Self-assembled monolayer fiduical grids for spatial-phase-locked electron-beam lithography

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Spatial-phase locked electron-beam lithography (SPLEBL) relies on the signal from an electron-transparent fiducial grid to provide feedback control of e-beam position.[1, 2] The fiducial grid must provide a high signal-to-noise ratio (SNR) secondary-electron signal while not significantly scattering the primary electron beam. Here we characterize a new fiducial grid based on a self-assembled monolayer (SAM) that is particularly well suited to low-energy (<5 keV) SPLEBL. SAMs exhibit significantly different secondary-electron yield compared to the metal films on which they are formed.[3-6] In addition, SAMs are not expected to strongly scatter the primary beam, even at low energies, because they are less than 2-nm thick and are composed of low atomic number elements.

For this study we prepared Si-PMMA-Au samples as shown in Fig. 1. However, actual low-energy SPLEBL exposures will require the substitution of a lower atomic number metal suitable for SAM formation.[7] A 400-nm period octadecanethiol (ODT) fiducial grid was contact printed onto the gold layer using a polydimethylsiloxane (PDMS) stamp. Secondary electron signals were recorded using the in-lens detector of a Raith E-LiNE electron-beam lithography system. Beam energies ranging from 1 to 5 keV were employed at a dose of 20 $\mu C/cm^2$. We calculated SNR using a discrete Fourier transform to estimate the amplitude, A, of the grid's fundamental spatial-frequency components and the variance of the noise, σ^2. Fig. 2 shows the secondary-electron micrographs of the ODT grid along with the corresponding SNR, given by A^2/σ^2. As expected, SNR decreases with increasing beam energy as overall secondary-electron yield decreases. The absolute values of SNR, as well as the signal contrast, compare favorably to previously employed fiducial grids.[2, 8, 9] If high-resolution SAM grids can be formed on lower atomic number inter-layers, then they will provide a nearly ideal solution for low-energy SPLEBL.

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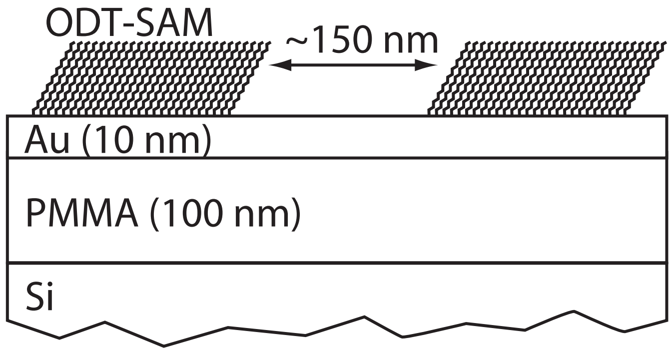

Fig. 1. Schematic (not to scale) of samples used to study SAM fiducial grids. Silicon samples were spin coated with PMMA and sputter coated with gold. 400-nm period octadecanethiol (ODT) monolayer grids were contact printed onto the gold surface using a PDMS stamp. Lines were formed in ODT while ~150-nm diameter openings remained to the underlying gold.

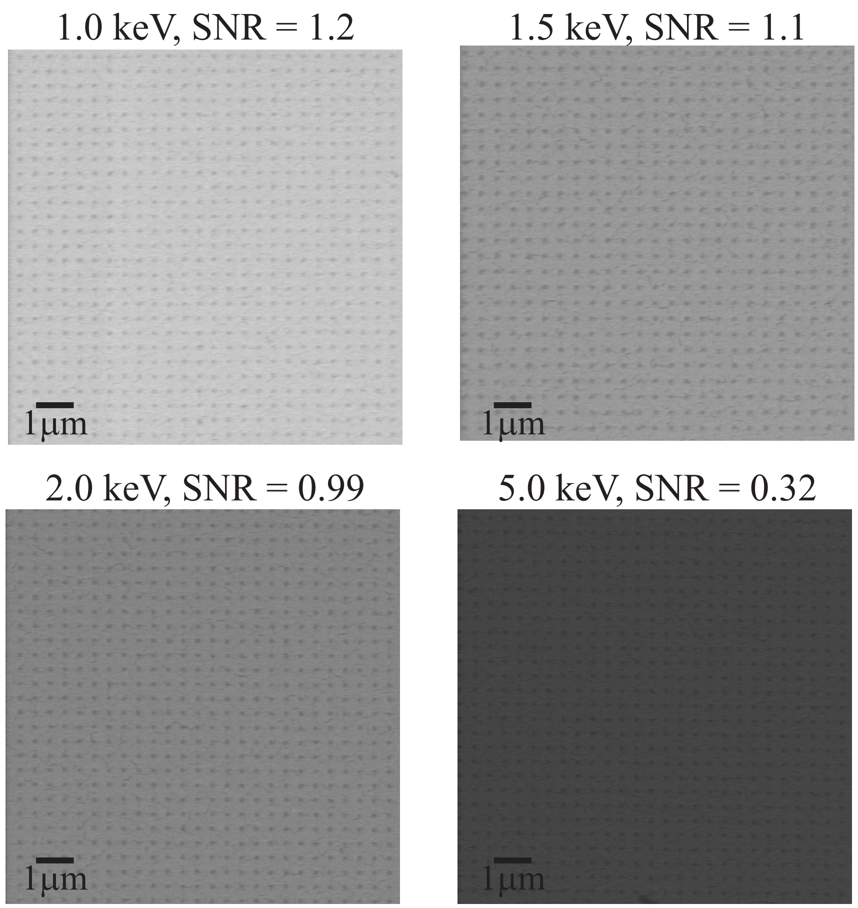

Fig. 2. Secondary-electron micrographs of 400-nm period ODT grids on Si-PMMA-Au samples. Primary beam energies ranged from 1 to 5 keV and the dose was 20μC/cm^2. Brighter areas correspond to ODT while darker areas correspond to Au. SNR is given for each beam energy.