Block Copolymer Directed Self-Assembly Two-Hole Pattern inside Peanut-Shaped Templates

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Block copolymer directed self-assembly (DSA) has attracted significant interest and attention due to its promising potential as next generation lithography solution [1-3]. To date, tremendous progress has been made in achieving and controlling periodic DSA patterns over large areas. However, most IC layouts patterns are irregular and semiconductor device fabrication does not require any long range order. Previously, we have demonstrated the use of small topographical templates to flexibly control DSA for sub-15nm contact hole patterning [4]. Through proper design of the size and the shape of the guiding templates as well as the polymer film thickness, one could control the number and location of cylindrical micro-domains formed inside the small templates [5]. Among all possible shapes of DSA templates, the peanut-shapes are specifically important as they represent the case where two separate circular templates merge due to limited pitch resolution of conventional lithography. However, one of the advantages of DSA is that a two-hole pair can still form inside the merged template as a useful pattern. As the scaling pitch is a key limiting factor for conventional lithography, this pattern is attractive as it also represents the case where the pitch exceeds resolution of lithography but the maximum DSA hole pitch as well. In this paper, we explore the design space of the peanut-shaped templates for the DSA 2-hole pair pattern.

The peanut-shaped templates were fabricated using 100keV e-beam lithography and etched down to 50 nm. We use 70:30 PS-b-PMMA diblock copolymer dissolved in PGMEA. The DSA process is similar to the previous report [6]. We use 3 parameters to characterize the peanut shape: template length, width, and the width of the connection part. Among these 3 parameters, the connection width is the most important factor that leads to the distance variation between the two holes. In our experiment, we fix the template width at 70 nm to eliminate the variation brought by the width difference. We varied the template length from 135 nm to 150 nm (Fig. 1), and also varied the connection width from 20 nm to 60 nm. Note that due to e-beam lithography resolution limits, it is very challenging to accurately control the exact width of the connection part. Therefore we extract the connection width length for each individual template using image analysis. The design space is summarized in Fig. 2. The average hole size is ~20nm independent of template size variations. As seen from the figure, the DSA hole pitch is nearly linear with the connection width, which shows that the shape fidelity of the templates is just as important as its overlay accuracy and sizes.

[1] Hawker, C. J. et al.MRS Bull 30, 952–966, 2005.
[2] Black, C. T. et al. IBM J. R&D, p. 605, 2007.
[3] Bencher, C. et al. SPIE, 2012.
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[6] L.-W. Chang et al. IEDM, p. 752, 2010.

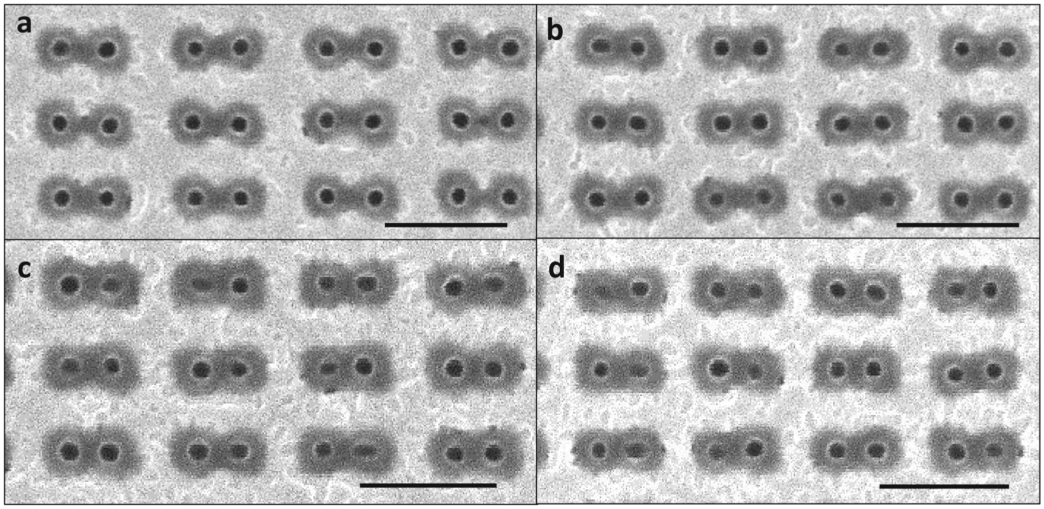

Figure 1: SEM images of DSA patterns confined by peanut-shaped templates with different lengths and connection widths. The length of templates: (a) 150 nm, (b) 145 nm, (c) 140 nm, (d) 135 nm. The width of all templates is 70 nm. It is shown that the length of template as well as the width of connection has a strong impact on the distance between the two DSA holes. Scale bar: 200 nm.

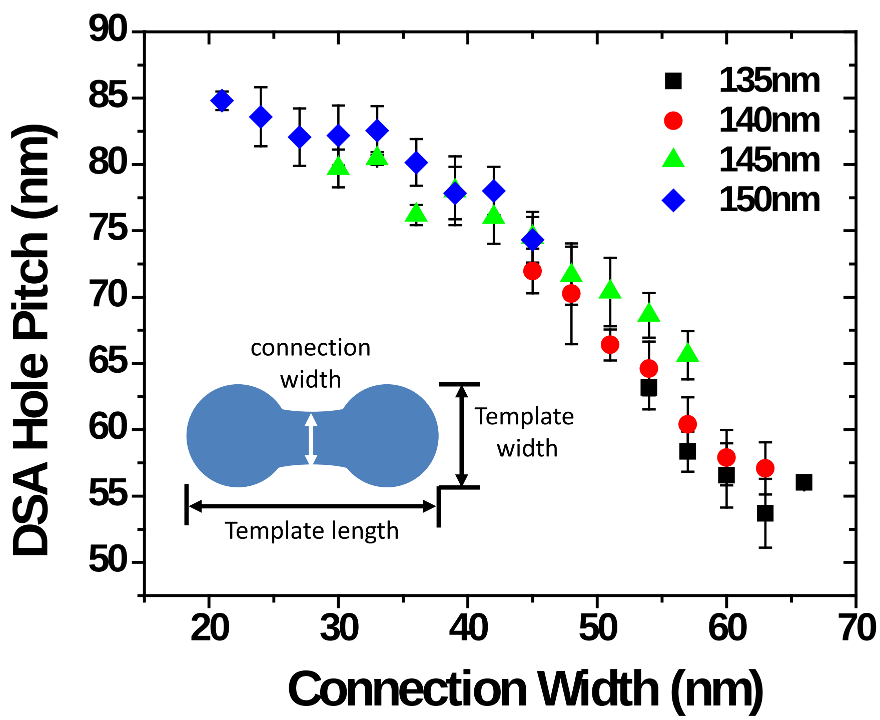

Figure 2: Design space of DSA pattern in peanut-shaped template. Each data point represents a specific peanut-shaped template length and connection width combination that leads to a 2-hole pair. Different point symbols represent different template lengths. The standard deviation of the hole-pitch is reflected as the error bar in y axis.