Positive Electron Beam Resists for 5nm Lithography

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We compare inorganic and organic electron beam lithography resists for their sensitivity and resolution. Nanostructures with dimensions below 5nm have been fabricated with all of these resists. Wet processed as well as self-developing and dry processed resists were characterized for performance and ability as etch or deposition masks to generate nanometer scale structures. Nanostructures were defined using electron microscopes with spot sizes ranging from 0.2nm to 3nm at voltages ranging from 30kV to 200kV, and the electron beam interaction volumes at different voltages are compared by high fidelity electroplating into dot and line patterns.

By using 160kV electron beams in a 30nm thick ytterbium fluoride resist, we expose and develop 1.5nm structures at different pitches (Figure 1). Dense structures with 2nm half pitch are compared with 3nm, 4nm, 5nm and 10nm half pitch arrays. We compare YbF_2, AlF_3, LiF (Figure 2) and other fluoride resists and show trends for sensitivity and resolution of these fluorides when used as resists while maintaining their high resolution. We also show fluorides that do not respond to electron irradiation. These structure sizes and resist sensitivities of fluorides are compared with wet-processed PMMA, where we have defined 3nm structures using 70nm thick spun-coated layers developed in isopropyl alcohol.

We also compare wet and dry processed positive resists for resolution and sensitivity. Although electron beam lithography enables patterning of resists down to 1nm, the transfer of these patterns through conventional methods such as lift-off or dry etching becomes very challenging as feature sizes are reduced below 5nm. New pattern transfer techniques need to be optimized to take advantage of the small features that can be defined in high resolution resists. Wet development often leads to the deterioration of the fidelity of resist structures through surface tension and delamination, providing incentive to develop new dry processed resists.

These structures can be transferred into other materials by either electroplating or dry etching. We show that angled nanostructures can be defined by electron beam exposing coated substrates at angles. After exposure and development, electroplating enables us to create new three dimensional metallic geometries (Figure 3).

Figure 1. *1.5nm diameter holes beam-written in YbF_2 and etched into Si_3N_4 with 20nm, 7nm and 4nm center to center spacing*

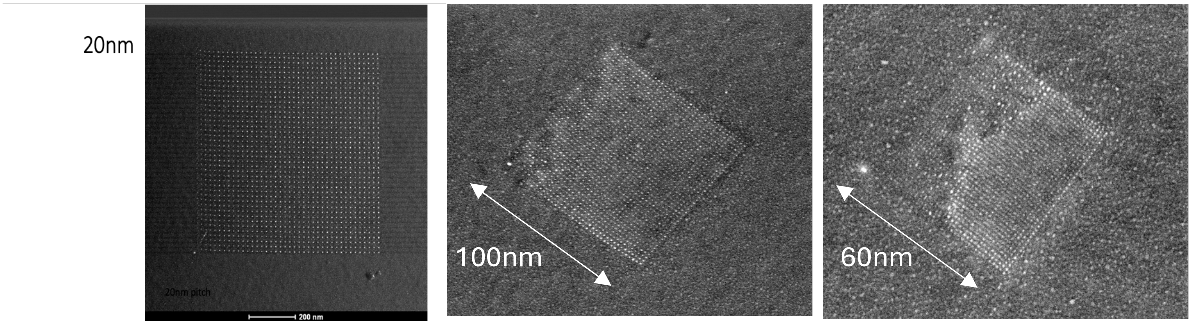
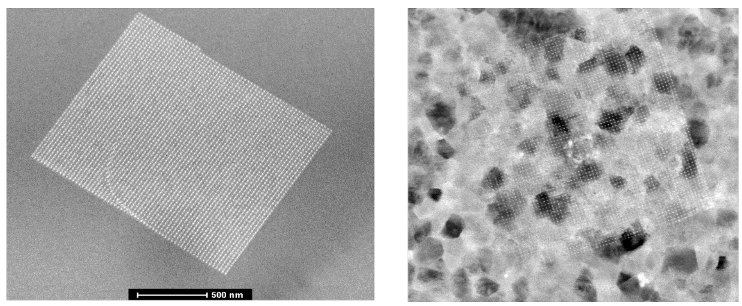


Figure 2. *25nm period dots exposed in aluminum and lithium fluoride*



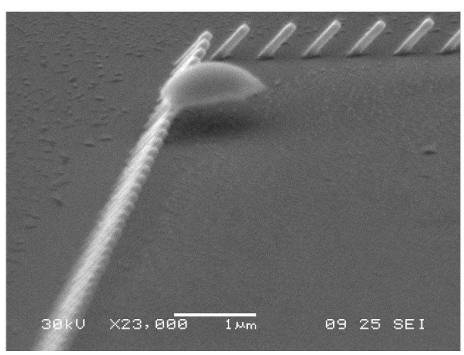


Figure 3. *Angle electro-deposited gold pillars after 30kV electron beam writing of PMMA*