EUV Resist Funding Gap Analysis

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IEUVI Resist TWG Funding Analysis

Background:
- The IEUVI Board at the recent July ’06 meeting recommended each TWG to conduct a funding assessment to attain 32 nm HP performance by 2012–2013.

REQUESTED INPUT:
- Provide your input based on your knowledge and input for as many items as possible.
- Inputs reviewed, assembled, and overall results provided back to the IEUVI TWG.
- The results will be presented to the IEUVI Board and feedback will be shared with the IEUVI Resist TWG on Oct. 19 ’06 at the Barcelona meeting.
# EUV Resist Funding Analysis

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Alpha 2006-07</th>
<th>Beta 2009-10</th>
<th>Production 2012-13</th>
<th>Assessment--see choices below</th>
<th>Solutions for Meeting Production Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current**</td>
<td>Spec</td>
<td>Spec</td>
<td>1, 2, 3, or 4</td>
<td>What is required?</td>
</tr>
<tr>
<td>Resolution 1:1</td>
<td>35nm/45nm (C/S)</td>
<td>32nm</td>
<td>32nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution contacts</td>
<td>N/A</td>
<td>40nm</td>
<td>35nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution Isolated Lines</td>
<td>30nm/40nm (C/S)</td>
<td>25nm</td>
<td>21nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photospeed (mJ/cm²)</td>
<td>21mJ/cm² E-size @ 50-nm 1:1</td>
<td>10mJ/cm²</td>
<td>10mJ/cm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outgassing (molecules/cm²·sec)</td>
<td>1.60E+13</td>
<td>TBD</td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Choices
1) Manufacturable solutions exist and are being optimized
2) Manufacturable solutions are known
3) Interim solutions are known
4) Manufacturable solutions are NOT known

**What is required to meet the specs? Use additional pages if necessary.**
1) Who should address the problem?
2) Approximately how much will it cost?
3) What other help is needed?

**Measured top down values for Rohm and Haas resist MET-1K.**

C/S=cross section
# EUV Resist Funding Analysis (8 respondents)

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Alpha 2006-07</th>
<th>Beta 2009-10</th>
<th>Production 2012-13</th>
<th>Assessment--Median Results</th>
<th>Assessment--Average Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution 1:1</td>
<td>Current**</td>
<td>Spec</td>
<td>Spec</td>
<td>1, 2, 3, or 4</td>
<td>1, 2, 3, or 4</td>
</tr>
<tr>
<td>Resolution contacts</td>
<td>N/A</td>
<td>40nm</td>
<td>35nm</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Resolution Isolated Lines</td>
<td>30nm/40nm (C/S)</td>
<td>25nm</td>
<td>21nm</td>
<td>3</td>
<td>3.4</td>
</tr>
<tr>
<td>Photospeed (mJ/cm²)</td>
<td>21mJ/cm² E-size @ 50-nm 1:1</td>
<td>10mJ/cm²</td>
<td>10mJ/cm²</td>
<td>3</td>
<td>2.6</td>
</tr>
<tr>
<td>Line Width Roughness (3 σ)</td>
<td>~4 nm @ 50-nm 1:1</td>
<td>&lt; 2.5nm</td>
<td>&lt; 1.7nm</td>
<td>4</td>
<td>3.7</td>
</tr>
<tr>
<td>Outgassing (molecules/cm²·sec)</td>
<td>1.60E+13</td>
<td>TBD</td>
<td>TBD</td>
<td>3</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Assessment Choices**
1) Manufacturable solutions exist and are being optimized
2) Manufacturable solutions are known
3) Interim solutions are known
4) Manufacturable solutions are NOT known efficiently

**Measured top down values for Rohm and Haas resist MET-1K. C/S=cross section**
Solutions & Comments:

Contrast Loss at 32 nm

- This needs to be specified. Resolution is not enough. Proposal: Resist contrast loss ≤ 40%

Resolution 1:1

- 32 nm HP will be required much earlier than 2012! We estimate 32 nm in 2010 for Flash segment. Timing needs to be accelerated.
- Meeting the resolution has been demonstrated. Challenge is now to have sufficient process window on a full field tool (flare!)
- Resist suppliers may need some financial support from IC manufacturers - like JDP
- Tool access for resist optimization
- For beyond 22 nm HP, non-CAR system is necessary
Solutions & Comments:

Resolution contacts
- There is very little contact hole data available. Based on acid diffusion considerations, resolution will be a big problem
- 32 nm 1:1 needed by 2010 for Flash
- Resist suppliers may need some financial support from IC manufacturers - like JDP
- Suppliers need tool access for resist optimization

Resolution Isolated Lines
- Flare will be a major concern for isolated lines; need to specify flare level
- Resist is not a critical issue. Good adhesion with substrate is required
- Film thickness may not support "next step" in processing
- Resist suppliers may need some financial support from IC manufacturers - like JDP
- Suppliers need tool access for resist optimization
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Solutions & Comments:

Photospeed (mJ/cm²)

- Ultimately this is linked to the source roadmap. Right now, it is not clear that the source will be able to reliably meet the dose requirements. (Don’t rely on the source to supply more photons.)
- The photospeed in itself has been demonstrated for multiple samples and is not an issue.
- LWR, LWR, LWR
- Trade-off between photospeed and LWR. Difficult to meet both specs simultaneously.
- Stable light source with in-band wave length.
- Resist suppliers may need some financial support from IC manufacturers - like JDP
**Solutions & Comments:**

**Line Width Roughness (3 σ)**
- For Flash, LWR should be relaxed (to about 2.6 nm, guess) in 2010. The numbers in the ITRS seem to be for MPU (the tightest).
- A Nobel Prize Winner.
- Fundamental research is required to reduce the LWR. Requirements seem to specific to MPU. Probably need breakdown for different segments.
- New concept required.
- Resist suppliers may need some financial support from IC manufacturers - like JDP.
- Need to apply new materials and new process. (Development, etc.)
- Good image contrast (NILS) should be obtained.
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**Solutions & Comments:**

**Outgassing (molecules/cm²-sec)**

- More research is required to more efficiently test this. Does not seem to be a showstopper.
- Joint effort between tool supplier (more robust design to lens contamination) and resist supplier (less outgassing material).
- Tool access.
- Current level is unclear. Need to determine measurement method and spec.
- Current resists may meet the specification.
- According to the ASML results, it does not make sense to report outgassing in these units. There is too little data with their suggested method.
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Additional Comments:

- As of today, none of the resist companies has in-house capability for high resolution printing or outgassing testing. They are sharing the METs and any available facilities at SEMATECH, Wisconsin, etc. The lack of in-house development equipment will seriously slow their speed of resist formulation development.
Slightly Revised Specifications

Reflects 2005 ITRS changes
# EUV Resist Specification Roadmap

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spec</td>
<td>Current**</td>
<td>Spec</td>
</tr>
<tr>
<td>Resolution 1:1</td>
<td>45nm</td>
<td>35nm/45nm (C/S)</td>
<td>32nm</td>
</tr>
<tr>
<td>Resolution contacts</td>
<td>55nm</td>
<td>TBD</td>
<td>40nm</td>
</tr>
<tr>
<td>Resolution Isolated Lines</td>
<td>32nm</td>
<td>30nm/40nm (C/S)</td>
<td>25nm</td>
</tr>
<tr>
<td>Depth of Focus</td>
<td>200nm</td>
<td>100nm for 35-nm 1:1; 200nm for 50-nm 1:1</td>
<td>225nm</td>
</tr>
<tr>
<td>Photospeed (mJ/cm²)</td>
<td>10 mJ/cm²</td>
<td>21mJ/cm² E-size @ 50-nm 1:1</td>
<td>10mJ/cm²</td>
</tr>
<tr>
<td>Line Width Roughness (3 σ)</td>
<td>&lt; 4 nm (LER)</td>
<td>~4 nm @ 50-nm 1:1; ~7 nm @ 35-nm 1:1</td>
<td>&lt; 2.5nm</td>
</tr>
<tr>
<td>Wall Profile Angle</td>
<td>&gt;85º</td>
<td>80º @ 50-nm 1:1</td>
<td>&gt; 85º Measure cross-sections</td>
</tr>
<tr>
<td>Outgassing</td>
<td>4.7E13 molecules/cm²·sec</td>
<td>1.60E+13</td>
<td>TBD</td>
</tr>
<tr>
<td>Pattern Collapse</td>
<td>&gt;3</td>
<td>None observed</td>
<td>&gt;3</td>
</tr>
<tr>
<td>Unexposed Film Thickness Loss</td>
<td>&lt; 10%</td>
<td>10nm</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>PEB Sensitivity</td>
<td>&lt; 2.5 nm/deg C</td>
<td>TBD</td>
<td>&lt;1.5 nm/deg C</td>
</tr>
<tr>
<td>Delay Stability @ &lt; 1ppb amine</td>
<td>30min</td>
<td>TBD</td>
<td>30 min a) pre-exposure, b) under vacuum, c) post-exposure</td>
</tr>
<tr>
<td>Etch Resistance</td>
<td>Similar to novolak</td>
<td>TBD</td>
<td>Similar to novolak</td>
</tr>
</tbody>
</table>

**Measured top down values for Rohm and Haas resist MET-1K. C/S=cross section  Green = spec is met, Orange = spec is not met**