Dose Calibrations

for EUV Exposure Tools

(Is there a disconnect with the source community?)

Robert Brainard and Kim Dean
Calibration Chain

EUV 10X1 ➔ NA = 0.088
Copper Plasma Source

EUV-2D Resist
XP98248B

6.8 mJ/cm²
100nm Dense Lines
125 nm Thick (?) SB:130/60
PEB: 130/90

EUV 10X2 ➔ NA = 0.088

Engineering Test Stand ➔ NA = 0.1

Berkeley MET ➔ NA = 0.3

MET-1K*
(XP4502D) ➔
19 mJ/cm²
100 nm Dense
21 mJ/cm²
50 nm Dense
125 nm Thick

MET-2D ➔
XP5271F
18.3 mJ/cm²
50 nm Dense

ASML EUV Alpha ➔ NA = 0.25

PSI IFL Tool

* Tool test resist for Berkeley and Albany METs
EUV Round II DOE
"D Resist of 2nd Round 1998"

Very Low UFTL Polymer

85 nm Thick Film
100 nm Dense Lines
Exposed by EUV

Increasing PAG Level

Increasing PAG Strength

Shipley /RHEM

EUV-2D = XP98248B

EUV-2D = XP98248B
EUV-2D (XP98248B)

**Table 5 - Resist Attributes of UTR Material 2D**

<table>
<thead>
<tr>
<th>Resist Attribute</th>
<th>Current Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/S Resolution (1:1 pitch)</td>
<td>80 nm with 0.088 NA</td>
</tr>
<tr>
<td></td>
<td>70 nm with 0.1 NA</td>
</tr>
<tr>
<td>Iso Resolution</td>
<td>70 nm with 0.088 NA</td>
</tr>
<tr>
<td>Photospeed</td>
<td>6-7 mJ/cm²</td>
</tr>
<tr>
<td>LER (3σ)</td>
<td>5.5 nm for 100 nm L/S*</td>
</tr>
<tr>
<td></td>
<td>7.3 nm for 80 nm L/S*</td>
</tr>
<tr>
<td></td>
<td>(* with 0.088 NA)</td>
</tr>
<tr>
<td>Depth of Focus (± 5% CD)</td>
<td>&gt; 1.5 μm for 100 nm L/S (with 0.088 NA)</td>
</tr>
<tr>
<td>Exposure Latitude (± 5% CD)</td>
<td>10% CD</td>
</tr>
</tbody>
</table>


**Brainard, Robert L.; Henderson, Craig; Cobb, Jonathan; Rao, Veena; Mackevich, Joseph F.; Okoroanyanwu, Uzodinma; Gunn, Scott; Chambers, Janet; Connolly, Susan. Comparison of the lithographic properties of positive resists upon exposure to deep- and extreme-ultraviolet radiation.** Journal of Vacuum Science & Technology, B: Microelectronics and Nanometer Structures (1999), 17(6), 3384-3389.
Rohm and Haas Round 2 Experiments on Berkeley MET 2004

50 nm Dense Lines In 125 nm Films
Berkeley MET Dipole Illumination

Acid Size

<table>
<thead>
<tr>
<th>Resist</th>
<th>EL (%)</th>
<th>LER 3σ (nm)</th>
<th>E_{size} (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MET-2D</td>
<td>13</td>
<td>4.1</td>
<td>18.3</td>
</tr>
<tr>
<td>MET-1K</td>
<td>17</td>
<td>5.9</td>
<td>22.6</td>
</tr>
</tbody>
</table>


MET-2D (XP5271F) "D Resist of 2nd Round"
MET-2D (XP5271F)
"D Resist of 2nd Round"
18.3 mJ/cm² for 50 nm Dense Lines
125nm Films, SB: 130C/60s PEB: 130C/90s Dev.: 45s CD-26

<table>
<thead>
<tr>
<th>Resist</th>
<th>PAG No.</th>
<th>Relative quencher level</th>
<th>$L_d$ (nm)</th>
<th>EL (%) 50 nm dense</th>
<th>LER 3σ (nm) 50 nm dense</th>
<th>$E_{size}$ (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>0.7</td>
<td>68</td>
<td>15</td>
<td>6.9</td>
<td>6.2</td>
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<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>65</td>
<td>5</td>
<td>NA</td>
<td>9.6</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1.4</td>
<td>68</td>
<td>11</td>
<td>6.1</td>
<td>15.5</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>2</td>
<td>62</td>
<td>13</td>
<td>4.1</td>
<td>18.3</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>0.3</td>
<td>54</td>
<td>9</td>
<td>15.5</td>
<td>3.5</td>
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<tr>
<td>F</td>
<td>2</td>
<td>0.7</td>
<td>52</td>
<td>16</td>
<td>10.2</td>
<td>3.3</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>1</td>
<td>57</td>
<td>17</td>
<td>9.7</td>
<td>9.3</td>
</tr>
<tr>
<td>H</td>
<td>2</td>
<td>1.4</td>
<td>52</td>
<td>20</td>
<td>7.5</td>
<td>17.2</td>
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<tr>
<td>I</td>
<td>2</td>
<td>2</td>
<td>50</td>
<td>17</td>
<td>5.9</td>
<td>22.6</td>
</tr>
<tr>
<td>J</td>
<td>2</td>
<td>3</td>
<td>39</td>
<td>NA</td>
<td>4.6</td>
<td>36.8</td>
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<tr>
<td>L</td>
<td>3</td>
<td>1</td>
<td>36</td>
<td>28</td>
<td>8.3</td>
<td>11</td>
</tr>
<tr>
<td>N</td>
<td>3</td>
<td>2</td>
<td>33</td>
<td>18</td>
<td>5.2</td>
<td>21.9</td>
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<tr>
<td>O</td>
<td>4</td>
<td>1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>12.9</td>
</tr>
<tr>
<td>P</td>
<td>4</td>
<td>2</td>
<td>40</td>
<td>18</td>
<td>10</td>
<td>25.2</td>
</tr>
</tbody>
</table>

Calibration Chain

**EUV 10X1**
- NA = 0.088
- Copper Plasma Source

**EUV-2D Resist**
- XP98248B
- 6.8 mJ/cm²
- 100nm Dense Lines
- 125 nm Thick
- SB: 130/60
- PEB: 130/90

**EUV 10X2**
- NA = 0.088

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- NA = 0.1

**Berkeley MET**
- NA = 0.3

**MET-1K**
- (XP4502D)
- 19 mJ/cm²
- 100 nm Dense
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- 50 nm Dense
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**MET-2D**
- XP5271F
- 18.3 mJ/cm²
- 50 nm Dense

**ASML EUV Alpha**
- NA = 0.25

**PSI IFL Tool**

* Tool test resist for Berkeley and Albany METs
PSI Dose Calibration

MET-2D vs. PEB Temp.: Dose to Mask

MET-2D 50nm L/S 130/130 Processing

Line Width (nm)

W10  100p Line CD
W17  100p Line CD

Dose to Mask (mJ/cm²)
MET-2D Calibration of PSI Doses

MET-2D (XP5271F)
Softbake = 130C/60sec
PEB = 130C/90 sec

<table>
<thead>
<tr>
<th>PEB</th>
<th>Esize</th>
<th>Ave</th>
<th>Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>57</td>
<td>58.25</td>
<td>1.77</td>
</tr>
<tr>
<td>130</td>
<td>59.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion Factor:

\[
\frac{58.18}{18} = 3.236 \pm 0.1
\]
Is there a disconnect with the source community?

ASML Alpha Tools have calibrated sources.

Have they compared what the source output with Resist Imaging Dose?
MET-2D on INVENT Alpha Tool
40 nm half pitch: 270 nm DOF @ 0.25NA

Dose = 18 mJ/cm²
(16.7 mJ/cm²)

Slide courtesy ASML
MET-2D on INVENT Alpha Tool
0.25NA

50 nm L/S
LER = 2.7 nm

40 nm L/S
LER = 5.1 nm

35 nm L/S

Dose = 18 mJ/cm²
(16.7 mJ/cm²)

Slide courtesy ASML
Questions/Discussion about Tool/Source Calibration

• How to compare photospeed results from these tools?

• How to compare photospeed results with Source Work?!?

• Rohm and Haas will supply MET-2D (XP5271F) for Tool Dose Calibration.

**MET-2D (XP5271F)**

18 mJ/cm² for 50 nm Dense Lines
120 nm Films, SB: 130 °C/60s  PEB: 130 °C/90s  Dev.: 45s CD-26
Questions/Discussion about Tool/Source Calibration

• Suggestion: Measure Ezero of MET-2D on calibration and standards beamline; transfer information to MET
• Record age of resist
• Compare to ASML wafer plane sensor

MET-2D (XP5271F)

18 mJ/cm² for 50 nm Dense Lines
120 nm Films, SB: 130 ºC/60s  PEB: 130 ºC/90s
Dev.: 45s CD-26
Thanks!
MET-2D vs. PEB Temp.

MET-2D Esize (to Mask) vs. PEB

- Esize (Dose to Mask; mJ/cm²)
- PEB Temp (C)

Graph showing MET-2D Esize (to Mask) vs. PEB Temp (C) with data points and a trend line.
MET-2D vs. PEB Temp.

MET-2D 50nm L/S 130/110 Processing

MET-2D 50nm L/S 130/130 Processing

MET-2D 50nm L/S 130/120 Processing

Line Width (nm) versus Dose to Mask (mJ/cm²) for different processing conditions.

- MET-2D 50nm L/S 130/110 Processing:
  - W8: 100p Line CD
  - W16: 100p Line CD
  - Dose to Mask: 50-90 mJ/cm²
  - Line Width: 35-55 nm

- MET-2D 50nm L/S 130/130 Processing:
  - W10: 100p Line CD
  - W17: 100p Line CD
  - Dose to Mask: 55-80 mJ/cm²
  - Line Width: 35-55 nm

- MET-2D 50nm L/S 130/120 Processing:
  - W9: 100p Line CD
  - Dose to Mask: 50-80 mJ/cm²
  - Line Width: 35-55 nm
MET-2D Calibration of PSI Doses

### MET-2D (XP5271F)

**Softbake = 130C/60sec**

<table>
<thead>
<tr>
<th>Wafer</th>
<th>PEB</th>
<th>Esize</th>
<th>Ave</th>
<th>Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>W8</td>
<td>110</td>
<td>60.8</td>
<td>59.8</td>
<td>1.41</td>
</tr>
<tr>
<td>W16</td>
<td>110</td>
<td>58.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W9</td>
<td>120</td>
<td>62.7</td>
<td>62.7</td>
<td></td>
</tr>
<tr>
<td>W10</td>
<td>130</td>
<td>57</td>
<td>58.25</td>
<td>1.77</td>
</tr>
<tr>
<td>W17</td>
<td>130</td>
<td>59.5</td>
<td></td>
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</tbody>
</table>

**Conversion Factor:**

\[
\frac{58.18}{18} = 3.236 \pm 0.0982
\]

\[
3.250 \pm 0.1
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