Fabrication of Metallic and Dielectric Nanowires for Realizing Optical Filters

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Introduction:

Light has three main components—intensity, wavelength, and polarization. Intensity and wavelength can be detected by the human eye; however, polarization cannot. This is because polarization is the orientation at which the wave travels forwards in space. Polarization can be manipulated using optical filters, such as using aluminum nanowires (Al NWs) oriented in 45° angles to each other. When polarized light is shown on these filters, areas of the filters appear dark and others appear bright. This is because the angle of polarization at the dark areas is perpendicular to the angle of the array; therefore, the light is blocked. The array in the light areas is parallel to the angle of the light's polarization.

Our lab this summer was fabricating arrays of micron squares using contact photolithography in order to further study the crosstalk effect between pixels. Contact photolithography is achieved by printing an image on a substrate by the use of a photomask and ultraviolet light. After the array is complete, photos are taken using an optical microscope. The samples are then subjected to a reactive ion etch using various gases to etch through the photoresist, silicon dioxide, aluminum oxide layers and partially through an aluminum layer. More pictures are taken to verify the shape.

We attained squares from 3 × 3 μm to 7 × 7 μm. These arrays will further be used to measure the crosstalk effect between a pixel and the neighboring pixels.

Photoresist AZ 5214
Coating:
Step 1: 500 rpm at 100 rpm/s for 10 sec
Step 2: 3000 rpm at 300 rpm/s for 30 sec
Step 3: 0 rpm at 300 rpm/s down for 1 sec
Pre-Bake:
110°C for 1 min
Expose:
10.7 sec
Reversal Bake:
110°C for 2 min
Flood Exposure:
30 sec
Develop:
AZ 327 for 40 sec with slight agitation
Rinse with deionized water and dry with N_2

Photoresist S1805
Coating:
Step 1: 6000 rpm at 300 rpm/s for 30 sec
Step 2: 0 rpm at 300 rpm/s down for 1 sec
Pre-Bake:
115°C for 1.5 min
Expose:
12 sec
Reversal Bake:
115°C for 1.5 min
Develop:
MF-319 for 1 min with slight agitation
Rinse with deionized water and dry with N_2

Photoresist SU-8 2 with OmniCoat Under-Layer
OmniCoat®
Coating:
Step 1: 500 rpm at 100 rpm/s for 5 sec
Step 2: 3000 rpm at 300 rpm/s for 30 sec
Bake:
200°C for 1 min
Cool to room temperature.
SU-8 2
Coating:
Step 1: 500 rpm at 100 rpm/s for 5 sec
Step 2: 3000 rpm at 300 rpm/s for 30 sec
Step 3: 0 rpm at 300 rpm/s down for 1 sec
Pre-Bake:
65°C for 7 min
95°C for 10 min
120°C for 8 min
Expose:
30 sec
Post Bake:
65°C for 10 min
95°C for 10 min
120°C for 5 min
Develop:
SU-8 developer for 10 min with slight agitation
Rinse with isopropyl alcohol and deionized water. Dry with N_2

Table: Photoresist recipes using contact photolithography to produce squares.

Experimental Procedure:

The process used was contact photolithography, which required many different steps. The objective was to optimize each photoresist's recipe to produce the most replicable and accurate square results. First, the sample was coated with a photoresist—a UV light sensitive material [1]. Next the sample followed the processes listed in Table 1, depending on the type of photoresist being used.

Results and Conclusions:

The photoresists used during contact photolithography each gave a significantly different result even after trying to optimize exposure, baking, and development times.

The AZ 5214, as a negative photoresist, produced the least effective results. In Figure 1, it is evident that the 7 × 7 μm square is a four-pointed star. We speculate that perhaps the photoresist was over-developed because a small square is seen within the center of the star with the points radiating from the sides of the square figure.

The next photoresist was SU-8 2, which produced diamond figures for all squares ranging from 3 × 3 to 7 × 7 μm, as seen in Figure 2. This photoresist was optimized up to a 50 minute pre- and post-bake time combined. This, however, did not improve the efficiency as projected. We assume that this photoresist cannot achieve such features on a micron or nano scale.

The photoresist that was the most successful was the positive S1805. This still fabricated a failed result of octagons as seen in Figure 3. Changing the bake time, as in the past two photoresists, did not affect the outcome we achieved, leading us to conclude that this photoresist cannot perfectly attain the squares we require.

Electron beam lithography obtained the most successful squares as seen in Figure 4. This process had the greatest success and precision, but it increased the cost of the mask produced.

Our lab concluded that the photoresists may be causing the shape formation; however, after more study we deduced that the samples we were creating contained a thicker layer of photoresist around the edges; edge beads. This phenomenon caused problems in the subsequent steps and was probably the reason our shapes were not squares.

Future Work:

The next process for the experiment is to attach the pixel mask array to a photodiode. This will allow the team to block a pixel and measure the overall crosstalk effect by quantifying how many photons have left neighboring pixels to enter the blocked pixel. When the crosstalk effect is fully understood, the lab will be able to correct for this shift in photons when using the polarization camera. This camera will then be used further in the imaging of cancerous cells which emit a polarized light versus normal non-cancerous cells that emit no polarization characteristics.

Acknowledgements:

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References:

[1] S. Campbell. The Science and Engineering of Microelectronic Fabrication. 2001.

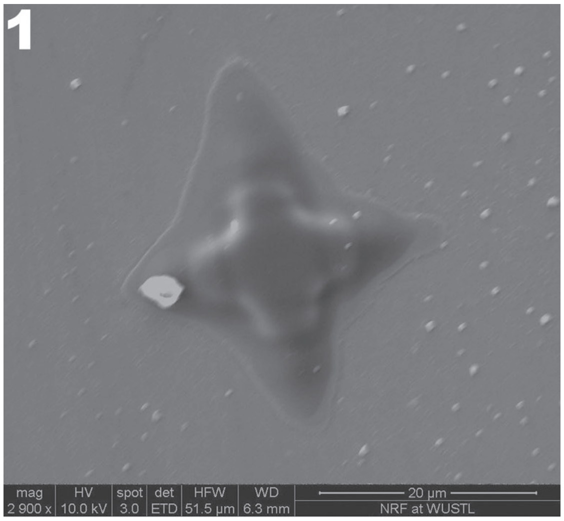

Figure 1: AZ 5214, a negative photoresist, produced a four-pointed star.

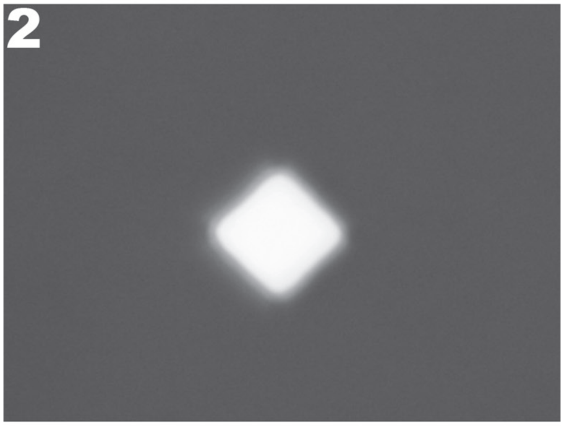

Figure 2: SU-8 2 produced diamond figures for all squares ranging from 3 × 3 to 7 × 7 µm.

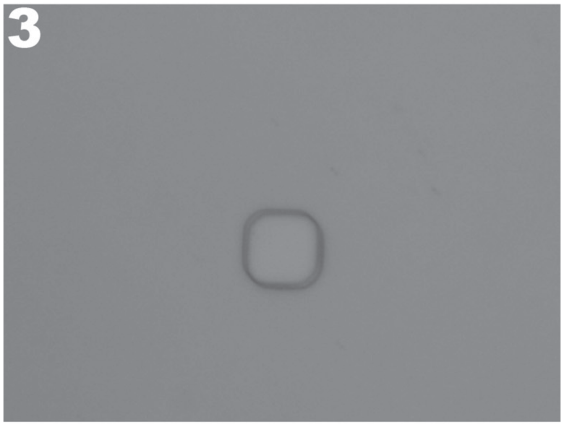

Figure 3: Positive S1805 photoresist was the most successful, but still fabricated a failed result of octagons.

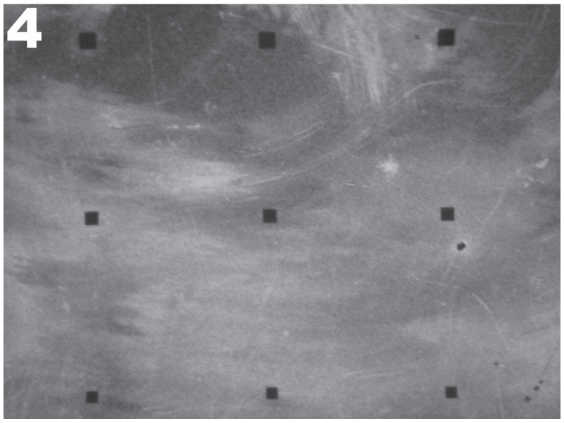

Figure 4: Electron beam lithography obtained the most successful squares with the greatest success and precision.