Submicron Poly Acrylic Acid Patterning by Electron Beam Lithography

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Previously it has been reported that poly acrylic acid (PAA) is a hydrogel that can be patterned directly by electron beam lithography (EBL)[1,2]. Hydrogel volume is sensitive to environmental variables such as pH, temperature, ionic strength, analytes and biomarkers. Furthermore, hydrogels are biocompatible and biodegradable. Therefore, hydrogels are being investigated in emerging applications such as drug delivery, biosensors, tissue engineering, wound healing bandages and more. The ability to lithographically pattern hydrogel materials to specific dimensions at the micro and nanoscale can be very useful in devices and sensors. What makes this material further interesting is that its carrier solvent, developer, and remover are all water alone, which may make it attractive for processes or materials that cannot tolerate solvents, acids, and bases used with other common EBL resists. Previously, the reported pattern resolution was 1.8 µm line widths and dot diameters[1,2]. This new recent work investigates how to pattern PAA to smaller dimensions.

One method to improve resolution that was investigated was to reduce the film thickness. A 25% solution of 50,000 molecular weight PAA in water from Polysciences, Inc. was diluted with water to a 2% solution. This solution was spincoated at 2000 RPM for 60 sec to achieve a 25 nm film thickness onto oxgen plasma treated silicon substrates. The sample was hot baked at 100 °C for 60 sec. Line and dot array patterns were exposed at varying dose using GenISys BEAMER proximity effect correction (PEC) software using an Elionix ELS-G100 EBL system at 1 nA and 100 kV. The samples were developed in deionized water for 10 seconds. PAA exhibits negative tone behavior. Minimum line widths of 147 nm were achieved with 107 $\mu C/cm^2$ dose as shown in Figure 1. Minimum dot diameters of 167 nm were achieved with 120 $\mu C/cm^2$ dose as shown in Figure 2. These dimensions are one order of magnitude lower than previous results. These results will be discussed in more detail along with other results. This work was partially supported by an Institute for Matter and Systems Research Initiative award.

[1] D. K. Brown, EIPBN, La Jolla Torrey Pines, 2024, 3A-5
[2] D. K. Brown, J. Vac. Sci. Technol. B 42(6), 2024

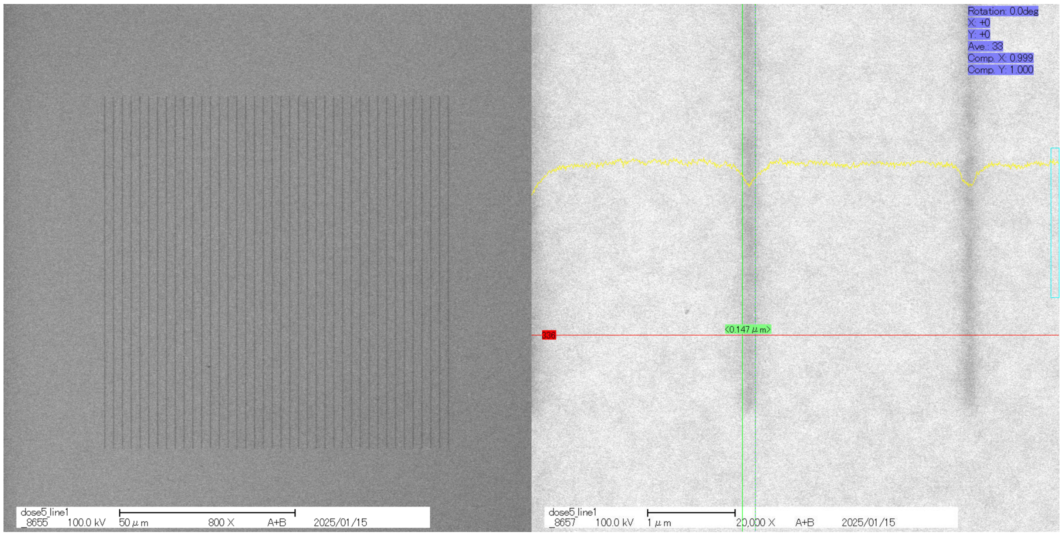

Figure 1: SEM image (left) of a vertical line array on 2.5 µm pitch occupying a ~ 100 x 100 µm square area. SEM image (right) at higher magnification showing line widths in the array are 147 nm.

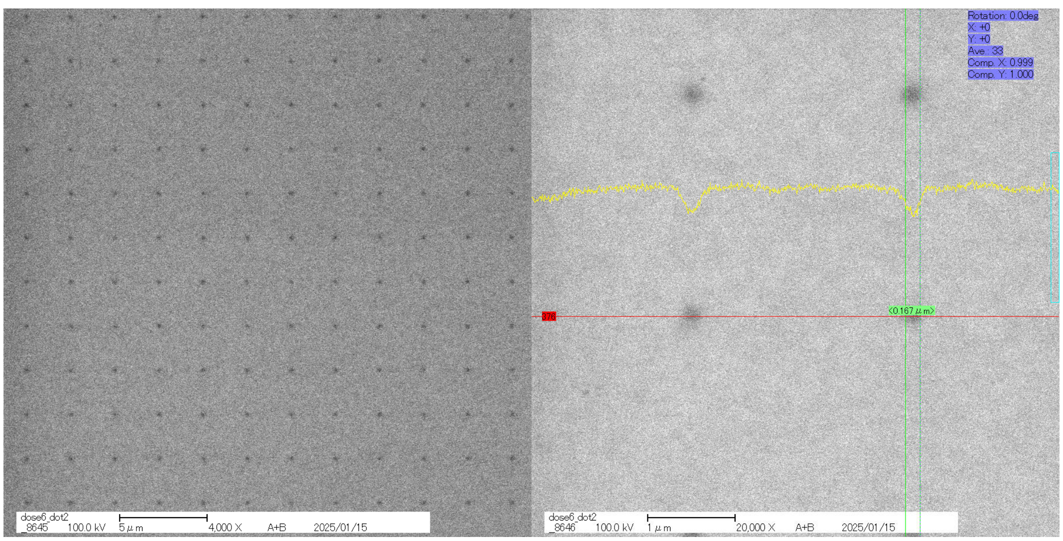

Figure 2: SEM image (left) of a dot array on 2.5 µm pitch in x and y directions. SEM image (right) at higher magnification showing dot diameters in the array are 167 nm.