Recent developments in construction of metrology, calibration, and resist testing tools for the successful HVM implementation of EUV lithography

Rupert C. Perera
EUV Technology
Martinez, CA

EUV Litho (Maui, HI)
June 7, 2012

About EUV Technology

- Pioneered the development of stand alone EUV Metrology Tools (in 1999)
- Products;
  - EUV Reflectometer
  - EUV Resist Outgassing tool
  - Hydrogen radicle cleaners.

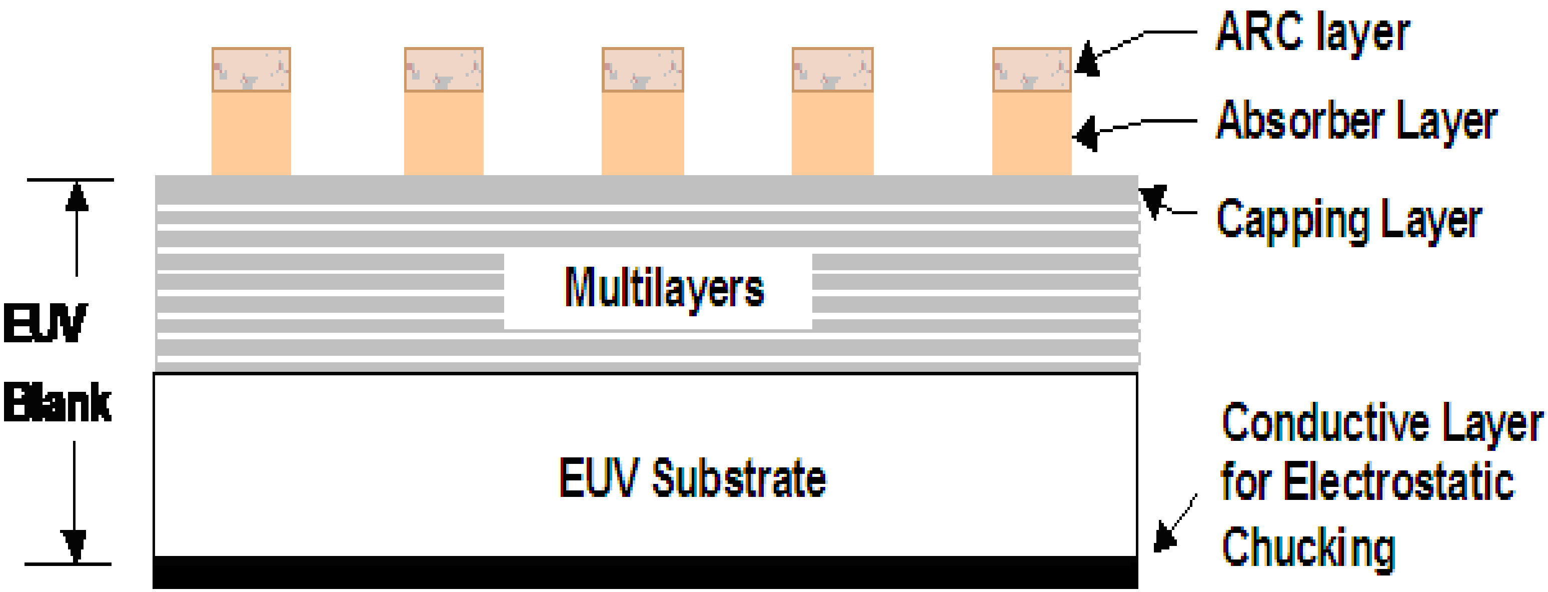
Challenges in developing tools

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

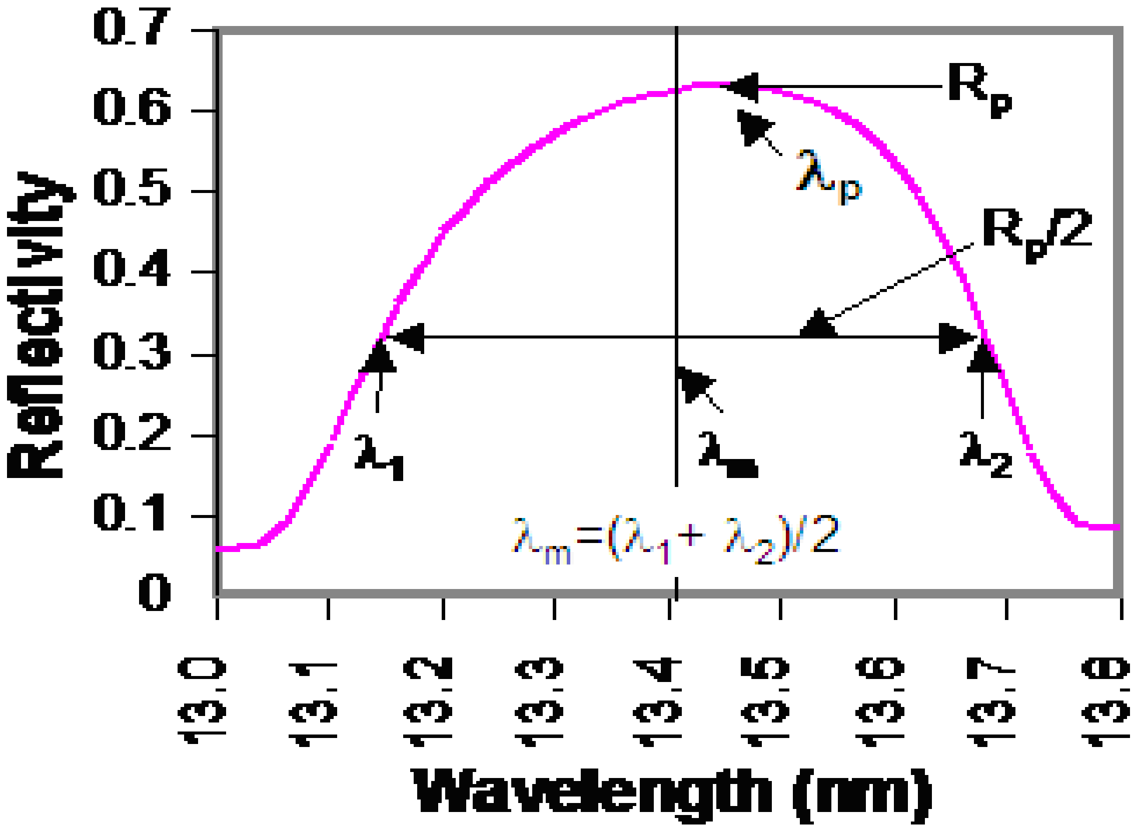
EUV Reflectometer

EUV Litho (Maui, HI)
June 7, 2012

Cross section schematic of an EUVL Mask: 5 layers

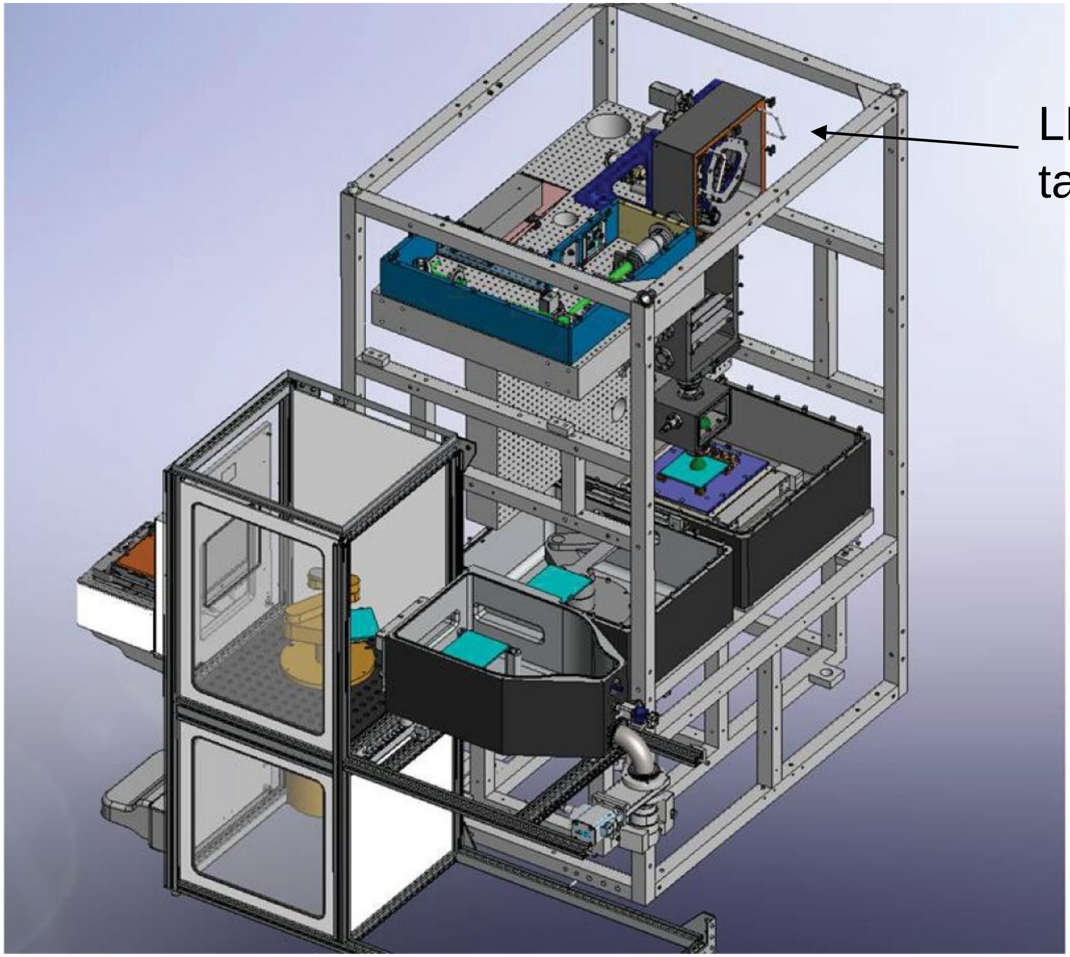


Definition of peak EUV reflectivity (R_p) and median wavelength (λ_m).



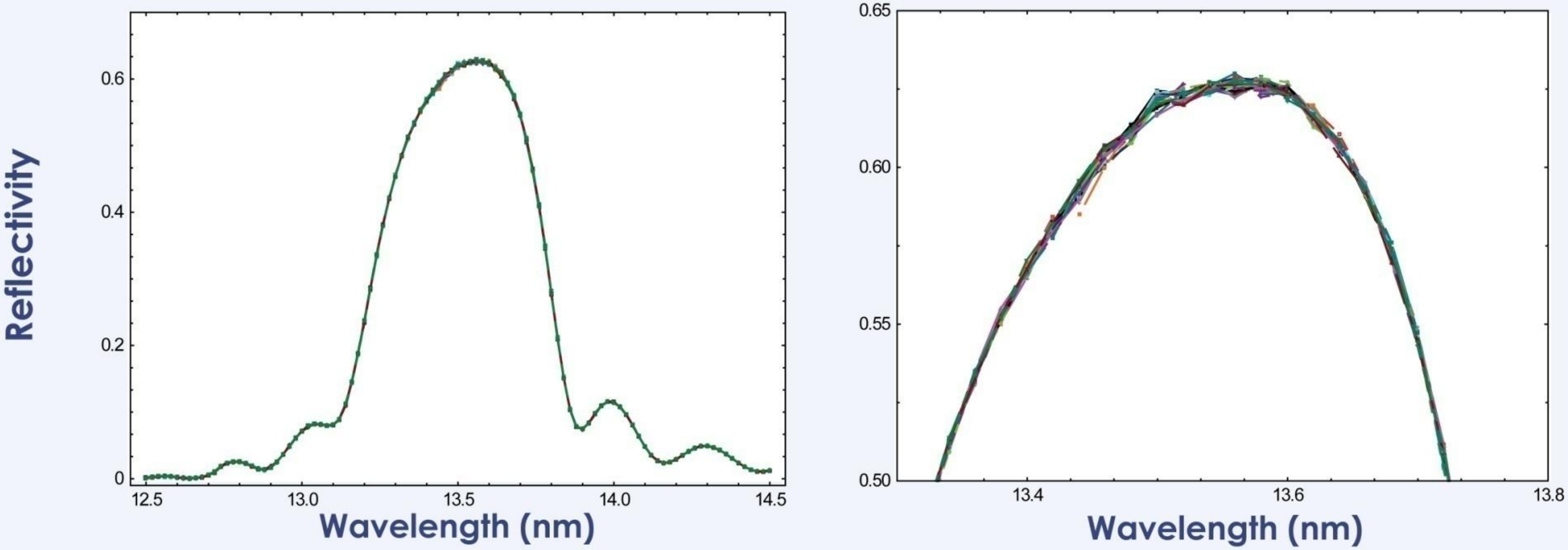
Side view of the tool

EUV Reflectometer



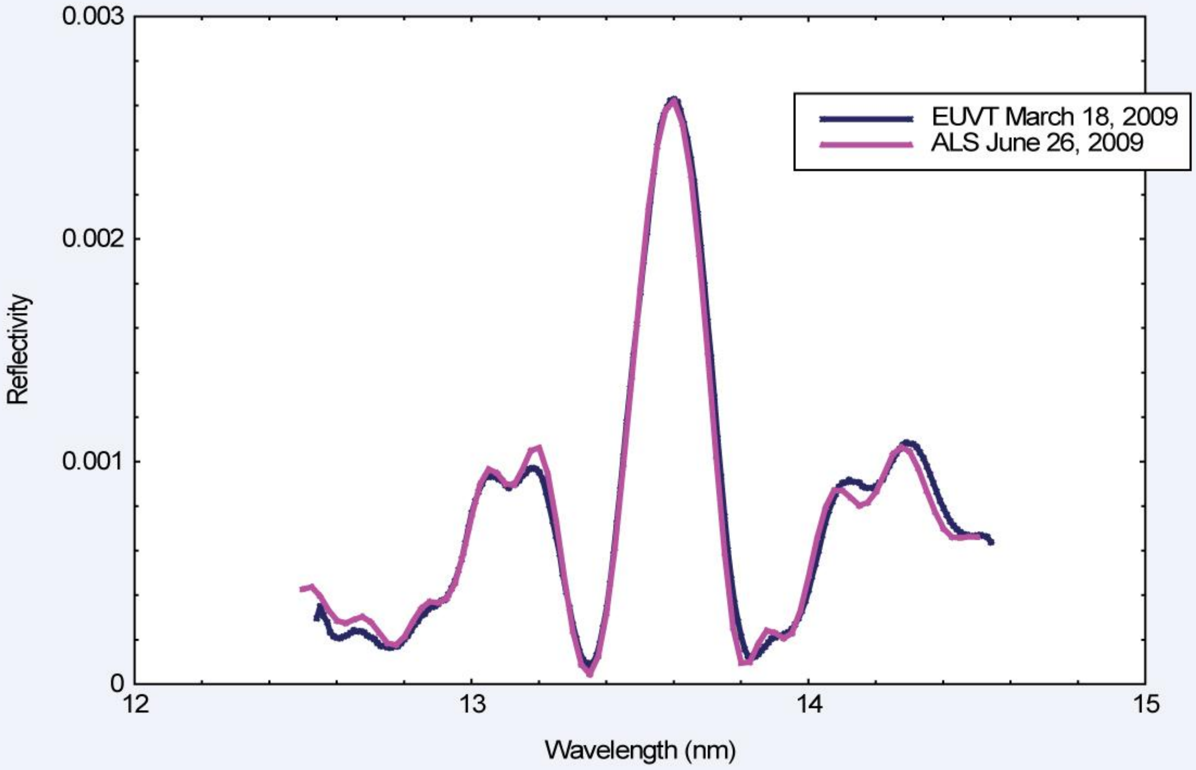
LPP source. Cu target 5 to 20 nm

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.

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

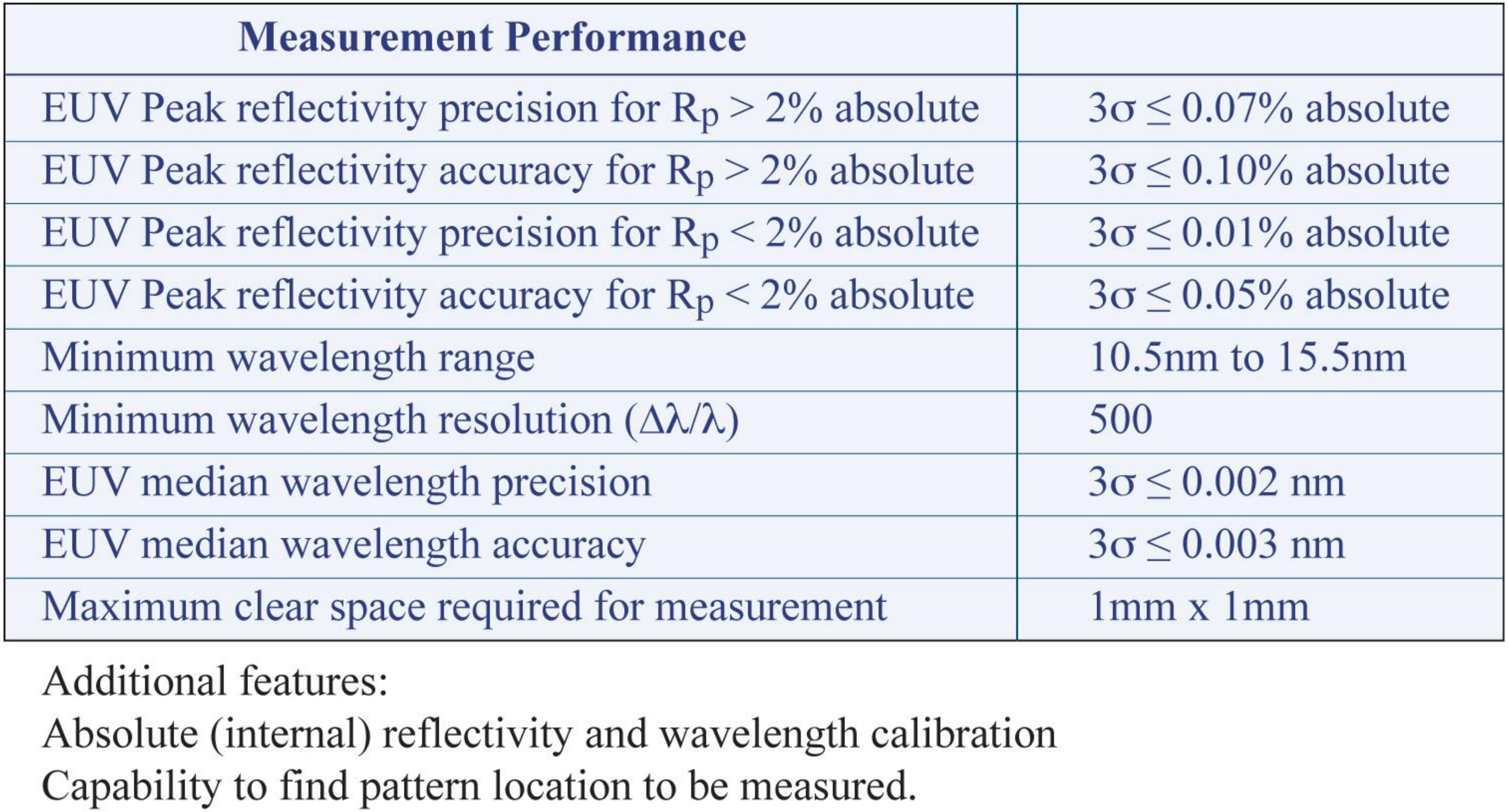


Peak Reflectivity = 0.27 %	Precision (3σ) = 0.003%
Wavelength = 13.594nm	Precision (3σ) = 0.0014 nm

EUV Technology Reflectometer Road Map

- Field upgrade current design to 6.x nm region
- HVM Reflectometer
  - High precision
- EUV Reflectometer for patterned masks
  - Small spot

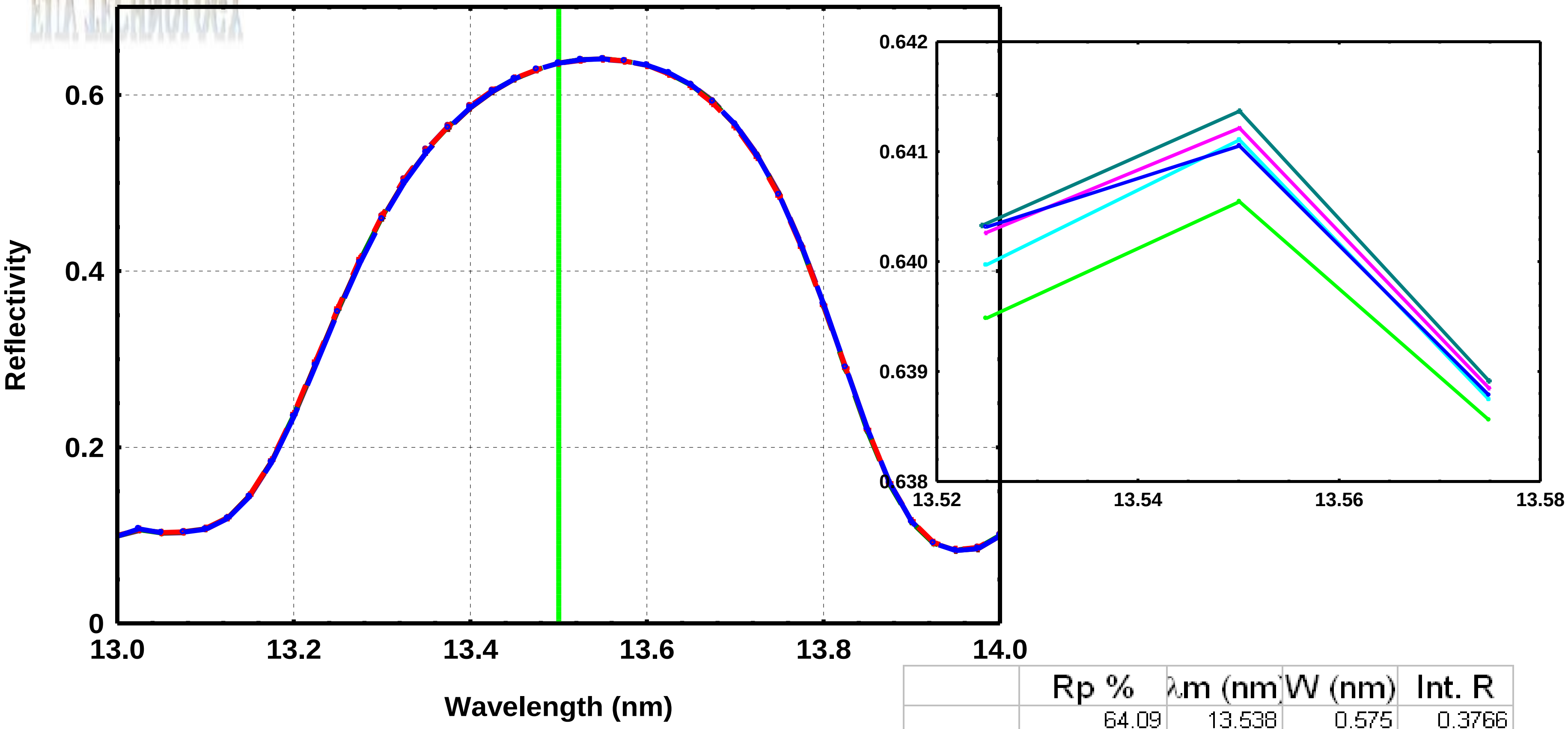
Required Performance for the HVM Reflectometer

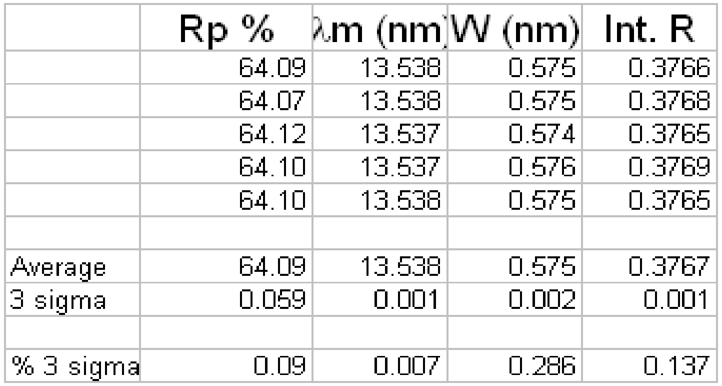


Measurement Performance	
EUV Peak reflectivity precision for $R_p > 2\%$ absolute	$3\sigma \le 0.07\%$ absolute
EUV Peak reflectivity accuracy for $R_p > 2\%$ absolute	$3\sigma \le 0.10\%$ absolute
EUV Peak reflectivity precision for $R_p < 2\%$ absolute	$3\sigma \le 0.01\%$ absolute
EUV Peak reflectivity accuracy for $R_p < 2\%$ absolute	$3\sigma \le 0.05\%$ absolute
Minimum wavelength range	10.5nm to 15.5nm
Minimum wavelength resolution ($\Delta\lambda/\lambda$)	500
EUV median wavelength precision	$3\sigma \le 0.002$ nm
EUV median wavelength accuracy	$3\sigma \le 0.003$ 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

EUV Litho (Maui, HI)
June 7, 2012

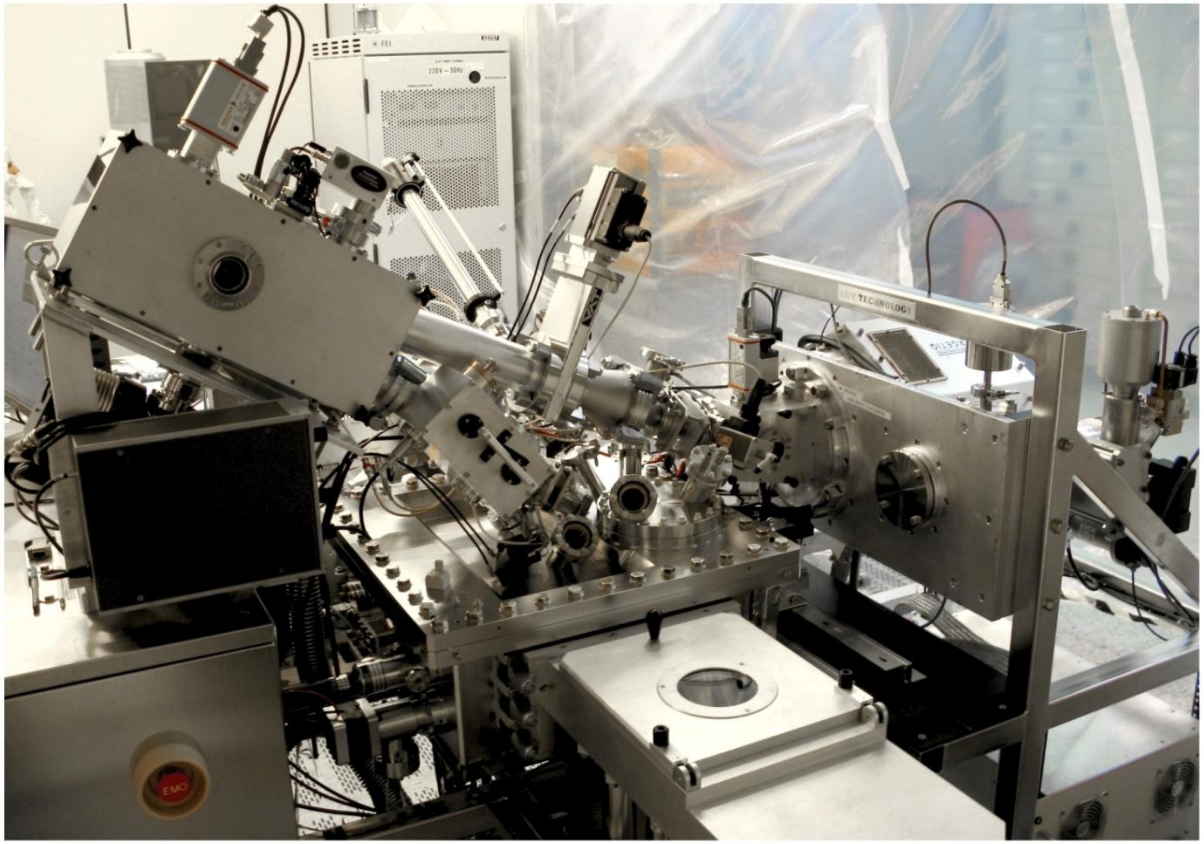
EUV Reflectometer for patterned masks

- 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

EUV Resist Outgassing and Contamination Tool

EUV Litho (Maui, HI)
June 7, 2012

EUV Resist and Outgassing Prototype tool deliverd to IMEC in October 2008: ADT guidelines

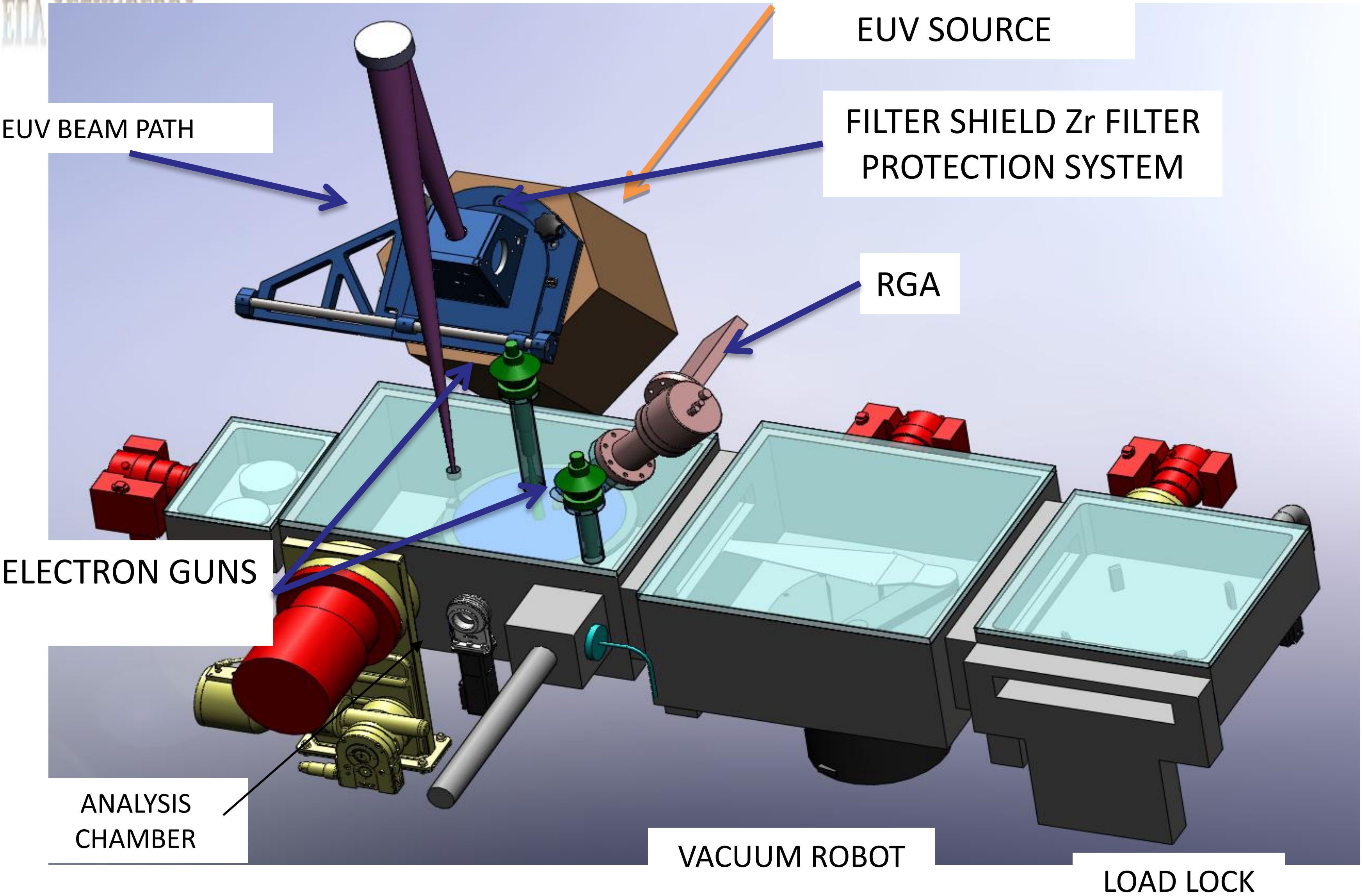


Updated to NXE3100 guidelines and in the process waiting for the ASML certification

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.

For resist testing e-beam exposure was proposed as a low cost alternate to EUV



ENERGETIQ EQ-10 HP
EUV SOURCE

EUV BEAM PATH

FILTER SHIELD Zr FILTER
PROTECTION SYSTEM

RGA

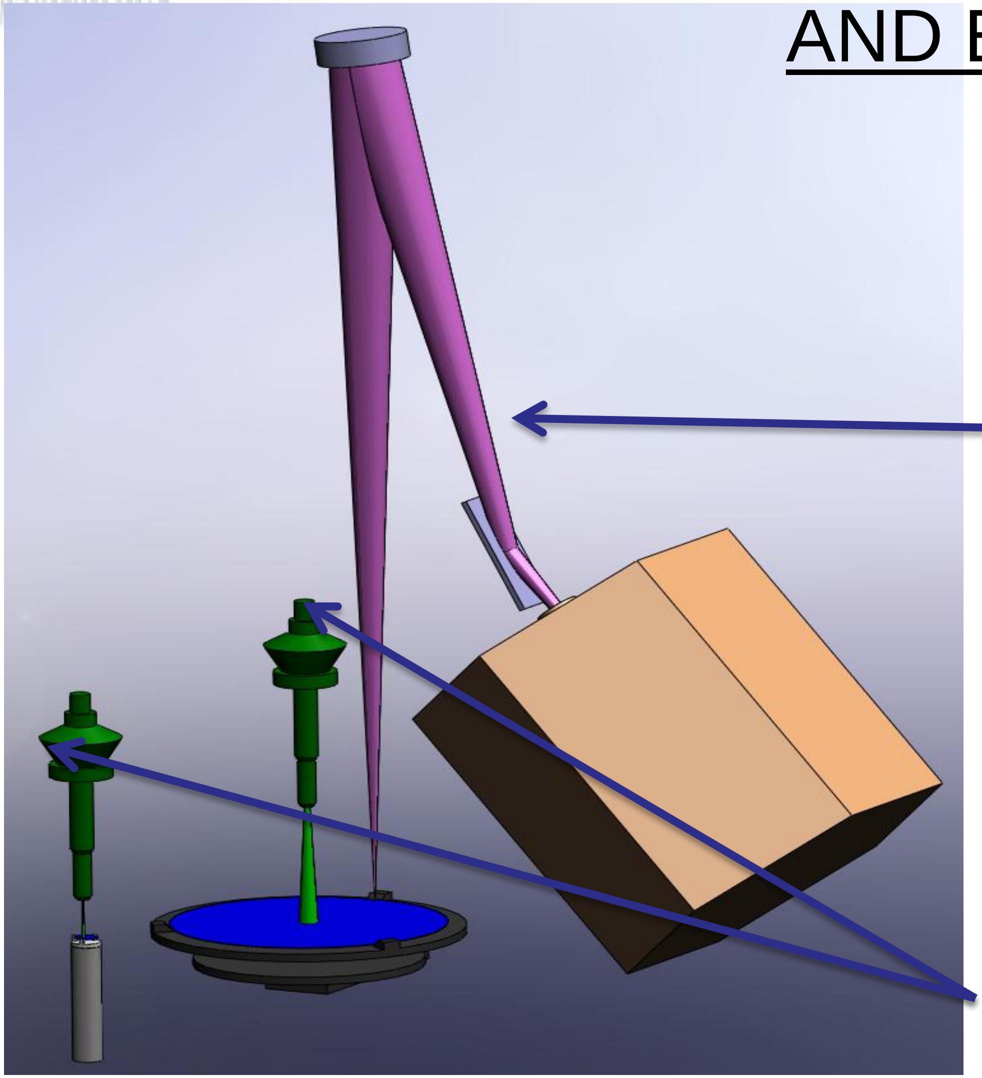
ELECTRON GUNS

ANALYSIS
CHAMBER

VACUUM ROBOT

LOAD LOCK

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

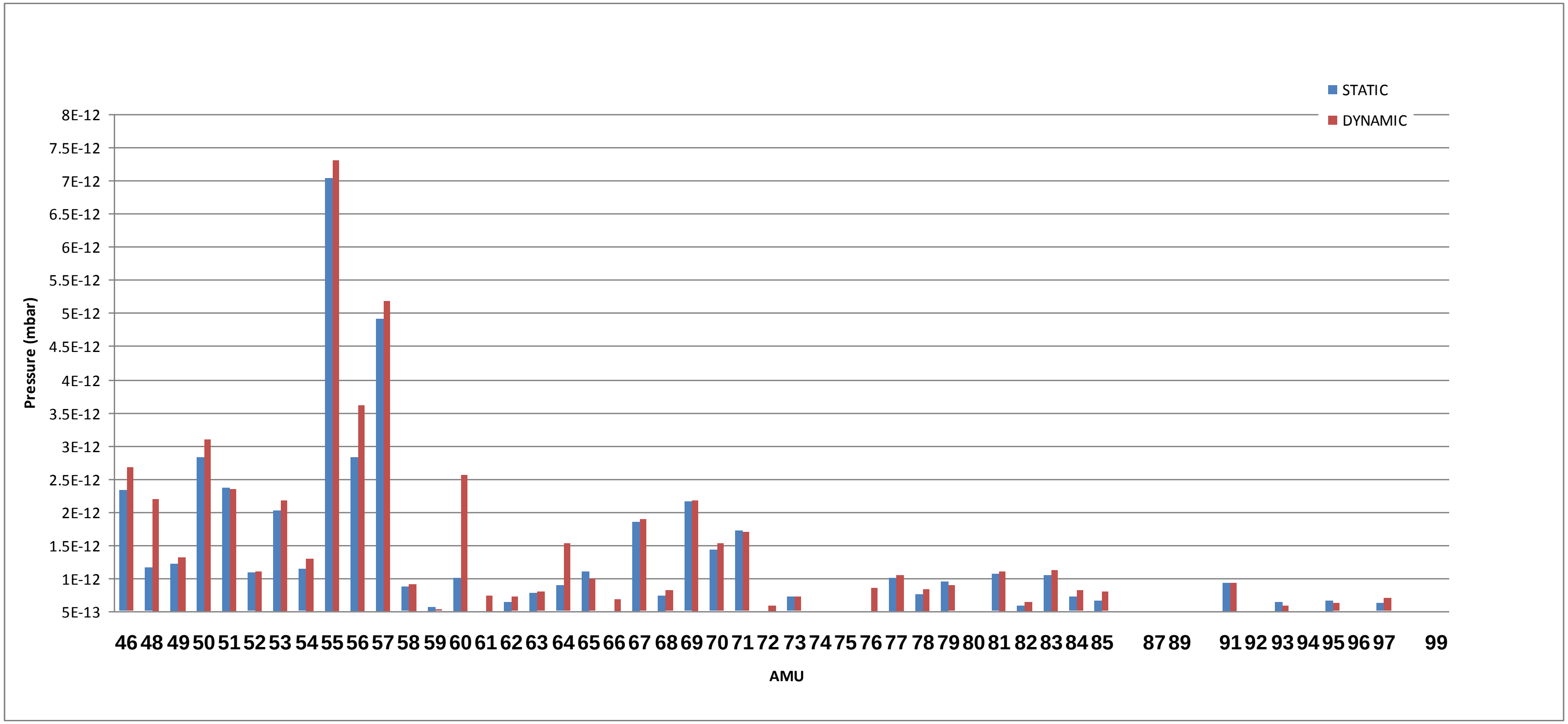
- WS EXPOSURE GUN WITH 2.5mm DIA BEAM
- WAFER EXPOSURE GUN WITH 20mm DIA BEAM

Resist Testing Tool

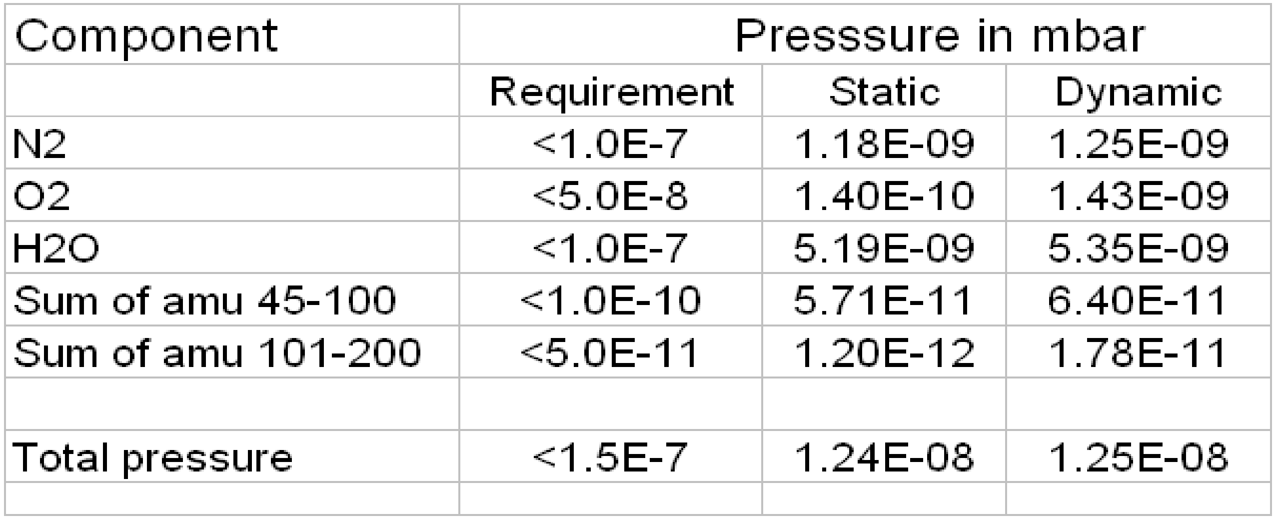
Process chamber vacuum environment

- All metal components
  - – Except transfer gate valve seal
- R-theta in-vacuum stage
- No motors in the process chamber
- Pumping speed <265 l/s

RGA testing of the stage. Static Vs. Dynamic. AMU 45-100 region



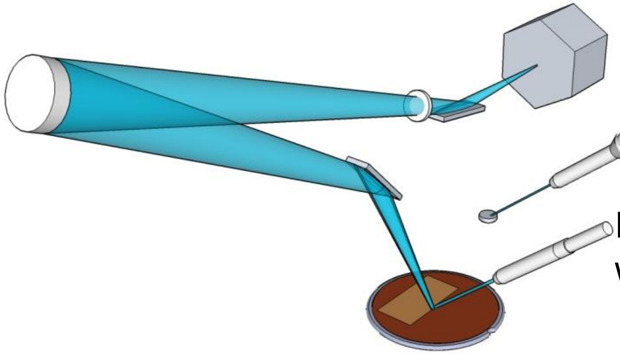
RGA testing

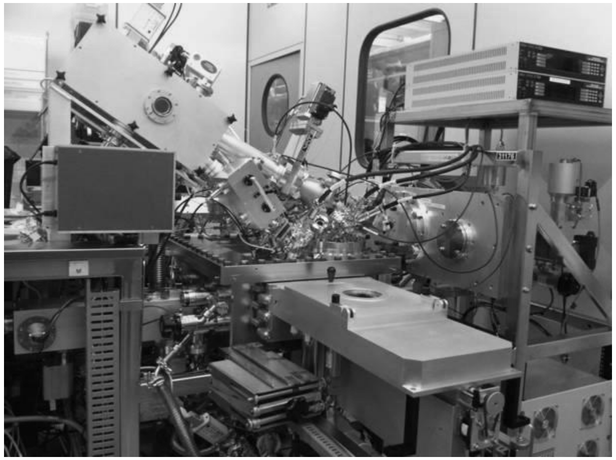


Component	Presssure in mbar		
	Requirement	Static	Dynamic
N2	<1.0E-7	1.18E-09	1.25E-09
O2	<5.0E-8	1.40E-10	1.43E-09
H2O	<1.0E-7	5.19E-09	5.35E-09
Sum of amu 45-100	<1.0E-10	5.71E-11	6.40E-11
Sum of amu 101-200	<5.0E-11	1.20E-12	1.78E-11
Total pressure	<1.5E-7	1.24E-08	1.25E-08

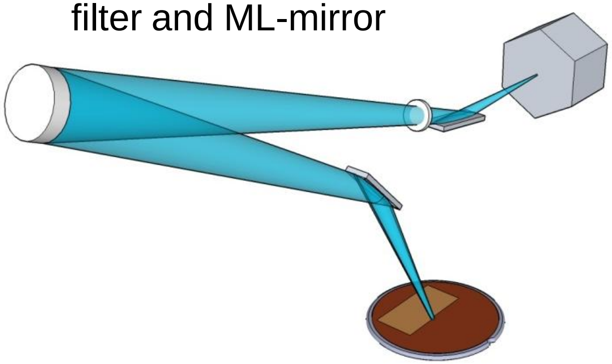
No significant outgassing from stage movements

- Experimental set-up

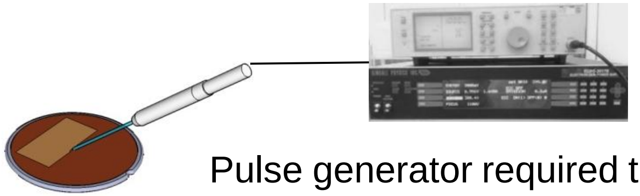




Energetiq EUV source with Zr-filter and ML-mirror



Not optimized ! Possibly some variability in emission current is present in results !



Pulse generator required to get sufficiently low electron current

DOSE-TO-CLEAR (E_0)

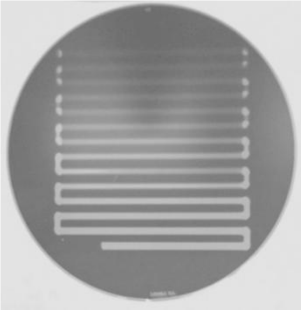
- Dose-to-clear (E_0) determination by meander exposure
  - From line to line the exposure dose is increased
  - Resist thickness of each line is measured by ellipsometry

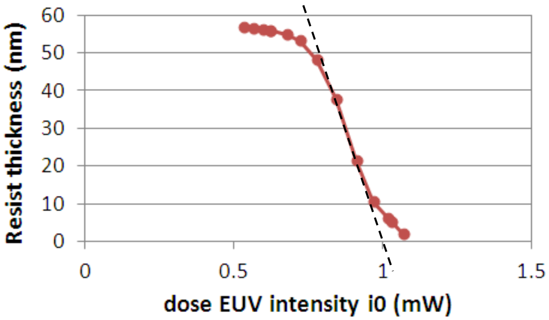
Examples

EUV

(reference)

Dose change by Energetiq source intensity change (Xe-pressure)

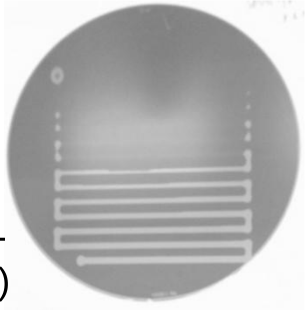


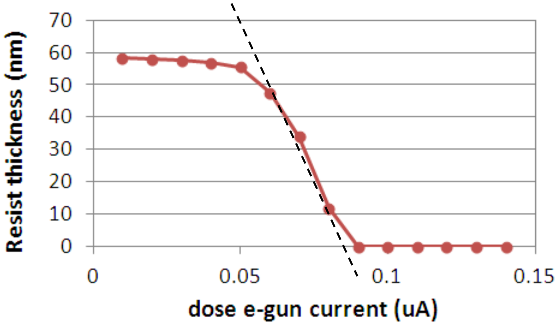


E-gun

(focus is adjusted to have similar spot size)

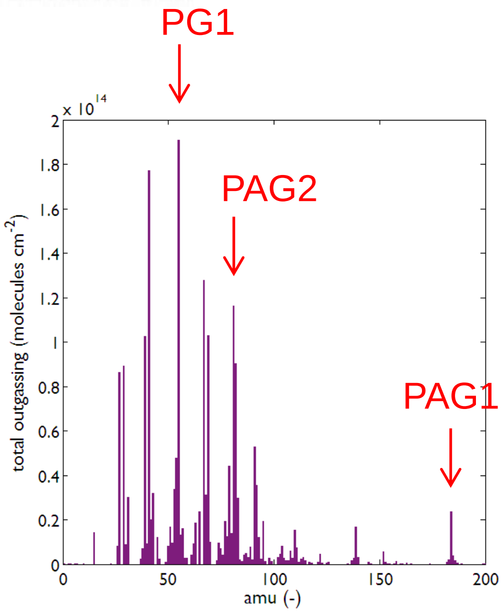
Dose change by change in e-gun current (pulse duty cycle)



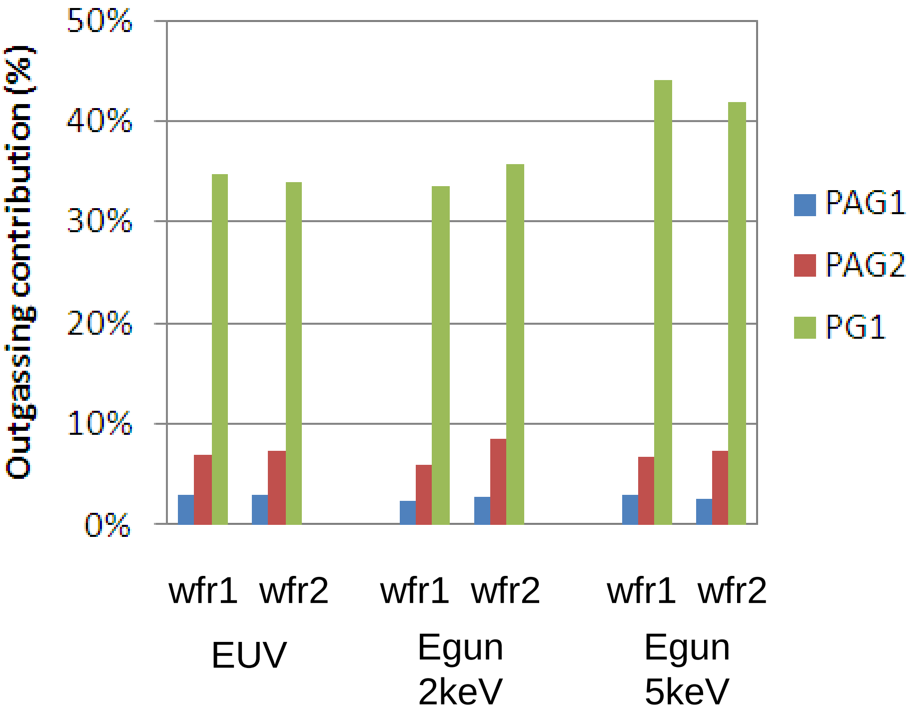


Close setpoint for E0 exposure can be obtained in both cases

RGA OUTGASSING: RESIST 1



From the RGA spectrum of resist 1 some species can be identified, e.g. species related to PAG (Photo acid generator) or PG (protection groups).



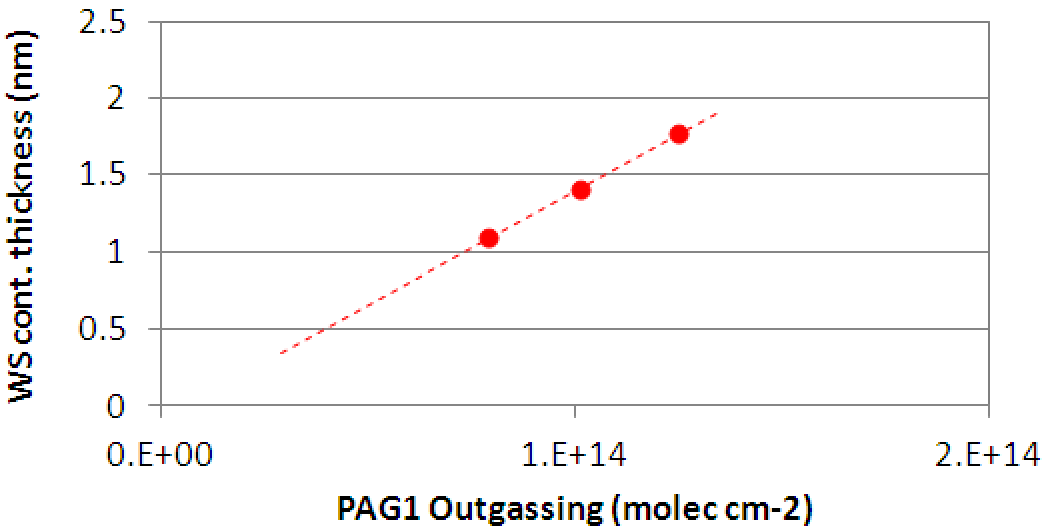
The contribution of the identified species PAG1, PAG2, and PG1, are compared towards the total outgassing. Over-all this confirms that a very similar composition of outgassing is obtained both for EUV and Egun exposure.

WS testing

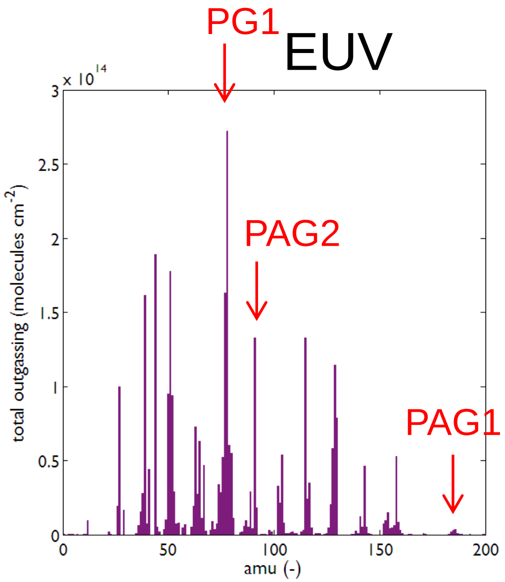
Resist 1

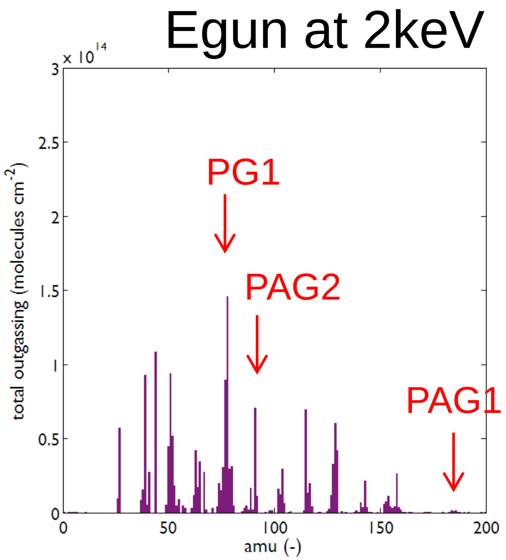
	Total outgassing	PAG1	WS cont. (nm)
EUV	4.20E+15	1.25E+14	1.77
Egun 2keV	3.10E+15	7.90E+13	1.09
Egun 5keV	3.70E+15	1.01E+14	1.4

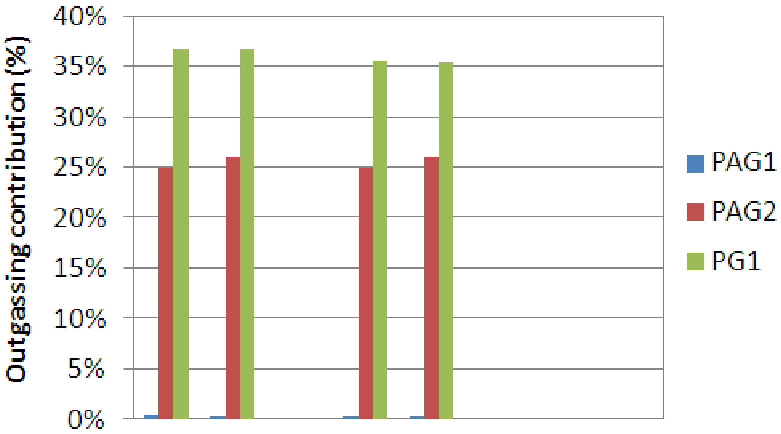
Differences in WS contamination are observed. It is believed that these changes are mainly due to changes in dose (less good control for Egun exposures). For this resist it is known that the WS contamination is determined by the PAG1 outgassing species.

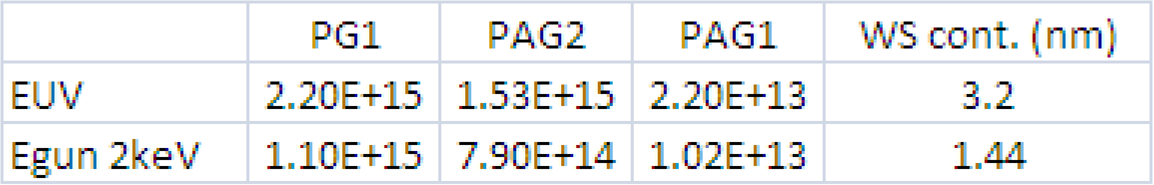


RGA OUTGASSING COMPARISON: RESIST 2


EUV


Egun at 2keV





	PG1	PAG2	PAG1	WS cont. (nm)
EUV	2.20E+15	1.53E+15	2.20E+13	3.2
Egun 2keV	1.10E+15	7.90E+14	1.02E+13	1.44

Similar conclusions can be drawn for Resist 2. The composition of the outgassing is quasi-identical, but the magnitude is different due to differences in dose control (it was verified by resist development after testing that Egun exposed with less dose than EUV.

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.

Filament Based H2 Radical Cleaner for EUV Resist Testing

(Based on NIST design)

EUV Litho (Maui, HI)
June 7, 2012

H2 Flow Control

MFC to control the H_2 flow

Another MFC to control the N_2 flow.

Diluted to 1% by volume before exhausting.

Interlocked so that H_2 will not flow if there is not sufficient N_2 flow to dilute the H_2

In the process of upgrading the design to increase the cleaning rates

Mahalo nui loa