Investigation of Coat-Develop Track System for Placement Error of Contact Hole Shrink Process

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Outline

♦ Goal
♦ Data summary
♦ Experimental
  ✓ DSA Shrink Process with Leti-Planarization
  ✓ DSA Placement Error Measurement
♦ Results and Discussions
  ✓ DSA Shrink Placement Error
  ✓ Relative Position Error of Each Step
  ✓ Relative PE Measurement of Each Step
  ✓ Thermal Shrink Relative Position Error
♦ Conclusions
♦ Acknowledgment
Goal

- **Placement error after CH shrink with DSA**

- **Comparison with Relative position error of CH to next CH for each process.**
  - Lithography
  - Etching
  - DSA

- **Comparison with Relative position error of thermal shrink and DSA shrink.**
### Data Summary

#### Shrink Process

<table>
<thead>
<tr>
<th>SEM Image</th>
<th>DSA Shrink</th>
<th>Thermal Shrink</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD (nm)</td>
<td>23.2</td>
<td>30.3</td>
</tr>
<tr>
<td>Relative position error 3σ (nm)</td>
<td>3.93</td>
<td>6.97</td>
</tr>
<tr>
<td>Placement error 3σ (nm)</td>
<td>1.59</td>
<td>-</td>
</tr>
</tbody>
</table>

*DSA Shrink
- Initial CH size : 52.2nm
- Initial CH pitch : 121.4 nm

*Thermal Shrink
- Initial CH size : 50.5nm
- Initial CH pitch : 102.0 nm

- DSA shrink process has shrinkage and relative position error advantages over thermal shrink process.
DSA Shrink Process with Leti-Planarization

CD; CDU-w; L-CDU are measured at each step: (a), (b) and (c)
PE is measured at step (c)
DSA Placement Error Measurement

HOW DGMAGE WORKS?

Overlay vector
Guiding pattern
BCP pattern

Calibration (recipe creation)

DGmage routine

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**DSA Shrink Placement Error**

**Placement Error with DSA Shrink**

**DGmage (Software by Leti)**

- **PE-X (nm)**
  - Mean (nm): 0.06
  - 3σ (nm): 0.85

- **PE-Y (nm)**
  - Mean (nm): 0.46
  - 3σ (nm): 1.34

3σ_{total} = 1.59

\[ \sigma_{total} = (\sigma_x^2 + \sigma_y^2)^{0.5} \]
## Relative Position Error of Each Step

<table>
<thead>
<tr>
<th>SEM Image</th>
<th>After litho</th>
<th>After etch</th>
<th>After DSA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relative position error 3σ</strong></td>
<td>3.65nm</td>
<td>3.08nm</td>
<td>3.93nm</td>
</tr>
<tr>
<td><strong>Pitch Vertical, Horizontal</strong></td>
<td>121.4nm</td>
<td>121.5nm</td>
<td>121.4nm</td>
</tr>
<tr>
<td><strong>Pitch Diagonal</strong></td>
<td>171.8nm</td>
<td>171.8nm</td>
<td>171.3nm</td>
</tr>
<tr>
<td><strong>CD</strong></td>
<td>52.2nm</td>
<td>40.0nm</td>
<td>23.2nm</td>
</tr>
</tbody>
</table>

- Relative Position Error is similar for each process step.
- Pattern pitch is consistent.
### Relative PE Measurement of Each Step

<table>
<thead>
<tr>
<th></th>
<th>After litho</th>
<th>After etch</th>
<th>After DSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM Image</td>
<td><img src="image1" alt="SEM Image" /></td>
<td><img src="image2" alt="SEM Image" /></td>
<td><img src="image3" alt="SEM Image" /></td>
</tr>
<tr>
<td>Error Histogram Vertical / Horizontal</td>
<td><img src="image4" alt="Histogram" /> (3\sigma_{V/H} = 3.55)</td>
<td><img src="image5" alt="Histogram" /> (3\sigma_{V/H} = 3.08)</td>
<td><img src="image6" alt="Histogram" /> (3\sigma_{V/H} = 3.95)</td>
</tr>
<tr>
<td>Error Histogram Diagonal</td>
<td><img src="image7" alt="Histogram" /> (3\sigma_D = 3.77)</td>
<td><img src="image8" alt="Histogram" /> (3\sigma_D = 3.06)</td>
<td><img src="image9" alt="Histogram" /> (3\sigma_D = 3.93)</td>
</tr>
<tr>
<td>Relative PE 3(\sigma)</td>
<td>3.65nm</td>
<td>3.08nm</td>
<td>3.93nm</td>
</tr>
</tbody>
</table>
### Thermal Shrink Relative Position Error

<table>
<thead>
<tr>
<th>SEM Image</th>
<th>After litho</th>
<th>Thermal Shrink</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>50.5nm</td>
<td>29.5nm</td>
</tr>
<tr>
<td>Pitch</td>
<td>102.0nm</td>
<td>102.0nm</td>
</tr>
<tr>
<td>Pitch</td>
<td>142.3nm</td>
<td>142.0nm</td>
</tr>
<tr>
<td>Relative position error 3σ</td>
<td>3.36nm</td>
<td>6.97nm</td>
</tr>
</tbody>
</table>

*Relative Position Error is worse after thermal shrink.*
Conclusions

**DSA Shrink is better than thermal shrink.**

- Shrinkage: 29nm (DSA), 21nm (Thermal Shrink)
- Relative position error: 3.9nm (DSA), 7.0nm (Thermal Shrink)

**Outlook**

- Comparison with other shrink process.
- Improve DSA Relative position error using high contrast SEM image.
- Limitation temperature of thermal shrink process.
Thanks to the following for:

- **DSA shrink with planarization process:**
  Isabelle Servin, Maxime Argoud, Ahmed Gharbi, Celine Lapeyre, and Raluca Tiron

- **DSA guide pattern:**
  Cedric Monget
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