Improved Sensitivity of Positive E-beam Resist by Pre-Exposure to DUV Radiation

Raghunath Murali, Devin Brown, Kevin P. Martin, James D. Meindl
Microelectronics Research Center, Georgia Institute of Technology, Atlanta GA

Electron beam lithography is the process of choice for high resolution patterning but write-time limits throughput[1]. Chemically amplified resists (CAR) overcome this issue to some extent by having high sensitivity but usually have lower resolution than non-CAR resists[2,3]. Increasing the resist sensitivity limits resolution because of a fundamental limiting factor – the shot noise limit. To pattern a 1 cm^2 chip with 50% fill factor would take 14 hours (assuming a beam current of 2 nA and a dose of 200 uC/cm^2). Clearly, a big improvement in resist sensitivity is needed to be able to pattern sub-50nm structures with good throughput.

It is well known that many DUV resists are sensitive to an e-beam and the property has been made use of to develop processes for DUV resists using e-beam lithography. A limited amount of work has been done on mix and match lithography on the same layer[4]. But very little has been studied on the effect of a pre-exposure of e-beam resists to DUV radiation. In this work, we have studied the positive resist ZEP-520 (from Zeon Chemicals); a pre-exposure to DUV radiation (flood exposure) is followed by e-beam lithography.

A film of ZEP 520 (300 nm or 80 nm) was spin-coated on a Si substrate. This was followed by varied amounts of exposure to DUV radiation. A Karl Suss mask aligner was used for blanket exposure; the source was a 240 nm lamp with a power density of 6.0 mW/cm^2. The DUV pre-exposure time was varied between 1 min and 8 min. This was followed by e-beam lithography using a JEOL JBX-9300 FS at 100 kV; the beam current was 2 nA corresponding to a beam diameter of 15 nm. The address grid size was either 8 nm or 10 nm depending on the required dose. This was followed by development in amyl-acetate for either 30s or 60s. Table 1 shows the dose-to-clear and contrast for various DUV pre-exposure times and develop times. It can be seen that 8 min. of DUV exposure causes a large dissolution of unexposed areas. A 4 min. DUV exposure result in lesser (40 nm) loss of resist while a 2 min. exposure results in almost no loss of resist. A 2 min. exposure is also seen to improve the resist sensitivity from 148 uC/cm^2 for regular e-beam lithography to 98 uC/cm^2; this leads to a 34% improvement in resist sensitivity. Figs. 1 and 2 show line/space patterns with 2 min. and 1 min. DUV exposures, respectively. Sub-50nm patterns were obtained in 300 nm resist, leading to 6:1 aspect ratio structures with line-widths less than 3x the beam diameter. Features around 2x the beam diameter and 3x the address grid were obtained in 80 nm resist. This shows that there is little loss of resolution with a slight DUV pre-exposure. Depending on the resolution needed, the pre-exposure time can be tailored to the necessary level to obtain the corresponding contrast and sensitivity.

References

1. L.R. Harriott, *Proc. IEEE*, **89**, 3 (2001)
2. D.R. Medeiros et al, *IBM J. Res. Dev.*, **45**, 5 (2001)
3. E. Ainley et al, *Micro. Eng.* **46** (1999)
4. M. Narihiro et al, *Jap. J. App. Phys.* **39**, 12 (2000)

Table 1: Comparison of various pre-exposure conditions and develop time, for two different resist (ZEP 520) thicknesses.

Initial Resist Thickness (nm)	Pre-expose time (min)	Develop time (s)	Dose to clear 80% of resist thickness (uC/cm^2)	Contrast	Resist dissolution in unexposed areas (nm)
307	0	60	148	6.53	2
307	2	60	98	2.66	3
307	4	60	65	1.71	49
307	4	30	91	2.11	19
307	8	60	10	-	226
80	0	60	142	-	6
80	1	60	131	-	8
80	2	60	83	-	26

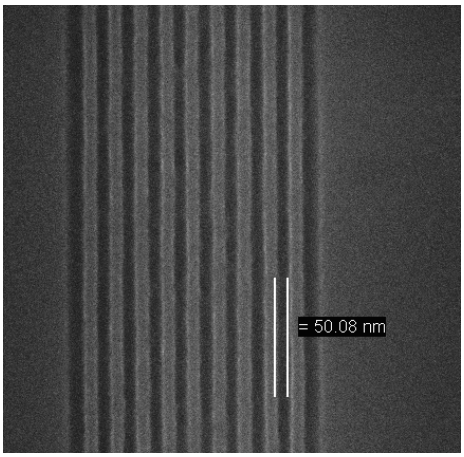

Fig. 1: Line/space pattern in 300 nm thick ZEP 520; the DUV pre-exposure was for 2 min. and the linewidth is 50 nm.

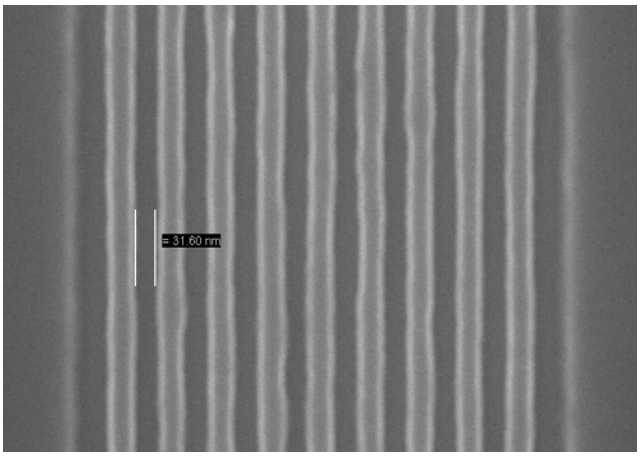

Fig. 2: Line/space pattern in 80 nm thick ZEP 520; the DUV pre-expose was for 1 min and the achieved linewidth is 31 nm.