High sensitivity electron beam lithography using ZEP resist and MEK:MIBK developer

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Electron beam lithography (EBL) is well known for its low throughput. To reduce the exposure time, one can use higher beam current, more sensitive resist, (for positive resist) stronger developer/higher development temperature, or lower electron beam energy. Chemically amplified resists like SU-8 and NEB 22 have very high sensitivity, but low resolution (more strictly speaking, half pitch for dense periodic line array pattern). Non-chemically amplified resist like ZEP, though ~3× more sensitive than PMMA, is still very insensitive when using high resolution developers of amyl/hexyl acetate or xylene [1] (e.g. sensitivity ~100 μC/cm^2 at 30 keV in Ref. [2]).

In this work we will show that the sensitivity for ZEP (520A) resist can be substantially increased to 2.6 μC/cm^2 at 5 keV beam energy by using MEK (methyl ethyl ketone) : MIBK (methyl isobutyl ketone) = 40 : 60 developer, which resulted in a fair resolution of 60 nm (half pitch).

In the experiment, the as-purchased ZEP resist was diluted with anisole to obtain 45 nm thickness, and exposed using LEO 1530 FE-SEM equipped with NPGS system. After exposure, the resist was developed by dipping into the MEK:MIBK mixture for 0.5-2 min at room temperature. Fig. 1 shows the contrast curve at 5 keV with a development time of 30 sec, which indicates a sensitivity of 2.6 μC/cm^2 and contrast of 1.8. The sensitivity is much higher than ZEP resist developed using high resolution developer, but at the cost of reduced contrast (e.g. contrast=3.6 in Ref. [2]). This is in agreement with the observation that higher sensitivity typically leads to lower resolution (due to lower contrast), with roughly a relationship of $L \propto D^{-1/2}$ (here L is resolution, D is sensitivity) [2]. In addition, the unexposed area was found to be slightly dissolved by the developer by ~4 nm within 30 sec. To study the resolution, we wrote dense periodic line array patterns over large area (larger than the range of backscattered electrons at 5 keV), and found the densest pattern that could still be fairly well resolved was 120 nm pitch grating (60 nm half pitch) (see Fig. 2a), though the lines were not as well defined as in the larger pitch patterns (see Fig. 2b for 180 nm pitch). For comparison, typically ~50 nm pitch grating can be well resolved for high resolution resists (when using high resolution developer) [3].

[1] S. Bentley, X. Li, D. A. J. Moran and I. G. Thayne, *Microelecton. Eng.* 86, 1067, 2009.
[2] L. E. Ocola and A. Stein, *J. Vac. Sci. Technol. B* 24(6), 3061, 2006.
[3] B. Cui and T. Veres, *Microelecton. Eng.* 85, 810, 2008.

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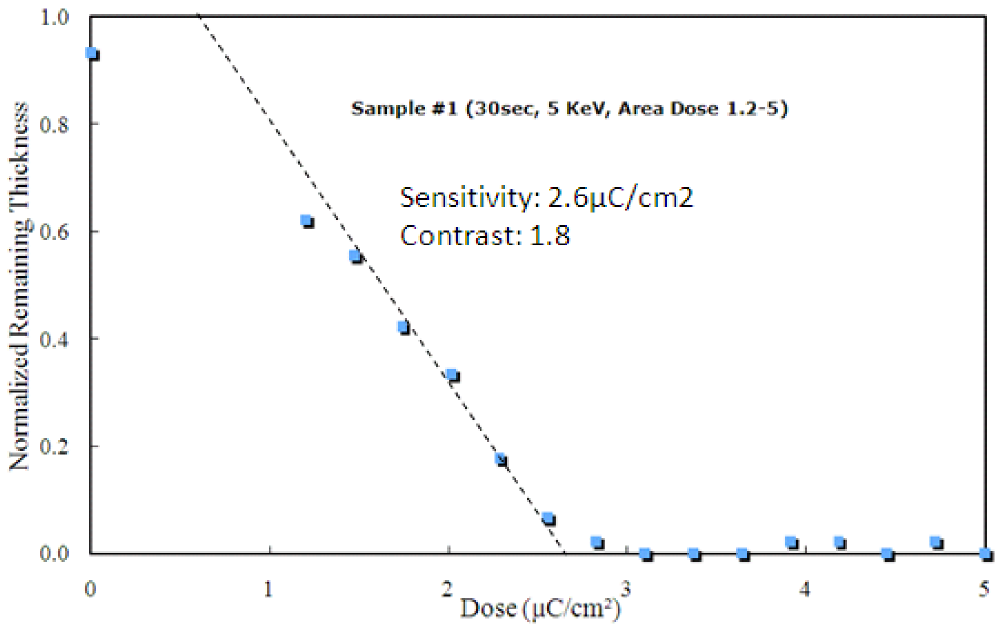

Figure 1 Contrast curve for ZEP-520A resist developed using MEK:MIBK = 40:60 for 30 sec at room temperature.

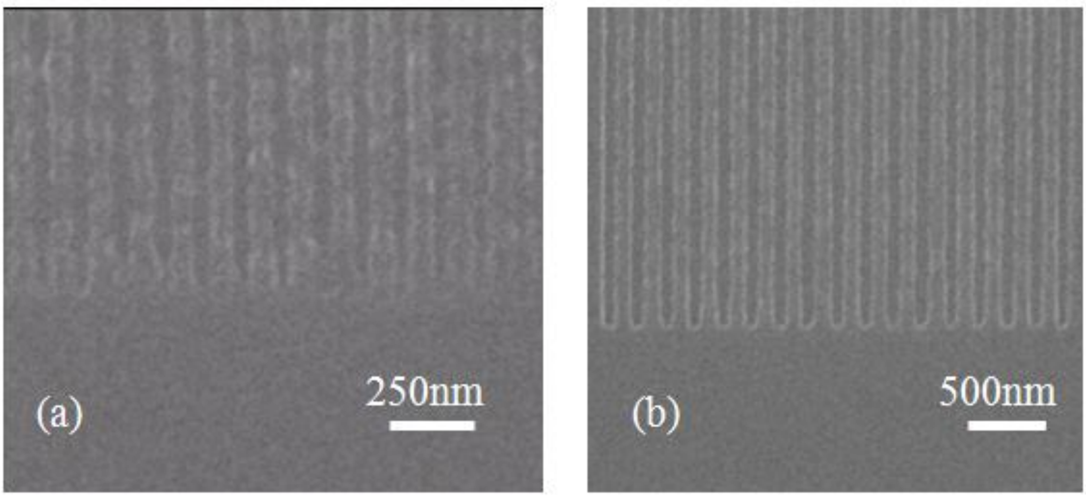

Figure 2 SEM images of (a) 120 nm, and (b) 180 nm pitch grating patterns in ZEP-520A resist developed using MEK:MIBK=40:60 for 30 sec at room temperature.