Impact of trench width roughness on the directed self-assembly of block copolymers on topographic substrates

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The use of topographically patterned substrates in conjugation with block copolymers is an attractive technology to insert self-assembling materials into traditional manufacturing processes for microelectronics. This combination of top down features created with current lithography tools and the bottom up assembly of block copolymers, leads to sub-lithographic structures that could reduce the expense of patterning at ever increasing resolution[1]. Vital and active areas of research are focused on how to use this technique to deliver registered features[2] with fewer defects,[3] and to assembly templates amendable to pattern transfer.[4, 5] Here we investigate the constraints on the quality of topographic features needed for directed self-assembly, showing the impact of trench width roughness (TWR) on feature size uniformity and defect formation.

A schematic of the directed assembly process is shown in Fig.1. Topographically patterned substrates were prepared using chemically amplified photoresist and reactive ion etching in conjunction with commercially available lithographic tools and masks. A dose/focus array was utilized to systematically produce a wide range of trench sizes (40 – 400 nm) and roughness (5 – 30 nm). After modifying the surface with a polymer brush to render the surface neutral in wetting, a thin film of cylindrical forming poly(styrene-*b*-methyl methacrylate) (PS-*b*-PMMA) was deposited and annealed to create well-ordered arrays[5]. SEM micrographs were taken and analyzed using offline software for the metrology of the trenches and ordered block copolymer domains after the removal of the PMMA cylinders[5]. Fig. 2 shows images of assembled block copolymer with varying degrees of trench roughness.

Fig. 3a is a plot showing no variation in domain diameter with respect to the TWR of lithographically defined features. SEM micrographs analyzed of a neutral flat surface shows the same variation in feature diameter (19.6 ± 0.3 nm); hence the use of topographical patterns does not impact the size of the features in this study, rather the size distribution seems to be determined by the thermodynamics of the block copolymer system itself.

The impact of TWR on defect formation is qualitatively investigated by classifying all images as having very few, few, some, or many defects. A table showing the images classified as having very few or few defects can be seen in Fig. 3b. Strikingly, it is not the TWR that plays a dominate role in the formation of defects, rather the commensurability between the natural length scale of the block copolymer (l_0) and the trench width (W).

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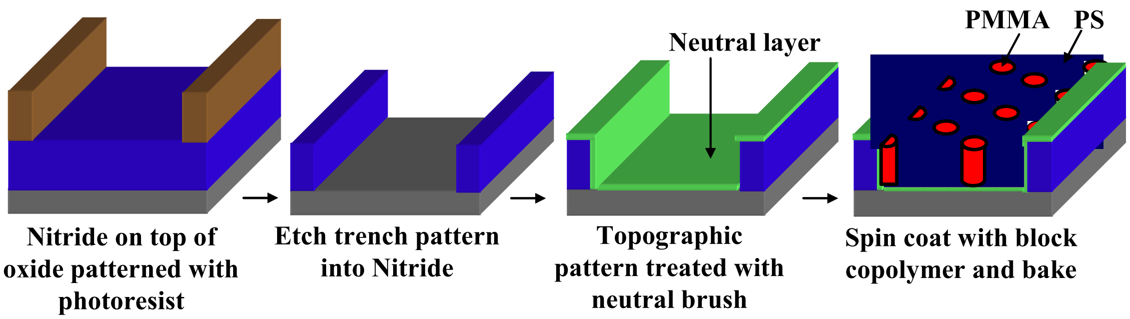


Figure 1: Schematic of topographic assembly of cylindrical forming block copolymer. The PMMA is subsequently removed using a DUV exposure and development in acetic acid.

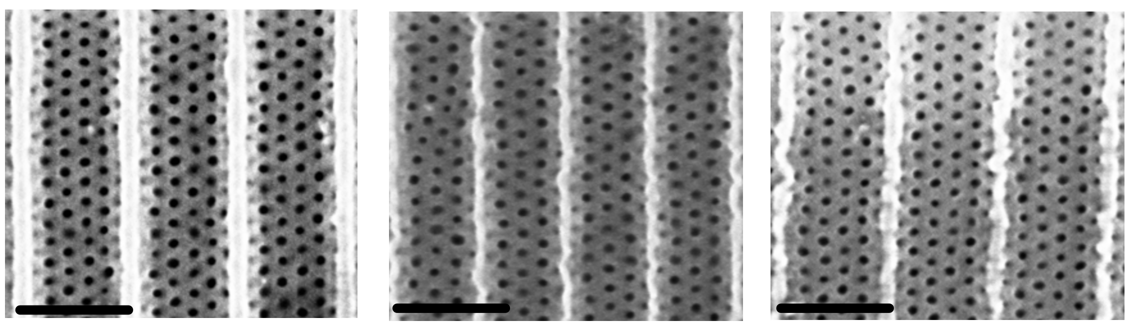
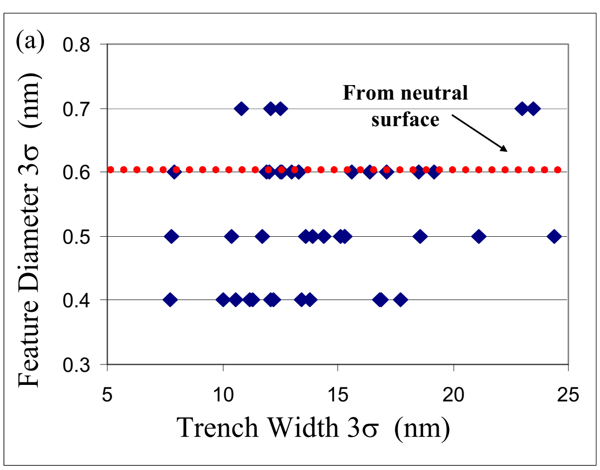


Figure 2: Three representative SEM images showing few defects with trench width roughness measuring 8, 12, and 19 nm respectively. (Scale bar = 200 nm)



(b)

TWR (nm)	Defects	TW (nm)	W/l_0 -1
12.6	few	101	1.89
15.4	very few	110	2.14
15.6	very few	145	3.14
17.0	few	135	2.86
19.3	very few	135	2.86
20.0	very few	110	2.14
21.6	few	176	4.03
24.5	few	169	3.83
27.6	very few	139	2.97

Figure 3: (a) Scatter plot of the variation in feature size diameter versus the trench width roughness. The variation in sizes from a neutral surface is shown for comparison. (b) Table showing the trench width roughness and commensurability of the polymer and the trench for images showing very few or few defects.