Mirror reflectivity loss and resist outgassing rates

Optics Contamination TWG, SPIE 2008

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There are concerns on determining acceptable resist outgassing

- Degas of resist is not correlated to mirror reflectivity, but the real requirement is mirror lifetime
- Resist exposure in many tests are not matched or scaled to litho system in many outgassing tests. Parameters of worry are
  - Intensity
    - Energy per pulse
  - Pulsed source (Vs continuous)
  - Dose calibration
  - Spectral content
- Reports with various test methodologies do not usually give
  - Measurement repeatability
  - Initial vacuum conditions

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Specifications vary among the various groups for resist outgassing requirements

Entity	Specification	Units
ASML	For ADT only: < 2% Reflectivity Loss for 1 300mm wafer Guidance (not correlated to mirror reflectivity loss): H_2O: $7x10^{15}$ CxHy(1-200): $7x10^{13}$ Σ [F, Cl, I]: $5x10^{14}$ Σ [S, P]: $5x10^{11}$ Σ Si: $5x10^{9}$	(%) Molecules cm^{-2} s^{-1} Molecules cm^{-2} s^{-1} Molecules cm^{-2} s^{-1} Molecules cm^{-2} s^{-1} Molecules cm^{-2} s^{-1}
Nikon	H_2O: $7x10^{14}$ CxHy: $7x10^{12}$	Molecules cm^{-2} s^{-1} Molecules cm^{-2} s^{-1}
SEMATECH	$6.5x10^{14}$	Molecules cm^{-2}
ITRS (2006)	Outgassing rate for 2 minutes under the lens < $5x10^{13}$	Molecules cm^{-2} s^{-1}

Only ASML has stated that the spec is tied to a litho tool and its environment

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Speculation on linking resist degas to mirror reflectivity

wafer size	300	mm	
Rate	2.72E+11	mol/(cm²-s)	
Accumulation	3.20E+14	mol/cm²/wafer	
Total mol out gassed	2.26E+17	mol/wafer	
Average Weight	60	amu	
Density of carbon	2	gm/cm²	
Mirror size	1	cm²	
dist to mirror	3	cm	
Suppression device transmission	100%		**We assume that all molecules that can hit mirror, hit the mirror**
%mol hit mirror	1.77	%	
% of molecules that stick	100%		**We assume that all molecules that hit the mirror, stick to the mirror**
Total mol that stuck to mirror	4.00E+15	mol/cm²/wafer	
% of molecules that contribute to C layer	100%	<----------	**We assume that all molecules that stick to the mirror contribute**
thickness of contamination	2.00	nm/wafer	cm -> nm requires 1E-7

This rate is impossible

Average might not work

Reflectivity Loss:		
Hydrocarbon	2.0	%/wafer
Oxides	6.0	%/wafer

Other assumptions:

1. Outgassing is Isotropic (hence 1/r² dependence on mol that hit mirror)
2. Average molecular weight is 60 AMU

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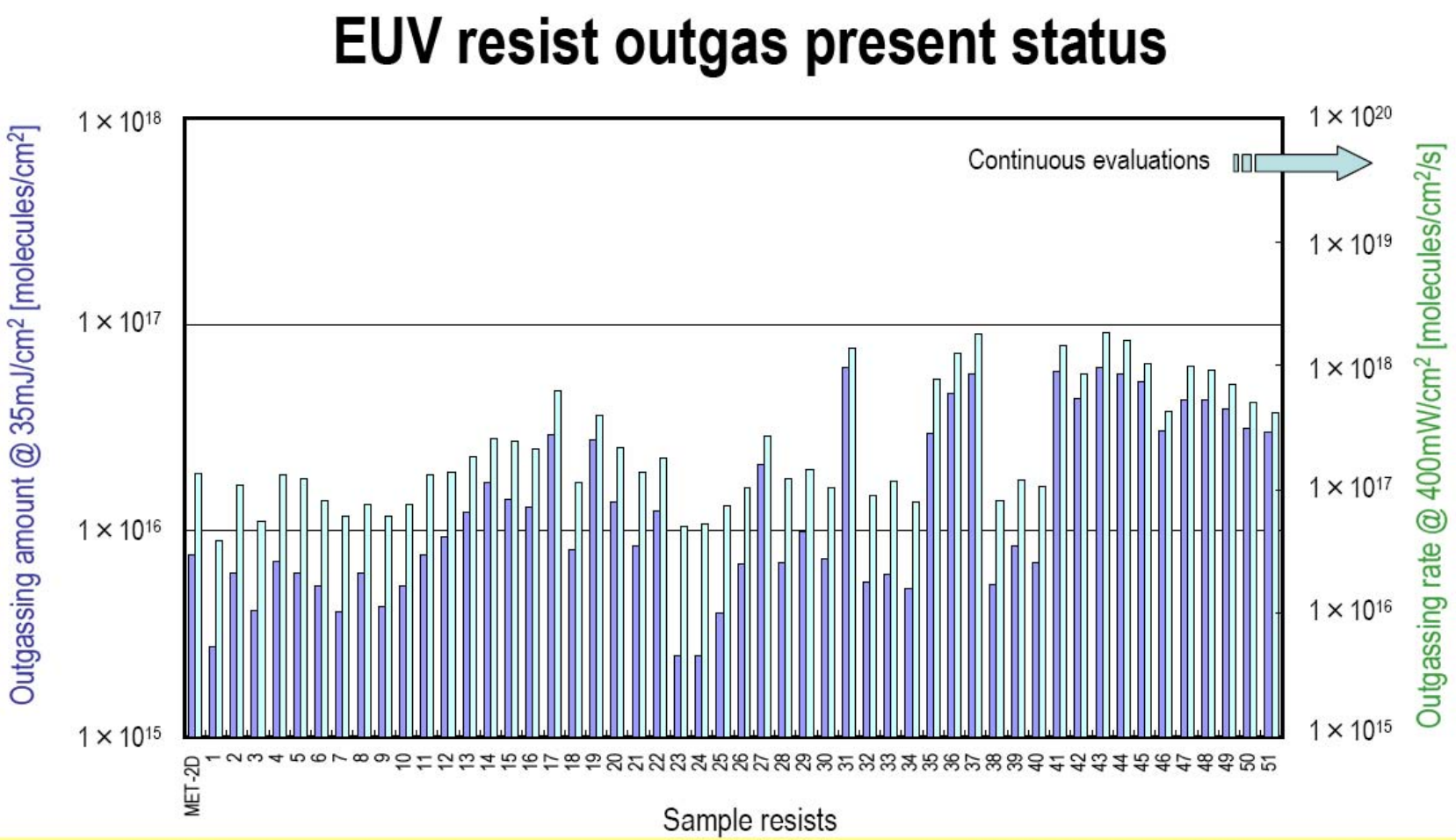
Resist outgassing requirements cannot be met with the assumptions in the previous slide

IRAI

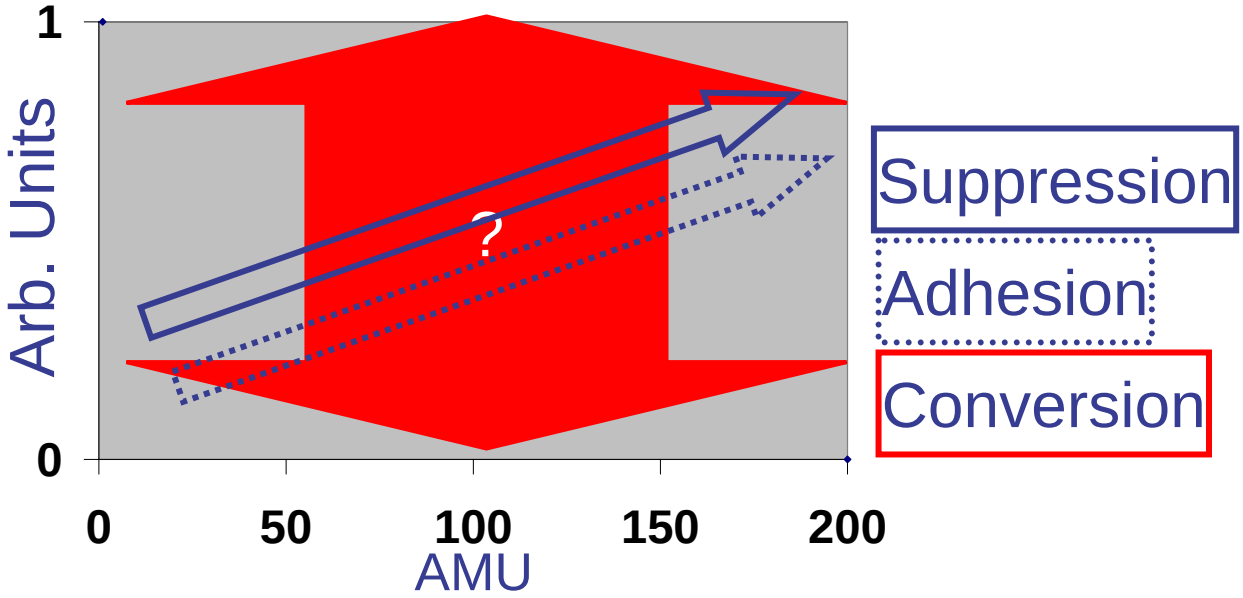
Selete



Majority of the resist samples evaluated have an outgassing rate of 2 x 10^{17} [molecules / cm^2/ s] or lesser assuming an EUV source intensity of 400mW/cm^2.

These things need to be known if we want to correlate degas to mirror reflectivity

In general, we know that heavy hydrocarbons stick better than lighter ones



Since there is photo-chemistry involved there may be no AMU dependency of conversion to contamination

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Linking mirror reflectivity change to resist outgassing rates will require more detailed data

- In order to connect outgassing to mirror reflectivity loss we need to understand the following with respect to the outgas species
  - Suppression
  - Adhesion
  - Conversion to C-layer
- In order for these tests to be repeatable, agreements must be made on
  - Intensity
    - Energy per pulse
  - Pulsed source (Vs continuous)
  - Dose calibration
  - Spectral content
  - Initial vacuum conditions

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Reference slides from ASML’s 2007 Sapporo presentation

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

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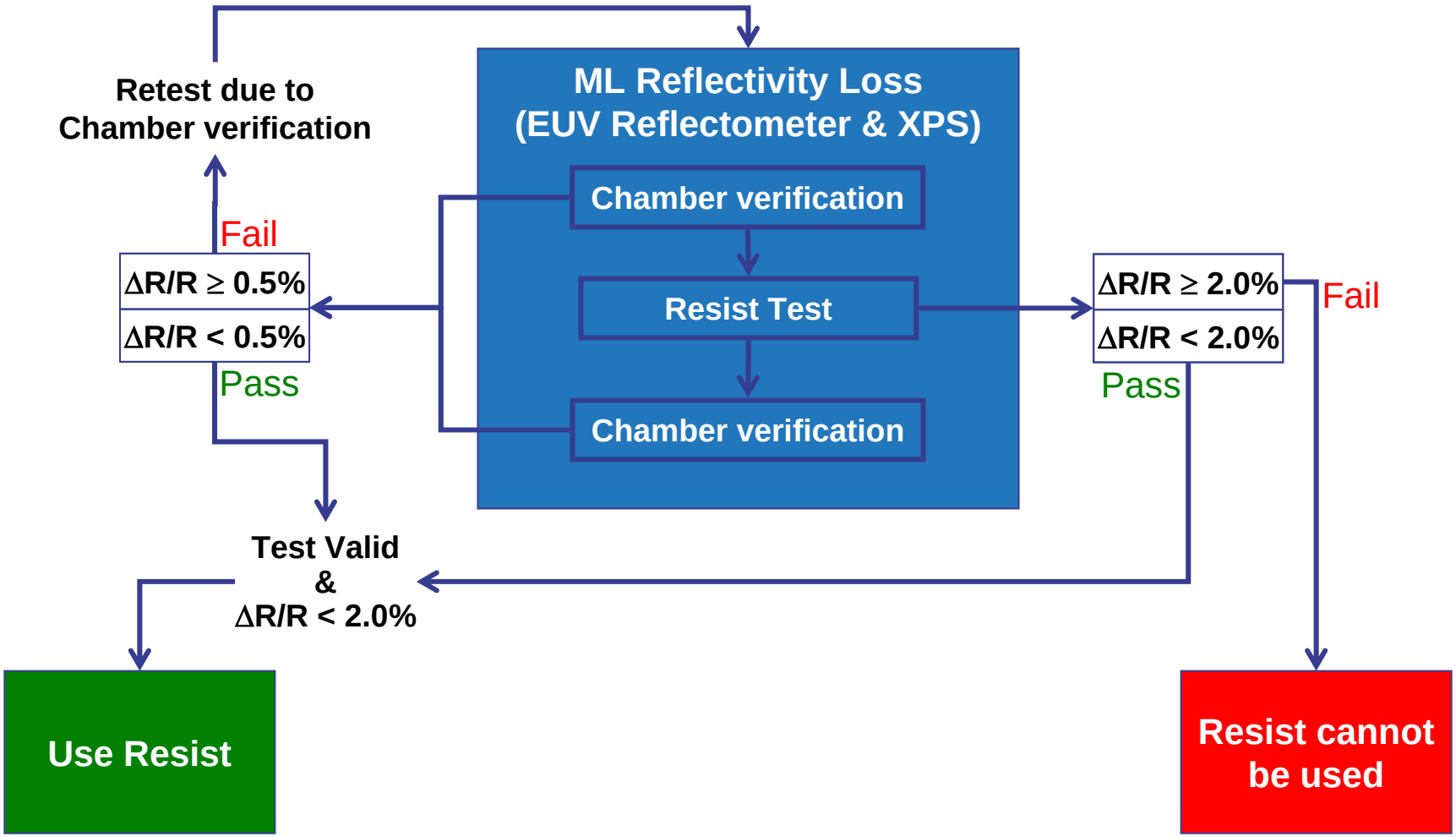
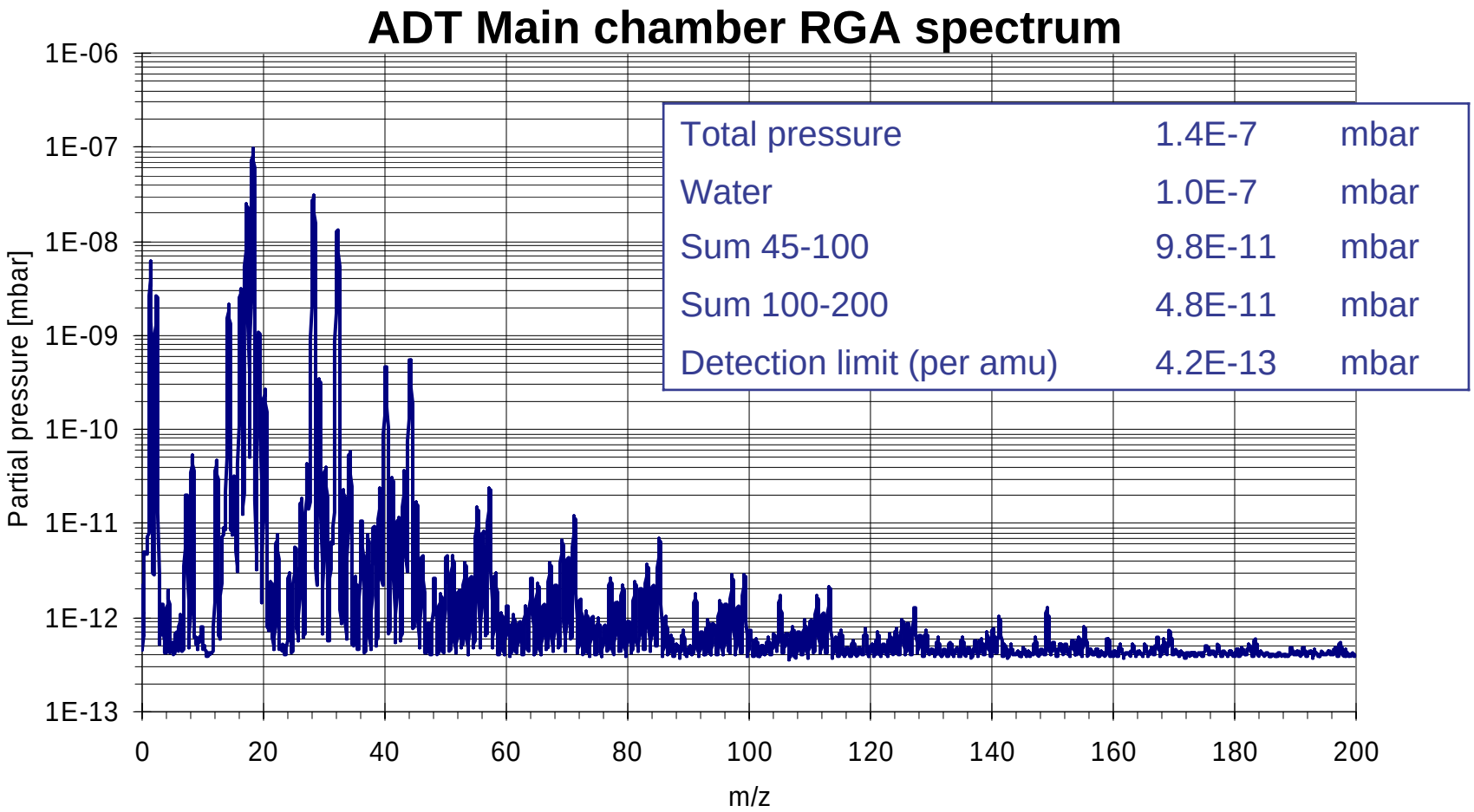
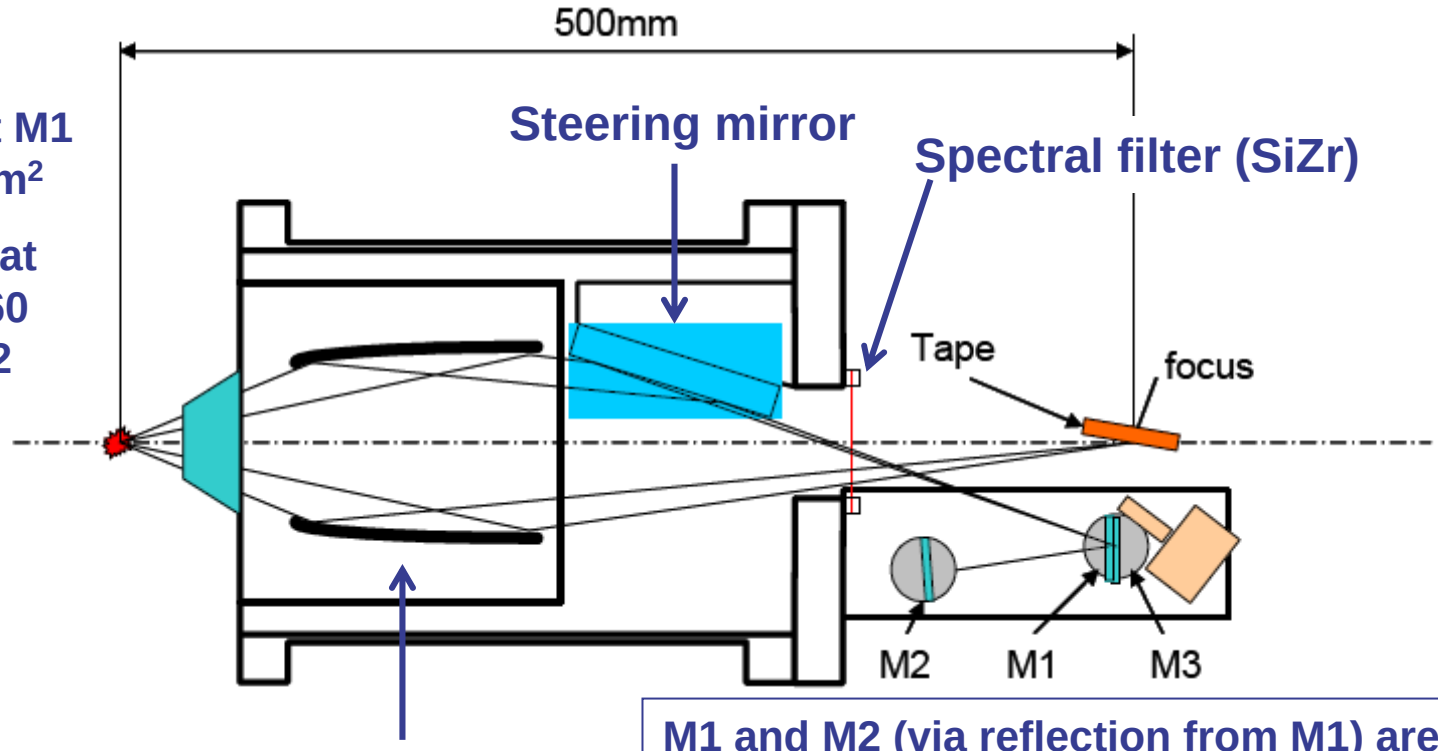
Test protocol determines ΔR/R per 300mm wafer for identifying resist with acceptable outgassing



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



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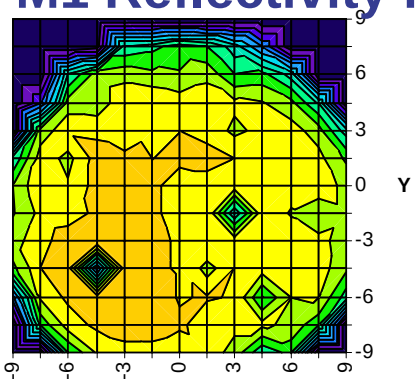
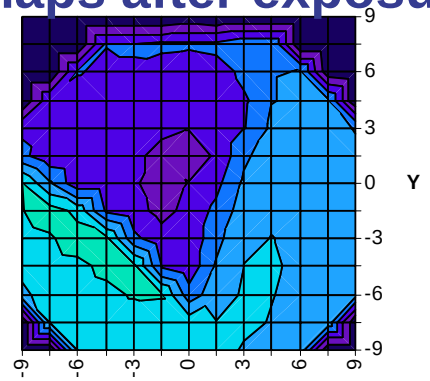
The ΔR/R is calculated on a point by point basis from the reflectivity maps from before and after exposure and the maximum is reported

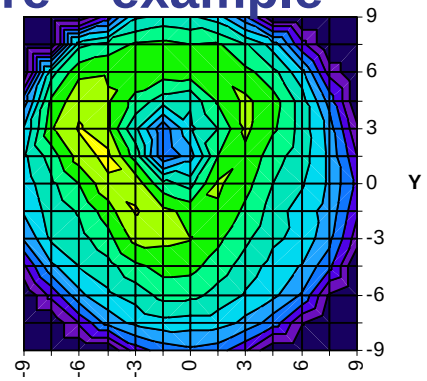
M1 Reflectivity maps after exposure – example



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