EUV Pellicle Progress and Strategy

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IEUVI Mask TWG
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Toyama, Japan
ASML EUV Pellicle Progress and Strategy Agenda

- The EUV mask particle defect challenge
- EUV pellicle requirements
- Overview testing for Phase 1 qualification
- Material qualification summary
- Imaging summary
- Next step: Phase 1
- Next step: Phase 2
The mask particle defect challenge

ASML achieved 10x per year improvement for pellicle-less operation (baseline is to build a clean scanner that meets customer requirements)

Progress made on ASML machines on added particles per reticle exchange over the past few years

Added particles > 92 nm per reticle pass

EUV Reticles (13.5nm)

Reflective multilayer

Absorber pattern

Reflected illumination

Reticle

Customer requirement for full production without pellicle @ resolution
The mask particle defect challenge

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EUV Reticles (13.5nm)

- Reflective multilayer
- Absorber pattern
- Pellicle
- Reflected illumination

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<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material requirements</strong></td>
<td></td>
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<tr>
<td>EUV transmission</td>
<td>90% single pass (81% double pass)</td>
</tr>
</tbody>
</table>
| Size | Reticle inner reserved area: 110 x 144 mm  
Reticle outer reserved area: 117 x 151 mm  
(update planned Dec 2013) |
| EUV peak power in scanning slit @ reticle | 5 W/cm² (250 W source) |
| Lifetime (EUV+H₂) | >315 hrs (=4e5 J/cm² dose) |
| Max. acceleration | 100 m/s²: during scanning, 200 m/s²: end stops |
| **Imaging requirements** |  |
| EUV transmission spatial non-uniformity | <0.2% at reticle → CDU impact < 0.1nm |
| EUV transmission angular non-uniformity | < 300 mrad max. local pellicle angle  
→ CDU impact < 0.1nm |
| **Pellicle + frame requirements** |  |
| Standoff distance | 2 ± 0.5 mm |
| Max. pressure rate of change | 3.5 mbar/s (peak during pump-down in the load lock) |
ASML pellicle program now in Phase 1 started early 2013

<table>
<thead>
<tr>
<th>2H ‘12</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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</thead>
<tbody>
<tr>
<td>Research and scoping of work</td>
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<tr>
<td><strong>Phase 0</strong></td>
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<tr>
<td>Prototyping phase – towards full-size pellicle incl lithographic performance</td>
<td></td>
<td></td>
<td><strong>Phase 2</strong></td>
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<td><strong>Phase 1</strong></td>
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<td>Industrialization</td>
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- Tested EUV transmission, deflection, heat loads, imaging
- Next step: continue scaling towards half size

Good progress in free standing material development

50mm x 50mm and 80mm x 80mm poly Si samples tested

½ size ~75mmx 115mm planned for 2013

full size ~110mmx 144mm planned for 2014
ASML EUV pellicle program
Phase 1: EUV Pellicle film feasibility study

<table>
<thead>
<tr>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td><strong>Phase 1: prototyping – pellicle material</strong></td>
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<tr>
<td>Pellicle Scaling up to proto size testing half full size: ~75 x 115</td>
<td>Pellicle Scaling up to final full size: 110 x 144</td>
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<tr>
<td><strong>Phase 2: industrialization</strong></td>
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<tr>
<td>1) Suppliers – Pellicle industrialization</td>
<td>2) Reticle infrastructure adaptation</td>
<td>3) ASML - Scanner “pellicle ready”</td>
</tr>
<tr>
<td>Frames, glues, EIP: Work started for prototyping</td>
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<tr>
<td>Free-standing Multi-Lattice</td>
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<tr>
<td>Free-standing poly-Silicon</td>
<td></td>
<td></td>
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<tr>
<td>Grid-supported pellicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative pellicle materials (Research)</td>
<td></td>
<td></td>
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<tr>
<td>Today</td>
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</tbody>
</table>

• ASML will support the industrialization phase
• ASML needs help to drive infrastructure to HVM:
  - EIP => pod manufacturers
  - Frames => pellicle manufacturers
  - Glues => glue manufacturers
  - Mounting technology
  - Inspection technology
• The industry needs to become involved for HVM.

End 2013: Intermediate EUV Pellicle Material Feasibility Review
Standard qualification tests performed for each pellicle

A new batch of pellicles arrive at ASML

1. Material Qualification (offline)
   - EUV Transmission
   - Transmission Uniformity
   - Heat load
   - Wrinkle Mapping
   - Pressure Delta Test

2. Mechanical Qualification (NXE)
   - Pump/Vent in RH
   - Acceleration
   - Air Flow

3. Imaging Qualification (NXE)
   - FEM (Focus & Energy Matrix)
   - Full Wafer CDU

Provide feedback to pellicle vendor to improve material

Scale-Up
Current status of leading pellicle material

<table>
<thead>
<tr>
<th>Material properties</th>
<th>Optical</th>
<th>Mechanical</th>
<th>Thermal</th>
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</thead>
<tbody>
<tr>
<td>EUV transmission</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Pellicle deflection (sagging)</td>
<td>OK</td>
<td>OK</td>
<td>NOK</td>
</tr>
<tr>
<td>Heat load (40 W)</td>
<td>OK</td>
<td>NOK</td>
<td>NOK</td>
</tr>
<tr>
<td>Heat load (80 W)</td>
<td>OK</td>
<td></td>
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<tr>
<td>Heat load (120 W)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat load (250 W)</td>
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</table>

- **Poly-Silicon** material shows potential in meeting requirements for EUV pellicle
  - Improvements needed to meet the final requirements for EUV transmission and heat load.
Prototype frame design changes to support pellicle proto size scaling

Supports:
- 20 mm Ø round pellicles
  - ML - Phase 1A
- Supports up to:
  - 40 mm Ø round & 20 x 20 mm² square pellicles
  - pSi - Phase 1A

Needed to support:
- 75 x 115 mm² rectangular pellicles
  - pSi - Phase 1E
  - ML - Phase 1E

ML - Phase 1B,C,D

Supports up to:
- 60 x 60 mm² square pellicles

Needed to support:
- 110 x 144 mm² rectangular pellicles
  - Full size* - Phase 1F

~ 117 mm
~ 151 mm
Summary imaging tests results with pellicles
No measurable impact of pellicles in imaging (within measurement noise)

ML Imaging tests
5 pellicle positions
20 mm diameter,
25 nm thickness

Imaging performance:
• Small decrease in process window, difficult to calculate due to strong process fingerprint
• DOF range without pellicle limited by available focus fields on wafer

Defectivity performance:
• Large printed particles (~30um to >100um) due to pellicle manufacturing/handling outside cleanroom

ML pellicle film quality:
• Impact of pellicle/wrinkles not visible

Poly-Si Imaging tests
2 pellicle positions
11mm x 11mm, 75 nm thickness

Imaging performance:
• No measurable difference w/ and w/out pellicle: no variation in exposure latitude and focus window (all within measurement noise, strong process fingerprint)

Defectivity performance:
• No measured printed particles in imaging data

pSi pellicle film quality:
• Variation in EUV transmission observed in CD variation; pellicle manufacturing process improvement required
Next step: Phase 1

- ASML has an active EUV pellicle project to develop and qualify a full size working EUV pellicle prototype by mid 2014.
- Includes project leader, team leads, material architect, and imaging expertise involvement along with customer collaborations, multiple film suppliers, marketing, purchasing, and ASML research support.

- If you have material films or other related capabilities to contribute to Phase 1, please contact:
  - Daniel Smith: daniel.smith@asml.com
Next step: Phase 2

• ASML will support the industrialization phase, but the mask infrastructure needs help to drive EUV pellicles to HVM:
  • EIP => pod manufacturers
  • Frames => pellicle manufacturers
  • Glues => glue manufacturers
  • Mounting technology
  • Inspection technology
Summary

We are making good progress demonstrating EUV pellicle feasibility.

Infrastructure efforts are required to make EUV pellicles ready for HVM.

Join in - this is important and useful work.

For more details: see Proc. SPIE. 8679, Extreme Ultraviolet (EUV) Lithography IV 867904
Investigation of EUV pellicle feasibility