Actual Status and Perspectives of EUV Lithography

Winfried Kaiser
SPIE Fellow

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"Moore’s Law" drives the Semiconductor Industry

Moore’s Law (1965)
The number of transistors is doubling every 18 months.

Moore’s Law has driven the industry for more than 40 years.
Litho enables Moore’s Law towards 10 nm resolution

Resolution = $k_1 \cdot \frac{\lambda}{NA}$
ASML EUV Scanner NXE 3100
ASML EUV Scanner - a closer look inside…

- Illumination System
- Reticle (Mask)
- EUV Source
- Wafer
- Projection Optics
EUV Scanner - a closer look inside…

- EUV Source
- Wafer
- Projection Optics
- Reticle (Mask)
- Illumination System
EUV Source: Key for Productivity

Laser-Produced Plasma (LPP)

CO2 laser

Sn droplets

plasma

Multilayer collector

Source: Chr. Wagner / ASML, SPIE 2010

Source Power Progress to ~90W on Test stand
<+/−0.35% dose control demonstrated

In-Band EUV Power at I.F. (W)

Open Loop: 3σ = 5.1% (10ms Window)

Source: D. Brandt / Cymer, 2009
EUV Optics Concept based on Mirrors only

- \( \lambda \) 13.5 nm
- NA 0.25
- Resolution 22 nm (hp)
- Field 26 x 33 mm\(^2\)
- Reduction 4x
EUV Optics Technology: Mirror Requirements

Figure

- [Image]

2D-isotropic PSD

- [Image]

Lateral Frequency [μm⁻¹]

- [Image]

Power [nm²]

- [Image]

Figure

- [Image]

MSFR

- [Image]

HSFR

- [Image]

Figure

- [Image]

→ aberrations, distortion

→ CDU, overlay

→ flare

→ CDU

→ reflectivity

→ productivity
EUV Mirror Polishing: Champion Results

<table>
<thead>
<tr>
<th></th>
<th>Mirror 1</th>
<th>Mirror 2</th>
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<tbody>
<tr>
<td>Figure</td>
<td>45 pm</td>
<td>31 pm</td>
</tr>
<tr>
<td>MSFR</td>
<td>68 pm</td>
<td>59 pm</td>
</tr>
<tr>
<td>HSFR</td>
<td>70 pm</td>
<td>95 pm</td>
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Low MSFR numbers are required for highest imaging contrast!
Mirror Specs: compare to real world

Surface roughness corresponds to peaks of 1 mm in the area of Japan.

200 mm

3776 m

of 100 pm
Polishing and Metrology of EUV Mirrors

Computer Controlled Polishing

Ion Beam Figuring

Metrology of Surface Figure

- Repeatability ~ 12 pm RMS
- Reproducibility ~ 20 pm RMS
EUV requires (nearly) perfect Nanolayers…

EUV coatings: Mo/Si Bragg reflectors

- High peak reflectance and large FWHM
- Wave-length matching
  - > 70%
  - < 0.01 nm

Challenges

Coating Chambers at SMT and FOM / Netherlands
5 optical systems for the NXE:3100 shipped to ASML

Illumination System

Projection Optics
EUV: high resolution potential with single exposure

26 nm FLASH pattern

24 nm L/S

30 nm contact holes

ASML/IMEC/LBL: Ultimate resolution actually limited by resist performance
EUV DRAM Integration Result

DRAM contact layer was successfully integrated with EUVL

In-Fab. Monitoring Data

Yield: ~ 80%

* Check board exposure due throughput issue

R&D Center
Litho Forum, 2010.05.11, New York
High NA EUV Solutions Roadmap

Solution overview:

<table>
<thead>
<tr>
<th>NA</th>
<th>0.25</th>
<th>0.32</th>
<th>0.5</th>
<th>0.7</th>
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<tbody>
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<td>6M</td>
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<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
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<tr>
<td>Res.</td>
<td>22 nm</td>
<td>16 nm</td>
<td>11 nm</td>
<td>8 nm</td>
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<tr>
<td>NXE</td>
<td>3100</td>
<td>3300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We see design solutions for high NA systems enabling 11 nm and beyond!

*W. Kaiser et al., SPIE 2008*
...for even more fascinating electronics devices...
We make it visible.