On the Trends and Application of Isofocality for Negative Resists in Electron Beam Lithography

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Continuing our research on isofocality in electron beam lithography (EBL) to enable process robustness and repeatability, this work examines the isofocality of commercially available negative resists, namely, Medusa 82 by AllResist GmbH and maN-2403 by Micro Resist Technology GmbH. Isofocality is the operating point in a given process where a specific dose (isofocal dose) results in the same feature size (isofocal feature) independent of the $blur_{eff}$ as illustrated in Figure 1. The $blur_{eff}$ is a lumped parameter that includes the effects of resist processing, spot size, beam focus, forward scattering, etc. which contributes to the final resist image.

Empirically, the isofocal feature is typically larger than the drawn target critical dimension (CD). The difference between the isofocal feature size and the CD target defines the isofocal bias. By analyzing the exposure latitudes across 0%, 50% and 100% pattern densities (ρ) for 300 nm tower patterns, the approximate pattern density dependent isofocal doses (IFD_ρ) and isofocal biases ($IF\Delta_\rho$) will be identified for a silicon substrate for negative resists given their fixed processes by influencing the $blur_{eff}$ via the beam spot size and exposing said patterns with a focused and defocused beam. Examining the trends in isofocality in these negative resist processes, proximity effect correction will be adjusted to provide the empirically found IFD_ρ for a silicon substrate.

In previous work, the trends in isofocal behavior for positive resists showed that as pattern density increases, the IFD_ρ decreases while the $IF\Delta_\rho$ increases. However as our preliminary data shows in Figure 2, as pattern density increases, the IFD_ρ also decreases, however, the $IF\Delta_\rho$ decreases as well. In the text that follows, we will review the techniques used to empirically identify the IFD_ρ, potentially investigate other negative resists and explain the reverse phenomena found for $IF\Delta_\rho$ in negative resists.

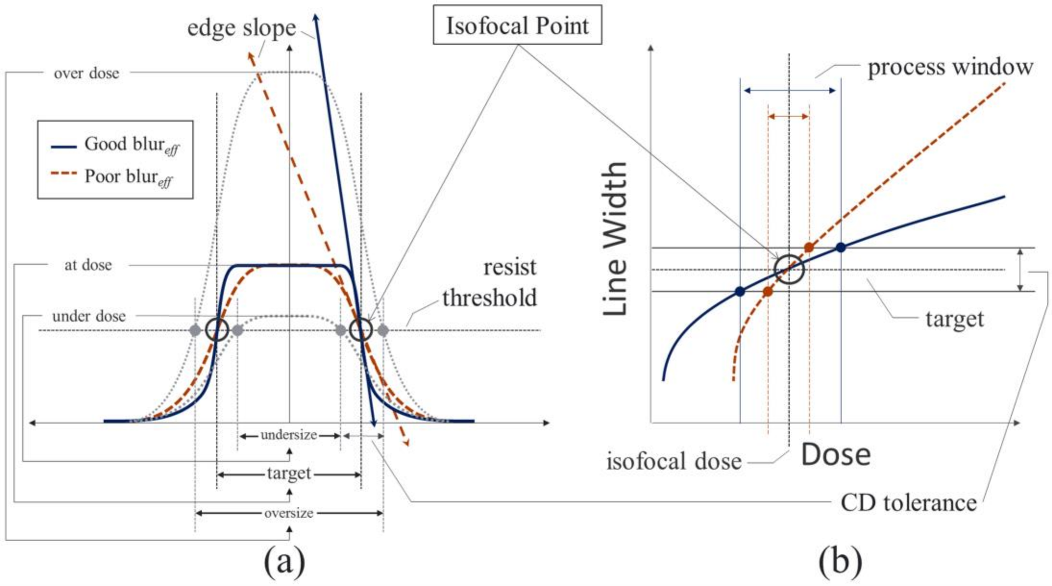

Figure 1: The illustration connects the isofocal behavior to the blur$_{eff}$ and exposure latitude. The *blur$_{eff}$* is depicted in (a). The exposure latitude depicted in (b) is the change in CD with respect to dose. The isofocal point is the intersection of different *blur$_{eff}$* for a target CD at the resist threshold as shown in (a). This corresponds to the intersection of the exposure latitude curves that result from exposing from two or more different *blurs$_{eff}$* as shown in (b). As the dose increases, as expected, the CD also increases. As the dose decreases, the CD decreases. The edge slope of the blur (a) directly impacts the slope of the exposure latitude and ultimately the process window for given CD tolerance, both of which are illustrated in (b). A good *blur$_{eff}$* with a steep edge slope at the resist threshold, solid blue line in (a), yields an exposure latitude curve with a shallow slope, the solid blue line in (b). A poor *blur$_{eff}$* with a shallow edge slope at the resist threshold, dashed red line in (a), yields an exposure latitude curve with a steep slope, the dashed red line in (b). The process window in (b) for a good blur is much wider than the process with a poor blur.

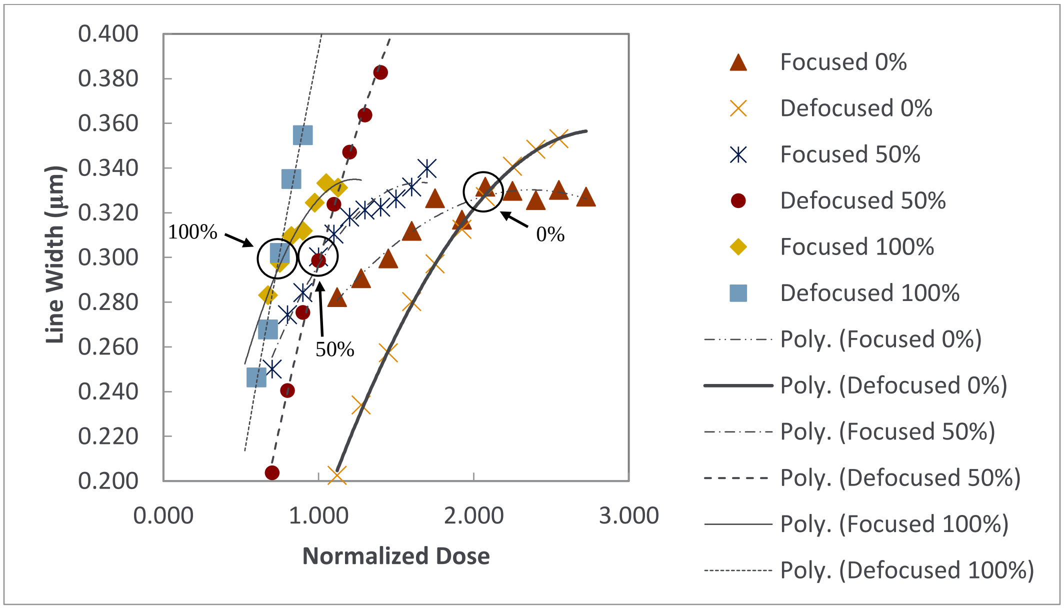

Figure 2: Pattern Density Dependent Isofocal Doses for maN-2403 at 50 keV: The isofocal doses are found from the crossover points for 0%, 50% and 100% pattern densities. As expected, isolated features require higher dose. Also note that the isofocal bias decreases with increasing pattern density.