Development of Coherent EUV Scattering Microscopy For the Inspection of EUV Mask Patterns

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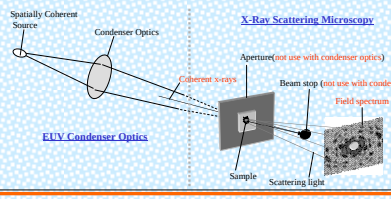
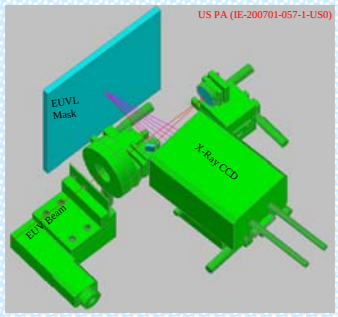
Purpose: Development of mask metrology tool with (1) low cost of ownership, (2) high throughput, (3) accurate actinic CD, and (4) aerial image measurements

Reflective Type of X-Ray Scattering Microscopy with EUV Condenser Optics
→ Coherent EUV Scattering Microscopy (CSM)

- Ability of phase information extraction
- Ability of accurate CD measurements (some patterns)
- Ability of aerial image measurements (all patterns)



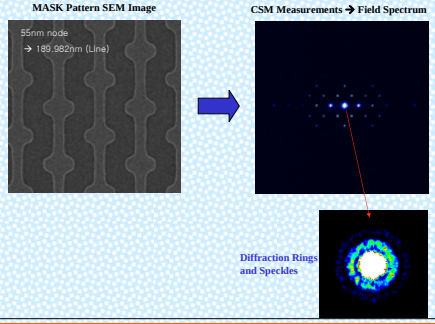
Design of the coherent scattering microscopy (CSM)



- EUV Beam From Synchrotron
- Inc. Angle = 6 deg. (Reflection)
- Wavelength: 13.4 nm
- Band Width: 0.3 nm (FWHM)
- Field Of View: 5^2~20^2 um^2
- Min. Resolution = 55 nm
- Visible Shadow Imaging
- X/Y Stages for 6" Mask
- 6" Mask Load-Lock Chamber

Field spectrum of the coherent EUV beams

MASK Pattern SEM Image — CSM Measurements → Field Spectrum



Visible Image & CSM's Numerical Aperture (NA)

Visible Shadow Image — H/V L/S Pattern's Field Spectrum

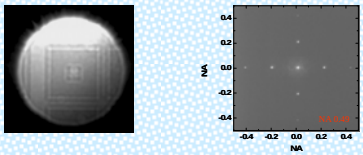


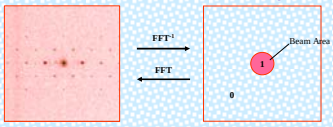
Fig. (Left) Visible shadow image of the mask pattern obtained with a 4-mm diameter aperture and a thin glass window to block the EUV beams. (Right) Field spectrum obtained from 32-nm node (for m=1/4 imaging system) patterns of horizontal and vertical L/S.

DRAM Pattern's Field spectrum

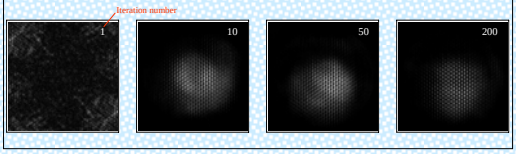
33-nm node Gate — 30-nm node Contact — 33-nm node Bitline

Mask Pattern Image Reconstruction Using Iterative Algorithm

|Amplitude| of the Field Spectrum — Mask Image

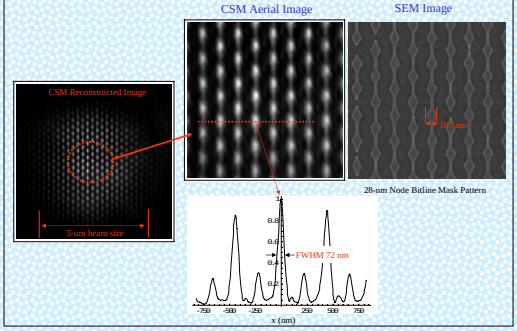


Iteration number



Mask Pattern Image Reconstruction Using Iterative Algorithm

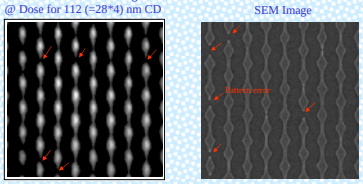
CSM Aerial Image — SEM Image



28-nm Node Bitline Mask Pattern

Mask Pattern Error Printability Simulation (Constant Threshold Resist Model)

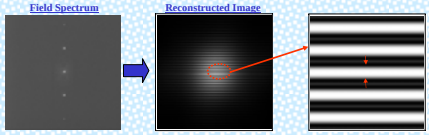
From the CSM Aerial Image @ Dose for 112 (=28*4) nm CD — SEM Image



28-nm Node Bitline Mask Pattern

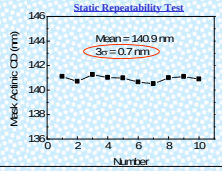
High Accurate Critical Dimension(CD) Measurements

Field Spectrum — Reconstructed Image



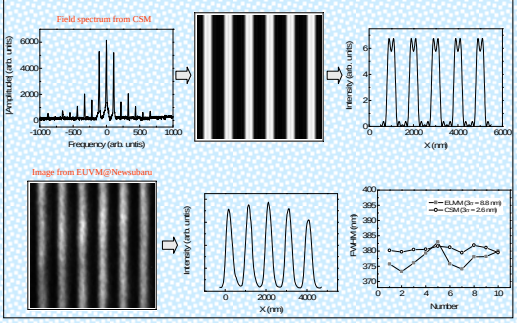
32-nm Node L/S Pattern

Static Repeatability Test



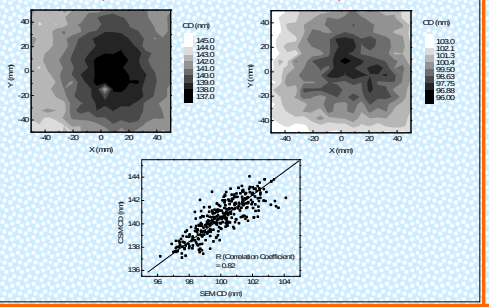
EUV Microscopy VS. CSM for 1-um Pitch EUV Mask Patterns

Field spectrum from CSM

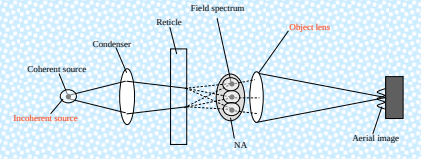


6"x6" Mask CD Uniformity Measurements (324 pts. Measurements)

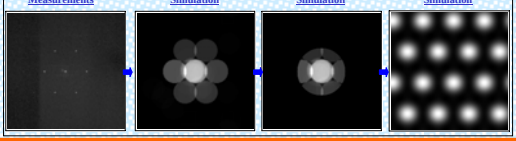
CSM Unif. Map: 3σ = 4.7 nm — SEM Unif. Map: 3σ = 4.4 nm



Aerial Image Simulation From the Field Spectrum

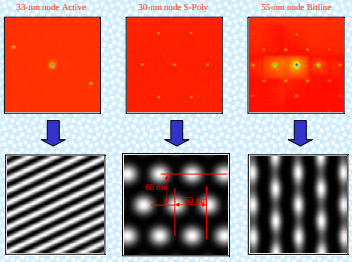


Field Spectrum Measurements — Incoherent Source Simulation — NA Simulation — Aerial Image on Wafer Simulation



Aerial Image Simulation of the DRAM Patterns from the Field Spectrum

33-nm node Active — 30-nm node S-Poly — 55-nm node Bitline



- HCD = 30.27 nm
- VCH = 29.77 nm
- HCD-VCD = 0.5 nm

3-D Pattern's Shadowing Effects Measurements

Field Spectrum From 30~90 nm Contact Patterns — Horizontal CD – Vertical CD

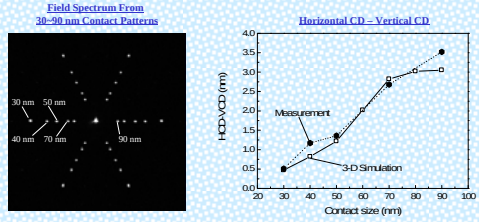


Fig. (Left) Field spectrum overlapped all the four spectra from each contact patterns with a different size of 30, 40, 50, 70, and 90 nm on the wafer, respectively, (Right) The difference of X and Y direction size on aerial image depending on its size of the aerial image of the contact. The aerial image was simulated under the EUV imaging tool's illumination conditions of M=1/5, NA=0.25, and σ =0.5. "HCD" and "VCD" denote the horizontal and vertical critical dimension of the pattern, respectively.

CSM Setup Results And Its Application Summary

1. Field Spectrum Measurements → NA= 0.49 for M=1/4
   - EUV phase-shifting mask development
2. Mask Actinic CD Measurements → 3σ=0.7 nm for 32-nm Node L/S Pattern
   - EUV mask's patterning development
   - Study of the contamination & cleaning effects on pattern
3. Aerial Image Simulation → Shadowing Effects are Decreased as Decreasing CNT Size
   - Mask's 3-D effects investigation
   - Development of new absorber and capping layers
   - Mask pattern error's printability simulation