Resist Bias Measured from Iso-focal Structure

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In modern photolithography as feature sizes reduce, manufacturing process simulation requires increased simulation accuracy to comprehend process effects in process models. While the optical simulation calculated by a process model is in good agreement with first-principle simulators, an accurate and computationally inexpensive resist model has yet to be developed. By inspecting the wafer data, one can only see the results after development, which is the mixture of optical and resist effects. To isolate the effect contributed by resist, it is necessary to separate the optical and resist components. This can be accomplished by checking the resist bias in the iso-focal structure.

According to theory, for a fixed dose an optically iso-focal structure remains iso-focal after resist effect, and vice versa. The difference between the resist iso-focal CD (critical dimension) and aerial image iso-focal CD is the resist bias, as shown in figure 1. Although it is not practical to measure the optical CD directly, one can take advantage of iso-focal structures to find the common crossing point of the optical profiles calculated from simulation under different defocus values, from which the iso-focal image CD can then be determined. On the other hand, the resist iso-focal CD can be obtained from wafer data that is measured from SEM picture under different defocus conditions. The optical measurement and the CD calculation can then be subtracted to find the resist bias.

Experimental data were acquired under nominal dose and three different defocus conditions (best focus, negative and positive focus). The wafer CDs were first inspected and the iso-focal structure was determined to be a nested line structure with line width of 170 nm and duty ratio of 1.0. The wafer CDs of this structure are: 154 nm, 154 nm and 156 nm for the three defocus conditions. As plotted in figure 2, the aerial image profiles of the structure were generated from a process model and showed a common crossing point for all the three curves. The optical CD determined by the crossing point is 170 nm or so, indicating a resist bias of 16 nm. And the optical intensity at the crossing point is 0.32, which is used as the optical threshold for other structures. To check the validity of the resist bias, another nested structure with line width of 80 nm and duty ratio of 0.8 was tested. It yielded an optical CD of 92 nm when its aerial image profile was sliced by the same optical threshold. The resist bias obtained from this structure is 12 nm, which is not too far from 16 nm determined by the iso-focal structure given the facts that the structures are different from each other and there are other noise sources from metrology.

The same process conditions were input to a first principle simulator and the results calculated after resist effect under different focal conditions are summarized in figure 3. As clearly seen, under the dose of 49.5 mj the same structure with line/space 170 nm shrank to about 155 nm after the development procedure, which is in a close agreement to the CDs predicted by the process model with resist bias. A detailed analysis of resist effects on modern photolithography simulation will de discussed in the full paper, as well as the application of these effects.

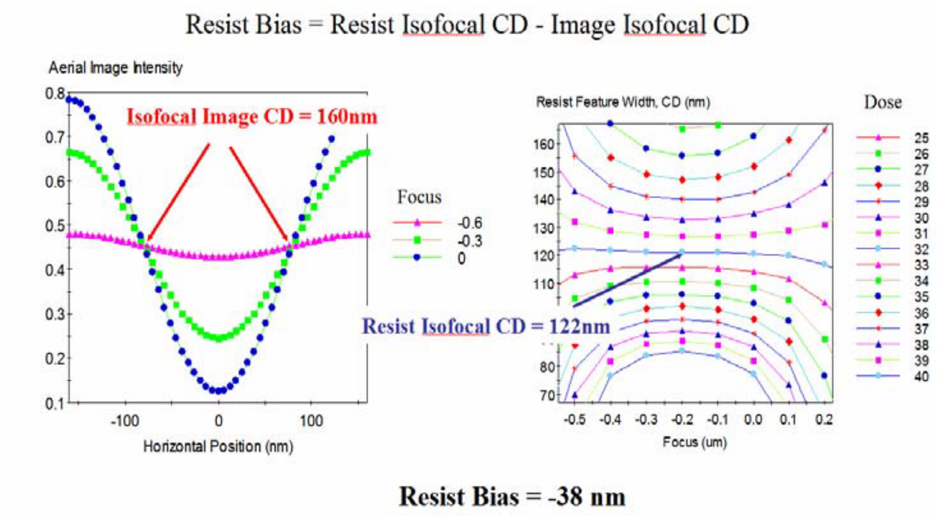

Figure 1

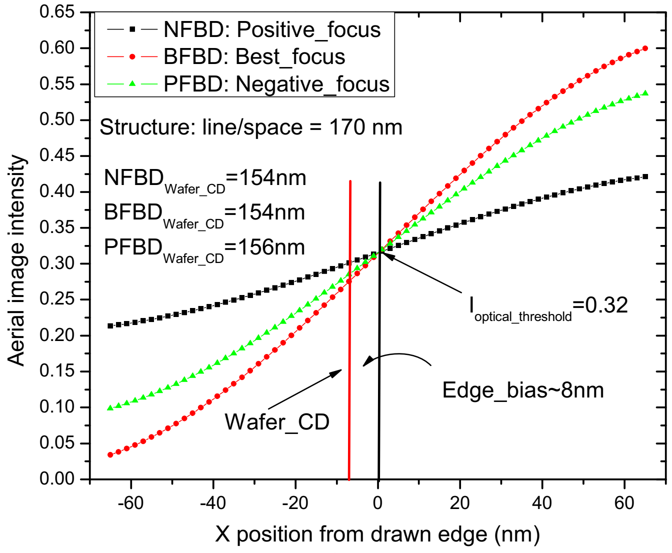

Figure 2

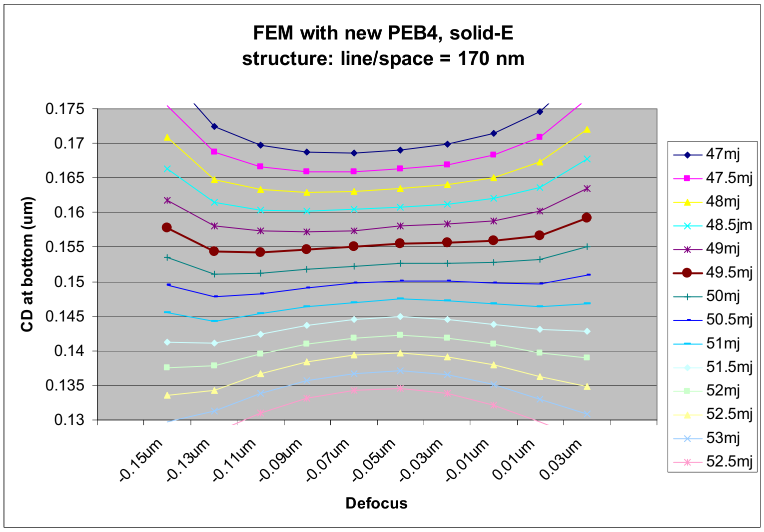

Figure 3