The integration of block copolymer directed assembly with 193 immersion lithography

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As the critical dimension of integrated circuits and memory devices approaches the resolution limit of 193 nm lithography, and while next generation lithography technologies may not be ready for another two or three years, double patterning (DP) techniques[1, 2] could be the most viable candidate for bridging the resolution gap in the interim.[3] Directed assembly (DA) of block copolymer (BCP) films is an alternative and non-traditional patterning technique that may allow for doubling or even tripling the density of features compared to those defined in a single exposure, at lower cost and decreased process complexity than DP.

The starting point for DA of BCP is defining and controlling the dimensions and chemistry of the lithographically defined chemical pre-pattern. For line (lamellar) structures, the substrate is typically patterned with lines with similar critical dimension (CD) as the final assembled structures, but with a pitch 2 or 3 times the pitch of the final assembled structures. The chemistry of the lines is chosen so as to be strongly preferentially wet by one of the blocks of BCP, and the adjacent regions are more chemically compatible with both blocks. A very thin imaging layer is usually patterned on top of the substrate to achieve the desired properties for DA. One of the key concerns with the integration of BCP DA with 193 nm lithography is that an anti-reflective coating (ARC) is required to resolve sub-wavelength patterns.[5] A consequence is that film stack design, pattern transfer feasibility, and chemical pattern formation for DA are convoluted and must be carefully engineered.

The results of this study show that a thin layer of silicon nitride (or other inorganic materials) can be used underneath the brush layer as the ARC, simplifying the process and alleviating pattern transfer difficulties. A trim etch, as shown in Fig. 2a-b, is enabled by the use of the cross-linkable polystyrene[6] (X-PS)/end-hydroxyl brush imaging layer system. The pattern was lithographically defined by 193 immersion interference lithography with commercial PR coating on top of the X-PS. The PR was trimmed and the X-PS was etched with oxygen plasma. The PR was then removed by warm solvent and sonication, then a random copolymer brush was grafted in the sections of the pattern where the X-PS was etched away to facilitate the block copolymer assembly. The CD after trim etch was ~15 nm and the pitch was 90 nm. A PS-*b*-PMMA BCP with a natural period of 30 nm, was then directed to assemble on this chemical pattern, yielding a pattern consisting of parallel lines, effectively tripling the density of the lithographic pattern, as shown in Fig. 2c. The integration of multiple patterning of copolymer directed-assembly with 193nm immersion lithography provides a comparable pattern quality with existing DP techniques, and thus could be a promising candidate for extending the use of current lithography tools and lowering the overall patterning cost while pursuing higher pattern density.

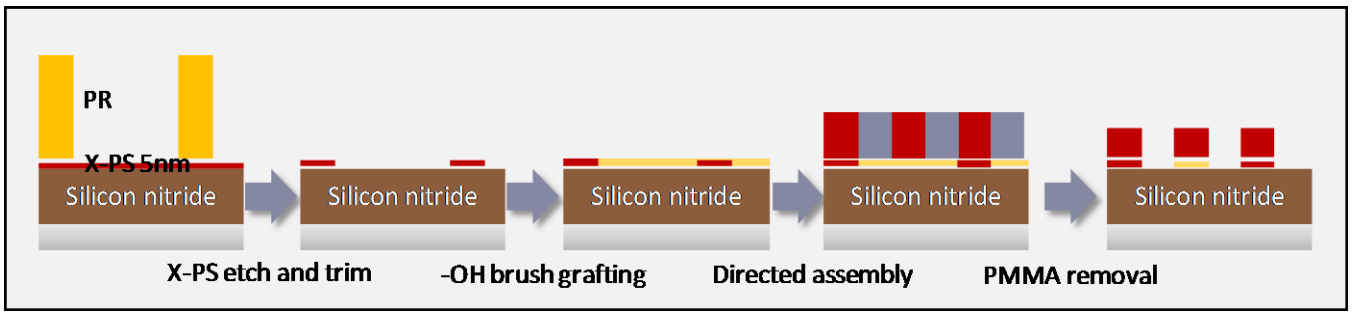

Fig. 1: Schematic illustration of the proposed method.

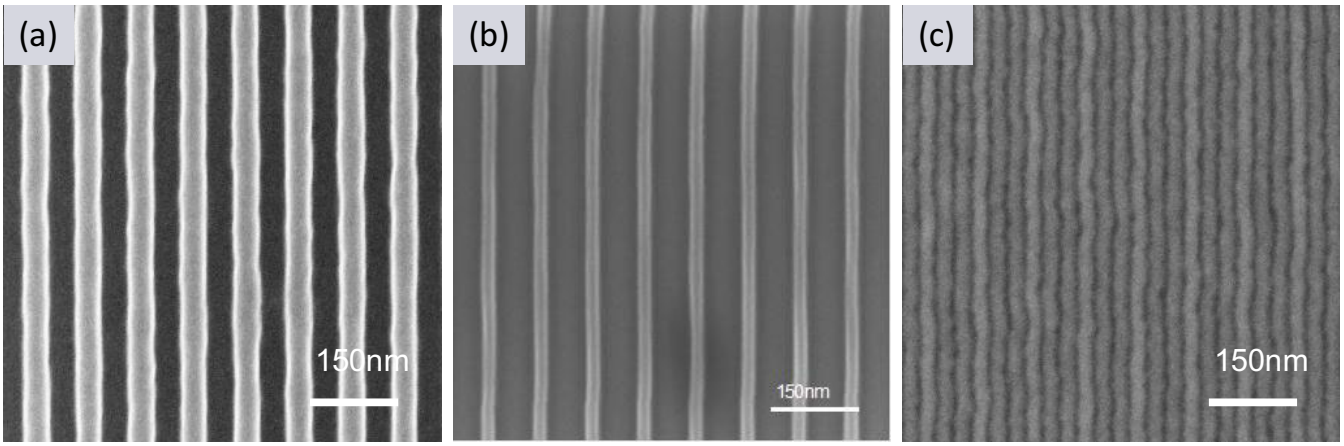

Fig. 2: Top-down SEM images of (a) photoresist before trim etch, (b) photoresist after trim etch, and (c) block copolymer after directed assembly.

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