Review of Resist Outgassing Round Robin and Some Comments

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Outgassing Results (I)

Institute	Source Method	Results		Estimate Rate Molecules/cm^2/s @Prod. Tool (0.4 W/cm^2)
		Molecules/cm^2 @5.6 mJ/cm^2 dose	Molecules/cm^2/s @each intensity condition	
Intel Wisconsin	Synchrotron Accumulation method	4.4×10^{11}	2.9×10^{10} 0.33 mW/cm^2 33-550 amu*	1.3×10^{13}
SEMATECH Wisconsin	Synchrotron Accumulation method	3.9×10^{13}	2.6×10^{12} 0.33 mW/cm^2 35-435 amu*	1.1×10^{15}
ASET	Synchrotron Pressure rise method	1.9×10^{14}	4.5×10^{12} 0.13 mW/cm^2 1-200 amu	5.7×10^{15}
Univ. of Hyogo	Synchrotron Pressure rise method	9.4×10^{14}	4.5×10^{13} 35-200 amu	6.7×10^{16}

*Excluding 44 amu (CO_2)

Outgassing Results (II)

Institute	Method	Results		Estimate Rate
		Molecules/ cm^2 @5.6 mJ/cm^2 dose	Molecules/ cm^2/s @each intensity condition	Molecules/cm^2/s @Prod. Tool (0.4 W/cm^2)
SEMATECH U. Albany	Stand-alone source Summing method	3.3×10^{14}	1.94×10^{13} 0.9 mW/cm^2 35-200 amu*	9.9×10^{15}
CEA/LETI	Stand-alone source Summing method	1.2×10^{15}	4.5×10^{11} 2 $\mu W/cm^2$ 1-200 amu*	3.6x1016
ELETTRA Trieste	Synchrotron Summing method	1.4×10^{16}	1.4×10^{15} 0.72 mW/cm^2 1-100 amu	4.2×10^{17}
BOC Edwards	Stand-alone source Summing method	2.8×10^{14}	5×10^{13} 1 mW/cm^2 35-200amu*	8.3×10^{15}

*Excluding 44 amu (CO_2)

Review and comment on resist outgassing requirement

Resist Outgassing Rate Specifications

Assigned 1% of total outgassing budget to resist.

Component	Spec for Outgassing (molecules/cm^2-sec)
$H_2 0$	4.7E15
$C_x H_y$ (integr.> 44 AMU)	4.7E13
Fluorine/Clorine	4.7E11
Sulfur/Phosphorus	4.7E11
Silicon	4.7E9

But…..what is the resist thickness?

is there an intensity dependence for outgassing?

is the angular distribution cosine

is the gas released quickly? and for how long?

Species were identified in experiments under ExCITe program using 248nm and EUV resists.

Current resist qualification is mass spectroscopy

- Mass spectroscopy (RGA) while resist is exposed with EUV is currently used
- Specifications for degassing rates proposed a few years ago by ASML for Alpha Demo (AD) tool are

	($molec/cm^2/s$)
H_20	4.7E15
C_xH_y (integr. > 44 AMU)	4.7E13
F/Cl	4.7E14
S/P	4.7E11
Si	4.7E9

Updated Acceptable Outgassing Rate

Assumption

Degree of Vacuum of PO	$1E10^{-5}$ Pa for H_2O
	$1E10^{-7}$ Pa for CxHy
Resist Outgas/Residual Gas	1/20

Updated Acceptable Rate for α-tool

	Outgassing Rate [molecules cm^{-2} s^{-1}]
H2O	$7E10^{14}$
CxHy (] 45 amu)	$7E10^{12}$

How to convert from molecules/cm^2 to molecules/cm^2/s

If the outgassing amount of molecules, M molecules/cm2 is obtained using resist of ε J/cm2 (Esize), outgassing rate（amount of outgassing molecules in 1s) can be calculated as follows

Exposure time for Esize in EUV intensity of I_{euv} W/cm^2

= ε (J/cm2) / I_{euv} (W/cm^2) = ε / I_{euv} (s)

overhead correction factor (duty ratio) = α

Light-on time in 1 s = α (s)

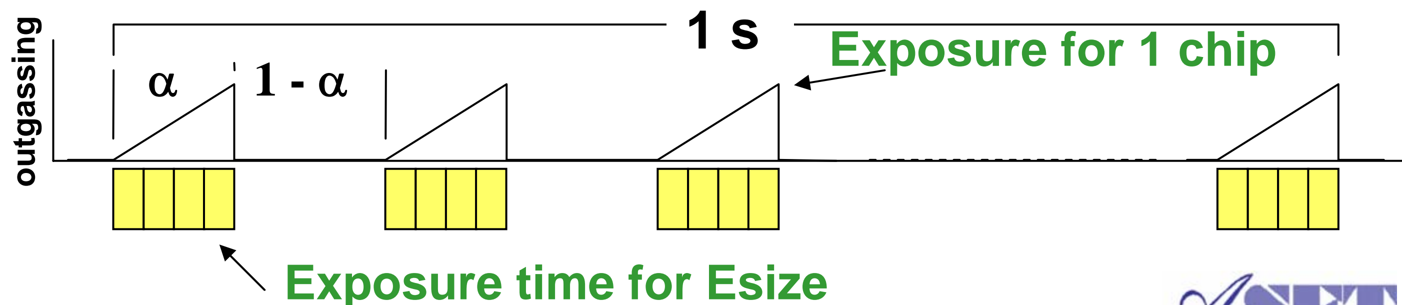
number of irradiations for Esize exposure = αI_{euv} (s) / ε

Outgassing amount in 1 s = M × αI_{euv} (s) / ε

If α=0.4, ε = 5.5 mJ /cm^2, and I_{euv} =0.4 W/cm^2 is assumed,

conversion factor: α I_{euv}(s) / ε = 30

So, 10^{12} molecules/cm^2 in accumulation method corresponds to the outgassing rate of 3 x 10^{13} molecules/cm^2



Unit Conversion from Tool supplier's requirements to resist-community-friendly requirements(1)

Speceies	ASML original requirement (Rate)	Converted requirement (Quantity) in HVM	Converted requirement (Quantity) in α tool
	molecules･cm-2･s-1	molecules･cm-2	molecules･cm-2
H2O	4.7E15	1.6E14	1.6E15
CxHy	4.7E13	1.6E12	1.6E13
F/Cl	4.7E11	1.6E10	1.6E11
S/P	4.7E11	1.6E10	1.6E12
Si	4.7E9	1.6E8	1.6E9

Cf) Intel's Spec for MET: 6.5E13 molecules･cm-2

1/10 power of HVM is assumed for α tool

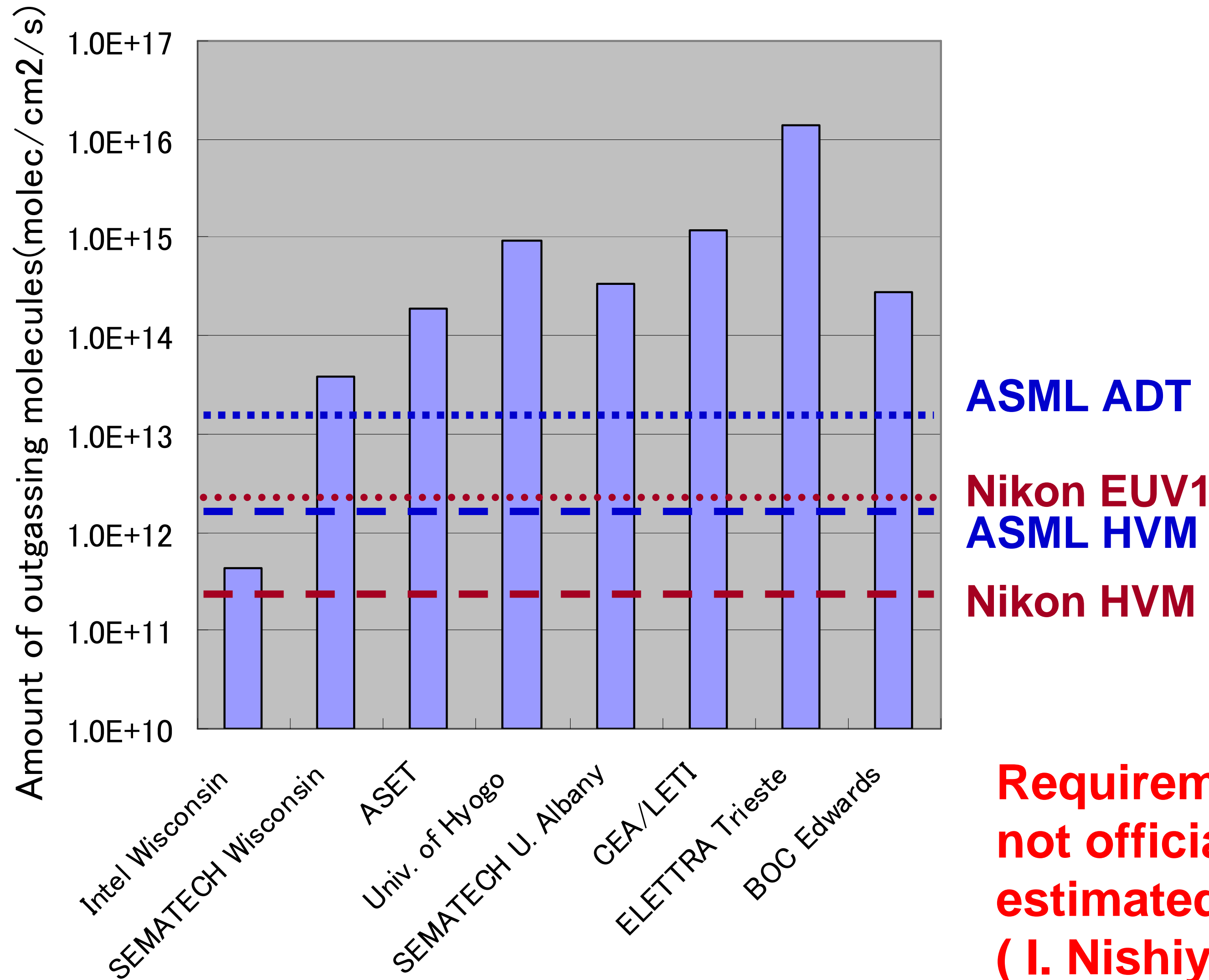
Unit Conversion from Tool supplier's requirements to resist-community-friendly requirements(1)

Speceies	Nikon new requirement (Rate)	Converted requirement (Quantity) in HVT	Converted requirement (Quantity) in α tool
	molecules・cm-2・s-1	molecules・cm-2	molecules・cm-2
H_2O	7E14	2.3E13	2.3E14
CxHy	7E12	2.3E11	2.3E12

Cf) Intel's Spec for MET: 6.5E13 molecules・cm-2

1/10 power of HVM is assumed for α tool

Reported RR results and requirement

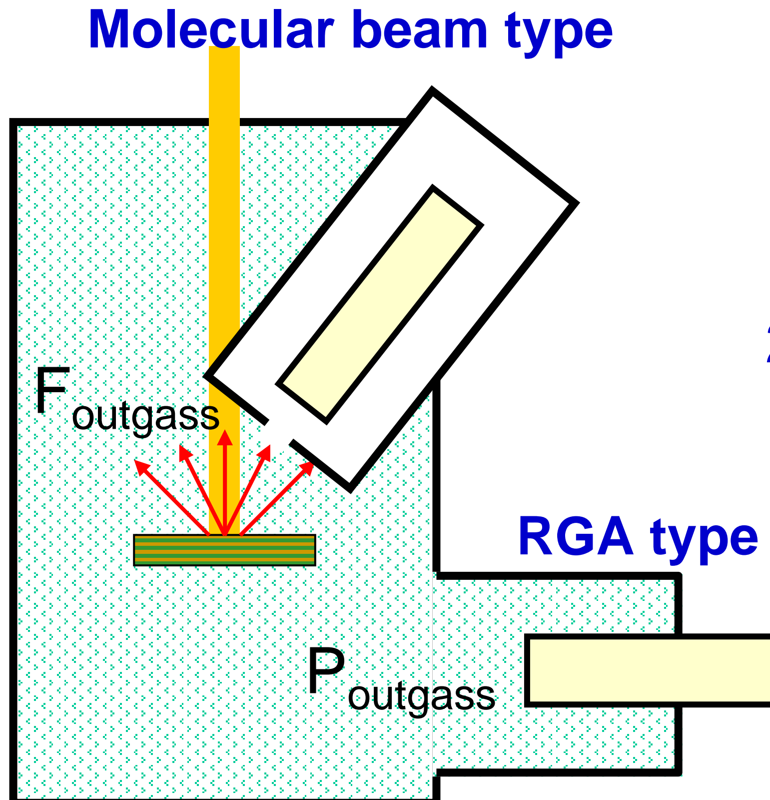


Requirement levels are not official. They are estimated privately. (I. Nishiyama, 061019)

Comments on in situ monitoring of outgassing rate

Comment on in situ monitoring of outgassing rate

There are two concepts for monitoring outgassing molecules.



1)Molecular beam type

- Measure outgassing flux
- Rate is calculated from the flux directly by considering the angular distribution.
- Contribution from background pressure should be suppressed.

2)RGA type

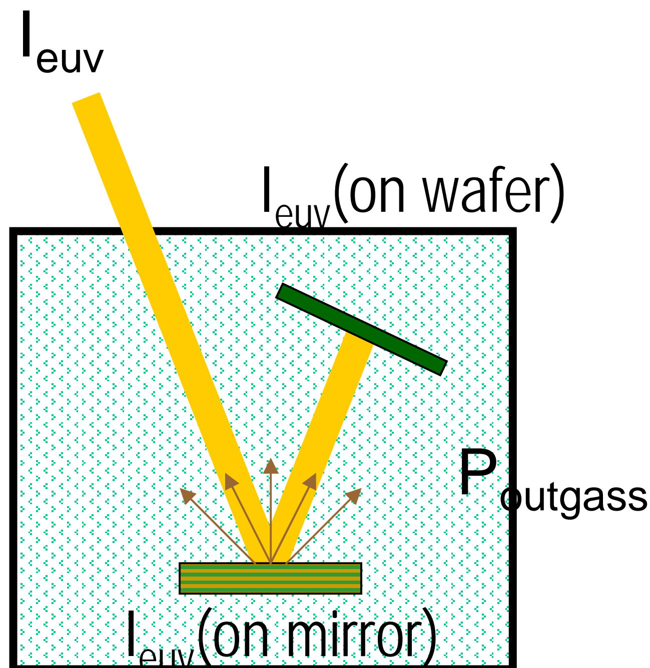
- Measure pressure caused by outgassing
- Rate is calculated from pumping speed.
- Contribution from direct beam should be suppressed.

Worning:

When pressure rise method is used, direct beam contribution causes overestimation of outgassing rate.

Comments on ASML's New requirement

Comment on ASML's New requirements



Growth rate is basically proportional to the product of Ieuv(on wafer) x Poutgass

$$R \propto I_{euv} \times P_{outgas}$$

I_{euv}: dependent on beam condition

What type beam condition is assumed, parrarel or divergent?

P_{outgas} : dependent on Pumping speed

Pumping speed should be defined.

- **This requirement is practical since it consider the contamination growth speed of outgassing species.**
- **This requirement is ambiguous.**
- **Quantitative requirements such as molecules·cm-2 are better for resist researchers.**