Defect printability of thin absorber mask in EUV lithography with refined LER resist

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Outline

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- Breakdown of Printed LER/LWR

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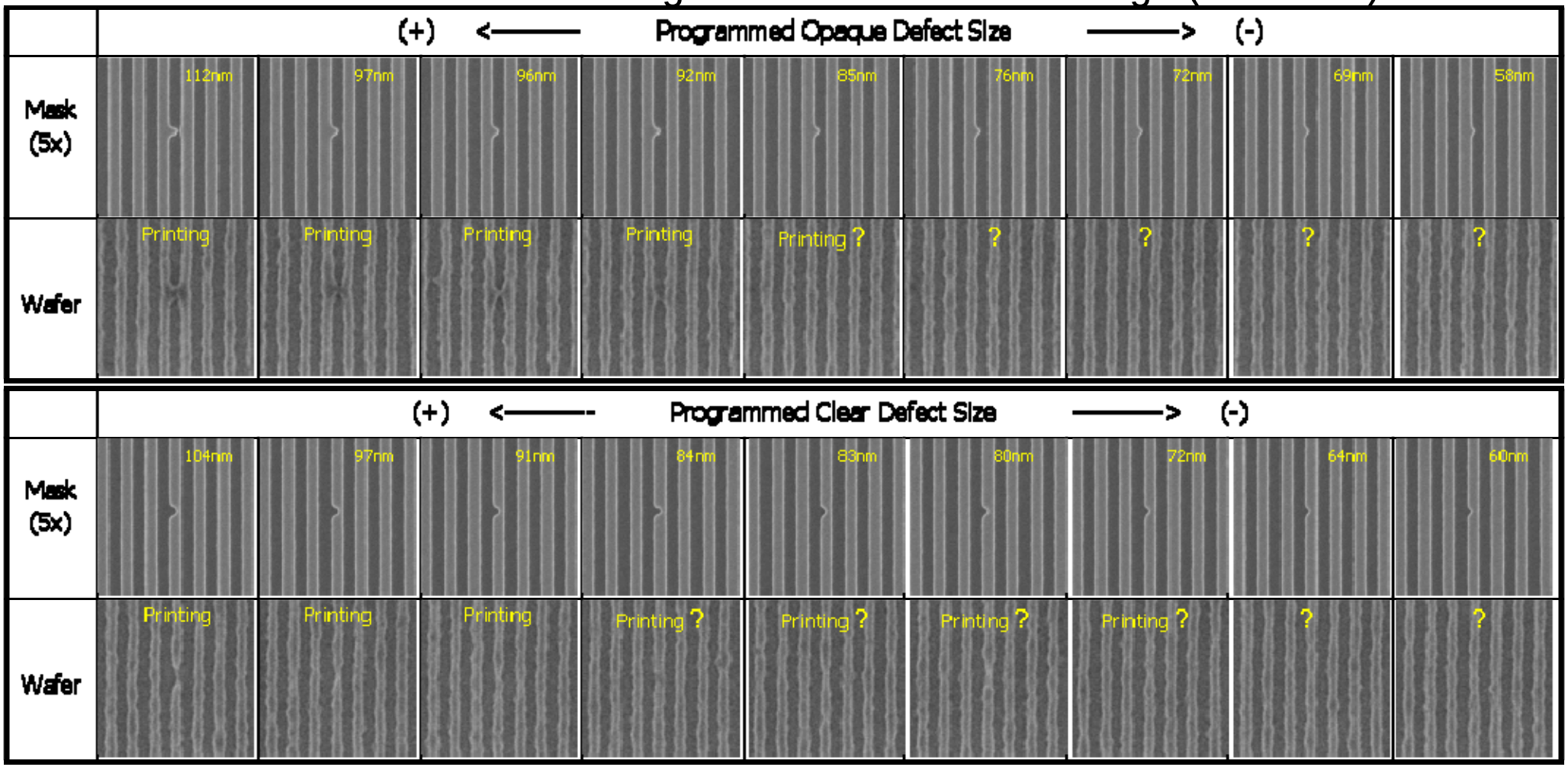
Hurdle on Defect Printability Evaluation

Table Mask Pattern Image and Resist Pattern Image (32nm HP)



T. Kamo, et al., SPIE Advanced Lithography 2009

It is difficult to measure critical defect size precisely because printed pattern's line-edge/width-roughness (LER/LWR) is larger than the CD tolerance of 32nm HP and beyond.

Breakdown of Printed LER/LWR

[1] Mask/Blanks Process

- LER/LWR of Absorber Pattern
- Roughness of Multilayer Surface

} Systematic LER/LWR

[2] Contrast/NILS of Aerial Image

- Exposure Tool / Condition (NA, **σ**, Flare, ...)
- Mask Structure (Binary, Att-PSM *, ...)

[3] Resist Process

- Resist Material
- Resist Stack (Under Layer, ...)
- Post Exposure Treatment

} Random LER/LWR

is reduced by

CD averaging method of multiple exposure shots.

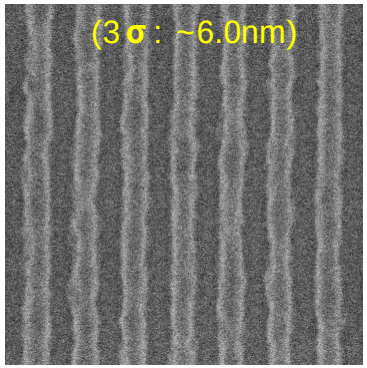
*) T. Kamo, et al., "Effect of mask absorber thickness on printability in EUV lithography with high resolution resist", Proc. SPIE 7028 (2008)

How to Improve LER/LWR of Printed Image ?

Improvement of resist and mask process

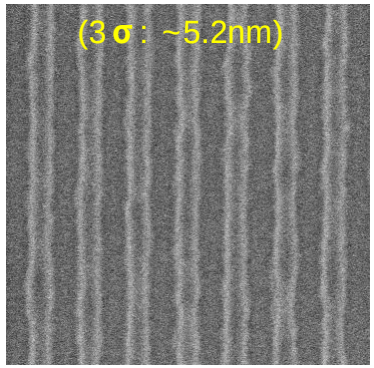
32nm L/S printed image

Resist: SSR3, Mask: Conv.



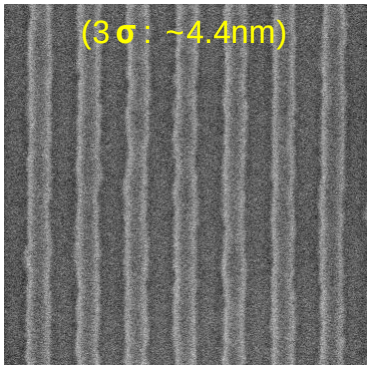
Resist Improvement

Resist: SMR83, Mask: Conv.



Mask Improvement

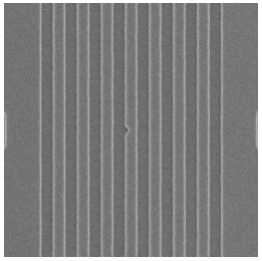
Resist: SMR83, Mask: Improved



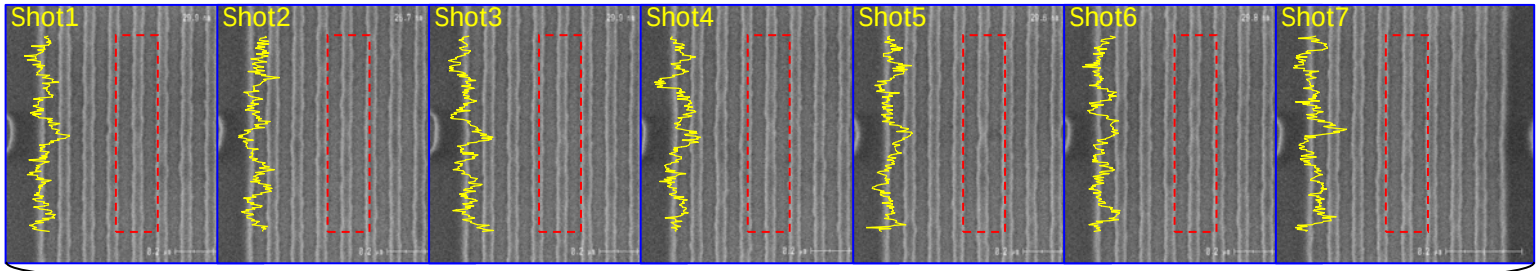
CD averaging method of multiple exposure shots

to extract systematic component from printed pattern with LWR by reducing random components

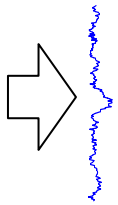
Mask Pattern



Printed Image



CD Ave.



CD averaging

Experimental Condition

Blanks / Masks

Blanks structure :	LR-TaBN(51nm) / CrN buffer(10nm) / Si cap (11nm) / M.L. 40pairs (Mo/Si) / substrate
Mask defect evaluation:	Mask CD-SEM NGR4000 (NGR)

SFET Experiment

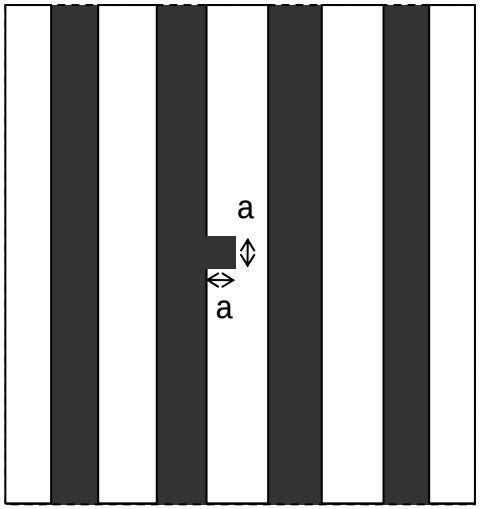
Exposure condition:	NA=0.3 (central obscuration: 30%), sigma (inner/outer)=0.3/0.7, Incident angle=6deg, Magnification=1/5
Resist :	Selete Model Resist 83 (60nm thickness)
Resist CD evaluation:	S9380II (HITACHI High-Technologies)

Lithography Simulation

Simulator :	EM-Suite™ (Panoramic Technology Inc.)
Exposure Condition :	NA=0.3(Central Obscuration : 30%), sigma (inner /outer)=0.3/0.7, Incident angle=6deg, Magnification=1/5 , λ =13.5nm, No lens aberration, No flare, Resist blur model (sigma=9nm)
Pattern :	32nm L/S with program isolated/edge defect (Parallel to EUV light projection)

Definition of Defect Size and Pattern Orientation

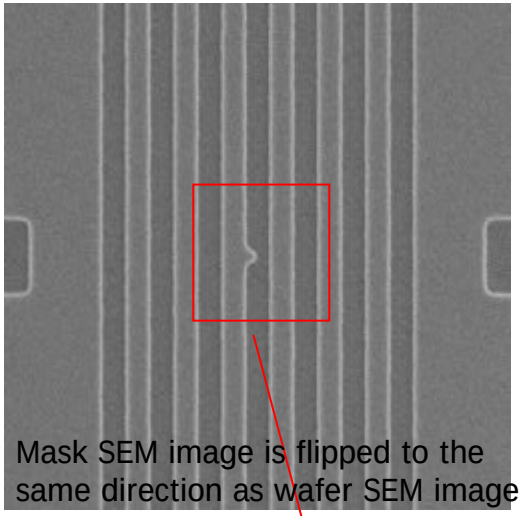
Mask (Design)

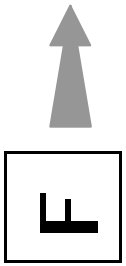


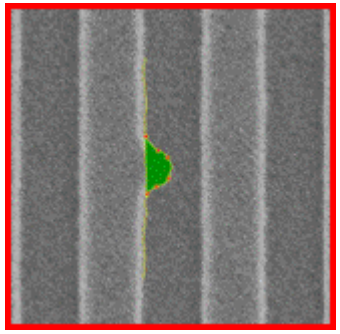
Defect Size (Design) = a

Square shape programmed mask defect for simulation and design

Mask (Measured)



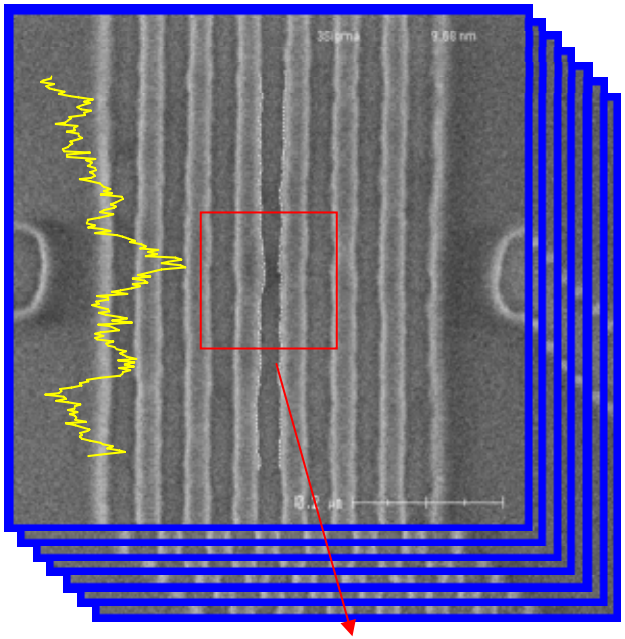


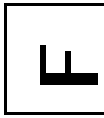


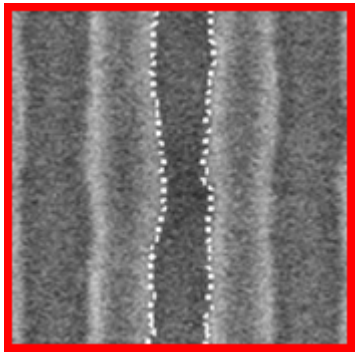
EUV Light

Defect Size = $\sqrt{S}$ (S: Area)

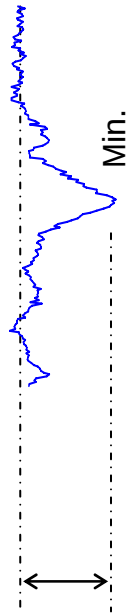
Wafer (Measured)







Averaged CD



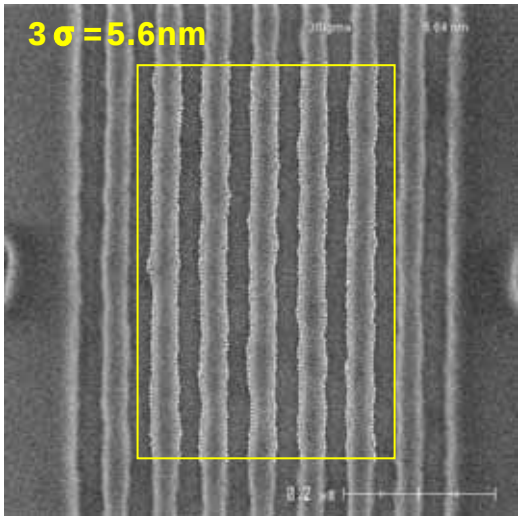
CD at programmed defect

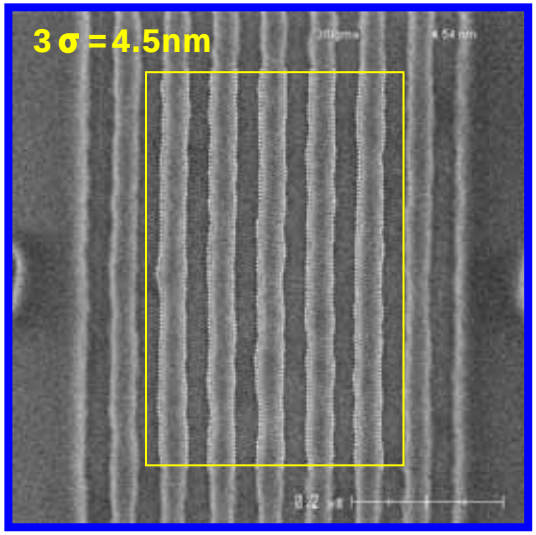
Gauge of LWR, Printed CD at Programmed Defect

Raw data

1 plot: Ave. of 16pixes (21.1nm Length)

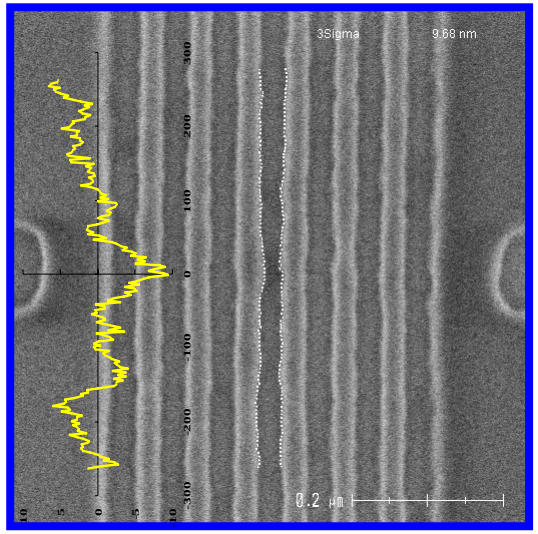
LWR at No Programmed Defect

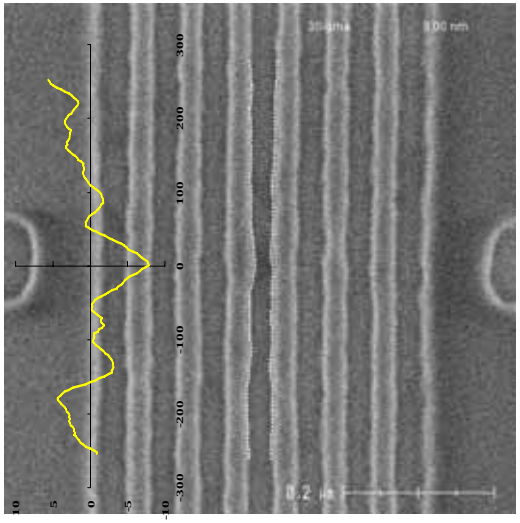




LWR value depends on parameters of CD analysis.

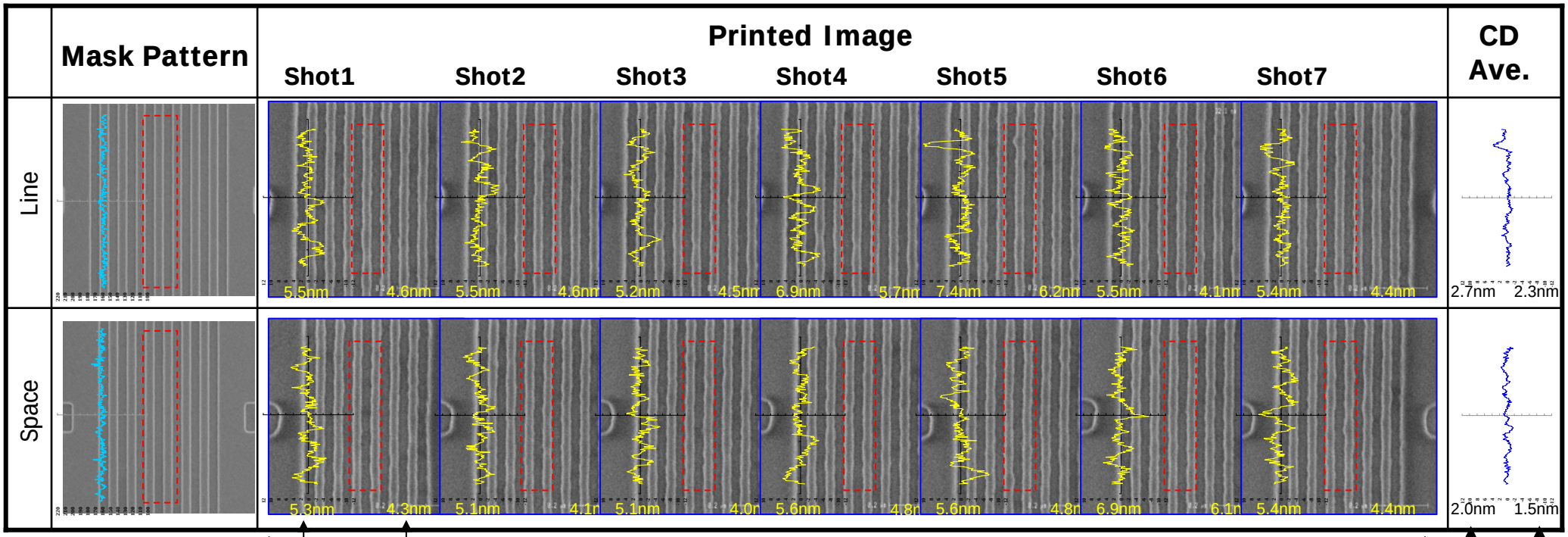
Printed CD at Programmed Defect





Average of 16pixels (21.1nm length) is too large to measure accurate CD at programmed defect.

Mask and Printed Image at No Programmed Defect



LWR (raw data)

LWR (1plot: 21.1nm Length)

LWR of 1 shot: Systematic LWR, $Random1_{shot}$

LWR (raw data)

LWR (1plot: 21.1nm Length)

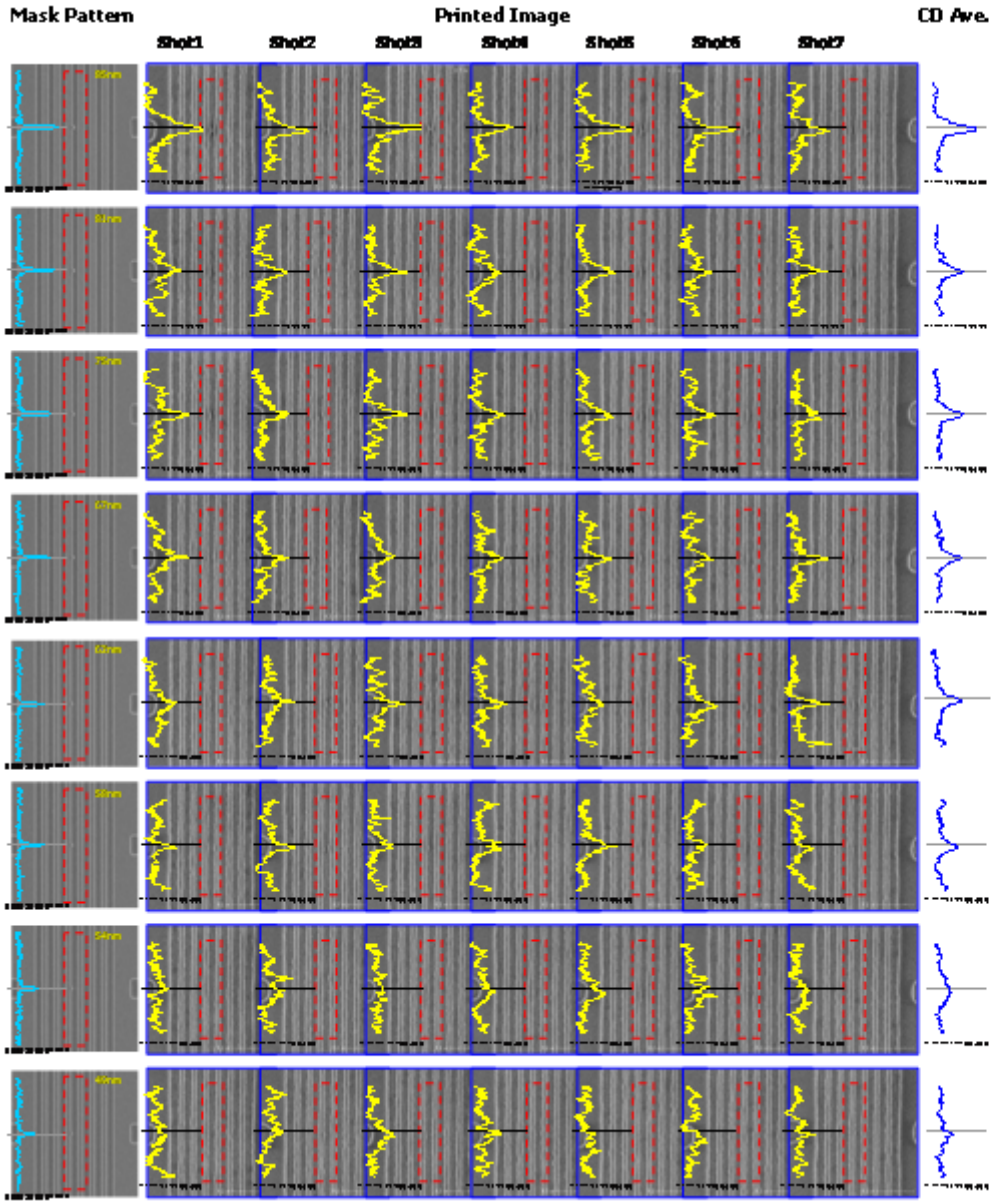
LWR of CD averaging:

Systematic, $Random1_{shot}/\sqrt{N}$ (N: 7shots)

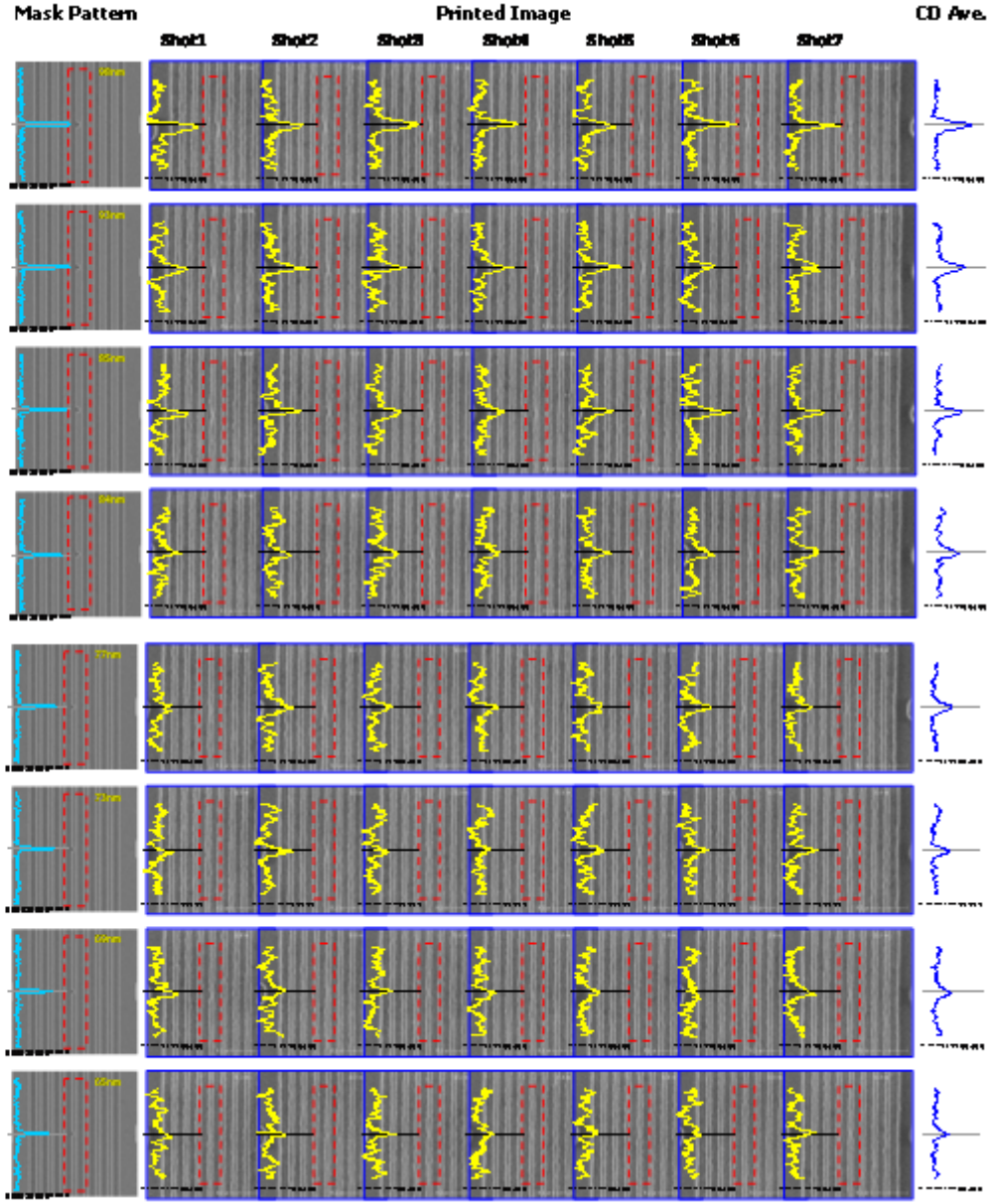
Systematic component of printed LWR of 1shot is smaller than random component and is estimated to be less than 10% of 32HP.

Mask and Printed Image at Programmed Defect

Edge Opaque

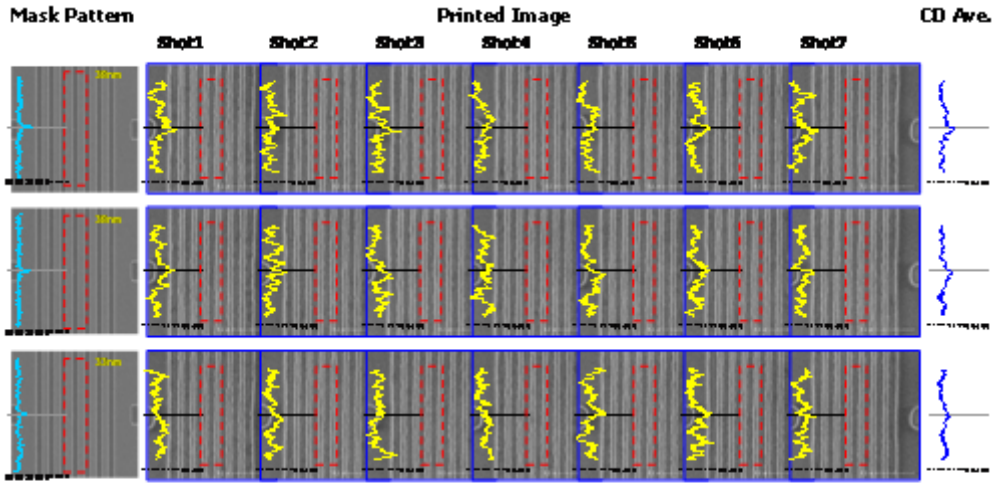


Edge Clear

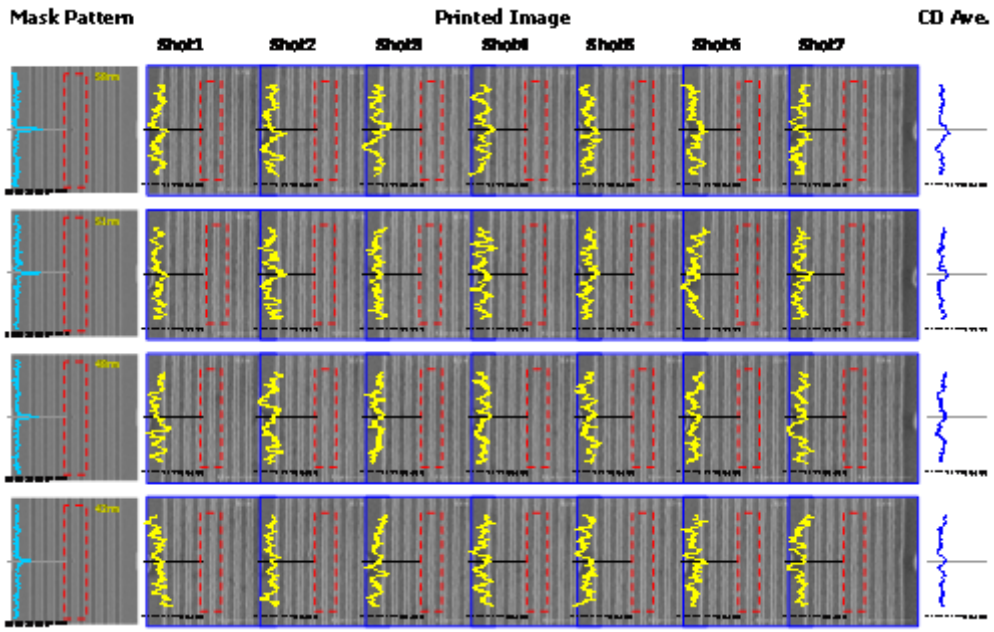


Mask and Printed Image at Programmed Defect

Edge Opaque

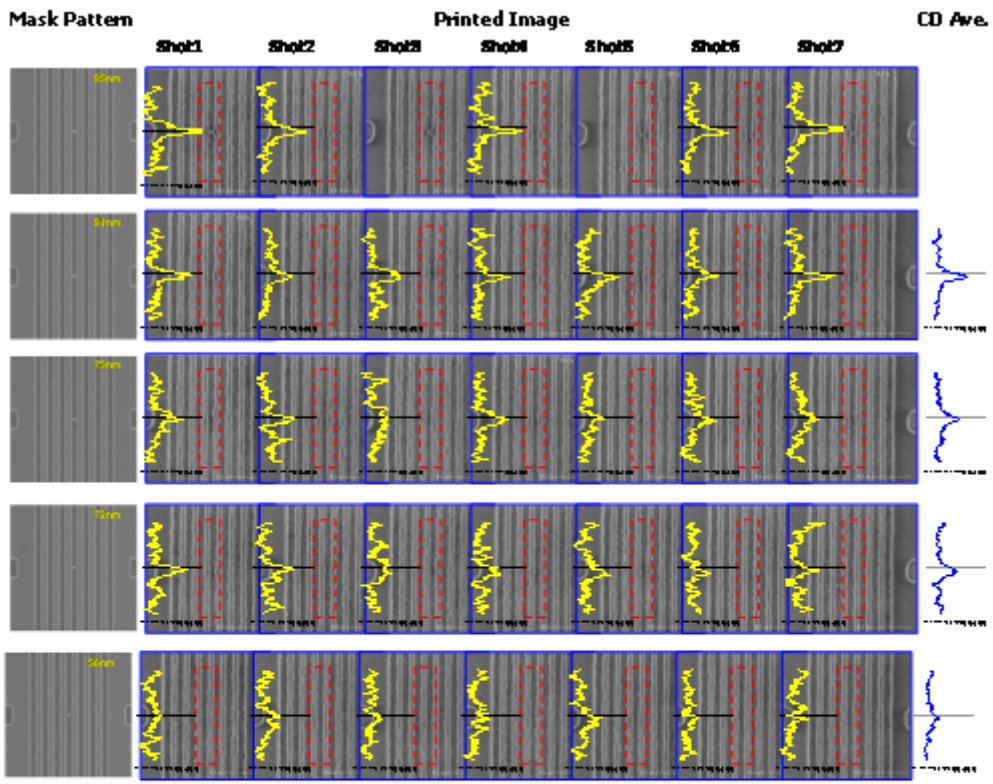


Edge Clear

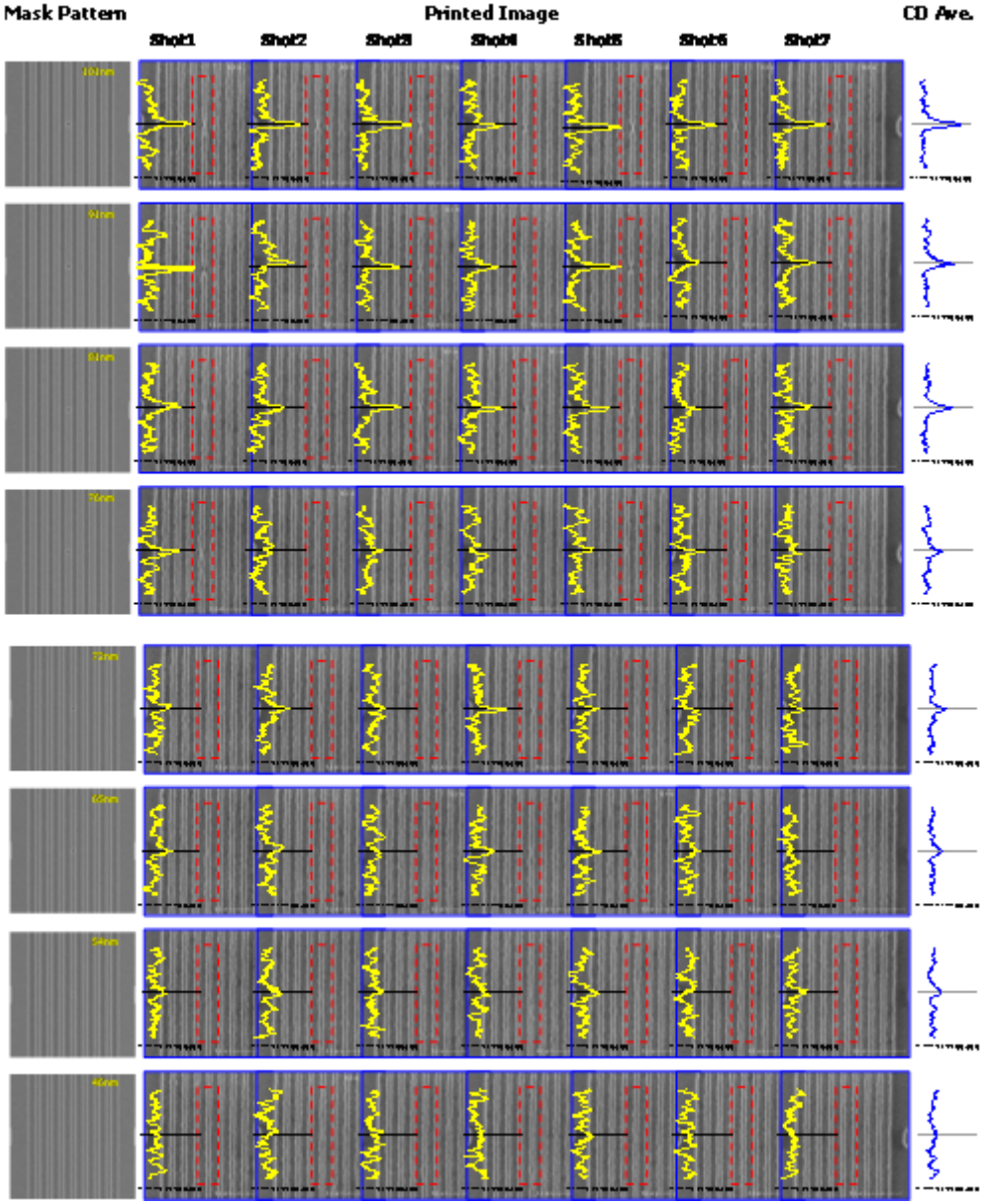


Mask and Printed Image at Programmed Defect

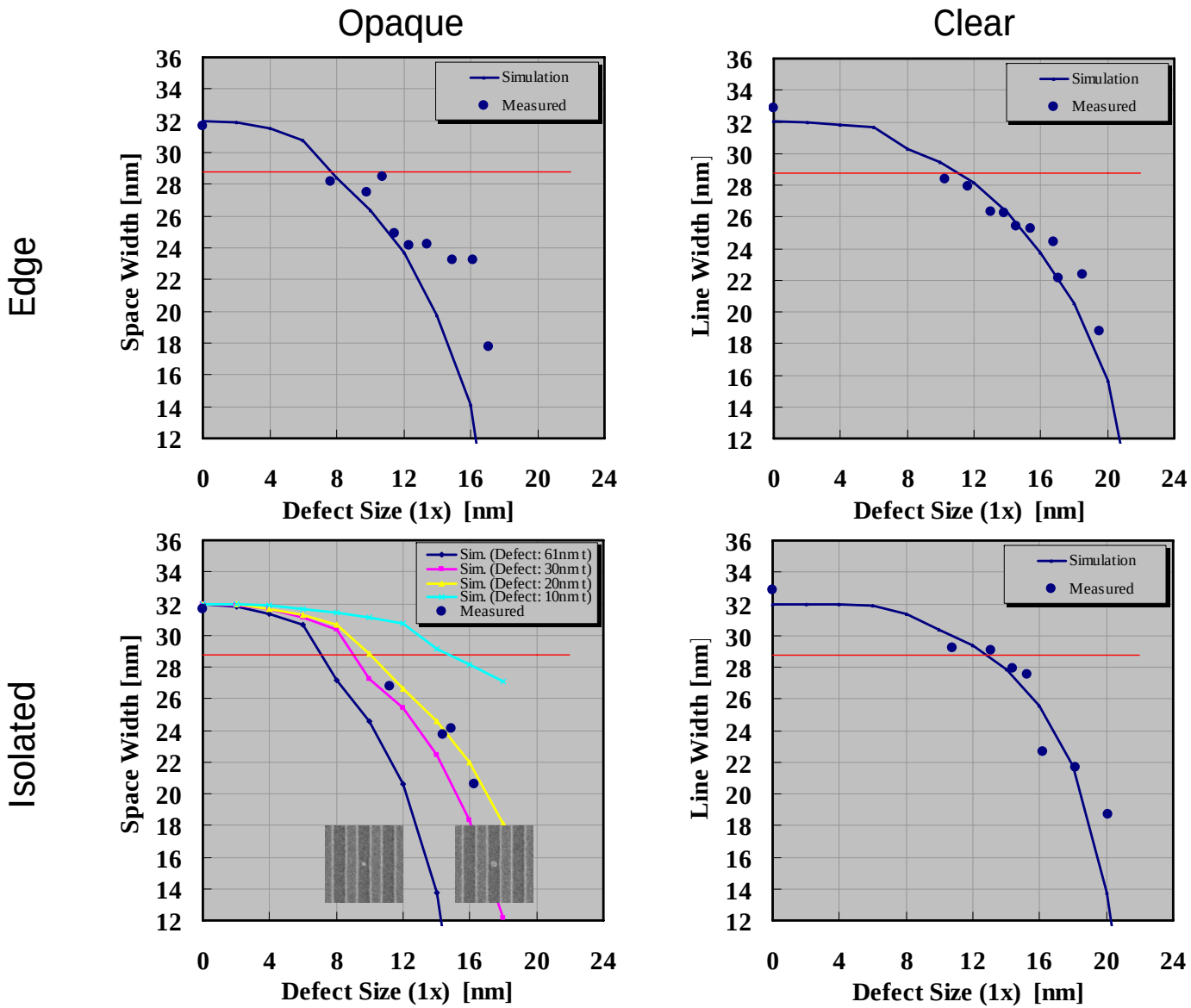
Isolated Opaque



Isolated Clear



Printed CD vs Programmed Mask Defect Size



Except isolated opaque defect, good agreement is achieved between measured and simulated results.
Reduction of isolated opaque defect height is possibly the reason of difference between measured and simulated results.

Summary

With conventional experimental procedure, it is difficult to measure precise critical defect size because printed pattern's line-edge/width roughness (LER/LWR) is larger than the CD tolerance of 32nm HP and beyond.

In order to reduce systematic LER/LWR, mask process is improved.
In order to reduce random LER/LWR, low LER resist material and CD averaging method of multiple exposure shots is introduced.

Systematic component of printed LWR is smaller than random component and is estimated to be less than 10% of 32nm HP.

Except isolated opaque defect, good agreement is achieved between measured and simulated results.
Reduction of isolated opaque defect height is possibly the reason of difference between measured and simulated results.

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