Resist Outgassing Qualification for Alpha Demo

ASML Recommended Test Protocol

October 2007

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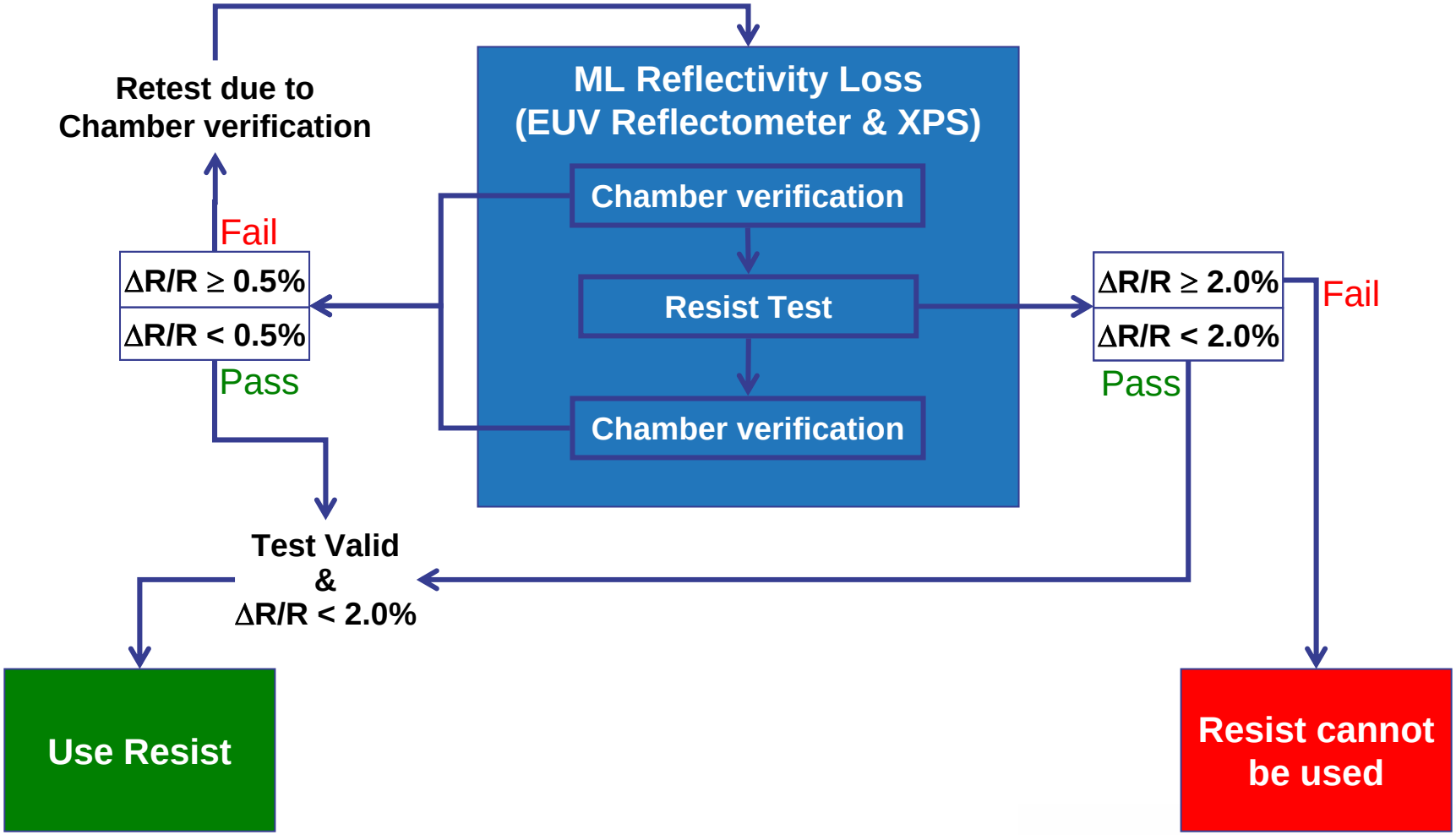
Introduction

- EUV resist outgassing is one source of reflectivity loss in EUV optics
- To maintain productivity, each multilayer mirror in the EUV optical system should not loose more than 2% reflectivity ($\Delta R/R$) where $\Delta R/R \equiv$ Reflectivity Loss
- The ASML Alpha Demo Tool (ADT) has a mitigation strategy in place to minimize the effect of resist outgassing. This system reduces the resist outgassing components into the main chamber and thus the total allowable reflection loss can be scaled to one 300mm wafer exposed *without* resist outgassing mitigation
- A resist outgassing test protocol has been established in order to ensure that ADT optics usage is maintained
  - A multilayer mirror reflectivity loss ($\Delta R/R$) test (normalized to one 300mm wafer)
  - Optional <u>additional</u> testing: RGA outgassing analysis

Test protocol determines ΔR/R per 300mm wafer for identifying resist with acceptable outgassing



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RGA qualification of the chamber is an important part of a successful test

- Qualify the sample vacuum chamber for resist outgassing with an RGA and meet the following requirements for partial pressure
  - Sum{ C_xH_y [44 < 100 amu] } < 10^{-9} mbar
  - Sum{ C_xH_y [101 < 200 amu] } < 10^{-9} mbar
  - H_2O < 10^{-7} mbar
  - O_2 < 10^{-8} mbar

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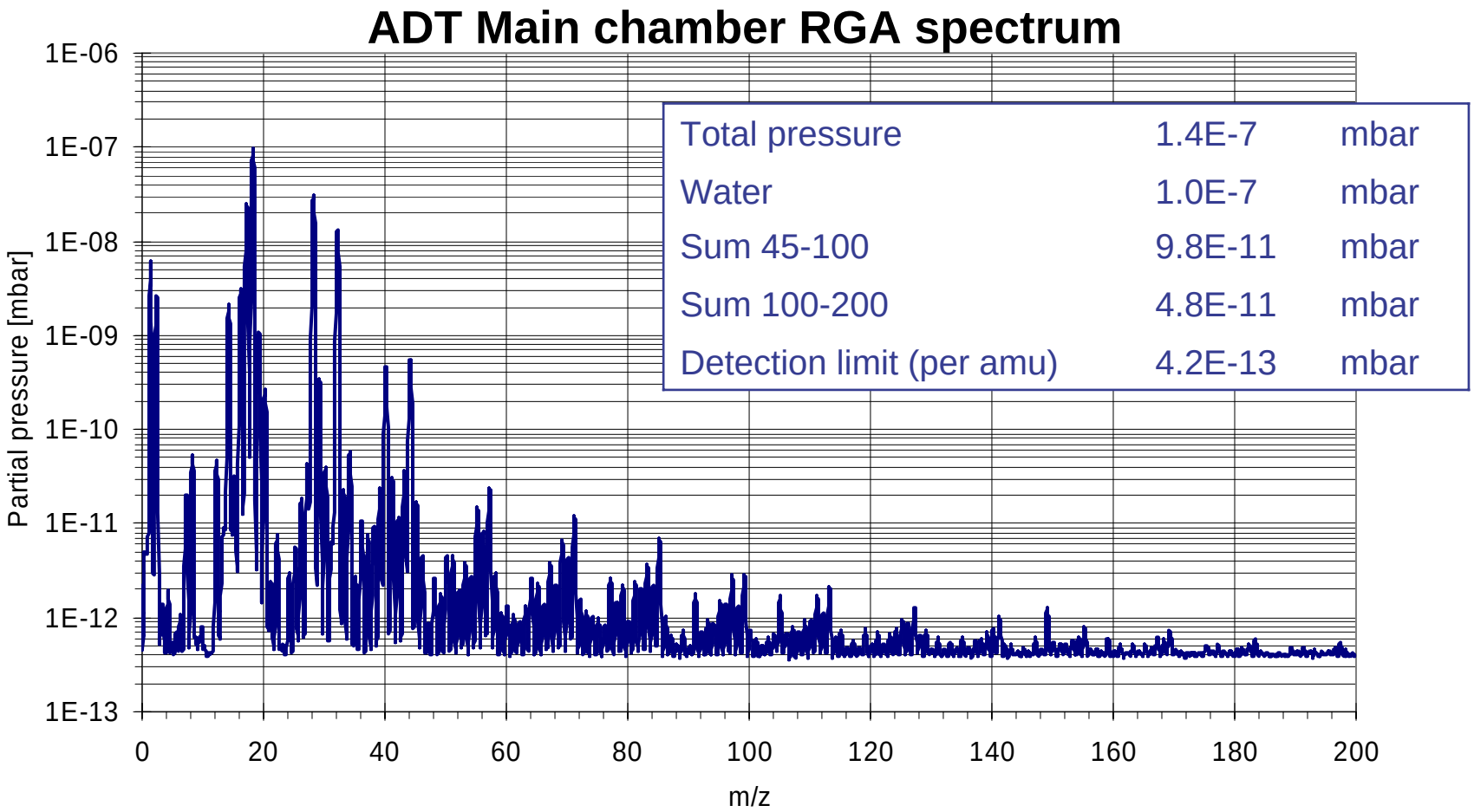
The chamber vacuum qualification is done to match what is expected for the ADT



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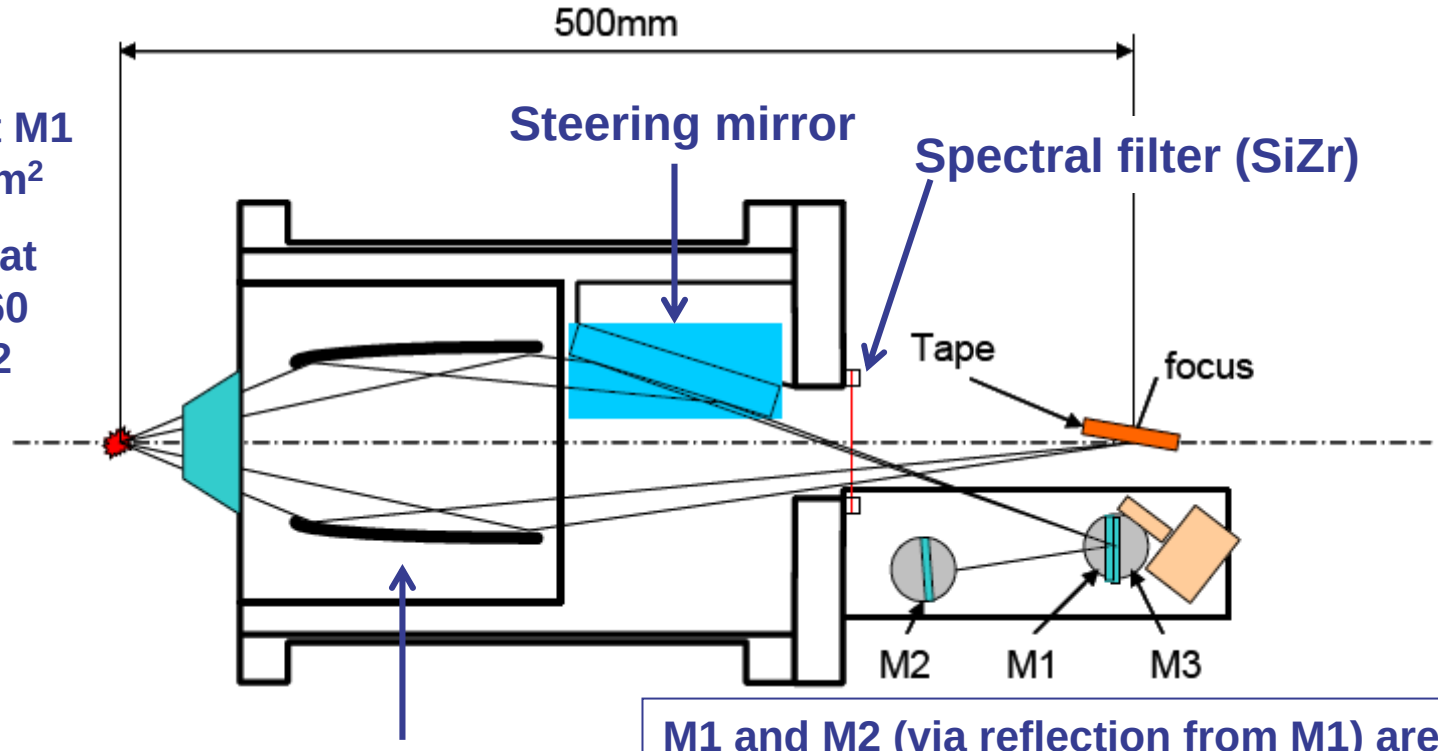
Guidelines are provided for the RGA resist outgassing test which is for information only

- Expose a resist sample in the test chamber and measure the outgassing components with an RGA
  - The background from the qualification part can be removed as part of the resist RGA analysis
  - RGA testing can be done during the resist reflectivity loss testing if the chamber design supports this
- While there are no firm requirements it is advised that ASML be contacted if any of the following species are detected which exceed the out gassing values given:
  - H_2O 5×10^{15} mlc cm^{-2} s^{-1}
  - C_xH_y Σ[m45-m100] 5×10^{13} mlc cm^{-2} s^{-1}
  - Σ [F, Cl, I] 5×10^{14} mlc cm^{-2} s^{-1}
  - Σ [S, P] 5×10^{11} mlc cm^{-2} s^{-1}
  - Σ Si 5×10^{9} mlc cm^{-2} s^{-1}

ASML experimental set-up for determining ΔR/R uses 3 ML mirror samples per test



Intensity at M1 ≥ 1 mW/cm²

Intensity at resist ≥ 60 mW/cm2

M0 – Lab witness sample (Travels with M1, M2, and M3)

M1 and M2 (via reflection from M1) are exposed to EUV radiation
M3 is not directly exposed to EUV radiation (and is a control)
M2 and M3 are optional but M3 is highly recommended

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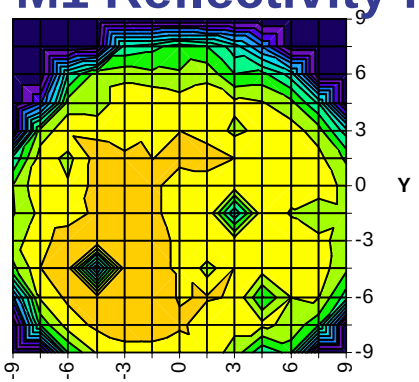
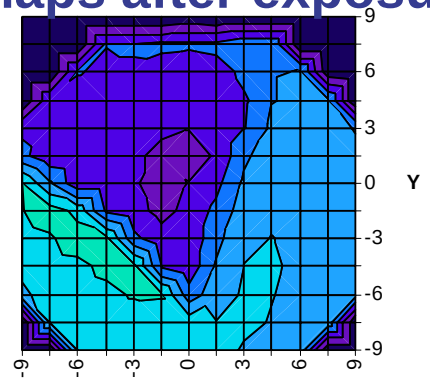
The ΔR/R is calculated on a point by point basis from the reflectivity maps from before and after exposure and the maximum is reported

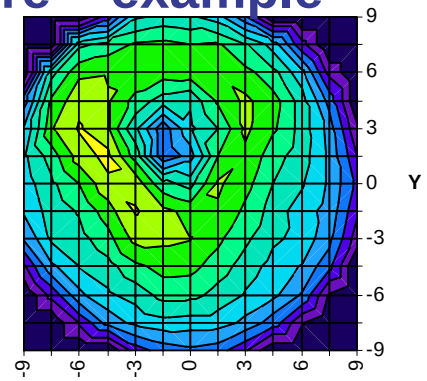
M1 Reflectivity maps after exposure – example



Pre-verification



Resist Test

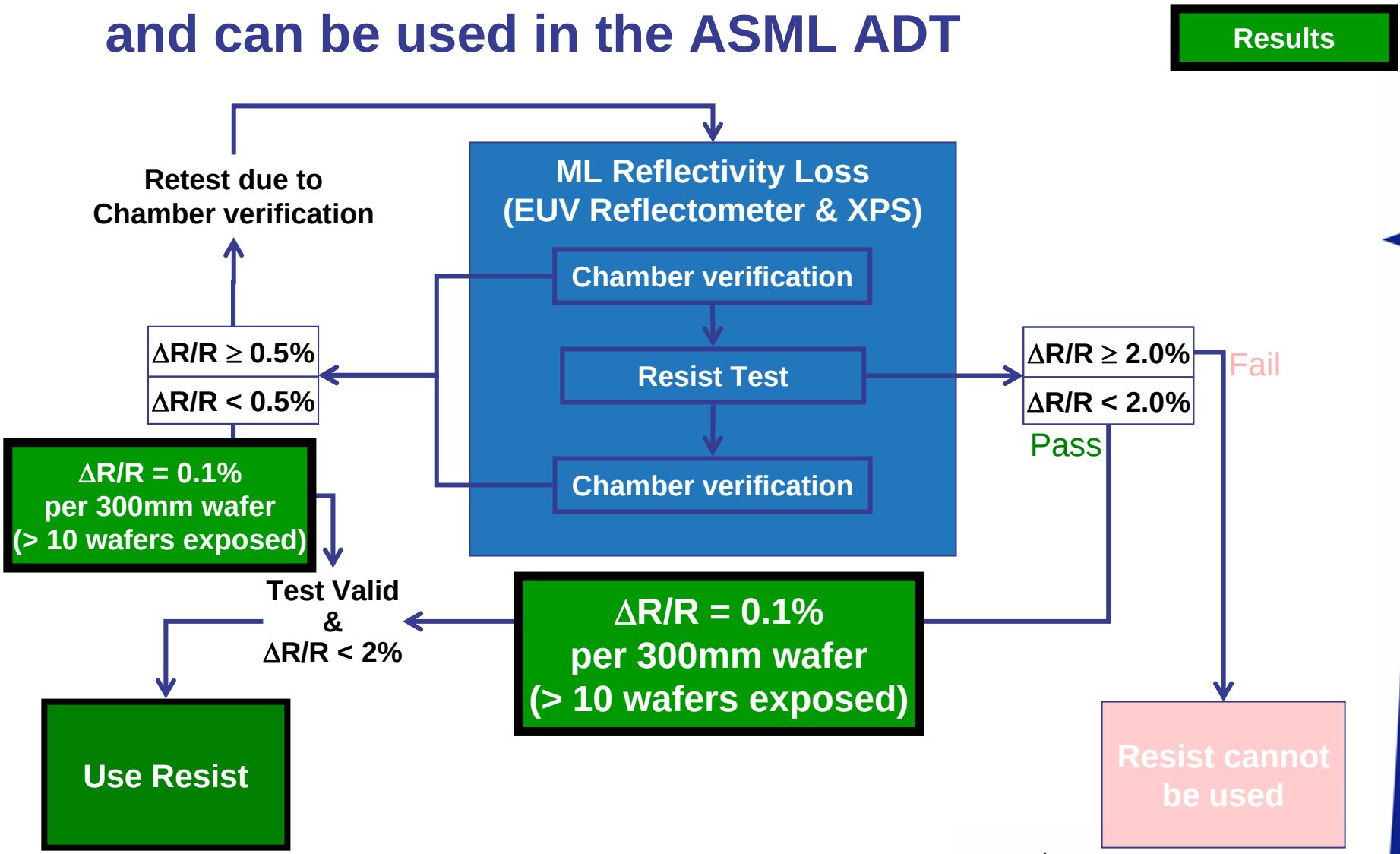


Post-verification

~300 points measured over ~500 mm²

MET-2D	Effective # of 300mm wafers exposed	Mirror Locations	ΔR/R (%)	ΔR/R per 300mm wafer (%)	ΔR/R (%) w/o background per wafer	Req. (%)
Pre Chamber Verification	22.2	M1	0.9	0.0		< 0.5
		M2	0.9	0.0		
		M3	0.6	0.0		
Resist Test	45.85	M1	8.3	0.2	0.1	≤ 2.0
		M2	5.0	0.1	0.1	
		M3	2.7	0.1	0.0	
Post Chamber Verification	22.2	M1	0.9	0.0		< 0.5
		M2	1.2	0.1		
		M3	0.4	0.0		
Lab Witness		M0	0.9			

MET2D meets resist out gassing requirements and can be used in the ASML ADT



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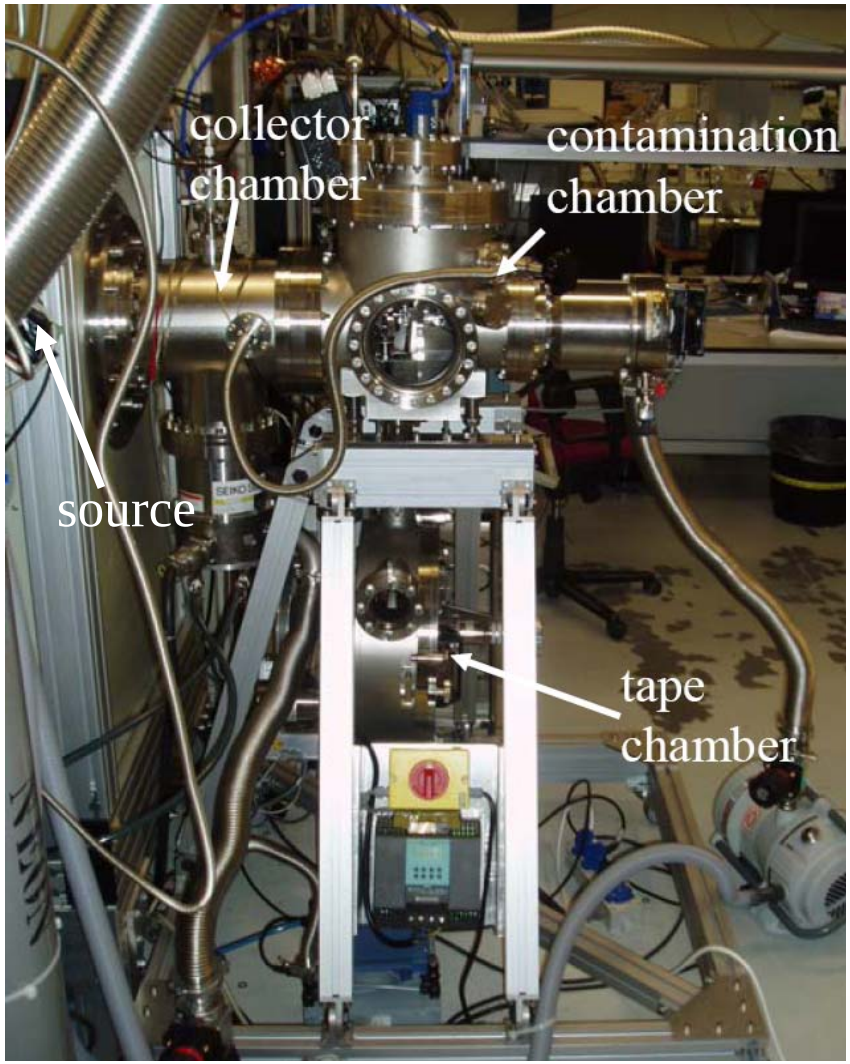
ASML is enabling a resist outgassing test facility for industry use

- ASML has a requirement that resist be qualified for outgassing before being used on the Alpha tool
- Three resists have been qualified by ASML and the expectation was that others would continue this work in new test facilities
- These other facilities have been having difficulty getting qualified, so to provide an alternate facility for resist testing, ASML has put together a plan with TNO that would enable TNO to provide a resist testing service to industry
- To get the TNO facility on line by year end, ASML is lending a source + collector + chamber and the tape deck facility used previously by ASML to qualify resists
- ASML is also funding the necessary work and additional HW that must be procured to design / build / qualify the facility at TNO

TNO contact is Marco Meijerink; marco.meijerink@tno.nl

The experimental set up at TNO will be a modification to the earlier set up used at ASML



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Resist outgassing tests will be done by TNO

- The estimated cost to run a full resist test cycle is 35 k€ and the deliverable will be a test report like the ones created by ASML (see previous MET 2D report)
  - The customer must provide 0.5 liter of properly diluted photoresist
- Each test cycle could take as long as 8 weeks driven by the turn around time for reflectometry at one of the beam lines (Germany, US) (accuracy needed is < 0.2%)
  - Suggestions on how to get better service at either location would be appreciated, but this is the typical timing experienced by ASML
  - With the TNO plans and the ASML type of test chamber, running the test is not the limitation to the testing (this can be done in days); metrology is
- The baseline plan is that any company can contract with TNO to test a resist and the testing will be confidential, but ASML will get copies of all results

Test Materials and Procedure

Materials required for multilayer mirror reflectivity loss testing – Part 1 of 3

- Test Chamber and EUV source
  - Must be able to hold resist sample holder and at least 1 multilayer (ML) mirror sample – 3 ML samples are preferred
  - Pulsed source < 50 kHz (ASML source is 900 Hz)
  - Power at mirror and resist influences carbon growth rate on M1 and time to do the test
    - An intensity of at least 1 – 10 mW/cm^2 on M1 must be used for $\Delta R/R$ determination
    - At 60 mW/cm^2 at the resist it takes ~8 hours to expose the equivalent of 10 300mm wafers coated with MET-2D in the ASML set-up (which uses a continuous copper tape to hold the resist samples)
    - More power at the resist will shorten the overall test time

Materials required for multilayer mirror reflectivity loss testing – Part 2 of 3

- 2 Resist sample holders (one is coated the other is not coated)
  - The total area of the resist sample exposed depends on
    - Accuracy of the reflectometer
    - Desired level of uncertainty in the calculations
    - Time to perform the test
  - An exposed resist area greater than the one equivalent 300 mm wafer (at least 10) is highly recommended
    - This can be a coated copper tape whose length x EUV spot width is greater than the area of a 300mm wafer
    - This can also be multiple wafers whose total area is greater than one 300mm wafer

Materials required for multilayer mirror reflectivity loss testing – Part 3 of 3

- 10 Multi-Layer Mirror Samples are needed per test
  - With the ASML configuration, 6 are for chamber qualification, 3 are for the resist testing, 1 is a lab witness sample
  - ML samples need reflectivity > 65%, reflectivity uniformity ± 0.2%
- EUV Reflectometer
  - Accuracy < 0.2%
- XPS (optional)

Multilayer reflectivity loss test details – 1 of 2

1. Measure the EUV reflectivity for all 10 multilayer samples prior to any testing
   - This can be done in-situ
2. Obtain resist coated sample holder and an uncoated sample holder for testing
   - The total area of the sample tape should be greater than the area of a 300mm wafer. This can also be a coated and uncoated wafer. ASML typically exposes the equivalent of more than 10 300mm wafers per test. Larger total exposure area yields greater accuracy.
3. Pre chamber verification test. Place the first 3 mirrors into the chamber and expose the uncoated resist sample holder as if there were resist on it. The resist sample should be moving within the beam area so that the whole sample receives the same dose. The total dose should identical to the resist exposure. The minimum exposure dose should be equivalent to $2*E_0$ of the resist that will be used in the test. Remove the multilayer mirror samples if the reflectivity measurements are done ex-situ.

Multilayer reflectivity loss test details – 2 of 2

4. Resist Test. Place the second 3 mirrors into the chamber and expose the coated resist sample holder. The dose should be identical to the dose used in the pre vacuum validation test. Remove the multilayer mirror samples if the reflectivity measurements are done ex-situ.
5. Post chamber verification test. Using the last 3 mirrors, repeat the pre chamber verification test.
6. Measure the reflectivity for all 10 samples
   - This can be done in-situ
7. Optional: XPS analysis

ML Reflectivity loss test analysis overview – 1 of 2

1. Measure the EUV reflectivity of all 10 samples
2. Calculate $\Delta R/R$ for all samples – Reflectivity Loss
   - This is done on a point-by-point basis with the before and after exposure reflectivity maps
   - The maximum $\Delta R/R$ is used in the following
3. Verify the lab witness sample meets requirements if measurements are done ex-situ
   - The requirement for the lab witness sample is $\Delta R/R < \pm 0.2\%$

ML Reflectivity loss test analysis overview – 2 of 2

4. Verify the pre and post chamber validation
   - The requirement for the chamber validation is $\Delta R/R < 0.5\%$ (per effective 300mm wafer)
   - If not OK stop – clean and retest because resist test is not valid
5. Verify that $\Delta R/R$ per 300mm wafer for M2 and M3 are less than $\Delta R/R$ per 300mm wafer for M1 if they were used in the test
6. The requirements for M1 are
   - Pass: $\Delta R/R < 2.0\%$ per 300mm wafer
     This can be corrected for background based on chamber validation data
   - Fail: $\Delta R/R \geq 2.0\%$ per 300mm wafer

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“Artificial” data and calculations to show steps leading to final ΔR/R per 300mm wafer

	effective # of 300mm wafers exposed	Mirror Locations	pre-Reflectivity (%)	post-Reflectivity (%)	ΔR/R (%)	ΔR/R per 300mm wafer (%)	ΔR/R (%) w/o background per wafer	Req. (%)
pre Chamber Verification	11	M1	65.0	62.0	4.6	0.42		< 0.5
		M2	65.0	64.5	0.8	0.07		NA
		M3	65.0	65.0	0.0	0.00		NA
Resist Test	16	M1	65.0	55.0	15.4	0.96	0.6	< 2.0
		M2	65.0	63.0	3.1	0.19	0.1	NA
		M3	65.0	63.9	1.7	0.11	0.1	NA
post Chamber Verification	14	M1	65.0	63.0	3.1	0.22		< 0.5
		M2	65.0	64.0	1.5	0.11		NA
		M3	65.0	65.5	-0.8	-0.05		NA
Lab Witness		M0	65.0	64.7	0.5			

- Multiple wafers ensure that the error from the reflectometer is minimized
- Green cells meet requirements
- Background removed is just the average pre and post verification ΔR/R per 300mm wafer removed for each mirror position

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