Self-assembly for the definition of hierarchical patterns in thermal imprint

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Self-assembly of polymers has been utilized in several approaches to define specific patterns [1, 2, 3]. The advantage of such patterns is that they, as they result from simple surface minimization rules, allow the definition of very regular patterns. However, the controlled utilization of self-assembly requires a kind of guidance of the polymer, determining the periodicity and shape of the resulting patterns. Such guidance may be established in manifold ways, by local preparation of the substrate [1], via an electrical field [2], or by placing a pre-patterned master in a defined distance to the polymer [3].

Our approach is to exploit the sidewalls of a stamp cavity to guide the self-assembly of the polymer. There, the contact angle between the stamp and the polymer [4] was found to have paramount impact on the polymeric patterns, provided that the filling of the cavities is not yet complete.

Figure 1 gives an example for a pattern resulting from sidewall guided self-assembly. There a 200 nm thick PMMA layer was imprinted by periodic patterns (5 μm lines with 5 μm cavities). Due to the fact that the contact angle between the stamp and the polymer was sufficiently high, the polymer was able to self organize. It 'climbed up ' the sidewalls of the stamp, completely retracted itself from the middle of the cavity and exposed the substrate in the form of a continuous line (Fig. 1 left). Thus, hierarchical patterns of approximately 2 μm width could be fabricated (compare Fig. 1).

Within our approach we will show, that the definition of hierarchical structures by means of sidewall guided self-assembly is also possible with structure dimensions by far lower. Figure 2 for example shows the imprint of 300 nm lines with 500 nm cavities. After 90 min at an imprint temperature of 190 °C, the polymer almost completely 'climbed up' the cavity walls, resulting in patterns < 50 nm wide and app. 300 nm high. Obviously, it is possible to define hierarchical patterns even with very small structure dimensions. The width of such patterns at least can be reduced by a factor of five compared to the initial width (500 nm). These fine patterns may be used as a mask for lithography.

Further, we will comment on the impact of the 'guiding structures' that, on the one side are required to define such hierarchical patterns but on the other side limit their periodicity in terms of small spacing.

[1] R. Ruiz et al, *Science* 321 (2008) 936-939
[2] E. Schäffer et al, *Nature* 403 (2000) 874-877
[3] S.Y. Chou et al, Appl. Phys. Lett. 75 (1999) 1004-1006
[4] N. Bogdanski et al, *J. Vac. Scie. Technol. B* 26 (2008) 2416-2420

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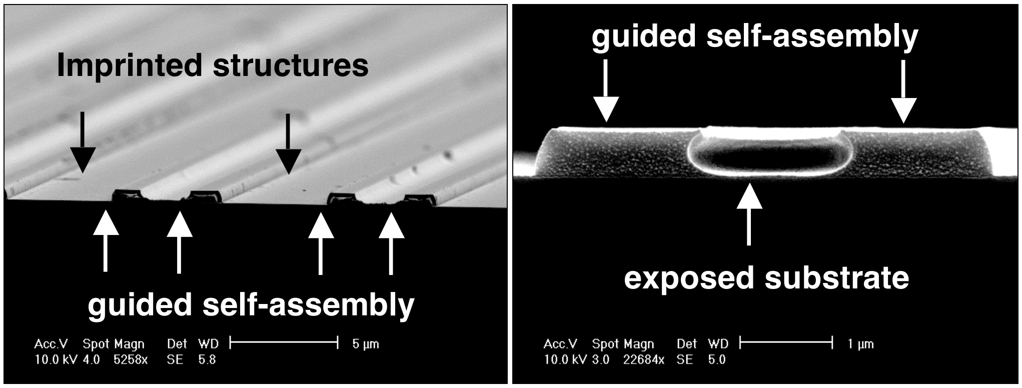

Fig. 1: Imprint into PMMA 25 kg/mol at 180°C, 3 min (stamp with 5 μm lines and spaces, 500 nm high). The initial layer thickness was 200 nm, leading to incomplete cavity filling. Left: Overview, the polymer 'climbed up' the sidewalls of the stamp, leaving a continuous line in the middle of the cavity that reaches down to the substrate. Right: Close up micrograph, highlighting the hierarchical patterns.

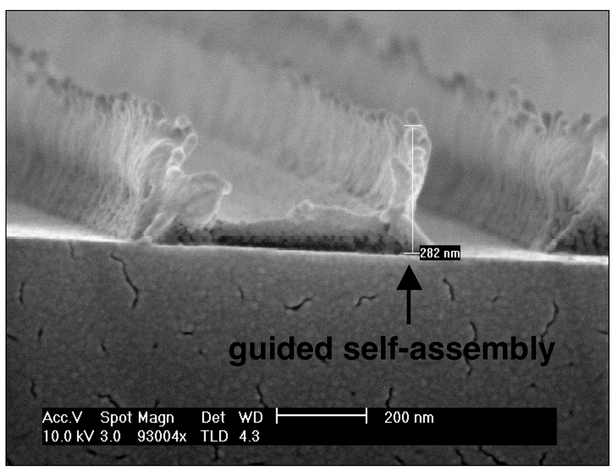

Fig. 2: Imprint into PS 350 kg/mol, 50 nm thick, at 190°C (stamp with 300 nm lines and 500 nm spaces, 300 nm high). At an imprint time of 90 min, the polymer 'climbs up' the stamp walls almost up to the complete stamp height, defining hierarchical patterns of < 50 nm width.

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