Development Status of Canon’s EUVL Exposure Tool

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Canon Inc.
Outline

Development schedule
- EUVL exposure tool roadmap

Mirror fabrication and evaluation
- Surface figuring
- Multilayer evaluation

Optics lifetime
- Atomic hydrogen cleaning

Optical design
- 6-mirror high-NA PO

Summary
# EUVL Tool Roadmap

<table>
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<tbody>
<tr>
<td>2 year cycle (nm)</td>
<td>45</td>
<td>32</td>
<td>22</td>
<td>16</td>
<td>11</td>
<td>8</td>
<td></td>
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<tr>
<td>DRAM (hp)</td>
<td>57</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td>36</td>
<td>32</td>
<td>28</td>
<td>25</td>
<td>23</td>
<td>20</td>
<td>18</td>
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<tr>
<td>Flash (hp)</td>
<td>45</td>
<td>40</td>
<td>36</td>
<td>32</td>
<td>28</td>
<td>25</td>
<td>23</td>
<td>20</td>
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<td>13</td>
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## HVM Platform
- **HVM tool (VS2)**
  - NA > 0.32
- **HVM tool (VS3)**
  - TP Enhancement

## Prototype
- **SFET Installed at SELETE**
- **6-mirror (PO1) NA0.3**
  - In-house test

## Specifications of VS2

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>NA</td>
<td>&gt; 0.32</td>
</tr>
<tr>
<td>Aberration</td>
<td>&lt; 0.35 nm RMS</td>
</tr>
<tr>
<td>Flare</td>
<td>5 %</td>
</tr>
<tr>
<td>Dense Lines</td>
<td>&lt; 25nm</td>
</tr>
<tr>
<td>Isolated lines</td>
<td>17nm</td>
</tr>
<tr>
<td>Dense Contacts</td>
<td>&lt; 28nm</td>
</tr>
<tr>
<td>Overlay (SMO)</td>
<td>&lt; 3 nm</td>
</tr>
<tr>
<td>Throughput</td>
<td>100wph @200w IF</td>
</tr>
<tr>
<td></td>
<td>10mJ/cm²</td>
</tr>
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</table>
PO1 System

PO1 is being fabricated to evaluate and improve our fabrication technology.

Features

- Low-thermal expansion ceramic structure.
- Position of 5 mirrors are controlled in real time.
  - High stability of mirror position against vibration.
  - Aberration can be compensated.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
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<tbody>
<tr>
<td>NA</td>
<td>0.3</td>
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<tr>
<td>Slit size</td>
<td>26 x 2 mm²</td>
</tr>
<tr>
<td>Aberration</td>
<td>0.55 nm RMS</td>
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<tr>
<td>Flare</td>
<td>7 %</td>
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</tbody>
</table>
**IBF process capability**

**Effective spatial resolution range; small beam IBF**

- **Effective range**
- **Figure correction**

![IBF tool]

- Small beam operation has 1.2mm wavelength resolution.
Mirror Surface Accuracy

Flare calculated from PSD curve is less than 5%.
(Range of spatial frequency that causes the flare is 4.5 decades.)

Figure accuracy also satisfies requirements for HVM tools.
Wavefront of reflected light is determined by:
- shape of the mirror surface
- phase shift on multilayer reflection.

Therefore, we have to measure and control them with high accuracy.
Reflection Phase Measurement

Standing wave is a superposition of the incident light and the reflected light. Electric field of the standing wave depends on phase shift and reflectivity.

Photoelectron intensity is proportional to electric field intensity on the multilayer surface approximately, because escape depth of low energy (<100eV) electron is small compared to thickness of each layer.
At-wavelength Multilayer Evaluation System

Features
- High accuracy of wavelength (Kr gas absorption spectrum, source emission spectrum)
- Reflectivity and phase measurement at same time
- Polarization control

Reflectivity Repeatability: 0.2%

Extinction factor: <1E-3
Phase shift by multilayer reflection can be measured using standing wave method.
Wavefront error caused by phase shift deviation was estimated to about $2m\lambda(\sigma)$. 
Optics lifetime/ Carbon deposition

Carbon deposition rate was estimated using experimental results under accelerated condition.
- Decane gas introduced
- SR beamline of Super-ALIS (NTT)

Assumption:
- Decane pressure of 1E-7Pa
- Linear extrapolation

Estimated carbon deposition rate of HVM exposure tool: 0.03 nm/hr (max)

Considering other factors:
- EUV intensity distribution in PO
- Source frequency
- Residual gas species
- Mitigation technologies
  carbon deposition rate can be mitigated.

- Carbon deposition rate was measured using SR beamlines.
- Repeated cleaning of deposited carbon on optical surface is needed.
Contamination Cleaning Using Atomic Hydrogen

Atomic hydrogen cleaning is a promising method for Cleaning of deposited carbon on optical surface.

advantages: - High etching rate, - No oxidation effect
concern: - Damage for resin materials

Damage test was performed for variety of materials.

Set up of irradiation tests
Surface Damage caused by Atomic Hydrogen Irradiation

Irradiation time: 180 min (corresponds to the etching depth of 50 nm)

<table>
<thead>
<tr>
<th></th>
<th>AFM (30μm range)</th>
<th>SEM (10,000X)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>PTFE</td>
<td><img src="image" alt="AFM PTFE Before" /> <img src="image" alt="AFM PTFE After" /></td>
<td><img src="image" alt="SEM PTFE Before" /> <img src="image" alt="SEM PTFE After" /></td>
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<tr>
<td>THV</td>
<td><img src="image" alt="AFM THV Before" /> <img src="image" alt="AFM THV After" /></td>
<td><img src="image" alt="SEM THV Before" /> <img src="image" alt="SEM THV After" /></td>
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<tr>
<td>Epoxy</td>
<td><img src="image" alt="AFM Epoxy Before" /> <img src="image" alt="AFM Epoxy After" /></td>
<td><img src="image" alt="SEM Epoxy Before" /> <img src="image" alt="SEM Epoxy After" /></td>
</tr>
</tbody>
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EUVA Report 2008

◆ Atomic hydrogen cleaning causes no significant damage to several kinds of resin material.
6-mirror high-NA Projection Optics
- Target of Wavefront aberrations

NILS - Defocus

Cross-pole illumination is chosen for HP16nm LS due to large DOF with NILS > 1.2

Target value of aberrations is < 0.35nm RMS for delta CD < 1.12nm (7% of CD)
6-mirror high-NA Projection Optics - Optical design

All combination of 6Mirror

(M5=convex, M6=concave. so, there are 16 combination by M1,M2,M3 and M4)

- Optical Design Result of Projection Optics

**Performance**

- NA : $> 0.32$
- Flare : $\leq 5\%$
- final aberration : $\leq 0.35$ nmRMS
Summary

- Fabrication technologies for projection optics
  - Surface figuring technologies satisfy requirements for HVM tool.
  - At-wavelength multilayer evaluation system for thickness and phase measurements has been developed.

- Optics lifetime
  - Atomic hydrogen cleaning method has advantage of low damage and reasonable etching rate.

- Optics Design
  - Optical design of 6-mirror High-NA projection optics has been completed.
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