High Aspect Ratio SML Resist Patterning using 30 keV Electron Beam Lithography

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Recently, SML brand electron beam resist has been introduced for high aspect ratio (AR) nanolithography applications.[1,2] The molecular structure of SML resist is intended to reduce the proximity effects related to primary electron scattering and nearly eliminate the secondary electron generation.[2] While SML resist shows promise, there has been little work to date for understanding the process characteristics of the resist.

In this work, we present a detailed characterization of SML resist at 30 keV (and lower voltage) exposures. Our aim is to co-optimize the exposure and development conditions and to maximize the sensitivity and AR. To study the experimental trends of SML resist,[3] we exposed contrast curves and grating patterns as test structures. Fig. 1 compares contrast curves for SML 300 and PMMA resists (275-290 nm thick), both exposed at 10 and 30 keV and developed at room temperature in MIBK: IPA 1:3 for 20 sec followed by an IPA quench for 20 sec. For both exposure voltages, SML resist has 37-56% higher contrast at the cost of 70-80% lower sensitivity compared to PMMA. At the higher voltage, SML exhibits 7% greater contrast compared to 20% improvement in PMMA. Fig. 2 shows cross-section micrographs of 275-290 nm thick (a, b) and > 1500 nm thick (c) SML resist exposed at 30 keV. Currently, AR's of 6-7.5:1 have been achieved without the use of resolution enhancement or pattern collapse prevention techniques. We have also begun testing other developers such as IPA: H_2O 7:3 due to its higher sensitivity and lower swelling when used with PMMA.[4] Fig. 3 shows contrast curves at 10 and 30 keV for SML resist developed for 20 sec in IPA: H_2O 7:3 compared to PMMA developed for 20 sec in MIBK: IPA 1:3. For both 10 and 30 keV, IPA: H_2O 7:3 development improves SML sensitivity to within 7-20% of PMMA sensitivity. Based on the current results, we believe SML resist can yield aspect ratios of up to 15:1 at comparable sensitivity to PMMA. In addition, we have begun evaluating the etch durability of SML resist to common Si etch chemistries.

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[1] S. Lewis, et. al., "Characterization of an ultra high aspect ratio electron beam resist for nano-lithography," NSTI-Nanotech 2010, vol. **2**, 195-198.

[2] S. Lewis, et. al., "High acceleration voltage characterization of SML electron beam resist for ultra high aspect ratio nano-lithographic applications" EIPBN 2011, Presentation 7A.5.

[3] Spin coated SML resist samples courtesy of Daniel Royston at *E M Resist Ltd UK*.

[4] S. Yasin, D.G. Hasko, and H. Ahmed, *Appl. Phys. Lett.* **78**, 2760 (2001).

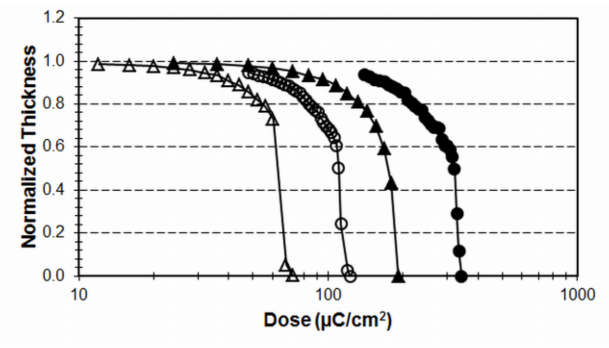

Figure 1: Contrast curves for SML resist (circles) and PMMA resist (triangles) exposed at 10 keV (open symbols) and 30 keV (closed symbols). Both resists were developed for 20 sec in MIBK: IPA 1:3 at room temperature (RT).

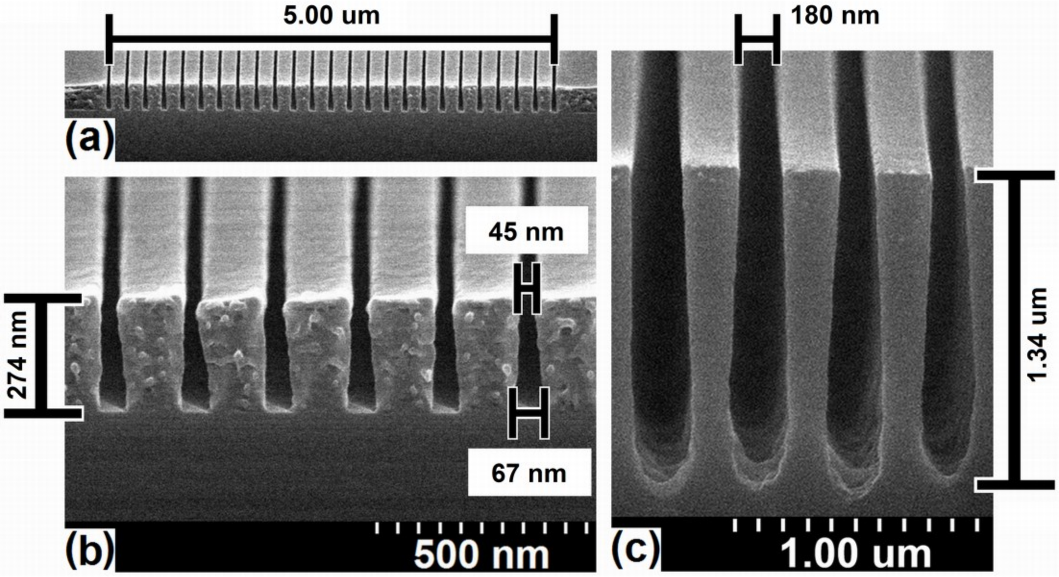

Figure 2: Cross-section micrographs (14° tilt) of 30 keV e-beam patterned SML resist (a) 5 um array of 200 nm pitch gratings in 274 nm thick resist, (b) magnified image showing pattern widths, and (c) 400 nm pitch gratings in > 1500 nm thick resist. The exposure doses were 3.6 nC/cm (a,b), and 700 μC/cm^2 (c) and all samples were developed for 20 sec in MIBK: IPA 1:3 at RT.

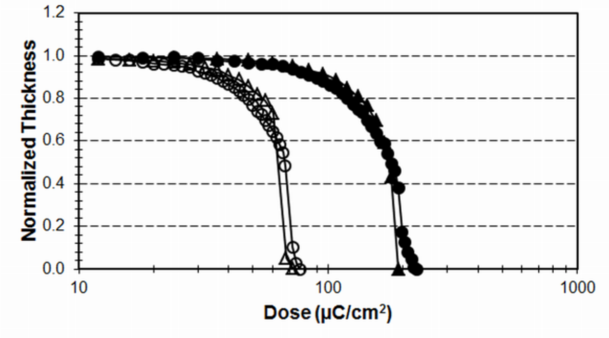

Figure 3: Contrast curves for SML resist (circles) and PMMA (resist) triangles at 10 keV (open symbols) and 30 keV (closed symbols). SML samples were developed for 20 sec in IPA: H_2O 7:3 and PMMA samples were developed in MIBK: IPA 1:3, both at RT.