Self-aligned double patterning by directed self-assembly of block copolymers

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As the critical dimension (CD) of integrated circuits and memory devices approaches the achievable resolution limits of 193 nm optical lithography, and while higher resolution lithographic technologies, such as extreme ultraviolet lithography, 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 gap between current and future lithography technologies. In this study, we propose a DP technique using directed assembly of polystyrene-*block*-poly(methyl methacrylate) block copolymer (PS-*b*-PMMA). The proposed process not only provides self-alignment between the guiding pattern and the doubled pattern but also incorporates attractive properties from directed assembly of block copolymers, such as low line-edge roughness and good CD uniformity.[3, 4] Furthermore, unlike previous work on density multiplication with block copolymers[3, 5], the proposed process does not use hydrogen silsesquioxane (HSQ), which is only sensitive to 157 nm wavelength and below[6], as a photoresist and guiding pattern, and therefore is compatible with current DP processes. The results of this study showed that DP with self-assembly of PS-*b*-PMMA provided pattern quality equal to that of existing DP techniques, while only requiring spin-coating and hotplate annealing. Hence it could also be a promising intermediate for extending the use of current lithography tools and lower the overall cost.

In this work our process started with a lithographically defined guiding pattern in a 70-nm-thick PMMA photoresist on top of a 12-nm-thick layer of cross-linkable polystyrene (X-PS).[7] The X-PS was etched with an oxygen plasma to yield a series of parallel lines of X-PS separated by relatively, wide trenches that were free of X-PS. The X-PS pattern had a line:space ratio of 1:3, a line-width of 20 nm, and a pitch of 80 nm. After removal of the photoresist with warm solvent and sonication, a hydroxyl-terminated random copolymer[8] was grafted in the trench area to facilitate the perpendicular orientation of PS-*b*-PMMA domains during a subsequent self-assembly step. The neutral brush only reacted with the native oxide surface at the bottom of the trenches, such that the X-PS covered area remained untreated. PS-*b*-PMMA with a lamellar period of 41 nm was then self-assembled on this substrate. Large areas with a high degree of perfection were observed after self-assembly, yielding parallel lines of PS domains with a domain width of 20 nm. Based on previous work[9, 10], the PS domains could serve as a template for further pattern transfer.

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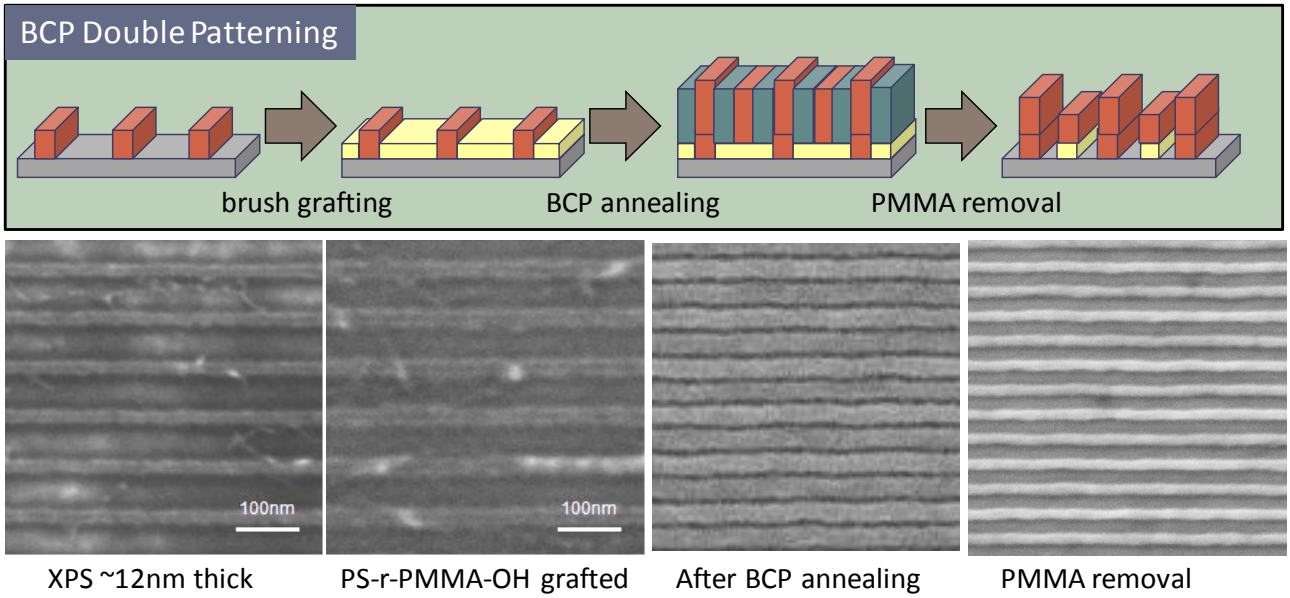

Fig. 1 Process flow of block copolymer double patterning and top-down SEM at each stage. From left to right, top-down SEM image of (1) X-PS guiding pattern after PR removal, (2) after neutral brush grafted, (3) after PS-b-PMMA self-assembly and (4) after selective PMMA removal. All the SEM images are 0.5um x 0.5um.