Ultra-Thin Film Effects on Photoresist Imaging Performance

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As pattern sizes shrink sub-50 nm, likewise the resist film thicknesses must shrink as well. The reduction in film thickness is required due to pattern collapse that occurs in most standard resist patterns when they have aspect ratios of 2:1 to 3.5:1.[1] This reduction in film thickness is a concern for several reasons such as etch resistance, but it is especially important as film thicknesses shrink below 100 nm. The sub-100 nm film thickness regime is where ultra-thin film effects become a major issue due to the confinement of the material at the interfaces; i.e. the interfacial layer between the substrate and the resist and the interfacial layer at the free surface of the resist film become significant relative to the total film thickness. These ultra-thin film effects have shown to result in dramatic changes in the properties of the materials such as raising or lowering the glass transition temperature[2], changing the mobility of the material[3], and orders of magnitude reduction in the diffusivity of small molecules such as acid and water.[4] These changes can cause identical resist films of different thicknesses to behave significantly different such as the dose-to-size shifting due to the changes in photoacid diffusivity and glass transition temperature. This study examines the effect of film thickness on pattern collapse by determining the modulus and critical stress at the point of pattern collapse (Fig. 1) at varying film thicknesses for an assortment of photoresists. Likewise, positive tone and negative tone resists will be compared to determine the different pattern collapse effects of cross-linked and non-cross-linked films. Figure 2 shows a plot of critical stress vs. thickness for a negative tone molecular resist (4-Ep). It can be seen that the critical stress is approximately constant until the film thickness is below 100 nm and then decreases as the film gets thinner.

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[1] ITRS 2007 Lithography.
[2] Singh, L., Ludovise, P. J., et al., *Proc. SPIE*, **2004**, 5376, 369.
[3] Soles, C. L., R. L. Jones, et al., *Proc. SPIE,* **2003**, 5039, 366.
[4] Vogt, B. D., C. L. Soles, et al., *Langmuir*, **2004**, 20, 1453.

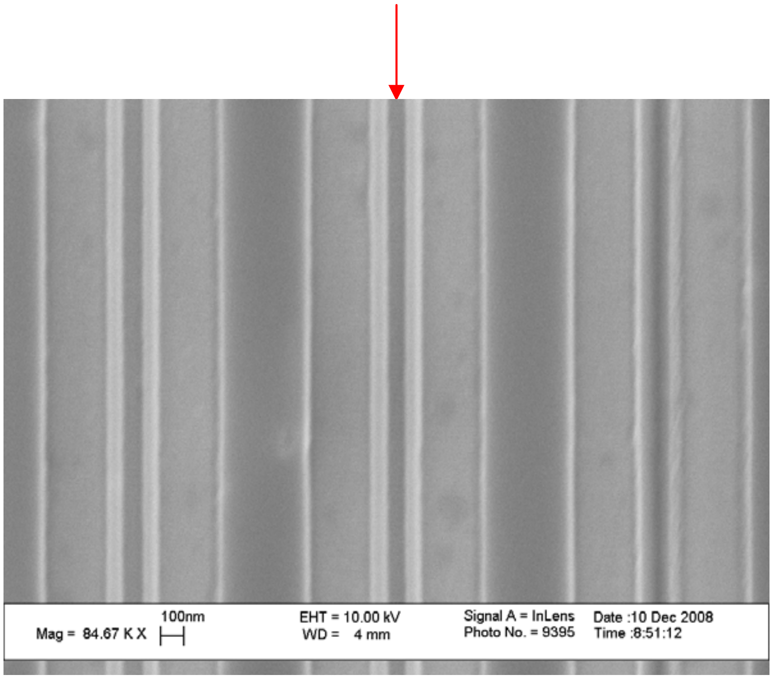

Figure 1. SEM image of an e-beam lithography-patterned photoresist showing the critical stress point above which pattern collapse occurs.

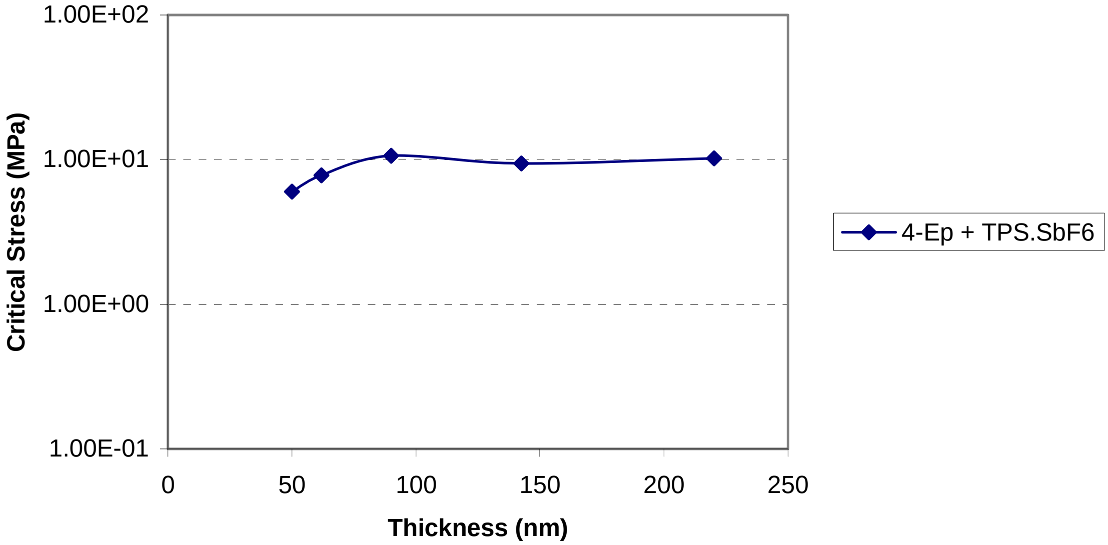

Figure 2. Critical stress vs. thickness for 4-Ep demonstrating a decrease in the critical stress as the thickness decreases.