The effect of thin metal over-layers on the electron beam exposure of poly-methyl methacrylate

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Several electron-beam lithography based fabrication processes require deposition of thin metal layers on top of an electron-beam resist to prevent local charging.[1] In addition, thin metal layers,[2] or even patterned metal layers,[3] are used as electron-transparent fiducial grids in spatial-phase locked electron beam lithography. Despite the frequent use of such layers, a careful characterization of their effects on exposure contrast and resolution has not been presented. Here we consider the effect of thermally evaporated aluminum and chromium films on the contrast and resolution of poly-methyl methacrylate (PMMA) electron beam resist exposed at different primary beam energies.

A 100-nm thick PMMA layer (950K molecular weight) was coated with 5-nm thick metal layers of Al or Cr by thermal evaporation. PMMA and metal layer thicknesses were confirmed with spectroscopic ellipsometry. To measure contrast, large 100 μm × 50 μm features were exposed on all the samples using beam energies from 2 KeV to 30KeV at exposure doses ranging from 10 to 300 $\mu C/cm^2$. To evaluate resolution single pixel lines were exposed as well. After patterning both Al and Cr were etched using standard wet etchants. The samples were developed in a solution of 1:3 of methyl-iso-butyl-ketone: isopropyl alcohol and residual film thickness was measured using a surface profiler.

Fig. 1 shows the contrast curves for normal PMMA and metal coated PMMA. In all cases the presence of the metal layer slightly increases the clearing dose. For all but the 30 KeV case, the higher atomic number chromium shifts the clearing dose more than the lower atomic number aluminum. We attribute this to primary electron energy loss in the metal coatings resulting in increased electron interaction with the resist. However, contrast remains essentially constant for all three samples. We conclude that low atomic number metal coatings such as aluminum and chromium a few nanometers thick have a minimal adverse impact on contrast and clearing dose even at relatively low beam energies. We also discuss the impact of such coatings on pattern resolution. When applied properly thin metal coatings provide an alternative to conductive polymers and an excellent foundation for fiducial grids used in spatial-phase locked electron beam lithography.

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3 J. T. Hastings, F. Zhang, and H. I. Smith, Journal of Vacuum Science & Technology B 21, 2650 (2003).

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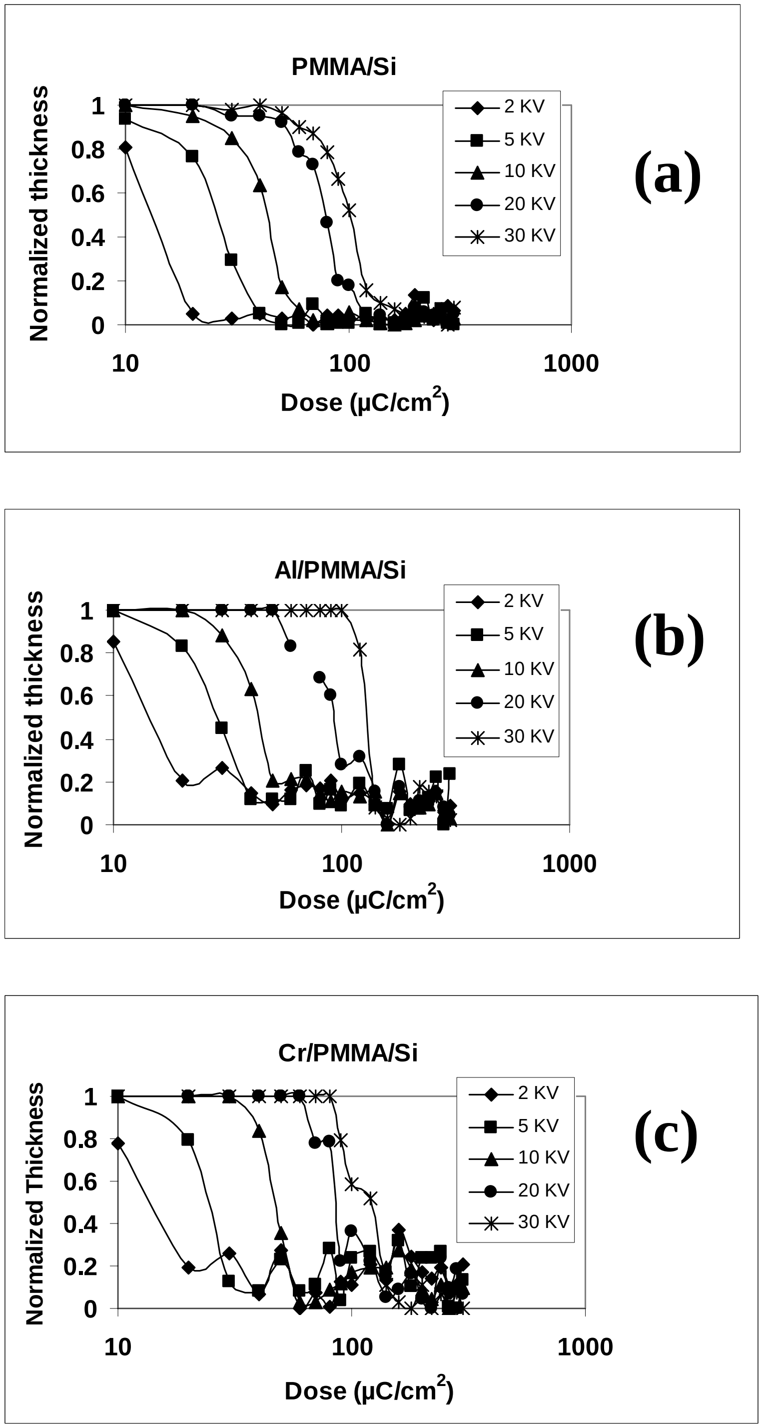

Figure 1. Normalized residual resist thickness vs. exposure dose for large features in (a) Normal PMMA, (b) Aluminum and (c) Chromium coated PMMA at primary beam energies from 2 to 30 KeV. In all cases the presence of a metal over-layer increases the required clearing dose, but has little effect on the contrast.