Defect Evolution in Thin Films of Self-Assembling Lamella Forming Block Copolymers on a Neutral Surface

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Lithographic applications of block copolymers in the fabrication of integrated circuits and bit patterned media require extremely low levels of defects. One of the key issues encountered in the development of directed self-assembly processes is fundamental understanding of the origin of defects and their prevention, particularly with respect to the intrinsic properties of block copolymer materials themselves. In the present work, defects formation and annihilation in self-assembly of poly (styrene-block-methyl methacrylate) (PS-b-PMMA) on a non-preferential wetting surface is investigated. Compared to chemical patterned surfaces, neutral surfaces provide an ideal platform to study the defect thermodynamics and kinetics because of the large number of defects formed and their slow annihilation rate.

Non-preferential wetting surfaces for the PS and PMMA blocks of the copolymer were created by deposition of a 6-8 nm thick cross-linked mat of poly (styrene-random-methyl methacrylate) with composition 57% styrene, 39% methyl methacrylate, and 4 % glycidyl methacrylate. A thin film of thickness 65 nm PS-b-PMMA (molecular weight: 66K-63K; lamellae periodicity: 65 nm) was spin coated and was annealed at temperature ranging from 190 C to 230 C. The top down SEM images were analyzed using in house image processing software (Figure 1), allowing data collection over hundreds of images and therefore large sample areas.

Fingerprint patterns of lamellar morphologies lacking long range order and high densities of defects on two dimensional plane of the film was observed. The end and branch points in both PS and PMMA domains were counted using the image processing. Annihilation of defects with increasing annealing time and temperature was observed (Figure 2). PS is more susceptible to form branches while PMMA is more likely to form the end points. Defect annihilation with time was observed to follow $t^{-\alpha}$ scaling (Figure 3). The two dimensional radial distribution functions were obtained to determine the correlation in the position of the defect pairs. The correlation distance and the curvature of lamella domains depend on annealing temperature and time. The results are discussed in terms of the relative importance of kinetic and thermodynamic origin of defects and their prevention.

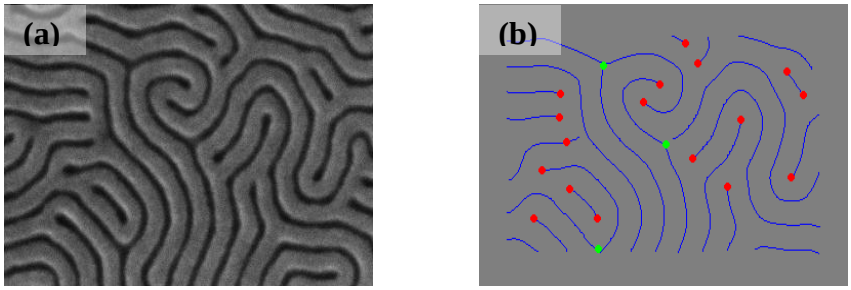

Figure 1: (a) Top down SEM images of the fingerprint lamellar morphology. (b)Information about defects location and morphology structure extracted using image processing techniques. End points and branch points are marked by red and green dots respectively.

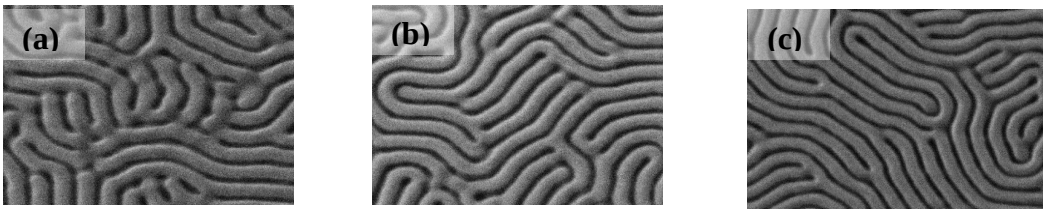

Figure 1: Top down SEM images of the PS-b-PMMA copolymer fingerprint patterns at different times (a) 3 hours, (b) 9 hours and (c) 18 hours during thermal annealing at 190 C.

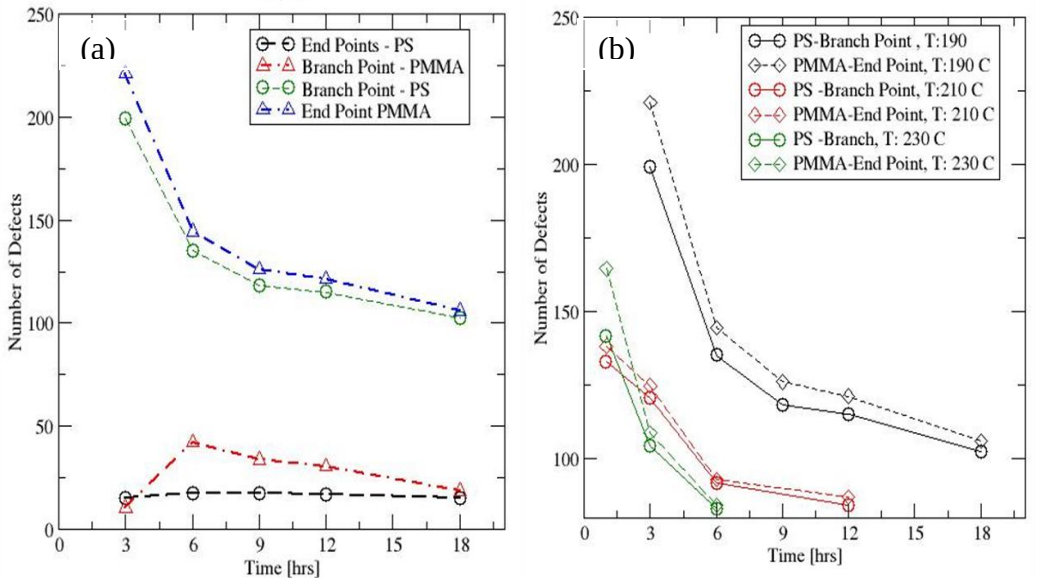

Figure 1: (a) Annihilation of branch points and end points for PS-b-PMMA copolymer annealed at 190 C. Vertical axis show the average number of defects per image of area ~ 3μm^2. Branches in PMMA and end points in PS do not show significant change with time. (b) Annihilation of branch points and end points for PS-b-PMMA copolymer for temperature ranging 190 C-230 C.