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IEUVI Resist TWG meeting & Optics Contamination Workshop

Review of Resist Outgassing Round Robin and Some Comments

ASET EUV Process Technology Laboratory

Iwao Nishiyama

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/c m 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 (CO₂)



Accelerating the next technology revolution.

Outgassing Results (II)

Institute	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	
SEMATECH U. Albany	Stand-alone source Summing method	3.3x10 ¹⁴	1.94 × 10 ¹³ 0.9 mW/cm ² 35-200 amu*	9.9 × 10 ¹⁵
CEA/LETI	Stand-alone source Summing method	1.2x10 ¹⁵	4.5x10 ¹¹ 2 μW/cm ² 1-200 amu*	3.6x10 ¹⁶
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 (CO₂)



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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 O	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 ₂ O	4.7E15
C _x H _y (integr. > 44 AMU)	4.7E13
F/Cl	4.7E14
S/P	4.7E11
Si	4.7E9

How to convert from molecules/cm² to molecules/cm²/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

$$\text{Exposure time for Esize in EUV intensity of } I_{\text{euV}} \text{ W/cm}^2 \\ = \epsilon \text{ (J/cm}^2\text{)} / I_{\text{euV}} \text{ (W/cm}^2\text{)} = \epsilon / I_{\text{euV}} \text{ (s)}$$

$$\text{overhead correction factor (duty ratio)} = \alpha$$

$$\text{Light-on time in 1 s} = \alpha \text{ (s)}$$

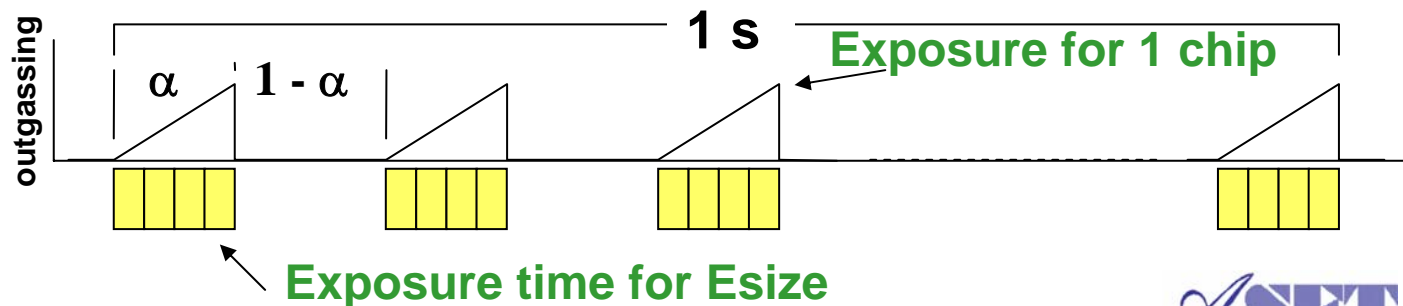
$$\text{number of irradiations for Esize exposure} = \alpha I_{\text{euV}} \text{ (s)} / \epsilon$$

$$\text{Outgassing amount in 1 s} = M \times \alpha I_{\text{euV}} \text{ (s)} / \epsilon$$

If $\alpha = 0.4$, $\epsilon = 5.5 \text{ mJ/cm}^2$, and $I_{\text{euV}} = 0.4 \text{ W/cm}^2$ is assumed,

$$\text{conversion factor: } \alpha I_{\text{euV}} \text{ (s)} / \epsilon = 30$$

So, 10^{12} molecules/cm² in accumulation method corresponds to the outgassing rate of 3×10^{13} molecules/cm²



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

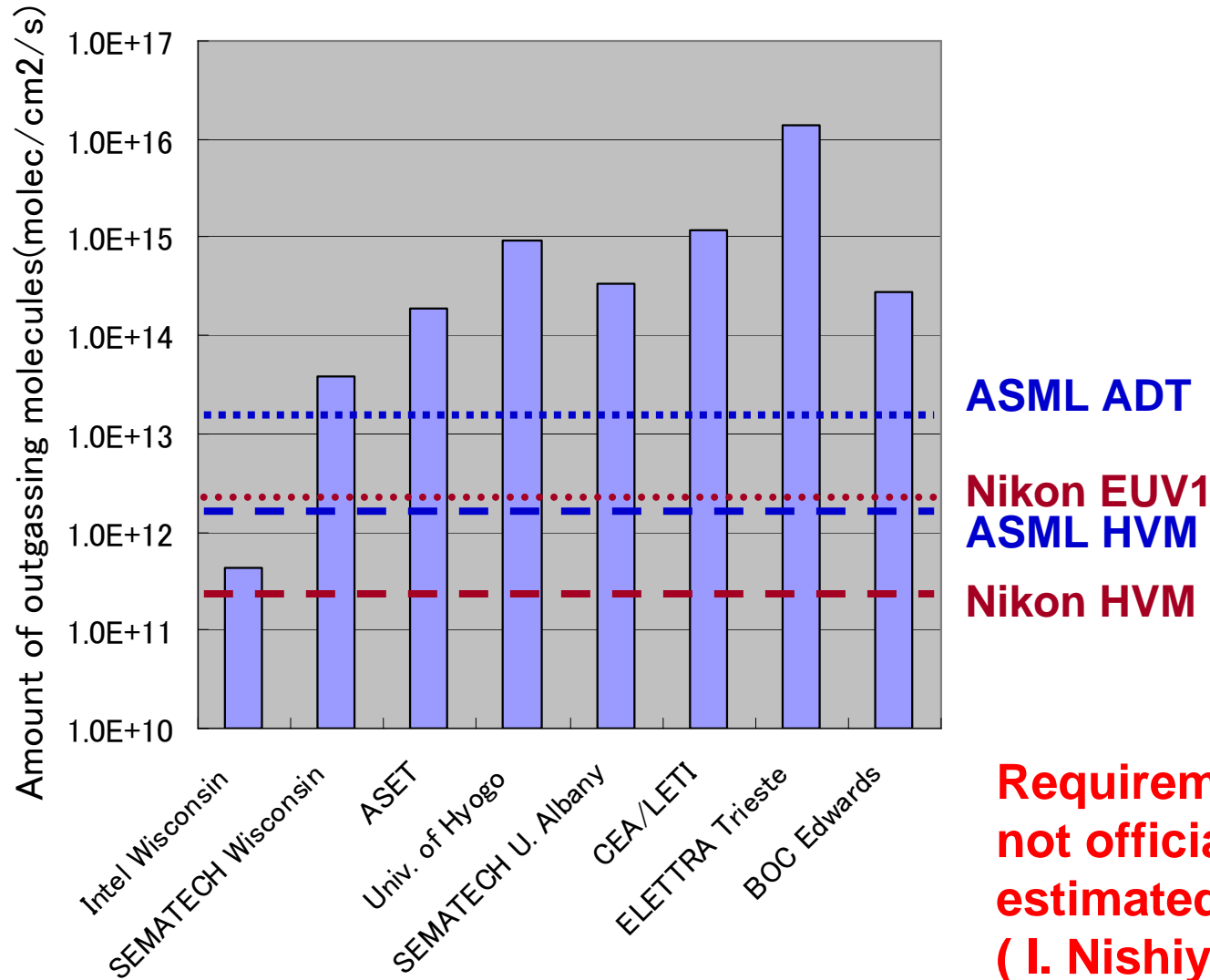
Unit Conversion from Tool supplier's requirements to resist-community-friendly requirements(1)

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
H2O	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



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

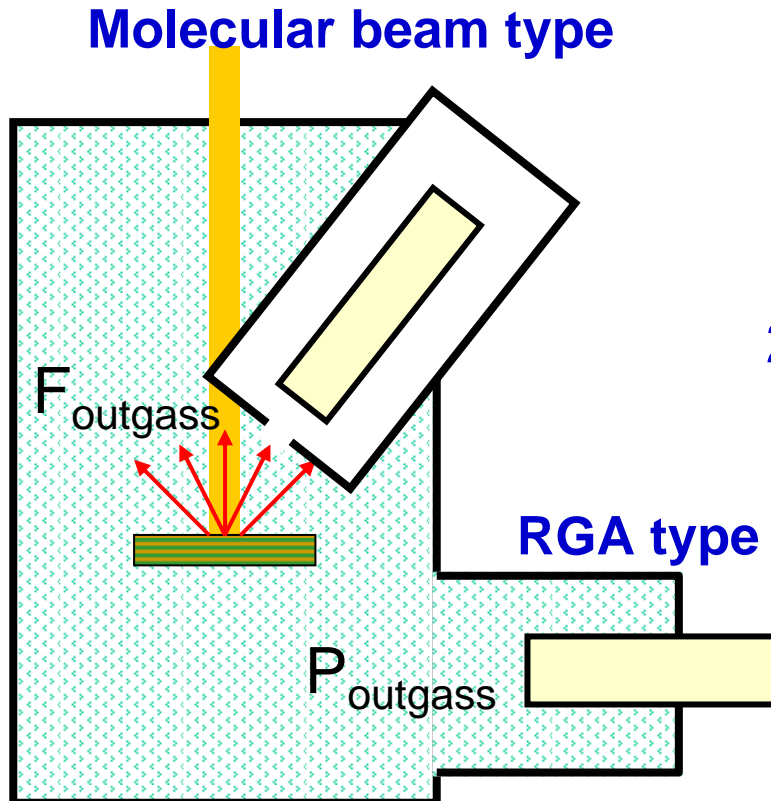
- Measure outgassing **flux**
- Rate is calculated from the flux directly by considering the angular distribution.
- Contribution from background pressure should be suppressed.

2) RGA type

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

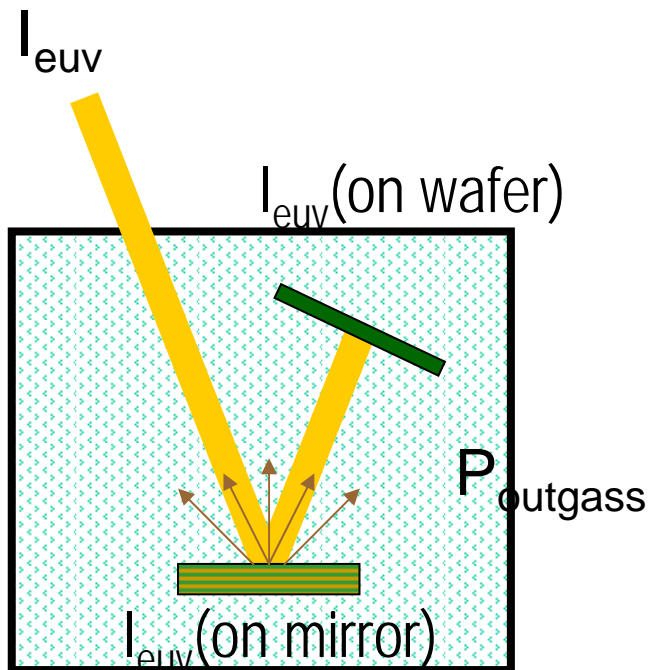
Warning:

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 $I_{euv}(\text{on wafer}) \times P_{outgass}$

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

I_{euv} : dependent on beam condition

What type beam condition is assumed, parallel or divergent?

$P_{outgass}$: 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 $\cdot \text{cm}^{-2}$ are better for resist researchers.