The dry etching performance of EUV mask absorbers

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1-1. Motivation (1)

Extreme Ultraviolet Lithography (EUVL) is considered as a candidate to fabricate LSI devices for 22 nm node and beyond. To make finer EUV absorber patterns, thinner EB resists are desired in mask making process.

The current EUV absorber is composed of bi-layer of tantalum (Ta) based film, and the dry etching mechanisms of its upper layer and lower layer are different. In general, the etching process of the EUV absorber is divided into two steps to acquire the high selectivity ratio to the EB resist.

We aimed to find the simplified etching condition that was able to achieve the high selectivity ratio.
1–1. Motivation (2)

**Two steps** etching process

<table>
<thead>
<tr>
<th>Fluorocarbon Plasma</th>
<th>Chlorine Containing Plasma</th>
</tr>
</thead>
</table>

Pros.;
High selectivity to resist

Cons.;
Complex process

**One step** etching process; using only fluorocarbon plasma

<table>
<thead>
<tr>
<th>Fluorocarbon Plasma</th>
<th>Fluorocarbon Plasma</th>
</tr>
</thead>
</table>

Pros.;
Simple process

Cons.;
Low selectivity to resist

We try to develop “One step” process as well as high selectivity.
Absorber materials

**Type A**
LR-TaBN absorber is designed low reflection at 257 nm wavelength.

**Type B**
LR-TaSi absorber is designed low reflection at from 193 nm to 257 nm wavelength.

**Type A: LR-TaBN Absorber**
- LR-TaBN
- Buffer Layer: 6025Qz

**Type B: LR-TaSi Absorber**
- LR-TaSi
- Buffer Layer: 6025Qz
1–2. Experiments (2)

**Experimental Conditions**

- EB Resist: Posi CAR, 170 nm thickness
- EB Writer: Vac.=50 kV, VSB
- Dry-etcher: ICP type
  - Gases; Fluorocarbon-based mixture gases
- CD Measurement tool: CD-SEM

**Evaluation items**

- Etching Bias Linearity
- Etching Bias Uniformity
  - 128 nm Dense-Clear Pattern @ 121 mm square
- Cross sectional SEM
1–3. Results (1)

Etching bias linearity

**Type A**

<table>
<thead>
<tr>
<th>Design Size (nm)</th>
<th>Iso Clear</th>
<th>Dense Clear</th>
<th>Iso Opaque</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>200</td>
<td>1.07</td>
<td>0.87</td>
<td>1.08</td>
</tr>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type B**

<table>
<thead>
<tr>
<th>Design Size (nm)</th>
<th>Iso Clear</th>
<th>Dense Clear</th>
<th>Iso Opaque</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>200</td>
<td>1.75</td>
<td>1.61</td>
<td>1.08</td>
</tr>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This value was calculated between 88 nm and 500 nm.

These results suggest that the CDL of etching bias is sufficient for both of absorber etching.
1-3. Results (2)

Etching bias uniformity

**Type A**

- Range: 6.58 nm
- $3\sigma$: 3.93 nm

**Type B**

- Range: 5.87 nm
- $3\sigma$: 2.72 nm

CDU of Type A and Type B are different tendency.
Cross sectional SEM (Design: 88 nm)

Type A
- Iso Clear
- Iso Opaque
- Dense
- Dense Hole

Type B
- Iso Clear
- Iso Opaque
- Dense
- Dense Hole
1–3. Results (4)

Cross sectional SEM (Resolution Limits)

**Type A**
- Design: 52 nm
  - Meas.: 51.7 nm
- Design: 64 nm
  - Meas.: 58.7 nm
- Design: 56 nm
  - Meas.: Clear 54.2 nm
  - Opaque 58.5 nm
- Design: 72 nm
  - Meas.: 54.4 nm

**Type B**
- Design: 52 nm
  - Meas.: 46.1 nm
- Design: 64 nm
  - Meas.: 57.4 nm
- Design: 56 nm
  - Meas.: Clear 46.0 nm
  - Opaque 66.8 nm
- Design: 80 nm
  - Meas.: 61.0 nm
1–4. Summary

<table>
<thead>
<tr>
<th></th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Structure</td>
<td>LR-TaBN / Buffer / Qz / Backside coating</td>
<td>LR-TaSi / Buffer / Qz</td>
</tr>
<tr>
<td>Selectivity to Resist</td>
<td>0.97</td>
<td>1.16</td>
</tr>
<tr>
<td>Etching Bias Linearity</td>
<td>Iso Clear: 1.07 nm</td>
<td>Iso Clear: 1.75 nm</td>
</tr>
<tr>
<td></td>
<td>Iso Opaque: 1.08 nm</td>
<td>Iso Opaque: 1.08 nm</td>
</tr>
<tr>
<td></td>
<td>Dense Clear: 0.87 nm</td>
<td>Dense Clear: 1.61 nm</td>
</tr>
<tr>
<td>Etching Bias Uniformity</td>
<td>Dense Clear: 3.93 nm</td>
<td>Dense Clear: 2.72 nm</td>
</tr>
<tr>
<td>128 nm Dense Clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>121 mm square, 3σ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution Limit</td>
<td>Iso Clear: 51.7 nm</td>
<td>Iso Clear: 46.1 nm</td>
</tr>
<tr>
<td>(Actual Size)</td>
<td>Iso Opaque: 58.7 nm</td>
<td>Iso Opaque: 57.4 nm</td>
</tr>
<tr>
<td></td>
<td>Hole: 54.4 nm</td>
<td>Hole: 61.0 nm</td>
</tr>
</tbody>
</table>

1. Optimized “One step etching” process with the high selectivity to resist was obtained.

2. These results suggested backside coating has some impact for etching bias uniformity.

Next, we investigated the influence of backside coating on dry etching performance.
1. The Dry etching performance of absorbers by one step etching
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2. Comparison of dry etching performance w/wo backside coating
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3. Conclusion
2–1. Preliminary Test (1)

As for the Previous result, etching bias uniformity had tendency.
We confirmed which material or plasma was the cause of signature.

**Two Processes demonstrated using the same material.**
2–1. Preliminary Test (2)

<Definition>

1. 1st = 2nd → depends on material
2. 1st ⊥ 2nd → depends on plasma distribution

* A random element was subtracted

These results indicate depending on material.

Next, we focused on the dry etching performance w/wo backside coating.
2–2. Experiments

Stack structures

- **Type C**  With backside coating
- **Type D**  Without backside coating

**Type C**
- LR-TaBN Buffer Layer
- Si cap. ML
- 6025Qz
- Backside Coating

**Type D**
- LR-TaBN Buffer Layer
- Si cap. ML
- 6025Qz
2-2. Experiments

Pattern layout and evaluation items

- **Etching bias Linearity**
  - Load < 1 %
  - Load 30 %
  - Load 60 %
  - Load 90 %

- **Etching bias Uniformity**

- **Cross sectional SEM**

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2–3. Results (1)

Etching bias linearity

Type C

- Load < 1 %
- Load 30 %
- Load 60 %
- Load 90 %

Type D

- Load < 1 %
- Load 30 %
- Load 60 %
- Load 90 %

Iso Clear

Dense Clear
2-3. Results (2)

Etching bias linearity

- No difference of etching bias linearity w/wo backside coating
- No impact of load factor
- Negligible gap of etching bias w/wo backside coating
2–3. Results (3)

Etching bias uniformity
(128 nm Dense Clear, 132 mm square)

**Type C**

- Load < 1 %
- Load 30 %
- Load 60 %
- Load 90 %

**Uniformity Data**

<table>
<thead>
<tr>
<th>Range</th>
<th>3.26 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3\sigma$</td>
<td>2.00 nm</td>
</tr>
</tbody>
</table>

**Type D**

- Load < 1 %
- Load 30 %
- Load 60 %
- Load 90 %

**Uniformity Data**

<table>
<thead>
<tr>
<th>Range</th>
<th>2.26 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3\sigma$</td>
<td>1.59 nm</td>
</tr>
</tbody>
</table>

* A random element was subtracted

Backside coating was degraded etching bias uniformity.
2–3. Results (4)

Cross Sectional SEM (Design 88nm)

<table>
<thead>
<tr>
<th>Type C</th>
<th>Type D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load</strong></td>
<td><strong>Load</strong></td>
</tr>
<tr>
<td>&lt; 1 %</td>
<td>&lt; 1 %</td>
</tr>
<tr>
<td>30 %</td>
<td>30 %</td>
</tr>
<tr>
<td>60 %</td>
<td>60 %</td>
</tr>
<tr>
<td>90 %</td>
<td>90 %</td>
</tr>
</tbody>
</table>

Neither backside coating nor load factor influenced the pattern profile.
2–4. Summary

LR-TaBN performance by **one step** etching,

- **Etching bias linearity**
  - No influence of load factor and w/wo backside coating

- **Etching bias uniformity**
  - Degraded by backside coating

- **Pattern profile**
  - No impact of load factor and w/wo backside coating
3. Conclusion

We developed **one step** absorber etching process. However, systematic uniformity error has seen in etching bias uniformity.

It was clarified that backside coating influenced etching bias uniformity.

**Future work**

We will challenge to improve mask making processes to meet all ITRS requirements.

We will investigate the factor that cause the influence of etching bias uniformity with backside coating.