Comments on Resist Outgas Measurements to remove the confusion in outgassing discussion

ASET EUV Process Technology Laboratory

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Background - Confusion in outgas round robin -

There is huge discrepancy in outgas speed data reported to resist TWG !! It is beyond the experimental error. It should be caused by misunderstanding.

<table>
<thead>
<tr>
<th>Organization</th>
<th>molecules/cm$^2$</th>
<th>molecules/cm$^2$/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel/UW</td>
<td>4.37E+11</td>
<td>7.28E+09</td>
</tr>
<tr>
<td>ASET</td>
<td>----</td>
<td>2.2 E+14</td>
</tr>
</tbody>
</table>

There is fatal lack of information in ASML’s requirement.

There are two type method in outgas metrology.

1. Accumulation methods (U. Wisconsin)
   \[ \text{molecules/cm}^2 \text{ at } E_{\text{size}} \]
2. Pressure rise method (Many organization)
   \[ \text{molecules/cm}^2/\text{s at } I_{\text{exposure}} \]

Different physical quantities were measured, however conversion method between each values were not established.
Resist Outgassing Results

• Five groups reported values, the other two will report at February 2006 meeting

• Outgassing rates varied between E+11 and E+13 molecules/cm²-sec, a huge variation in results!

• Different methods were used, group discussed ways to better compare results

• Much discussion of ASML specs and what is really important, hydrocarbons or heteroatoms, low or high molecular weights?
Lack of information in ASML requirement

**ASML’s Requirement**

<table>
<thead>
<tr>
<th>Gas</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>4.7E15 molecules·cm⁻²·s⁻¹</td>
</tr>
<tr>
<td>CₓHᵧ</td>
<td>4.7E13</td>
</tr>
<tr>
<td>F/Cl</td>
<td>4.7E11</td>
</tr>
</tbody>
</table>

Based on 1 % budget of Back Ground gas in Exposure Tool

- **There is a lack of information of EUV intensity on wafer** in this specification.

- **We cannot calculate the outgassing rate corresponding to ASML requirement** from experimental data without the disclosure of intensity in production tool.

*cf) IEUVI resist TWG meeting in Miyazaki*
Estimation of EUV intensity on wafer in production tool

Method-1: from the source power of 115 W@IF.
Total reflectivity loss of by 12 multilayer mirror (R=68%) = 0.01
Reflectivity loss by mask (65%) = 0.65
Other loss (50%: not sure) : 0.5 → Total: 0.35%
EUV power leaching onto wafer is 0.4 W. If the exposure area is assumed to be 0.5 cm², EUV intensity on wafer is 0.8 W/cm².

Method-2: from throughput of 100 WpH and resist sensitivity of 5 mJ/cm²
Exposure area = π x (15 cm)² x 80% (effective area ratio) = 565 cm²
Exposure time = 3600 s / 100 x 40% (overhead correction) = 14.4 s
Power = \( \frac{5 \text{ mJ/cm}^2}{14.4 \text{ s}} \times 565 \text{ cm}^2 = 0.2 \text{ W} \)
EUV intensity = 0.2 W / 0.5 cm² = 0.4 W/cm²

Though there are twice discrepancy, it is not so bad..

Temporary, we adopt 0.2 W for power and 0.4 W/cm² for intensity.
How to convert from molecules/cm\(^2\) to molecules/cm\(^2\)/s

If the outgassing amount of \(M\) molecules/cm\(^2\) is obtained using resist of \(\varepsilon\) J/cm\(^2\) (Esize), outgassing amount in 1s can be calculated as follows:

- Exposure time for Esize in EUV intensity of \(I_{euv}\) W/cm\(^2\)
  \[E = \frac{\varepsilon \text{ (J/cm}^2\text{)}}{I_{euv} \text{ (W/cm}^2\text{)}} = \frac{\varepsilon}{I_{euv} \text{ (s)}}\]

- Overhead correction factor (duty ratio) = \(\alpha\)

- Number of irradiation for Esize exposure = \(\alpha I_{euv} \text{ (s)} / \varepsilon\)

Outgassing amount in 1 s = \(M \times \frac{\alpha I_{euv} \text{ (s)}}{\varepsilon}\)

If \(\alpha = 0.4\), \(\varepsilon = 5.5\) mJ/cm\(^2\), and \(I_{euv} = 0.4\) W/cm\(^2\) is assumed,

conversion factor: \(\alpha I_{euv}(s) / \varepsilon = 30\)

So, \(10^{12}\) molecules/cm\(^2\) in accumulation method corresponds to the outgassing rate of \(3 \times 10^{13}\) molecules/cm\(^2\)
Comment on Intel/Wisconsin Experimental Data

cf) IEUVI resist TWG meeting in Miyazaki

Outgassing from Sematech Round Robin Resist
Exposure at UW & GC/MS at Intel

<table>
<thead>
<tr>
<th>Sample</th>
<th>LL-TF-99246</th>
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<tbody>
<tr>
<td>R.T. (min)</td>
<td>detected compound</td>
</tr>
<tr>
<td>----------</td>
<td>------------------</td>
</tr>
<tr>
<td>12.051</td>
<td>tert-Butylbenzene</td>
</tr>
<tr>
<td>17.228</td>
<td>Methylstyrene</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

- Outgassing conc of 4.37E+11 molecules/cm² corresponds to outgassing rate of 1.3E+13 molecules/cm² in my calculation.
- This is close to ASML specification for hydrocarbon outgassing rate of 4.7E+13.
- Discrepancy with ASET Data (2.2 E+14) is reduced to one order of magnitude. It is still large, but seems likely because experimental method is quite different.
Conclusion

- There is huge discrepancy in outgas speed data reported to in resist TWG !! It causes confusion in outgassing discussion.

- There is fatal lack of information on the **EUV intensity** in production tool in ASML’s requirement.

- EUV power and intensity on wafer in productin tool were estimated to be about **0.2 W** and **0.4 W/cm²** respectively. *(Kim-san should be confirm this value to ASML key person.)*

- Conversion constant from outgassing conc (molecules/cm²) to outgassing rate(molecules/cm²s) is estimated about 30 based on the estimated intensity on wafer.

- By using the estimated conversion constan, discrepancy between Intel and AET Data was reduced to within one order of magnitude.