Improved Projection Lithography Image Illumination by Sources Far from Optical Axis

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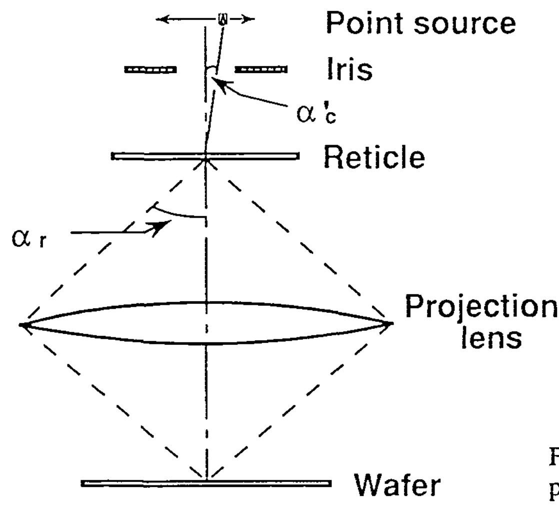
In a projection lithography system having fly-eye elements, a virtual source is created as an array of approximately mutually incoherent point sources. An arbitrary points on the mask are illuminated by light irradiated from all point sources. In order to analyze the optical proximity effects of the mask-projected image, we simulated the light amplitude and phase of the image for a point source and discussed the dependence on the point source location. The complex amplitude in an image corresponding to a coherent point source on the Gaussian image plane is given as a function of the point source location[1]. We defined this location as σ' (Fig. 1), where α_C' is the angle relative to the optical axis and α_T(=const.) the maximum aperture angle at the object plane. Figures 2a and b show the results of simulating the light amplitude and phase at point source locations $\sigma'=0.0$ and $\sigma'=0.5$. We pay attention to the solid line showing the sum of the complex amplitude diffracted from two 0.4 ($\cong$0.4 λ/NA) μm spaces. Comparing the two cases, both the peak value and contrast at $\sigma'=0.5$ are higher than those at $\sigma'= 0.0$. This result can be explained by the effect of the interference between the main lobe and side lobe diffracted from the adjacent aperture, i.e., at $\sigma'=0.0$, the side lobe peak decreases the main lobe peak of the adjacent aperture by the sum of the complex amplitude. At $\sigma'=0.5$, however, the side lobe peak increases the main lobe peak. Figure 3a shows the result for the resist profile simulation of 0.4 μm lines and spaces under the conventional conditions. Figure 3b shows the result under conditions illuminated by point sources located between $|\sigma'|=0.4$ and $|\sigma'|=0.5$. This result indicates that resolution has been improved.

As mentioned above, we simulated the complex amplitude of the mask-projected image for a point source and the dependence on the point source location, showing that the projected image illuminated by point sources far from the optical axis was improved by the effect of interference between the apertures.

1) J. W. Goodman, Introduction to Fourier Optics, New York: McGraw Hill (1968).



Location of point source : σ'

$$\sigma' = \frac{\sin \alpha'_c}{\sin \alpha_r}$$

Fig.1 Definition of point source location on the plane situated perpendicular to the optical axis.

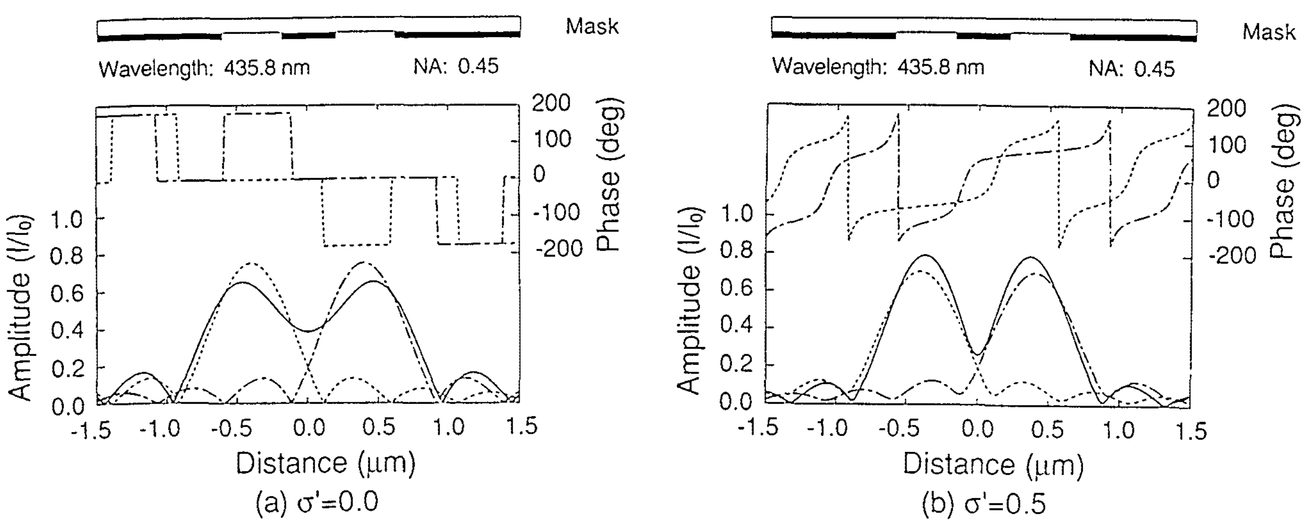


Fig.2 Light amplitude and phase for the 0.4 μm space at left (dashed line) and at right (dot-dash-line) at (a) σ'=0.0 and (b) σ'=0.5. The solid line is the sum of the complex amplitude for the two spaces.

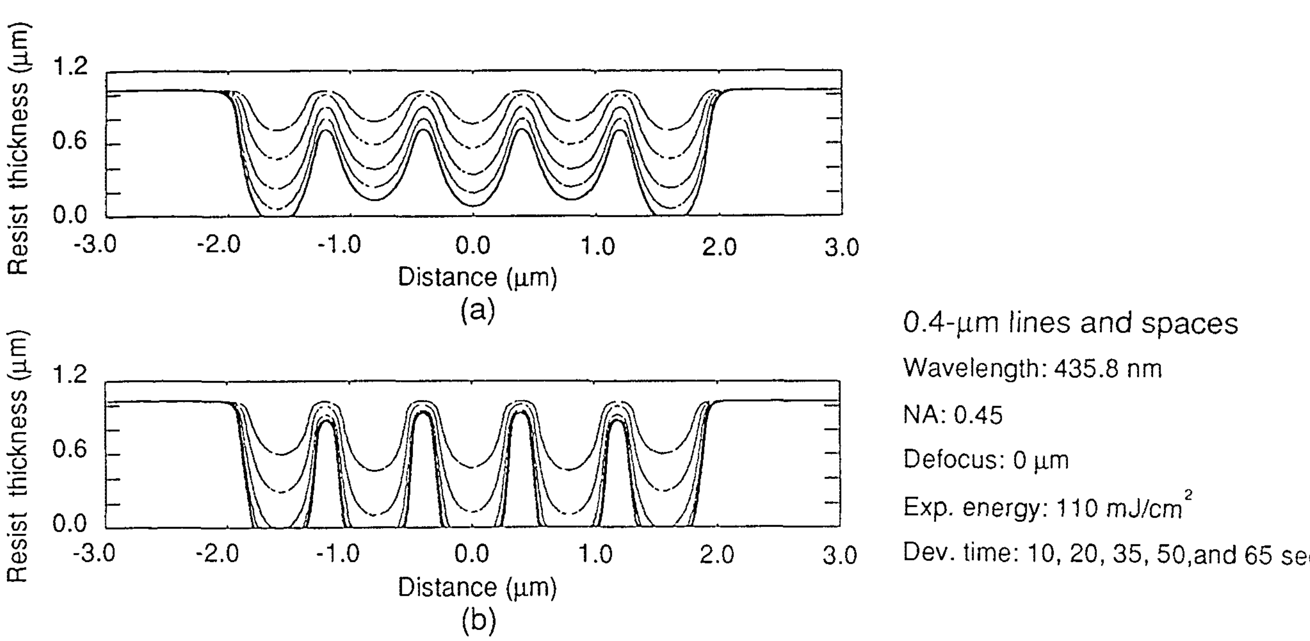


Fig.3 Simulated resist profile under (a) conventional conditions and (b) conditions illuminated by point sources far from optical axis.