Study on defect control of resist process for production ready EUV lithography

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Contents

1. Comparison between ArF immersion vs. EUVL
2. Proposal for resist process defect generation mechanism.
3. EUV defect classification.
4. Defectivity evaluation with real device.
5. Conclusion
### Comparison of EUV transition to DUV's

<table>
<thead>
<tr>
<th></th>
<th>KrF → ArF</th>
<th>ArF → Immersion</th>
<th>Immersion → EUV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td>≈</td>
<td>=</td>
<td>≠ Laser Plasma</td>
</tr>
<tr>
<td><strong>Resist</strong></td>
<td>≠ PHP→Acrylic</td>
<td>≈ Top coat</td>
<td>≠ RLS trade-off Resist defect</td>
</tr>
<tr>
<td><strong>Mask</strong></td>
<td>= Quartz</td>
<td>=</td>
<td>≠ Reflective mask, Blank defect, flatness→overlay</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>=</td>
<td>≠ Immersion hood</td>
<td>≠ Vacuum</td>
</tr>
<tr>
<td><strong>Optics</strong></td>
<td>= Quartz</td>
<td>≈ Catadioptric</td>
<td>≠ All Reflective</td>
</tr>
<tr>
<td><strong>Pellicle</strong></td>
<td>≈ Polymer</td>
<td>=</td>
<td>≠ No pellicle P-SI</td>
</tr>
<tr>
<td><strong>Infra</strong></td>
<td>=</td>
<td>=</td>
<td>≠ OPC, New pods, inspection, etch, cleaning...</td>
</tr>
</tbody>
</table>

- Introduction of EUV means “everything will change”
- Well presented of definitive changes in EUV but not much updated on "Resist process defect"
Resist process defects had been studied a lot in immersion and a lot of effort required to control them.
Nothing much different from ArF immersion except for exposure system, though some brand new materials are engaged.
Something different in EUV

EUV reaction mechanism

Chemically amplification + Photon absorption
13.4nm [92eV] source
EUV only
1. Photon Absorption by Resist Matrix
2. Secondary electron generation
3. PAG reaction w/ thermal electrons
4. Acid Diffusion
5. Deprotection Sphere

EUV resist structure

Backbone (A,B,C ...)

Protecting group
PAG (Photo Acid Generator)
Sensitizer
Others

- EUV resists use secondary electron to activate PAG
- But, main structure is almost identical to DUV CAR Resist except for some ingredients and its synthesis
Shot noise and LWR

- Shot noise is inevitable phenomena in EUV lithography
- LWR in extreme extent can be seen as a defect

Photon absorption by a volume in ArF and EUV at 10 mJ/cm²

\[ n_{\text{absorbed}} = \frac{200 \times 10^{-15}}{4 \times 10^{-15}} = 50 \] photons

\[ E_{\text{absorbed}} = 2354 \text{ keV} \]

- About 14x more photons absorbed at ArF than EUV

Biafore, Thackeray, SPIE2009
### Generation of resist process defect

**Mechanism-1:** Defects originated from substrate and coating process on track

<table>
<thead>
<tr>
<th>Issue</th>
<th>Possible Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisoning from substrate</td>
<td>Underlayer adoption</td>
</tr>
<tr>
<td>Underlayer coating irregularity</td>
<td>Track system performance improvement</td>
</tr>
<tr>
<td>Resist coating irregularity</td>
<td></td>
</tr>
</tbody>
</table>
Generation of resist process defect

Mechanism-2; Defects induced from resist and exposure process

<table>
<thead>
<tr>
<th>Issue</th>
<th>Possible solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot Noise</td>
<td>High performance EUV resist sufficient EUV source power</td>
</tr>
<tr>
<td>Resist irregularity</td>
<td>High performance EUV resist</td>
</tr>
</tbody>
</table>
# Generation of resist process defect

## Mechanism-3: Defects induced from develop process on track

### Issue vs. Possible Solution

<table>
<thead>
<tr>
<th>Issue</th>
<th>Possible Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop on Particle</td>
<td>Clean develop system</td>
</tr>
<tr>
<td>Develop Residue</td>
<td>Optimization of develop recipe</td>
</tr>
<tr>
<td>FIRM related</td>
<td>Optimization of FIRM and develop recipe</td>
</tr>
</tbody>
</table>

### Diagram:

- **Developer Rinse FIRM**
- **Underlayer**
- **Substrate**
- **Resist**

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EUV Symposium, 2015
EUV Process defect classification

- Wafer Inspection has been performed with Real Device patterns
- Defects are classified based on similarity of its location and shape

Defects can be sorted by previously suggested mechanism with unavoidable ambiguity
Effect of process steps

Case 1; FIRM rinse skip

Case 2; Underlayer skip from case 1

- As we skip both material, reduction of defect observed according to appropriate category of each mechanism
Effect of process materials

- Selection of appropriate materials with good compatibility is necessary for reducing defect
Same resist with different synthesis method

- Both samples have same polymers and composition with slightly changed synthesis method

- Method of resist synthesis has significant effect on defect
- Quality Control of EUV resist material is very important for EUVL high volume manufacturing
Track process recipe tuning

- Variety of track recipes are prepared by modifying from reference recipe

- Optimizations of process recipe helped to reduce defect, though not sufficient.
Finally

EUV defect has decreased down to 25% of initial condition
Conclusion

- 3 types of process defect generation mechanisms are suggested and defects are classified according to them.
- The selection of Materials with good compatibility is important and process recipe optimization is helpful to reduce defects.
- Quality control of new EUV materials such as resist, underlayer and FIRM are essential for successful EUV High Volume Manufacturing.
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