CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323

Lecture 60 Lithography: Extreme Ultraviolet

Chris A. Mack
Adjunct Associate Professor

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

$$R = k_1 \frac{\lambda}{NA} \geq 0.25 \frac{193nm}{1.35} = 36nm$$

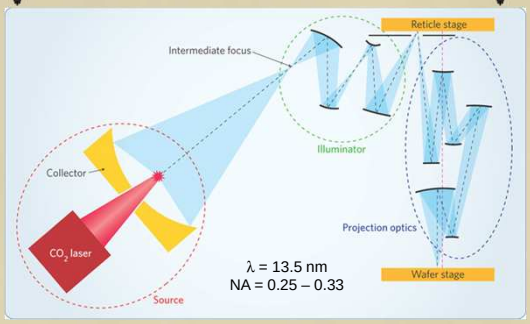
- Can we reduce wavelength?
  - 157 nm (F_2 laser) was initial attempted, then abandoned
  - Lower wavelengths require vacuum and mirror-only optics

EUV Lithography

- What's new?
  - λ = 13.5 nm
  - Optics
  - Mask
  - Source
  - Resist

Source: ASML

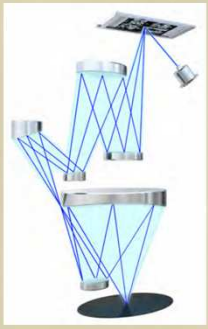
EUV Optics

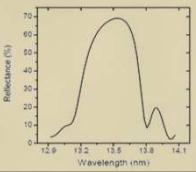


 Nature Photonics **4**, 24 - 26 (2010)

Extreme ultraviolet lithography (EUV)

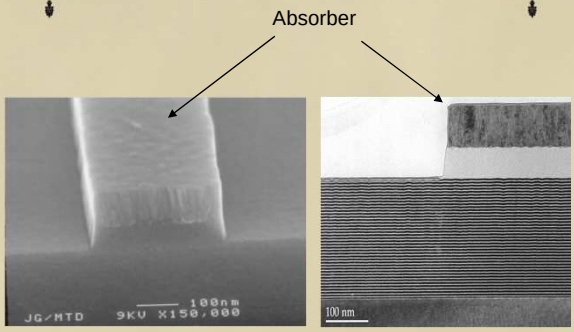
- EUV lithography involves all-reflection optics and masks
- Bragg reflector: 50 or more alternating Mo/Si layers give the mirror its reflectivity – max of ~70%
- Seven reflections = 8% transmission





Zoethout *et al.*, Proc. SPIE **5037**, 872 (2003)

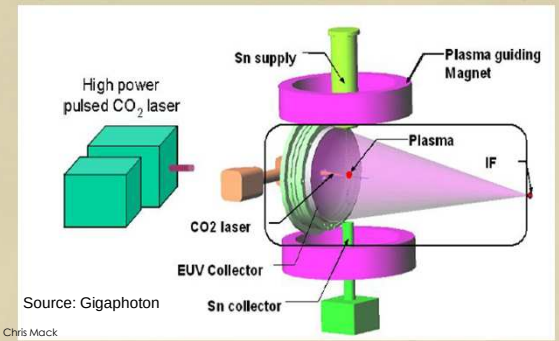
EUV Lithography: the Mask



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)

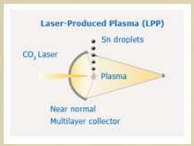
EUV Lithography: the Source



Source: Gigaphoton

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



Source: cymer.com

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?