Agenda

- Motivation
- Latest Reticle Inspection Advances
- Latest EUV Inspection Results
- EUV Actinic Patterned and Blank Mask Inspector Introduction
- Summary
Lithography History and Near Future

wavelength ($\lambda$)  NA $k_1$  ($k_1$ or $\lambda$)

365nm  248nm  193nm  180nm  130nm  90nm  65nm  45nm  32nm  22nm  14nm  10nm  7nm??

EUV?

OPC  Immersion  OPC+  Comp-Litho  OPC++?

Litho $\lambda$  Logic Generation

Reticle and Photomask Product Division
Mask Inspection Challenges for Advanced Node

- **Mask types** – add EUV and quartz etch masks
- **Optics** – keep defect SNR high
  - high NA imaging at limit
  - boost defect signal with illumination
  - reduce imaging noise
- **Database Modeling**
  - complex EUV, quartz etch, exotic OPC
  - more complex modeling – reduce errors
  - higher computational load – keep speed
- **Defect Detectors**
  - new defect types – local CD, shifted, stripes, etc
  - manage nuisance – mask processes challenged
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Latest Reticle Inspection Advances

Teron 630 for $\geq 10\text{nm} / 1\times\text{hp Generation}$ – Optical* and EUV

- Defect detector advances
- 3rd generation database modeling
- Latest generation image computer and dataprep
- EUV compatible cleanliness
- Flexible Imaging for high sensitivity
- Noise reduction for false reduction
- High accuracy stage*
- EUV compatible reticle handling
- EUV dual-pod load port

* 10nm generation optical reticles in development  
August-2013

Reticle and Photomask Product Division
Latest Reticle Inspection Imaging Advances

Imaging advances to boost defect signal / reduce noise

- Flexible imaging conditions – NA, sigma, pupil, polarization
- Reduced aberrations, vibration, focus error
- EUV demonstrated – applicable to optical

Up to 50% defect signal boost
Latest Database Modeling Advances

**new Gen3 modeling for EUV, quartz etch, complex OPC**

- Advanced physics-based 3D modeling
- Models complex EUV and quartz etch illumination physics
- Low errors for best defect detection SNR – find small defects
- Optimized for high speed reticle inspection (10x10cm in ~2hr)
- Extendable to standard optical reticles with aggressive OPC

Gen2 modeling error  ➔  Gen3 modeling error  ➔  Gen3 Initial release  ➔  Gen3 2nd release

EUV 14nm reticle

50% RMS lower errors

25 to 30% further noise reduction
Latest EUV Die-to-Die Algorithm Advances

- New Advanced EUV Die-to-Die Algorithm developed
  - In-house testing completed
  - Recent Beta site installation

- Technical advances for die-to-die
  - Optimized imaging – OAI and polarization
  - New autofocus method - reduces false
  - EUV defect detectors

- Sensitivity expected to meet process development requirements
### ML Phase Defect Location Accuracy Advances

<table>
<thead>
<tr>
<th>Location Accuracy (nm)</th>
<th>Timing</th>
<th>Change</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 1000 - 3000</td>
<td>Q4 CY10</td>
<td>Initial capability</td>
<td>610</td>
</tr>
<tr>
<td>~ 200 - 250</td>
<td>Q2 CY11</td>
<td>2 pt alignment (plate rotation)</td>
<td>610</td>
</tr>
<tr>
<td>~ 100 - 120</td>
<td>Q4 CY12</td>
<td>3 pt alignment, scale, ortho compensation, template matching</td>
<td>610 / 630</td>
</tr>
<tr>
<td>~ 50</td>
<td>1H CY14</td>
<td>HW improvements</td>
<td>630</td>
</tr>
<tr>
<td>~ 30</td>
<td>1H CY15</td>
<td>Algorithm / sw development</td>
<td>630</td>
</tr>
</tbody>
</table>

Continuous improvements supporting industry needs
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Testing Program

- Internal testing for beta start – completed Nov’12
  - 22nm / 14nm generation optical and EUV reticles
  - 15ea EUV reticles from 9ea reticle manufacturers

- Field beta testing - started in Dec’12
  - qualified for optical production Jan’13
  - qualified for EUV die-to-database Mar’13
  - inspect reticles with black borders May’13
  - EUV die-to-die testing in progress – complete Sep’13

- Continue testing as 10nm generation reticles are available
630 EUVdb 5-Sys Test – 56nm pitch hole

630 EUVdb Test*
5ea 630 systems
2ea KT PDMs

630 EUVdb 100% Spec*
All 5x2 100%*
< 5x2 100%*
610 EUVdb 1x1 Test 100%*
Defect SEM Size, nm or % area

Stack: 50nm TaBN + 2nm TaBO
PDM = Programmed Defect Mask
* 5 consecutive inspections
EUV Die-to-die 2-Sys Test – 56nm pitch hole

630 EUVdd Test
2ea 630 systems
2ea KT PDMs

630 EUVdd 100% Spec*
All 2x2 100%*
< 2x2 100%*

14 defect types – 9 shown

Defect SEM Size, nm or % area

Stack: 50nm TaBN + 2nm TaBO

PDM = Programmed Defect Mask
* 5 consecutive inspections

Reticle and Photomask Product Division
EUV Die-to-DB, Die-to-Die Sensitivity Characterization

**Die-to-Database shows its superior sensitivity**

Max sensitivity capability with <100 false/nuisance per run criteria
Particle Mode Sensitivity Characterization

SiO₂ on ML – High capture rate down to 30 nm

<table>
<thead>
<tr>
<th>SiO₂ Size</th>
<th>Defects Present</th>
<th>Defect count</th>
<th>Capture rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 nm</td>
<td>1785</td>
<td>1803</td>
<td>100%</td>
</tr>
<tr>
<td>70</td>
<td>1925</td>
<td>1918</td>
<td>100%</td>
</tr>
<tr>
<td>60</td>
<td>1809</td>
<td>1800</td>
<td>100%</td>
</tr>
<tr>
<td>55</td>
<td>1996</td>
<td>2072</td>
<td>100%</td>
</tr>
<tr>
<td>50</td>
<td>1910</td>
<td>1903</td>
<td>100%</td>
</tr>
<tr>
<td>45</td>
<td>1929</td>
<td>1919</td>
<td>100%</td>
</tr>
<tr>
<td>40</td>
<td>1614</td>
<td>1820</td>
<td>100%</td>
</tr>
<tr>
<td>35</td>
<td>unknown</td>
<td>2007</td>
<td>High capture</td>
</tr>
<tr>
<td>30</td>
<td>unknown</td>
<td>1633</td>
<td>High capture</td>
</tr>
</tbody>
</table>
Motivation

Latest Reticle Inspection Advances

Latest EUV Inspection Results

EUV Actinic Patterned and Blank Mask Inspector Introduction

Summary
Lithography and Inspection Wavelength

Litho @ 193-nm

5xx @ 257-nm

6xx @ 193-nm <Actinic>

13.5-nm <Actinic>

NBA1 @ 193-nm

NBA2 @ <1-nm(eBeam)

EUVL presents unique challenges of Inspection strategy – Actinic or two extreme ends

KLA Tencor
Reticle and Photomask Product Division
EUV Actinic Patterned Mask and Blank Inspection Tool

- EUV actinic inspection is a must for EUVL High Volume Manufacturing due to:
  - Phase defects
  - ML Blank defects
  - Contamination defects
  - Throughput
  - Through-pellicle inspection

7xx Program
The world’s only EUV Actinic Patterned Mask Inspection System
7xx Program Status

Actinic platform requirements
- Target node – 16-nm and 11-nm HP node
- Target throughput – 2 to 5 hour inspection per mask
- All defect types capture including Phase defects, ML Blank defects, Contamination defects which impact wafer patterning

Partnership in place to accelerate Actinic Patterned Mask Inspector production readiness
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- Latest DUV reticle inspector – 630 Series released and supporting early EUV defectivity learning
  - platform extensions planned for 10nm / 1xhp generation

- EUV Actinic Patterned and Blank Mask Inspector development in progress with collaboration with key customers
  - target 7nm / 1xhp generation high volume manufacturing and below