Control of the Critical Dimensions and Line Edge Roughness with Pre-organized Block Copolymer Pixelated Photoresists

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Chemically amplified (CA) photoresists, which consist of photoacid generators (PAGs) and polymeric materials with acid-labile functional groups, are the predominant resists used in current manufacturing.[1] However, CA resists have limitations on the developed resolution due to their own chemical properties.[2,3] As the length scales decrease, the critical dimensions (CD) of patterned resist structures approach the molecular scale, and the line edge roughness (LER) shrink to the sub-molecular scale of resist materials. Among the several controlling factors for LER, non-uniform spatial distribution of resist components is one of the primary barriers to high resolution patterning of the resist materials. The pre-organized pixel-forming resists created from block copolymers with desirable and well-defined material structures control the size and the resist heterogeneity, and also reduce LER of the structure.[4]

In this study, asymmetric poly styrene-*block*-poly(*t*-butyl acrylate) (PS-*b*-P*t*BA) diblock copolymer, which formed PtBA spheres within a PS matrix, is used as pre-organized photoresist by adding catalytic amounts of PAG. PAG segregates into the P*t*BA block, the deprotection chemistry of CA occurs only in the P*t*BA spherical domains. The pixel-forming resists shows a significant solubility switch after electron-beam exposure and post-exposure bake, such that the tBA in the exposed regions transforms to acrylic acid molecules and the resist in the unexposed regions dissolves in hydrophobic organic solvent (negative patterning). As shown in figure 2, the spherically organized structures after lithographic process are matched with the characteristics of the block copolymer, and the exposed width of lines of resist is increased linearly but the widths of the developed structures are increased step-wise and quantized with respect to the width of one row of spheres (pixels). Moreover, highly well-defined pre-organized PS-*b*-P*t*BA/PAG resist, which was assembled on topographic surfaces, controls the CD and LER of the developed resists with the number and the size of pixels regardless of the exposed width of the process.

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[1] H. Ito, J. Polym. Sci., Part A: Polym. Chem. **41**, 3863 (2003).
[2] P. Naulleau *et al.*, IEEE J. Quantum Electron. **42**, 44 (2006).
[3] G. M. Wallraff *et al.*, J. Vac. Sci. Technol. B **22**, 3479 (2004).
[4] Y.-H. La *et al.*, J. Vac. Sci. Technol. B 25, 2508 (2007).

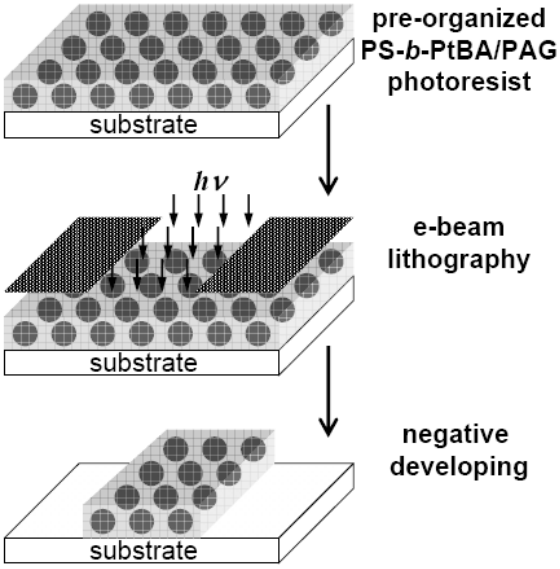

Figure 1.
Representation of the negative patterning process using the pre-organized PS-b-PtBA/PAG thin films on silicon wafer

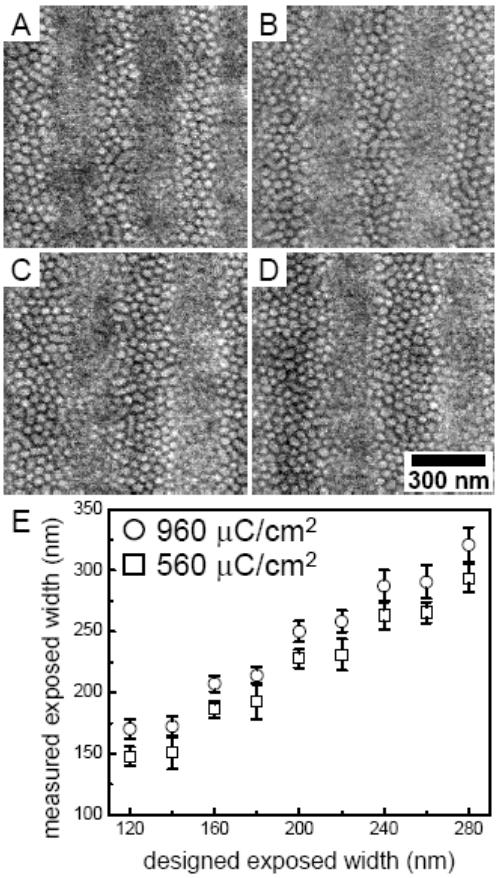

Figure 2.
Top-down SEM images of the processed PS-b-PtBA/PAG thin films on silicon wafer using e-beam lithography with controlled width of the patterns as 140 (A), 180 (B), 220 (C) and 260 nm (D). The graph shows the actual patterned width versus the designed width (E).

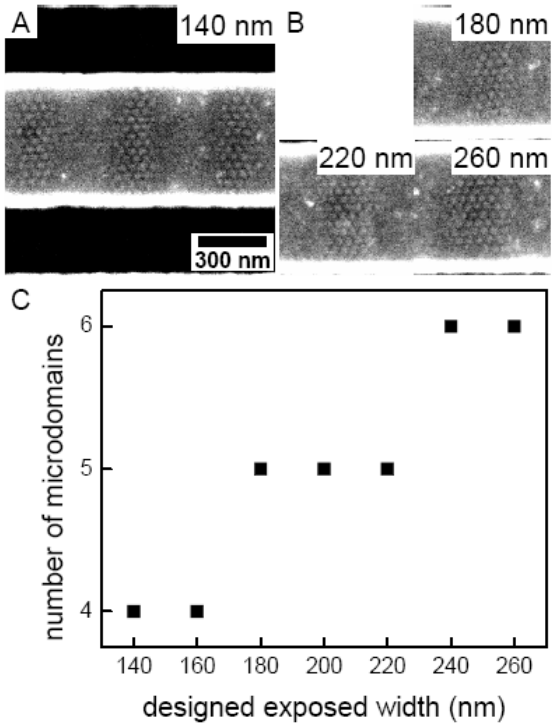

Figure 3.
Top-down SEM images of the processed PS-b-PtBA/PAG thin films on topographically patterned silicon wafer using e-beam lithography with controlled width of the pattern and graph for the comparison of the actual patterned width with the designed width of the pattern.