Fabrication of periodic sub-wavelength nano-structures in a 150nm thick gold layer on glass slides for optical studies.

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Generation of two-dimensional arrays of openings in gold layers by electron beam lithography (EBL) using a negative tone resist is reported. Methods based on negative tone resists allow to avoid problems such as isotropic gold wet etching, large EBL exposure times encountered with positive tone resists or sample contamination and damage as noted with ion milling methods[1]. We present the fabrication of periodic openings in a 150nm thick gold layer on a transparent substrate. The gold films possess a theoretical optical transmission of $1.7 \cdot 10^{-8}$ at 632nm wavelength. This thickness allows accurately observing and studying of optical phenomena such as gold surface plasmons or transmission enhancement by arrays of sub-wavelength apertures[2].

The electron lithography equipment is based on a JEOL 6400 JSM scanning electron microscope (SEM) with LaB_6 thermionic emitter. The electron beam is controlled with a Nabity Systems Patterning Software (NPGS).

The commercial micro resist technology® ma-N 2410 resist was chosen as it allows a 5.2-aspect-ratio-patterning with 150nm resolution[3]. We produced 30µm x 30µm large arrays of lines (290nm and 390nm wide, periods of 690nm and 1.81µm), cylinders (400nm diameter with period of 1.81µm), and coax apertures (250/330nm and 310/330nm inner/outer diameters with period of 600nm) in a 700nm thick resist coating. Exposure doses ranging from 100 to 350$\mu C/cm^2$ were tested and vertical sidewalls for lines, dots, and coax aperture arrays are obtained with exposure doses of 220, 250, and 250$\mu C/cm^2$ respectively.

Exposure parameters were tuned in parallel on naturally oxidized silicon samples and 0.17mm thick transparent microscope slide and appear to be identical for both materials, confirmed by Monte-Carlo simulations of electron scattering. A 10nm thick sol-gel coating of antimony doped tin oxide[4] on the glass substrate suppressed electron beam charging effects.

The exposed line patterns show sharp edges and vertical sidewalls after developing in the surfactant containing developer MF 319 (Shipley) and oxygen plasma treatment (see Fig. 1). Proximity effect was corrected by means of Monte-Carlo based simulations. Gold lift-off was achieved in an ultrasonic acetone bath. The line edge roughness is acceptable for our studies (see Fig. 2).

Figure 3 shows the transmission of white light through a matrix of sub-wavelength holes of 400nm diameter (see Fig. 4) and 1.81µm period. Talbot patterns observed prove the reliability of the lift-off process.

Arrays of coax structures as shown in figure 5 showed wavelength filtering of white light illumination source (see Fig. 6).

Further spectroscopic, near-field optical characterizations will be presented.

References

[1] Fadi Issam Baida, Daniel Van Labeke, and Brahim Guizal, Appl. Opt. **42 (34)** (2003), 6811
[2] R. M. Ranade, S. S. Ang, and W.D. Brown, J. Electrochem. Soc. **140 (12)** (1993), 3676
[3] H. Elsner and H.-G. Meyer, Microelectronic Engineering **57-58** (2001), 291
[4] S. C. SANDU, PhD thesis, Université Claude Bernard-Lyon 1, 2003

Figures

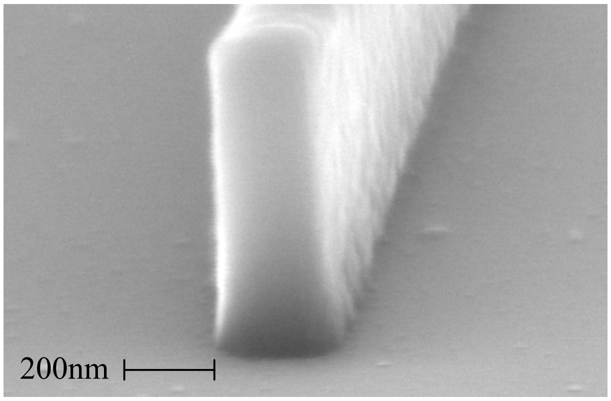

Fig. 1: *SEM image (70° tilt view) of line pattern after development.* Bottom line width 260nm, line spacing 1.81µm. Exposure area dose 220µC/cm^2.

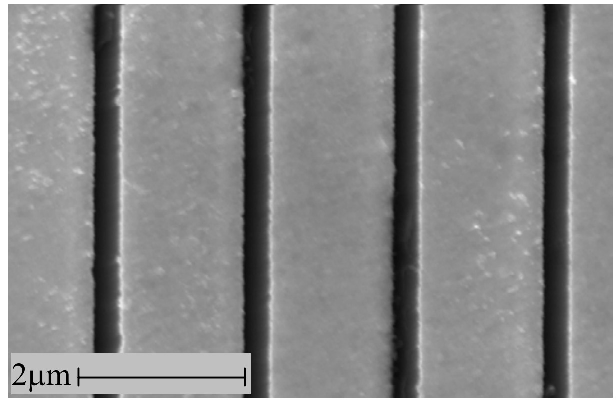

Fig. 2: *SEM image (top view) of line pattern after lift off in ultrasonic acetone bath.* Final line width 290nm, line spacing 1.81µm.

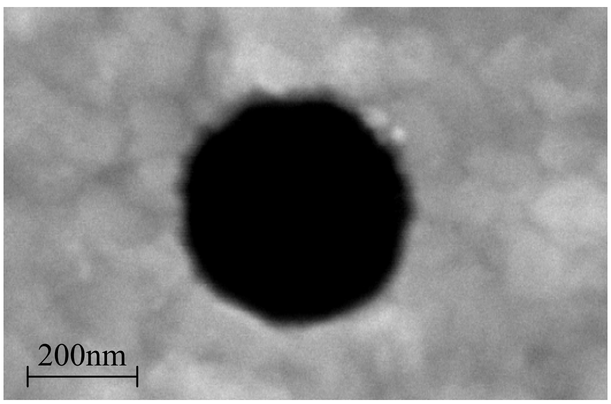

Fig. 3: *SEM image (top view) of dots pattern after lift off.* Final dot diameter 400nm, Exposure dose 250µC/cm^2.

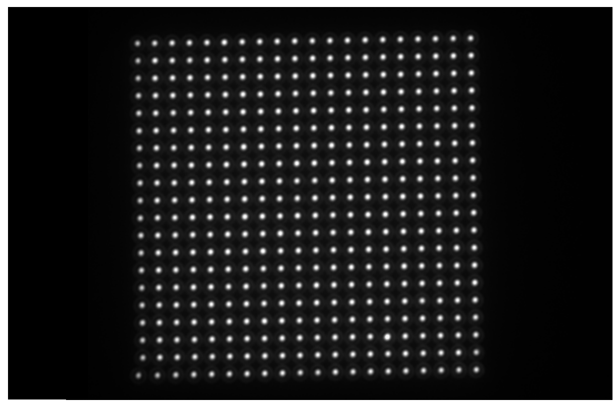

Fig. 4: *Optical microscope image of white light transmission though a 20x20 array of holes of 400nm diameter.*

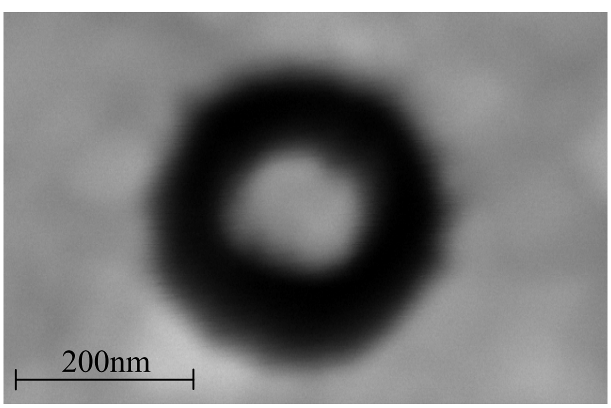

Fig. 5: *SEM image (top view) of a coax after lift off.* Exposure dose 250µC/cm^2.

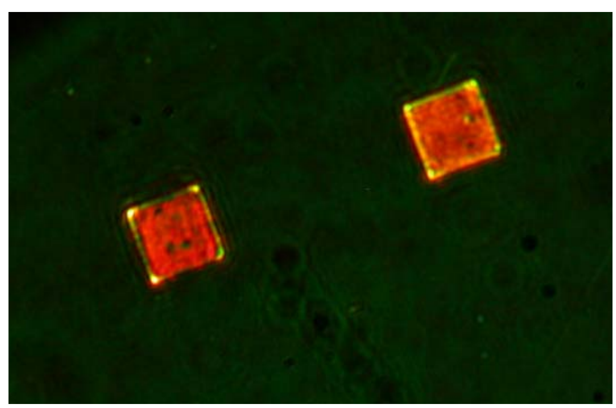

Fig. 6: *Optical microscopy images of light transmitted through the coax arrays. Wavelength filtering effect observed at λ=650nm.*