

Study of Extreme Ultra-Violet Photoresist Quality for 32 nm Pattern Formation

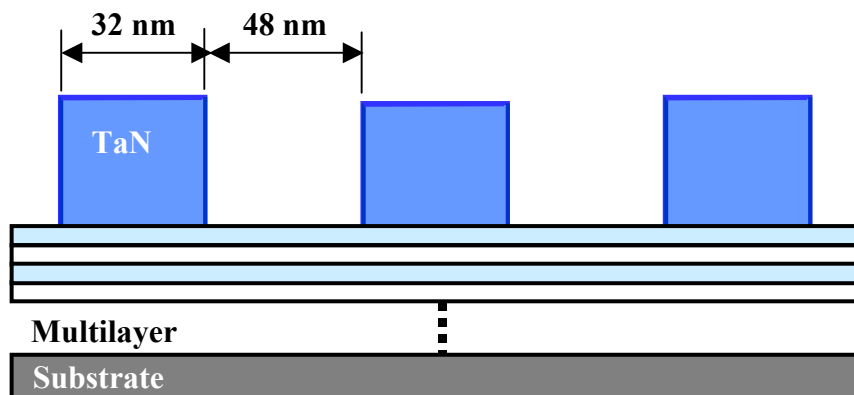
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Introduction

Extreme ultraviolet lithography (EUVL) is one of the patterning technologies proposed for the next generation lithography which can make patterns less than 32 nm critical dimension. In order to make minute patterns, it needs different methods from the present one. Thus we must investigate the EUV source, mask and exposure tool. Although the photoresist information, which is one of the key issues to define the smaller patterns, is important, it is not much known to apply for EUVL. The information about many process factors of photoresist affects pattern formation. To obtain better results, we have to get the exact information about many resist parameters such as Dill ABC exposure parameters, post exposure bake and develop parameters, etc. We can compare simulation result with experimental result, and we can check the accuracy and apply to formulation of resist. In this paper, we will discuss about each parameter, such as refractive index n and k , Dill ABC parameters and so on. We will also discuss about several quantities of resist in order to make 32 nm pattern. Furthermore we will apply new parameters to the development of new resist and process of EUVL. We used SOLID-EUV simulator of Synopsys.

Simulation Condition



32 nm L/S pattern

Material information (at 13.4 nm)

	Material	Thickness (nm)	n	k
Mo/Si (40 pair)	Mo	2.8	0.925356	0.0062201
	Si	4.2	0.9820859	0.0144074
Absorber	TaN	50	0.9272114	0.0429262
Resist	EUV-2D	80	-	-

Resist Dill parameter

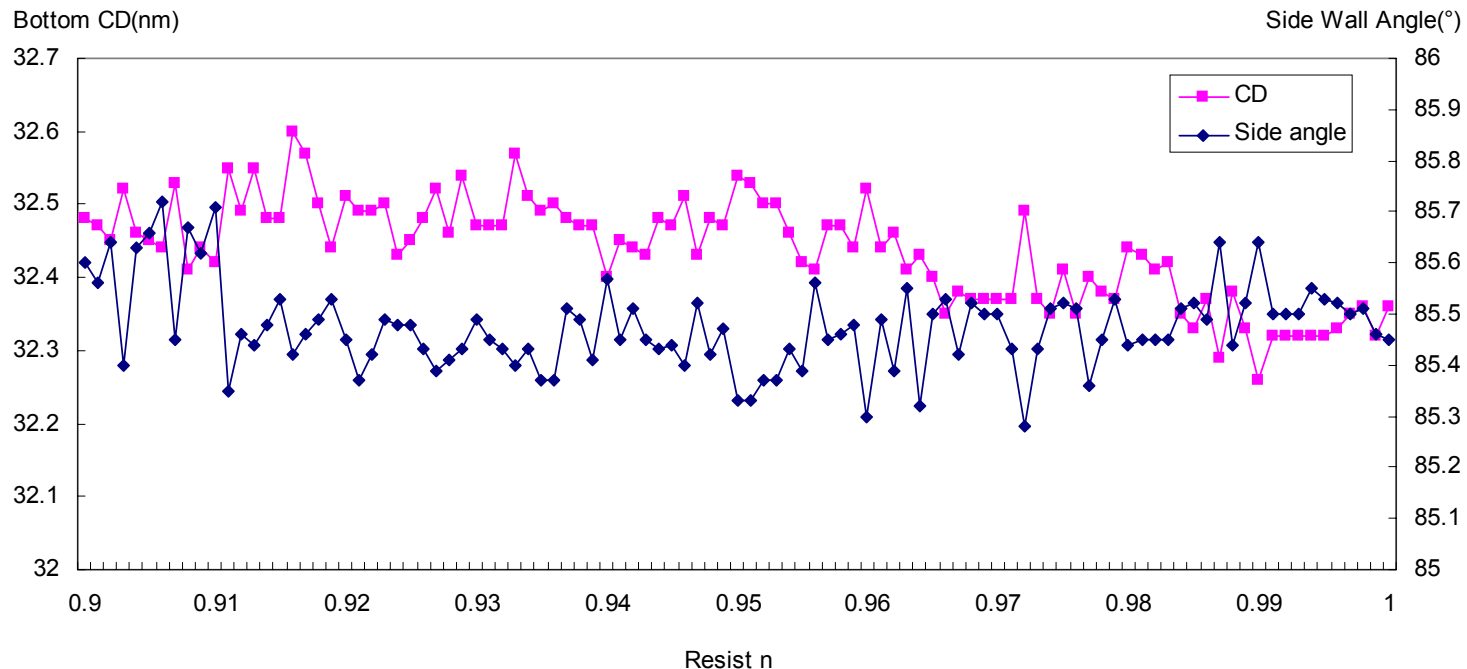
Reflective Index n	0.9765
Dill parameter A ($1/\mu\text{m}$)	0
Dill parameter B ($1/\mu\text{m}$)	5.1851
Dill parameter C (cm^2/mJ)	0.195

Develop Model

R_{max}	451.2 nm/s
R_{min}	0.15 nm/s
M_{th}	0.55
N	9.2

Photoresist Quality

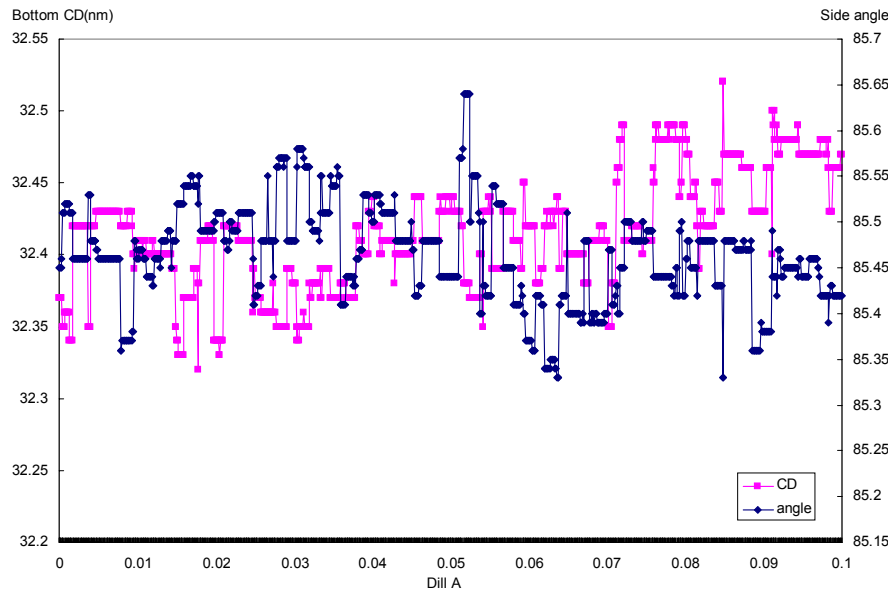
Resist Refractive Index



- **32 nm \pm 5 % CD value.**
- **Effect of refractive index change is very small.**
- **Side wall angle has stayed over 85 degree.**

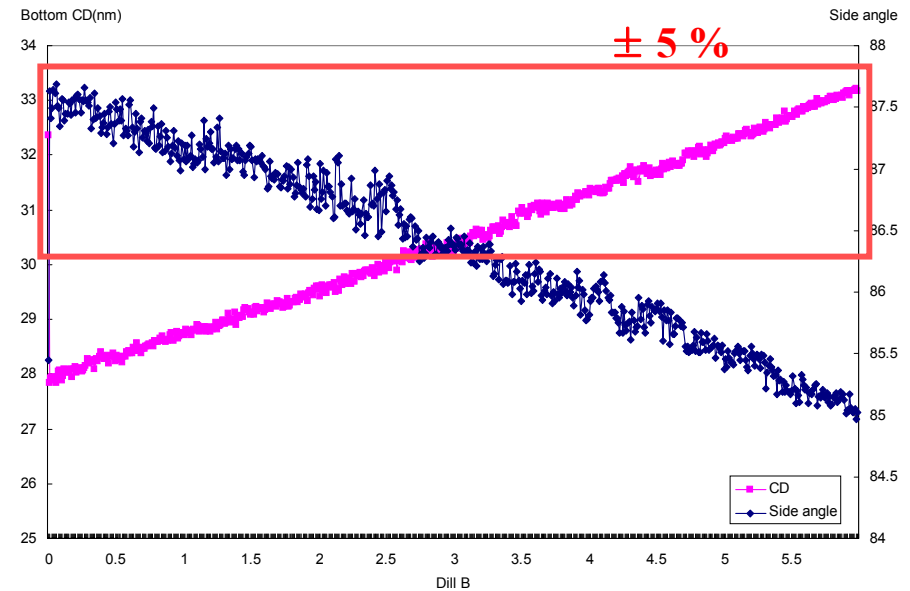
Photoresist Quality

▪ **Dill A parameter :**
Bleachable Absorption Coefficient (μm^{-1})



- Dill parameter A has '0' in EUV wavelength.
- Change of Dill A has almost no effect in this result.

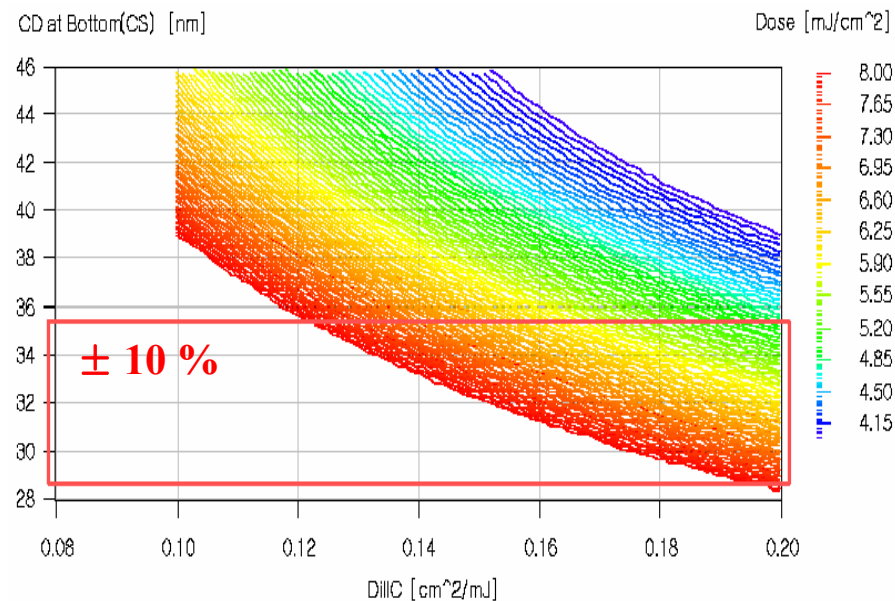
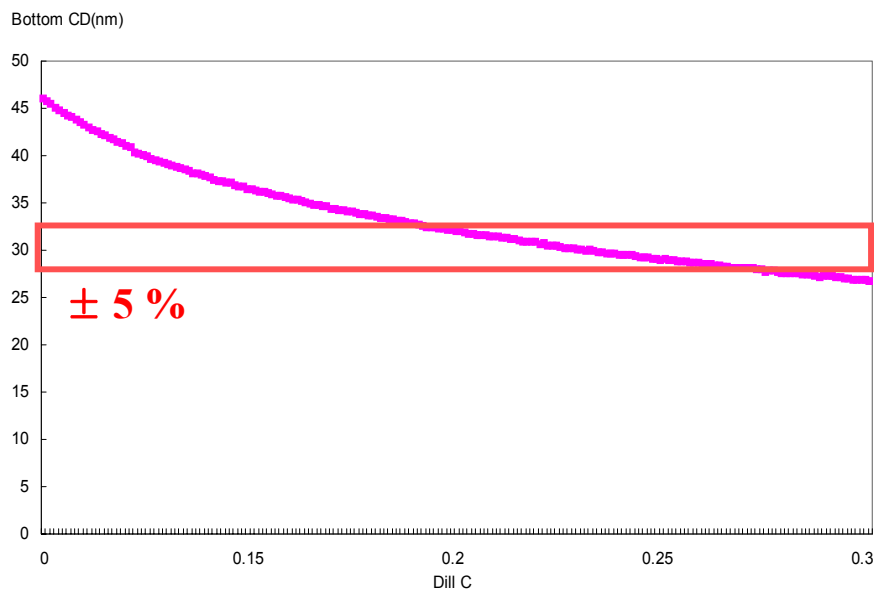
▪ **Dill B parameter :**
Non-Bleachable Absorption Coefficient (μm^{-1})



- If Dill parameter B goes large, resist bottom CD is increased and side wall angle is decreased.

Photoresist Quality

- Dill C: Standard exposure rate constant (cm^2/mJ)

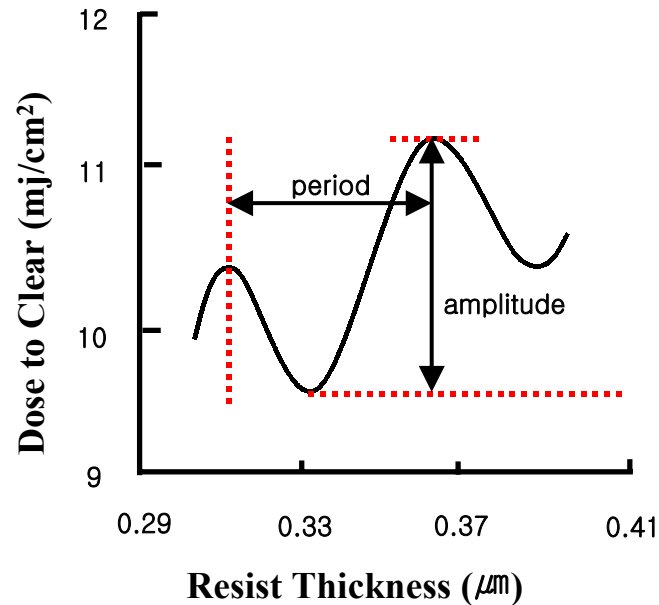


- Dill parameter C: $0.17 \sim 0.23$ [cm^2/mJ] for $32 \text{ nm} \pm 5\%$ target CD.

- Change of dose and bottom CD as a function of Dill parameter C.

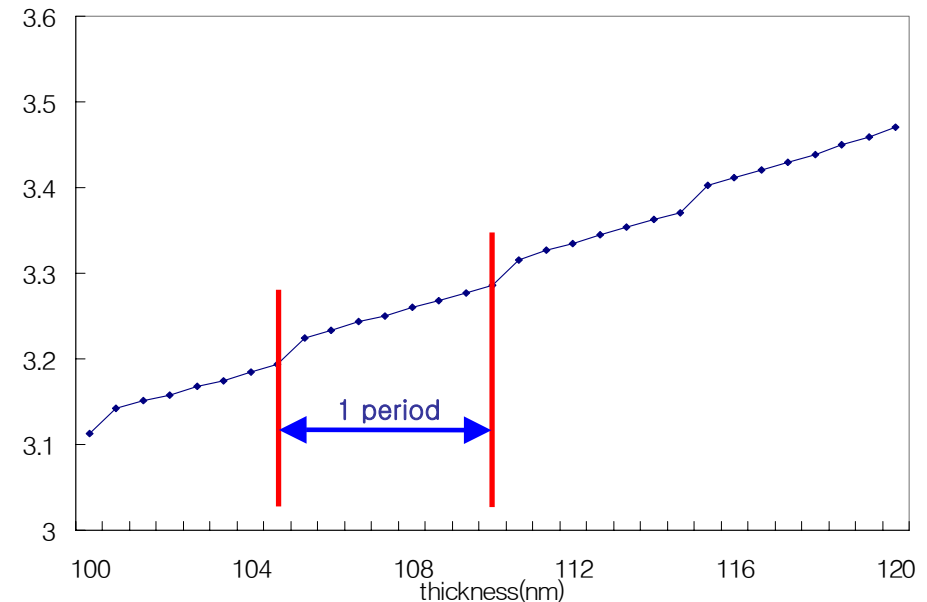
Swing Curve

Swing Curve Graph



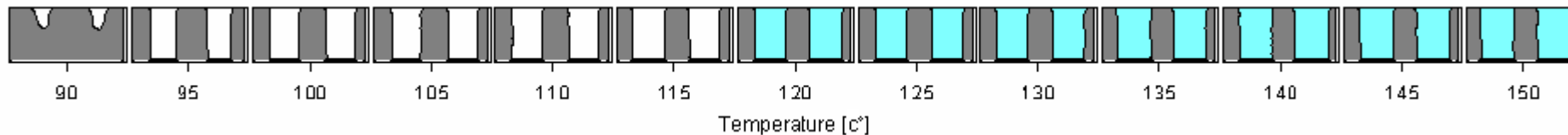
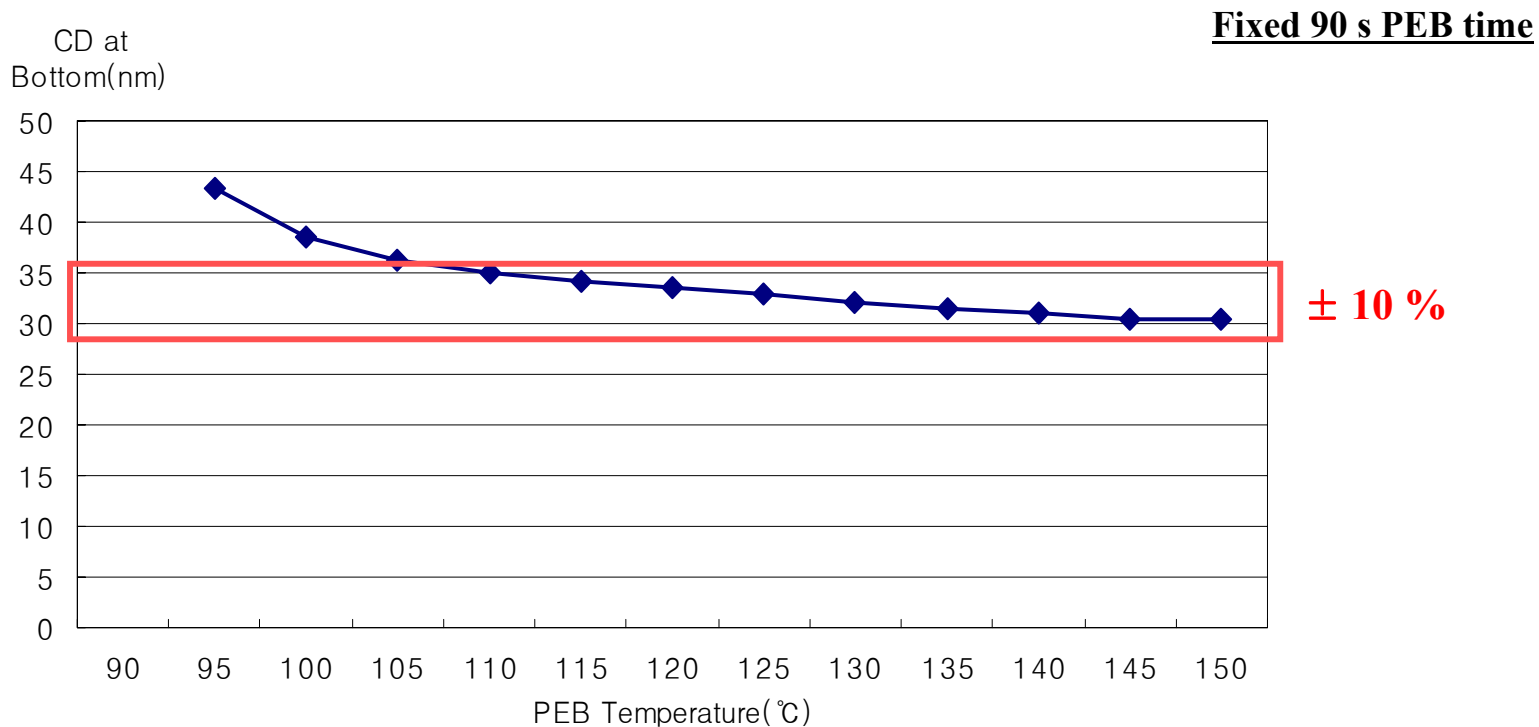
Swing Curve Simulation

Dose to Clear



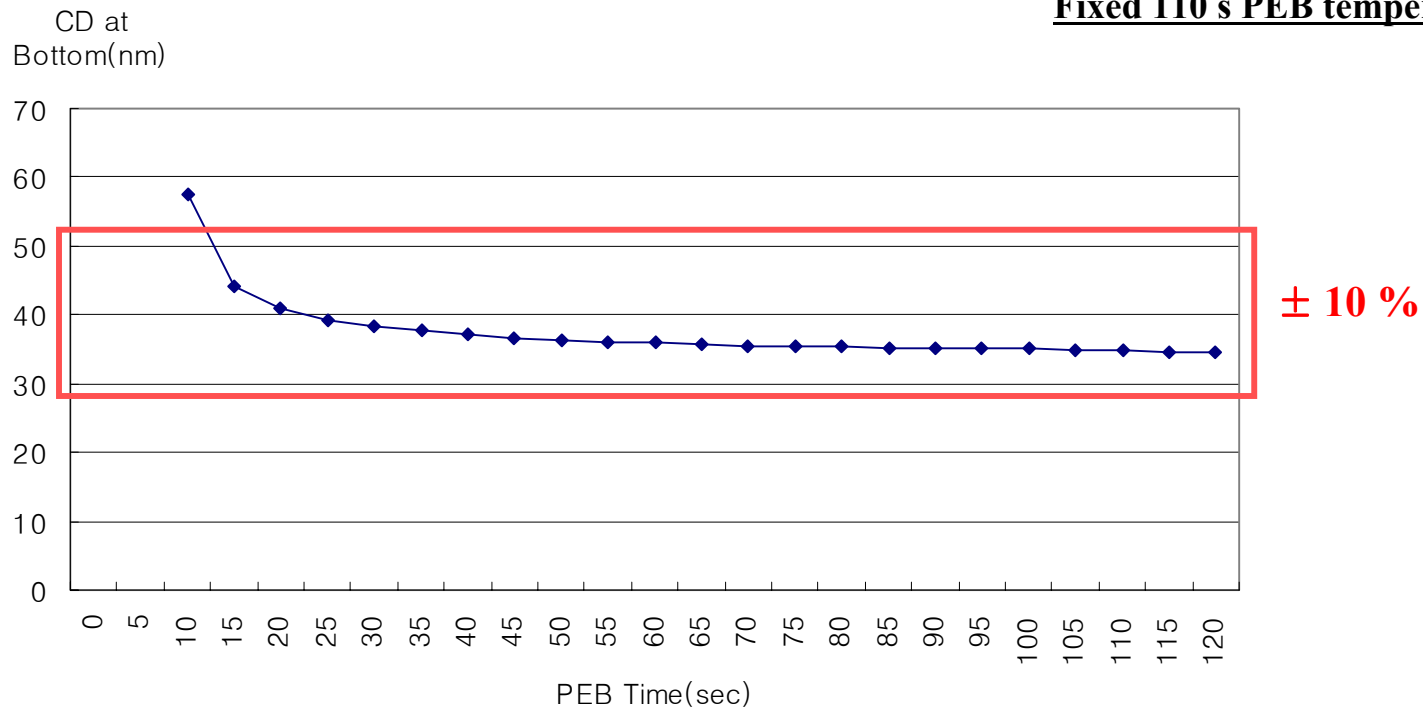
- Simulation result indicates the swing period of 5.3 nm and this tells us the refractive index of 1.27 (from $\lambda/2n$), which is different from the known refractive index.
- There is something goes on and we need to get Dill ABC from these.

Post Exposure Bake



Post Exposure Bake

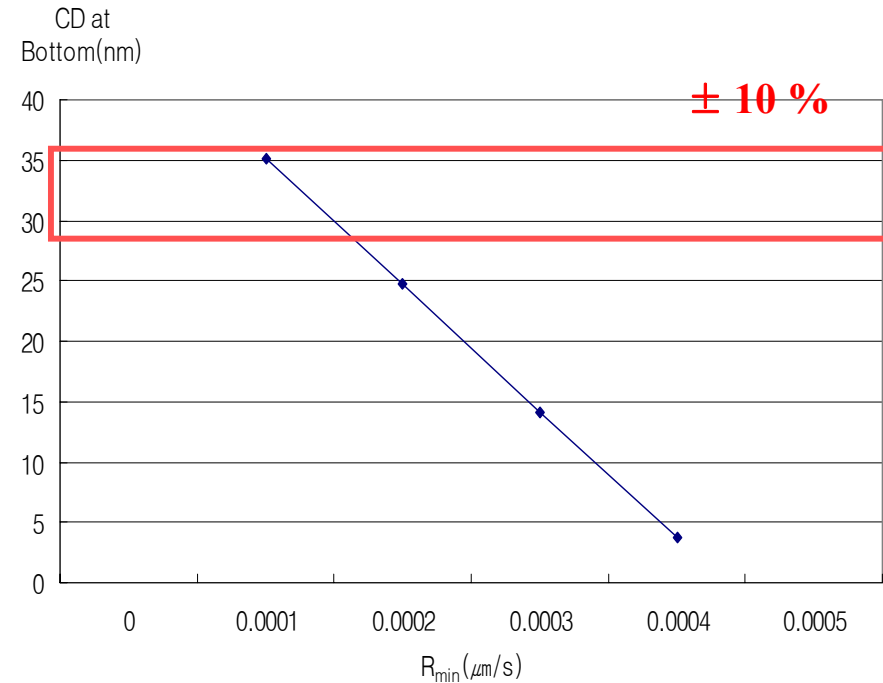
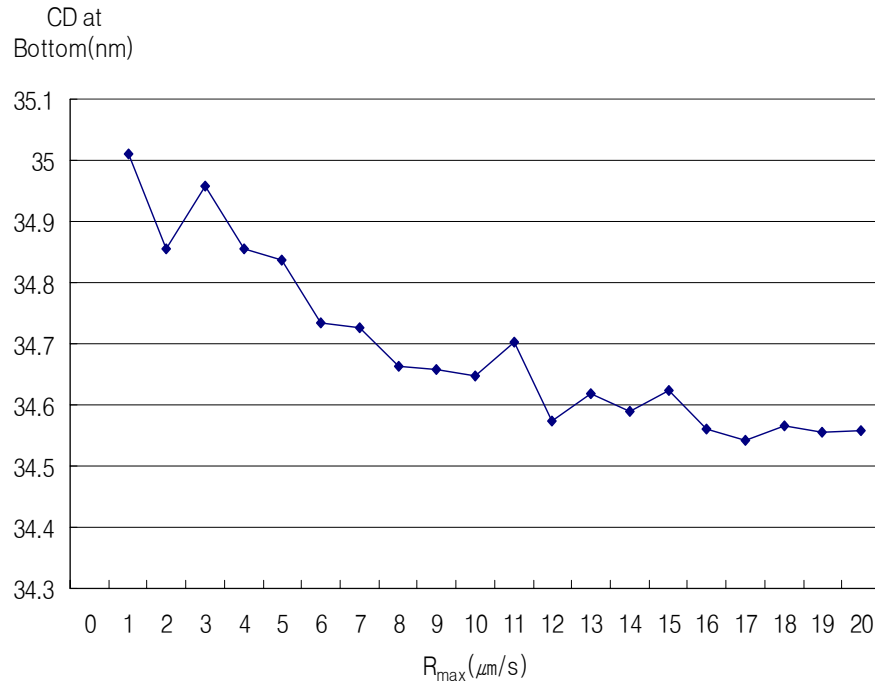
Fixed 110 s PEB temperature



Develop (R_{max} , R_{min})

R_{max} : maximum (fully exposed, $m=0$) dissolution rate

R_{min} : minimum (unexposed, $m=1$) dissolution rate



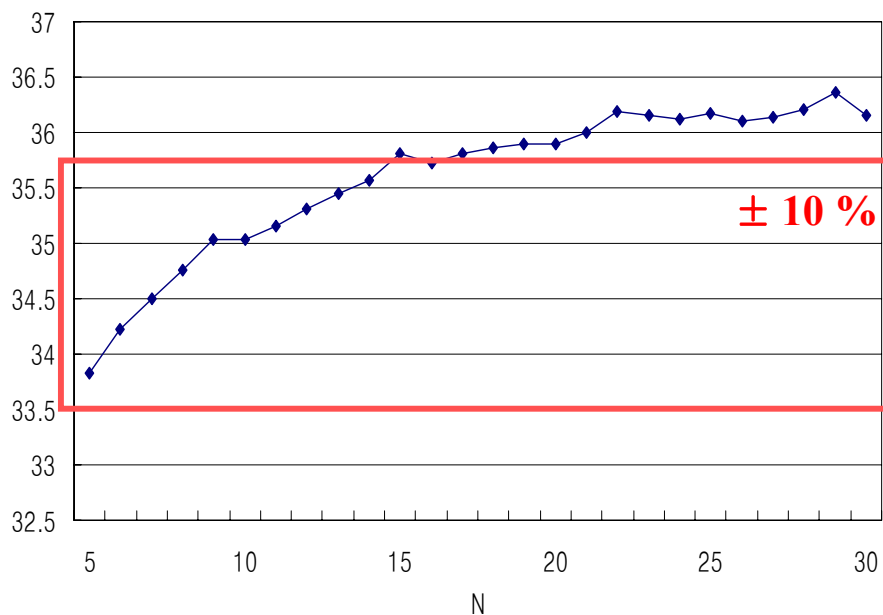
- If R_{max} is increased, resist bottom CD is decreased.
- If R_{min} is increased, CD decreases very fast. ($R_{min} < 0.2 \text{ nm/s}$ is desirable)

Develop (N, M_{th})

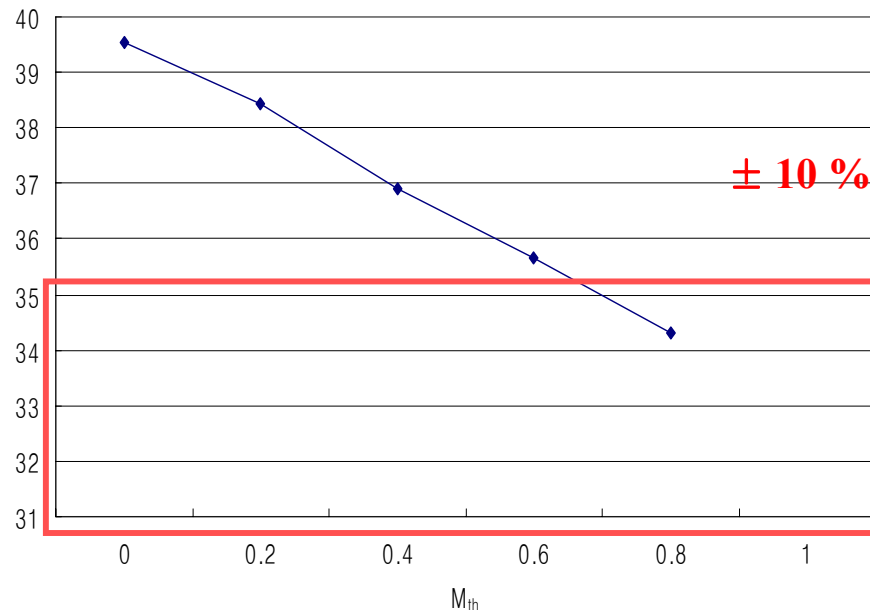
N : dissolution selectivity

M_{th} : threshold PAG.

CD at Bottom(nm)



CD at Bottom(nm)



- If N increases, resist bottom CD is decreased. ($N < 10$ is desired)
- If M_{th} increases, CD is decreased. ($M_{th} > 0.6$ is desired)

CONCLUSION

- **1:1.5 32 nm L/S resist developed profile and CD are studied to get information about the resist process of EUV.**
- **Instead of threshold model from the aerial image study only, we would like to get more information for EUV photoresist.**
- **Trend of Dill ABC exposure parameters are found.**
- **From swing curve, refractive index of resist can be extracted.**
- **Effect of PEB temperature and time is also studied.**
- **Desirable develop parameters are also found.**
- **Resist and process parameters should be studied for making better resist and for better process to get 32 nm and below.**