Lecture 60
Lithography: Extreme Ultraviolet

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Hitting the Resolution Limit

- Wavelength is currently at 193 nm, the highest NA we have is 1.35, and \( k_1 \) is limited to 0.25

\[
R = k_1 \frac{\lambda}{NA} \geq 0.25 \frac{193\text{nm}}{1.35} = 36\text{nm}
\]

- Can we reduce wavelength?
  - 157 nm (F\(_2\) laser) was initially attempted, then abandoned
  - Lower wavelengths require vacuum and mirror-only optics

EUV Lithography

- What’s new?
  - \( \lambda = 13.5 \text{ nm} \)
  - Optics
  - Mask
  - Source
  - Resist

Source: ASML

EUV Lithography: The Mask

- EUV lithography involves all-reflection optics and masks
- Bragg reflector: 50 or more alternating Mo/Si layers give the mirror its reflectivity – max \( \sim 70\% \)
- Seven reflections = 8% transmission

Absorber

Source: ASML
EUV Lithography: the Mask

• A defect on the mask that prints on the wafer will have a devastating yield impact
• In 193-nm lithography, any defects on the mask are found through inspection and repaired. Then the mask is covered with a pellicle to keep new defects off
• For EUV masks, we don’t have:
  – Defect-free mask blanks
  – Adequate inspection technology that can find all printing defects
  – Adequate repair methods
  – A pellicle (although one is under development)

Source Problems

• Brightness – we still need a factor of 10-100X increase in brightness
• Reliability and uptime
  – Current source availability is 70%
• Tin debris mitigation
  – The collector can be damaged by tin debris
  – Long-term impact is unclear

EUV Lithography: the Source

EUV Lithography: the Resist

• Resists used are very similar to 248-nm and 193-nm resists (CAR)
• Since EUVL light sources are still being developed, resist suppliers have a hard time running the experiments needed to develop materials
• The biggest problem is line-edge roughness (LER), especially at low doses
  – It is hard to achieve high resolution, low LER, and good sensitivity (low dose) at the same time

Lecture 60: What have we Learned?

• What is the current resolution limit of single patterning?
• Why does EUV imaging use only mirrors in the projection system?
• What are the main challenges in EUV masks?
• What are the main challenges in EUV sources?
• What are the main challenges in EUV resists?