Defect Reduction of Peanut-Shaped Direct Self-Assembly using Hompolymer

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As conventional optical lithography approaches its limit in resolution, the advancement of next generation lithography methods becomes increasingly important [1]. Block copolymer directed self-assembly is one such method that has attracted attention due to its high throughput and low cost [2]. We have previously demonstrated the ability to pattern contact holes using a set of physical guiding templates [3]. In these experiments, we found peanut-shaped templates to be especially important, as it allows for a two hole pair to be formed at a pitch unattainable by conventional lithography [4]. However, defectivity of DSA patterns in peanut-shaped templates is a problem that needs further study, because the block copolymer may assemble into non-ideal structures. Simulations have suggested that the addition of a majority phase homopolymer to the block copolymer solution will lower the defectivity of these two hole pairs by congregating the homopolymer in the neck of the template [5]. In this paper, we explore this hypothesis of defectivity reduction experimentally.

A variety of peanut-shaped templates on Si were created using 100 keV e-beam lithography and etched down to 50 nm depth. The e-beam mask used to form the peanut-shaped templates involved two 64 nm squares connected by a connector of varying length and width, as shown in Figure 1. Two solutions were prepared for the purpose of this experiment: the first was 70:30 PS-b-PMMA diblock copolymer (46k-21k molecular weight) dissolved in PGMEA and the second had an additional 10% of a PS homopolymer (25k molecular weight) also dissolved in PGMEA. These solutions were used in the DSA process described previously [6]. The resultant DSA structures were then imaged by SEM and the defects characterized into categories based on the number of holes present in the structure: no holes, one hole, two non-ideal holes, and three or more holes. As seen in Figure 2, one hole structures were the dominant source of defectivity in both the sample with homopolymer and the sample without. The addition of the homopolymer, however, caused an across the board reduction in the quantity of defects as shown in Figure 3. In total, the defectivity in the peanut-shaped templates was found to be halved by the addition of the homopolymer. Furthermore, the pitch of the two holes in the non-defective peanuts was measured. As shown in Figure 4, the addition of the homopolymer caused no significant change in pitch, with the average pitch varying between 90 and 100 nm depending on the template connector length. Thus, we demonstrate that the introduction of majority phase homopolymer into the block copolymer solution in peanut-shaped templates very significantly reduces overall defectivity without altering the pitch.

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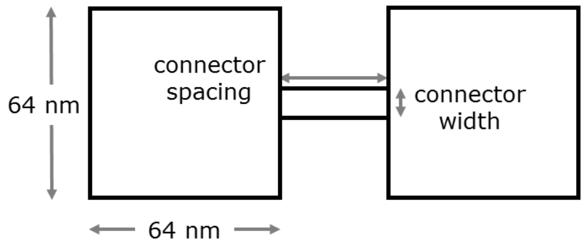

Figure 1: E-beam mask template for peanut shapes. The mask we used to form the templates was two 64 nm squares joined by a connector of varying dimensions. We used connector lengths of 30 and 40 nm and connector lengths of 8, 16, and 32 nm.

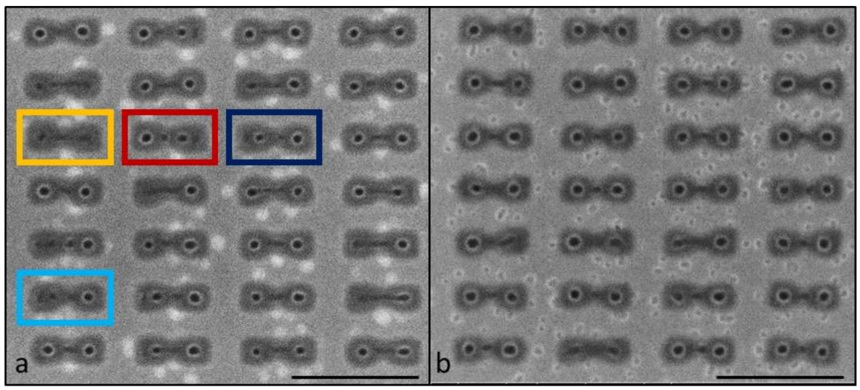

Figure 2: SEM images of DSA structures in peanut-shaped templates. These images compare the defectivity of DSA structures (a) without homopolymer and (b) with 10% homopolymer and highlight the reduced frequency of defects in the case with hompolymer. Also given in (a) is an example of each type of defectivity: 3+ holes (dark blue), 1 hole (light blue), 0 holes (yellow), and 2 non-ideal holes (red). Scale bar: 300 nm.

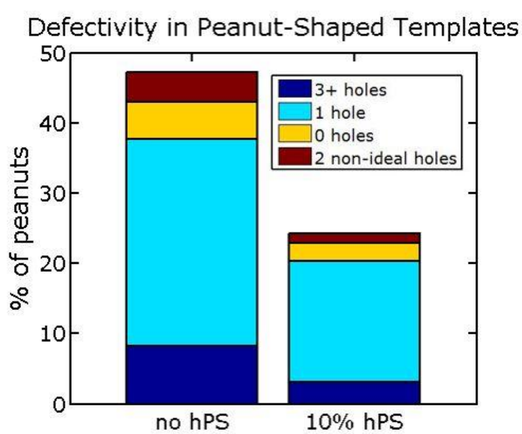

Figure 3: Average percentage of defects in peanut-shaped templates. The two bars show how the total percentage of defects is on average distributed amongst the types of defects. The average percentages shown were obtained by averaging the percentage of defects across all of the template sizes.

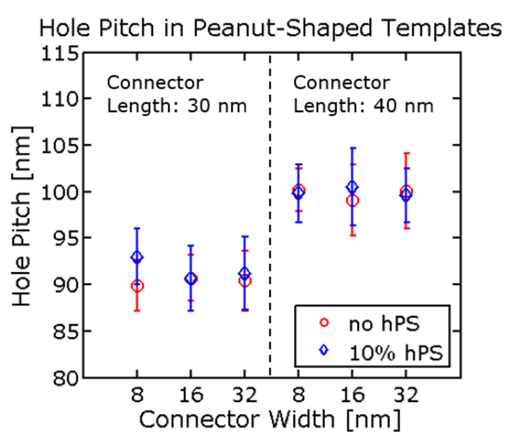

Figure 4: Average pitch of the DSA hole pair in peanut-shaped templates. Each of these points indicates the average pitch of the DSA hole pair for a given connector length and width. Due to the longer total template length, we see that the templates with a 40 nm connector length have a longer pitch.