Multi-beam mask writer MBM-1000

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The trend of shot count increase and shift to lower sensitivity resist continues toward N5 and beyond. EUV lithography is expected to be inserted to production shortly. It will allow further shrinkage of patterns to increase figure count beyond the limit of optical lithography.

We have developed a multi-beam mask writer MBM-1000 for N5. It is designed to accomplish throughput higher than a single-beam VSB writer EBM-9500[1] and to have capability to write complex OPC patterns with fidelity.

MBM-1000 uses a multi-beam system with a single electron source and multi-beam aperture plates accommodated in an electron optical column. Broad e-beam illuminates shaping aperture array plate to form bemlets, which are individually turned on or off by deflection at a blanking aperture plate and then collectively positioned on the target by using common deflectors. The total beam current with all beamlets turned on is 500 nA with the standard configuration of the current density at $2A/cm^2$ and the beam size at 10 nm. The configurations for larger total current are also supported.

Mask writing systems need variety of correction functions to achieve pattern CD uniformity, image placement and pattern fidelity. Writing systems using e-beam need to cope with secondary dose brought by electron scattering as shown in Fig. 1. Corrections of proximity effect correction (PEC), fogging effect correction and (FEC) has been used along with loading effect correction (LEC). MBM-1000 has new corrections covering the interaction range smaller than 10 um; EUV-PEC for the 1-um range correction needed for EUV substrates, PLDC[2] for resolution and fidelity improvement and the beam-by-beam correction to correct dose profile distortion incurred by image distortion in electron optics.

PLDC corrects dose profile which is blurred by resist process. It also enhances dose profile so that dose gradient at pattern edge is steeper. In both cases, dose level at pattern edge is adjusted to be at constant level in order to have size and shape of patterns concordant to design. PLDC modifies the dose profile by modulating dose of each pixel. To determine modulated dose, PLDC performs a

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[1] H. Matsui, T., Kamikubo, S., Nakahashi, H., Nomura, N., Nakayamada, M., Suganuma, Y., Kato, J., Yashima, V., Katsap, K., Saito, R., Kobayashi, N., Miyamoto, M. and Ogasawara, Proc. SPIE 9985, 998508 (2016).

[2] H., Zable H., Matsumoto K., Yasui R., Ueba N., Nakayamada N., Shirali Y., Masuda R., Pearman A. and Fujimura A., Proc. SPIE 10454, 104540D-1 (2017).

mask process simulation on the fine mesh smaller than the dose blur range. Example of writing results with and without PLDC is shown in Fig. 2. Breakage of narrow pattern and disappearance of small patterns occurred when PLDC was not applied, and these defects were solved when PLDC was applied.

We will describe the writing system and correction functions of a multi-beam writer MBM-1000 in comparison with a VSB writer EBM-9500. We will show writing results with MBM-1000 and PLDC.

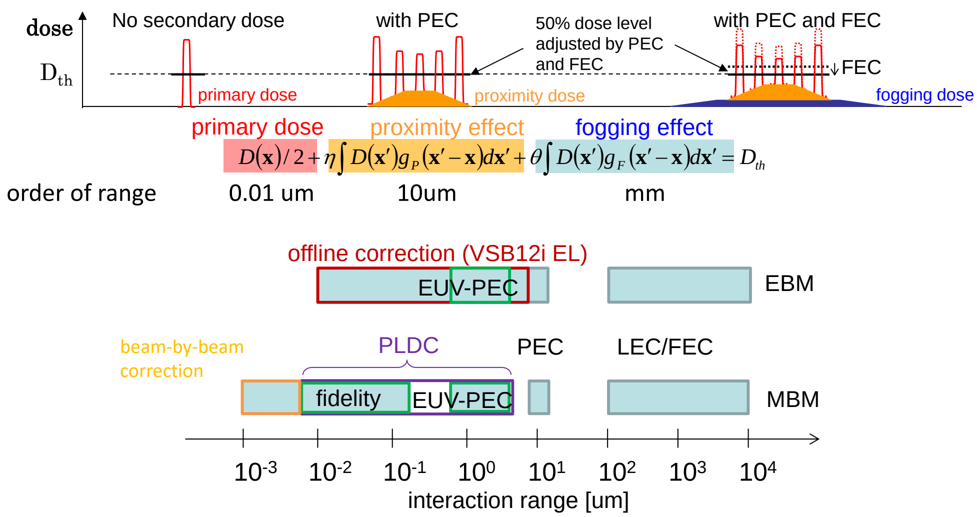

Figure 1: Correction functions of EBM series and MBM-1000.

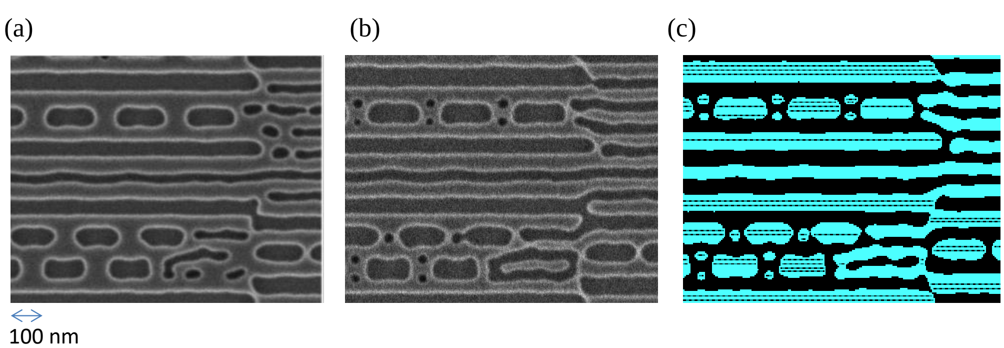

Figure 2: OPC patterns printed (a) without and (b) with PLDC compared with (c) CAD data.