Multi-beam mask writer MBM-1000 for advanced mask making

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Shrinkage of semiconductor devices has slowed down, but strong motivation for further shrinkage persists. ArF immersion lithography has been extended by introducing multiple patterning technique and aggressive OPC, and finally production by EUV lithography is about to start. Advanced lithography is posing challenges of writing accuracy and large figure count for mask writer.

For leading-edge mask making, single variable shaped beam (S-VSB) writer has been used as it has high TPT and good resolution with VSB system. We have released EBM-9500[1] for N7 lithography, with high current density of 1200 A/cm^2, thermal effect correction and fast three-stage deflection system. However, perpetual extension of VSB writer throughput seems technically difficult, and multi-beam writers are claimed to be essential for EUV lithography.

We have developed a multi-beam mask writer MBM-1000 for N5 production. It is based on large area projection optics with blanking aperture array (BAA) for individual beam blanking as shown in Fig. 1. For patterning resolution, it uses 10-nm beam size and new optics with smaller aberration. Writing results demonstrates better resolution of MBM-1000 than EBM-9000 [1].

To further extend patterning resolution, pixel level dose modulation (PLDC) is developed for MBM-1000. It modulates exposure dose pixel by pixel, to enhance dose contrast at pattern edge[2]. It improves CD linearity, pattern fidelity and enlarges dose margin. PLDC runs inline in parallel to writing, and thus does not require calculation before writing.

PLDC also corrects linearity, and effectiveness of correction is evaluated by simulation as shown in Fig.2. CD linearity is corrected even without extra dose modulation, and dose margin is improved with additional dose modulation of 140%, and further improvement is gained with 200% dose modulation. User can specify maximum dose modulation allowed for PLDC to balance correction gain and write time increase. According to the simulation result, 140% modulation is a good condition balancing write time increase and linearity correction gain by dose modulation.

REFFERNCES

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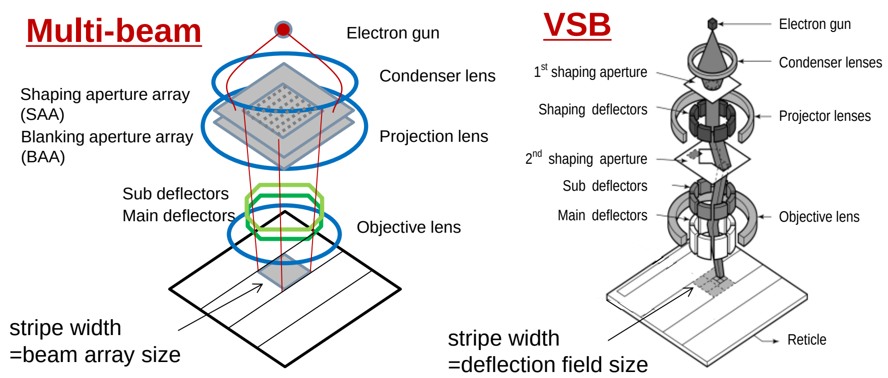
[2] Zable H., Matsumoto H., Yasui K., Ueba R., Nakayamada N., Shirali N., Masuda Y., Pearman R., Fujimura A., "GPU-accelerated inline linearity correction: pixel-level dose correction (PLDC) for the MBM-1000," Proc. SPIE 10454, 104540D-1 (2017).



	MBM-1000	EBM-9500
beam size	10 nm beam in 512×512 array	variable 350 nm
current density (A/cm^2)	2	1200
max. total current (nA)	500	700
stripe width (um)	82 (beam array size)	81 (deflection field size)

Figure 1: Configurations of MBM-1000 and EBM-9500

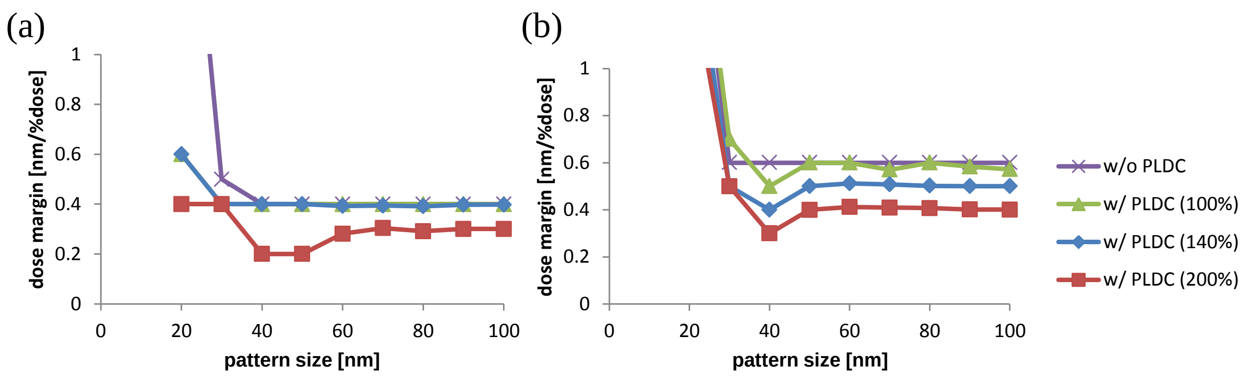


Figure 2. Dose margin (dose latitude) of line and space pattern with (a) 5% density and (b) 50% density simulated with threshold dose model.

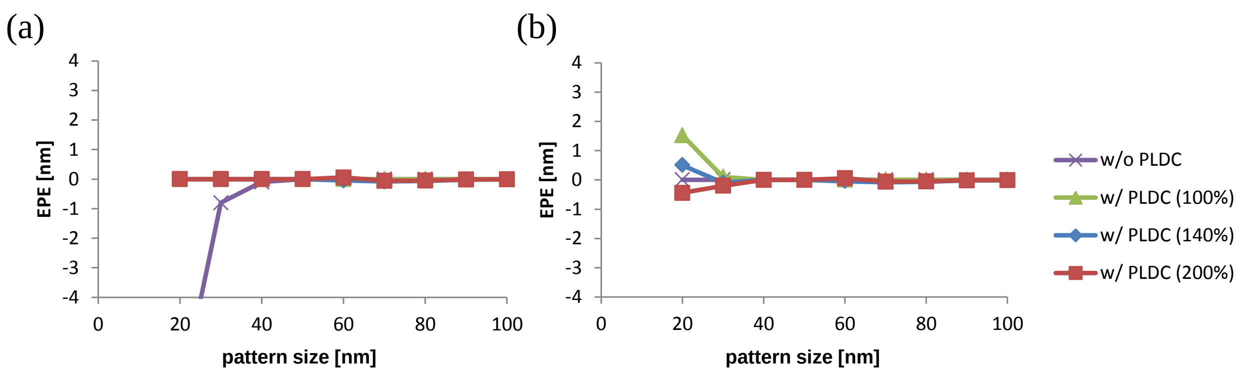


Figure 3. Edge placement error of line and space pattern with (a) 5% density and (b) 50% density simulated with threshold dose model.