Challenges in development and construction of metrology, calibration, and resist testing tools for the implementation of EUV lithography

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About EUV Technology

• Pioneered the development of stand alone EUV Metrology Tools (in 1999)
• EUV Reflectometer Model No. LPR1016-FS1515 was selected by the R&D Magazine as the 100 Most Technologically Significant New Products of the year 2005.
• Two key products;
  – EUV Reflectometer
  – EUV Resist Outgassing tool
Challenges in developing tools

- Low volume
- Specifications are still evolving.
- Custom designs
- Particle issues
  - Detecting >60 nm particles.
  - No data for most of the 3\textsuperscript{rd} party products.
EUV Reflectometer
Cross section schematic of an EUVL Mask: 5 layers
Definition of peak EUV reflectivity ($R_p$) and median wavelength ($\lambda_m$).
Side view of the tool
EUV Reflectometer

LPP source. Cu target 5 to 20 nm
Misconceptions and facts

- Misconceptions
  - Reflectivity parameters are difficult to measure with required accuracy

- Facts
  - Reflectivity measurements are very easy to perform
  - Takes about 30 seconds per measurement
  - Currently, we can measure $R$ with $3\sigma$ of 0.05% and lambda $3\sigma$ of 0.0005nm

These values far exceed HVM requirements
(a) Twenty reflectivity measurements at the center of a Mo-Si multilayer to illustrate the repeatability (precision) of our Reflectometer. This multilayer was also measured at ALS, BL 6.3.2. 
(b) X and Y axes magnified to show the actual 25 curves.
Absorber Plate (100nm La-TaBN): Measured Reflectivity

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Reflectivity</th>
<th>Precision (3σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.594</td>
<td>0.0030</td>
<td>0.0014 nm</td>
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</tbody>
</table>

Peak Reflectivity = 0.27 %
Precision (3σ) = 0.003%
## Comparison with beam line 6.3.2 at ALS (Berkeley, CA)

<table>
<thead>
<tr>
<th></th>
<th>ALS</th>
<th>EUV Technology</th>
<th>MADT (EUVT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precision (3σ)</td>
<td>0.0003 nm</td>
<td>0.0005 nm</td>
<td></td>
</tr>
<tr>
<td>(with load and unload)</td>
<td>0.0027 nm (0.021%)</td>
<td>0.0006 nm</td>
<td>0.0008 nm</td>
</tr>
<tr>
<td>Accuracy (3σ)</td>
<td>0.0042 nm (0.033%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peak Reflectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precision (3σ)</td>
<td>0.24%</td>
<td>0.20%</td>
<td></td>
</tr>
<tr>
<td>Accuracy (3σ)</td>
<td>0.42%</td>
<td></td>
<td>0.03%</td>
</tr>
</tbody>
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EUV Technology
Reflectometer Road Map

• Field upgrade current design to 6.x nm region (2011/12)
• HVM Reflectometer (2012/13)
  – High precision
• EUV Reflectometer for patterned masks (2012/13)
  – Small spot
<table>
<thead>
<tr>
<th>Measurement Performance</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUV Peak reflectivity precision for $R_p &gt; 2%$ absolute</td>
<td>$3\sigma \leq 0.07%$ absolute</td>
</tr>
<tr>
<td>EUV Peak reflectivity accuracy for $R_p &gt; 2%$ absolute</td>
<td>$3\sigma \leq 0.10%$ absolute</td>
</tr>
<tr>
<td>EUV Peak reflectivity precision for $R_p &lt; 2%$ absolute</td>
<td>$3\sigma \leq 0.01%$ absolute</td>
</tr>
<tr>
<td>EUV Peak reflectivity accuracy for $R_p &lt; 2%$ absolute</td>
<td>$3\sigma \leq 0.05%$ absolute</td>
</tr>
<tr>
<td>Minimum wavelength range</td>
<td>10.5nm to 15.5nm</td>
</tr>
<tr>
<td>Minimum wavelength resolution ($\Delta\lambda/\lambda$)</td>
<td>500</td>
</tr>
<tr>
<td>EUV median wavelength precision</td>
<td>$3\sigma \leq 0.002$ nm</td>
</tr>
<tr>
<td>EUV median wavelength accuracy</td>
<td>$3\sigma \leq 0.003$ nm</td>
</tr>
<tr>
<td>Maximum clear space required for measurement</td>
<td>1mm x 1mm</td>
</tr>
</tbody>
</table>

Additional features:
- Absolute (internal) reflectivity and wavelength calibration
- Capability to find pattern location to be measured.
5 measurements on a very good ML
EUV Reflectometer for patterned masks

• Small inspection area
  – Measurement spot size (dark to dark):
    • 50 X 50 micron.
    • Can be outside the printing area

• Require extremely high accuracy for Wavelength and Reflectivity

• Semi-automatic fiducial mark detection system
EUV Resist Outgassing and Contamination Tool
EUV Resist and Outgassing Tool

EUV Lithography (Maui, HI)  
June 16, 2011
Schematic Diagram of EUV
RER 1314

ML mirror

Zr SPF

Beam split mirror

RGA

Xe-source
Energetiq
(10W/2πsr)

witness
plate

200mm wafer
(mask) loadlock

EUV Lithography (Maui, HI)  June 16, 2011
Dose Snake
REDUCTION OF BG OUTGASSING

Before upgrade

02nov10

After upgrade

23dec10

Static

No significant difference!

A lot of heavy HC are generated

Dynamic (stage)

Significant improvement in dynamic operation

EUV Lithography (Maui, HI) June 16, 2011
WS RESULTS USING E-GUN

• First resist related WS contamination test on EUVT outgassing tool using E-gun

>2nm contamination thickness (~10x more than with EUV; note no scaling factor is used here) ! Clear difference with BG !

EUV Lithography (Maui, HI)

June 16, 2011
RER-300-PEX: Design philosophy

• Based on our previous model of resist outgassing and contamination measuring tool delivered to IMEC in 2008 (Model No. EUV-RER1314; Patent Pending)

• Based on new ASML (confidential) guidelines for NXE scanners dated Nov. 30, 2010 and Feb. 2011.
EUV Lithography (Maui, HI) June 16, 2011
TWO EXPOSURE METHODS: E-BEAM AND EUV

EUV FOR WAFER EXPOSURE
• CONSISTS OF ENERGETIQ SOURCE, TWO GLANCING MIRRORS AND A MULTILAYER

System is designed in such a way that it can be ordered with one mode of operation and field upgraded to add the other option.

ELECTRON GUNS
• WS EXPOSURE GUN WITH 2.5mm DIA BEAM
• WAFER EXPOSURE GUN WITH 20mm DIA BEAM

EUV Lithography (Maui, HI)  June 16, 2011
Advantages of using 13.5 nm pulsed photons over electrons

• EUVL stepper utilize photons.
  – True dose to clear exposure.

• Non destructive.
  – Only detect photo-induced decomposition.

• Represent bulk properties.
Mahalo nui loa