An Analytic Study of Exposure Contrast over Feature Edge in Electron Beam Lithography

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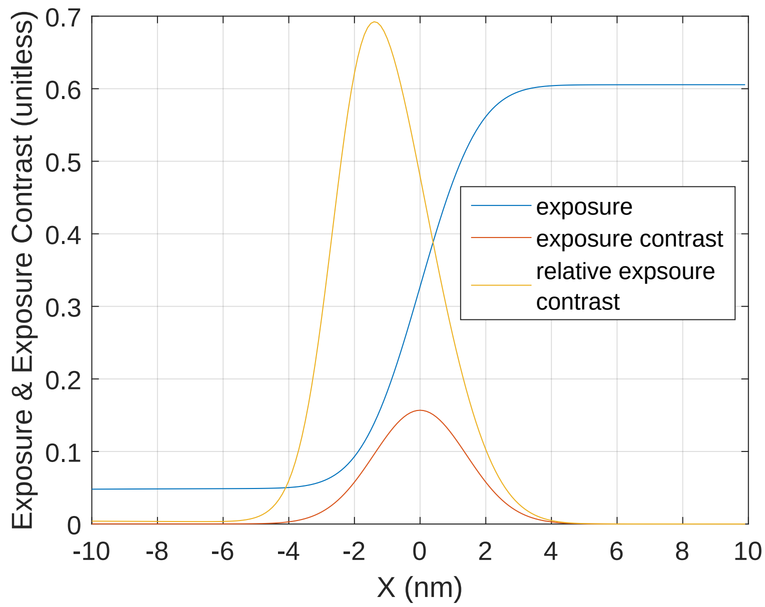
The exposure (energy deposited in the resist) contrast over the feature edge is an important metric in electron-beam (e-beam) lithography, which affects the stability of edge location in the developed feature. In general, a higher exposure contrast leads to a smaller variation of edge location due to stochastic uncertainty in the e-beam lithographic process, e.g., the stochastic variation in developing time, concentration and spatial distribution of developer, etc. In this study, the dependency of exposure contrast on e-beam lithographic and PEC (proximity effect correction) parameters is investigated using an analytic model.

The spatial distribution of exposure is fundamentally determined by the PSF (point spread function) and the exposure contrast over the feature edge depends on the main lobe of PSF which represents the forward scattering range of electrons in the resist. For a sharper main lobe, i.e., a smaller forward scattering range, the exposure contrast is higher. The PEC may also alter the exposure distribution and therefore the exposure contrast by modifying the dose distribution (dose correction) and/or the feature area to be exposed (shape correction). In addition, the feature density in a large pattern can have a substantial effect on the exposure contrast.

It is important to understand the effects of the above-mentioned parameters on the exposure contrast in order to optimize the e-beam lithographic process, especially when the feature size is small relative to the main lobe of PSF. To obtain closed-form mathematical expressions of exposure distribution and contrast, an analytic approach is taken with a double-Gaussian approximation of PSF. In Fig. 1, the exposure distribution and contrast computed by the mathematical expressions are plotted for two cases. The analytic results from this study will allow us to see the behaviors of exposure contrast explicitly and clearly without a time-consuming simulation for each individual case.

(a)



(b)

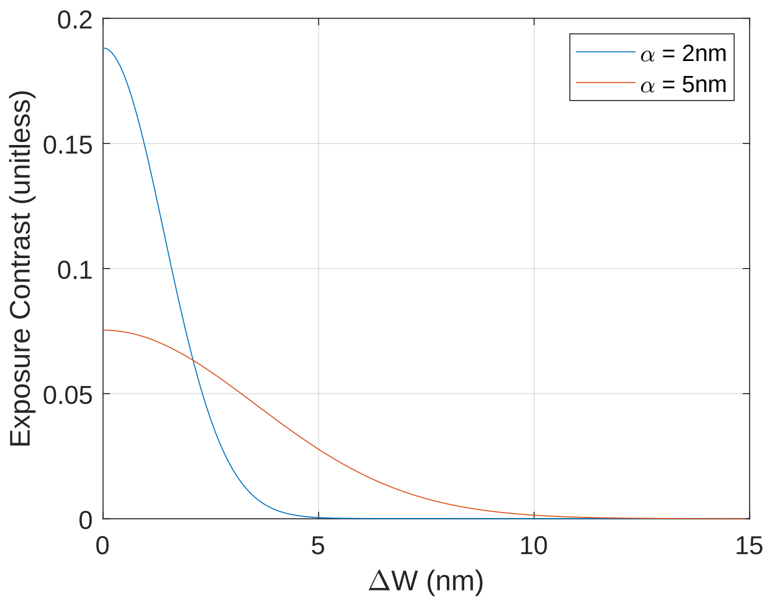


Figure 1: (a) Exposure distribution and contrast over the left edge ($X = 0$) of a single line where the line width is 20nm, the forward and back scattering ranges are 2nm and 100nm, respectively, and the back-scattered energy fraction is 0.8, and (b) exposure contrast at the left edge of a single line as a function of line-width reduction (ΔW on each side) for the shape correction of PEC line where the line width is 30nm, the back scattering ranges is 100nm, respectively, and the back-scattered energy fraction is 0.5 (two different forward-scattering ranges, α, are considered). *Relative exposure contrast* is defined as the exposure contrast divided by the exposure.