Placement error study of cylindrical phase self-assembly guided by graphoepitaxy

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Directed self-assembly (DSA) of block copolymers (BCP) has gained considerable attention in recent years as a potential resolution enhancement technique of current optical lithography due to its small size and ability to form regular patterns. In particular, it has the advantage of "shape change," *i.e.*, by printing trenches lithographically and applying a cylindrical phase block copolymer (BCP), contact holes (CHs) can be obtained. Here, we present a study on the effect of the lithographic trench width on the self-assembly of BCP in the trench.

In this work, we studied a cylindrical phase block copolymer (PS-PMMA) with its self-assembly guided by 193i optical lithography patterns (trenches) on 300 mm substrates. The trench width was systematically varied between 50 and 170 nm, resulting in 2 to 6 rows of CHs in the trench.

For every trench width, a large number of SEM images across the wafer were used. This allowed a statistical analysis of BCP pitch in the X direction (hole row-to-row distance through the trench), pitch in the Y direction, critical dimension, critical dimension uniformity (CDU), and placement error in X and Y (Figure 1).

The BCP contact hole row-to-row distance in the X direction across the trench was found to be dependent on the lithographic trench width and the number of rows. Evidence was found for the presence of a thin 'dead layer' of BCP at the walls of the trenches. Good agreement between a simple model including a 'dead layer' and the experimental results was found (Figure 2).

A placement error study (where placement error is defined as the additional overlay error to the lithographic overlay error) was performed by two fitting methods: 'fitted pitch' and 'fixed pitch'. The 'fitted pitch' method fits the optimal pitch per SEM image per trench width. Using this method, random placement error effects of 2.5 to 3 nm were estimated. The 'fixed pitch' method uses a fixed pitch for all SEM images of the same trench width. The placement error obtained from this fit consists of both random placement error effects and pitch related effects. Placement errors of about 7 nm were obtained for the 'fixed pitch' method. Such an increase in the placement error mainly resulted from the placement error in the Y direction (along the trench) as the BCP is not confined by the trench walls in this direction. This resulted in variations of the pitch in the Y direction.

In conclusion, we have studied the influence of the trench width on the lithographic performance of CHs obtained from the use of the self-assembled block co-polymer. Control over the BCP pitch across the trench is obtained.

However, confinement in one direction is not sufficient to control the placement of the CHs in X and Y.

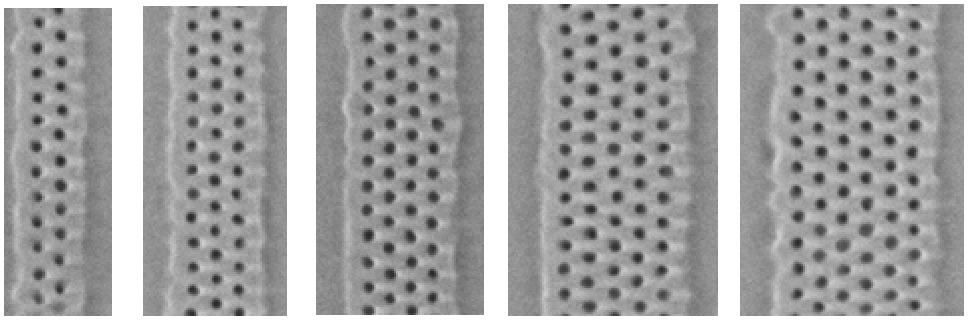

Figure 1: Typical SEM images of lithographic trenches of varying width filled with self-assembled cylindrical phase block copolymer forming 2 to 6 rows of CHs.

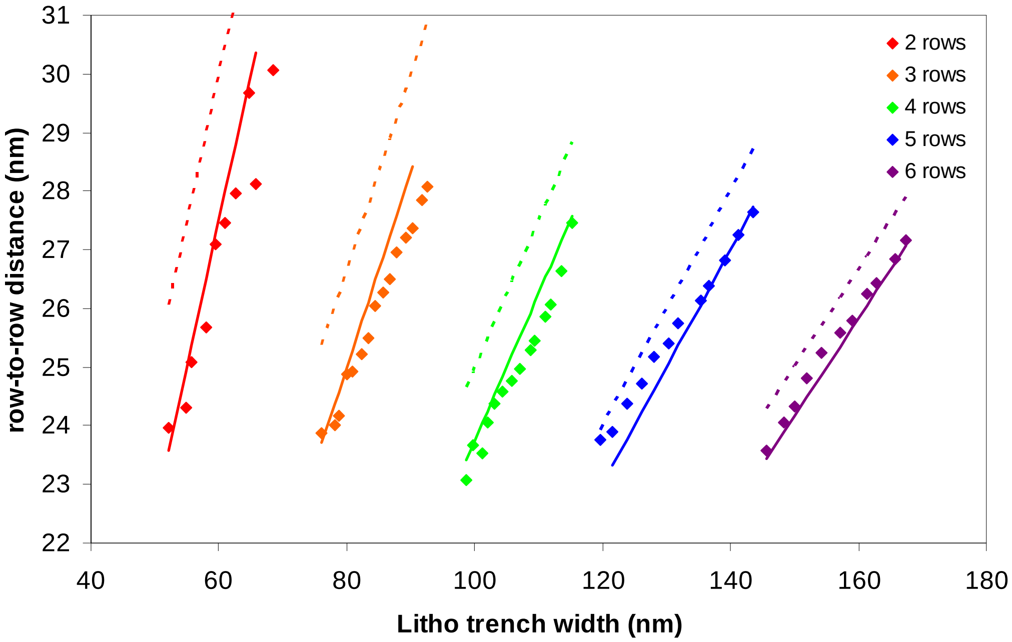

Figure 2: Row-to-row distance of self-assembled CHs plotted versus the lithographic trench width measured for 2 to 6 rows of CHs. The diamonds are measured row-to-row distances per lithographic trench width. The dotted line represents the lithographic trench width divided by the number of rows of CHs. The solid line also includes a dead layer of BCP at the wall of in total 5nm.