PMMA removal options for DSA contact shrink application

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Directed Self Assembly (DSA) of block copolymers (BCP) complements conventional lithography (EUV, immersion ArF) by overcoming intrinsic exposure limitations to enable final critical dimension (CD) feature and pitch reduction making DSA a promising process for the 14nm technology node and beyond[1,2].

The DSA process for contact hole shrink patterning using polystyrene-*b*-polymethylmethacrylate (PS-*b*-PMMA) di-block copolymers was previously studied to target contact holes CD down to 15nm[3,4,5] (Fig.1). Random and block-copolymers materials were supplied by ARKEMA. One of the key steps in DSA flow integration is the selective PMMA block removal from the PS matrix; thereby establishing a pattern for plasma etch transfer into underlayers.

Primary objective was to determine options for improving the PMMA removal process by different pre-treatments prior to PMMA wet development (Fig.2)[6]. Pre-treatments were found to be efficient to assist PMMA removal by inducing the PMMA de-polymerization and, as well, PS crosslinking. Different pre-exposure options (UV exposure at 2 different wavelengths, E-beam and ion implantation) have been investigated on un-patterned wafers showing that pre-treatments improve PMMA degradation to enable complete removal by wet development in acetic acid. It was also discovered that select pre-treatments prevented CD size increases induced by the random (brush) layer dry etching step that was required in case of wet development alone. Complementary SEM (scanning electron microscopy) and AFM (atomic force microscopy) surface topography characterizations were utilized on confirm results.

Finally, we also demonstrated UV pre-treatment hardened resists sufficiently to enable resist-based DSA integration (BCP directly coated on resist). This approach simplified patterning flow with fewer process steps (vs tri-layer based stack) and successfully transfers into underlayers by dry etching.

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[1] C. Bencher et al., Proc. of SPIE 2012, 8323-22
[2] H. Yi et al., Adv. Mater, 2012, 24, 3107-3114
[3] Muramatsu, et al., MNC Conference, 2012
[4] R. Tiron et al, Proc. of SPIE 2012, 8323-23
[5] I. Servin, et al., MNC Conference, 2013
[6] R. Tiron et al, Proc. of SPIE 2013, 8680-12

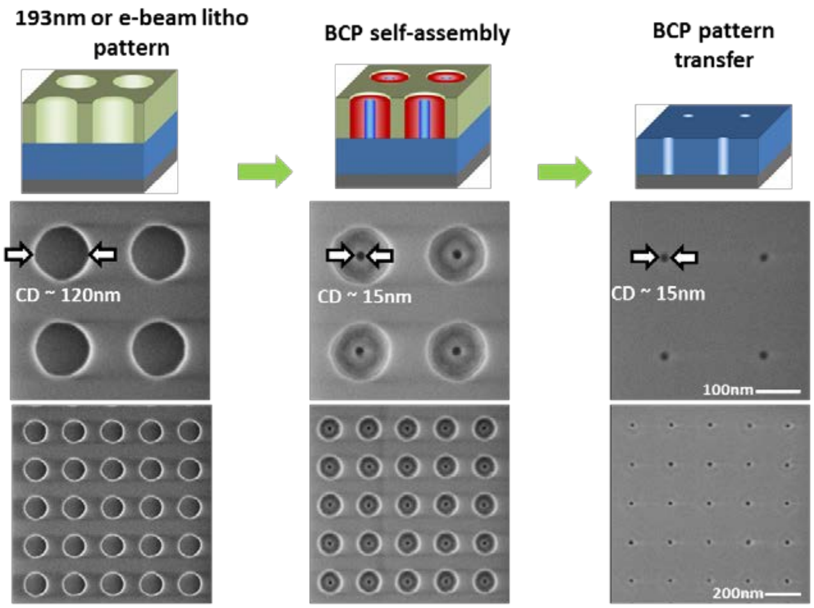
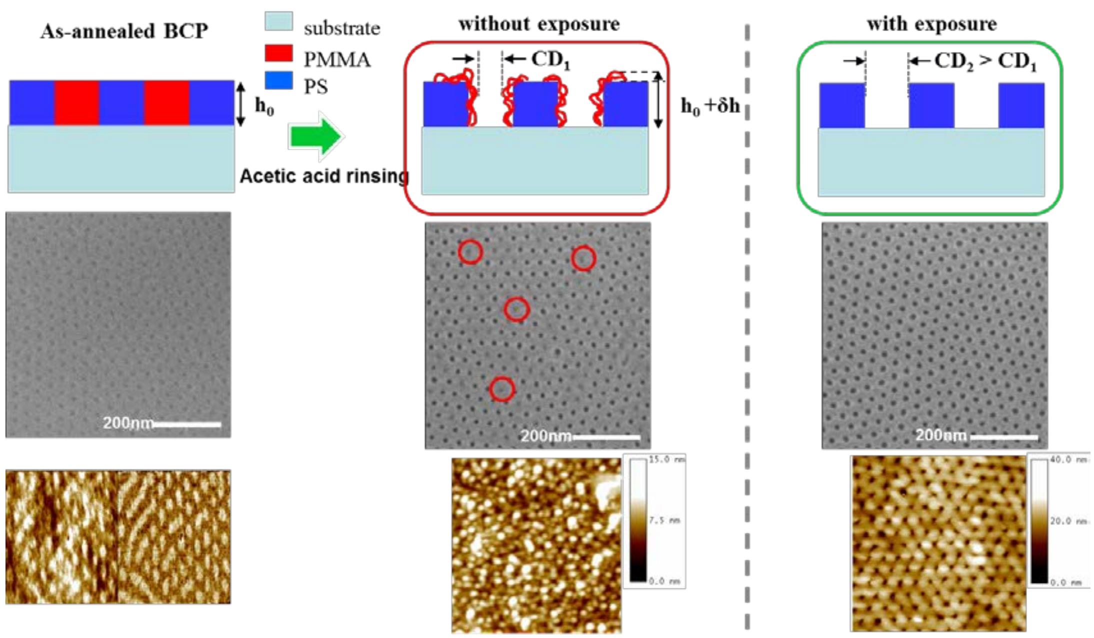


Figure 1: DSA process of reference (lithography and etch) available on 300 mm pilot line at CEA-Leti



(a) (b) (c)

Figure 2: Schematic representation of self-assembled PS-*b*-PMMA block-copolymer film and corresponding SEM / AFM images: (a) as annealed, (b) after only acetic acid development (Contact CD=12.1nm) and (c) after pre-exposure followed by acetic acid rinse (Contact CD=12.9nm)

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