SEMATECH's infrastructure for defect metrology and failure analysis to support its EUV mask defect reduction program

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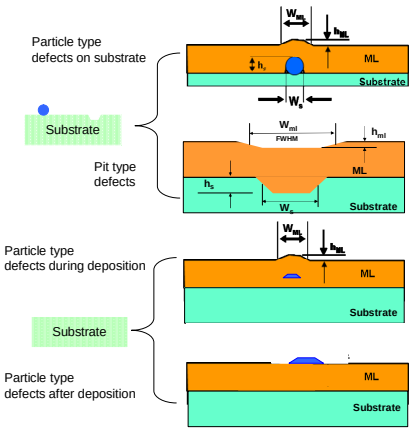
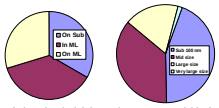
EUV Mask blank defects



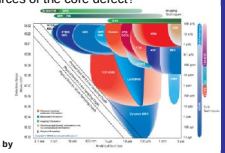
Perform failure analysis and determine sources of defects in EUV mask blanks

Objective

- What is the position of the core defect (on ML, in ML, on substrate)?
- What is the size and shape of the core defect and subsequent disruption in the multilayer (ML)?
- What are the composition and sources of the core defect?



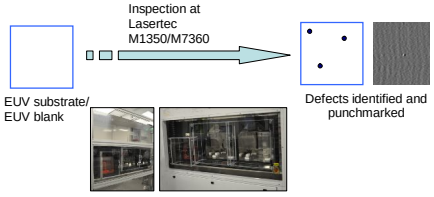
Description of typical defect ratios on EUV mask blanks by position and size



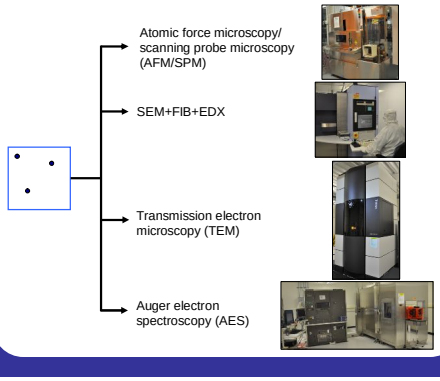
Metrology techniques overview
Courtesy of EAG[1]

SEMATECH has in-house capability and/or access to all above mentioned metrology techniques at Albany

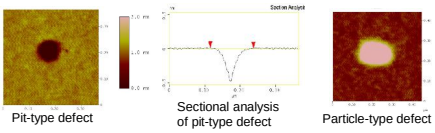
Advanced Metrology Instrumentation at SEMATECH for EUV Blank Defects



M1350 M7360



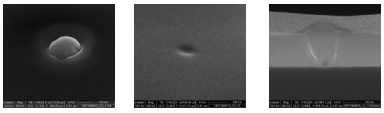
AFM



Pit-type defect — Sectional analysis of pit-type defect — Particle-type defect

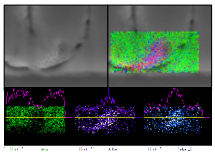
- Veeco Dimension 9000
  - Surface topography, surface area, volume and cross-sectional information can be derived
  - Cannot provide any information on the core and composition of the buried defects inside multilayer (ML)

SEM+FIB+EDX



Particle- type defect — Pit-type defect — Cross-section of particle-type defect on substrate

- FEI dual beam SEM-FIB- Altura 835
  - Accelerating voltages: 2-30kV, equipped with electron backscattered detector and Oxford energy dispersive X-ray spectroscopic (EDX) detector
  - Can handle 6" mask with precise location mapping
  - Provides size and shape analysis, cross-sectional analysis, elemental analysis, and information on the position of defect
  - Cannot provide elemental analysis for sub-100 nm defects, chemical information of defects, and disruption in the ML

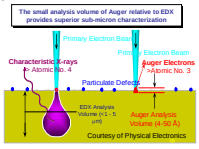


Small size defect as analyzed by EDX

EDX elemental map providing info on the shape, size, and elemental composition of defect

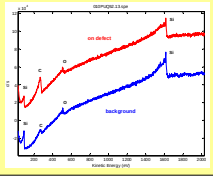
AES

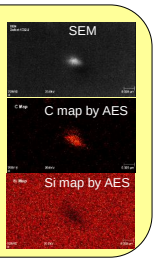
- Smart II Auger electron spectrometer
  - Energy resolution: 0.5%
  - SEM resolution: 6nm @ 1nA, 20kV
  - Spatial resolution: 8nm @ 1nA, 20kV
  - Sensitivity: 700 Kcps @10kV, 10nA
  - Vacuum: 5×10^{-10} torr
  - Sample size: 6" mask to small samples

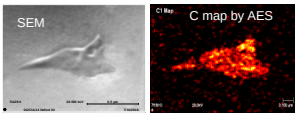


AES map shows the distribution of C and Si elements.

The example confirms analysis of defects up to 30 nm, which are extremely difficult to analyze under SEM with EDS.





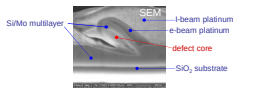


A flat carbon defect as analyzed by AES on insulator surface (EUV substrate)

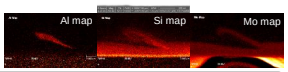
Such type of flat defects on insulator surfaces are beyond the sensitivity of SEM with EDS. Challenges of surface charging in AES analysis (especially when high voltage and small spot size are applied due to small defects) were resolved with accumulative knowledge.

AES

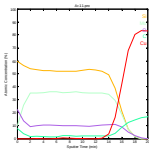
Cross-sectional analysis of defect by AES



The elemental mapping can precisely define the shape and elemental composition of defects



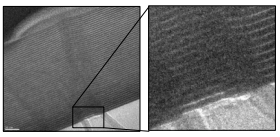
- Though AES provides very good depth resolution, the chemical information of the defect can not be derived



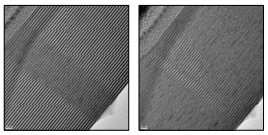
AES with depth profiling can also be used to characterize the EUV multilayer properties and change in elemental concentration with depth

TEM

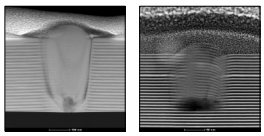
- FEI Titan S/TEM
  - Accelerating voltages: 80-300kV, Energy spread: 0.2-0.7ev
  - Point resolution: 80pm, STEM Resolution: 70pm
  - C_S corrector, Monochromator
  - Spectroscopy: EDS, EELS, & EFTEM



TEM analysis of a 5 nm high bump-type native defect on substrate

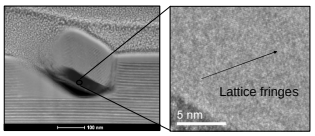


Conventional bright field imagin for a native pit-type defect.
The two images at different focus show either ML away from defect or disrupted ML in focus providing critical information on propagation of defect during ML deposition.



High angle annular dark field STEM image for a particle-type defect on substrate and during deposition

- Provides ultimate resolution to determine the composition of the defect
- 3D tomography and position of the defect can be determined
- Provides description of disruption in ML to accurately calculate phase changes
- Provide chemical information of the defect including crystallinity



A crystalline defect as determined by TEM analysis

Summary

- SEMATECH demonstrates complete capability of failure analysis on EUV mask blank defects down to 10s of a nm to determine shape, size, and composition. The critical information helps to identify sources and devise strategies to eliminate defects.
- Though SEM-EDX and AFM have been the typical workhorses for FA, AES and TEM have become necessary and decisive for analysis of increasingly smaller defects

Acknowledgements

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1. http://www.eaglabs.com/techniques/analytical_techniques/