Resolution improvement for positive tone poly(methyl methacrylate) resist

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Electron-beam lithography (EBL) is used to define sub-10 nm structures on poly(methyl methacrylate) (PMMA). Previously, 25-nm-pitch dot arrays, and 40-nm-pitch lines were obtained after AuPd pattern transfer[1]. The authors present an improvement over these results, resolving 20-nm-pitch dot arrays and 30-nm-pitch nested L's structures after Ti/Au lift-off. In addition, 15-nm-pitch isolated double-dot, and triple-dot structures are studied to learn more on the resolution limits of PMMA as electron-beam resist.

In this experiment, a 45 nm thick PMMA resist layer was used. Different baking and development temperatures were used in order to probe for the best resolution attainable. For this reason, samples were oven baked at 175, 200 or 225°C for 5 min, and later developed at 15, 6, -5, or -15°C in 3:1 isopropanol: methyl isobutyl ketone for 30 s. Afterwards, a 3 nm Ti and 7 nm Au layer was evaporated over the developed substrates, and finally acetone lift-off was done.

Results obtained are summarized on Figure 1. Lowering developing temperature gave larger dose latitude[2], whereas lowering the baking temperature enhanced the effect of acetone on PMMA, facilitating lift-off. The best results were obtained at development temperatures lower than 6°C, and resolution was not sensitive to baking temperature. This showed an improvement over previous results, by resolving 15-nm-pitch double and triple dots, 20-nm-pitch dot arrays, and 34-nm-pitch nested L's structures.

To better understand the results obtained, modeling of the dose contrast for the different geometries was done (Figure 2). The dose contrast gives the difference in dose between the highest and lowest dose structures, giving an estimate into the ability of resolving the different geometries. This was based on point spread function (PSF) measurements done previously on a similar process, and the same EBL tool[3]. As shown in this figure, the dose contrast is over 85% for all the resolutions, and geometries attained experimentally. Because of this, improved sample processing (development, lift-off, baking, etc.), to decrease the dose contrast needed to resolve structures is currently the key process to improve resolution, and resolve sub-10-nm pitch features with PMMA.

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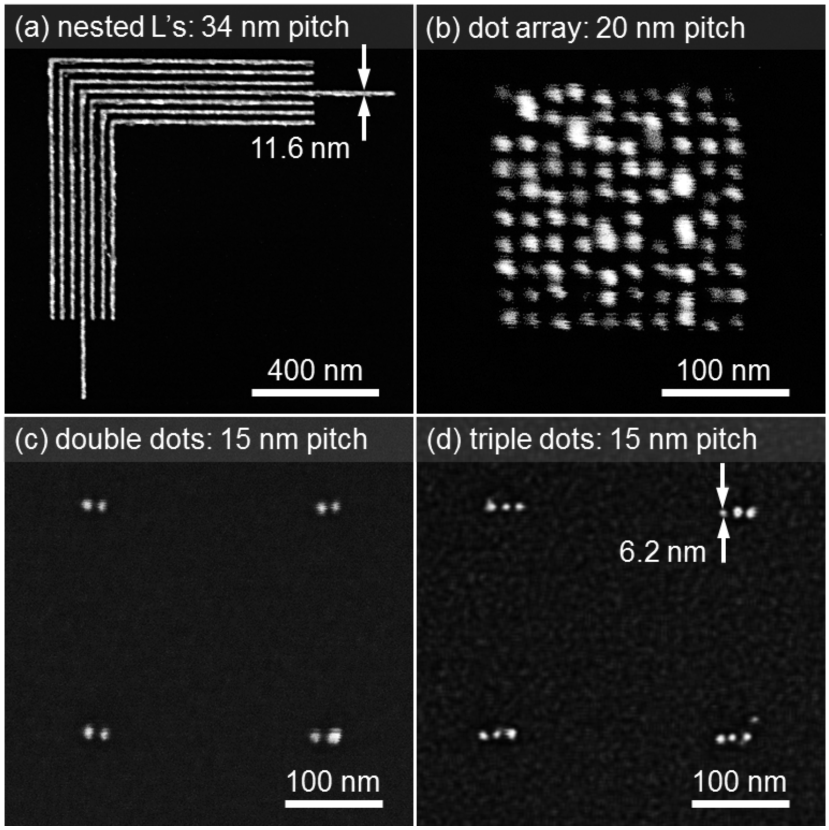

Figure 1: Resolution limits obtained after 10 nm Ti/Au acetone lift-off. Structures were written on a Raith 150 EBL system with a 30 keV accelerating voltage, 3-5 nm spot size, 150 pA writing current, 50 µm write field, 6 mm working distance, and 1 nm step size. Dot structures were written with single pixel exposures, and nested L's by single pixel lines. The structures resolved were (a) 34 nm pitch nested L's baked at 175°C and developed at -15°C, (b) 20 nm pitch dots array, baked at 175°C and developed at -15°C, (c) 15 nm pitch double dots L's baked at 225°C and developed at 6°C, (d) 15 nm pitch triple dots L's baked at 225°C and developed at 6°C

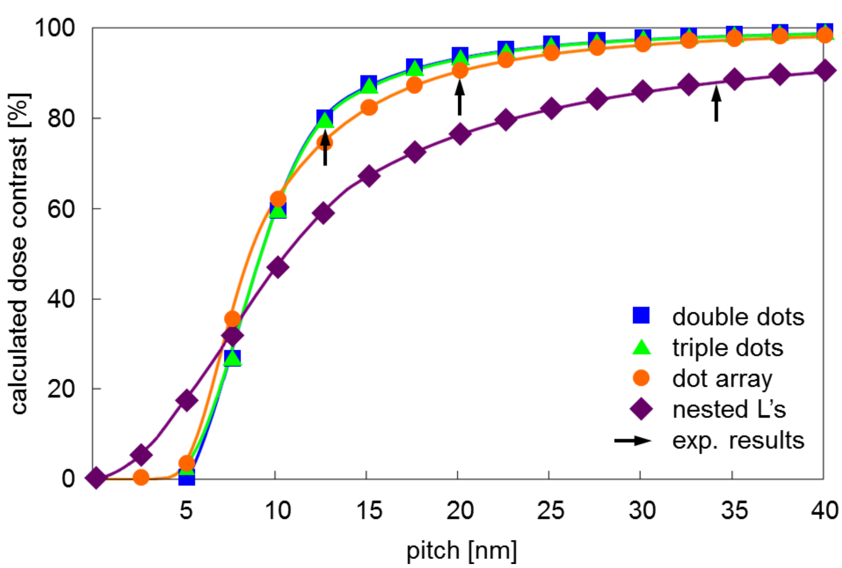

Figure 2: Calculation of the dose contrast as a function of pitch,

, for double dots (triangles), triple dots (squares), dot array (circles), and nested L's (diamonds). Experimental resolution limits for each structure are marked with an arrow. For all the resolved structures the dose contrast is higher than 85%.