High Resolution Dry Development

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As features sizes continue to shrink, new approaches are required to overcome roadblocks towards high-resolution lithographic patterning. One significant roadblock towards miniaturization is pattern collapse due to capillary forces during drying.[1] We have developed a dry development method for creation of high resolution and high aspect ratio resist features. We use resists that undergo an optical absorption change after exposure to high-resolution radiation (here we use electron beam lithography). This optical change allows the material to be selectively laser ablated such that the resolution is defined by the electron lithography and not limited by the laser spot size. Using methyl-acetoxy calix[6]arene, a sub 30 mW continuous wave 532 nm laser, and focal spot sizes on the order of 300 nm, we have produced features down to 10 nm in a film 120 nm thick, with pitch resolution down to 30 nm and aspect ratios of ~4:1 (Fig. 1). Calixarene was introduced as a high resolution electron-beam resist [2] and has demonstrated 12.5 nm half-pitch in extreme ultra-violet lithography.[3] Typically, thin films are used to prevent high-resolution pattern collapse in thicker films. By using dry development, the patterns we have developed are well defined even in thick, 120 nm films. It should be noted that the resist is negative with solvent development, as the cross-linked material can not be removed. In contrast, under dry laser development it is positive at the same electron-beam dose conditions.

We have systematically studied the optical absorption contrast behavior and mechanism using changes in functional groups, Raman and UV-Vis Spectroscopy, AFM, and mass spectrometry as a function of electron beam dose, laser wavelength, laser dose, and resist thickness. At 532 nm laser wavelength, we have identified a two photon absorption process and one functional group as responsible for the optical contrast. Having identified this functionality, we have been able to generalize the technique beyond methyl acetoxy calix[6]arene and calixarenes in general. The mechanism and alternative dry developable materials will be discussed.

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References

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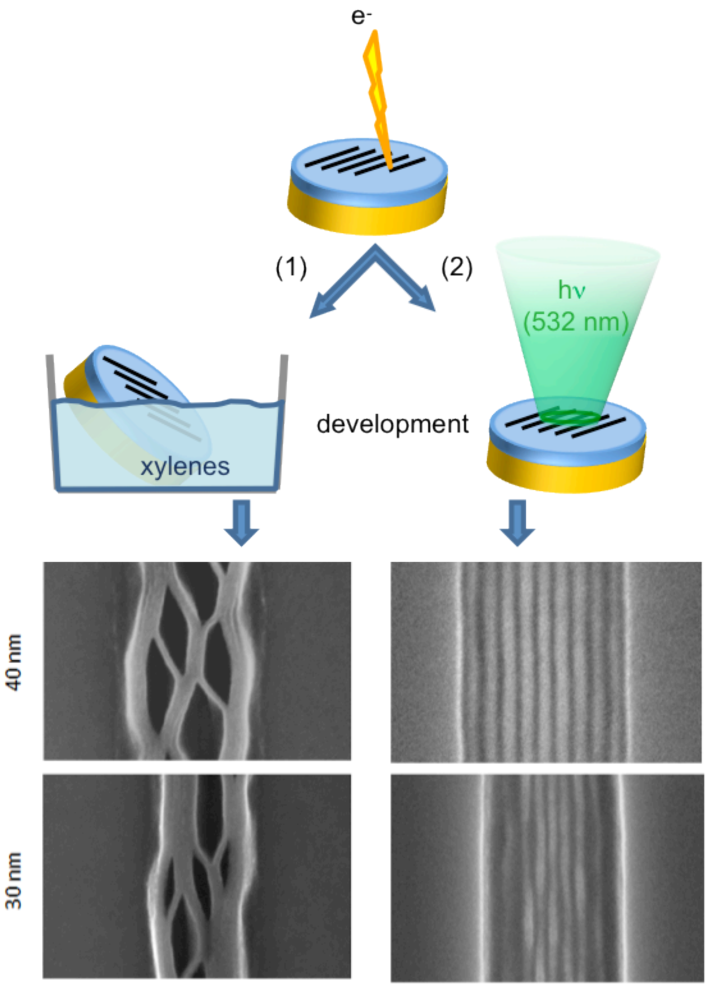

Figure 1. Comparison of methyl-acetoxy calix[6]arene developed in xylenes and dry developed with laser. The resist transforms from a negative resist with wet development to positive with dry development. Features were defined down to a 30 nm pitch.