EUV Interference Lithography

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Switzerland
Outline

- EUV Interference scheme
- Beam for EUV-IL
- Masks for EUV-IL
- EUV-IL results and understanding resist behavior
- Future of PSI EUV-IL tool
EUV-IL at the Swiss Light Source:
a nanofabrication facility for academic and industrial use

- In operation since 2003
- Available to users through proposals or for a fee
- EUV photoresist characterization – 300+ resists tested
- Major upgrade in 2009 - focus on below 20 nm patterning
EUV Interference Scheme

2-beam interference

- Frequency multiplication: Factor depending on the diffraction orders chosen
- Good match to undulator radiation
  - Achromatic (no temporal coherence needed)
  - Requires spatial coherence
EUV Interference Scheme

4-beam interference

- Frequency multiplication
- Grating phases determine the pattern
- Profile not sinusoidal

Simulated intensity
EUV beam for Interference Lithography

- Spatial coherence:
  - Undulator radiation
  - Spatial filtering (pinhole)
  - Nothing in the beam after pinhole (no optics, filters, windows etc)

- Uniform illumination

- Stable beam: SLS and beamline

- Bandwidth (interferometer dependent)
  - Grating interferometer (achromatic)
EUV beam for Interference Lithography
Grating Masks

Electron Beam Lithography + dry etching

- 35 nm to 2000 nm pitches
- Many pitches and patterns on one mask
Line/space Masks

- 0.8 mm lines - easy cross section - multiple period, multiple dose
- 20-50 nm h/p
- dose for EUV resist: 30-40 mJ/cm²

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Contact Hole Masks

- Lines and contact holes on one mask
- 20-50 nm h/p contact holes
- 15-35 nm h/p lines
- dose for EUV resist: 40-80 mJ/cm²

M394

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High efficiency Mo Masks

150 nm-pitch Mo grating
Thickens: 90 nm

* M. Saidani et al, MNE 08

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Zero-zeroth-order PMMA grating

600 nm-pitch PMMA grating
Thickness: 240 nm

Frame: EUV transmitted by membrane around square grating
Calixarene resist

20 nm

12.5 nm

TEBN-1 from Tokuyama, Japan

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Hydrogen silsesquioxane (HSQ)

Fox-12, Dow Corning

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Beyond the roadmap

11 nm h/p

Resist: Fox12 (Dow Corning)
Thickness: 20 nm

No FUNDAMENTAL limit down to 11 nm!
Testing resist performance

FOX12 - HSQ - Hydrogen silsesquioxane

50 nm h/p  42.5 nm h/p  32 nm h/p
25 nm h/p  21.5 nm h/p  19.5 nm h/p

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EUV resists

More than 300 resists were tested!
Effect of substrate electrons

<table>
<thead>
<tr>
<th></th>
<th>Absorption length (nm)</th>
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<tbody>
<tr>
<td>Si</td>
<td>585</td>
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<tr>
<td>Cr</td>
<td>28</td>
</tr>
<tr>
<td>Au</td>
<td>21</td>
</tr>
<tr>
<td>Ni</td>
<td>15</td>
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Contrast curves

2% dose steps

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Resist contrast loss

<table>
<thead>
<tr>
<th>Half-pitch</th>
<th>NILS</th>
<th>EL/NILS</th>
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<tbody>
<tr>
<td>50</td>
<td>3.14</td>
<td>0.80</td>
</tr>
<tr>
<td>45</td>
<td>3.14</td>
<td>0.74</td>
</tr>
<tr>
<td>40</td>
<td>3.14</td>
<td>0.80</td>
</tr>
</tbody>
</table>

EL analysis by imec
Recent and Ongoing Upgrades

Full time facility

- From 15% to 100% operation
- Dedicated undulator
- Sample preparation/development at the beamline

WHEN:
fall of 2009

NEW electron beam writer
VISTEC
EBPG5000plus ES
100keV

for mask preparation
EUV IL at PSI

Sample processing:
- Spin coating and development in class 100
- Exposures in class 1000
- PEB right after each exposure
  - amine filtered env.

Performance
- Area: 1-4 mm² area
- Exposure time: 1-30 sec
- 11 nm … 1000 nm half-pitch
- Stable flux, 10-50 mW/cm²
- Throughput ~ 1 wafer/hour
- Sample stage for 4”, 6”, 8” wafers
- Stage travel size 80×80 mm²
- Software controlled exposure

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