Nanoimprint-induced orientation of localized wrinkles with SU-8

C. Steinberg, M. Runkel, M. Papenheim, S. Wang, A. Mayer, H.-C. Scheer
Microstructure Engineering, University of Wuppertal, 42119 Wuppertal, D
c.steinberg@uni-wuppertal.de

Controlled wrinkling has attracted increasing interest[1,2] with respect to applications e.g. for optics, for bioengineering, as device templates or for stretchable electronics[3]. PDMS[4] (poly-dimethylsiloxane), where a thin metal layer is deposited on top of the stretched or heated substrate, has been well studied. Wrinkling occurs upon substrate relaxation or cool-down. It was also shown that metal deposition can be replaced by an UV-ozone treatment[5] of the PDMS surface resulting in a thin hardened top layer of SiO_x. Previous work has already shown that this concept can successfully be applied with SU-8, a chemically amplified negative tone photoresist[6].

The procedure for confining the wrinkles to a pre-defined area is shown in Figure 1. After spin-coating the SU-8 layer is exposed in a mask aligner, where the mask pattern defines the wrinkling area. Subsequent flood exposure with an excimer lamp (VUV, λ = 172 nm) provides a thin, hard and cross-linked top layer during the post exposure bake, resulting in the formation of wrinkles in the previously masked (unexposed) areas.

We found that UV-lithography (UV-L) is suited to confine the wrinkling to well-defined areas, but less suited to align the wrinkles. Our idea is to apply a pre-pattern with geometries well below the wrinkling wavelength to realize the alignment.

The current study focuses on the impact of the type of pre-pattern on the wrinkling, within the well-defined areas induced by UV-L. The investigation shows that the pre-pattern has two different effects, i) it may induce alignment of the wrinkles and ii) it may induce anisotropy to the wrinkles. Figure 2 shows both effects, anisotropy and alignment, Figure 3 the effect of alignment, only. We discuss the correlation between the type of pre-pattern and the layer thickness of SU-8 with anisotropy and alignment. The experimental results will be substantiated by theoretical considerations.

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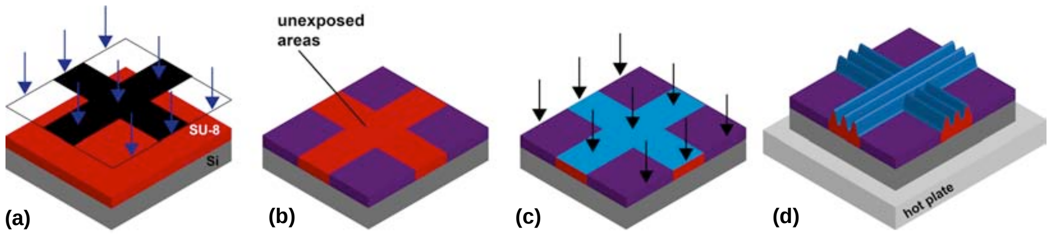

Figure 1: Processing sequence. (a),(b) Masked UV-exposure of SU-8 negative tone photoresist; (c) surface-near flood exposure by VUV (172 nm); (d) post exposure bake (1 min, 160°C); wrinkles develop within the areas not exposed during UV-exposure, where only a hard skin exists. (sketch (d) does not give a true picture of the wrinkles, only an indication.)

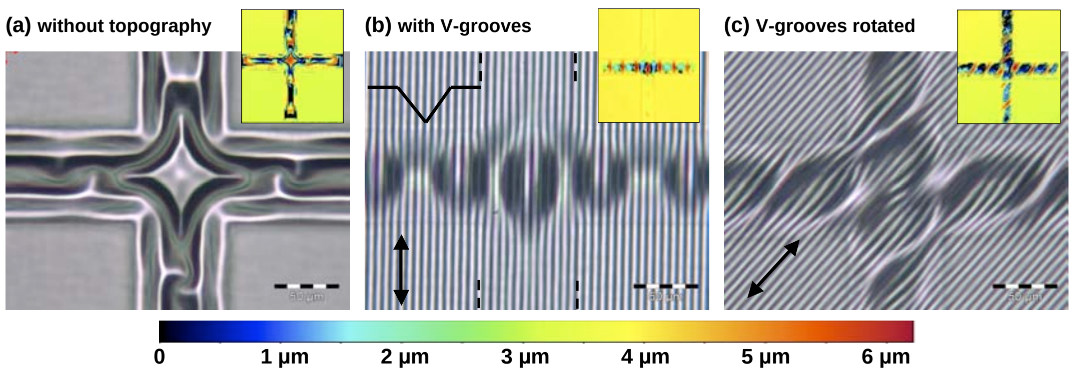

Figure 2: Control of wrinkling direction and anisotropy by use of V-groove topography (2.5 µm wide, 55°). Masked area: crossed lines (75 µm wide, 500 µm long), VUV-exposure: 3 min, example with 5 µm SU-8. Without topographical pre-pattern (a) and with a pre-pattern oriented parallel (b) and rotated (c) with respect to the mask edges. The orientation of the topography controls the direction and intensity of wrinkling.

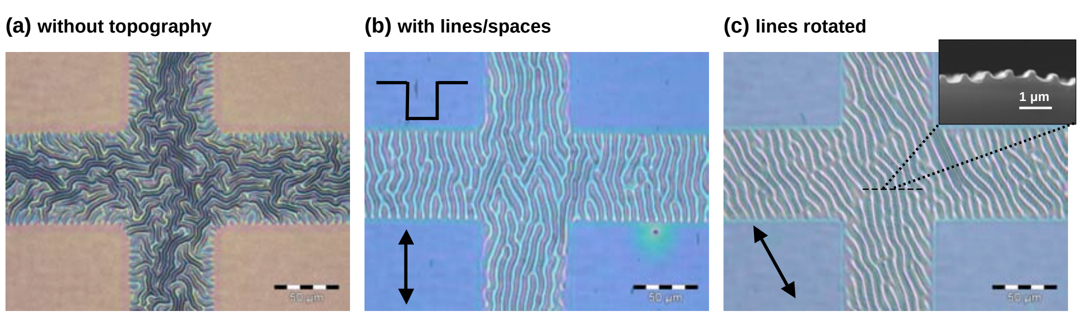

Figure 3: Control of wrinkling direction by use of lines topography (300/600 nm, 200 nm high). Masked area: crossed lines (75 µm wide, 500 µm long), VUV-exposure: 5 s, example with 300 nm SU-8. Without topographical pre-pattern (a) and with a pre-pattern oriented parallel (b) and rotated (c) to the mask edges. The orientation of the topography controls the direction of wrinkling, only.