The Recent Status of Resist Outgas Testing at EIDEC

Evolving nano-process Infrastructure Development Center, Inc. (EIDEC)

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1. Introduction
2. Overview of EIDEC resist outgas research program
3. Recent update of EIDEC resist outgas testing
4. Summary
EUV Resist Outgassing Issue

Early stage concern of resist outgassing from Chemically Amplified Resist (CAR)

EUV lithography system

• Hydrocarbons from CAR make contaminations on EUV mirror.
• The contaminations reduce reflectivity of EUV mirrors.
• Hydrocarbon contamination can be cleaned up.
Outgassing of Metal Containing Resists

2\textsuperscript{nd} stage concern of resist outgassing from Metal Containing Resist (MCR)

Outgassing model of MCR

- Hydrogen environment in scanner to suppress hydrocarbon contamination
- EUV lights generate hydrogen radicals

- Hydrogen radicals react with metal elements in metal containing resists.
- Metal hydrides outgas from the resists and make metallic contaminations on EUV mirror.
Recent Status of EUV Scanner against Outgassing

ASML proposed DGL-m to prevent the diffusion of resists outgassing to mirror.
No outgas testing is needed to evaluate resists in EUV scanner with DGL-m.
The priority of resist outgassing issue seems to be lower.

We don’t know what will happen in EUVL HVM.
Outgas testing method for MCR is not established yet.
Provision of MCR outgas testing have a meaning to support EUVL HVM.

Oktay Yildirim et al., Proc. of SPIE Vol. 10143 101430Q, 2017
Outline

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Conventional Test Protocol of Resist Outgassing

**Witness Sample (WS) method**

- **Outgas tester**
  - EUV or EB
  - Resist
  - Outgas
  - EUV or EB
  - Contamination

- **Spectroscopic ellipsometer**
  - WS
  - WS

- **Hydrogen radical cleaner**
  - WS
  - WS

- **XPS**
  - WS
  - X-ray

<table>
<thead>
<tr>
<th>Source</th>
<th>HPEUV</th>
<th>EUVOM-9000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resist</td>
<td>EUV (1700mW/cm²)</td>
<td>EB (250eV)</td>
</tr>
<tr>
<td>Resist</td>
<td>EUV (1700mW/cm²)</td>
<td>EB (2KeV)</td>
</tr>
<tr>
<td>Vacuum condition</td>
<td>3~4x10⁻⁷ Pa</td>
<td>3~4x10⁻⁷ Pa</td>
</tr>
</tbody>
</table>
Preliminary Test Results of Model Materials (1)

Model elements: Sn, Hf, Zr and Zn
(Popular elements used for metal resists)

EB-based outgas tester without hydrogen

Non-cleanable contamination: XPS

SnO₂  HfO₂  ZrO₂  Zn

- Non-cleanable were not observed by EB-based tests for Sn, Hf, Zr samples.
- Zn contamination was detected instead of no hydrogen environment.
Preliminary Results of Metal Model Material (2)

Test conditions

- Outgas tester: HPEUV irradiation tool
- Test material: SnO₂ (100nm Sputtered film)
- Environment: H₂ (100 Pa) or Vacuum
- Exposure dose: 360 J/cm²
- Exposed area: 8mm φ (0.1% of 300 mm wafer)

XPS spectrum of Sn of WS’s

- 360J/ cm² one-point exposure
  ≈ 300mJ/cm² × 300mm wafer area

- Sn contamination was observed in only hydrogen environment.
- Very high dose was needed to detect the metal outgassing.

One-point exposure

Outgas tester: HPEUV w H₂
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EUV-based Outgas Tester and Test Conditions

**High Power EUV Irradiation Tool (HPEUV)**

**Configuration**

**CAR Eth test by HPEUV**

**Test conditions**
- Outgas tester: HPEUV
- Source: EUV for Wafer and WS
- Material: Metal oxide / pure Metal (100nm)
- Vacuum: 100 Pa hydrogen
- Exposure dose: 300 mJ/cm² (~ 30 x of CAR's Eth)
- Exposed area: 80% of 300mm φ wafer
HPEUV EUV Exposure Test Result: XPS

Non-cleanable contamination

- No metal contamination were observed from HfO\textsubscript{2}, ZrO\textsubscript{2}.
- Sn contamination was also not observed on the contrary of the result of one-point exposure test.
- Zn contamination was detected from Zn as the result of EB-based tester.
Dose Dependency of Metal Hydride Outgassing

One-point Exposure vs Scan Exposure

- Hydrogen radical density by scan exposure was not sufficient to generate metal hydride to outgas.
- More exposure dose may be needed to detect by scan exposure.
HPEUV EUV Exposure Test Result : RGA

Zn : Mass number 50-150

- RGA result of HPEUV differs from that of EUVOM.
- Zn peak were covered by hydrocarbon contamination in H2.
Issues of Resist Outgas Testing at HPEUV

1. QMS detection in high pressure of hydrogen
   ⇒ Low S/N between metal hydride and hydrocarbon contamination in $\text{H}_2$
2. Very high exposure doses for contamination detection
   ⇒ High operation cost of EUV source
3. Achievement of contamination limited regime
   ⇒ Low EUV/EB power on WS

Alternative solution:
EB source + Hydrogen radical source
The preparation of test setup is ongoing.
Summary

- The outgas testing in hydrogen were carried out for model metal materials by HPEUV.
- Zn contamination was detected from Zn by HPEUV as the result with EB-based tester.
- Technical issues were clarified to improve outgas testing for metal containing resists.
- New test system was proposed using EB-based tester with hydrogen radical source.
Acknowledgement

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Thank you for your kind attention!!