E-Beam Patterning of Nanoparticle Filled Sucrose Resist

Kevin Roberts*, Bryan Cord, and Greg Cibuzar
University of Minnesota, Nanofabrication Center, Minneapolis, MN 55455

Nanoparticles (NPs) have been shown to be capable of being deposited onto substrates through many means. Of these, spin-coating of nanoparticle suspensions over existing thin film resist patterns has been shown to work with a fair degree of efficacy. However, this technique admittedly suffers from problems associated with the 'bounding effect', wherein the density of the particles is higher near the edge of the underlying pattern than near its center.[1] Consequently, more technically sophisticated methods of patterning nanoparticles using spin-coating techniques have been developed which employ either self-assembly[2], or directed self-assembly[3] strategies. While these methods yield improved results, they come at a cost of inherently more complex chemistries and/or the necessity to structure the substrate prior to the deposition of the nanoparticles. Alternatively, some researchers have taken a direct-write approach in which the nanoparticles are fixed to the surface by cross-linking their passivating ligands[4], or by using NPs dispersed in an e-beam compatible resist[5]. It is this very last approach the authors of this paper have chosen to explore while utilizing a sucrose and water based 'resist' system.

Resist solutions were prepared by dissolving 1% to 50% sucrose (common table sugar) in de-ionized water. Dry films were subsequently produced by spin-coating the sucrose solutions onto bare silicon wafers, and then dehydrating the films. The films were then characterized using a Dimension 3000 AFM. Film thickness ranged from 6 nm to 800 nm for dilutions of 1% to 50% sucrose, respectively (Fig. 1).

Nanoparticle filled resists were prepared by two different methods; either by adding dry NPs to existing sucrose resists and sonicating them until sufficiently dispersed, or by adding sucrose to pre-packaged, water-based suspensions of NPs. Nanoparticles that have been experimented with include: 100 nm Si NPs, 50 nm Al NPs, and 20 nm Au NPs.

Electron-beam patterning of both unfilled and filled sucrose resist has been demonstrated using a Vistec EBPG5000+. 100 nm line widths have been found to be readily achievable in the unfilled sucrose resists (Fig. 2).

Cross-linking of the sucrose appears to be the mechanism of fixing the resist. The dosage necessary to cross-link the sucrose has been found to be ~50 mC/cm^2 at 100kV. The NP filled sucrose which is not exposed can be subsequently removed with water and ultra-sonics. The cross-linked sucrose holding the NPs to the surface can be removed through oxygen plasma treatment if desired.

In the case of NP filled resists, 50 nm Al NPs have been demonstrated (Fig. 3), and tests with 20 nm Au NPs are on-going. Essentially, however, this technique should be amenable to most NPs at most sizes, especially those processed from water-based suspensions.

[1] Young-Kyu Hong *et al*. Appl. Phys. Letters 80(5), 844 (2002)
[2] Fu-Ken Liu *et al*. Microelec. Engineering 67-68, 702 (2003)
[3] Deying Xia *et al*. J. Vac. Sci. Technol. B 22(6), 3415 (2004)
[4] Martinus Werts *et al*. Nano Letters, 2 (1), 43 (2002)
[5] Luigi Martiradonna *et al*. Microelec. Engineering 83, 1478 (2006)

* rober074@umn.edu

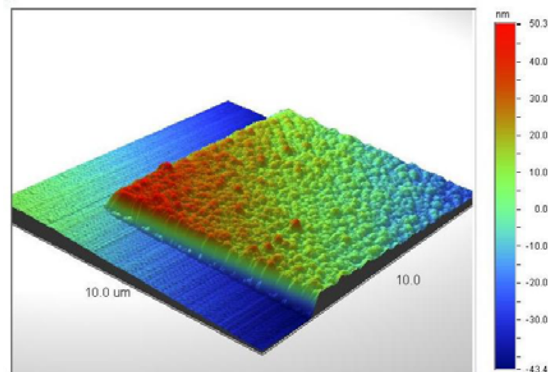

Fig. 1. AFM scan showing 5% sucrose (in water) resist thickness (~ 40 nm) after e-beam exposure and 15 sec. development with water. Exposure was 50 mC/cm^2 using 150 nA beam at 100kV.

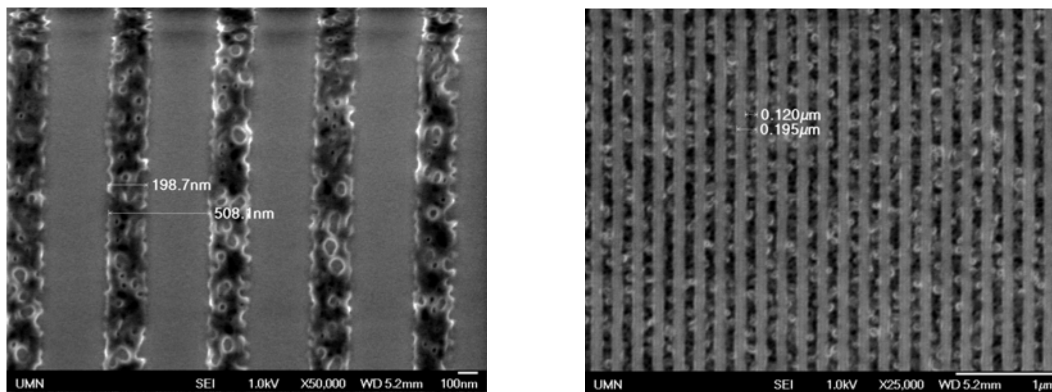

Fig. 2. SEM images showing morphology of exposed sucrose film on silicon substrate without NPs, post-exposure and post-development with water. Film is the result of spin-coating a 5% sucrose in water solution. Thickness of film is 40 nm. (a) 250 nm line width, 500 nm pitch. (b) 100 nm line width, 200 nm pitch.

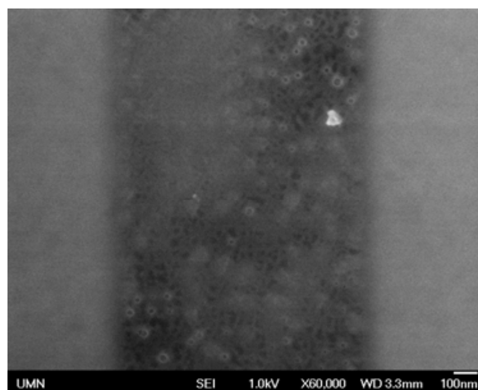

Fig. 3. SEM image showing 50 nm Al NPs embedded in cross-linked sucrose post-exposure and post-development. Cross-linked sucrose is 75 nm thick. Field region is bare silicon.