Resist process and Etch process techniques for LWR reduction

Shinichiro Kawakami, Shannon Dunn, Akiteru Ko
TEL Technology Center, America, LLC

Karen Petrillo, George Huang, Dominic Ashworth, Jacque Giorger,
Liping Ren, KY Cho, Warren Montgomery, Stefan Wurm
SEMATECH

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Introduction

• LWR is one of the critical problem that needs improvement as EUV moves towards manufacturing

Key gaps for 22nm HP manufacturing

- Key Gaps for 22 nm HP Patterning
1. Resist Collapse (30%)
2. Resolution (10%)
3. LWR (63%)
4. Pattern transfer with thin resist
   (35 nm remained resist pattern height with 50 nm coating resist thickness)
5. Defects (Bridge/ Scum)
6. Sensitivity
7. Resist outgassing:
   Need useful spec. for Pilot-line & HVM

<Reference>
Outline

- **LWR Improvement**
  - Approach for LWR reduction techniques
  - Resist process based techniques feasibility
  - Etch process based technique feasibility
  - Demonstration result of combined all techniques

- **Summary**
Approach for LWR reduction

Track-based process techniques
Resist Smoothing process

FIRM\textsuperscript{TM} (Finishing up by Improved Rinse Material) process off-line

Etch-based process technique
Track-Based Resist Smoothing and FIRM™ Treatment Feasibility Result

Exposure tool : SEMATECH eMET  
Coat/DEV : CLEAN TACK ACT™ 12(TEL)  
CD : 32nm HP  
EUV Resist : 60nm Film Thickness

- Smoothing 10% improvement  
- FIRM™ (offline) 2-5% improvement  
- Both techniques show good feasibility  
- Especially resist smoothing is significant

Initial | Post Smoothing  
--- | ---  
CD:30.6nm | CD:31.1nm  
LWR: 7.3nm | LWR: 6.6nm  
(9.6%) |  

Initial | Post FIRM™-A  
--- | ---  
CD:29.8nm | CD:30.8nm  
LWR: 7.6nm | LWR: 7.2nm  
(5.3%) |
**Etch-Based Smoothing Feasibility Result**

Exposure tool: ADT (ASML)
EUV Resist: 60nm Film Thickness
Etch system: Tactras™ (TEL)

<table>
<thead>
<tr>
<th></th>
<th>32nm HP</th>
<th>30nm HP</th>
<th>28nm HP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post Litho LWR</strong></td>
<td>3.52nm</td>
<td>3.76nm</td>
<td>4.29nm</td>
</tr>
<tr>
<td><strong>Post Etch LWR</strong></td>
<td>3.04nm</td>
<td>3.09nm</td>
<td>3.35nm</td>
</tr>
<tr>
<td><strong>Etch-based smoothing shows</strong> 13-22% LWR improvement, that shows great feasibility</td>
<td>13.6%</td>
<td>17.8%</td>
<td>21.9%</td>
</tr>
</tbody>
</table>
Through Etch LWR improvement Combined all of techniques

Initial LWR

1st Process
FIRM™ chemical treatment
2-5% improvement

2nd Process
Resist smoothing
10% improvement

3rd Process
Etch based smoothing
13-22% improvement

Post Etch
Best LWR?

Experiments stack

EUV Resist 60nm
SIARC
OPL
SiN
SiON
Si

Experiments Process Flow

Initial LWR
Process-A
Process-B
Process-C
Process-D
Etch based Smoothing

Etch stop on Si

Etched LWR

Exposure tool: ADT
Coat/DEV: CLEAN TACK ACT™ 12
Etch system: Tactras™(TEL)

2-5% improvement
10% improvement
13-22% improvement

2-5% improvement
10% improvement
13-22% improvement
SEM settings and Measurement

ITRS Recommendation
1. Inspection area \( L \geq 2 \text{um} \)
2. Measurement \( \Delta L \leq 10 \text{nm} \)

Rectangular magnification
Mag. (X) 300k
Mag. (Y) 52.7k Inspection area 400
Measurement point 200
\( \Delta L = 2 \text{um}/200 = 10 \text{nm} \)
Satisfied ITRS recommendation

Sampling number was optimized by using 95% interval confidence analysis

20 images in Exp. field
LWR is averaged 120 sets of data
### Result 25nm/P64nm

*Images are X300k Y52.7k rectangular magnification
*LWR is averaged 120 sets of data

<table>
<thead>
<tr>
<th>Process</th>
<th>Initial Resist Pattern</th>
<th>Post FIRM™ Resist Pattern</th>
<th>Post Smoothing Resist Pattern</th>
<th>Post Etching SIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CD:25.0nm LWR:4.95nm</td>
<td>CD:25.6nm LWR:4.91nm</td>
<td>CD:29.8nm LWR:4.29nm (13.2%)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CD:25.4nm LWR:4.96nm</td>
<td>CD:25.6nm LWR:4.34nm</td>
<td>CD:30.2nm LWR:4.25nm (14.5%)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CD:25.6nm LWR:4.96nm</td>
<td></td>
<td>CD:29.8nm LWR:4.17nm (15.9%)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>CD:25.3nm LWR:4.92nm</td>
<td>CD:25.5nm LWR:4.90nm</td>
<td>CD:30.4nm LWR:4.12nm (16.3%)</td>
<td></td>
</tr>
</tbody>
</table>

+1.3%
+2.7%
+3.1%
**Result 30nm/P70nm**

*Images are X300k Y52.7k rectangular magnification
*LWR is averaged 120 sets of data

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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CD:28.9nm LWR:4.58nm</td>
<td>CD:29.4nm LWR:4.56nm (0.26%)</td>
<td>CD:33.6nm LWR:4.10nm (10.3%)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CD:27.6nm LWR:4.57nm</td>
<td>CD:29.4nm LWR:4.56nm (0.26%)</td>
<td>CD:34.0nm LWR:3.98nm (12.9%)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CD:28.9nm LWR:4.57nm</td>
<td>CD:29.1nm LWR:4.57nm (0.5%)</td>
<td>CD:33.6nm LWR:3.86nm (13.5%)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>CD:29.1nm LWR:4.59nm</td>
<td>CD:29.3nm LWR:4.57nm (0.5%)</td>
<td>CD:34.0nm LWR:3.84nm (16.1%)</td>
<td></td>
</tr>
</tbody>
</table>

+2.6%
+5.3%
+6.1%
Demonstration Summary

- All techniques combination demonstrated the best improvement on post etch LWR
- Resist smoothing and Etch Smoothing is majority of the improvement
Averaged Power Spectral Density result - Process-D

- Resist smoothing process reduced PSD in over all regions, especially reduced in high frequency region
- Etch smoothing reduced PSD in middle frequency regions.
Post Etch cross-section Profiles

There is no significant differences in both images
FIRM and resist smoothing processes do not affect the post-etch profile
Post Etch Whole Wafer CDU and LWR
Combined FIRM™, Smoothing, Etch Based Smoothing

L30nm/P70nm

Process-A(reference)

Ave. CD=33.3nm
CDU=1.5nm
LWR=3.9nm
LWR 3sigma=0.45nm

Process-D(Combined all techniques)

Ave. CD=33.9nm
CDU=1.5nm
LWR=3.6nm
LWR 3sigma=0.32nm
Summary

- LWR is one of the key issues for EUV manufacturing phase
- Resist process and Etch based process techniques are available to improve LWR
- All techniques combination demonstrated the best improvement on Post Etch LWR
  - Track-based process – 12% improvement
  - Track-based and Etch-based process 16-17% improvement
- We’ll continue development of those techniques to accomplish further LWR improvement
Acknowledgements

SEMATECH
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Kazuki Narishige
Thank you for your attention
**Backup**

Sample Number Optimization from Pre test

95% Confidence Interval Result

<table>
<thead>
<tr>
<th></th>
<th>CG4000</th>
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<tbody>
<tr>
<td></td>
<td>28nm</td>
</tr>
<tr>
<td>95% Interval</td>
<td>CD</td>
</tr>
<tr>
<td>Confidence</td>
<td>Required sample No</td>
</tr>
<tr>
<td>+/- 0.10nm</td>
<td>136lines</td>
</tr>
</tbody>
</table>

28nm Mag:300k 7lines/image
32nm Mag:300k 6lines/image
40nm Mag:300k 4lines/image

![Graph showing 95% Confidence Interval vs Line count for different magnifications and protrusion levels](image_url)