HSQ on SOI Proximity and Process Loading Effects Correction from a Single 1D Characterization Sample

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It is well known that designs patterned using electron beam lithography have overexposed dense features and underexposed sparse features. This is typified by the limited process latitude of hydrogen silsesquioxane (HSQ) resist on SOI substrates used for silicon photonics, where it is common to have very high density features (grating couplers, ring resonators) mixed with very sparse features (inverse tapered waveguides) in a single pattern. We report specifically on the optimization of a proximity effect correction (PEC) based on our analysis of a single 1D characterization sample known as the Process Control Monitor (PCM). The PCM is a dose matrix composed of 200 nm wide lines (lines are 1D features, where 2D features are contacts and vias) with duty cycles encompassing a wide portion of the pattern density space from isolated (~1%) to dense (67%) features illustrated in Figure 1. SEM images were taken at the center of these regions and automatically analyzed using the author's ImageJ macro.[1] Using e-beam simulation, empirical CD measurements are fit with a point spread function (α= 5 nm, β= 30 μm and η= 0.6), an effective blur of 25 nm FWHM (to account for blurs in the resist and development process), and a pattern density dependent process loading effect (PLE) model. We validate this method using Dow Corning XR-1541 6% solids negative EBL resist on a SOI substrate, developed using AZ 300MIF. Our results show that a single fit can experimentally yield an RMS error of ±4.8 nm. We demonstrate the importance of including PLE by comparing PEC results with and without PLE.

Figure 2 shows the PCM sample's line widths versus dose plot overlaid with our model-based simulation data. The line widths versus job dose of our backscatter and process loading corrected verification sample is shown in Figure 3a for each pattern density tested. Note how close the data is to the 200 nm target, particularly for the 1.0x job dose factor. The remaining job dose factors illustrate the improved process latitude of this full PEC. Figure 3b plots the same for our backscatter corrected verification sample without PLE. Note the large spread in values (RMS error greater than ±22 nm without PLE versus ±4.8 nm with PLE) and large variation in process latitude. In fact, many of the high pattern density gaps have not been cleared.

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[1] J. Bickford, *Automatic Stripe Analysis Tool*. Adelphi, MD: ARL, May 2013. (U.S. Army Research Laboratory Tech Report #6469) http://imagejdocu.tudor.lu/doku.php?id=macro:analyze_stripes

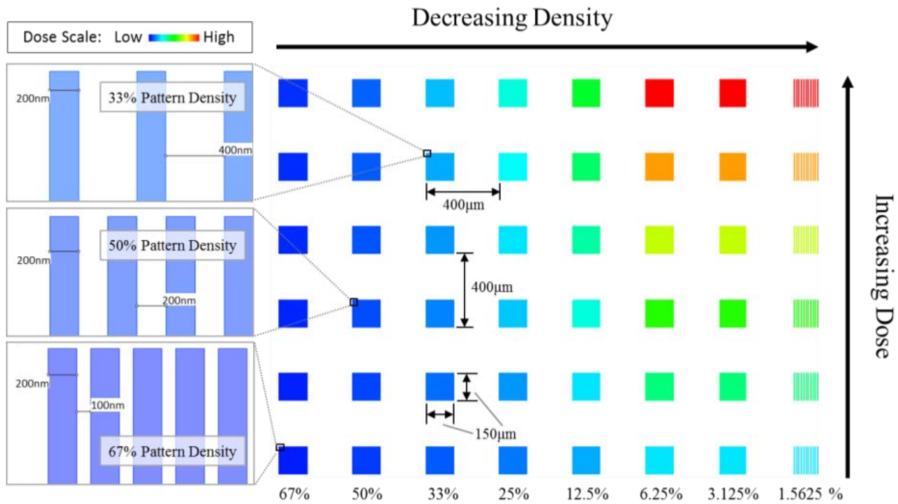


Figure 1: The PCM dose matrix sample layout. Pattern density increases by increasing the pitch from leftmost column to rightmost column (illustrated by zoomed views). The dose increases from the bottommost row to topmost row.

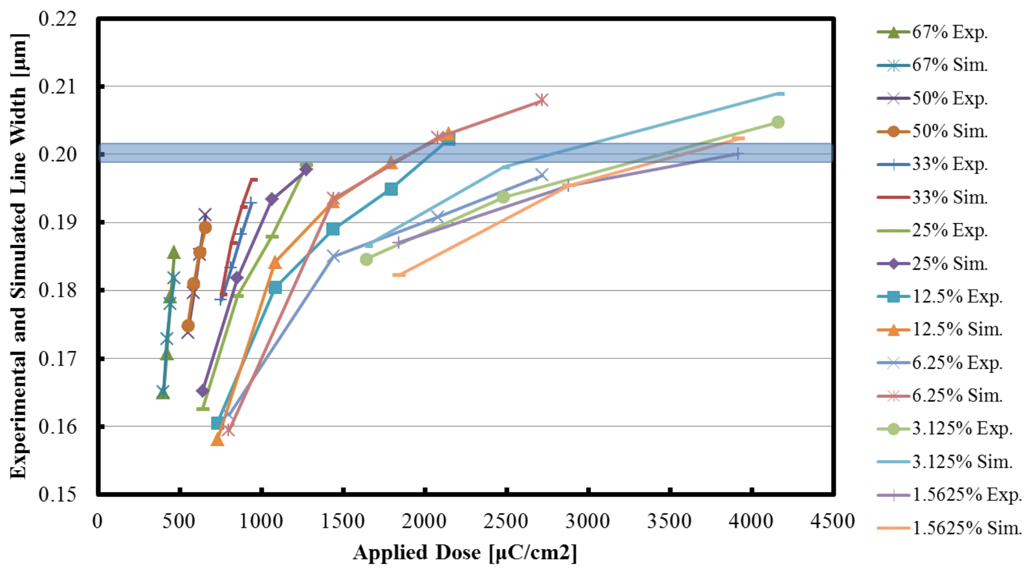
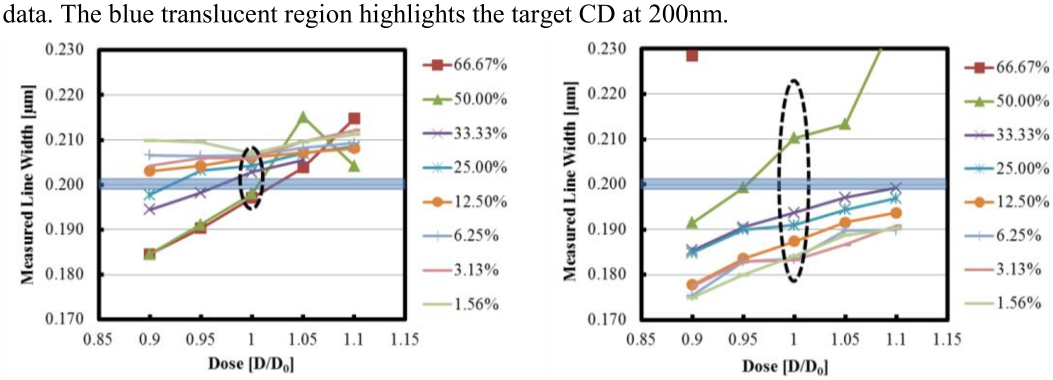


Figure 2: Experimental (Exp.) and simulated (Sim.) model fit of the PCM line width metrology data. The blue translucent region highlights the target CD at 200nm.



(a) (b)

Figure 3: Line width data of verification samples utilizing backscatter model with (a) and without (b) PLE. The verification was patterned with different job doses (0.9x - 1.1x) to show the process latitude of our PEC. The blue translucent region highlights the target CD at 200nm, while the dashed outline region highlights the spread in values for the optimal 1.0x job dose.