Selective neutralization for neutral last grapho-epitaxy directed self-assembly

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Directed self-assembly (DSA) is a technique for forming sub-lithographic line/space patterns utilizing the phase separation of block copolymers (BCP). In order to form vertically oriented line-space patterns with BCP domains, a neutral layer must be present at the bottom of the BCP layer. This imposes restrictions on the types of materials and processes that can be applied on top of the neutral layer prior to BCP coating. Although current integration schemes have successfully introduced DSA from lab to fab [1,2], only a limited set of materials and processes, such as photoresists, development and solvent strip, can be integrated. For example, a grapho-epitaxy template of neutral bottom layer and resist topography imposes many restrictions on thermal budget and etch budget of the DSA and pattern transfer process. Previous study shows grapho-epitaxy on a weak preferential template (i.e. slightly non-neutral) with a uniform surface treatment for both the bottom and sidewall surfaces [3].However, we find that that the non-neutral bottom surfaces can cause domain flipping. Other approaches use cylinder phase block copolymers to avoid the requirement for a neutral bottom surface, but line edge roughness and bridging problems are more severe with cylinder phase block copolymers[4]. In this paper, we demonstrate selective neutralization of the bottom surface of a template trench by coating a selective neutral brush after template formation. We show that a neutral brush with a grafting density determined by process temperature and substrate property exhibits superior neutral last DSA results than conventional brushes. The water contact angles of this neutral polymer are shown in figure 1. Figure 2 shows the process window comparison between different brushes. Finally, figure 3 shows that optimal trench sizes depend on the neutral layer surface property. So the choice of neutral layer can affect final pattern density in a grapho-epitaxy flow.

In summary, this selective neutralization process enables the use of variety of templates for grapho-epitaxy. By decoupling template lithography, template stack, and etch processes from the DSA formation process, this approach enables wider sets of materials and processes such as Extreme Ultraviolet (EUV) lithography, etch trim processes, and sidewall image transfer (SIT) to be readily integrated to pattern DSA templates.

brush temperature (C)	substrate type	
	bare silicon	post etch SiN
110	67.9	88
150	84.1	95
180	85.2	88.9
220	87.6	85
250	86.2	87.6

Figure 1: Water contact angle of the neutral brush: The grafting density of the brush and, therefore, the final surface property is determined by process temperature and substrate type.

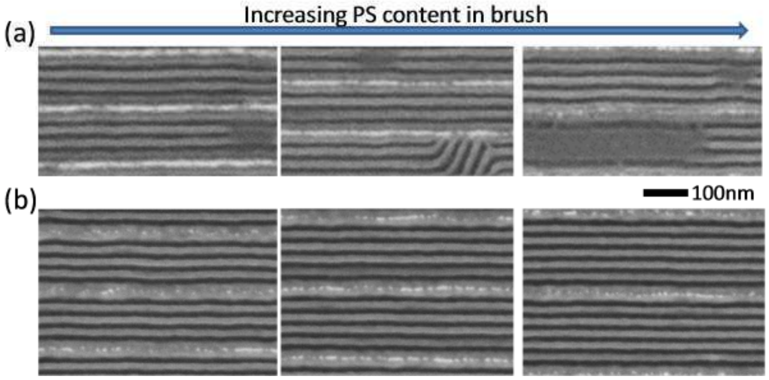

Figure 2: Process window comparison between different brushes: (a) With a series of conventional brushed baked at 250C with increasing polystyrene content, neutral last DSA can be achieved, but two types of defects form: perpendicular lines to guiding pattern and flipping lamellae domains. (b) DSA results with the selective neutral brush shows larger process window across a wider range of trench dimensions.

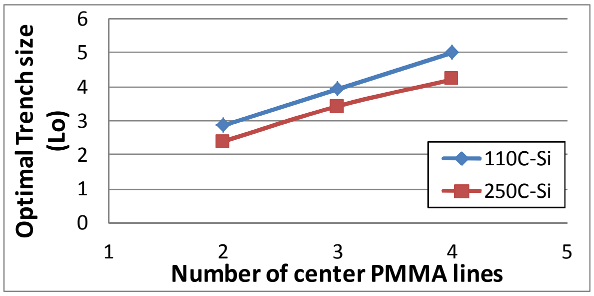

Figure 3: Optimal trench sizes depend on the neutral layer surface property: Although both weakly PS and PMMA preferential surfaces can form DSA, one yields larger optimal trench sizes than other for PS-b-PMMA.

References:
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[3] Han, Eungnak, et al. "Graphoepitaxial assembly of symmetric block copolymers on weakly preferential substrates." Advanced Materials 22.38 (2010): 4325-4329.
[4]Yaegashi, Hidetami, et al. "Important challenge for optical lithography extension utilizing double patterning process." Journal of Photopolymer Science and Technology 24.5 (2011): 491-495.