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Accelerating Yield

Electron Beam Inspection of NGL Reticles

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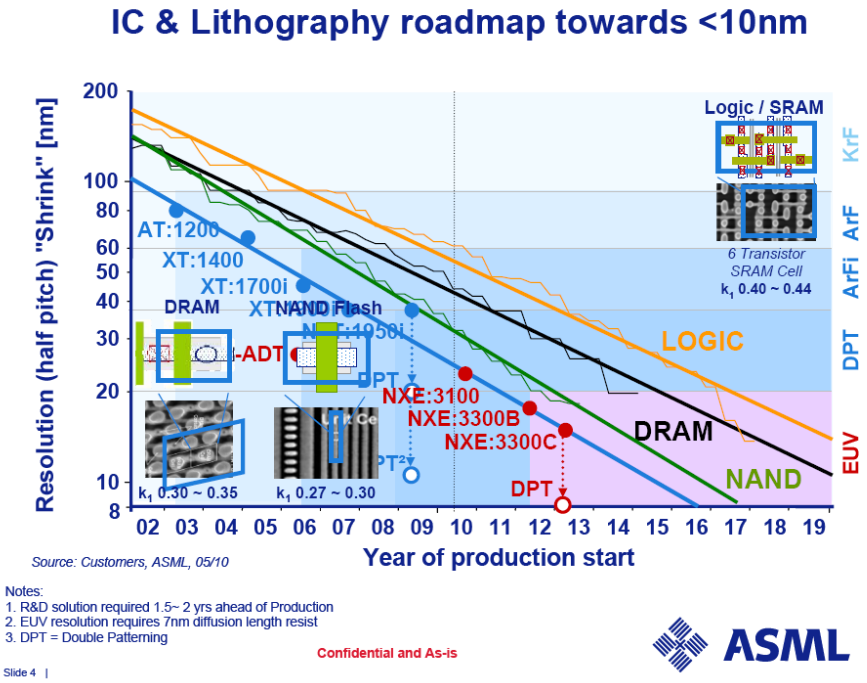
RAPID

Agenda

- Overview
- EBI Suitability for Reticle R & D
- EBI Challenges for Reticle Production
- Summary

Motivation

- Next Generation Lithography (NGL), including 193 / DPL, EUV and NIL, drives demanding requirements for reticle manufacturing, including inspection.
- Shrinking patterns and defect sizes drive demand for increased inspection performance (sensitivity, throughput, etc.).
- Mask Inspection for 193 Lithography will continue to be served by Optical Inspection.
- EUV is the leading candidate Lithography beyond 193.
- This presentation will focus on the suitability of EBI (Electron Beam Inspection) for EUV mask R & D and production.



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Roadmap: EUVL Blank & Mask Inspection

193nm optical for 22nmHP EUVL. New inspection approach required ≤16nmHP.

- Ready now for 32nmHP masks
- Upgrade 2011 for 22nmHP
- Blanks: Captures pits & bumps for Substrate, ML, Absorber
- Poster Paper on 193 Optical inspection.

DRAM 22nmHP
Logic N16

DRAM 16nmHP
Logic N11

Teron 6XX
193nm

6XX?
eBeam?
Actinic?

	Inspection Requirements			
DRAM Half-Pitch (nm)	32	22	16	11
Mask Damage	None	None	None	None
Resolution (vs. DR)				
Sensitivity ML Blank (nm z)	2.2	1.5	1.1	0.8
Sensitivity Mask 1D CD (nm)	13	9	6	4
Sensitivity Mask 2D (nm)	26	18	13	9
Cycletime Mask Shop (Hours)	4	4	4	4
Sensitivity Mask Particles (nm)	26	18	13	9
Cycletime Requal (Hours)	2	2	2	2

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- Ready
- Upgrad
- Blanks: Substra
- Poster

Critical to EUV Production:

- Mask damage and cleanliness
- Scan time → Cost-per-inspection & mask cycle time
- Sensitivity → Detect all defect types having >10% Wafer CD Impact
  - ML, Absorber, Particles, Films, etc.
- Signal-to-noise → Capture & False Rate
- Die-to-database →Single-die & Multi-die designs

Reticle EBI suitability for R & D

Reticle EBI challenges for Production:

- Mask Damage
- Throughput
- Sensitivity

DR				
Sensitiv				
Sensitivi				
Sens				
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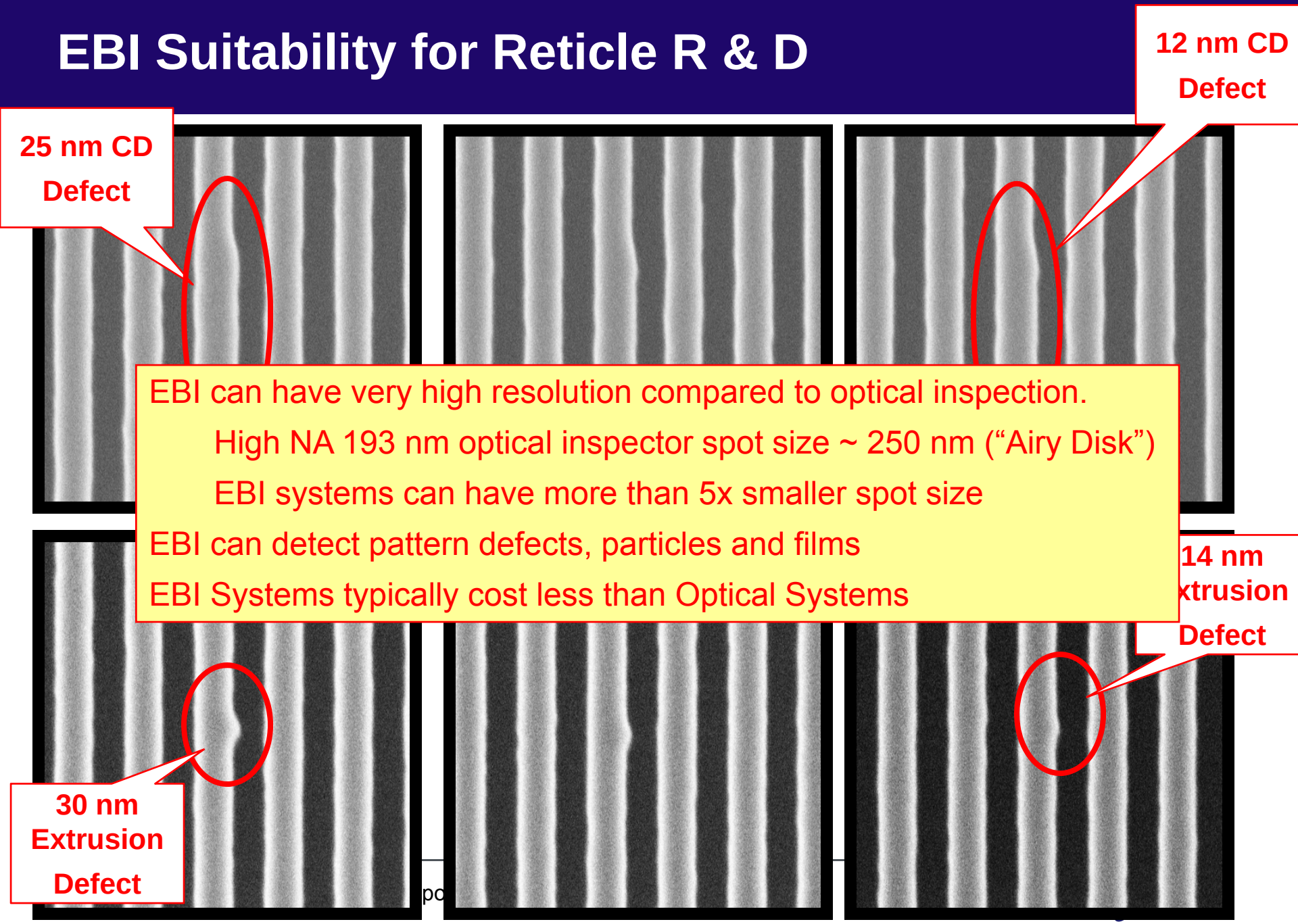
EBI Suitability for Reticle R & D



EBI can have very high resolution compared to optical inspection.

- High NA 193 nm optical inspector spot size ~ 250 nm (“Airy Disk”)
- EBI systems can have more than 5x smaller spot size

EBI can detect pattern defects, particles and films

EBI Systems typically cost less than Optical Systems

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  - Mask Cleanliness & Damage
  - Throughput & Sensitivity
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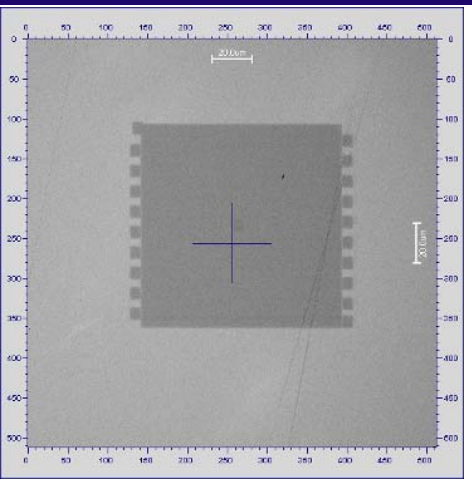
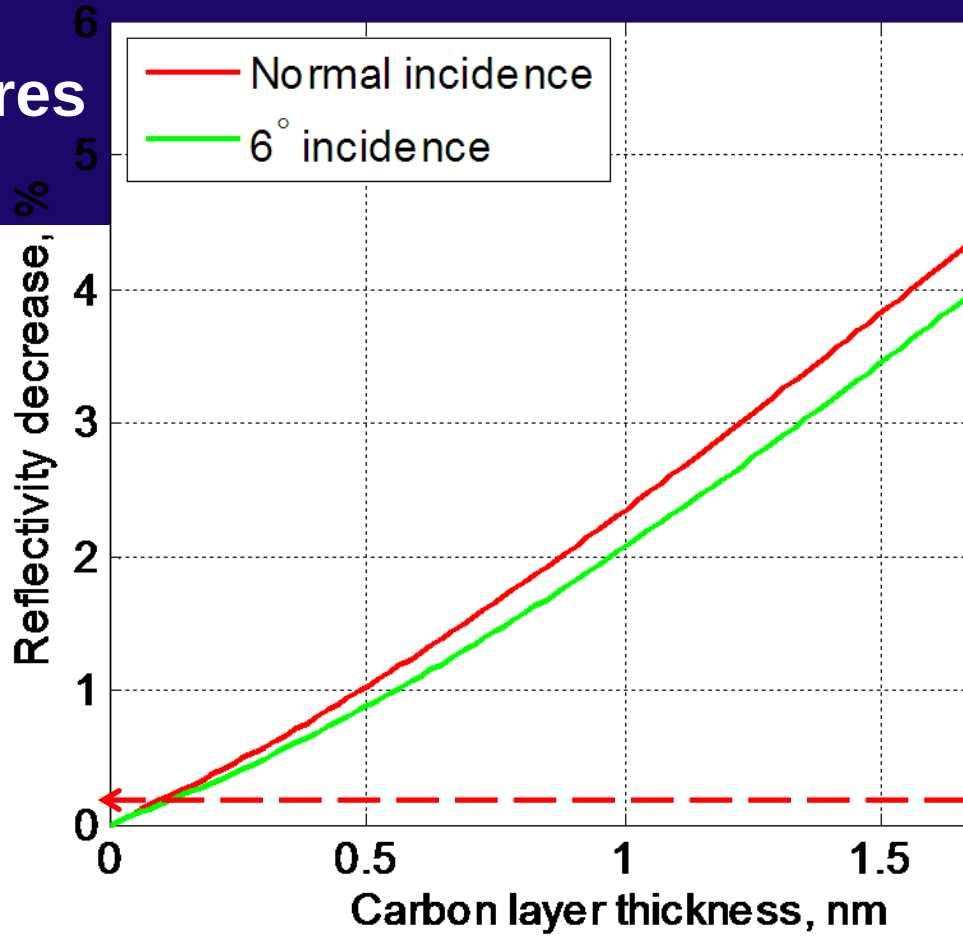
Production Reticle EBI requires ultra-clean system



Ebeam Exposure of EUV Blank
and Patterned Mask



- EBeam exposure can cause deposition of Carbon film on mask due to ionization of residual organics
- Film deposition can cause changes in reflectivity or center wavelength.
- Requires control of exposure conditions and development of exceptionally clean system.
- Current EBI systems typically achieve ~1 Particle per Reticle Pass (PRP) with 50 nm sensitivity. EUVL requirements are 0.05 w/ 20 nm sensitivity. Requires very significant improvement over today's EBI systems..

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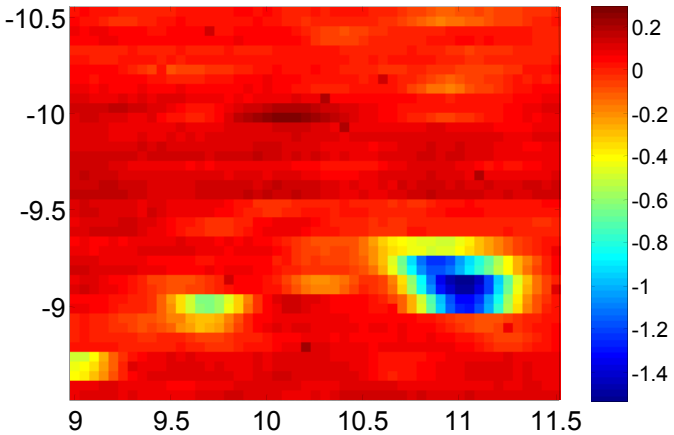
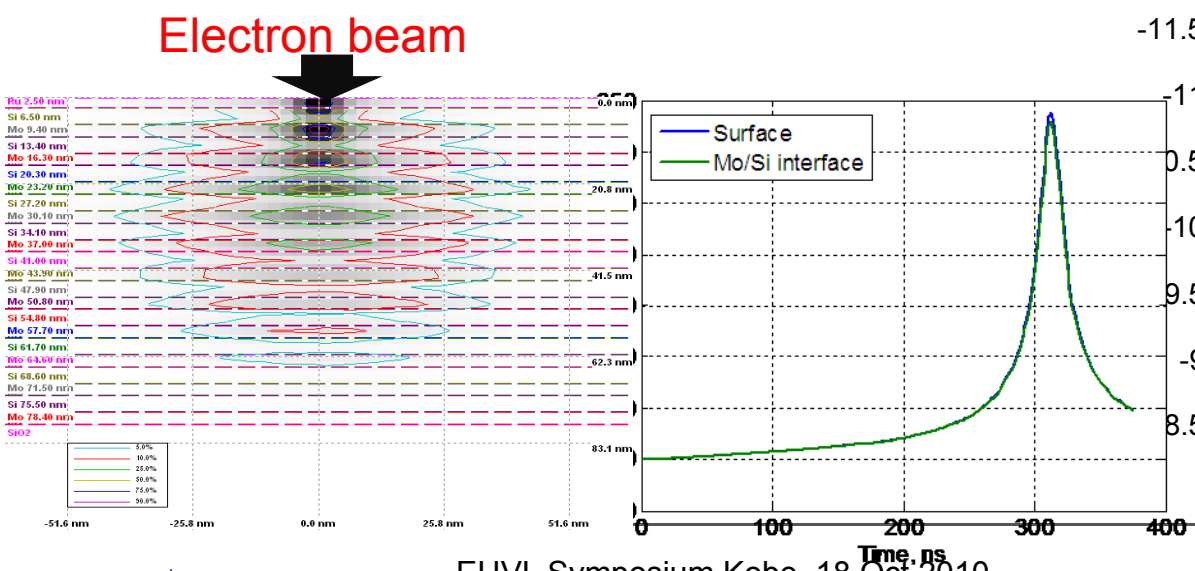
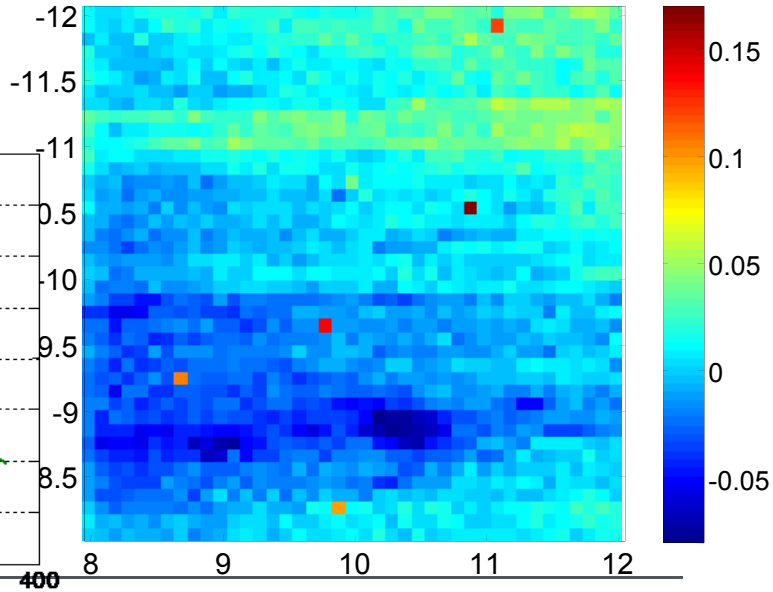
EBI can heat ML and reduce EUV Reflectivity

- EUV Mask Damage is a function of beam current, landing energy, spot size, duration, etc.
- EBeam systems typically have very high local power levels due to high current in a small spot resulting in high local heating.
- Certain beam conditions can result in over 300 C temperature rise
- Stringent requirements on mask reflectivity and center wavelength drive studies showing risk of damage above 100 C.







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Exposed sites on EUV Blank

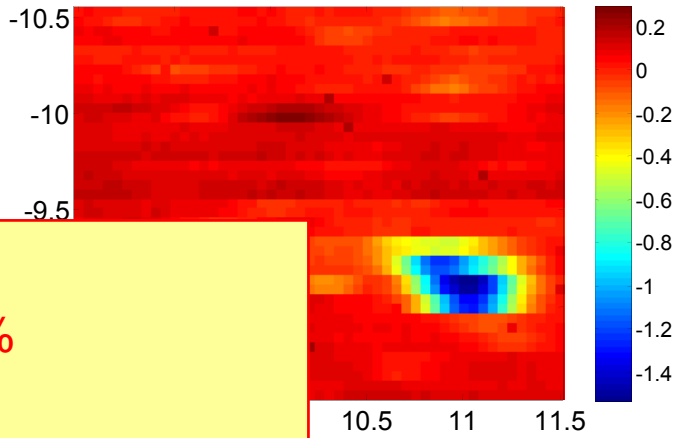
Measured EUV Reflectivity loss 1.5%

Cleaned Mask

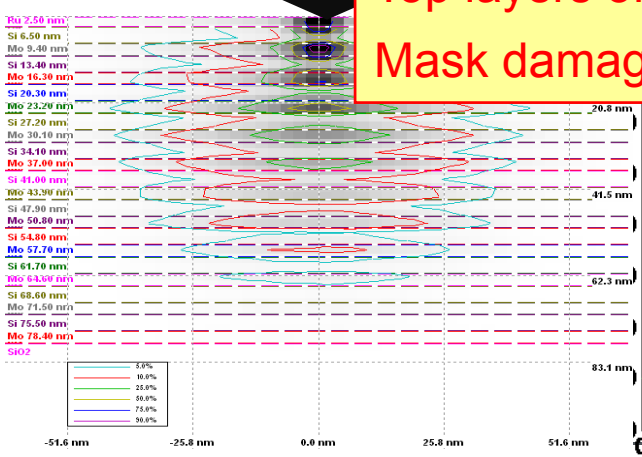
Measured EUV Reflectivity loss 0.1%

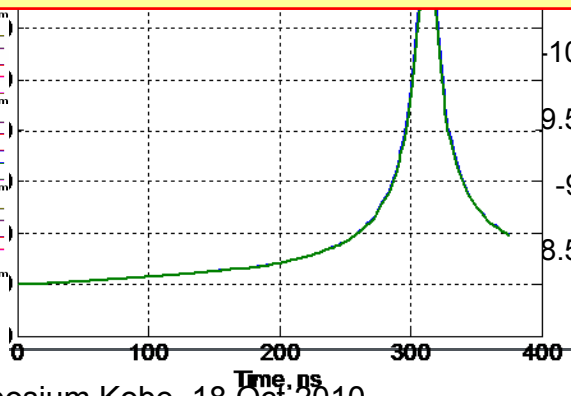
Further TOF-SIMS Analysis shows degradation of Top layers of Blank.

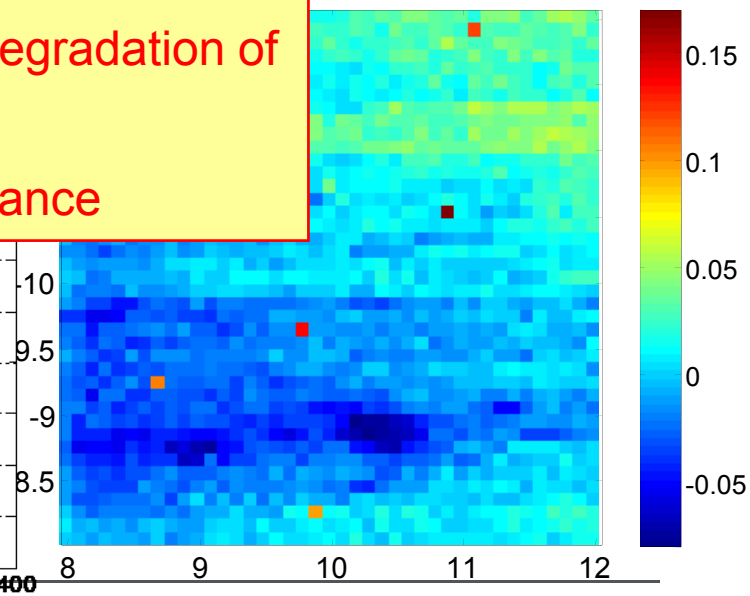
Mask damage may limit EBI performance



Electron







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  - Mask Cleanliness & Damage
  - Throughput & Sensitivity
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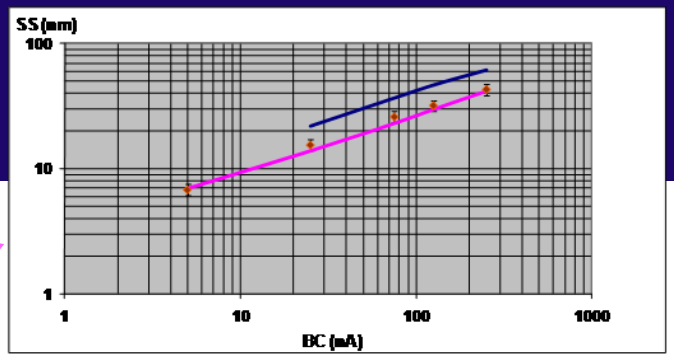
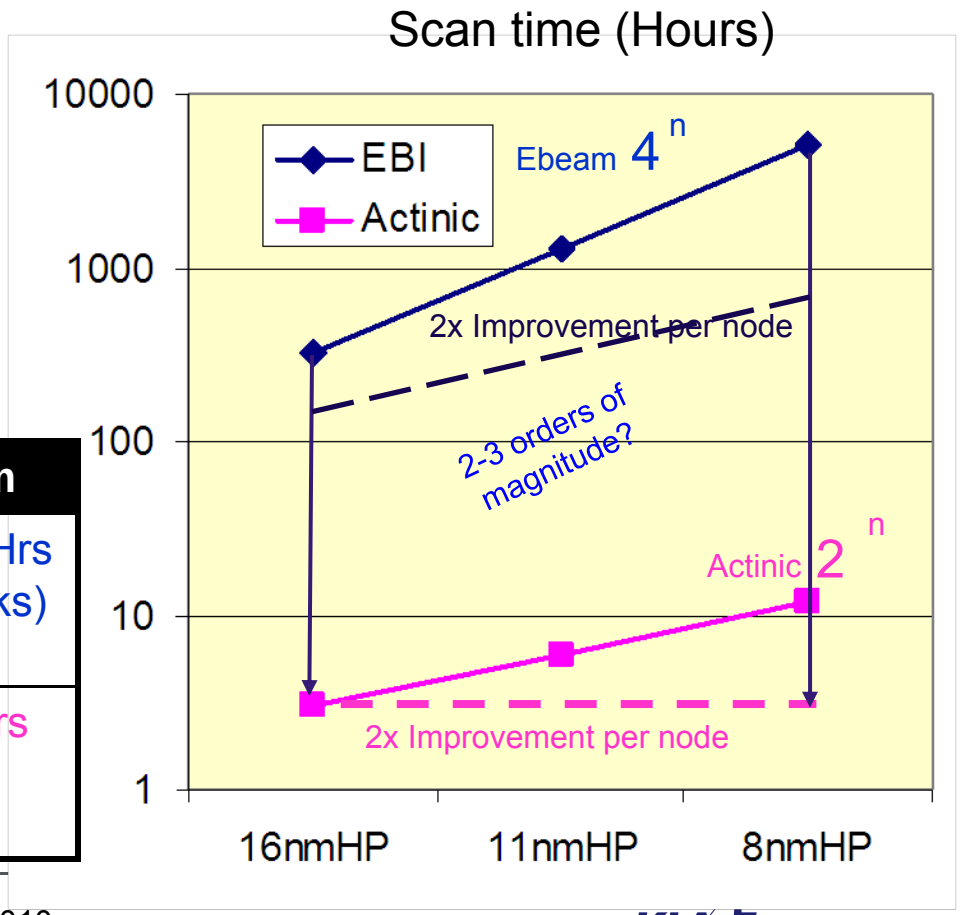
EBI Throughput
Decays 4x per node for fixed system



- Number of pixels inspected increases by 2x per node to maintain required sensitivity.
- Ebeam Spot size limited by Coulomb interactions. Ebeam Spot ~ √ (Beam Current). Optical Spot is independent of light level.
- Each node drives √2 smaller spot which in turn drives 2x lower Beam Current for specific system. Therefore Data Rate decreases by 2x per node to maintain constant noise.
- **EB Systems slow down 4x per node.**
- Best to date: Inspect 32nm mask < 20 hrs.
- 100 x 100 mm area
- 10% Δ CD

Scan Time	16 nm	11 nm	8 nm
EBI (Pattern only)	320 Hrs (2 wks)	1280 Hrs (8 wks)	5120 Hrs (30 wks)
Actinic (Blank & Pattern)	3 Hrs	6 Hrs	12 Hrs



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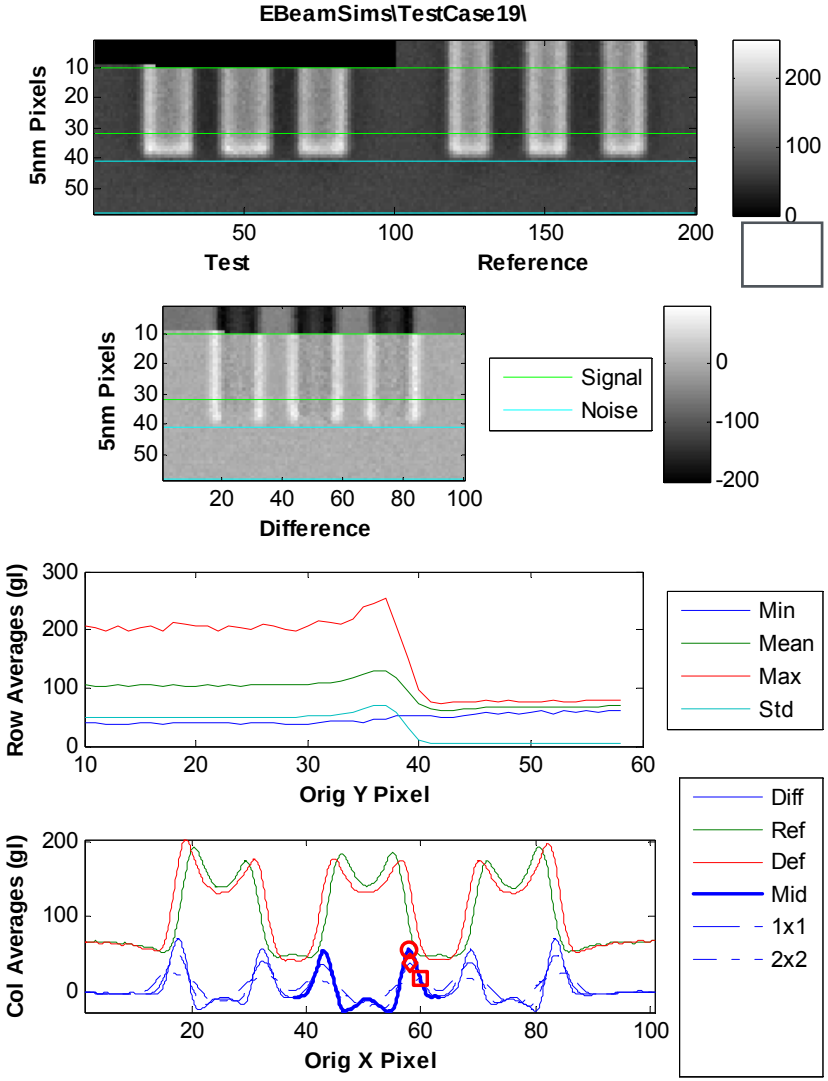
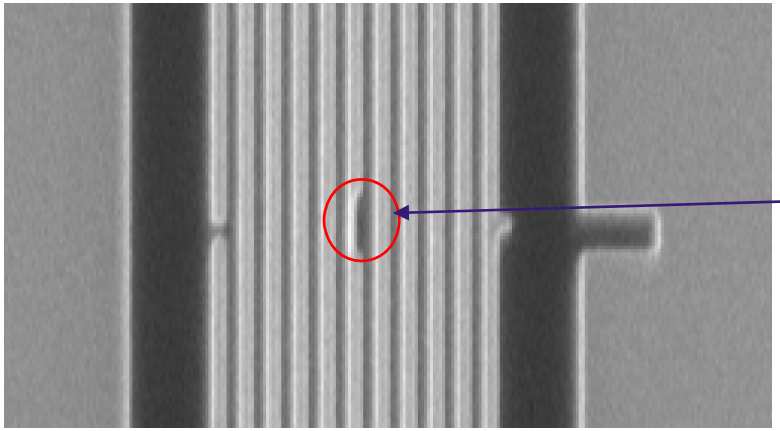
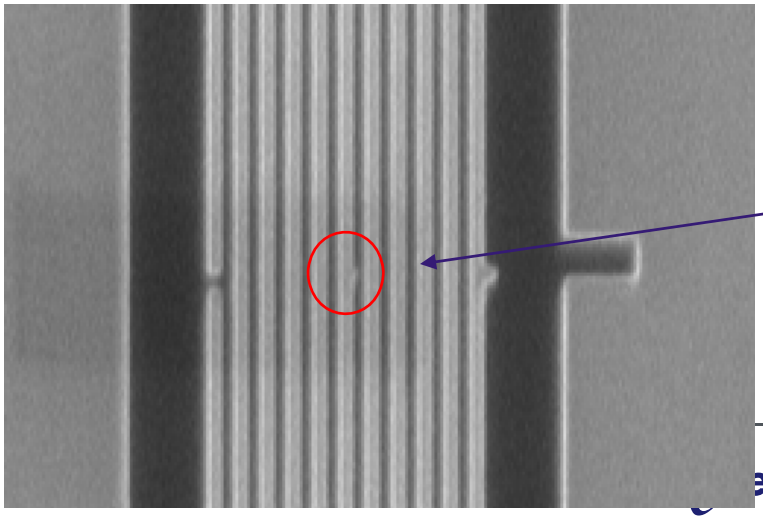
Simulation & Measurement of Defect Signals from EUV Masks



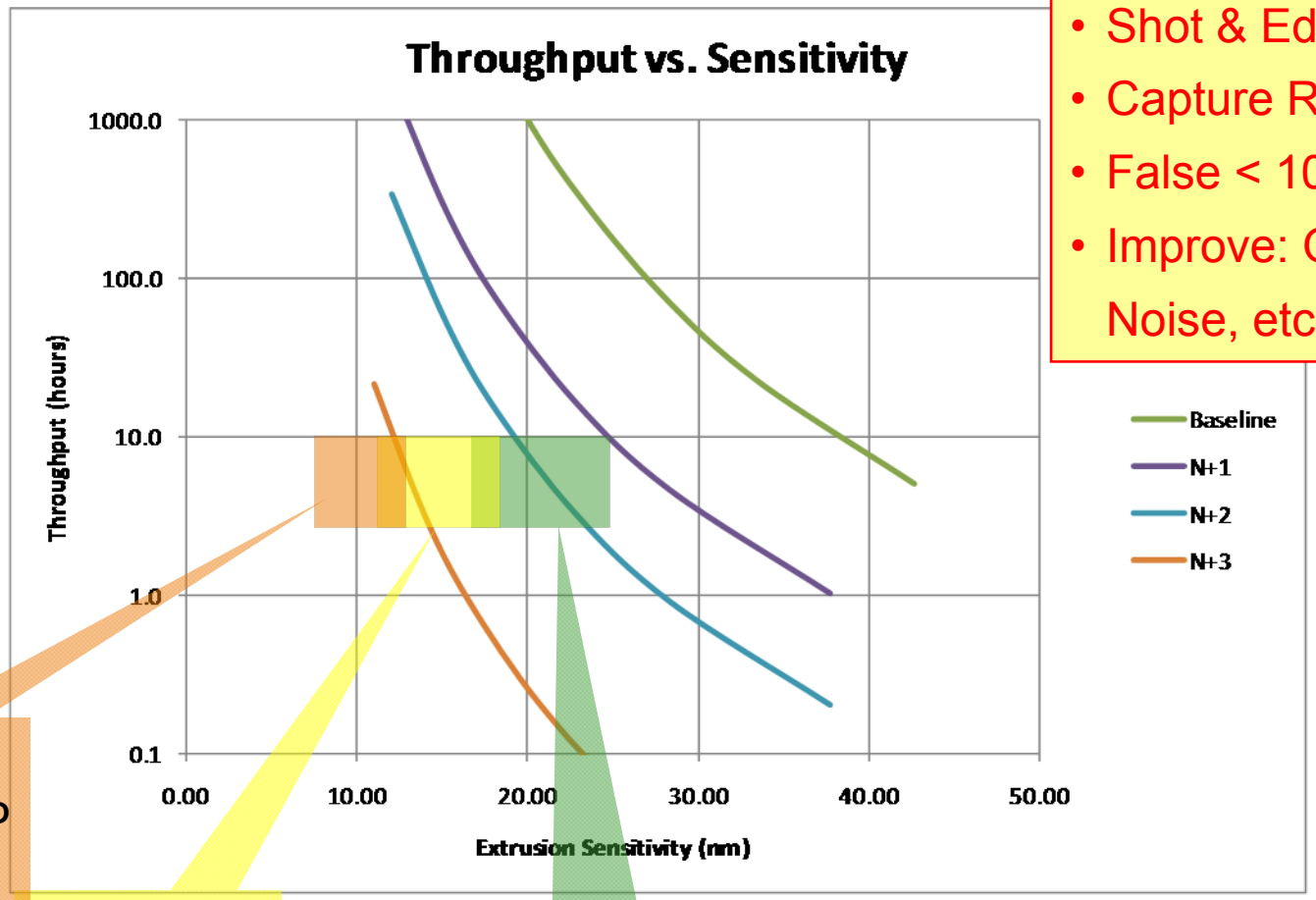




Sensitivity vs. Inspection Time

Production Conditions:

- 100 x 100 mm^2
- 100% coverage
- Shot & Edge Noise
- Capture Rate > 99%
- False < 100
- Improve: Optics, #Spots Noise, etc.



11 nm node
10% to 15% CD
3 to 10 hours

16 nm node
10% to 15% CD
3 to 10 hours

22 nm node
10% to 15% CD
Impact
3 to 10 hours

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EUV Mask Inspection Requirements & Options

		Node Half-Pitch (HP) in Production				
		32 nm	22 nm	16 nm	11 nm	8 nm
		2010	2012	2015	2017	2020
Sensitivity Requirements	2D Defects	26 nm	18 nm	13 nm	9 nm	6 nm
	1D Defects	13 nm	9 nm	6 nm	4.5 nm	3 nm
Optical Inspector	Throughput	3 hr	2 hr	4 - 8 hr	N/A	N/A
	Capture Rate	100%	100%	< 100%		
	False Count	< 100	< 100	< 100		
e-beam Inspector (2x improve / node)	Throughput	N/A	40-80 hr	80-160 hr	160-320 hr	320-640 hr
	Capture Rate		90%	90%	90%	90%
	False Count		100-1000	> 1000	> 1000	> 1000
EUV Actinic Inspector (2x improve / node)	Throughput	N/A	N/A	3 hr	3 hr	3 hr
	Capture Rate			100%	100%	100%
	False Count			< 100	< 100	< 100

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DRAM 22nmHP
Logic N16

DRAM 16nmHP
Logic N11

Teron 630:
- Promising for R&D
- Requires multi-pass

eBeam (EBI):
- Promising for R&D
- Very Challenging for production

EUV Actinic:
- Blank & Mask inspection
- Productivity, sync'd to EUVL

Teron 6XX
193nm

6XX
eBeam or
Actinic

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Inspection
Requirements

DRAM				
Res				
Sensitivity				
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Reticle EBI suitability for R & D

Reticle EBI challenges for Production:
- Mask Damage
- Throughput
- Sensitivity Limitations (noise & non-Actinic)

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Acknowledgements

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Questions?

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