EUVL Mask Defect Strategy

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EUVL MASK TECHNOLOGY

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Outline

- Introduction
- Overall Inspection and Repair Strategy
- Mask Substrate and Blank Inspection
- Pattern Inspection
- Defect Mitigation Strategy
- Summary

EUV Mask Flow Pictorial (selected steps)

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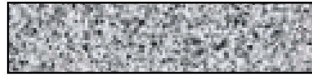
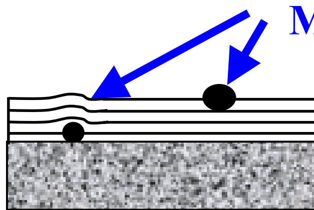


1. **LTEM fabrication, Substrate inspection**
2. **Cleaning, smoothing**

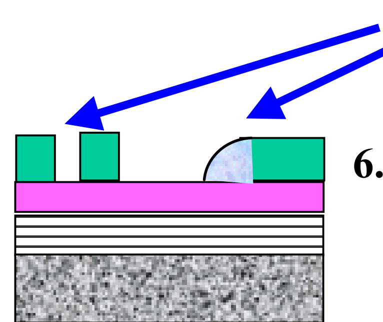
ML Defects



3. **ML deposition, blank inspection EUV AIM metro.**

5. **Absorber layer (AL) deposition**

Absorber Defects

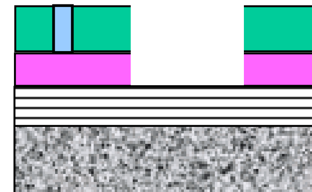


6. **Pattern generation, pattern transfer, Absorber inspection**

Must find multilayer defects by this point

Pattern inspection will not find embedded multilayer defects

4. **Buffer layer (BL) deposition**

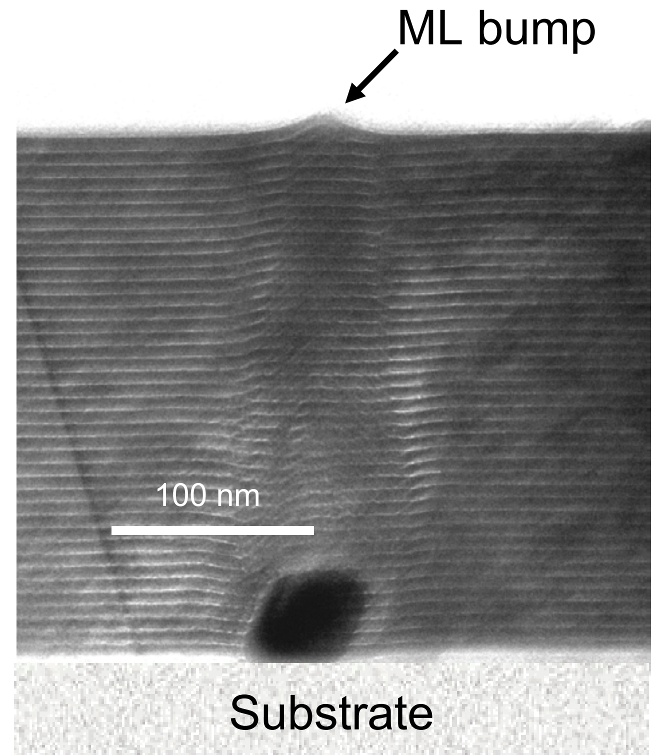


7. **Repair, Buffer layer etch, Final pattern inspection EUV AIM metro.**

Mask Substrate and Blank Inspection

- Printable ML defects are small:
  - Defect with 65nm x 1.5nm ML bump causes 20% CD change to a 25nm line
- Substrate defects causes phase bumps from ML decoration
  - A 25nm particle causes the above ML bump: 30nm PSL equivalent
  - Optical inspection is desired for ML blank inspection (fast, cheap)
- Substantial tool development needed
  - Mask substrate and blank inspection
    - Find bumps on surface
  - EUV Aerial Image Microscope
    - Measure actinic impact, disposition
  - Above combination substitutes for actinic mask blank inspection

XTEM of EUV ML stack



XTEM courtesy P. Mirkarimi, LLNL

Pattern Inspection

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- Can use conventional optical inspection tool in reflected light mode.
  - We inspect a metal pattern, as in CoG
- Requirements:
  - 45nm sensitivity, for 45nm technology node
  - Reflected light defect recognition algorithms
  - Reflected light database rendering software
  - Minimum feature size < 200 nm on mask.
- Also, EUV-specific requirement
  - Mask pattern must have contrast at the inspection wavelength.

Pattern Inspection Tool Needs

- 45 nm tool needed for development (2005) and production phases (2007)
  - Sub-200nm tool
  - Reflected light inspection option
- 65 nm tool need for pilot phase (2003)
  - High NA DUV tool
  - Reflected light inspection option
- Expect tools to be useful for both CoG and EUV
  - No EUVL specific tool needed if CoG tool supports reflected light inspection.

Need for Multilayer Defect Mitigation

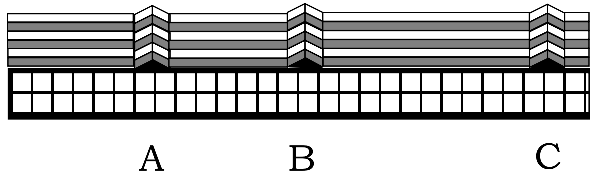
- Need quality masks for first exposure tools and silicon development
  - Need ***contingency plan*** in case defect-free mask blank yield is low
- Can masks print well even if the blanks are defective?
  - Defect Mitigation
- Benefit is earliest possible use of EUVL.
- Use only until defect-free blanks are available.

Proposed Defect Mitigation Methods

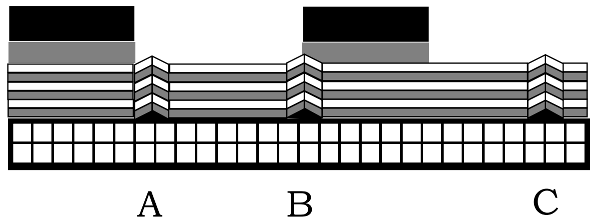
1. Mask Blank Sort
   – Commit best blanks to clear field layers
2. Defect Align
   – Align defects under absorbers
   – Need blank inspection and pattern generator alignment to mask blank fiducials.
3. Defect Proximity Correction
   – Feed forward EUV AIM metrology to alter pattern generator data to compensate for lower EUV reflectivity at defect
   – Need EUV AIM metrology and pattern generator alignment to mask blank fiducials.
4. Defect Proximity Repair
   – Trim absorber to compensate for lower EUV reflectivity at defect.
   – Need EUV AIM metrology and repair tool alignment to pattern

- Progressive elimination of defects

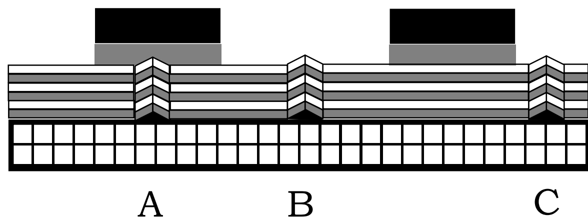
Managing Multilayer Defects – Example



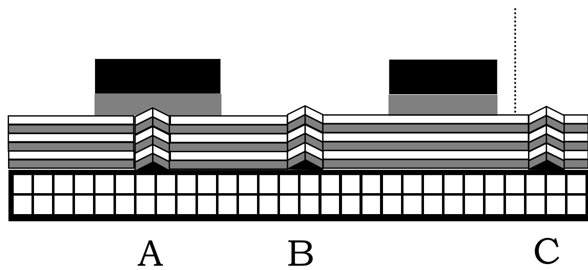
Bare multilayer blank with defects
- Mask Blank Inspection Tool finds defects
- EUV AIM determines reflectivity loss



Final mask with no defect mitigation
- Defects A and B will print
- Defect C may not print if far enough from pattern



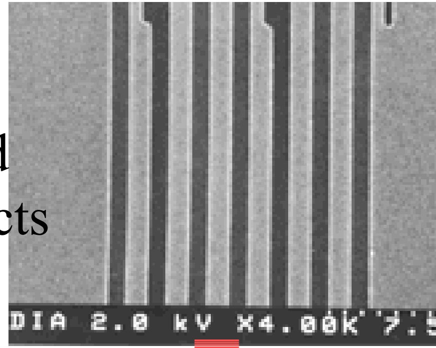
Final mask with Defect Align (DA)
- Defect A will not print
- Defect B may or may not print if far enough from edge
- Defect C will print
- Implement with pattern generator and blank inspection data



Final mask with Defect Align and Defect Proximity Correction (DA/DPC)
- Defect A will not print
- Defect B will not print or can be corrected
- Corrected effect of defect C using local OPC model
- Implement with pattern generator (DPC) and/or repair tool (DPR) using blank inspection and AIM data.

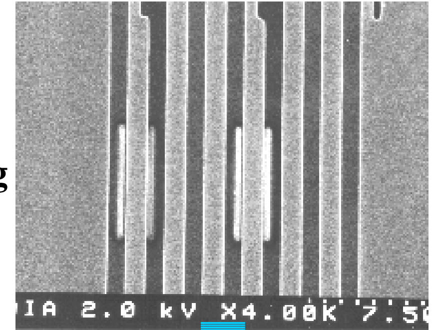
Example of Defect Proximity Repair (DPR)

Mask with (unseen) programmed substrate defects

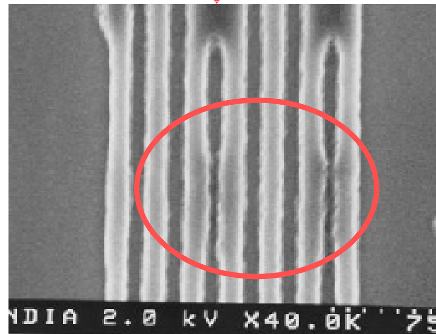


DPR
Courtesy Ted Liang

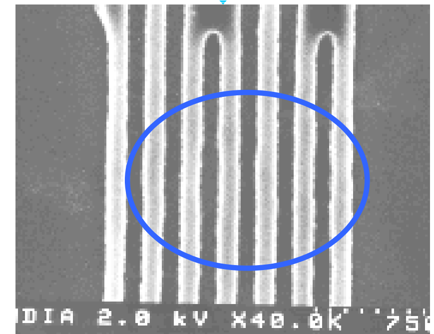
Mask with trimmed absorber pattern



EUV Print



EUV Print



- Mask with substrate defects looks good but prints bad
- Absorber trimmed by FIB to compensate lost reflectivity
- Print of repaired mask shows correction.
- Our implementation would use AIM data and correction of PG data (DPC), DPR as back-up

Sweeney; Donald W., Ray-Chaudhuri; Avijit K., “Method for mask repair using defect compensation,” U.S. Patent No. 6,235,434, May 22, 2001.

Summary

- Overall EUVL defect strategy proposed
  - Multilayer defects to be found at mask blank inspection
  - Pattern inspection tool can be optical
  - EUV AIM metrology required for multilayer defect dispositioning
  - Above substitutes for full actinic inspection.
- EUVL Mask Tool Requirements Defined
  - 30nm PSL sensitivity for optical mask blank inspection
  - 45nm hard defect sensitivity using reflected light at pattern inspection
- Significant Tool Development Is Required
  - EUV AIM tool will be complex and expensive.
- Contingency plan for defect-free EUVL mask fabrication proposed
  - Several defect mitigation steps will be investigated
  - Required tool development defined
  - Cost-benefit analysis to be completed

Acknowledgements

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