Proximity Effect Correction for Multiple-electron-beam Direct Write Lithography

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The Multiple-Electron-Beam Direct Write (MEBDW) lithographic tool using low beam energy at 5keV can provide lower resist dosage and less heating effect onto substrate, which are better for enhancing throughput, CD and overlay, comparing with that using 50-keV electron beam. However the lower energy suffers from the worse electron scattering effect inside imaging layer, which limits the resolution and induces severer proximity effect. Therefore none of the study for proximity effect correction (PEC) for 5keV has ever been published.

In this paper, the commercial OPC platform is proposed for PEC of 5keV electron beam direct writing. Because the maximum electron scattering range in the case of 5keV electron beam is less than 1μm that meets the basic requirement of the commercial optical proximity correction (OPC) tools. Performances of this method are examined by experiments using hydrogen silisesquioxane (HSQ) for variant 35 nm half-pitch test features. In addition, resolution down to 30-nm half pitch (HP) has been achieved by this 5keV Gaussian electron beam direct writing.

The impacts on CD shift at dense and isolated lines by various beam sizes were studied. Fig. 1 (a) shows that the CD enlargements induced by beam size changing from 12 nm to 25 nm were 3 nm and 6 nm for 100-nm pitch and 70-nm pitch respectively. It presents that the beam size has a stronger effect on CD at the denser pitch. Fig. 1 (b) reveals similar data for isolated lines at different drawn CD and shows that the CD shifts for beam-size changing from 12 nm to 25 nm were 2 nm and 4.5 nm for 32-nm and 44-nm drawn CD respectively. The beam size also has a stronger effect on the wider isolated lines, although it doesn't match with simulation result. Fig. 2 shows the comparison between with and without PEC for a 32-nm node logic clip.

In the study, we have demonstrated the 30-nm HP resolution on the 30-nm thick HSQ with 16-nm beam size, and verified the performance of PEC for 35-nm HP. The experimental proximity effect of 5-keV electron beam was characterized by using the in-house simulation software, MOSES, based on double-Gaussian function. At the 30-nm thick HSQ and 5-keV electron beam, the value of σ_b and η were 350nm and 1.3 respectively, while the value of σ_f depended on both the beam size and the resists thickness. Furthermore, we have successfully proven that PEC for the 5-keV MEBDW can be performed by shape correction using the commercial OPC platform. Last, we predicted the possibility for resolving 22-nm HP by 5keV at 20-nm beam size and 20-nm resist thickness.

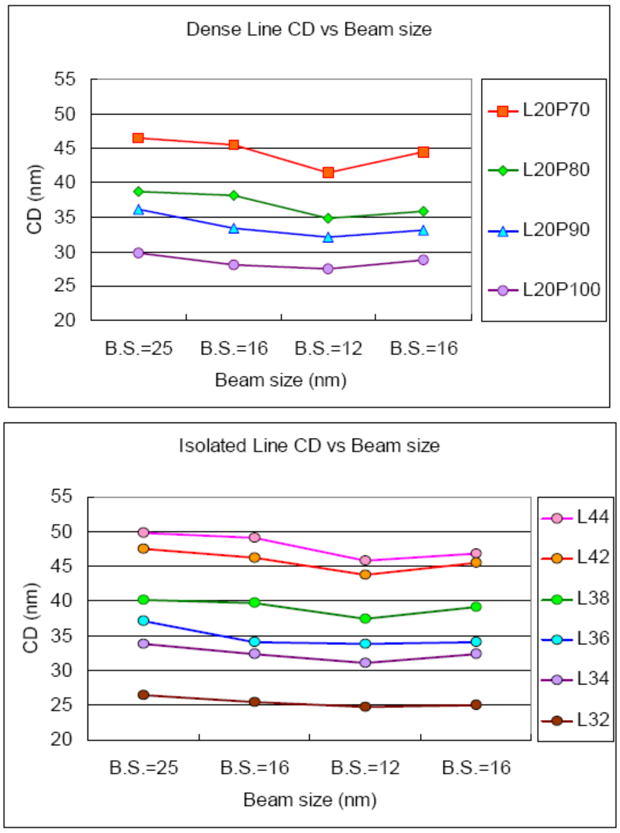

Fig. 1: Experimental data of drawn CD versus beam size for (a) dense lines at 20-nm drawn CD and variant pitches at 70 nm, 80 nm, 90 nm, and 100 nm (b) isolated lines of variant CD from 32 nm to 44 nm.

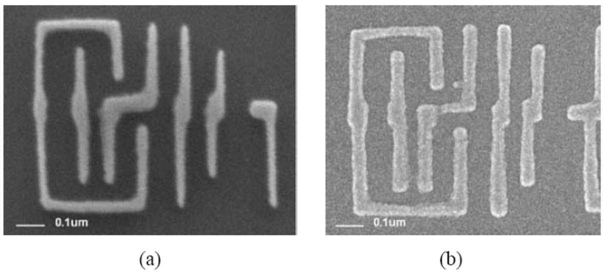

Fig. 2: The SEM pictures of a 32-nm node logic clip (a) without PEC, (b) with PEC.