# Influence of 3D mask topographic profile in hyper NA lithography

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ArF lithography using immersion technology has the potential to extend the applicability of optical lithography to 45-nm half-pitch and possibly beyond. [1] By keeping the same 4× magnification factor, the dimensions of the structures on masks are becoming comparable to the exposure wavelength or even smaller. The mask absorber is no longer treated as a negligible thin film and its profile should be carefully considered. Therefore, the sidewall angle effects of the mask for the sub-45nm node were explored in this work. The rigorous coupled-wave analysis (RCWA) [2-3] was applied to analyze the optical diffraction from the 3D topographic periodic features.

Fig.1 shows the definition of the sidewall angle in attenuated PSM (attPSM) mask. The phase absorber material is assumed to be MoSiON with the optical constant (2.343, 0.586). [4] Fig. 2 shows the diffraction efficiencies of 1:1 line/space attPSM with various sidewall angles. The diffraction efficiency of the $1^{st}$-diffracted light has stronger variations than that of the $0^{th}$-diffracted light. It tends to be smaller with a smaller sidewall angle for both of TE and TM illuminations. To visualize the intensity distributions after exposing light passes through the 3D topographic features, the TE near field distributions of the masks were calculated as shown in Fig. 3. The simulated patterns are 45-nm and 32-nm in the wafer scale. Because of the off-axis illumination in the advanced lithography, the case of off-axis illumination with an angle corresponding to $\sigma$NA = 1.17 was also simulated. The transmitted peak intensity is smaller and the side lobe is stronger in 32-nm line/space pattern. For a smaller sidewall angle, the near field image contrast is poorer because of a weaker $1^{st}$-diffracted light. The topographic effects for the contact/hole patterns could be even serious. Further study on the contact/hole topography and the sidewall angle effects to the aerial image formation will be reported.

1. ITRS 2006 edition, http://www.itrs.net/Links/2006Update/2006UpdateFinal.htm
2. L. Li, J. Opt. Soc. Am. A **14**, 2758-2767 (1997).
3. C. H. Lin et al., Microelectronic Eng. **83**, 1798–1804 (2006).
4. M. H. Bennett, et al., Proc. SPIE **5754**, 599-610 (2005).

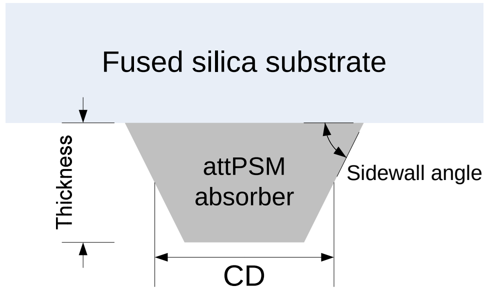
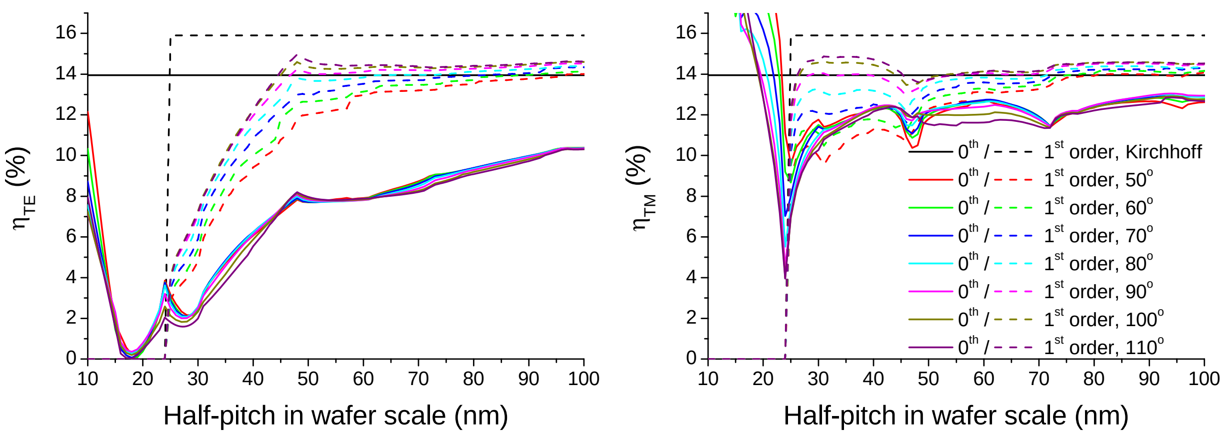
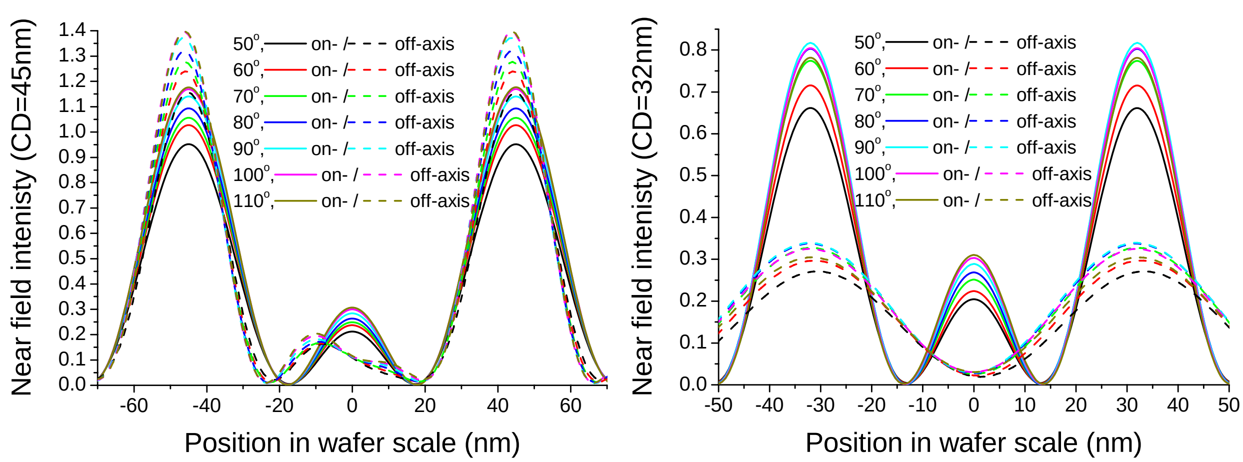



Fig. 1 Definition of the sidewall angle in attPSM mask.




(a) (b)

Fig. 2 Diffraction efficiencies of attPSM with various sidewall angles illuminated with (a) TE- and (b) TM-polarized light at normal incidence.




(a) (b)

Fig.3 Near field intensity distributions of (a) 45-nm and (b) 32-nm 1:1 line/space features in wafer scale. The illuminations of normal incidence and off-axis illumination with an angle corresponding to $\sigma NA = 1.17$ are compared.