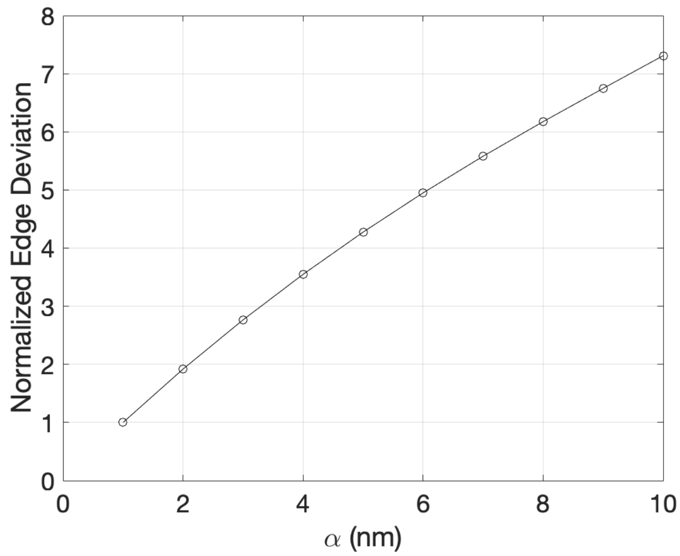
Effects of Lithographic and Pattern Parameters on Stability of Feature-Edge Location in Electron Beam Lithography

S.-Y. Lee
Department of Electrical and Computer Engineering, Auburn University, Auburn, AL 36849
leesooy@auburn.edu

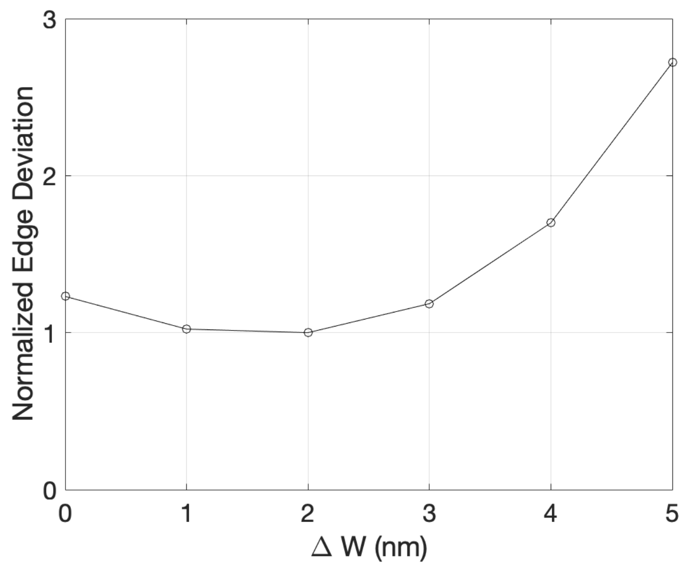
As the feature size continues to decrease, a high accuracy in achieving the feature boundary (“edge”) as designed becomes more essential. One of the reasons for any deviation of edge location is the proximity effect due to the electron scattering in the resist. Many proximity-effect correction (PEC) methods for electron-beam lithography have been developed and successful in minimizing the CD (critical dimension) error. Even with a perfect PEC, the non-ideal lithographic process can still lead to a deviation of edge location, e.g., the stochastic variation in exposure, developing time, concentration and spatial distribution of developer, etc. In general, the higher the exposure contrast over the feature edge is, the smaller the deviation of edge location due to such stochastic variation becomes.

The spatial distribution of exposure over the feature edge is fundamentally determined by the shape of point spread function (PSF), in particular, the main lobe of which the sharpness depends on the forward-scattering range of electrons in the resist. A smaller forward-scattering range leads to a sharper PSF and in turn a higher exposure contrast. Another factor affecting the exposure contrast is the PEC. Both shape and dose corrections affect the exposure distribution over the feature edge. For example, in the case of shape correction, the width of line to be exposed may be reduced with or without the spatial control of dose over the reduced width, which tends to lower the exposure contrast.

In this study, an analytic model is employed in understanding the effects of the lithographic and pattern parameters on the deviation of edge location due to the uncertainty in the e-beam lithographic process. Specifically, the closed-form mathematical expression of the deviation is derived in terms of the parameters which determine the exposure contrast. In Fig. 1, the deviation plotted using the expression is provided. The outcomes from this study should be helpful to understanding better the deviation of edge location without time-consuming repetitive simulation and developing a PEC method which enhances the stability of the feature boundaries in the written pattern against the stochastic variation of the lithographic process.



(a)



(b)

Figure 1: The normalized edge deviation is computed as $\frac{|\Delta X|}{|\Delta X|_{minimum}}$ where ΔX is the deviation of edge location when the developing time is increased 5% and $|\Delta X|_{minimum}$ is the minimum of ΔX in the range of parameter considered. It is assumed that the exposure varies linearly in the lateral direction over the feature edge and the resist is developed only in the vertical direction. The feature boundary after development is defined in the middle layer of resist. In this plot, the resist thickness is 100nm, the developing rate at the feature edge is 200nm/minute, the feature width is 20nm, and the ratio of the backscattered energy level to the forward-scattered energy level is 0.8. In (a), the forward-scattering range α is varied with no reduction of feature width and the backscattering range β of 15nm and in (b), the feature-width reduction ΔW is varied with $\alpha = 3$nm and $\beta = 20$nm.