Resolution Improvement for the Maskless Micro-Ion Beam Reduction Lithography Systems*

Ximan Jiang[a), c)], Qing Ji[b)], Lili Ji[a)], Audrey Chang[a)], and Ka-Ngo Leung[a)]

Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720

A novel ion beam projection lithography (IPL) system called Maskless Micro-Ion Beam Reduction Lithography (MMRL) System[1] has been built in Lawrence Berkeley National Laboratory (LBNL) (Fig.1). Compared with conventional IPL system, MMRL completely eliminated the ion beam illumination columns before the stencil mask in IPL. In MMRL system, ions drift out from a multicusp ion source through a beam-forming electrode and then are directly projected to the wafer. Due to its low energy in front of the beam-forming electrode, ion beams can be switched on and off by the universal pattern generator at a high speed. Using proper writing strategy, MMRL can directly write patterns on wafer without employing complicated and expensive masks.

As a candidate for the next generation lithography system, MMRL is designed for sub-100nm nodes. Third-order geometrical aberration and first-order chromatic aberration of the MMRL ion optical system were calculated at different numerical aperture (NA) (Fig.2). All the blurs decrease with NA. Spherical aberration dominates at high NA region. Chromatic aberration dominates at low NA. Due to the small wavelength of the ions, ion beam lithography system can work at a 10^{-5} NA before diffraction limited resolution dominates.

In the former MMRL system (Fig.1), aperture angle of the shaped ion beams are determined by the aspect ratio of the beam-forming electrode. The attainable aspect ratio limits the NA and the resolution. With a 10:1 aspect ratio beam-forming electrode, the corresponding NA on image side is about 0.01, the conservative ion optical simulation (Fig. 2) predicts about 1μm resolution. This is consistent with the exposure result on former MMRL columns, as shown in fig. 1. In order to obtain sub-100nm resolution, the NA of the MMRL needs to be smaller than 10^{-3}. This can be accomplished by installing a contrast aperture (< 200μm in diameter) at the beam crossover position (Fig. 4). The electric field penetrating into the contrast aperture hole has relatively large curvature, which will increase the geometrical blur. The two relatively thick electrodes on both sides of the contrast aperture can decrease the electric field gradient and minimize such an effect. More ion optical simulation suggests that elevating the potential of the contrast aperture relative to the two adjacent electrodes can prevent electric field from penetrating into the aperture and further decrease the edge effect of the contrast aperture. Preliminary resist exposure results with the contrast aperture show considerable improvement in resolution (Fig. 3) and depth-of-focus. Experiments on optimizing the aperture alignment, using 2×10^{-4} NA and elevating the contrast aperture potential are in progress, further improved results will be presented at the conference.

[1] V.V.Ngo, W. Barletta, R. Gough, Y. Lee, K.N.Leung, N. Zahir, and D. Patterson, J. Vac. Sci. Technol. B17, 2783 (1999).

---

* *This work is supported by DARPA and the U.S. Department of Energy under contract No. DE-AC03-76SF0099*

[a)] *also with Department of Nuclear Engineering, University of California, Berkeley, CA 94720*

[b)] *also with Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, CA 94720*

[c)] *Email address:* xjiang@lbl.gov

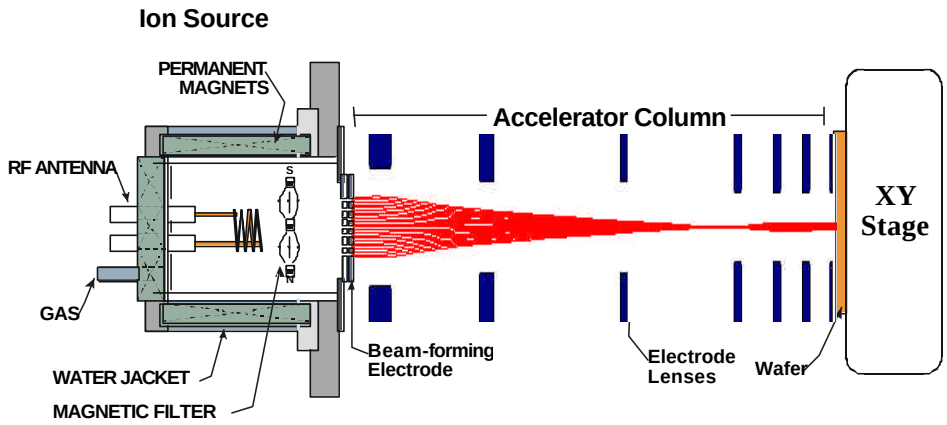


Figure 1: The MMRL system using a universal pattern generator (beam-forming electrode) to form lithographic patterns on wafer.

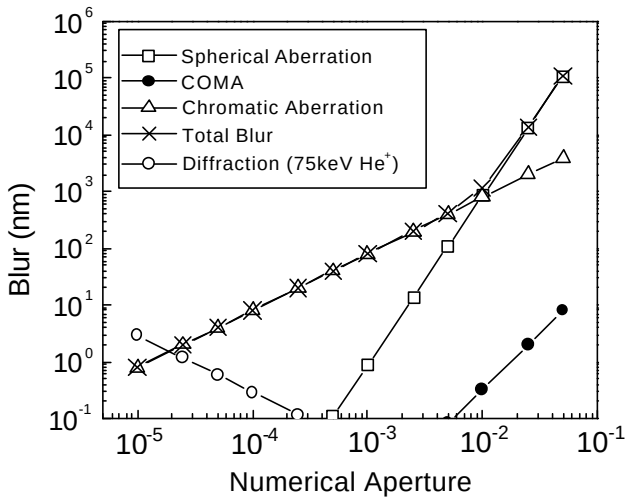


Figure 2: Characterization of the MMRL ion optical system. Image size 100nm and 5eV energy spread were set in calculation for a conservative estimation

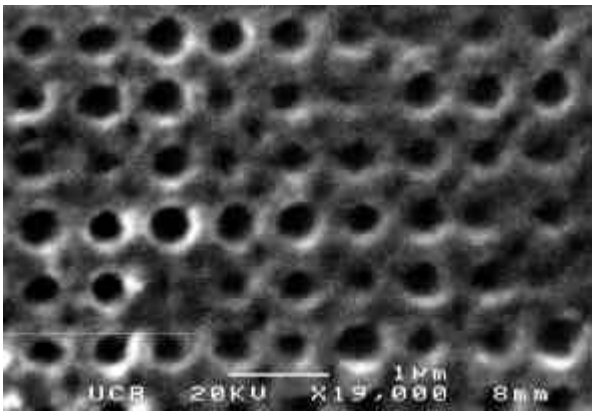


Figure 3: Contact hole pattern obtained by MMRL with contrast aperture. Hole sizes range from 160nm to 350nm due to the un-uniformity in beam- forming electrode. NA is at 2×10^{-3}.

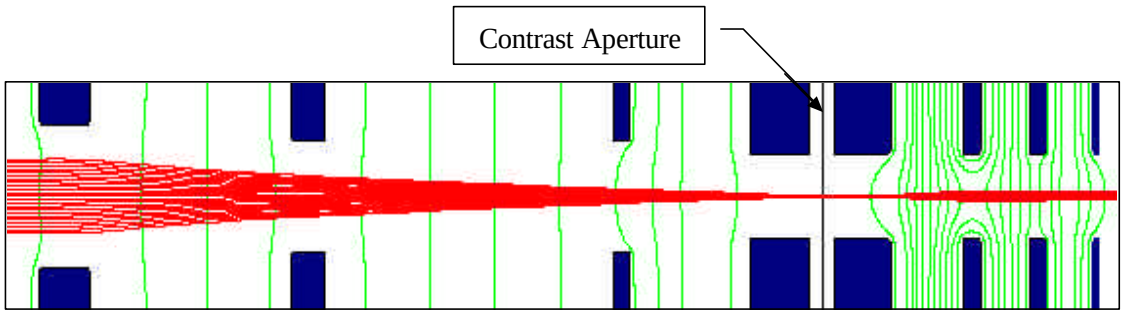
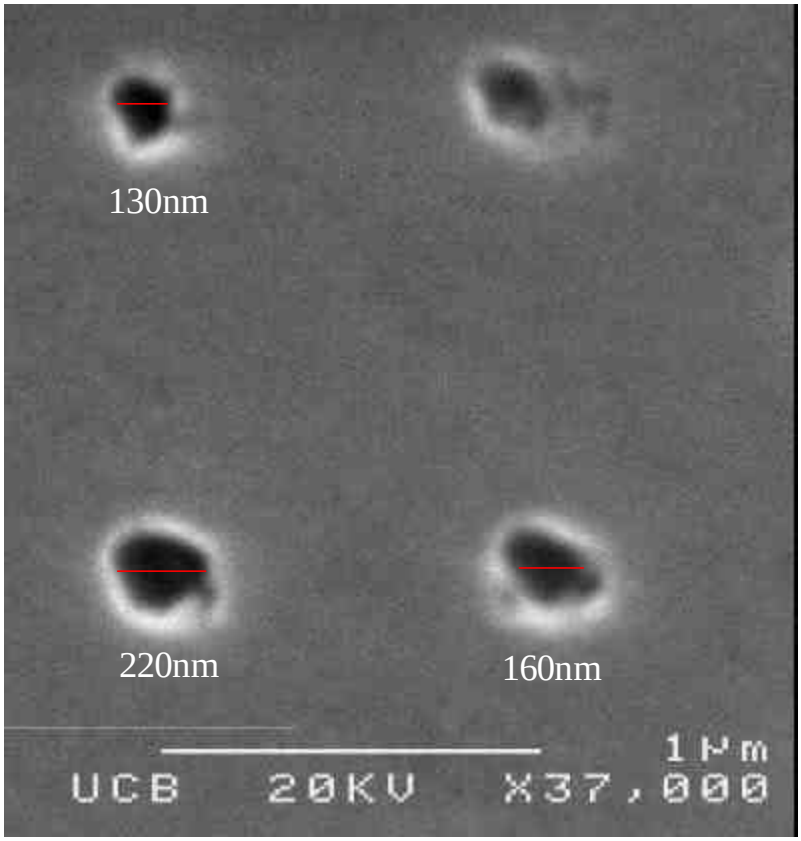


Figure 4: MMRL ion optical column with contrast aperture.


130nm
220nm
160nm
1μm
UCB 20KV X37,000