Extension of the mask lifetime and reduction of the line width variation by using the extreme ultraviolet pellicle

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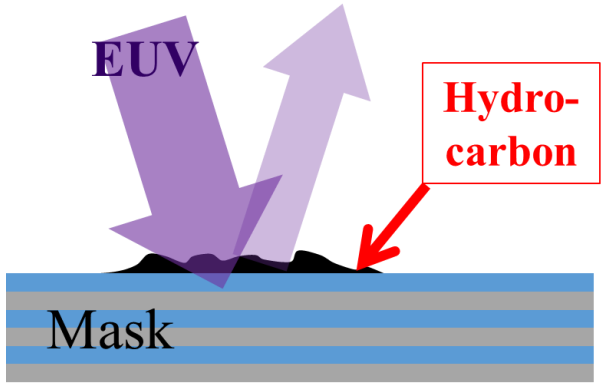
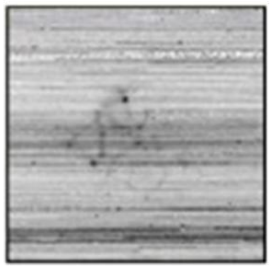
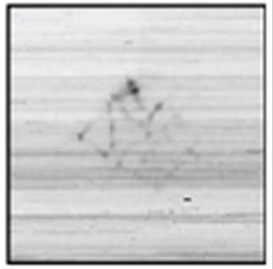
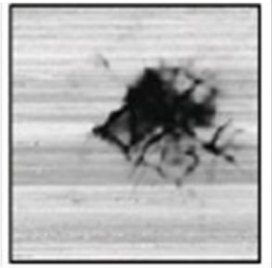
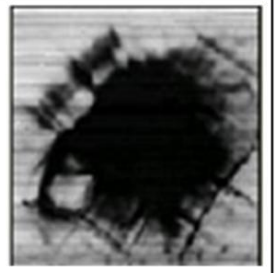
Introduction

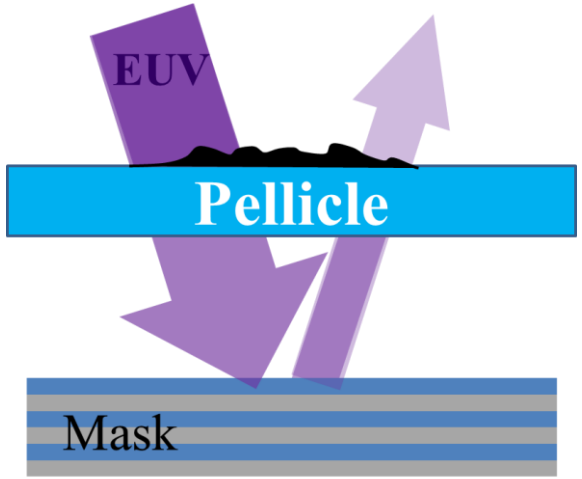
- **EUV Mask damage caused by carbon contamination**



Exposure time	5 Min	10 Min	20 Min	2 Hr
Blank mask w/ carbon contamination				
Reflectivity loss	Ignore		~ 1%	~ 6%

Ref) Han-Shin Lee et.al., "Effect of EUV exposure upon surface residual chemicals on EUV mask surface.", Proc. of SPIE Vol. 7748, 774804

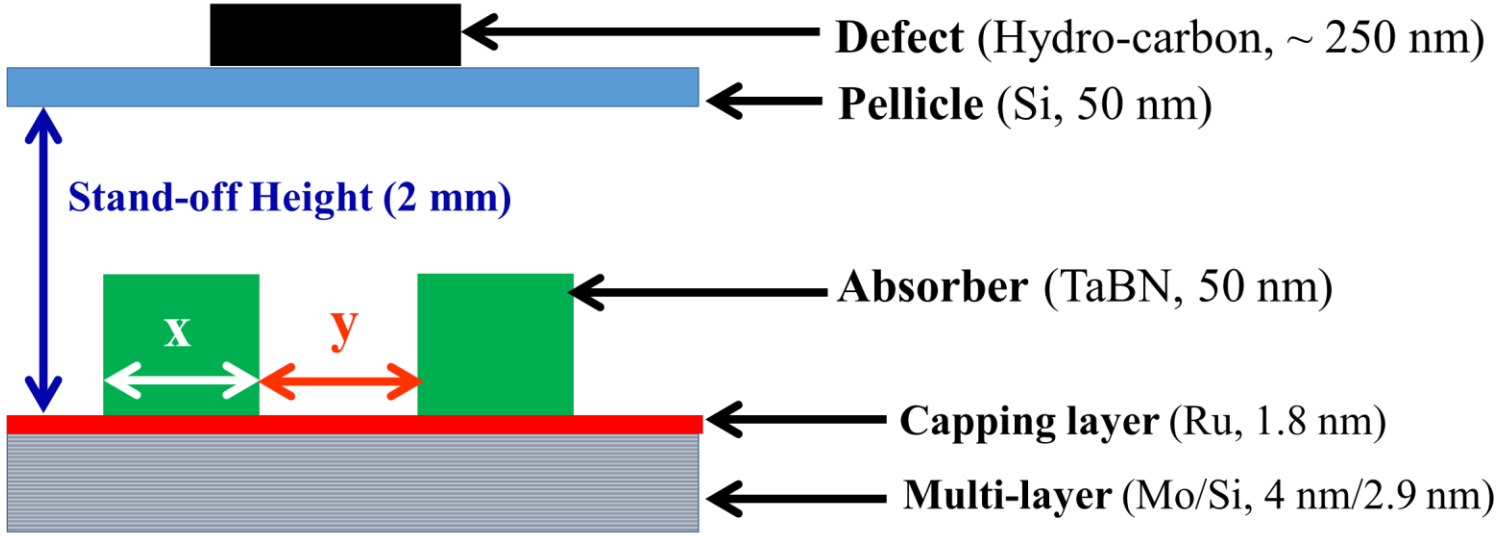
- **Consideration of the EUVL Pellicle**



- **Pellicle protects the mask from the contamination**
  → **Extend mask lifetime !!**
- **However, pellicle has problems such as**
  - **Transmission loss**
  - **Process latitude loss**
  - **CD variation caused by defects**

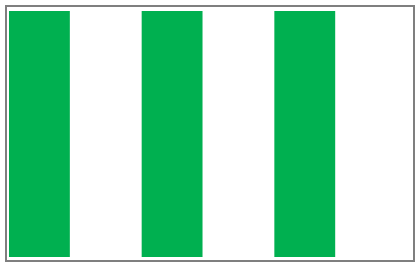
Is it OK?

Simulation Conditions

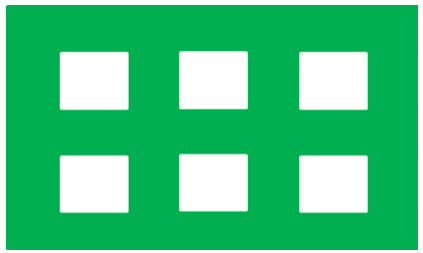


	Pattern size	X : Y
Line & Space	22 nm	1:1 ~ 1:9
Contact Hole	28 nm	1:1

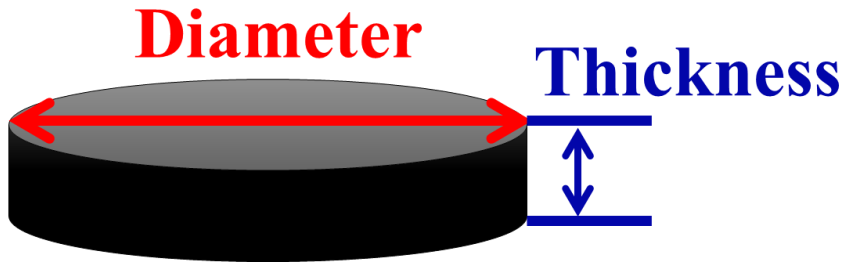
Material	Thickness	Diameter
Hydro-carbon ($C_5H_8O_2$)	0 ~ 250 nm	0 ~ 10 μm



<Line & Space>

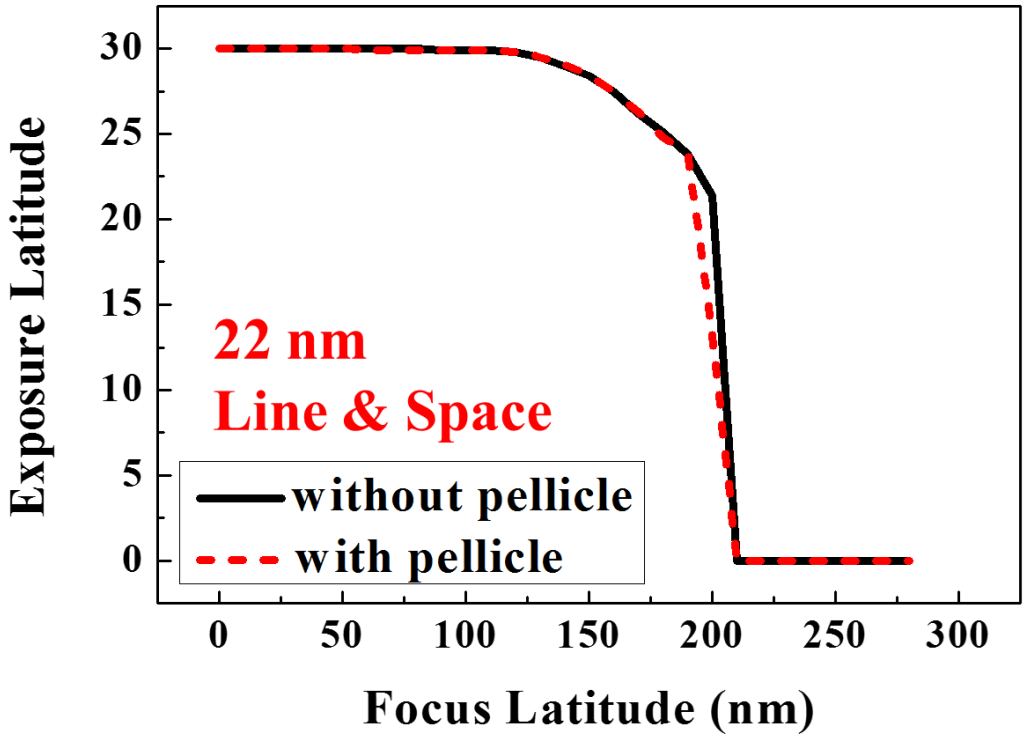


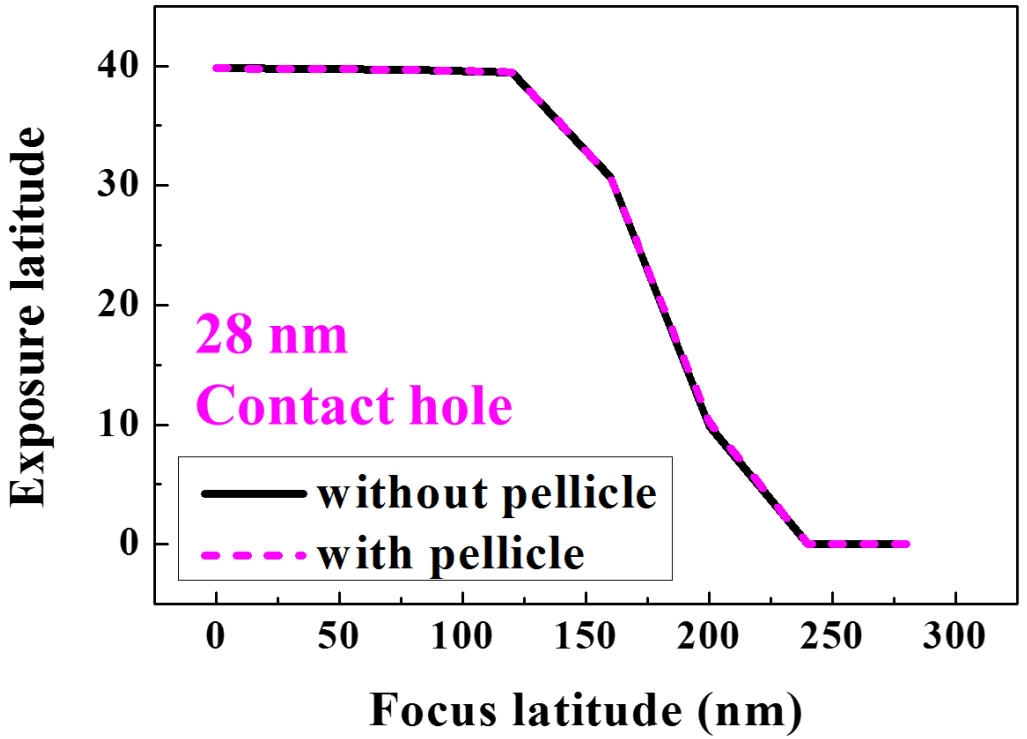
<Contact Hole>



Effect of existence of the pellicle

❖ **Process latitude variation caused by pellicle**

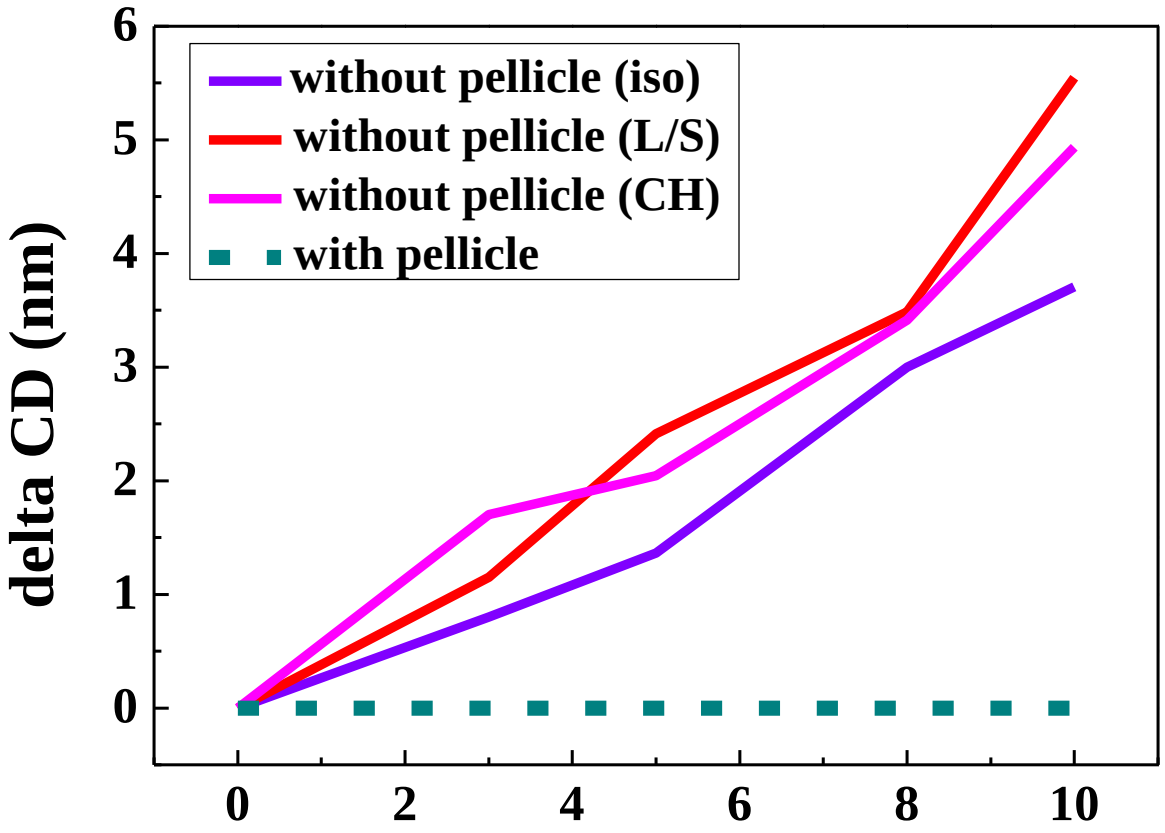


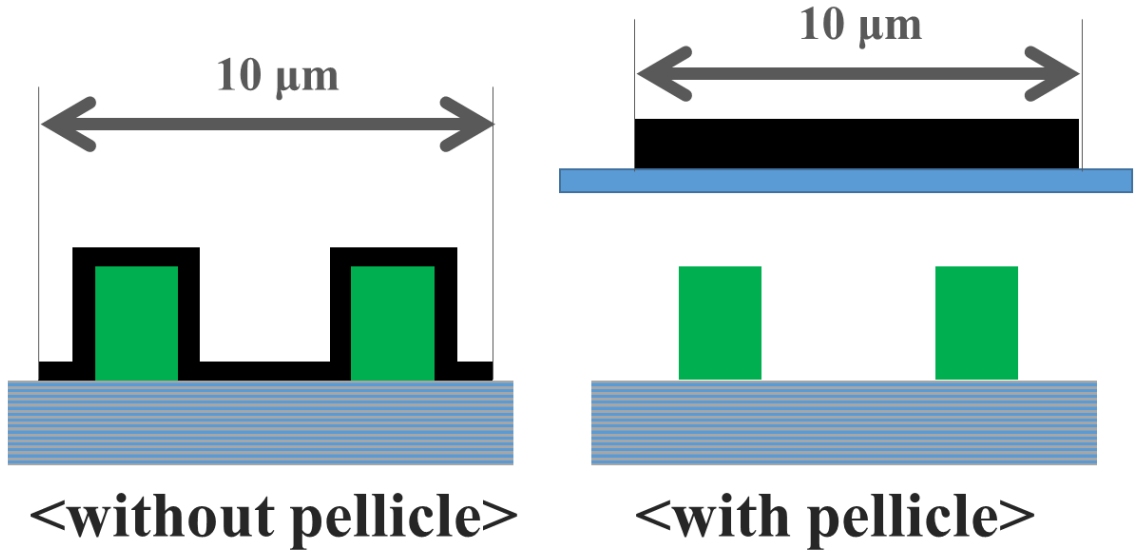


➢ **Even though the pellicle absorbs EUV light, the pellicle makes little change of the process latitude.**

Effect of existence of the pellicle

❖ **Influence of conformal contamination in terms of CD variation**

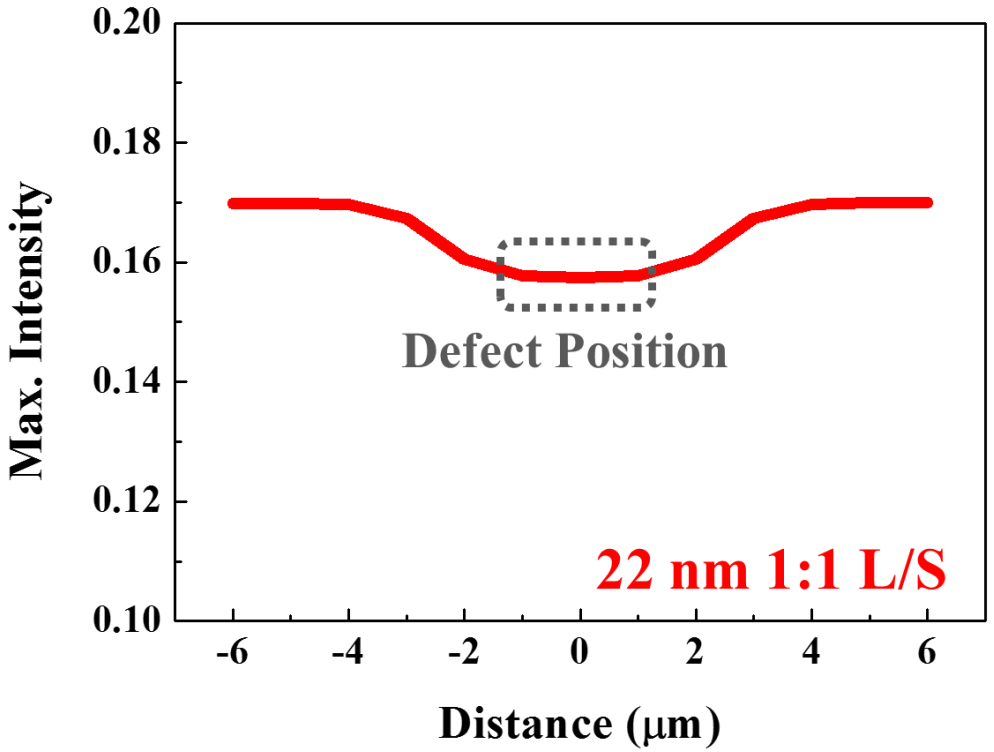


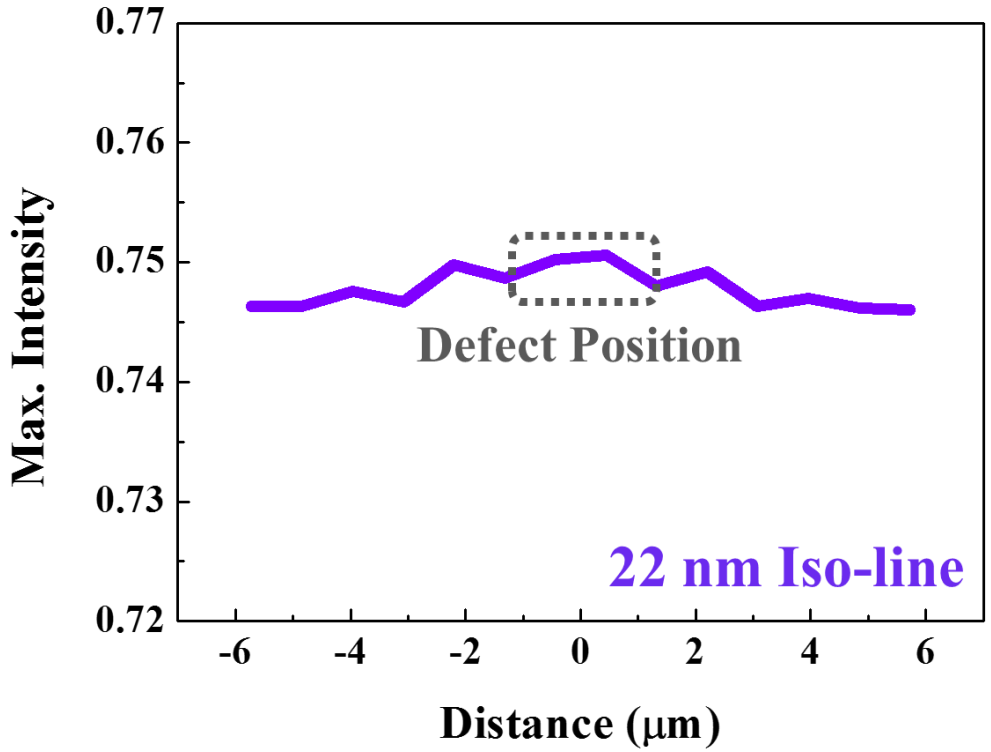


➢ **By applying the pellicle, we can reduce the effects of the contaminant dramatically.**

Influence of the defect on the pellicle

❖ **Intensity variation caused by defect (Dense L/S vs Iso-line)**



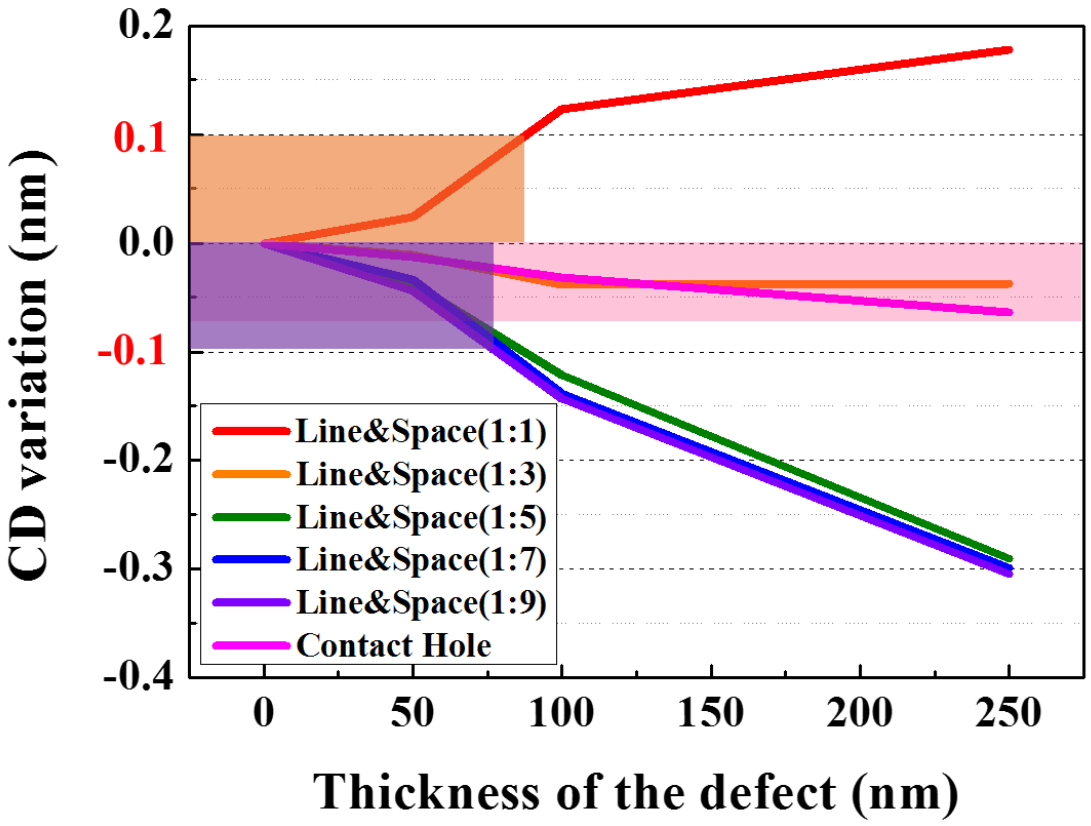


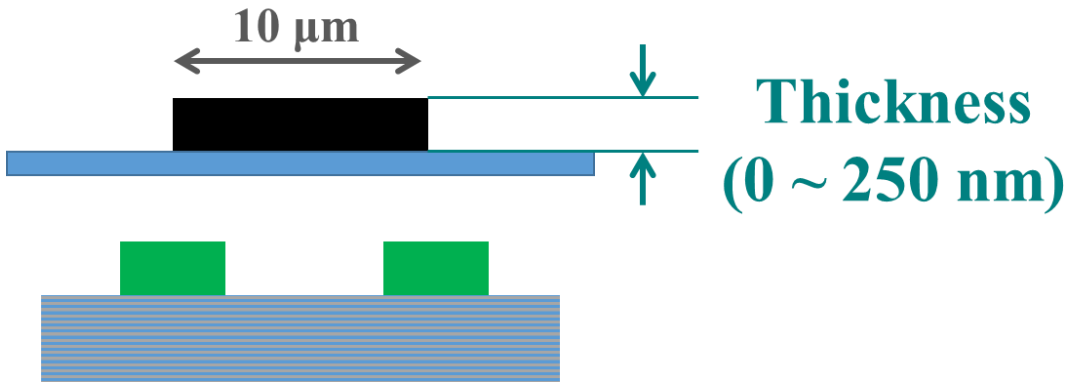
➢ **Defect placed on top of the pellicle leads intensity increase for the isolated line, while the intensity is decreased for the dense line & space.**

Influence of the defect on the pellicle

❖ CD variation caused by defect (22 nm L/S (1:1~1:9), 28 nm CH)

- CD variation with defect diameter



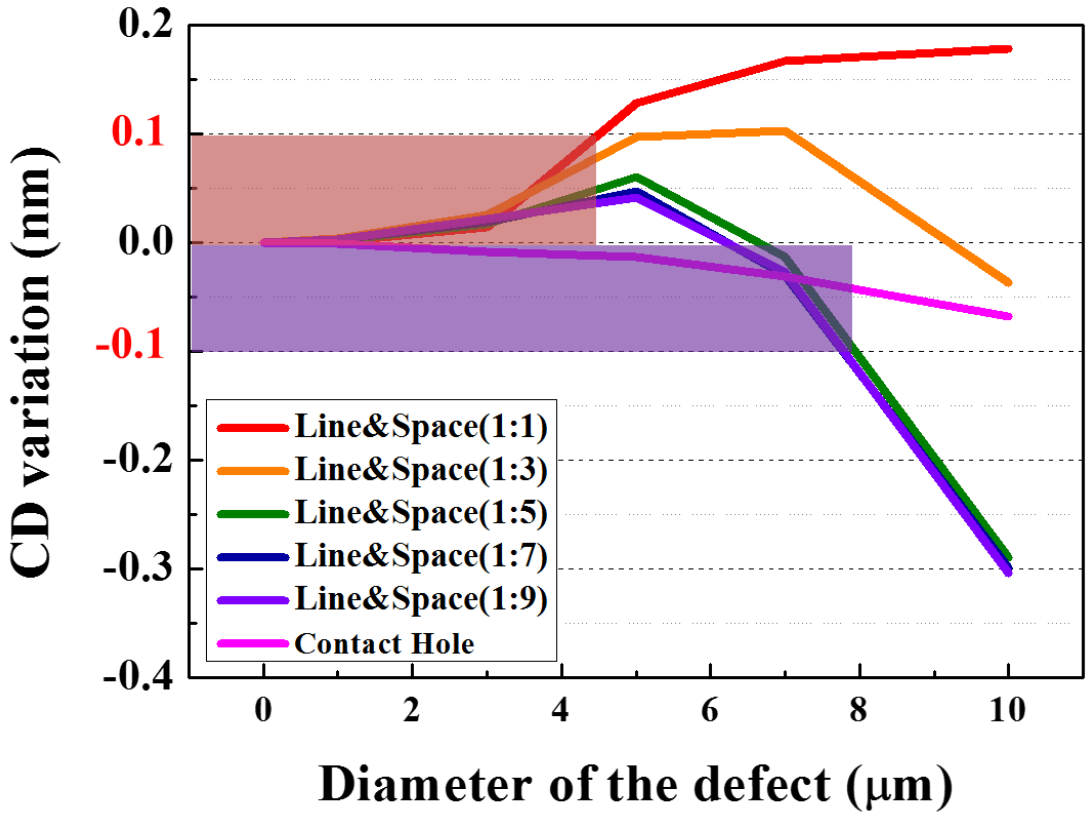


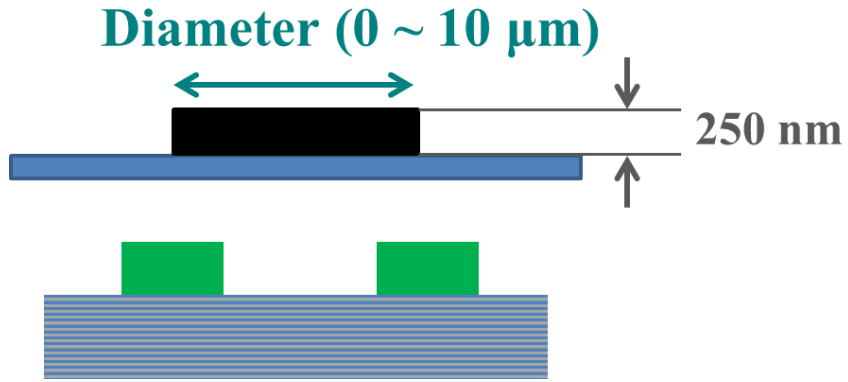
- For 10 µm defect size, defect thickness up to 100 nm would not make 0.1 nm CD variation for line & space pattern.
- However, the defect could be much thicker for contact hole pattern.

Influence of the defect on the pellicle

❖ CD variation caused by defect (22 nm L/S (1:1~1:9), 28 nm CH)

- CD variation with defect thickness





- For 250 nm thick defect, defect size of 5 μm would make CD variation larger than 0.1 nm for dense line & space pattern.
- However, the defect size can be larger up to 10 μm for contact hole pattern.

Conclusion

- By applying the pellicle, we can reduce the CD error caused by contaminants and ignore the change of the process latitude.
- Defects on the pellicle cause pattern shrink for the isolated pattern while the dense line & space pattern shows opposite behavior.
- Local defects on top of the pellicle cause CDU problem.
- Different size and thickness of the local defect would make different CD.
- CD variation for the different pattern pitches is different and is increased as the defect size and thickness grow.
- Defect should be smaller and thinner for dense L/S to have better CDU.