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[2,3] as shown in Fig. 1. To achieve best patterning resolution, it uses 10 nm beam size and 2 A/cm^2 current density bringing total current of 500 nA, which is comparable to beam current at maximum shot size of our VSB writers. Advantage of MBM-1000 in patterning resolution over EBM-9000 is verified by measuring dose latitude with p-CAR resist and dose margin 20-nm hp pattern and non-CAR resist. Complex OPC pattern was successfully printed with low sensitivity pCAR resist as shown in Fig 2.

To further extend patterning resolution, pixel level dose modulation (PLDC) is developed for MBM-1000. [4] It modulates exposure dose pixel by pixel, to enhance dose contrast at pattern edge. It corrects linearity, improves pattern fidelity, and enlarges dose margin. PLDC runs inline in parallel to writing, and thus does not require calculation before writing.

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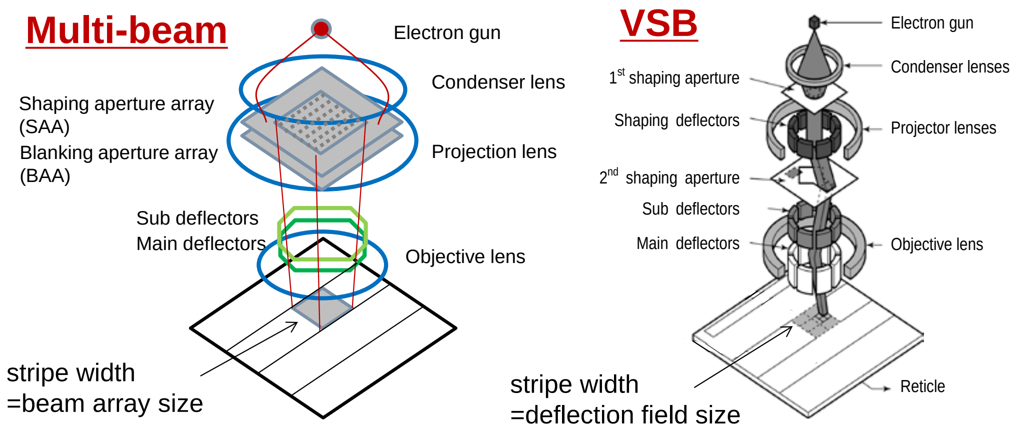
[4] H. Zable, H. Matsumoto, K. Yasui, R. Ueba, N. Nakayamada, N. Shirali, Y. Masuda, R. Pearman, A. Fujimura, Proc. SPIE 10454, 104540D-1 (2017).



	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

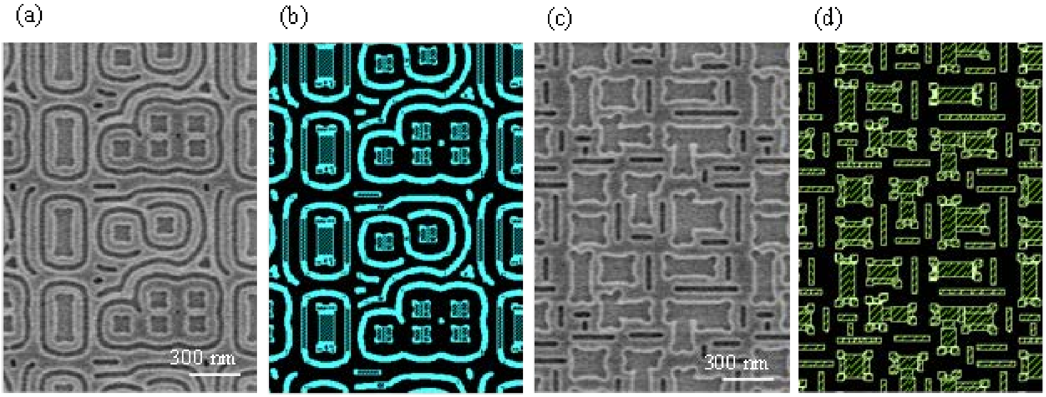


Figure 2: OPC patterns printed on low sensitivity pCAR resist (140 µC/cm2), compared with CAD design in MBF format.