Sub-10 nm Electron Beam Lithography by Using Rapid and Cold Development of ZEP-520A

C. Nien, C.H. Chung, V.C. Su, and C. H. Kuan
Graduate Institute of Electronics Engineering, National Taiwan University, Taipei City, Taiwan.
chkuan@ntu.edu.tw

The demands of improving the electron beam lithography to the sub-10 nm resolution increase as the great advance in many fields such as the nanophotonics and nanoelectronics. Generally, the resolution of electron beam lithography can be affected by several factors include the choice of resist,[1] electron scattering,[2] and the development process.[3] In this work, we study the effects of development time and the temperature on the exposure pattern and show that sub-10 nm pattern could be achieved by using a rapid and cold development process.

To investigate the relation between the development rate and electron distribution, we made sequences of single point exposures. The ZEP 520A resist was diluted with anisole thinner (ZEP-A) at the ratio of 1:1 and spin coated onto the silicon substrates to a thickness of ~150 nm. These substrates were exposed by 100 keV electrons with current of 100pA using an Elionix ELS-7000 electron beam lithography tool. Figure 1 shows the diameters of the point exposures after developed in ZED-N50 for 5 to 420 seconds at 20^{o}C for the gradually increasing dose. The steep curves for the first few seconds indicate the high development rate near the center of the point exposure is corresponding to the exposure region dominated by the forward scattered electrons of primary beam. The flat part of curves, in contrast, are corresponding to the secondary electrons. By controlling the development process in a short time, we could constrain the clear region in the forward scattering-dominated region.

Because it is practically difficult to control the development time in a very short duration precisely. We use the cold development process to reduce the fragment mobility during resist dissolution.[4] Figure 2 shows the scanning-electron-microscopy (SEM) images of point exposures for various development temperatures. It can be seen that there is a significant reduction in spot diameter at the lower developer temperature. Figure 3 shows by lowering the development temperature to -6^{o}C, we have achieved ~ 9nm isolated lines.

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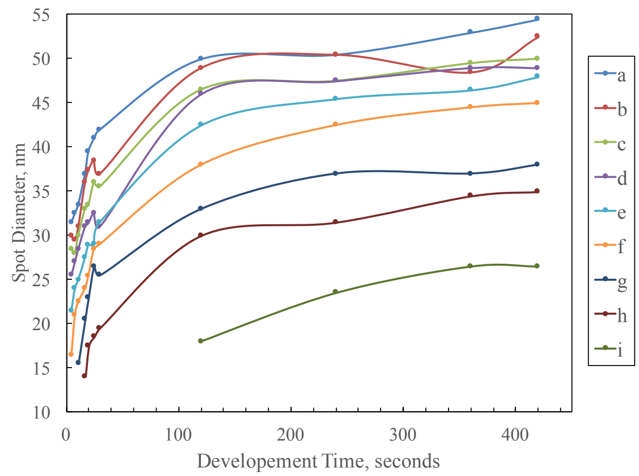

Figure 1: Diameter of developed point exposures of ZEP-520A exposed at 100 keV from different does: (a) 2 fC, (b) 3 fC, (c) 4 fC, (d) 5 fC, (e) 6 fC, (f) 7 fC, (g) 8 fC, (h) 9fC, (i) 10fC.

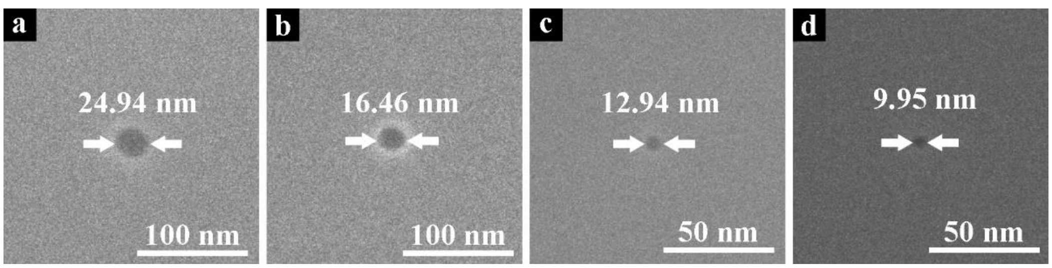

Figure 2: SEM image of ZEP-520A point exposures developed in ZED-N50 for 11 s at (a) 20°C, (b) 10°C, (c) 0°C, and (d) -6°C.

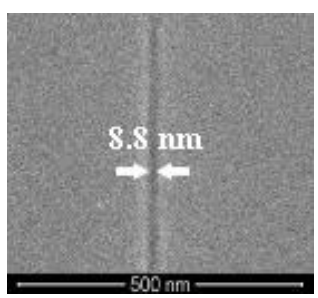

Figure 3: SEM image of an isolated line on ZEP-520A after 10 s development in ZED-N50 with the linewidth about 9 nm. The e-beam dose is 6μC/cm^2.