Negative-Tone Chemically-Amplified for Sub-20nm Lithography

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Here, we report 20 nm half-pitch (HP) patterning using a negative-tone chemically amplified (CA) molecular resist for E-beam or EUV exposure systems. Ladder-like cyclic small molecule ‘‘Noria’’ molecule (synthesized by Nishikubo group) is an excellent candidate for high-resolution resist material, because of its rigid structure and relatively high sensitivity. We first show that resolution and LER can be improved by moving from positive tone (Fig. 1a) to negative tone (Fig. 1b) and ultimately by adding oxetane cross-linking moieties to the system (Fig. 1c).

We study variable cross-linker additions (0, 5, 10, and 20 wt%) and characterize EUV exposed material pattern quality (Fig. 2a). To understand patterning performance, we investigate modulus and material redistribution during development. We find that even in small amounts, cross-linker increases the modulus as evaluated using a new PeakForce™ Tapping AFM analysis (Fig. 2b). In addition, cross-linking changes material redistribution kinetics and prevents material inhomogenities. We show the amount must be optimized appropriately considering the balance between cross-linking and deprotection reactions and the effects on modulus, swelling, redistribution kinetics, and excessive cross-linking, which can increase LER.

E-Beam exposures were done on negative resist sample without addition of cross-linker to evaluate how feature biasing can affect performance. Without increasing the overall exposure time, pattern bias improves the modulus contrast in the materials (Fig. 3a). In addition, the deprotection contrast is enhanced at the edge boundary of the exposed feature, and hence results in better LER performance (Fig. 3b). Collapse free structures were exposed down to 20 nm half-pitch. Hence, we combine molecular resists, cross-linking, and negative tone development for high performance lithography with a CAR.

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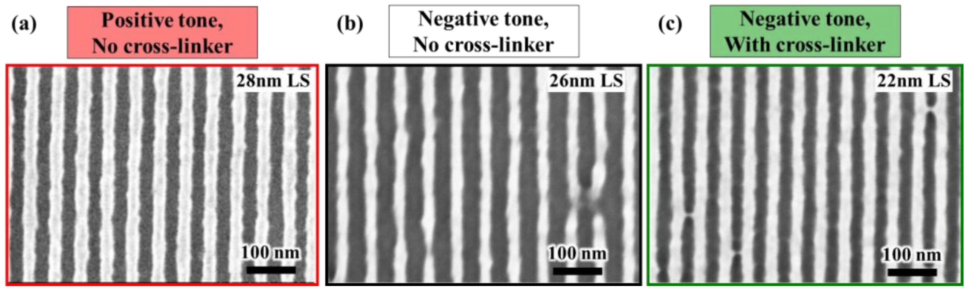

Figure 1 - SEM images of (a) positive resist, without cross-linker, (b) negative resist, without cross-linker, and (c) negative resist, with cross-linker, at their best resolution patterns.

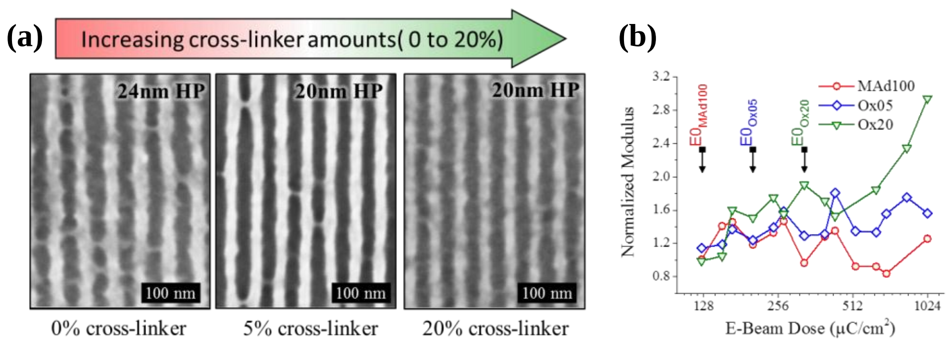

Figure 2 – (a) HRSEM images of the best resolution patterns for 0% cross-linker (i.e. MAd100), 5% cross-linker (i.e. Ox05), and 20% cross-linker (i.e. Ox20). (b) Modulus variation with increasing dose for cross-linked resists.

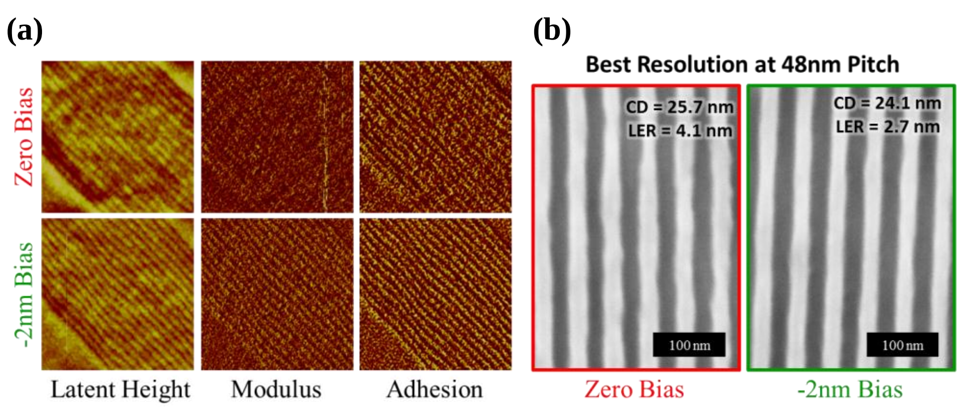

Figure 3 - (a) AFM topography, modulus and adhesion images for biased and unbiased pattern after exposure. (b) SEM image show best resolution 24 nm HP images for E-beam exposure. LER improvements with pattern biases can be noted.