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

Bonus Lecture 3: Introduction to Mask Making, Part 3

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Mask Inspection

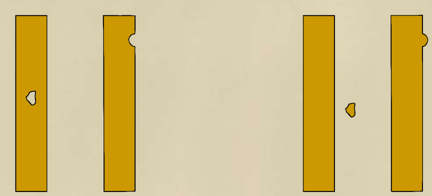
- One defect on a wafer kills one die, but one defect on a mask kills every die
  - We inspect and repair a mask to be 100% defect free at the time of its manufacture
  - Must find *every* printing defect
- Die-to-die vs. die-to-database inspection


Source: toppan.co.jp

Mask Inspection

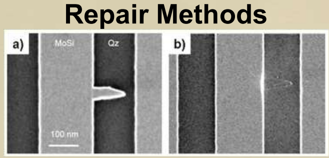
- High-resolution inspection (KLA-Tencor, Lasertec)
  - Uses smaller λ/NA than the lithography tool (taking mask magnification into account)
  - Does not require actinic (exposure) wavelength
  - Data processing required to make sense of image (will the found defect actually print?)
- Aerial image inspection (AMAT)
  - Use same wavelength and NA as lithography tool
  - Easy to determine if a defect matters
  - Worse signal/noise, potential to miss a defect

Mask Repair



Complications: phase-shifting masks, EUV masks

Repair Methods

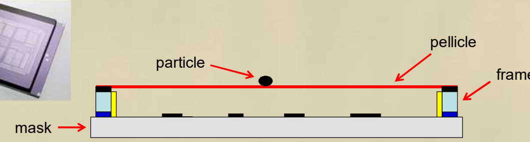


Source: Klaus Edinger, Carl Zeiss, FCMN 2013

- E-beam assisted etching and deposition
  - Can repair missing and extra material defects
  - Precise, but slow for large defects
- Ion-beam etching and deposition
  - Can repair missing and extra material defects
- AFM-Guided Nanomaching
  - Increasingly popular due to accuracy
  - Can only remove material

Pellicles and Defects

- Random particles can add defects to a mask at any time during its use
  - Pellicles are thin, transparent membranes that protect the mask patterns
  - Pellicles keep defects out of focus



Registration

- For wafers, we need to measure overlay
  - The relative positional difference between two separately printed patterns
- For masks, we need to measure registration
  - The positional accuracy of a pattern relative to an absolute grid

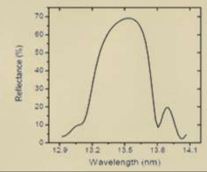
Zeiss PROVE system, introduced 2010

KLA-Tencor LMS IPRO6

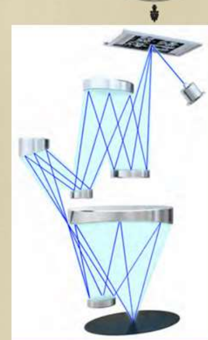
7

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 ~68%
- Eleven reflections = 1.4% transmission



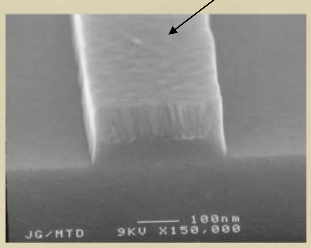
Zoethout *et al.*, Proc. SPIE **5037**, 872 (2003)

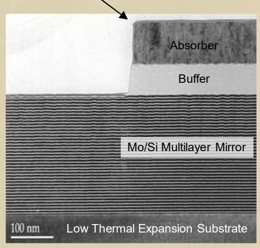


 8

EUV Lithography: the Mask

Absorber





Source: K. Nguyen, AMD

 9

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 (not all defects can be repaired)
  - A pellicle (although one is under development)
  - An understanding of mask lifetime

 10

Maskmaking – the Big Ideas

- Mask making is a lithography process, but without mass production
  - Direct write lithography, using e-beams for high-end masks
- The two most expensive steps in mask making are writing and inspecting
- Mask set costs typically rise 75% node to node
  - More masks per set, higher cost per mask
  - Higher resolution and more features increase write and inspection times
- EUV masks still have many challenges
  - Blank defectivity, actinic inspection, pellicle, lifetime

 11