MTR Resist for Reduced LER in EUV Lithography

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Background to Irresistible Materials

• Irresistible Materials is a UK spin-out company formed to commercialise university research in materials for semiconductor fabrication such as resist and spin-on-carbon

• Developing a new molecular resist system that demonstrates high-resolution capability based on the multi-trigger concept
RLS Control

Increased Quencher Loading
Higher Tg
Reduced Acid diffusion length
Traditional Chemically Amplified Resist (CAR)

Traditional Chemical Amplification

Unexposed → Reacting → Exposed

H⁺ + H⁺
Multi Trigger Resist (High dose areas – center of features)

Unexposed A → Activated A → Reacting A
Unexposed B → Activated B

Exposed

H^+ → H^+ → H^+ → H^+
Multi Trigger Resist (Low dose areas – feature edges)

Molecules A and B too far apart to react. Initiators quenched and reaction stops.
IM Multi-Trigger EUV Resist

The Irresistible Materials Multi-Trigger resist is a negative tone molecular resist, based on a proprietary resin (xMT).

Coating is from standard industry casting solvents, and development is in accepted negative tone developers including n-butyl acetate. Standard etch processes are applicable.
EUV exposure - PSI

Swiss Light Source

Interference Lithography
Improving Line Edge Roughness

Causes
• Pattern collapse
• Microbridging
• Resist mechanical strength
• Resist Stochastics

Approaches
• Increase multi-trigger component
• Increase crosslinking groups
• Addition of high Z sensitizer
• Optimize the film thickness
• Optimize the MTR ratio
The incorporation of quencher is typically at low concentration and contributes significantly to material stochastic variability.

<table>
<thead>
<tr>
<th>Stochastic Term(s)</th>
<th>Modeled LWR (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon</td>
<td>1.9 ± 2%</td>
</tr>
<tr>
<td>Acid</td>
<td>0.9 ± 2%</td>
</tr>
<tr>
<td>PAG</td>
<td>0.6 ± 2%</td>
</tr>
<tr>
<td><strong>Quencher</strong></td>
<td><strong>1.8 ± 2%</strong></td>
</tr>
<tr>
<td>Protecting Groups</td>
<td>0.2 ± 2%</td>
</tr>
<tr>
<td><strong>ALL</strong></td>
<td><strong>2.9 ± 2%</strong></td>
</tr>
</tbody>
</table>

2.2 nm

### Multi-Trigger Component Ratio

#### MTR2, no Quencher, varying MTR component ratio, p32, dose v CD

<table>
<thead>
<tr>
<th>CD/nm</th>
<th>Dose (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>14.5</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>15.5</td>
<td>60</td>
</tr>
<tr>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>16.5</td>
<td>100</td>
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</tbody>
</table>

#### MTR3, no Quencher, varying MTR component ratio amended to match # of MTR2, p32 dose v CD

<table>
<thead>
<tr>
<th>CD/nm</th>
<th>Dose (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.2</td>
</tr>
<tr>
<td>14.5</td>
<td>0.4</td>
</tr>
<tr>
<td>15</td>
<td>0.6</td>
</tr>
<tr>
<td>15.5</td>
<td>0.8</td>
</tr>
<tr>
<td>16</td>
<td>0.2</td>
</tr>
<tr>
<td>16.5</td>
<td>0.4</td>
</tr>
<tr>
<td>17</td>
<td>0.6</td>
</tr>
<tr>
<td>17.5</td>
<td>0.8</td>
</tr>
<tr>
<td>18</td>
<td>0.2</td>
</tr>
<tr>
<td>18.5</td>
<td>0.4</td>
</tr>
<tr>
<td>19</td>
<td>0.6</td>
</tr>
<tr>
<td>19.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>MTR2 ratio</th>
<th>LER/nm</th>
<th>Dose (mJ/cm²)</th>
<th>MTR3 ratio</th>
<th>LER/nm</th>
<th>Dose (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>6.5</td>
<td>23.3</td>
<td>0.2</td>
<td>5.9</td>
<td>13.8</td>
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<tr>
<td>0.4</td>
<td>4.8</td>
<td>36.6</td>
<td>0.4</td>
<td>4.8</td>
<td>33.9</td>
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<tr>
<td>0.6</td>
<td>5.1</td>
<td>53.0</td>
<td>0.6</td>
<td>4.6</td>
<td>45.2</td>
</tr>
<tr>
<td>0.8</td>
<td>6.1</td>
<td>66.5</td>
<td>0.8</td>
<td>4.7</td>
<td>61.0</td>
</tr>
</tbody>
</table>
Effect of quencher on LER

Effect on dose of changing MTR ratio and quencher level

Effect on LER of changing MTR ratio and quencher level

- 14nm and 18nm lines patterned at relaxed pitch to minimise bridging
- Increasing MTR ratio increases dose – large range achievable
- Adding quencher has larger effect on LER for low MTR ratio, and negligible effect on LER at high MTR ratio
- Best LER occurs with 5% quencher loading at 0.46 ratio, 0.23 ratio similar
Low MTR action – increasing quencher improves LWR (PSI)

MTR1220
- No quencher
  - 30.4mJ/cm²
  - CD 16.4nm
  - LWR 6.08nm

MTR1230
- Low level quencher
  - 45.3mJ/cm²
  - CD 15.8nm
  - LWR 4.07nm

MTR1200
- High level quencher
  - 59.7mJ/cm²
  - CD 16.2nm
  - LWR 3.36nm

Increasing dose
Decreasing LWR
Higher MTR action – towards Multi-Trigger at PSI

**Low MTR action**
- Increasing MTR
- Increasing dose
- Decreasing LWR

**Higher MTR action**
- Increasing MTR
- Increasing dose
- Decreasing LWR

**No quencher**
- **MTR1220**
  - Dose to size 30.4mJ/cm²
  - LWR 6.1nm
- **MTR1250**
  - Dose to size 38mJ/cm²
  - LWR 4.8nm

**Low level quencher**
- **MTR1230**
  - Dose to size 45.3mJ/cm²
  - LWR 4.07nm
- **MTR1240**
  - Dose to size 45mJ/cm²
  - LWR 4.1nm

**High level quencher**
- **MTR1200**
  - Dose to size 59.7mJ/cm²
  - LWR 3.36nm
- **MTR2211**
  - Dose to size 47mJ/cm²
  - LWR 2.5nm

**Increasing MTR**
- Increasing dose
- Decreasing LWR

**Decreasing LWR**
- Increasing MTR
- Increasing dose
- Decreasing LWR
Conclusions

• Material stochastics has an important effect on the LER of the structures printed.
• Optimizing the MTR ratio significantly reduces the LER.
• Quenching effect on LER saturates for high MTR ratio.
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