Robust, Efficient Grating Couplers for Planar Optical Waveguides Using No-PAG SU-8 EBL

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SU-8 has been revered as a high aspect ratio chemically amplified epoxy based negative UV photoresist since its original development by IBM.[1] SU-8 most often is cured by i-line exposure, but is also a highly sensitive EBL resist.[2,3,4] We require 250-450nm pitch gratings on Ta_2O_5-on-fused-silica planar optical waveguides for coupling near-IR light into/out of the waveguide film. Minimizing roughness of the Ta_2O_5 film is crucial for low-loss waveguide performance, thus processing the gratings must be benign to the waveguide surface. Additionally, the gratings must withstand a 150-200˚C vacuum bake, be vacuum compatible down to 10^{-12} Torr, and safe for biological solutions. SU-8 exhibits all the necessary qualities and was considered because we can minimize processing steps on the Ta_2O_5 surface. It should be noted that we previously created MgF_2 gratings on Ta_2O_5 using bilayer PMMA liftoff process, but this requires 9 process steps and Ta_2O_5 liftoff is non-trivial. EBL exposed HSQ initially seemed the perfect solution except that it is incompatible with many oxide films, including Ta_2O_5: we found that unexposed regions could not be removed from the surface. We report 450nm pitch gratings on Ta_2O_5 from SU-8 resin containing no-PAG (0-PAG SU-8), figure 1. We found that 0-PAG SU-8 requires exceptionally low E0 of less than $10uC/cm^2$ at 50kV for our gratings on Ta_2O_5 (c.f. ~20-$30uC/cm^2$ on Si), lower still for large structures due to proximity effects. High sensitivity is desired for speed and throughput concerns, but since we are limited to 10MHz blanking frequency on our Vistec EBPG5000 EBL system. Such low doses require small beam currents, equation 1, potentially resulting in line edge roughness concerns. Higher, or any PAG content for that matter, drives the dose too low for acceptable exposure quality. On our Ta_2O_5 surfaces we could not dose the commercially available formulation (5% PAG) low enough to prevent scum, but the small beam size effect is shown on Si which requires over two times higher dose than our waveguides, figure 2. Additionally, eliminating the photoacid component further reduces process complexity keeping with our desire to minimize handling/processing of the Ta_2O_5 surface.

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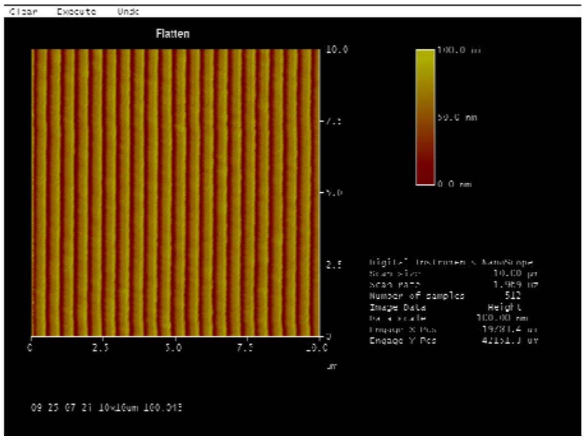

Figure 1: AFM image of 450nm pitch SU-8 grating on Ta_2O_5.

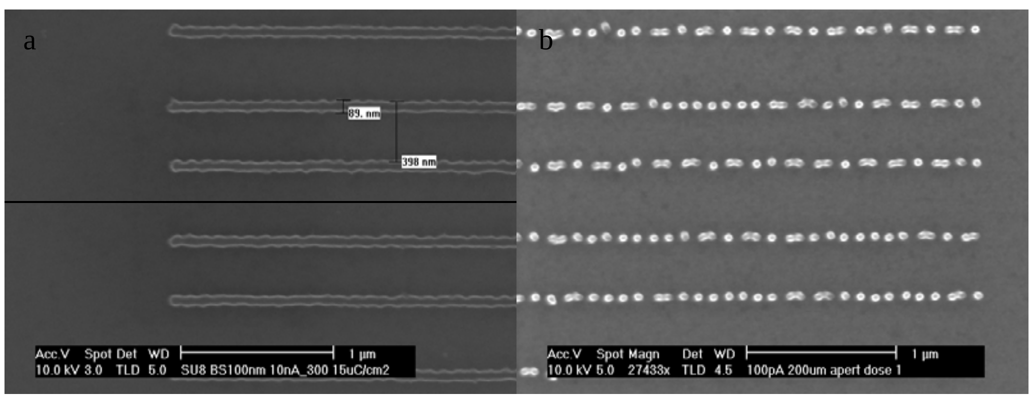

Figure 2: 5% PAG SU-8 lines on Si. Exposure dose was 15uC/cm^2 with a beam step size of 100nm and a)10nA beam b)100pA beam. The line edge roughness shows that the beam spot is too small for the BSS, but larger beams drive the blanking frequency above the 10MHz limit. Scum between the lines shows that even this low dose is too high for these process conditions. Lower resist sensitivity is necessary to improve pattern quality.

Equations

1) $BSF=I_b/R_s*BSS^2$ where BSF is beam step frequency (blanking frequency), I_b is beam current, R_s is resist sensitivity, and BSS is beam step size.