Combining Block Copolymer Lithography with Self-Aligned Double Patterning to Achieve 10 nm Full-Pitch Line/Space Patterns

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Abstract:

Directed self-assembly (DSA) of block copolymer (BCP) and self-aligned double patterning (SADP) are two commonly used frequency division techniques to increase the density of features of lithographic templates. DSA based on PS-*b*-PMMA using the LiNe flow has been successfully demonstrated to create 28 nm line/space patterns from 84 nm pitch 193i pre-patterns. Combination of 193i and SADP has been used in high volume manufacturing to convert 80 nm pitch photoresist patterns to 40 nm pitch features. It is challenging to extrapolate these frequency division techniques to 10 nm pitch patterns. In the case of DSA, a multiplication factor as large as 8 is needed. The density of defects, however, is predicted to increase as the multiplication factor increases. On the other hand, SADP alone is not enough to shrink the pitch from 80 nm to 10 nm. Self-aligned quadruple patterning (SAQP), or even self-aligned octuple patterning (SAOP) is needed, which involves several sacrificial layers and a multitude of additional etch and deposition steps.

Here we investigate the potential to combine DSA and SADP approaches to reach a density multiplication factor of 8 and a final line/space pitch as small as 10.5 nm. Figure 1 shows the schematic of combined DSA and SADP process. Starting with DSA using 84 nm pitch guiding stripes and a 21 nm L_0 P2VP-*b*-PS-*b*-P2VP, a multiplication factor of 4 was achieved. P2VP domains were selectively converted to AlO_x lines by sequential infiltration synthesis and polymer removal. SOG/SOC layers were etched and trimmed by dry etch with AlO_x lines as a mask. After stripping AlO_x and SOG by wet etch, SOC mandrels were left. For spacer deposition, a 5 nm thick Al_2O_3 film was conformally deposited onto the SOC mandrels by ALD. After spacer etch back, the SOC mandrels are removed leaving two spacer lines for each mandrel. The SADP process provided another factor of 2 using the mandrels defined by DSA pattern. A total density multiplication factor of 8 was realized. Figure 2 shows representative SEM images of fabricated structures in each step. The roughness evolution is systematically investigated throughout the process. These results show the promise of using DSA together with SADP as an effective scaling approach to fabricate dense sub-10 nm line/space patterns.

Figures

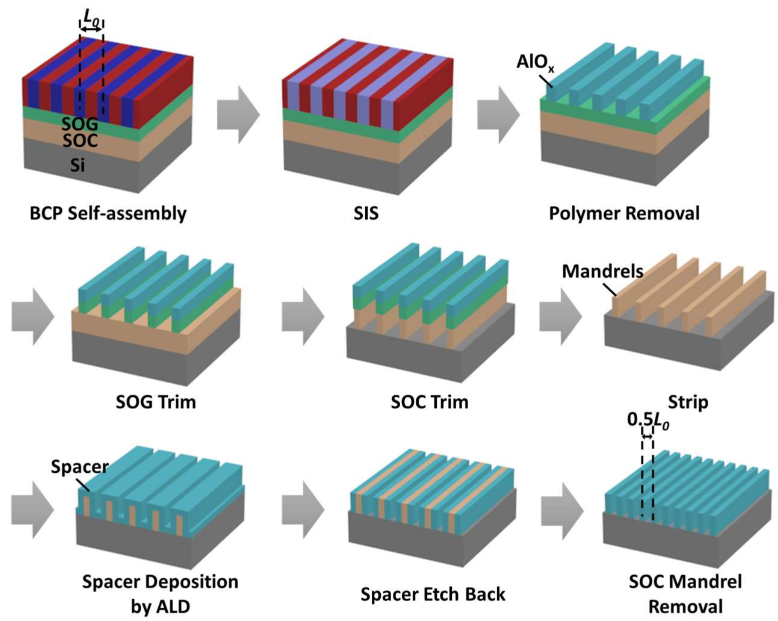

Figure 1. Schematic showing the SADP process on DSA patterns.

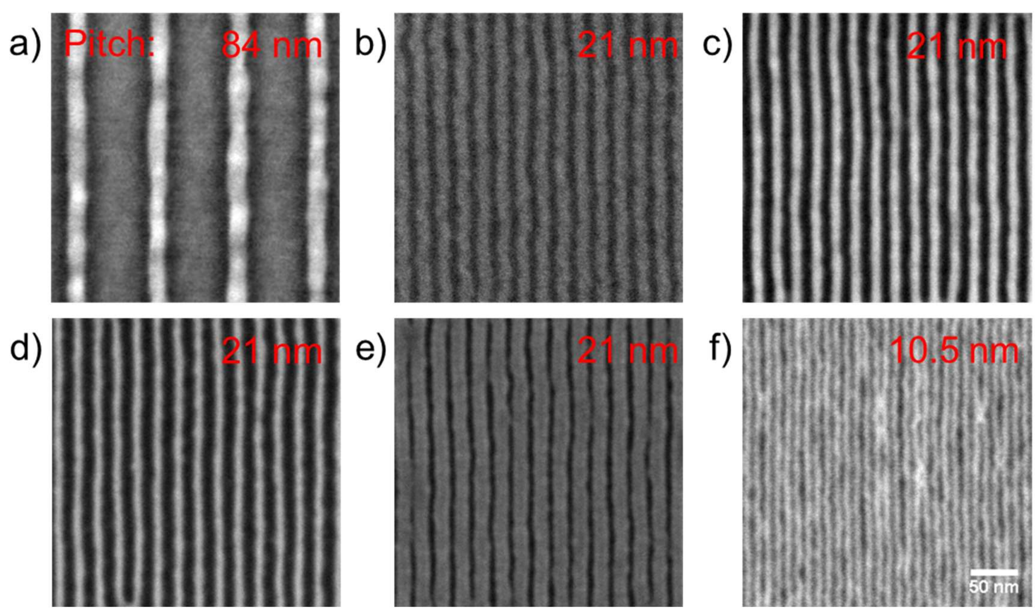

Figure 2. Representative SEM images showing: a) original E-beam patterns; b) DSA of P2VP-*b*-PS-*b*-P2VP; c) AlO_x lines; d) SOC mandrels; e) ALD spacer covered mandrels; f) spacer lines