Study of New Phase Shift Mask for the Reduction of Shadow Effect in 16 nm Node

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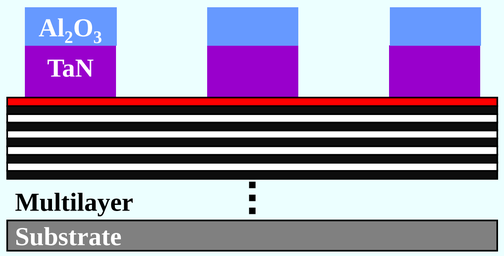
Introduction

- ❖ The EUV light shining 6 degree oblique incidence to the mask will make difficult to obtain the desired critical dimension because the shadow effect influences the pattern.
- ❖ Thus, many researchers studied the mask modification for reducing the shadow effect such as the phase-shift mask (PSM).
- ❖ A new etched multilayer binary mask is suggested for the reduction of shadow effect on 16 nm node.
- ❖ We compared the designed new etched multilayer binary mask with the binary mask that the absorber part was replaced with silicon material instead of multilayer.
- ❖ We suggested new etched multilayer binary mask has a good aerial image, contrast and shows good resist property compared to the binary mask for the 16 nm node.
- ❖ We can minimize the shadow effect in EUV with a new mask structure.

Simulation Condition



L/S pattern

❖ Exposure Condition

Exposure	16 nm Node
Wavelength	13.5 nm
Pupil Shape	Dipole (σ_{radius}=0.1, σ_{offset}=0.6)
Dose (mJ/cm^2)	7 mJ/cm^2
NA	0.25, 0.32
Incident angle	6°
Resist	EUV-2D (25 nm thickness)

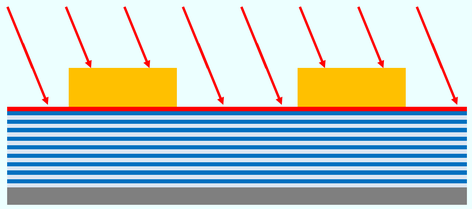
❖ Material Information (at 13.5 nm)

	Material	Thickness (nm)	n	k
Multilayer (Mo/Si)	Mo	4.1	0.999	0.00183
	Silicon	2.8	0.92388	0.00643
Capping Layer	Ru	1.8	0.88635	0.30171
Absorber	TaN	27.2	0.92599	0.04363
	Al_2O_3	20	0.96788	0.03899

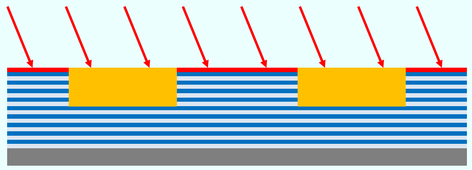
	Refractive Index	Dill A (1/μm)	Dill B (1/μm)	Dill C (cm^2/mJ)
EUV-2D	0.9765	0	5.1851	0.195

Simulation Results

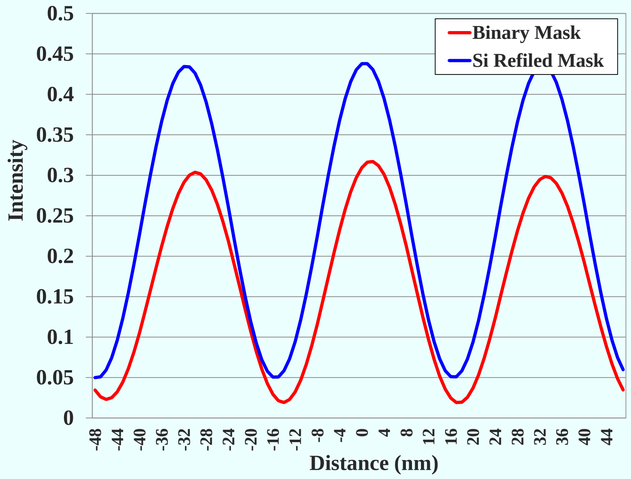
► Comparison of the new mask structure



Binary Mask



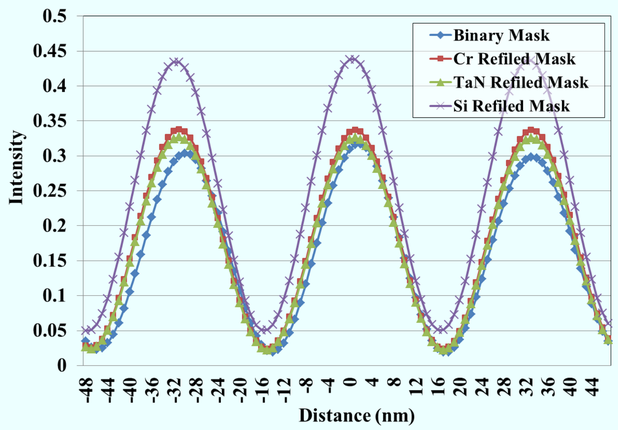
New Silicon Mask



- The absorber part was replaced with silicon instead of multilayer.
- The intensity of suggested mask is much larger than that of the conventional EUV binary mask.

Simulation Results

▶ Various Absorber Material on 16 nm

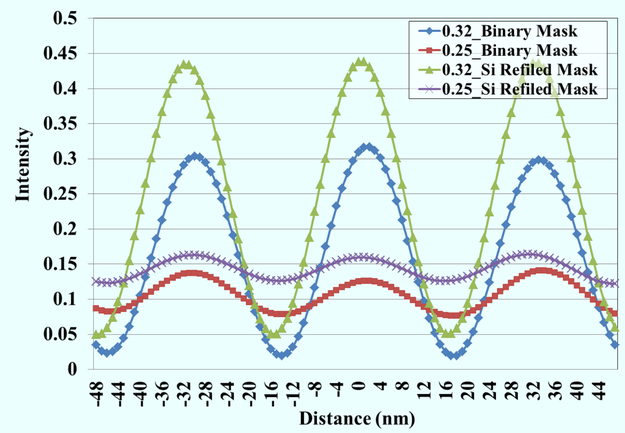


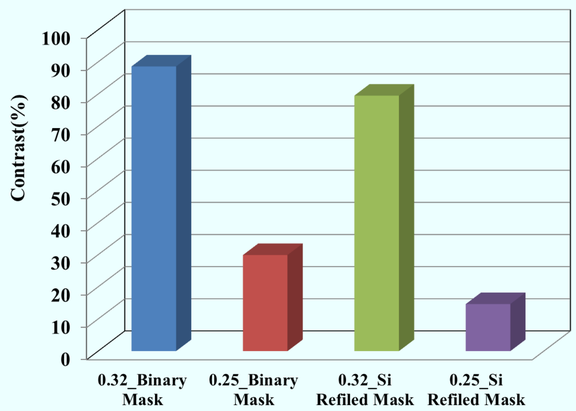
❖ **Absorber Material**

- Cr : 0.93245-0.03888i
- TaN : 0.92599-0.043631i
- Silicon : 0.99932-0.00183i

▪ When silicon is used as etched absorber, the maximum intensity increases much more than others.

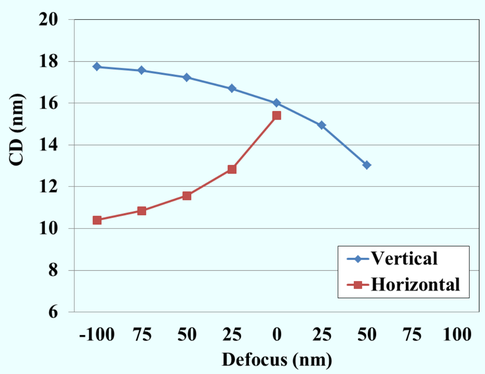
▶ Numerical Aperture (NA) on 16 nm





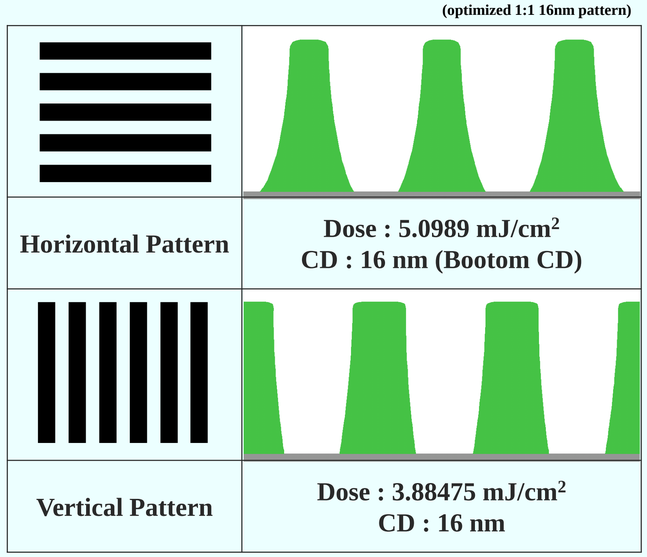
▪ 0.32 NA shows much higher intensity and contrast compared to those of 0.25 NA.

▶ Horizontal-Vertical bias on 16 nm

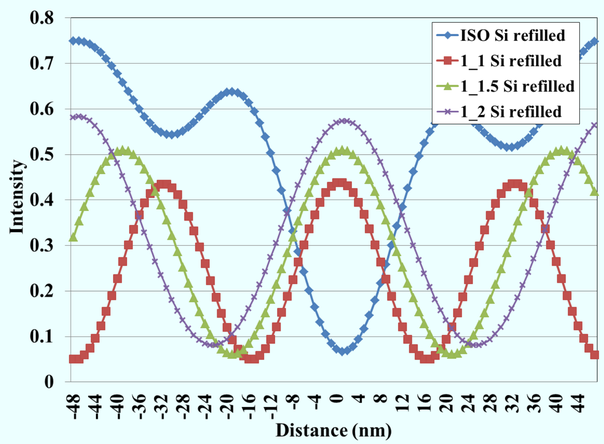


▪ New mask structure needs smaller dose for the vertical pattern for the 16 nm patterning.

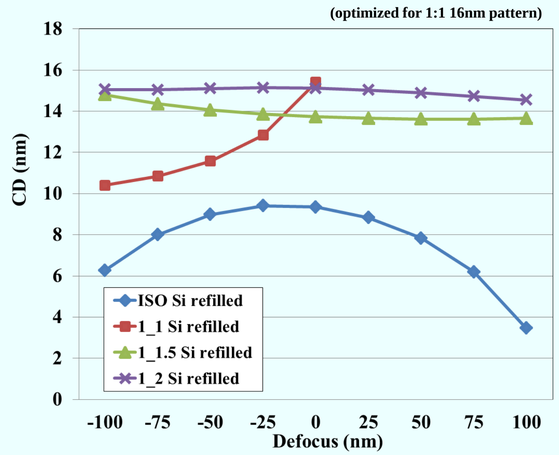
(optimized 1:1 16nm pattern)



▶ 16 nm new silicon mask structure



(optimized for 1:1 16nm pattern)



▪ Iso. silicon refilled multilayer shows the phase inversion.

▪ A suggested mask for 16 nm node also shows better depth of focus.

Conclusions

❖ A new silicon filled multilayer binary mask is suggested.

❖ It shows much better aerial image and contrast compared to the conventional EUV binary mask.

❖ It also shows the brightest intensity among the possible EUV mask.

❖ This much higher intensity could greatly reduce down the EUV source power burden.

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