EUREKA: A new Industry EUV Research Center at LBNL

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Operating model

• Core operational and infrastructure funding to build and preserve facilities provided by Core Members

• Differential funding for expanded operations and non-core upgrades provided by Supplier Members
Status

• Master agreement with Founding Core Members signed mid September

• Title to SEMATECH EUV assets in Berkeley transferred to LBNL on 9/25

• Multiple supplier members now in signing process

• Discussions underway with numerous other suppliers in resist, tool, and mask space
Cornerstone tools

Reflectometer/Scatterometer

EUV AIMS up to 0.6 NA

0.3-NA Litho

0.5-NA Litho coming soon

13-nm in non-CAR
Specifications

- Wavelength precision: 0.007%
- Wavelength accuracy: 0.013%
- Reflectance precision: 0.08%
- Reflectance accuracy: 0.08%
- Spectral purity: 99.98%
- Dynamic range: $10^{10}$
High accuracy measurements of optical constants of EUV resist and mask materials

PMMA ($\lambda=13.5$ nm)

$\delta=0.0242$, $\beta=0.0054$

d = 286.5 nm
EUV 0.3-NA MET

13 nm

Mag = 125.00 K X
VWD = 4.0 mm
EHT = 5.00 kV
Signal A = InLens
Pixel Size = 893.2 pm
Date : 13 Feb 2015
Time : 11:55:58
MET: engine for materials learning

Cumulative wafers

Cumulative materials
13-nm patterning achieved in non-CA resist

60 mJ/cm²

LWR = 3.1 nm
• NA = 0.5
• Magnification = 5x
• Resolution limit = 8 nm
• Programmable pupil fill
• Mask angle of incidence = 6°
• Integrated wavefront metrology
• Robotic linked track
7-axis reticle stage

<table>
<thead>
<tr>
<th></th>
<th>Spec</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>XY Low freq. (&lt;2Hz) PV</td>
<td>3 nm</td>
<td>0.92 nm</td>
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<tr>
<td>XY High freq. (&gt;0.5Hz) RMS</td>
<td>2 nm</td>
<td>0.33 nm</td>
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<tr>
<td>Z Low freq. (&lt;2Hz) PV</td>
<td>10 nm</td>
<td>1.7 nm</td>
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<tr>
<td>Z High freq. (&gt;0.5Hz) RMS</td>
<td>3 nm</td>
<td>0.61 nm</td>
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5-axis wafer stage/2-axis LSI carriage

<table>
<thead>
<tr>
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<th>Spec</th>
<th>Measured</th>
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<tbody>
<tr>
<td>XY Low freq. (&lt;2Hz) PV</td>
<td>3 nm</td>
<td>0.51 nm</td>
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<tr>
<td>XY High freq. (&gt;0.5Hz) RMS</td>
<td>1 nm</td>
<td>0.65 nm</td>
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<tr>
<td>Tip/Tilt RMS</td>
<td>18 mrad</td>
<td>0.15 mrad</td>
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<tr>
<td>Z Low freq. (&lt;2Hz) PV</td>
<td>10 nm</td>
<td>1.5 nm</td>
</tr>
<tr>
<td>Z High freq. (&gt;0.5Hz) RMS</td>
<td>3 nm</td>
<td>0.42 nm</td>
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</table>
**Individual mirrors better than spec**

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Specification</th>
<th>Result</th>
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<tbody>
<tr>
<td><strong>M1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure</td>
<td>CA – 3mm</td>
<td>&lt; 0.1nm rms</td>
<td>0.04 nm rms</td>
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<tr>
<td>Flare</td>
<td>3mm – 0.43um</td>
<td>&lt; 0.17nm rms</td>
<td>0.12 nm rms</td>
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<tr>
<td>HSFR</td>
<td>1um – 10nm</td>
<td>&lt; 0.15nm rms</td>
<td>0.08 nm rms</td>
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<tr>
<td><strong>M2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure</td>
<td>CA – 8mm</td>
<td>&lt; 0.1nm rms</td>
<td>0.08 nm rms</td>
</tr>
<tr>
<td>Flare</td>
<td>8mm – 1.2um</td>
<td>&lt; 0.17nm rms</td>
<td>0.14 nm rms</td>
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<tr>
<td>HSFR</td>
<td>1um – 10nm</td>
<td>&lt; 0.15nm rms</td>
<td>0.09 nm rms</td>
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</table>

Predicted POB EUV flare = 2.86%
System wavefront 2x better than spec

<table>
<thead>
<tr>
<th>Reticle field point (um)</th>
<th>WFE @ 30cycles across aperture (nm rms)</th>
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<tbody>
<tr>
<td>0, 0</td>
<td>0.21 (spec=0.5)</td>
</tr>
<tr>
<td>75, 500</td>
<td>0.43 (spec=1.0)</td>
</tr>
<tr>
<td>75, -500</td>
<td>0.41 (spec=1.0)</td>
</tr>
<tr>
<td>-75, -500</td>
<td>0.34 (spec=1.0)</td>
</tr>
<tr>
<td>-75, 500</td>
<td>0.36 (spec=1.0)</td>
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</tbody>
</table>
Platform integration nearly complete
Other relevant assets for EUREKA Members at LBNL
Instrumentation for direct characterization of EUV radiation chemistry

1: Introduce materials as molecular or nanoparticle beam
2: Irradiate with EUV or electrons
3: Measurement of electrons and chemistry
**RSoXS**: soft-x-ray potential for 3D chemically sensitive profile metrology

CD-RSoXS on Polymer Lithography Grating

Sunday et al. **JM3** 12 (3), 2013, 031103

Compared favorably to hard X-ray and provides benefit of chemical sensitivity for potential use in latent images.
Realtime in liquid AFM for development studies

Encased cantilever for fast response in liquid

Start of developer injection
Nano-Auguer for Surface Elemental Analysis

Chemical Analysis with sub-50 nm resolution on SEM-type samples

Mapping S and Mo in single monolayer CVD MoS$_2$ islands showing S deficit at grain boundaries

In-situ analysis of SiAu alloys above and below the Eutectic point

Auger

REELS