Optimization of Peanut-Shaped Template Geometry for Block Copolymer Directed Self-Assembly

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In the pursuit of viable alternatives to optical lithography, block copolymer directed self-assembly (DSA) has distinguished itself as a low-cost, high-throughput option [1]. It has previously been demonstrated that block copolymer DSA can be used to pattern arbitrarily placed contact holes by way of topographical guiding templates [2]. However, the use of DSA for large-scale patterning has been impeded by the relatively high defectivity rate in DSA patterns. For this reason, it is essential to understand how the guiding template geometry interacts with the resulting DSA morphology. In this abstract, we focus on the design space of peanut-shaped templates, which can be used to form two-hole pairs at a pitch unattainable by conventional lithography [3].

A sample e-beam pattern used to print peanut-shaped templates is given in Figure 1. Changes were made to this pattern by altering the neck width and length as shown in Figure 2 to achieve three main variations: a template with a short and wide neck called “Template A,” a template with a long and thin neck called “Template C,” and an in between case called “Template B.” These shapes were printed on silicon using 100 keV e-beam lithography at a range of doses. By using a range of doses, the critical dimension (CD) of the template could be adjusted while maintaining the general proportions of the template, as demonstrated in Figure 2. After etching the templates to 57 nm in depth, a solution of 70:30 PS-*b*-PMMA diblock copolymer (46k-21k molecular weight) dissolved in PGMEA was applied in the manner described previously [4]. The final DSA patterns were imaged using SEM and their defectivity characterized by the number of DSA holes in each template (see Figure 3): zero, one, two, or three holes.

In Figure 4, the defectivities of the peanut-shape variations at different CDs are shown. At the smallest template CDs, the vast majority of templates have zero holes. However, as the CD increases, the percentage of templates with one hole grows and eventually peaks, following which the percentage of templates with two holes also grows and eventually peaks. At the largest template CDs, the templates will increasingly shift to have three or more holes. As shown in Figure 4, the template CD at which the maximum percentage of one-hole defects appears is nearly constant (~49 nm) regardless of neck geometry. Likewise, the template CD at which the most two-hole pairs occur is very similar (~52 nm) across the various neck geometries. Given this optimal CD, we can then explore the role of the neck width and length. Figure 5 indicates that each neck geometry results in a different distribution of defects, causing the maximum number of two-hole pairs to change. This directs future work on peanut-shaped templates towards optimizing the neck width for a desired hole pitch.

[1] C. T. Black et al., IBM J. R&D, p. 605, 2007.
[2] H. Yi et al., Adv. Mater, 2012.
[3] H. Yi et al., EIPBN, 2013.
[4] L.-W. Chang et al., IEDM, p. 752, 2010.

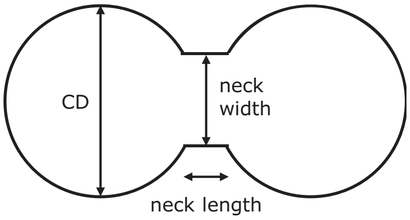

Figure 1: E-beam pattern for printing peanut-shaped templates. Neck width and length were controlled by varying the neck dimensions on the e-beam pattern, whereas CD was controlled by the dose.

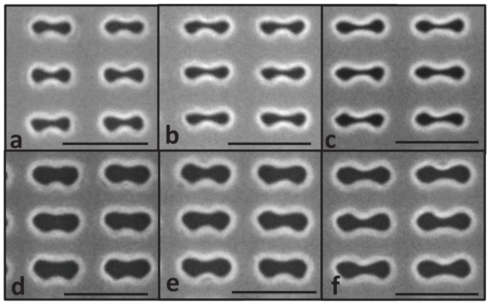

Figure 2: The three peanut-shaped template variations printed at the smallest (a-c) and largest dose (d-f) used in this study. (a) and (d) show Template A, (b) and (e) show Template B, and (c) and (f) show Template C. Scale bar: 250 nm.

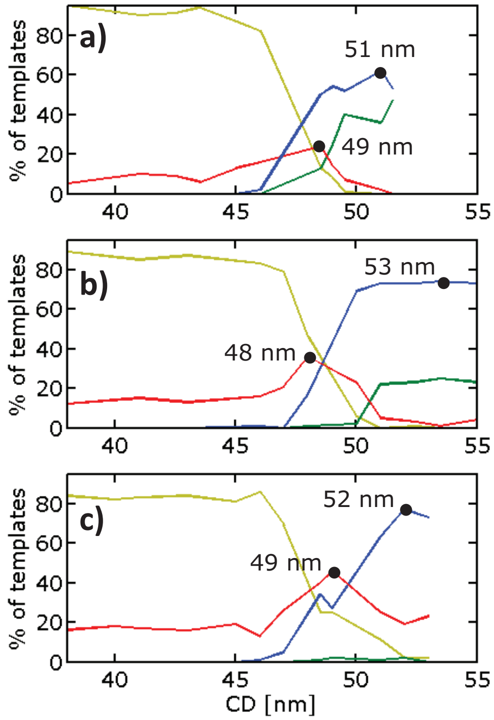

Figure 4: Defectivity as a function of CD for (a) Template A, (b) Template B, and (c) Template C. The CD at which the maximum percentage of one-hole and two-hole morphologies occur are labeled. Refer to the legend in Figure 3.

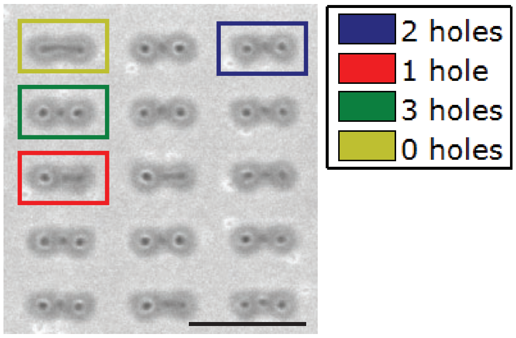

Figure 3: Example of the four categories used to characterize the DSA patterns by number of holes. Scale bar: 250 nm.

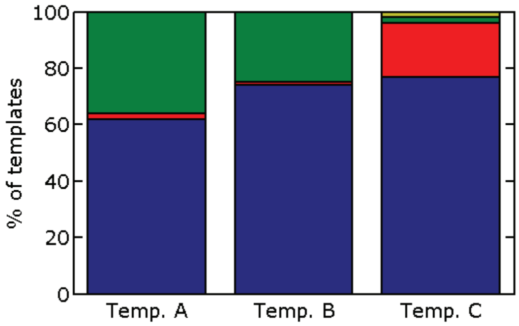

Figure 5: Defectivity distribution for each template type at the optimal CD. Refer to the legend in Figure 3.