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# Simulation Analysis of Defect Repair Methods for EUVL Mask Blanks

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*Association of Super-Advanced Electronics Technologies  
(ASET)*

*EUV Process Technology Research Laboratory*

*Takeo Hashimoto and Iwao Nishiyama*

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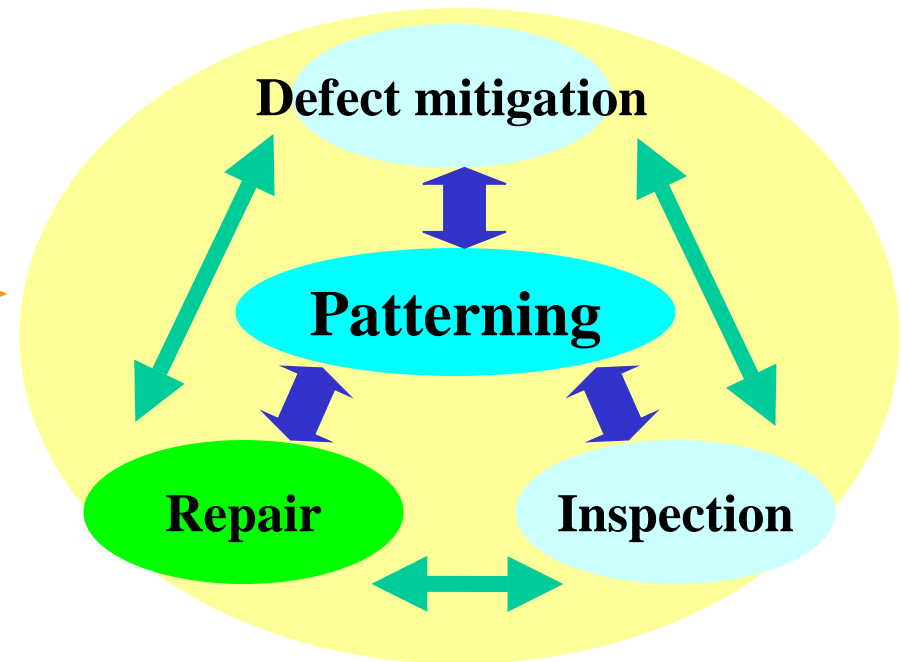
- **Amplitude defect repair**
- **Phase defect repair**
- **Defect covering by absorber pattern**

**5 . Conclusions**

# 1 . Background (1) -Critical issues for EUVL-

## Critical issues for EUVL

1. Source power and lifetime including condenser optics lifetime
- 2. Availability of defect free masks** →
3. Reticle protection during storage, handling, and use
4. Projection and illumination optics lifetime and contamination
5. Resist resolution, sensitivity, and LWR
6. Optics quality for 32nm node



Mo/Si Multilayer Mask Blanks

# 1 . Background ( 2 ) - Defect mitigation -

## Recent progress for defect mitigation

### SEMI P38 – 1102

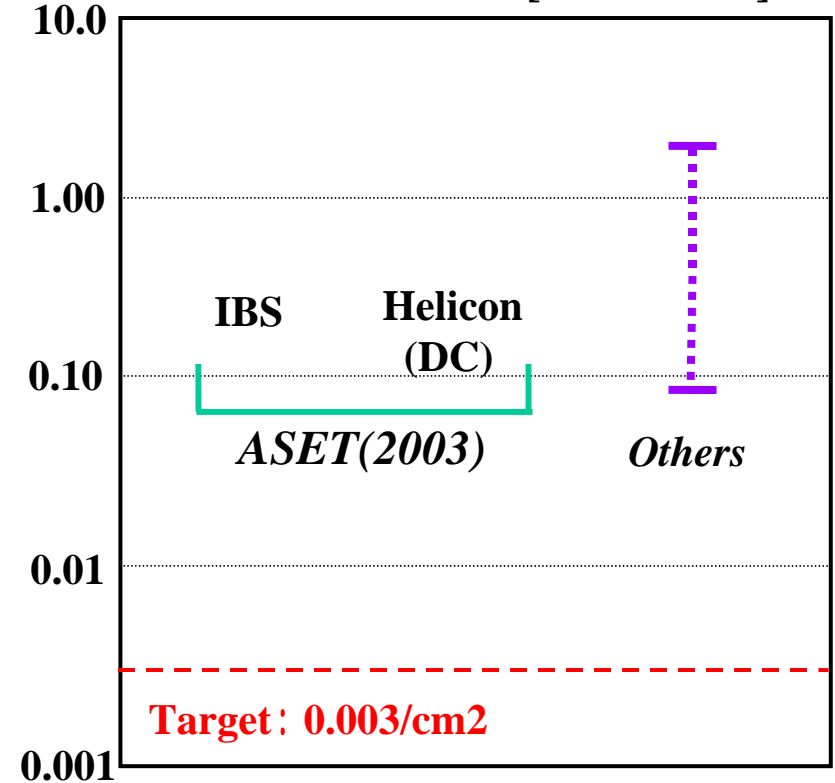
#### Defect requirements for multilayer stack

Class	PSL equivalent range (nm)	Maximum defect count
A	> 25	0
B	> 30	0
C	> 40	0
D	> 60	Agreed upon between user and supplier

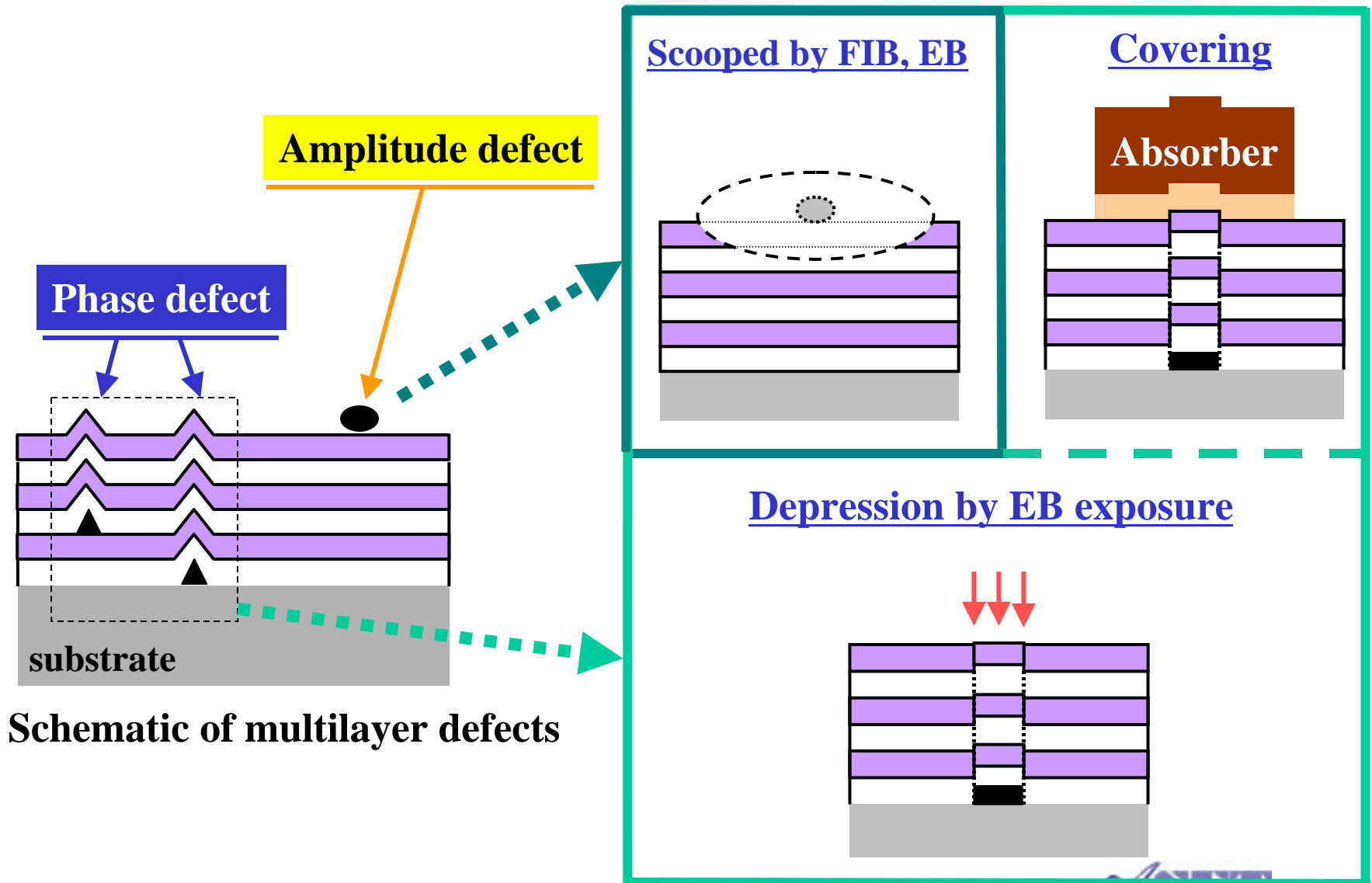
Defect density

( /cm<sup>2</sup>)

[>120-70nm ]



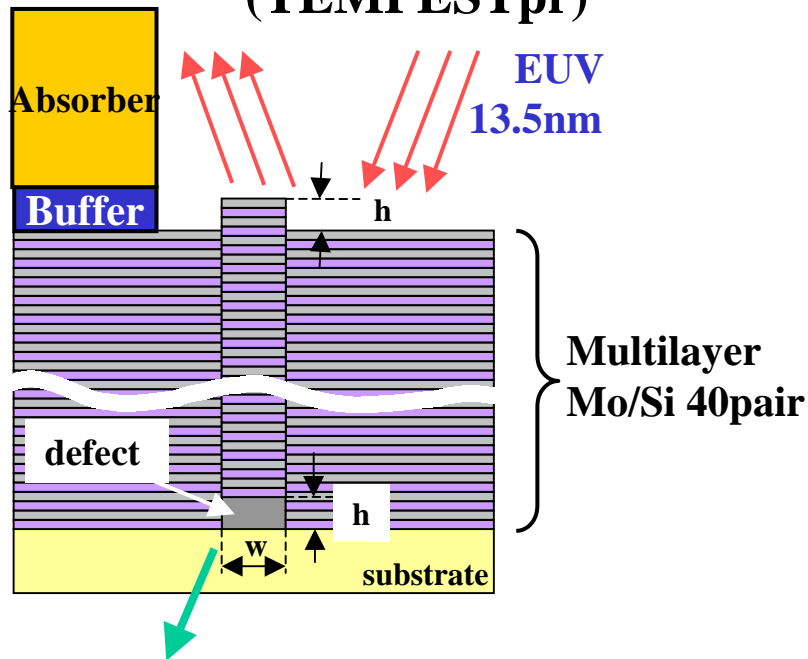
## 2 . Blanks repair methods



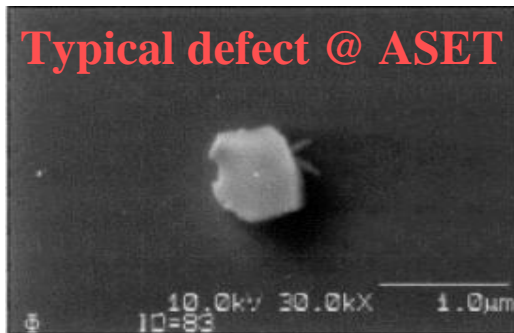
# 3 . Simulation method

Simulator: EM-Suite

(TEMPESTpr)



Typical defect @ ASET



Multilayer

Mo/Si pair: 40

d-spacing: 6.95nm(nominal)

: 0.4

Exposure tool

: 13.5nm

NA/ : 0.25/0.80

Incident angle: 6°

Magnification: x4

Mask structure

Buffer : Cr 10nm

Absorber: TaGeN 70nm

Cap : Non

Contrast : More than 100

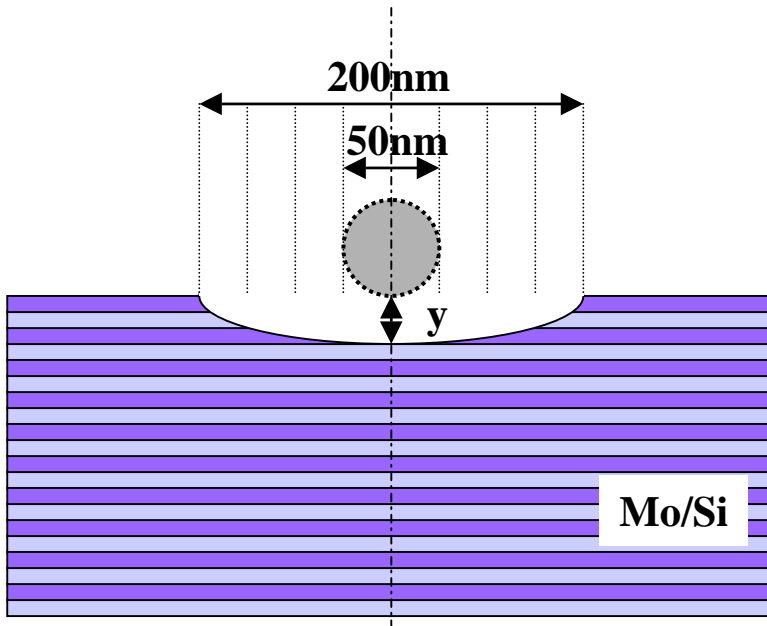
ASET

EUV Process Technology

# 4 . 1 . Amplitude defect repair ( 1 )

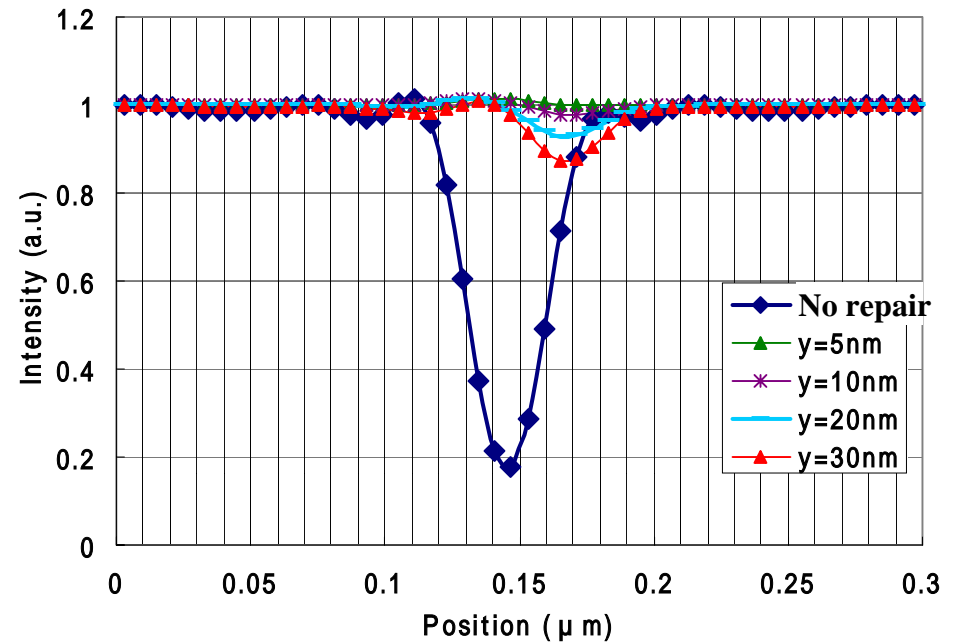
Scooped with FIB, EB and RAVE

Defect: 50nm , Mo



Aerial image after scooping repair

Crater depth dependency

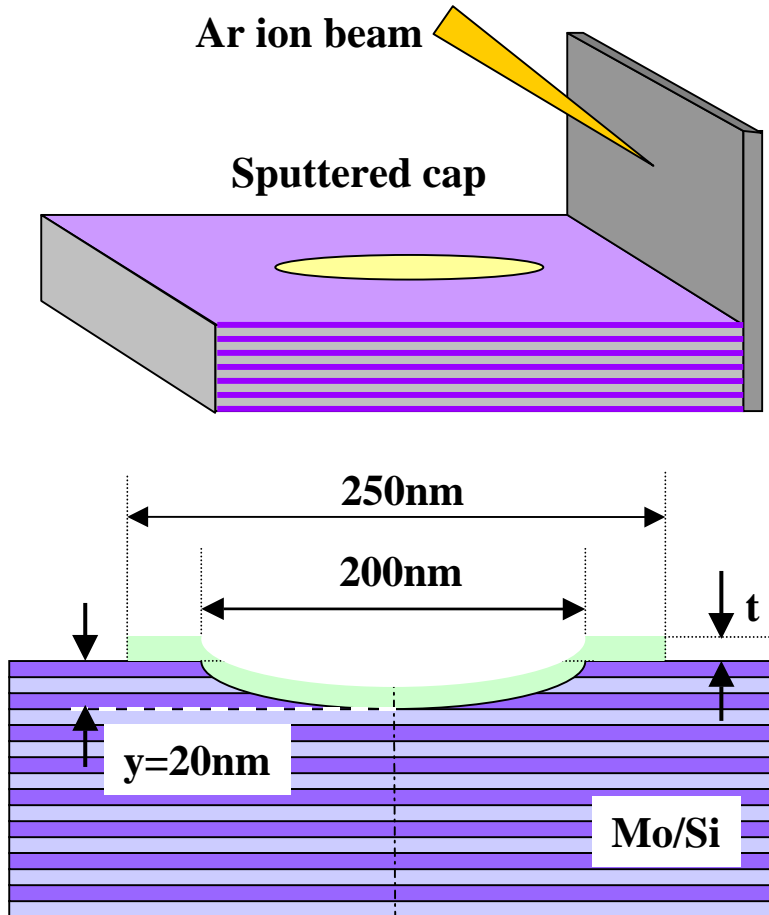


The intensity degradation is small in case of crater depth less than 20nm.

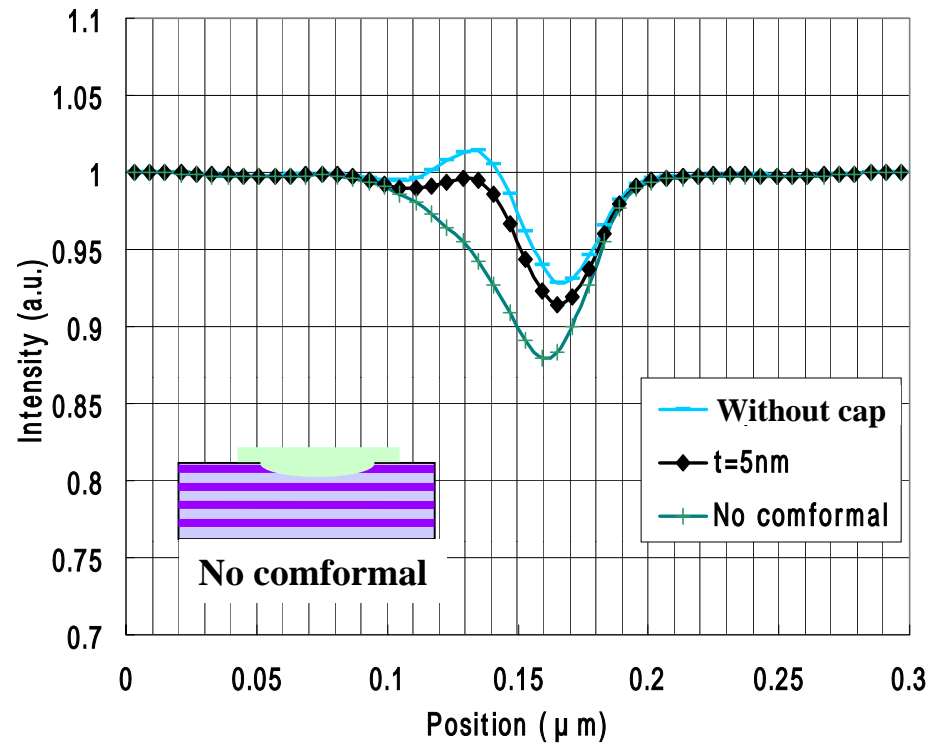
# 4 . 1 . Amplitude defect repair ( 2 )

## The effect of capping layer formation on a crater

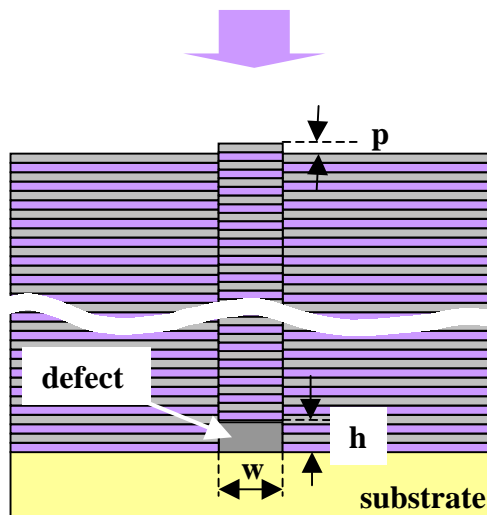
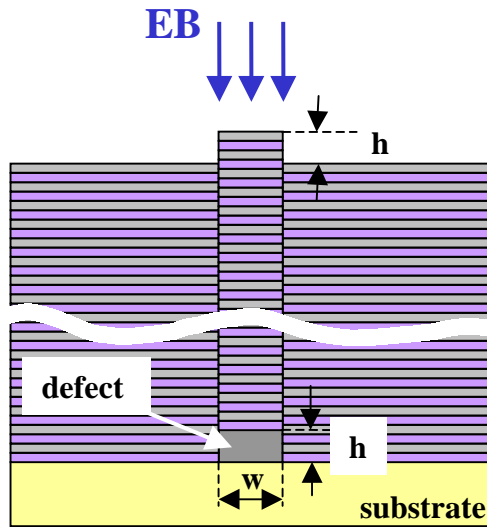
A. Barty et al. (SPIE 2002)



Cap material: Si  
Thickness:  $t=5\text{nm}$



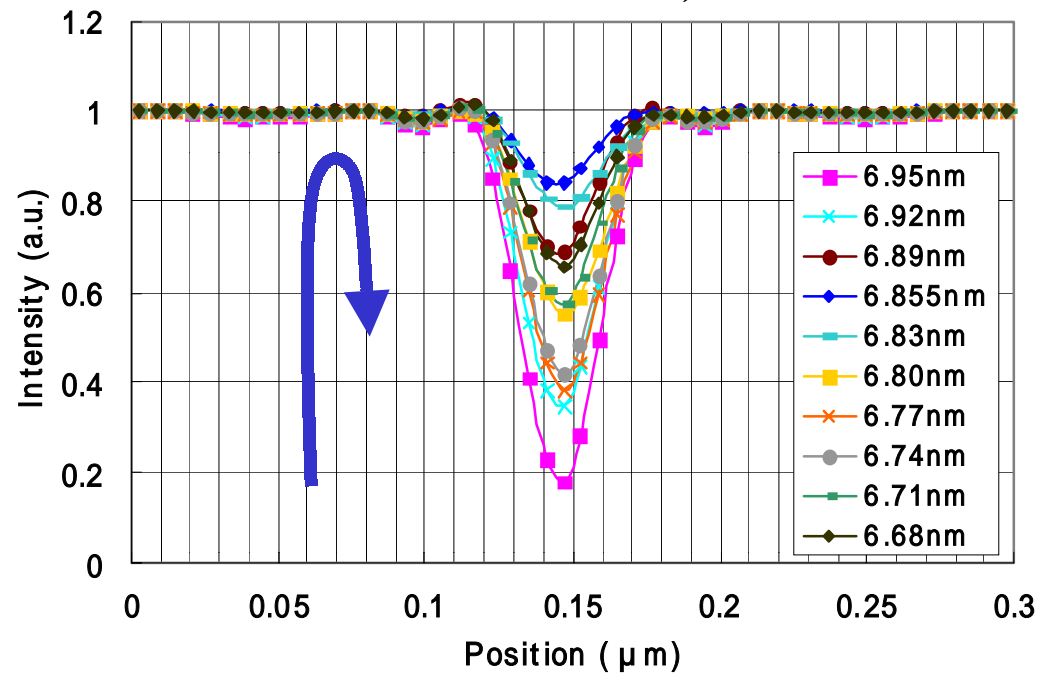
# 4 . 2 . Phase defect repair by EB exposure ( 1 )



No smoothing effect

Initial  $d : 6.95\text{nm}$   $\xrightarrow{\text{EB}}$  contraction

Defect size:  $h=10\text{nm}$ ,  $w=40\text{nm}$



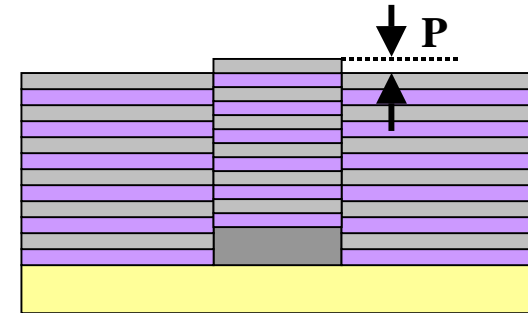
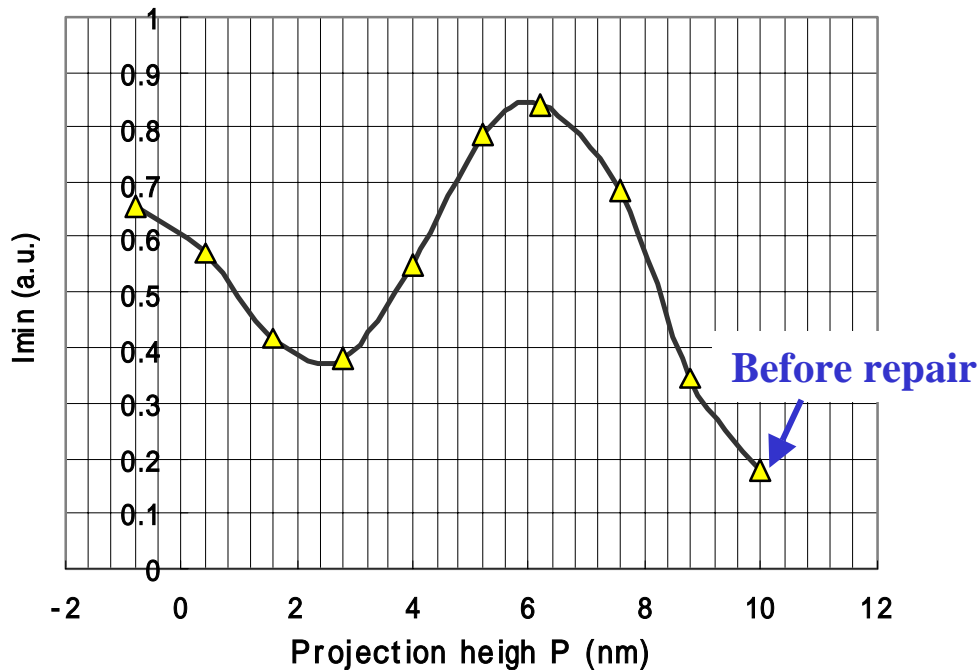
$I_{\text{min}}$  is recovered by d-spacing contraction due to EB exposure.

# 4 . 2 . Phase defect repair by EB exposure ( 2 )

## I<sub>min</sub> of aerial image after EB repair

### Defect size

h=10nm, w=40nm, on substrate



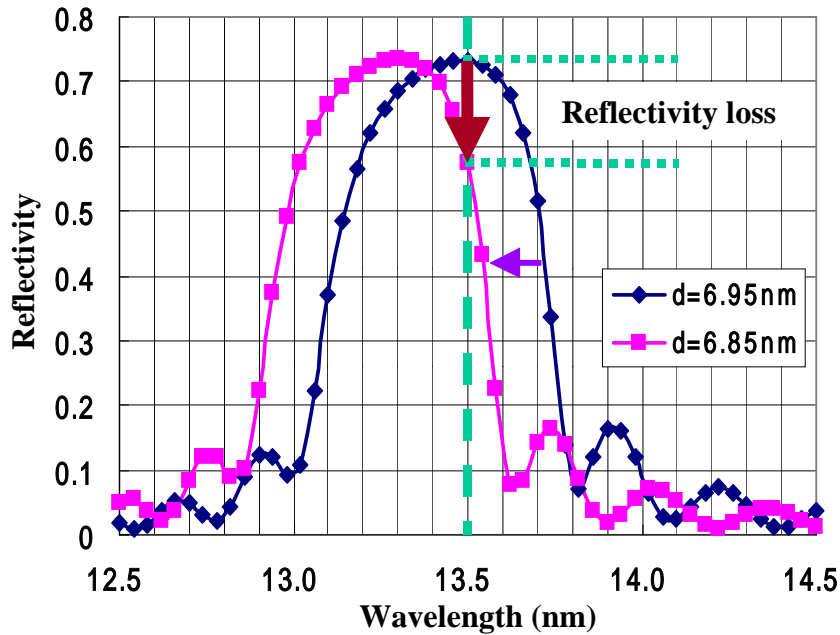
## The reason for insufficient recover of I<sub>min</sub>.

**Reflectivity loss accompanied by d-spacing reduction**

**Structure distortion inside multilayer stack (even though the surface of multilayer is flat.)**

# 4 . 3 . Phase defect repair method taking account of d-spacing reduction ( 1 )

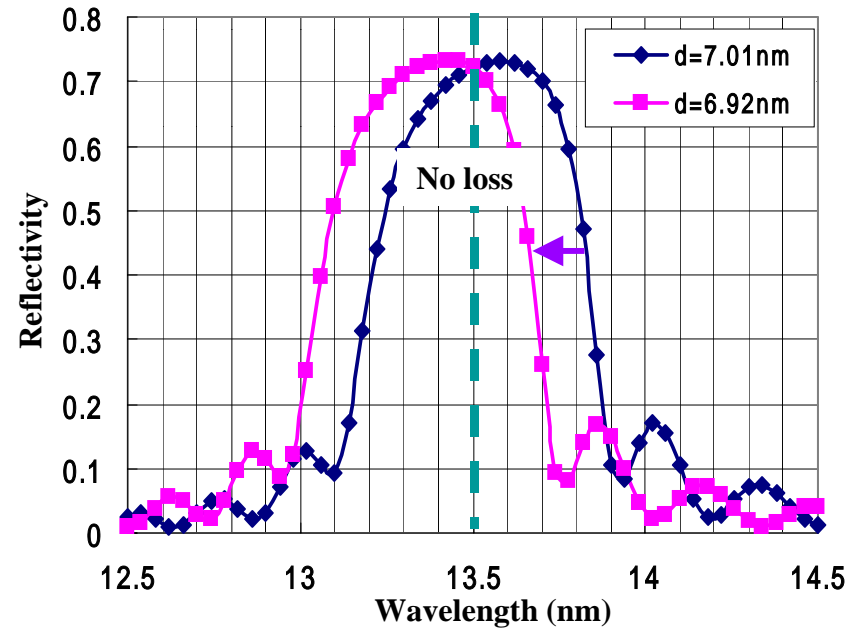
## Reflectivity loss



Initial d-spacing: 6.95nm

➡ After repair: 6.85nm

## No reflectivity loss



Initial d-spacing: 7.01nm

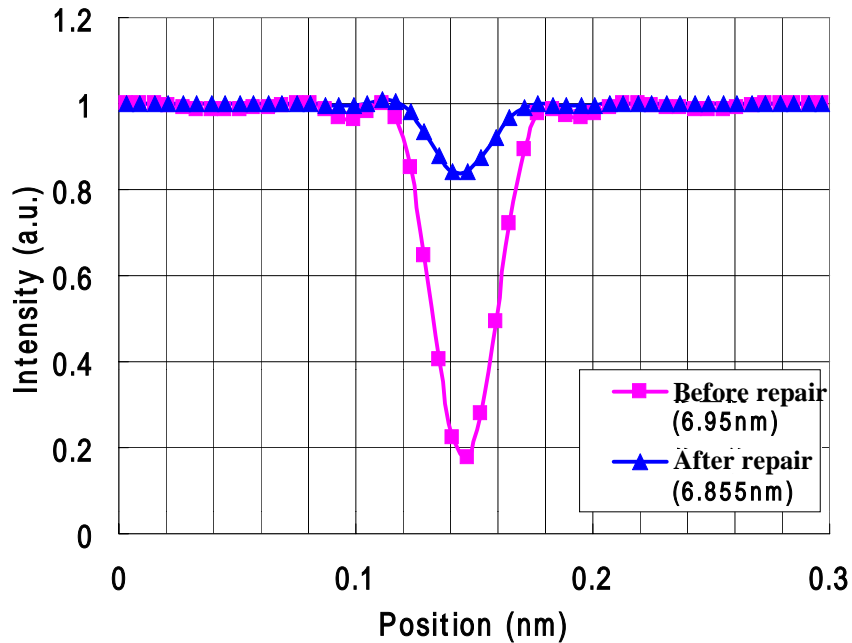
➡ After repair: 6.92nm

# 4 . 3 . Phase defect repair method taking account of d-spacing reduction ( 2 )

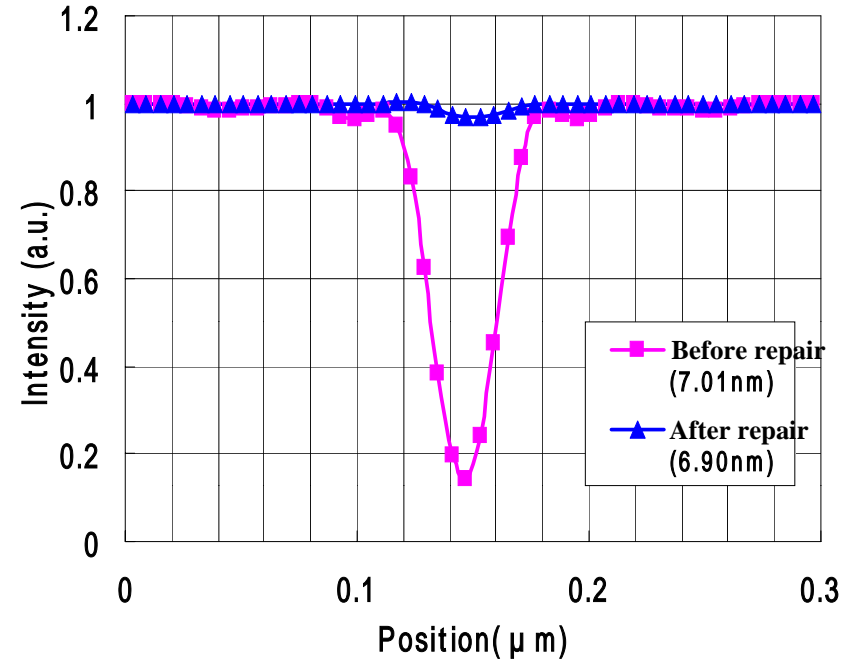
Defect on substrate (at the bottom of multilayer)

Defect size:  $h=10\text{nm}$ ,  $w=40\text{nm}$  (on Mask)

Initial d-spacing: 6.95nm



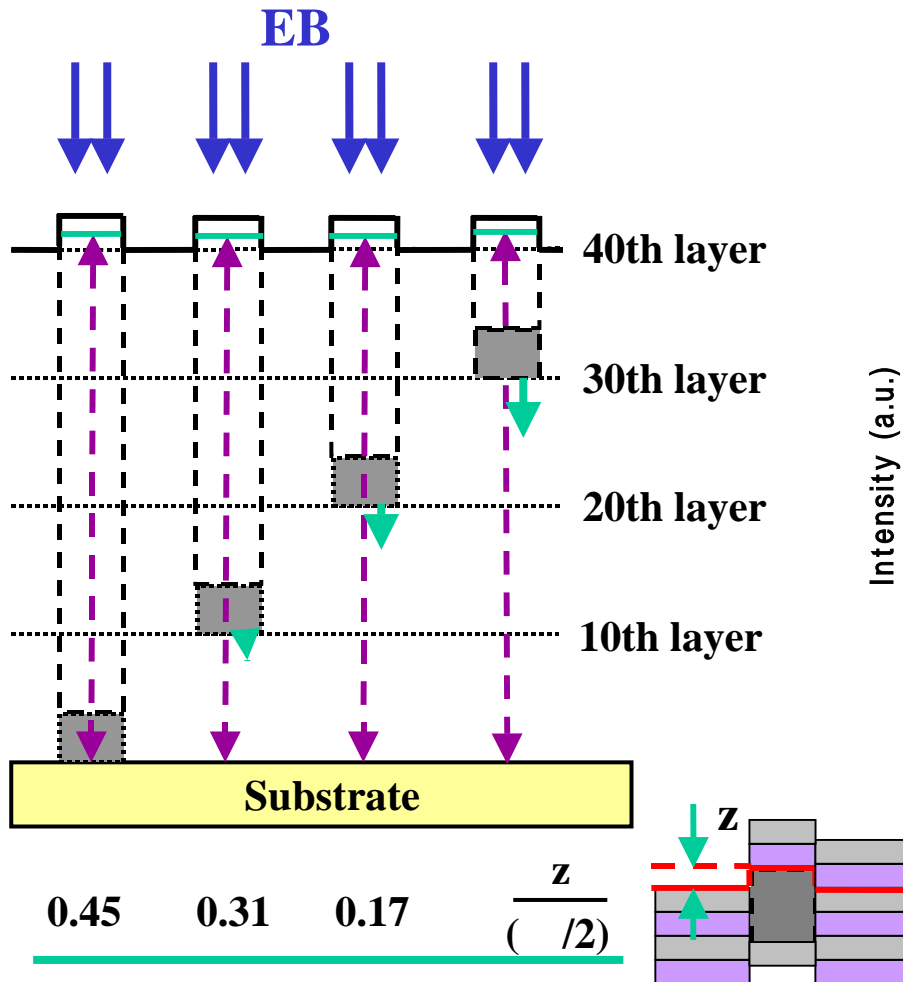
Initial d-spacing: 7.01nm



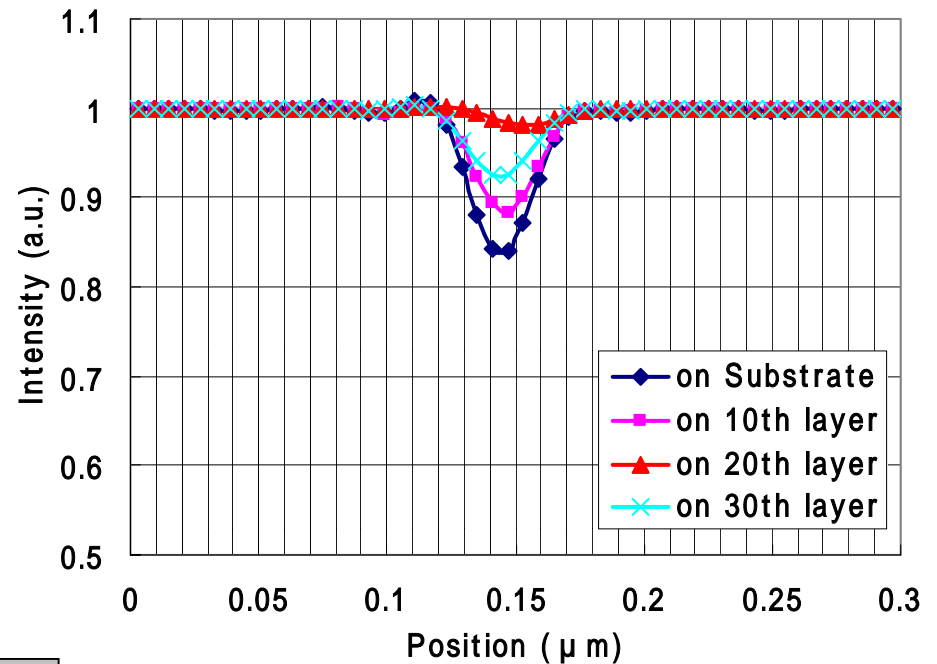
**Imin. of aerial image recovers sufficiently by taking account of initial d-spacing.**

# 4 . 4 . Effect of EB repair for defects in multilayer

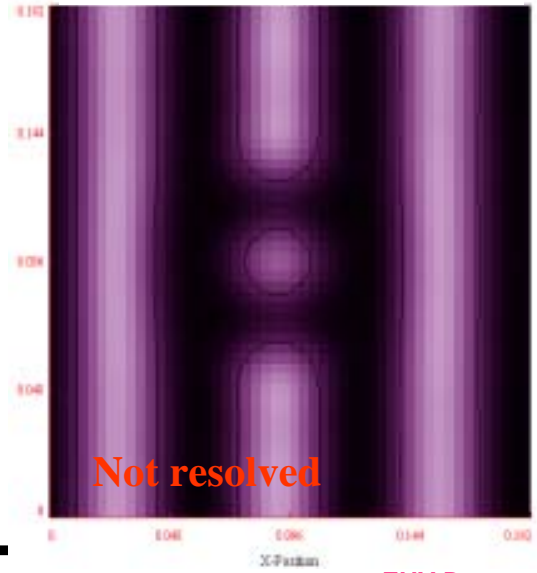
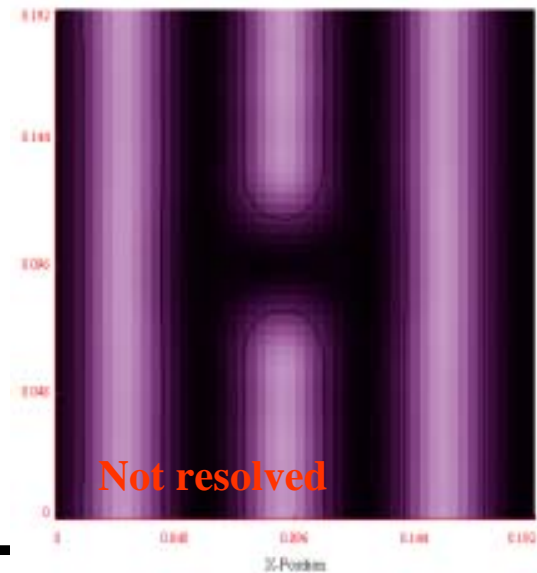
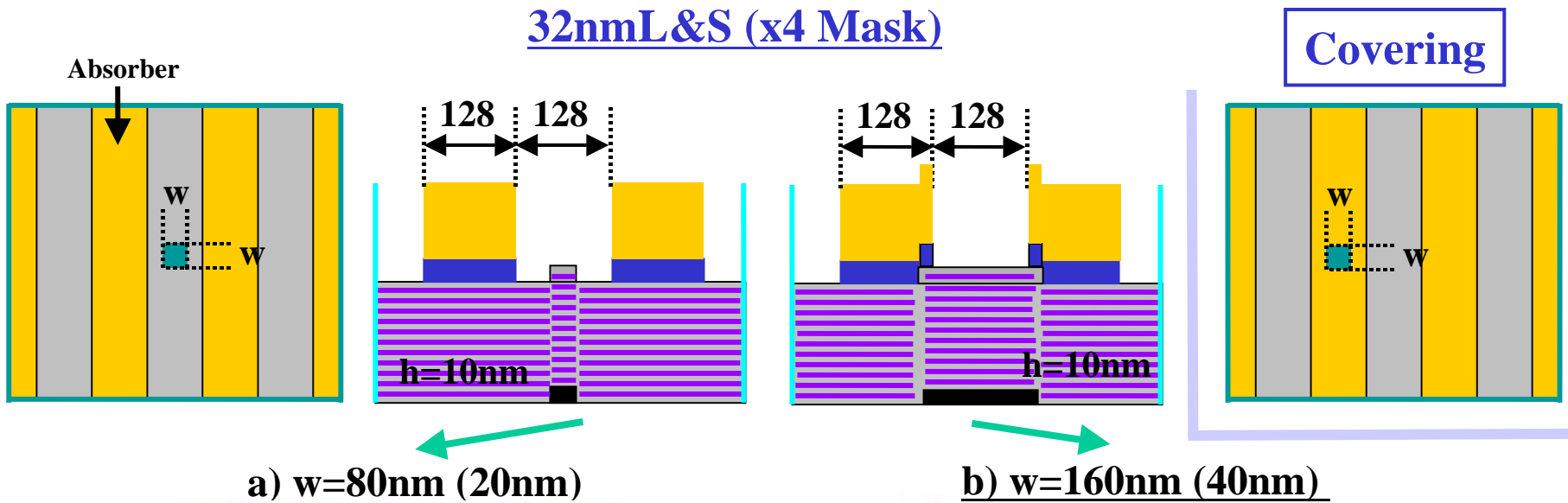
Defect size:  $h=10\text{nm}$ ,  $w=40\text{nm}$



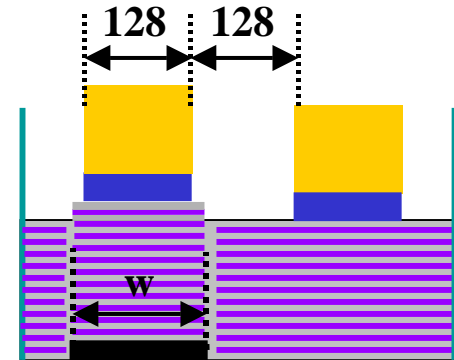
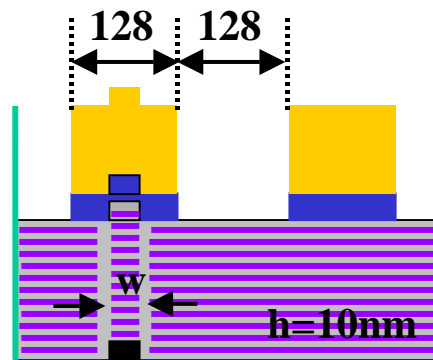
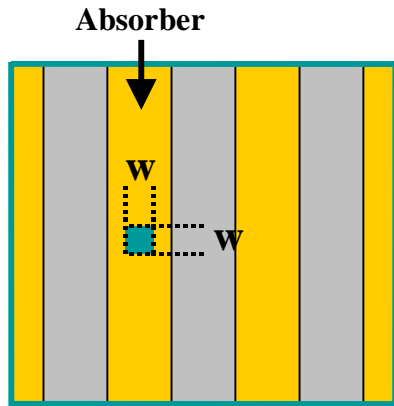
Aerial image for optimized contraction of d-spacing



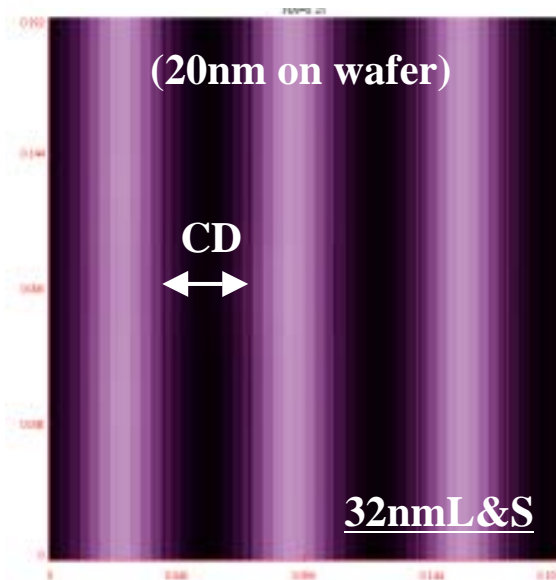
# 4 . 5 . Defect covering by absorber pattern ( 1 )



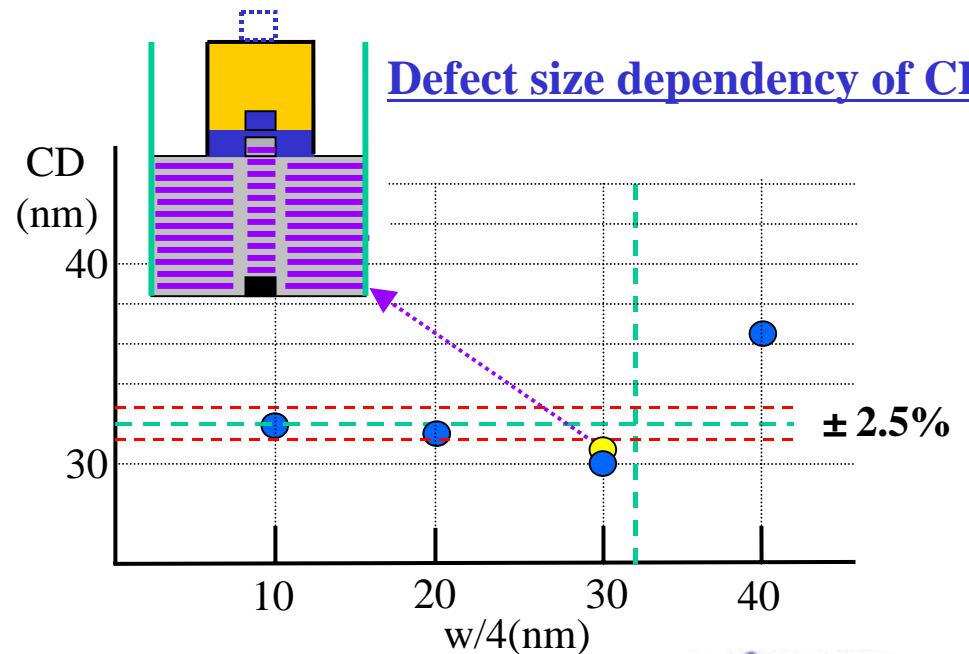
# 4 . 5 . Defect covering by absorber pattern ( 2 )



w=80nm intensity distribution



Defect size dependency of CD



# 5 . Conclusions

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- 1 . 3 kinds of defect repair methods for multilayer mask blank were evaluated through aerial image simulations. It was confirmed that they were effective for amplitude and phase defect repair.
- 2 . If defect density of mask blank is close to the target value in future, the defect covering by absorber pattern will be especially effective.
- 3 . Defect repair will be a useful countermeasure for EUVL mask blank defect issues.

## Acknowledgement

**This work was supported by NEDO.**