Guided wrinkling with nanoimprinted SU-8 surfaces

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Wrinkling is a well-known effect with PDMS (poly-dimethylsiloxane)[1]. Typically, a thick PDMS film is coated with a thin hard layer; the hard layer may be provided by deposited metal or, alternatively, by a UV-ozone treatment of the PDMS surface – the latter converts the PDMS surface into a SiO_x-like hard layer[2]. The PDMS is provided with a hard layer in an expanded state, either via heating or via mechanical expansion. The wrinkling then results from cool-down or the release of the mechanical strain. Without relaxation of the expanded state no wrinkling occurs.

Our work uses SU-8, a chemically amplified negative tone photoresist popular with MEMS applications, e.g. microfluidics. In the cross-linked state SU-8 has a high chemical and thermal stability, being thus well suited for polymeric stamps for nanoimprint. Then SU-8 has to be provided with an anti-sticking layer, e.g. by silanization. The OH-groups required can be generated by UV-ozone treatment. Our silane process is based on temperature. After silanization, we observe a wrinkling (Fig. 1) similar to the one with PDMS. The UV-ozone treatment time changes the amplitude and the period of the wrinkles. Control experiments clearly show that the reason for wrinkling is the temperature, only.

Guiding of the wrinkles can be a novel concept to provide self-defined structures. For guiding the wrinkles we give a topography to the SU-8 surface. UV-lithography and nanoimprint (hard/soft stamp) are equally suited. Fig. 2 shows a result obtained with a soft stamp making use of capillary forces. Similar to the results of Huck[3] we observe an orientation of the wrinkles perpendicular to the imprinted edges. There, wrinkles occured at the surface of elevated and recessed micrometer-sized structures. In our case, wrinkles exist in the micrometer-sized areas – Fig. 2b shows a detail – , but not in the nanometer-sized structures as documented in Fig. 2c. Thus, in contrast to literature, it is not only possible to induce well ordered wrinkles, but even to do this locally. Furthermore, no expanded state is required with SU-8 for the formation of wrinkles. Our study will show the impact of different stamp geometries on the formation of winkles or rather their avoidance.

In combination with masked UV-ozone treatment, nanoimprint offers a wide variety of local surface pre-processing to create even more complex wrinkling patterns. The fact that an increase in temperature will increase the wrinkle period might e.g. provide a novel means for the optical sensing of temperature.

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[1] N. Bowden et al., Letters to Nature 393, 146 (1998)
[2] K. Efimenko, W.E. Wallace, J. Genzer, J. Colloid Interf. Sci. 254, 306 (2002)
[3] W. T. S. Huck et al., Langmuir 16, 3497 (2000)

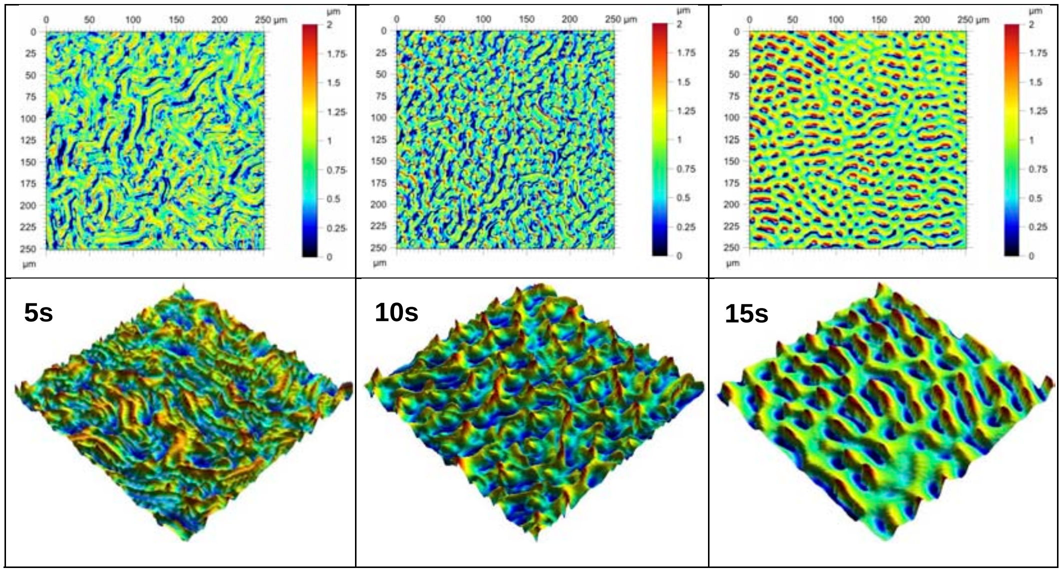

Figure 1: Appearance of the SU-8 surface after UV-ozone treatment followed by a silanization (90 min at 120°C) observed by white light interference. The UV-ozone treatment time was varied. With longer treatment times the amplitude of the wrinkles decreases whereas the period increases. With 30 s of UV-ozone treatment no more wrinkles can be observed. The reason for the formation of winkles is the temperature operating during the silanization step (120°C), not the silanization itself.

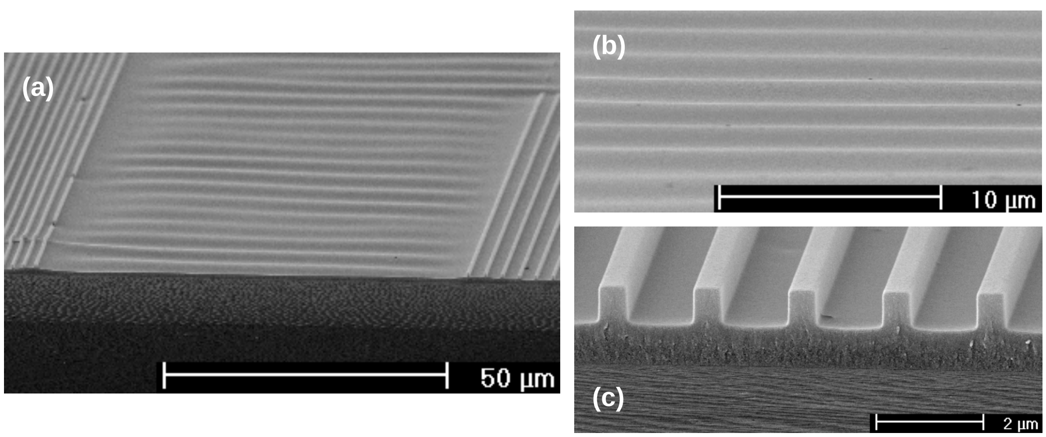

Figure 2: Local formation of guided wrinkles when using a nanoimprinted SU-8 surface. The imprint was performed by applying a soft stamp to the spin-coated layer on a hotplate at 95°C during ordinary prebake. The whole surface was UV-ozone treated and annealed.
The wrinkles are oriented perpendicular to the imprinted edges (a) within large structures, only. The wrinkle period is highly regular (b). Small structures do not show any wrinkling (c).
Masked UV-ozone treatment in combination with nanoimprint may offer further flexibility for providing self-forming patterns in specific locations, only.