Graphoepitaxy of block copolymers using 193nm lithography: a process and defectivity study

R.Tiron[1], X.Chevalier[1,2], C.Couderc[1], S.Gaugiran[1], C.Lapeyre[1], J.Belledent[1], C.Navarro[3], T.Chevolleau[4], G.Cunge[4], G.Fleury[2], G.Hadziioannou[2]
[1]*CEA LETI MINATEC, Grenoble, 38054 France*
[2]*Laboratory of organic polymer chemistry, Bordeaux, France*
[3] *Arkema, Lacq Research Center, 64170 Lacq, France*
[4]*LTM-CNRS, CEA-LETI, 38054 Grenoble, France*

Density multiplication of patterned templates by self-assembly of block copolymers (BCP) stands out as a promising alternative to overcome the limitation of conventional lithography[1]. Nevertheless the control of the mechanisms that determine the quality of self assembly process on patterned substrate needs to be understood to develop large scale industrial processes.

In this paper the work is focused on the direct assembly flow of PS-PMMA block copolymer in association with conventional 193 nm lithography. More precisely, in order to follow process robustness, a new methodology to qualify and quantify defects has been elaborated.

Pre-patterned structures used in graphoepitaxy approaches are generated using single exposure 193 nm dry lithography with commercial photo resist and BARC. Surface modification is done by grafting a random PS-r-PMMA copolymer. The PS-b-PMMA is spin coated and annealed in order to generate self assembly, then chemical treatment will remove PMMA leaving a PS mask (see fig. 1a). The transfer capability of the PS nanostructures into silicon substrate using plasma-etching technology is also investigated. Figure 1b highlights some result examples of pattern density multiplication by graphoepitaxy using lamellar and cylindrical block copolymers with a final resolution of less than 15nm. This study also presents that long range ordered networks can be generated by increasing polymer film thickness with respect to pattern height (see fig. 2).

As the self assembly process is based on a thermo-dynamical mechanism, induced defectivity problematic changes with respect to a standard lithographic process and new solution have to be investigated. Using the cylinders centers coordinates, a Delaunay triangulation is performed to find nearest neighbors[2]. This triangulation easily locates disclinations, characterized by having a number of nearest neighbors different from six (see fig. 3). Thus number of defects can be detected and reported. Furthermore a final image treatment enables the evaluation of block copolymer order period.

In conclusion, this simple methodology allows monitoring overall process improvement by following order optimization. This work confirms the high potential of block copolymer process and its ability to become a real CMOS lithography solution for future advanced nodes.

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[1] Guoliang Liu, Carla S. Thomas, Gordon S. W. Craig, and Paul F. Nealey, Adv.Func.Mater., 2010, 20, 1251.

[2] Seung Hyun Kim, Matthew J. Misner, Ting Xu, Masahiro Kimura, Thomas P.Russell, Adv. Mater 2004, 16, 226

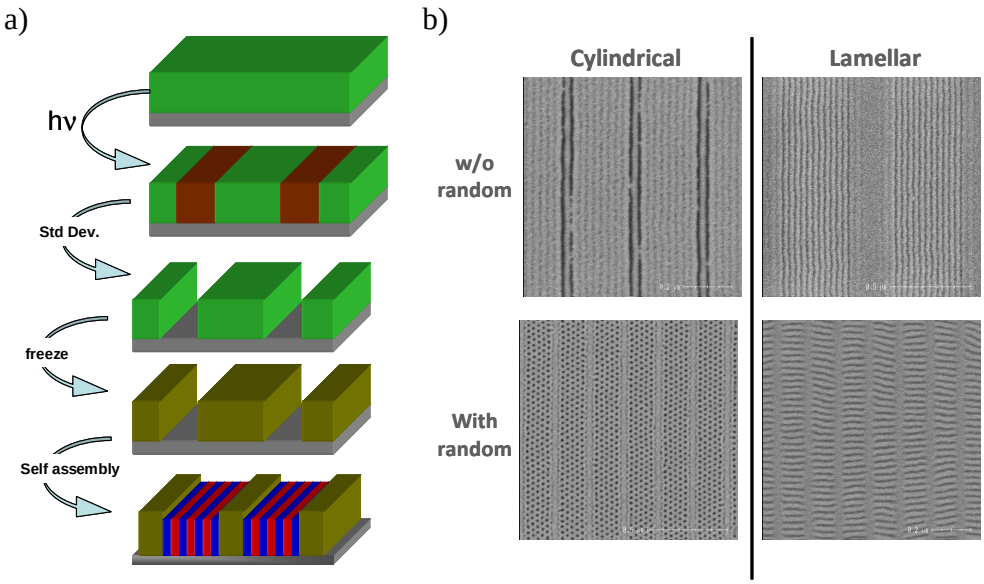

Figure 1: a) graphoepitaxy schema using 193 lithography; b) CD-SEM image of lamellar and cylindrical block copolymer graphoepitaxy on 193nm resist.

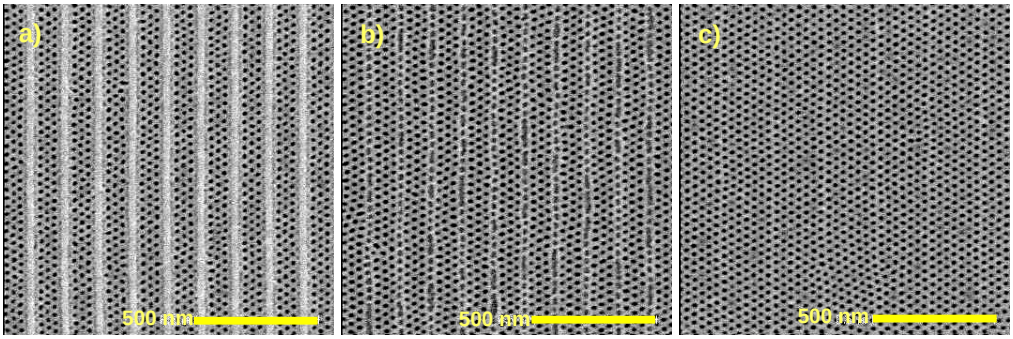

Figure 2: CD-SEM image of cylindrical block copolymer graphoepitaxy on 193nm resist when polymer thickness is increased.

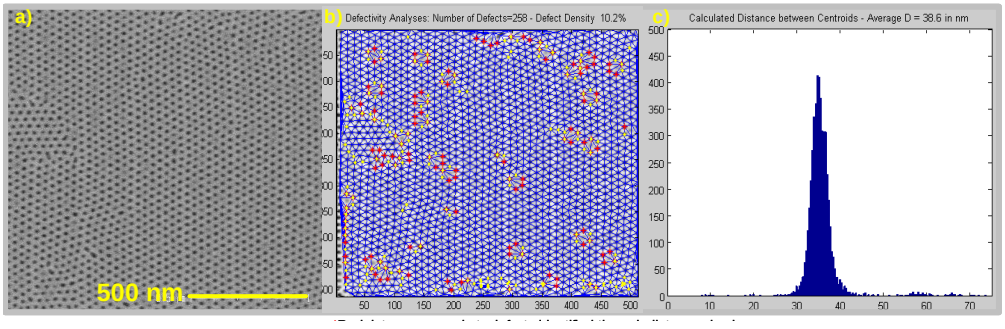

Figure 3: a) CD-SEM image of cylindrical block copolymer graphoepitaxy on 193nm resist with polymer thickness superior to resist thickness; b) Delaunay triangulation and defect analyses for image a, in red defects identified through distance checks, in yellow defects identified by number of neighbors c) measured center to center distance for image a.