Reliable High Power EUV Source Technology for HVM: LPP or DPP?

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Presentation Outline

• Source Technology Requirements
• Source Technology Performance
  – DPP
  – LPP
• Technology Trend
• Summary
## Source Technology Requirements: Change in Source Requirements Over Time

**Table 3.2 Changes in joint requirements for EUV sources**

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<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>13–14</td>
<td>13.5</td>
<td>13.5</td>
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<tr>
<td>EUV power (inband) (W)</td>
<td>47–120</td>
<td>80–120</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115&gt;115</td>
<td>115-180</td>
<td>115-180</td>
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<tr>
<td>Repetition frequency (kHz)</td>
<td>5</td>
<td>6</td>
<td>7–10</td>
<td>7–10</td>
<td>7–10</td>
<td>&gt;7-10</td>
<td>&gt;7-10</td>
<td>&gt;7-10</td>
<td>&gt;7-10</td>
<td>&gt;7-10</td>
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<tr>
<td>Etendue of source output (mm² sr)</td>
<td>1</td>
<td>1–3.3</td>
<td>1–3.3</td>
<td>1–3.3</td>
<td>1–3.3</td>
<td>3.3</td>
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<tr>
<td>Max. solid angle</td>
<td>0.2</td>
<td>0.03</td>
<td>0.03</td>
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EUV Source Supplier Update

• Philips Extreme UV
  – 7.2 W at IF (Full collector) – 100% Duty cycle for 120 Hours
    • Corresponding to 90 W at Source
    • 120 Hours operation, 3 MJ delivered at IF
  – 190 W at source demonstrated -100% duty cycle for 2 hours
  – Source size 1.3 mm
  – MTBF ~ 10 MJ
  – Tin consumption: 25 g/ MJ in 2 p
  – Proof of principal of 50 K Hz operation
  – Latest power results to be shown during 2008 EUVL Workshop
EUV Source Supplier Update

• Xtreme technologies
  – Xe DPP
    • 4 W at IF (100 % duty Cycle)
    • 225 W at Source (XTS 13-150 IF)
    • Dose stability of 0.25%
  – Sn DPP
    • 200 W at source (1. 4 K Hz, burst mode)
    • Source size 1.3 mm
    • No saturation of usable energy detected up to 14 J (droplet based tin delivery)
EUV Source Supplier Update
(Litho Forum, May 2008)
Please refer to proceedings for complete information

• Cymer (Sn LPP)
  – 10 kW Pulsed CO₂ laser
    • 50 K Hz, 30 % Duty Cycle
  – Measured power at source
    • 25 W average power for 1.5 hours (75 W at 30% duty cycle)
      – Assuming 33 % collection for IF power estimation (not measured) -25 W can be collected at IF
      – Power calculated at IF, assuming 5 sr collector, 50 % average reflectivity and 90% transmission
    • 15 W (300 W @ 5% duty cycle)
      – 100 W collectable at IF (estimated - not measured)
EUV Source Supplier Update
(Litho Forum, May 2008)

- EUVA / Gigaphoton (Sn LPP)
  - 6-13 kW Pulsed CO\textsubscript{2} laser (22 ns, 100 K Hz)
    - 100 % Duty cycle –M2= 1.1, pulse energy stability 2%
  - Measured power at source: 150 W (burst mode)
    - Collectable power at IF: 60 W (Estimated not measured)
    - Measured IF Power: 16 W (Burst mode measured with 1 sr collector)
  - Performance update provided in 2008 EUVL Workshop
EUV Source Supplier Update
(Litho Forum, May 2008)

• LP Photonics (Sn LPP)
  – New company (spin off from UCF in a joint venture with PowerLase)
  – 27 W at source in $2\pi$, 100% duty cycle
    • 9 W may be collected at IF (estimated and not measured)
  – One 1600 W PowerLase Nd: YAG laser
    • Plans to add additional laser to make input power 1.2 kW
    • Plans to upgrade to four lasers 1200 W each
  – Mass-limited liquid droplet targets
  – Demonstrated ~20 hours of continuous run
DPP Technology Trend

• DPP source power (integrated SoCoMo) has in the 5-10 W range for past many years, which were the requirements of the α level scanners
  – Focus of DPP suppliers has been to deliver reliable source collector modules for alpha level scanners

• Only fraction of power delivered from source has been used at IF
  – Sn DPP SoCoMo have 6-10 W of power at IF but alpha scanners throughputs correspond to much smaller source power!

• Power Scaling via increased Electrical input
  – Increase pulse energy and High frequency operation

• Risk: Thermal mitigation
LPP Technology Trend

• High power lasers are key enablers of this technology and allow increase of input energy
• ~16-25 W average power (estimated power at IF) in burst mode demonstrated (no integrated SoCoMo) and demonstrated power at source is growing quickly
• Integrated systems need to be demonstrated
• Power Scaling – higher input laser power
• Risk: Timely demonstration of integrated systems, Reliability and COO
Radiometric Improvement can help us Address Source Power Issue

- Illuminator design:
  - Eliminating reflections: 2.0× to 3.0×
- Increasing Etendue:
  - 0.35NA: 1.5× to 2.0×
- Multiplexing
  - LPP or DPP: 1.0× to 2.5×
  (one to three sources)
- **Recommended target:** ~3× to ~15× improvement

- Considerable development is needed to realize this opportunity.
- However, significantly less effort is needed then would be required to realize an equivalent source improvement.

Ref: Optical Design for Affordable EUV Lithography, M. Goldstein and V. Bakshi, 2007 EUVL Symposium
Summary

• Technology decisions need to be based on integrated SoCoMo performance and not on source performance alone
• DPP has stronger potential in near term
  – Need improvement in the integration of DPP based SoCoMo so that all of the power delivered to scanner can be utilized
• LPP has stronger potential in longer term
  – Confidence in LPP will increase by the demonstration of SoCoMo and integration of SoCoMo with scanners
• Solutions to scanner throughout /source power issue needs help from work on additional technical fronts:
  – New scanner designs, resist sensitivity improvement