Process Correction for E-Beam Exposure of HSQ

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Hydrogen Silsesquioxane (HSQ) resist is commonly used in electron beam lithography due to its high resolution and low line edge roughness. However, HSQ exhibits large critical dimension (CD) deviations from target depending on local pattern density, beyond that attributable to electron scattering. Thus, conventional proximity effect correction (PEC) is inadequate for accurate CD targeting for the range of pattern densities from isolated to fully-surrounded. The source of this additional effect has been speculated to be hydrogen diffusion[1], and some success at compensation has been reported by using an additional mid-range term in the PEC[2], or using process loading corrections[3], though neither demonstrated successful correction over a full range of local pattern densities. We describe a process calibration in which a calibration exposure is performed, the resulting CDs are measured, and the measurement data is then fitted to determine the correction for these additional process effects. This calibration has successfully demonstrated significant improvement in both standard test patterns and difficult device patterns.

The process of interest is the fabrication of photonic devices using HSQ resist as an etch mask for the active silicon layer of silicon-on-insulator chips[4]. The original process operating point was chosen by using PEC with a conventional two-Gaussian electron scattering model determined by Monte Carlo simulation, then the base exposure dose was determined by optimization of waveguide and grating coupler loss. While this process has been used successfully for hundreds of wafers with low-density photonic patterns, it has not been usable for patterns with large areas with high local pattern density. With this new calibration procedure, an improved process operating point was determined, having a much lower base exposure dose, and a proximity correction function with substantial additional energy in the mid-range, giving a significantly wider span of dose correction values over the density range. Results show the same lithographic performance for low-density devices, but significant improvement in the CD targeting and patterning results for high-density devices. In particular, large devices with very high pattern density are now able to be successfully fabricated.

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1. D. Olynick, J. A. Liddle, A. Tivanski, M. Gilles, T. Tyliszczak, F. Salmassi, K. Liang, and S. Leone, J. Vac. Sci. Technol., B 24, 3048 (2006)
2. D.K. Brown, N. Unal, and C. Sambale. Internal communication (2011)
3. J.R. Bickford, G. Lopez, N. Belic, and U. Hofmann. J. Vac. Sci. Technol., B 32, 06F511 (2014)
4. R.J. Bojko, J. Li, L. He, T. Baehr-Jones, M. Hochberg, and Y. Aida, J. Vac. Sci. Technol., B 29, 06F309 (2011)

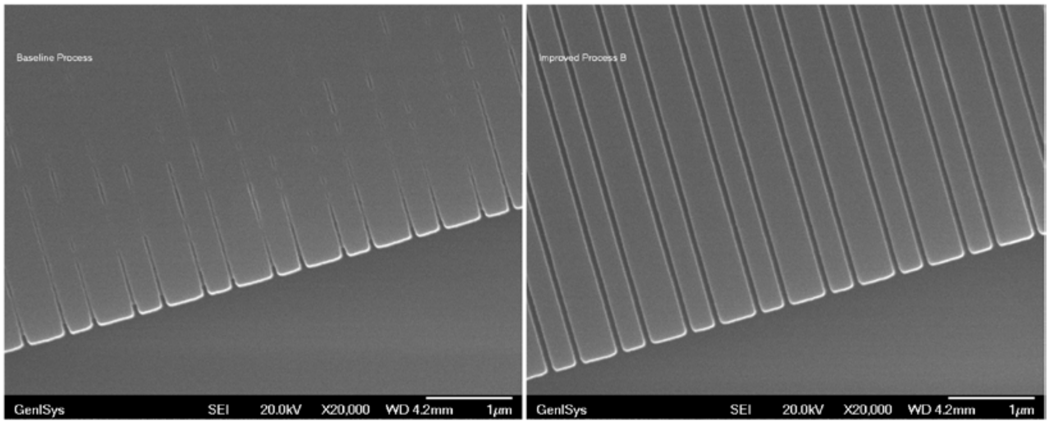

Figure 1: Resulting structure for a photonic coupler with very large pattern area and ~85% exposed pattern density, for baseline process (left) and process with improved calibration (right). With the baseline operating process, this device was not able to be successfully fabricated. The improved process correction resulted in a successfully-fabricated device.

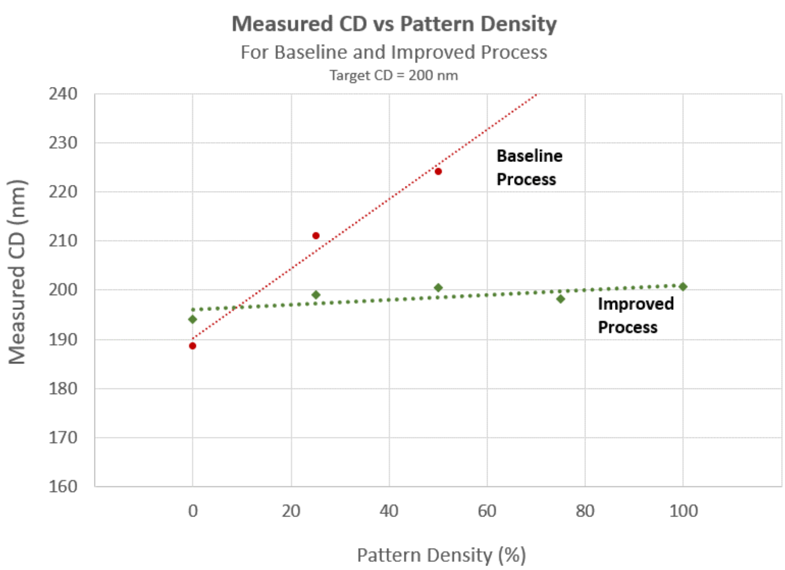

Figure 2: CD measurements versus local pattern density for baseline and improved process, for line with target CD of 200 nm. The improved correction process is within ±3% of target for all densities.