Defect review capability on Actinic blank inspection tool

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Contents

1. ABI tool development status
2. Defect review capability
3. Bright field review
4. Summary
ABI development chronicle

**Proof of Concept**
Mirai (2001-2005)
- Feasibility study
- Dark field Actinic imaging

**Full field Prototype**
Mirai-Selete (2006-2011)
- Full mask field inspection
- Phase defect imaging

**HVM Prototype**
EIDEC-Lasertec (2011-2015)
- Printable phase defect management
- 1nm(h)/50nm(w) sensitivity
- 45min inspection time
- Defect location identification

*Actinic Blank Inspection tool is ready for defect management in HVM*
ABI tool’s detection capability

All printable defects are manageable with the improved ABI

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Improve illumination optics

ABI detection capability

Yamane T., Photomask Japan 2015
Suzuki T., Photomask Japan 2015

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100% capture area

improved low aspect ratio
defect detection capability
ABIsignal intensity and Printability

ABI dark field review is effective for predicting whether a defect is perfectly covered by absorber or not.

Clear correlation between ABI signal intensity and printing result.

EIDEC, IMEC co-evaluation
Noriaki Takagi, Photomask Japan 2015
Defect location accuracy

Configuration of optics for defect location measurement

Accurate defect location measurement is available

Location measurement in full mask area

Measurement Repeatability
(21-point average, 3σ)

- 21-point cross mark measurement in 10-days sampling
- Position compensation using 4 FMs applied

x: 12.4 nm
y: 18.4 nm
ABI inspection and review - 2 years of experience

ABI tool is continuously evaluating EUV blanks;
- total scanned area up to $524 \times (100 \times 100)$ mm$^2$,
- total reviewed spots up to 173,000 points
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Defect characterization – ABI flow

- Defect map with DSI (defect signal intensity)
- False elimination
- Phase/Amplitude defect classification
- Pit/Bump classification
- Measurement of defect location and size

Review of each defect

1μm

High resolution

1μm
Defect review functions on ABI dark field

Accurate DSI evaluation

Amplitude classification with DUV illumination

Defect location & size measurement

Pit/Bump classification with through focus

Accurate DSI evaluation

Amplitude defect Signal intensity

EUV illumination < DUV illumination

Printing impacts are represented not by SEVD size but by ABI signal intensities

DSI : Defect Signal Intensity

DSI = 600 (au)

Defect location & size measurement

Pit/Bump classification with through focus

Focus offset -2.0um -1.0um 0.0um 1.0um 2.0um

A = 9000 nm²

Accurate defect location

Dark field imaging is effective to find the characteristics of defect

Printing impacts are represented not by SEVD size but by ABI signal intensities

Amplitude defect Signal intensity

EUV illumination < DUV illumination

Accurate DSI evaluation

Defect location & size measurement

Pit/Bump classification with through focus

Focus offset -2.0um -1.0um 0.0um 1.0um 2.0um

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Accurate defect location

Dark field imaging is effective to find the characteristics of defect
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- Pit/Bump classification
- Printability prediction based on bright field observation

New function
Optics configuration for Bright field review

CCD camera

EUV illumination

Scattered light from the mask

Dark field review

Switch mirror for bright field review
CRA : 6 degrees
Specular reflection from the mask

Bright field review

BF&DF review are available with ABI tool
Defect review images with BF/DF

<table>
<thead>
<tr>
<th>Defect</th>
<th>Bright field</th>
<th>Dark Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDM Pit</td>
<td><img src="image1.png" alt="Bright field image" /></td>
<td><img src="image2.png" alt="Dark Field image" /></td>
</tr>
<tr>
<td>DSI=400 40nm x 1.2nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle</td>
<td><img src="image3.png" alt="Bright field image" /></td>
<td><img src="image4.png" alt="Dark Field image" /></td>
</tr>
<tr>
<td>DSI=400</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Bright field review represents the specular reflection from the mask*
Through focus analysis using bright field

**Bright field simulation images** for Pit/Bump phase defects

<table>
<thead>
<tr>
<th>Focus [nm]</th>
<th>-800</th>
<th>-400</th>
<th>0</th>
<th>+400</th>
<th>+800</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pit</strong></td>
<td><img src="pit_100nm_1.0nm_-800.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_-400.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_0.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_+400.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_+800.png" alt="Image" /></td>
</tr>
<tr>
<td>100nm x 1.0nm</td>
<td><img src="pit_100nm_1.0nm_-800.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_-400.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_0.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_+400.png" alt="Image" /></td>
<td><img src="pit_100nm_1.0nm_+800.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Bump</strong></td>
<td><img src="bump_100nm_1.0nm_-800.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_-400.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_0.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_+400.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_+800.png" alt="Image" /></td>
</tr>
<tr>
<td>100nm x 1.0nm</td>
<td><img src="bump_100nm_1.0nm_-800.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_-400.png" alt="Image" /></td>
<td><img src="bump_100nm_1.0nm_0.png" alt="Image" /></td>
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<td><img src="bump_100nm_1.0nm_+800.png" alt="Image" /></td>
</tr>
</tbody>
</table>

- Pit and bump have different Bright/Dark characteristics
Through focus analysis using bright field (real image)

**Bright field observations for Pit/Bump phase defects**

<table>
<thead>
<tr>
<th>Focus [nm]</th>
<th>-800</th>
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<th>0</th>
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</thead>
<tbody>
<tr>
<td><strong>Pit</strong></td>
<td><img src="pit-800.png" alt="Image" /></td>
<td><img src="pit-400.png" alt="Image" /></td>
<td><img src="pit-0.png" alt="Image" /></td>
<td><img src="pit+400.png" alt="Image" /></td>
<td><img src="pit+800.png" alt="Image" /></td>
</tr>
<tr>
<td>100nm x 2.1nm</td>
<td><img src="pit-800.png" alt="Image" /></td>
<td><img src="pit-400.png" alt="Image" /></td>
<td><img src="pit-0.png" alt="Image" /></td>
<td><img src="pit+400.png" alt="Image" /></td>
<td><img src="pit+800.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Bump</strong></td>
<td><img src="bump-800.png" alt="Image" /></td>
<td><img src="bump-400.png" alt="Image" /></td>
<td><img src="bump-0.png" alt="Image" /></td>
<td><img src="bump+400.png" alt="Image" /></td>
<td><img src="bump+800.png" alt="Image" /></td>
</tr>
<tr>
<td>110nm x 0.9nm</td>
<td><img src="bump-800.png" alt="Image" /></td>
<td><img src="bump-400.png" alt="Image" /></td>
<td><img src="bump-0.png" alt="Image" /></td>
<td><img src="bump+400.png" alt="Image" /></td>
<td><img src="bump+800.png" alt="Image" /></td>
</tr>
</tbody>
</table>

*Through focus imaging with bright field is effective for defect analysis*
**Pattern defect review images with BF/DF**

<table>
<thead>
<tr>
<th>Design</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Design Image 1" /></td>
<td><img src="image2.png" alt="Bright field Image 1" /></td>
<td><img src="image3.png" alt="Dark Field Image 1" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Design Image 2" /></td>
<td><img src="image2.png" alt="Bright field Image 2" /></td>
<td><img src="image3.png" alt="Dark Field Image 2" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Design Image 3" /></td>
<td><img src="image2.png" alt="Bright field Image 3" /></td>
<td><img src="image3.png" alt="Dark Field Image 3" /></td>
</tr>
</tbody>
</table>

Bright lines in dark field images represent absorber pattern edges.

Difficulty in identifying a defect as INTRUSION or PROTRUSION.

*Bright field review brings useful information for lithographic impact prediction*
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Summary

1. The ABI HVM prototype supports to improve the quality of EUV mask blanks by its inspection and review functions.

2. Bright field review capability is additionally installed on the ABI tool. It facilitates predicting lithographic impact using the mask review images by the tool.
Acknowledgements

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