Amino-propyl-triethoxy-silane (APTES) on aluminum fiducial grids for spatial-phase-locked electron-beam lithography

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Spatial-phase locked electron-beam lithography (SPLEBL) uses feedback control based on an *in-situ* fiducial grid to achieve nanometer level pattern placement precision.[1] The fiducial grid must be electron transparent and provide a sufficient signal-to-noise ratio for high-precision phase-locking. Acceptable grids have been developed for higher beam energy (≥ 10keV) spatial-phase locking;[1, 2] however, a new grid must be developed to implement spatial-phase locking at the low-beam energies typical in micro-column SEBL systems. We have reported that fiducial grids can be made of alkanethiol based self-assembled-monolayers (SAM) on metallic surfaces.[3] Such grids should exhibit little difference in scattering between the SAM coated regions and exposed metal. However, total scattering of primary electrons by higher atomic number metals such as Au remains a major concern. Fiducial grids based on alkanethiol SAM coated metals with smaller atomic numbers, such as Cu, have thus far shown unacceptably low SNRs.[3]

Here we present a new approach using silane based monolayers on Al (Z=13) for low energy (~2 keV) SPLEBL. Silicon wafers with 50 nm of PMMA resist were coated with ~5 nm of Al by thermal evaporation. A PDMS stamp with a 400 nm period fiducial grid was used to micro-contact print 3-amino-propyl-triethoxy-silane (APTES) onto the Al coated PMMA. Signal-to-noise ratios were measured at beam energies ranging from 1-5 keV at a dose of 20μC/cm^2. Fig.1 shows the secondary electron micrographs of the APTES grid on the Al surface. To examine the influence of the grid on pattern fidelity, grating patterns were exposed on the APTES-Al-PMMA-Si and Al-PMMA-Si samples at beam energies of 2 and 5 keV. After patterning, the Al and APTES, if necessary, were removed using a standard Al wet etchant before developing the PMMA. Example patterns exposed through Al are shown in Fig. 2.

We calculated the SNR values of 0.02 (5 keV), 0.4 (2 keV), 0.2 (1.5 keV) and 0.02 (1 keV). We have compared SNR values for ODT based fiducial grids on Ag [0.002 (5 keV), 0.007 (2 keV), 0.04 (1.5 keV) and 0.02 (1 keV)], Cu [0.001 (5 keV), 0.003 (2 keV), 0.004 (1.5 keV) and 0.01 (1 keV)], and Au [0.32 (5 keV), 0.99 (2 keV), 1.1 (1.5 keV) and 1.2 (1 keV).[3]] Although fiducial grids made of ODT on Au provided excellent SNR, Au is not suitable due to strong scattering of primary electron beam during exposures. ODT based grids on Ag or Cu yielded inadequate SNRs. However, APTES based grids on Al provided good SNR values with reduced electron scattering.

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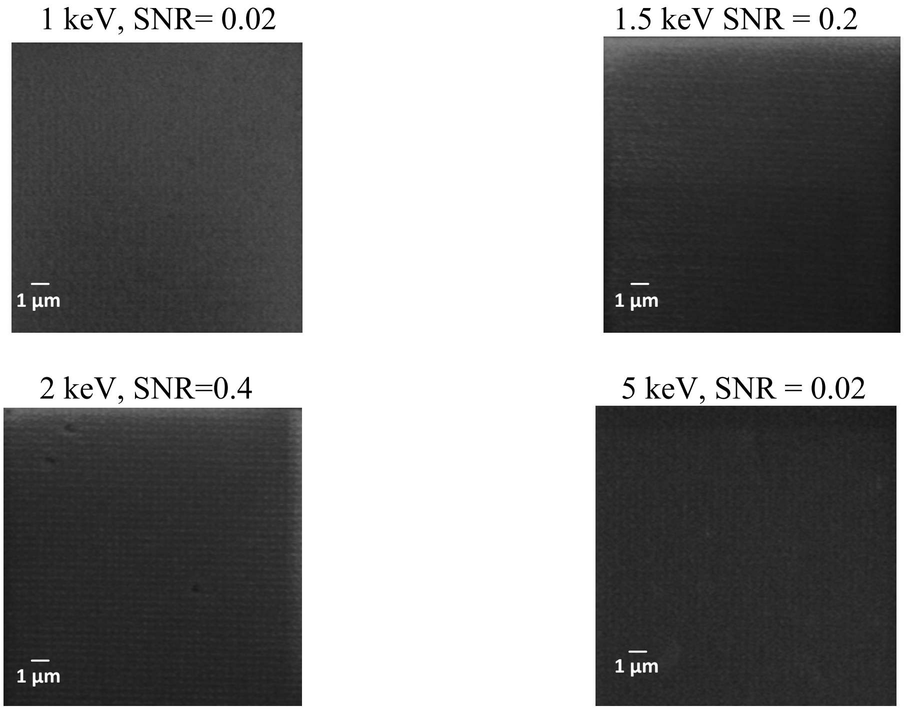

Figure 1. Secondary electron micrographs of the 400 nm period APTES fiducial grid on Al coated PMMA. The grid was formed by µ-contact-printing of APTES. Images and SNRs are shown for accelerating voltages of 1, 1.5, 2, and 5 keV at an exposure dose of 20 µC/cm^2.

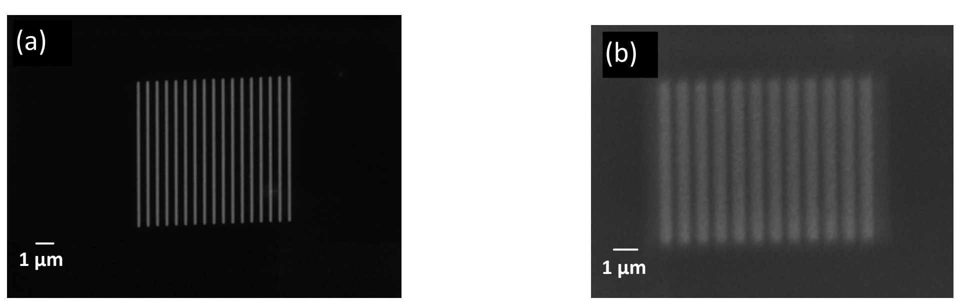

Figure 2. Example patterns exposed in PMMA at (a) 5keV, 600 nm pitch, and dose of 100 pC/cm and (b) 2keV, 800 nm pitch, dose = 70 pC/cm