On the Trends and Application of Pattern Density Dependent Isofocal Dose of Positive Resists for 100keV Electron Beam Lithography

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Proximity effect is a ubiquitous challenge in electron beam lithography (EBL). It is well-known that designs patterned using EBL can have overexposed dense features and underexposed sparse features. To resolve these uniformity issues, dose-based proximity effect correction (PEC) convolves the pattern with a point spread function (PSF) to evaluate the absorbed energy distribution, and then physically fractures the pattern, assigning the shapes a dose factor to deposit the appropriate energy so they develop to size. The isofocal dose in EBL is the dose that results in the desired feature size independent of the effective process blur ($blur_{eff}$). In other words, if the $blur_{eff}$ changes, the target critical dimension (CD) is still obtained by the same dose for a specific pattern density. In previous experiments, the dominant component of the $blur_{eff}$ have been shown to stem from the resist process such as developer temperature[1] or from the electron beam focus[2]. Moreover, at 50 keV for ZEP520A, when an isofocal dose is applied to its corresponding pattern density, the CD response is invariant to the beam focus[2]. The implication is such that if a PEC is isofocal, the desired feature sizes are consistently attainable across all pattern densities regardless of the beam focus accuracy.

This work demonstrates the impact of isofocal dose-based PEC at 100 keV. Two positive EBL resists (950 PMMA from MicroChem and ZEP520A from ZEON Chemicals) have had their pattern dependent isofocal doses extracted for Si (Figures 1 and 2) using a dose matrix of 300 nm line-space tower patterns consisting of various pattern densities. The dose matrix was exposed under three separate conditions: once with a focused beam, second with a 50 nm beam spot size and again with a beam spot size of 100 nm using a Raith EBPG 5200 at 100 keV EBL tool at 15nA with a 300 μm final aperture and a 20 nm beam step size. Data preparation was performed using BEAMER by GenISys, GmbH. Samples were developed at room temperature (21˚C). The patterns were then transferred 100 nm into the Si using an Oxford 80 Plus reactive ion etcher (RIE) using tetrafluoromethane (CF_4). Line-width measurements were performed by ProSEM by GenISys, GmbH. In the text that follows, we will review the techniques used to empirically identify the pattern density isofocal doses at 100 keV, investigate other positive resists and demonstrate the efficacy of applying an isofocal PEC on actual patterns.

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[1] C. M. Eichfeld and G. G. Lopez, J. Vac. Sci. Technol., B 32, 06F503 (2014).
[2] G. G. Lopez, M. Azadi, M. G. Metzler, N. Belic, U. Hofmann, J. Vac. Sci. Technol., B 32, 06G505 (2017).

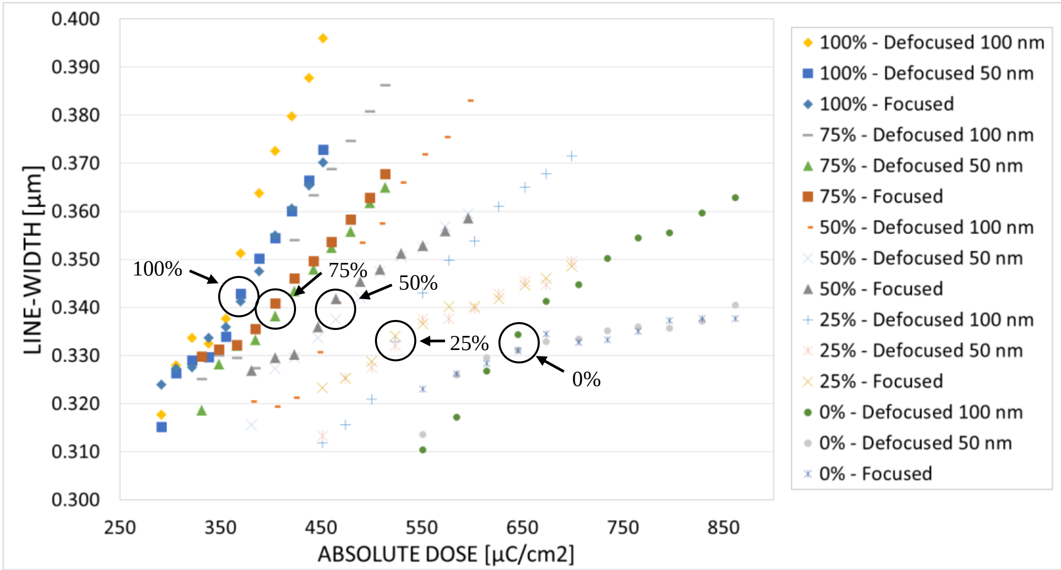

Figure 1: Pattern Density Dependent Isofocal Doses for 950 PMMA at 100 keV: The isofocal doses are found from the crossover points for each pattern density. As expected isolated features require higher dose. Also note that an isofocal bias increases with pattern density possibly from lateral development in the resist. The pattern dependent isofocal doses are roughly 646, 524, 465, 404 and 370 µC/cm^2 for 0%, 25%, 50%, 75% and 100% pattern densities, respectively, for 950 PMMA when exposed at 100 keV.

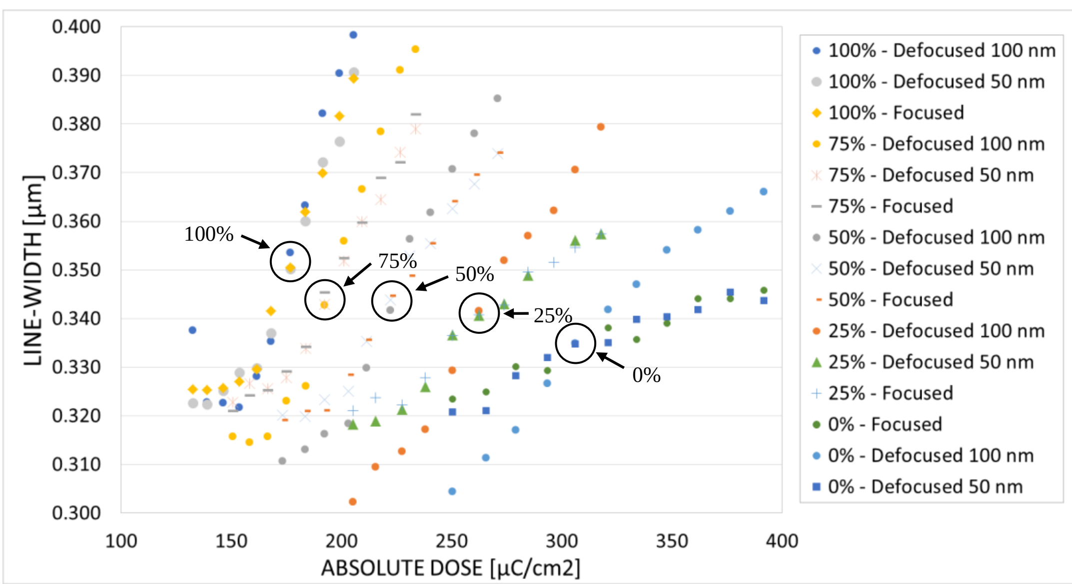

Figure 2: Pattern Density Dependent Isofocal Doses for ZEP520A at 100 keV: The isofocal doses are found from the crossover points for each pattern density. As expected isolated features require higher dose. Also note that an isofocal bias increases with pattern density possibly from lateral development in the resist. The pattern dependent isofocal doses are roughly 306, 263, 222, 193 and 177 µC/cm^2 for 0%, 25%, 50%, 75% and 100% pattern densities, respectively, for ZEP520A when exposed at 100 keV.