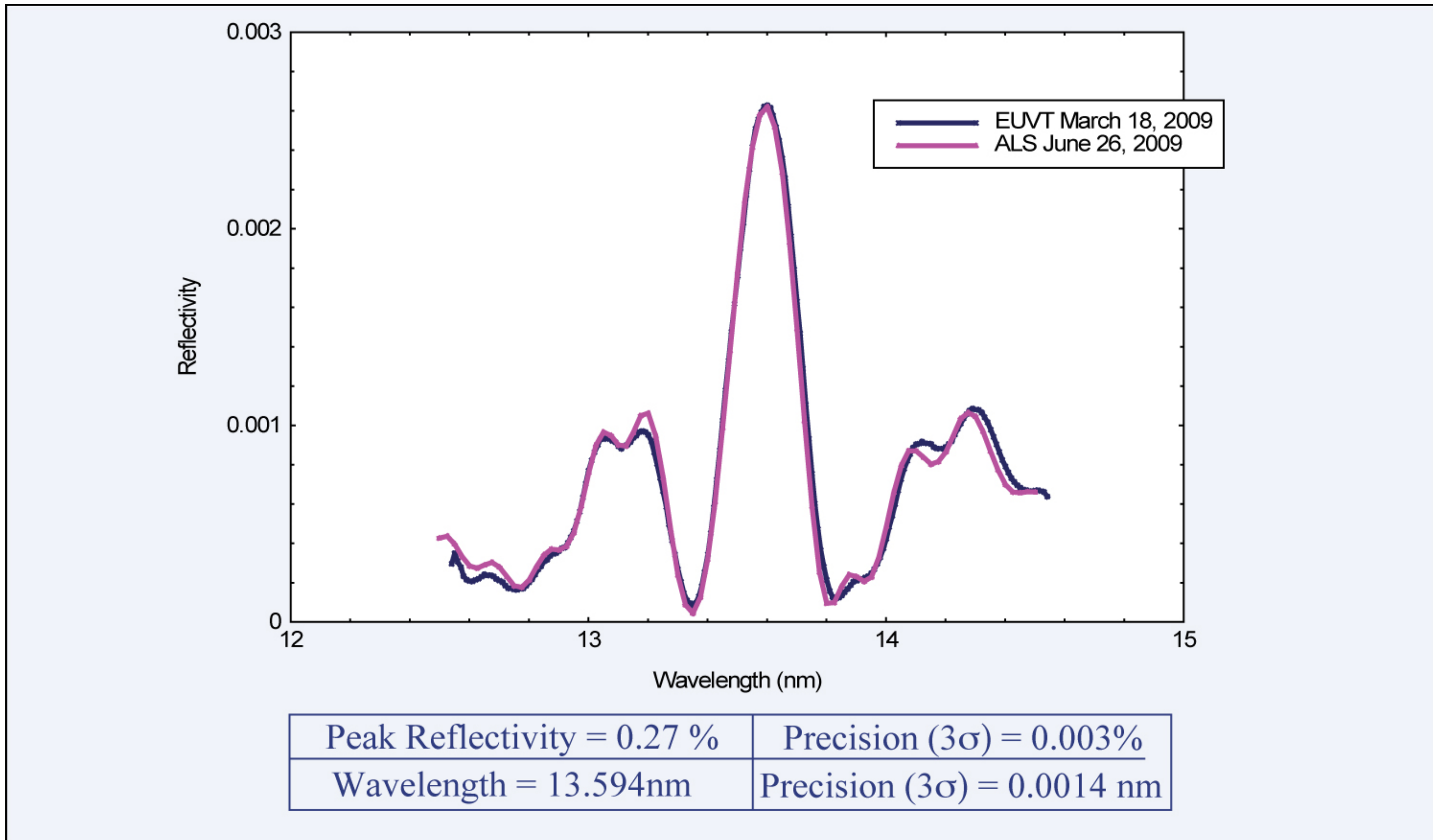
Absorber Plate (100nm La-TaBN): Measured Reflectivity



Peak Reflectivity = 0.27 %	Precision (3σ) = 0.003%
Wavelength = 13.594nm	Precision (3σ) = 0.0014 nm

Comparison with beam line 6.3.2 at ALS (Berkeley, CA)

	ALS	EUV Technology	MADT (EUVT)
Wavelength:			
Precision (3σ)	0.0003 nm	0.0005 nm	
(with load and unload)	0.0027 nm (0.021%)	0.0006 nm	
Accuracy (3σ)	0.0042 nm (0.033%)		0.0008 nm
Peak Reflectivity			
Precision (3σ)	0.24%	0.20%	
Accuracy (3σ)	0.42%		0.03%

EUV Technology Reflectometer Road Map

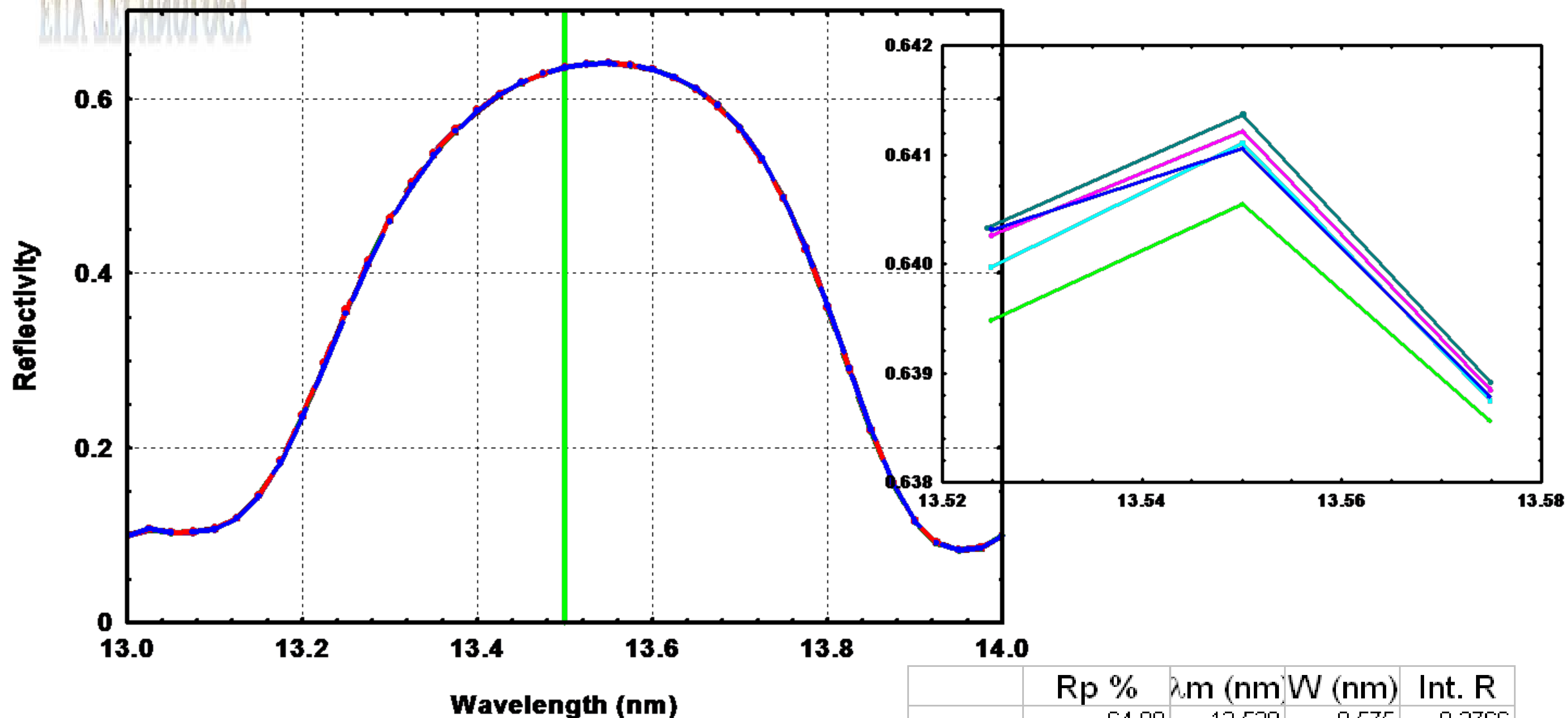
- Field upgrade current design to 6.x nm region (2011/12)
- HVM Reflectometer (2012/13)
  - High precision
- EUV Reflectometer for patterned masks (2012/13)
  - Small spot

Required Performance for the HVM Reflectometer

Measurement Performance	
EUV Peak reflectivity precision for $R_p > 2\%$ absolute	$3\sigma \leq 0.07\%$ absolute
EUV Peak reflectivity accuracy for $R_p > 2\%$ absolute	$3\sigma \leq 0.10\%$ absolute
EUV Peak reflectivity precision for $R_p < 2\%$ absolute	$3\sigma \leq 0.01\%$ absolute
EUV Peak reflectivity accuracy for $R_p < 2\%$ absolute	$3\sigma \leq 0.05\%$ absolute
Minimum wavelength range	10.5nm to 15.5nm
Minimum wavelength resolution ($\Delta\lambda/\lambda$)	500
EUV median wavelength precision	$3\sigma \leq 0.002$ nm
EUV median wavelength accuracy	$3\sigma \leq 0.003$ nm
Maximum clear space required for measurement	1mm x 1mm

Additional features:
Absolute (internal) reflectivity and wavelength calibration
Capability to find pattern location to be measured.

5 measurements on a very good ML



	Rp %	λm (nm)	W (nm)	Int. R
	64.09	13.538	0.575	0.3766
	64.07	13.538	0.575	0.3768
	64.12	13.537	0.574	0.3765
	64.10	13.537	0.576	0.3769
	64.10	13.538	0.575	0.3765
Average	64.09	13.538	0.575	0.3767
3 sigma	0.059	0.001	0.002	0.001
% 3 sigma	0.09	0.007	0.286	0.137

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EUV Reflectometer for patterned masks

- Small inspection area
  - Measurement spot size (dark to dark):
    - 50 X 50 micron.
    - Can be outside the printing area
- Require extremely high accuracy for Wavelength and Reflectivity
- Semi-automatic fiducial mark detection system

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EUV Resist Outgassing and Contamination Tool

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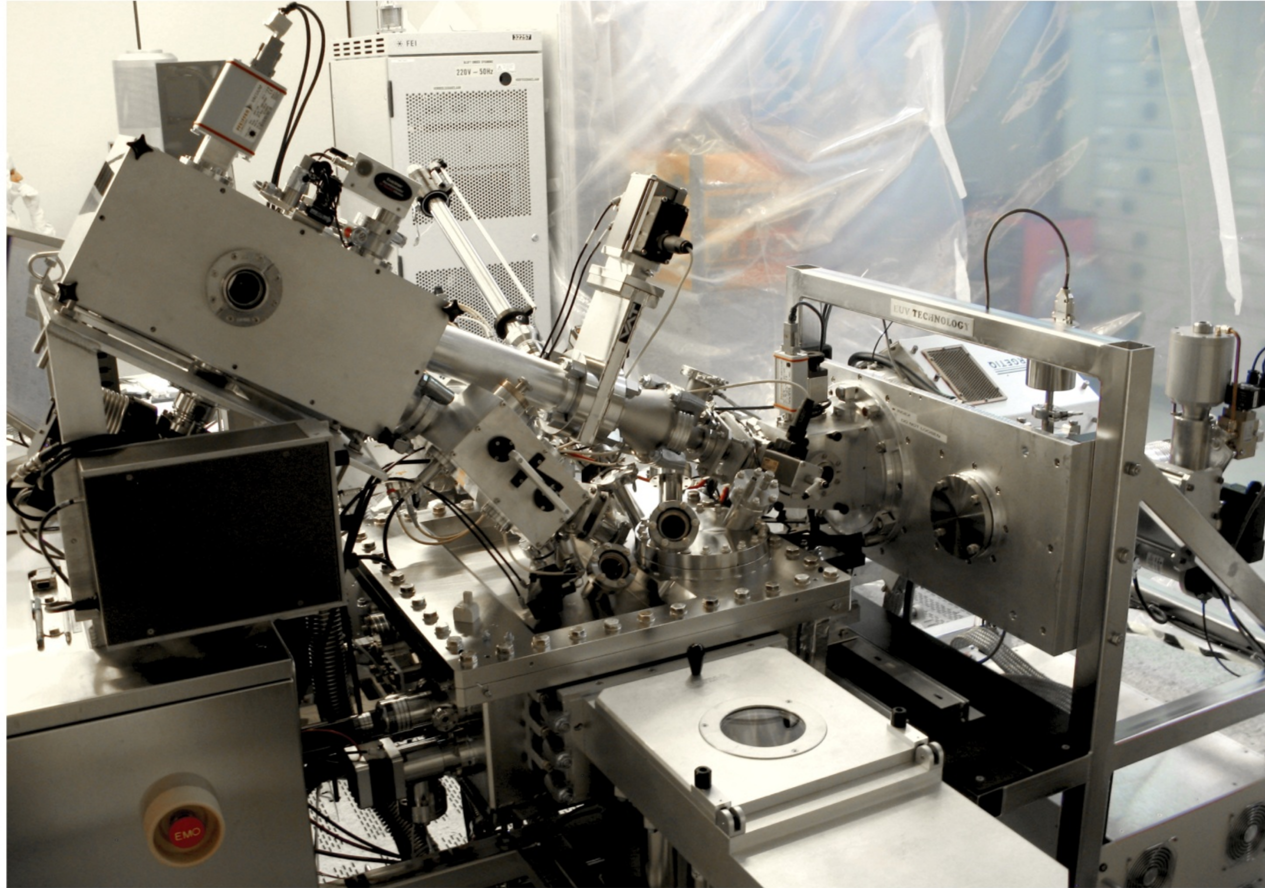
EUV Resist and Outgassing Tool



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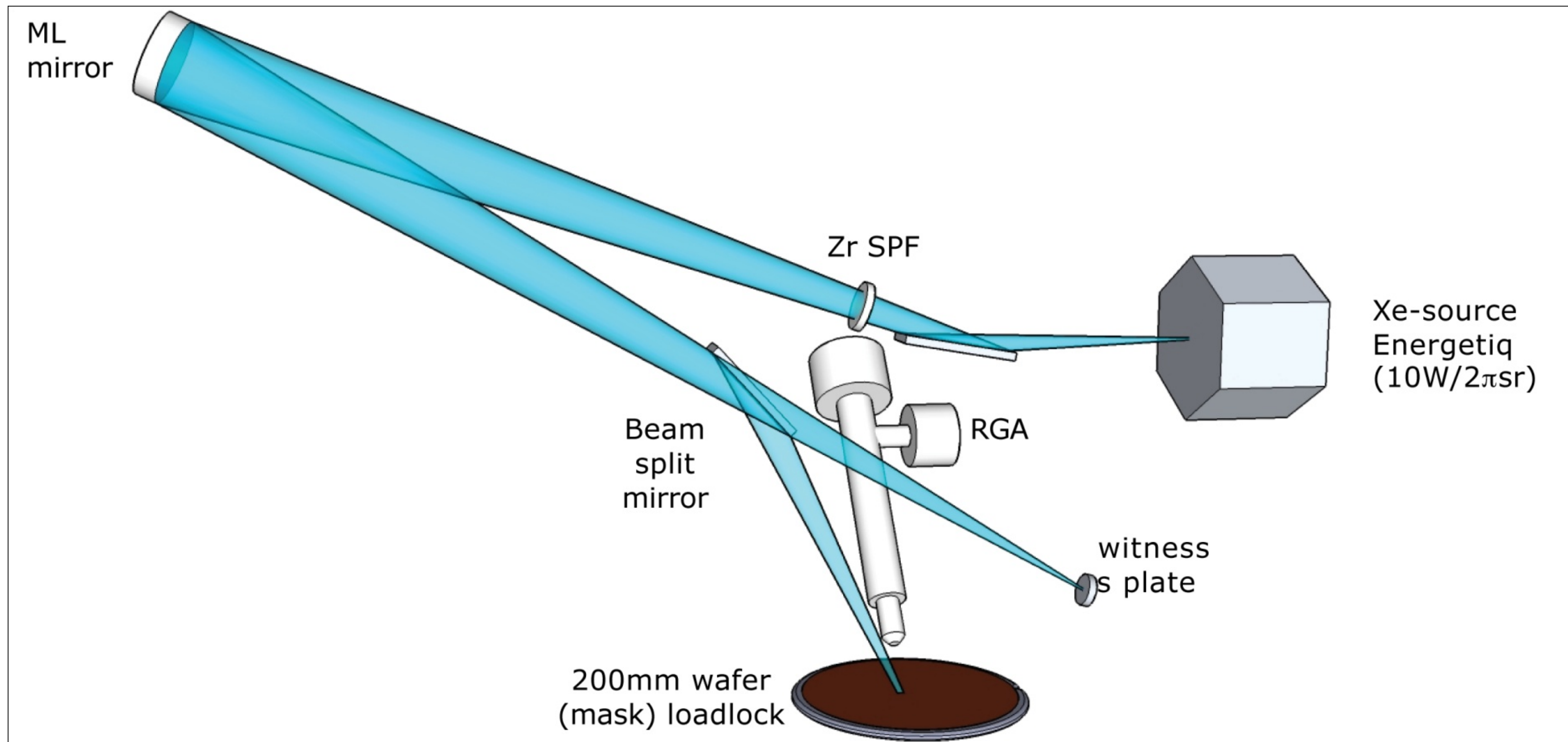
Schematic Diagram of EUV RER 1314



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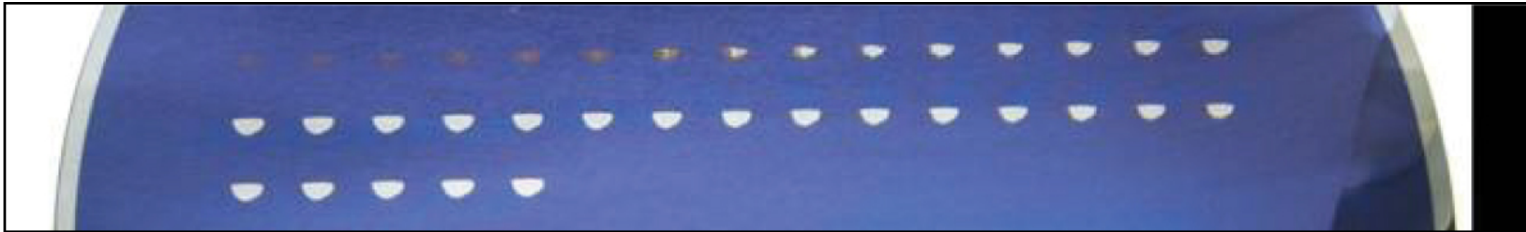
Dose Snake



REDUCTION OF BG OUTGASSING

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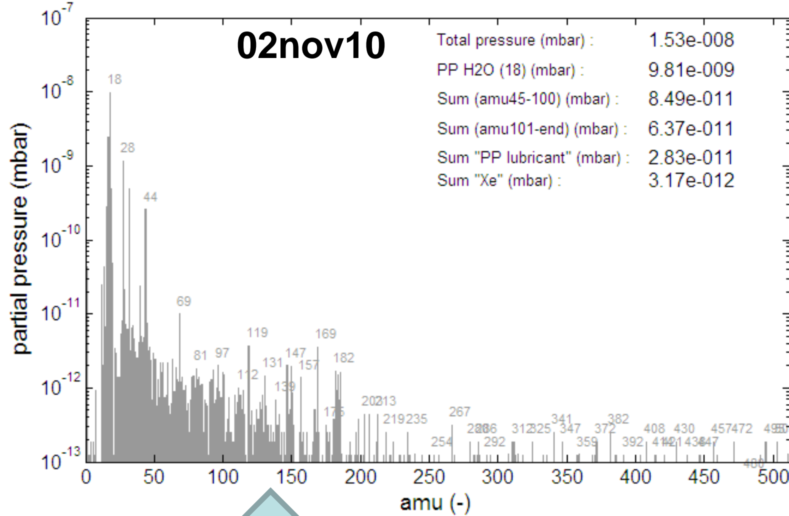
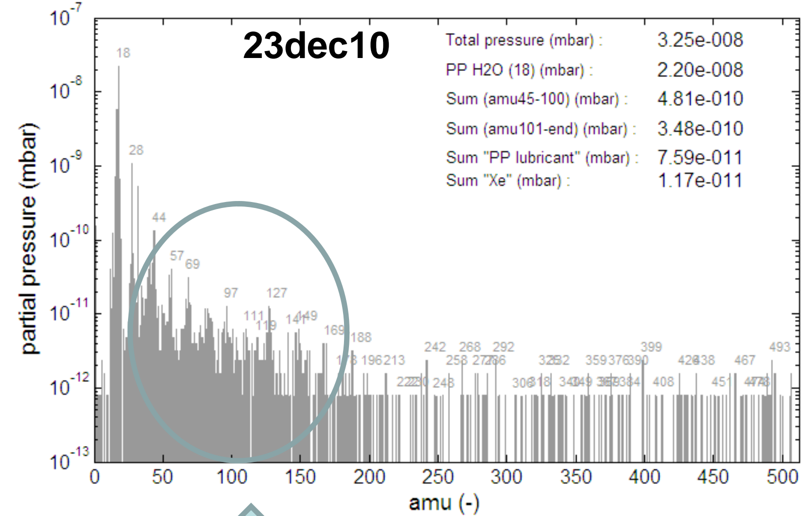
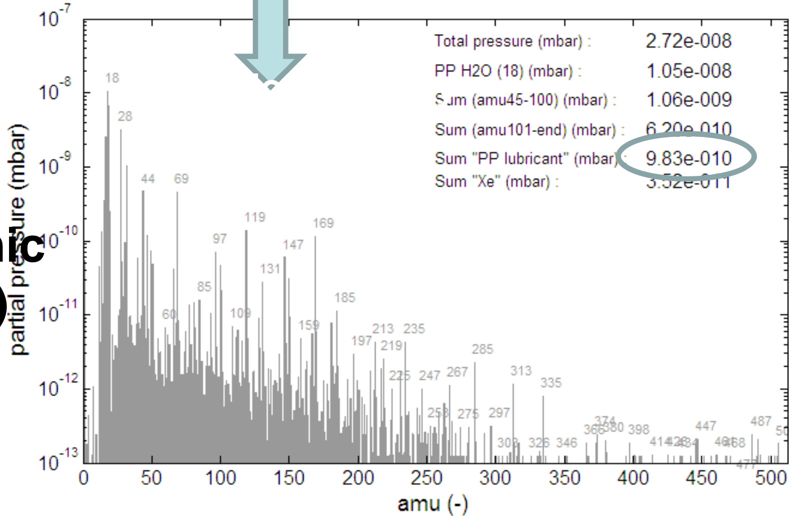
Before upgrade | **After upgrade**

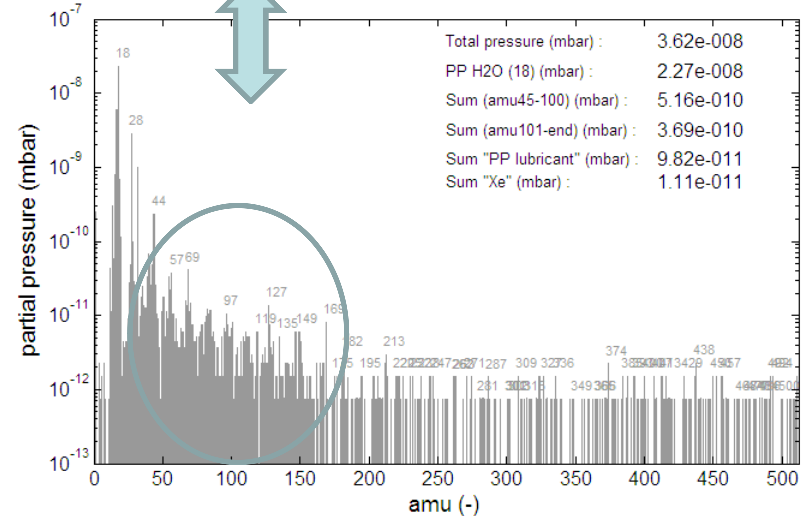
static





dynamic (stage)





Significant improvement in dynamic operation

WS RESULTS USING E-GUN

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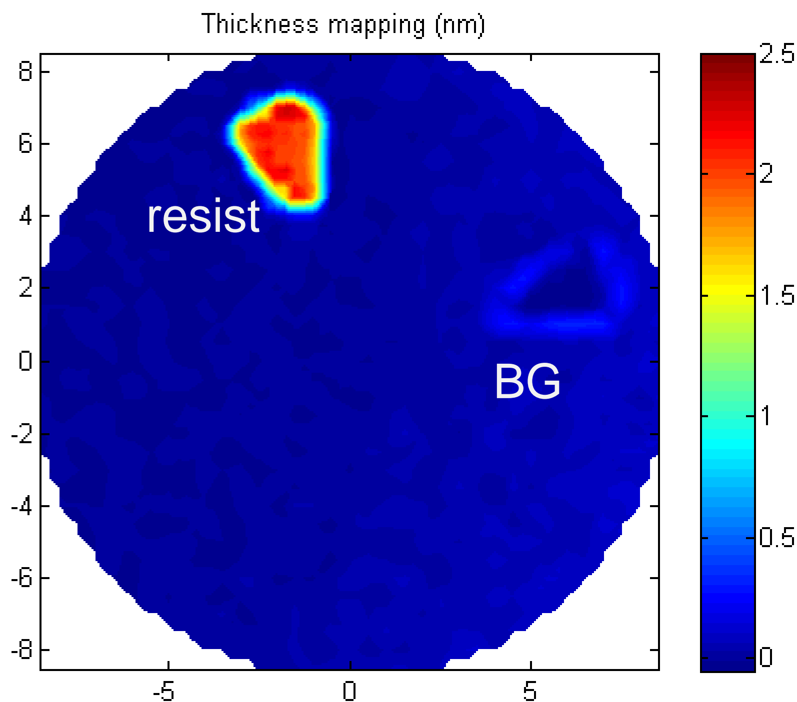
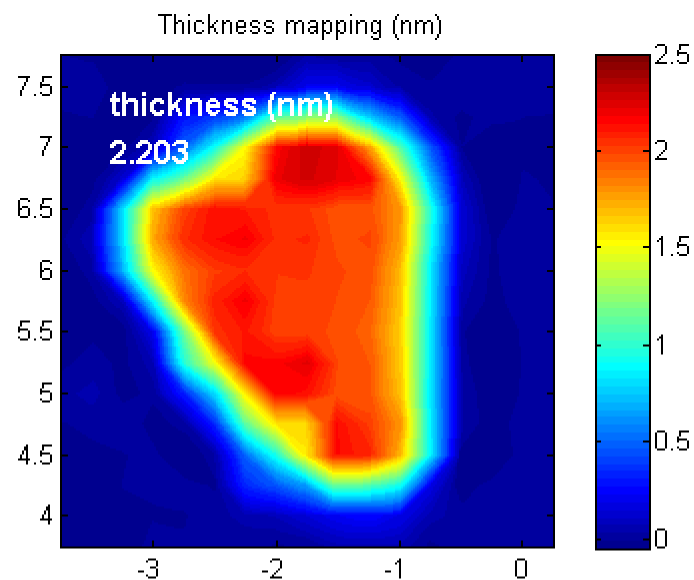
- First resist related WS contamination test on EUVT outgassing tool using E-gun





>2nm contamination thickness (~10x more than with EUV; note no scaling factor is used here) ! Clear difference with BG !

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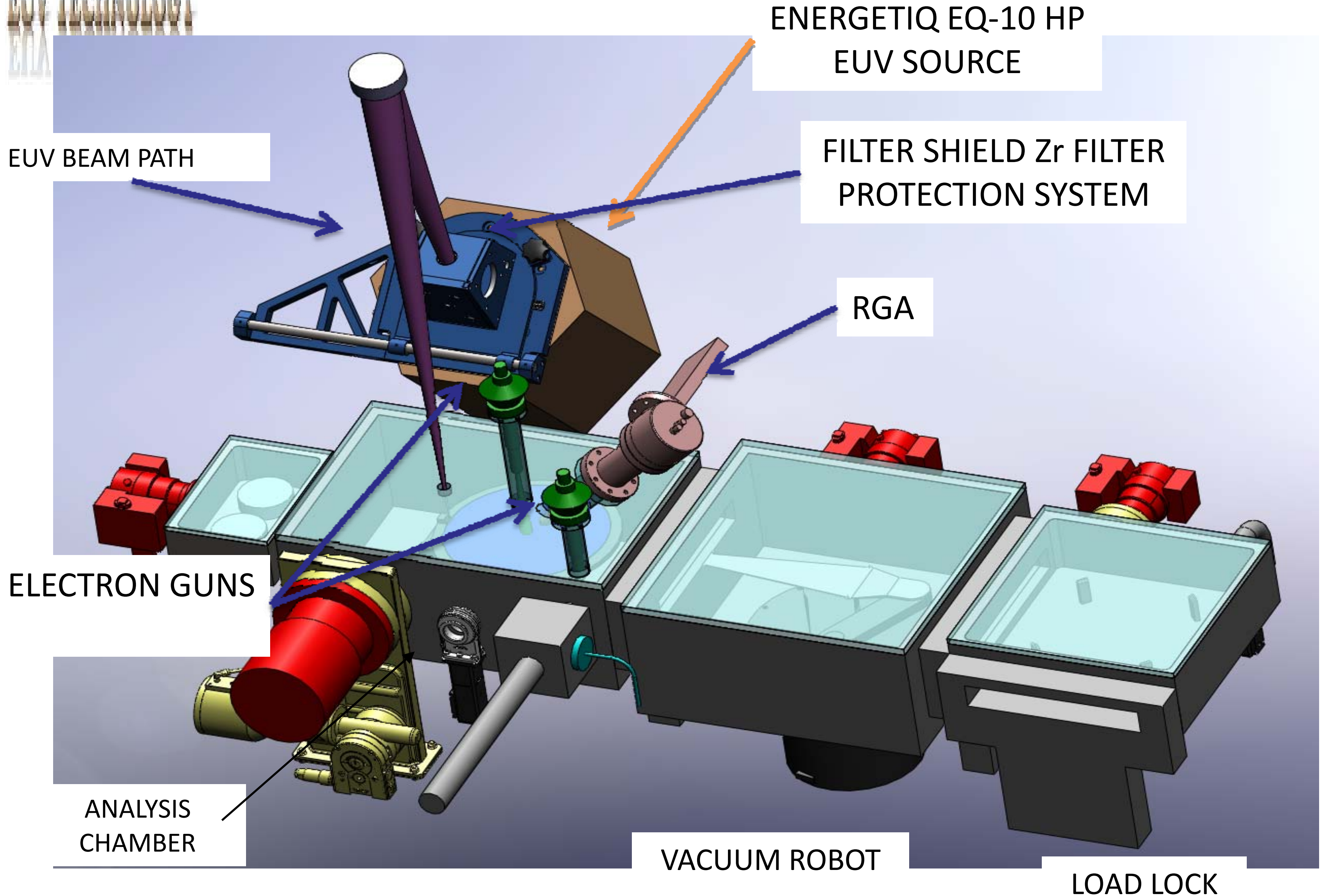
RER-300-PEX: Design philosophy

- Based on our previous model of resist outgassing and contamination measuring tool delivered to IMEC in 2008 (Model No. EUV-RER1314; Patent Pending)
- Based on new ASML (confidential) guidelines for NXE scanners dated Nov. 30, 2010 and Feb. 2011.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ENERGETIQ EQ-10 HP
EUV SOURCE
EUV BEAM PATH
FILTER SHIELD Zr FILTER
PROTECTION SYSTEM
RGA
ELECTRON GUNS
ANALYSIS
CHAMBER
VACUUM ROBOT
LOAD LOCK

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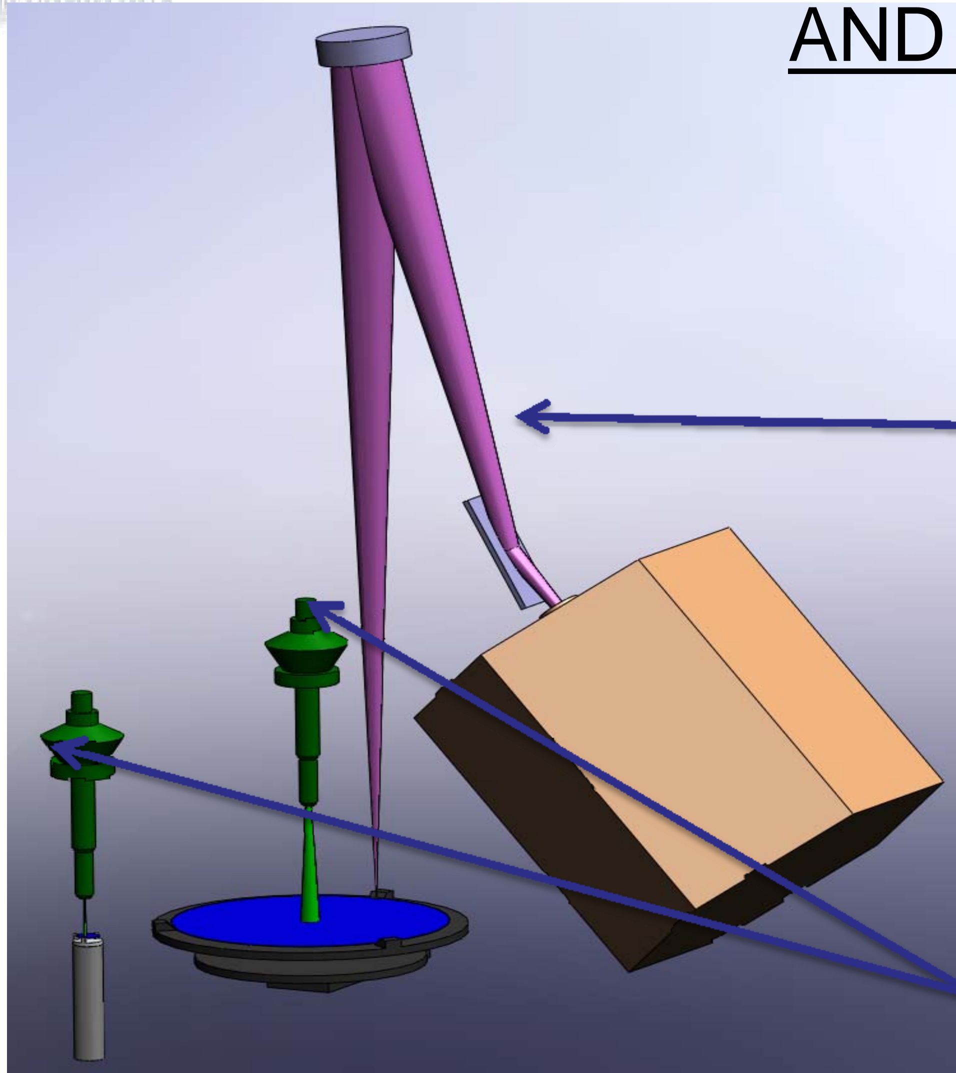
TWO EXPOSURE METHODS: E-BEAM AND EUV



EUV FOR WAFER EXPOSURE

- CONSISTS OF ENERGETIQ SOURCE, TWO GLANCING MIRRORS AND A MULTILAYER

System is designed in such a way that it can be ordered with one mode of operation and field upgraded to add the other option.

ELECTON GUNS

- WS EXPOSURE GUN WITH 2.5mm DIA BEAM
- WAFER EXPOSURE GUN WITH 20mm DIA BEAM

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Advantages of using13.5 nm pulsed photons over electrons

- EUVL stepper utilize photons.
  - True dose to clear exposure.
- Non destructive.
  - Only detect photo-induced decomposition.
- Represent bulk properties.

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Mahalo nui loa