Direct top-down ordering of diblock copolymers through nanoimprint lithography

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Limitations of conventional lithography to achieve nanostructures with feature size below 30 nm made researchers to think of alternative cost-effective lithography techniques. Block CoPolymer (BCP) self assembly creates periodical pattern with feature size below 10 nm, however ordering is only obtained in grains not larger than a few micrometers. Grain orientations are independent and randomly distributed which prevents the obtaining of a long range ordering. Segalman et al.[1] demonstrated that BCP self assembly in trenches of a pattern or above topography could create an order between the polymer microphases. The trench's wall confines the polymer and guides the chains organisation. Also, a work[2] published in 2004 showed that NanoImprint Lithography (NIL) could be used to induce long range ordering but pattern quality remains a challenge. Indeed, the direct imprinting of the di-block copolymer layer may induce long-range order, may localize the organized features, there is no need to pre-pattern the substrate like in conventional grapho-epitaxy and the mold can be reused for further processing.

In this work we performed direct thermal imprinting of PS-b-PMMA (f_a= 0.21) block copolymers on wafers up to 4". Different stamp designs and polarities have been tested. Stamps were treated with a low surface energy anti-sticking agent. The use of a random polymer brush to induce vertical organisation of PMMA cylinders has also been investigated. In order to get different organisation geometries without a random polymer brush, we studied also the influence of the copolymer layer thickness on the organisation. As a result it has been shown that the mold's anti-sticking treatment does not affect the polymer chains organisation but act in a very similar way as vacuum. This result is crucial since an antisticking layer is compulsory in NIL to obtain an efficient pattern formation. Layer thickness differences induced by the NIL process enables to create areas with different chains orientations on the same sample (Figure 1) and a long range ordering tendency was observed in polymer ridges fabricated by NIL (Figure 2). Also, we showed that it is possible to organize the BCP layer by separately imprinting the polymer for a few minutes and annealing it in a standard oven afterwards. A more systematic investigation of the influence of the mold treatment, mold's trench width, mold's depth and resist thickness is now undergoing to acquire additional knowledge on the organization process.

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[1] R. A. Segalman, H. Yokoyama, E. J. Kramer. Adv. Mater., 13 (2001), 1152.}

[2] H.-W. Li, W. T. S. Huck. Nano Letters, 4 (2004), 1633.

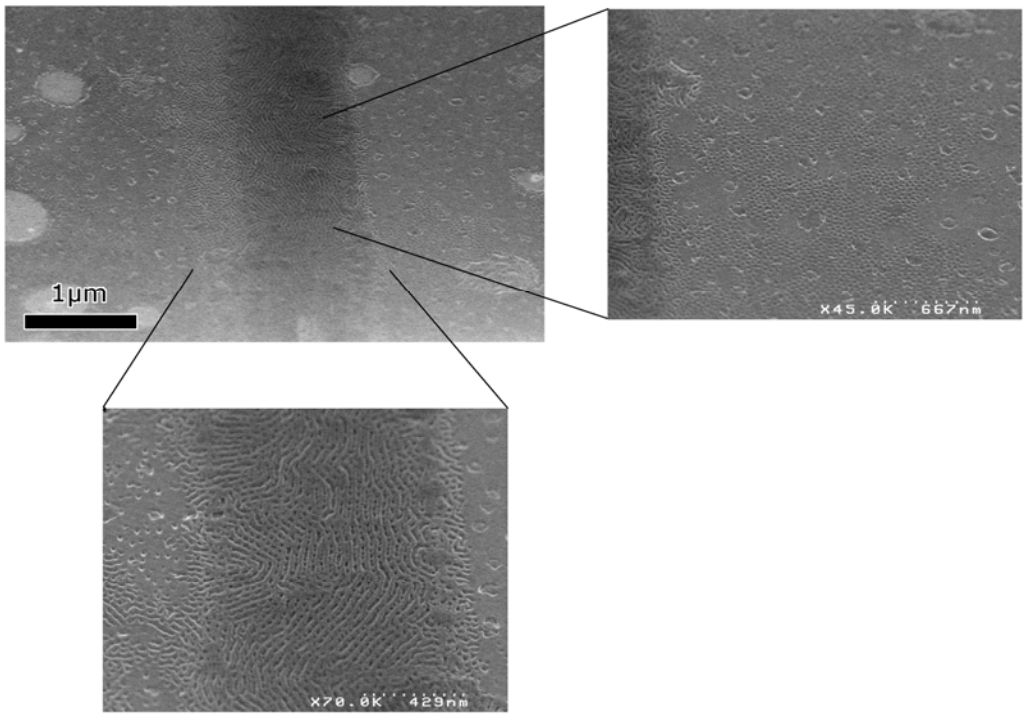

Figure 1: SEM pictures of a 1 µm wide line of PS-b-PMMA obtained after nanoimprint at 170°C under 25 bars for 15 hours (45 nm initial resist thickness). The right-hand side image shows the vertical alignment of the chains in the residual layer and the bottom image the horizontal alignment. The orientation difference is due to the thickness change between imprinted and not imprinted areas.

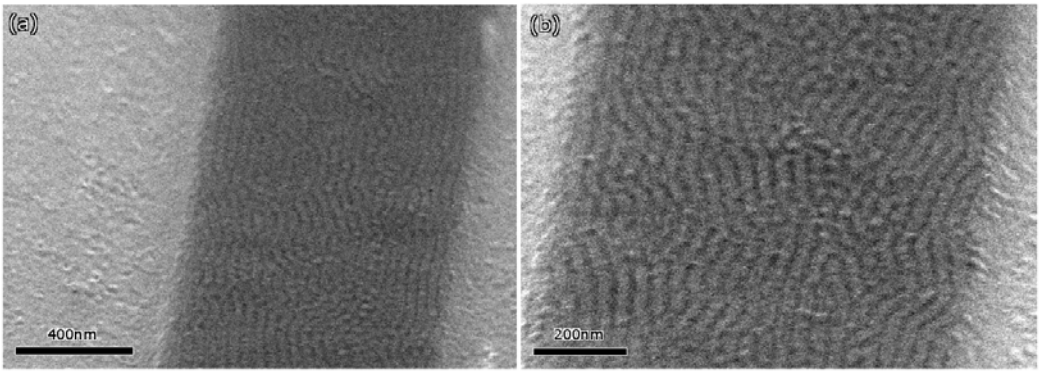

Figure 2: SEM pictures of a 1 µm wide line of PS-b-PMMA obtained after nanoimprint at 170°C under 25 bars for 15 minutes and annealed during 18 hours in a vacuum oven (70 nm initial resist thickness). The chains organisation is clearly confined within the trench and an orientation tendency along the sides is seen.

Acknowledgment

The authors would like to acknowledge the following source of funding which supported this work: European contract LAMAND (FP7-NMP-2009-245565).