Guided phase separation of polymer blends for patterns varying from micron to nanometer length scales

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Development of cost effective novel techniques for organizing soft materials like polymer chains in patterns with sub-micron length scales has found considerable technological interest [1]. Material scientists world-wide have focused their investigations on utilizing inherent properties of polymers and blends for segregation or phase separation to form sub-micron self-regulating patterns [2]. Such patterned polymer surfaces find applications as functional elements of photonic, opto-electronic and other functional devices [3]. Even though self-organization can establish a short-range order, the induced patterns often lack long range coherence. This problem can be addressed by combining the self-organization with a top-down pre-patterning. We present a technique for patterning polymer blends from micron to nanometer length scales based on guided phase separation of the polymer blocks in the hydrophilic/hydrophobic regions of the silicon substrates. Ion beam / plasma induced pre-patterning is used to fabricate surface structures which guide the polymer phase separation.

Silicon substrates were hydrophobised (contact angle of 107 ± 1° with water) by chemosorption of trichloroctadecyl silane (OTS). Hydrophobic silicon substrates were exposed to the accelerated (73 KeV) argon ion (Ar^+) beams / Ar^+ plasma (60 W) through the openings of the mask / TEM grid, respectively. Parallel Ar^+ beams, passing the small mask openings subsequently converged by a factor of 8 through the electrostatic lens system, produced pre-patterns below sub-micron length scales on the silane coated silicon wafers. The Ar^+ beams locally destroyed the silane coating in the exposed areas creating pre-patterns of hydrophilic / hydrophobic regions. In the case of argon plasma exposure through TEM grids, pre-patterns with several micron length scales were fabricated. Thin films (~ 10 nm) of a blend of Polystyrene (PS) and Poly tert-butyl acrylate (PtBA) were deposited on the pre-patterned silicon substrates by spin-coating the blend solution (0.4 and 0.8 % by wt) in toluene. Exposing these blend films to the toluene vapors for 24 hours triggered the phase separation of the PS and PtBA chains guiding them to their favored hydrophobic / hydrophilic regions (see fig 1).

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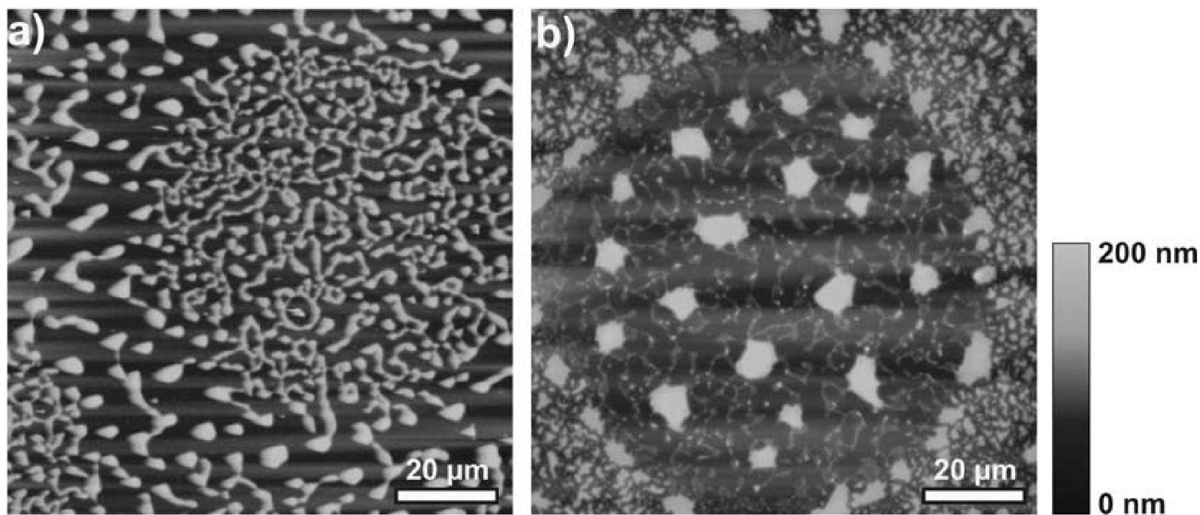

Fig 1: AFM images of the patterned PS / PtBA (1:1 wt ratio) blend film after a) 30 min & b) 24 hr. exposure to toluene vapors. The blend film was spin coated on the hydrophobised silicon substrate by silane chemosorption (contact angle of 107 ± 1º with water) & pre-patterned by exposing to argon plasma (60 W, 1 min) through TEM grid with circular openings of 72 micron diameter.