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One-step fabrication of hierarchical structures

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Introduction

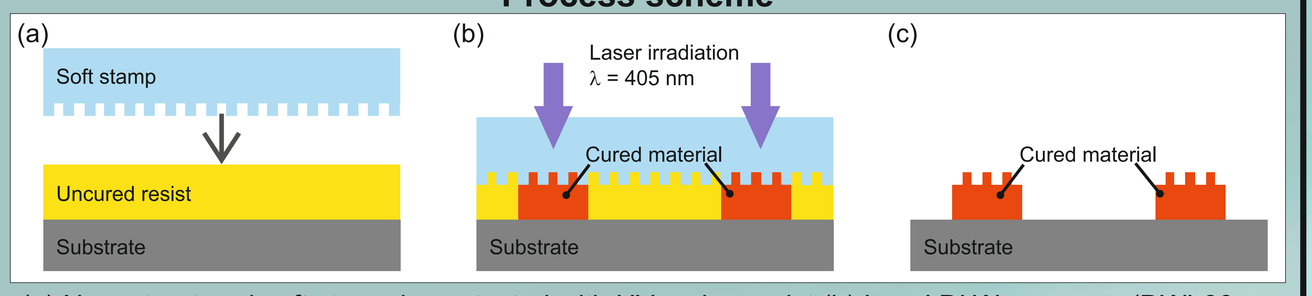
A combined fabrication of micro- and nanopatterns is required in several application fields, such as:

- Working molds for seamless „Step & Flash“-NIL
- Photonic and microfluidic applications [1,2]
- Hydrophobic surfaces (e.g. „Gecko“ structures)

We present a novel approach based on the combination of direct laser writing (DLW) and soft lithography molds [3].

The process is combining the high resolution of soft lithography with the high freedom of design of DLW.

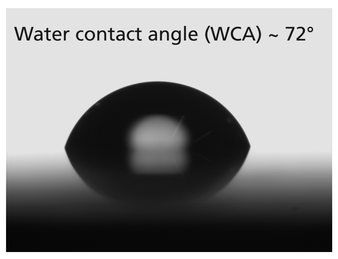
Process scheme



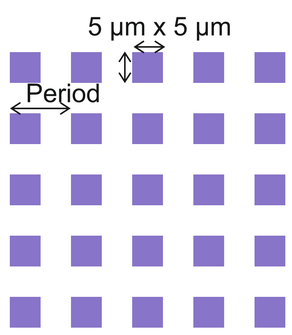
(a) Nanostructured soft stamp is contacted with UV curing resist (b) Local DLW exposure (DWL66+ Heidelberg Instr.) of resist through the stamp. Laser power and number of writing cycles are adaptable. (c) Remaining hierarchical structures after development step.

Hydrophobic structures

Unstructured hybrid polymer



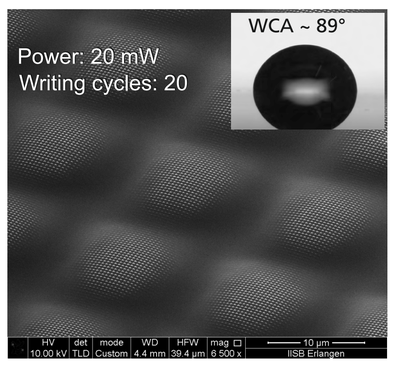
DLW pattern



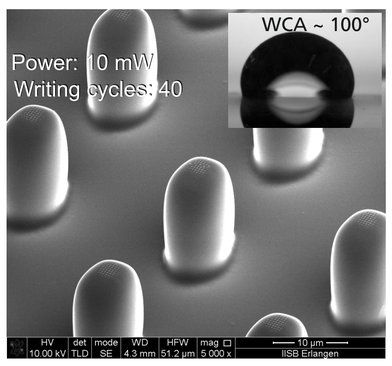
Pattern layout for DLW test structures. Squares of 5 µm x 5 µm were written with varying exposure parameters.

Structured hybrid polymer

Period: 10 µm



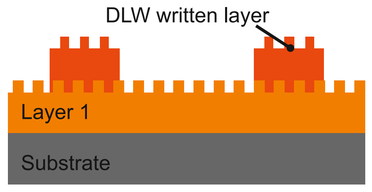
Period: 20 µm



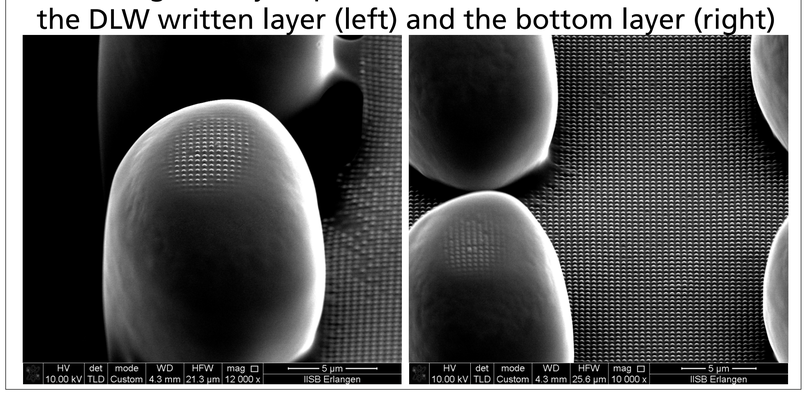
SEM images of DLW written microstructures in OrmoComp®. The applied soft stamp contains nanopillars. Water contact angles were determined for different exposure strategies. Images were taken under an angle of 52°.

Structured hybrid polymer on pre-structured surface

Adapted process scheme with a nanostructured intermediate layer

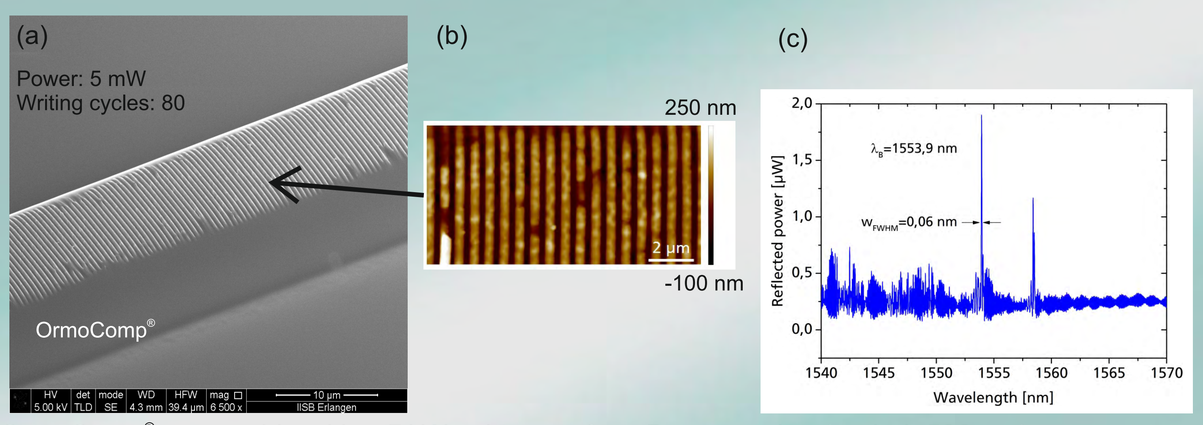


SEM images of hydrophobic structures with the focus on the DLW written layer (left) and the bottom layer (right)



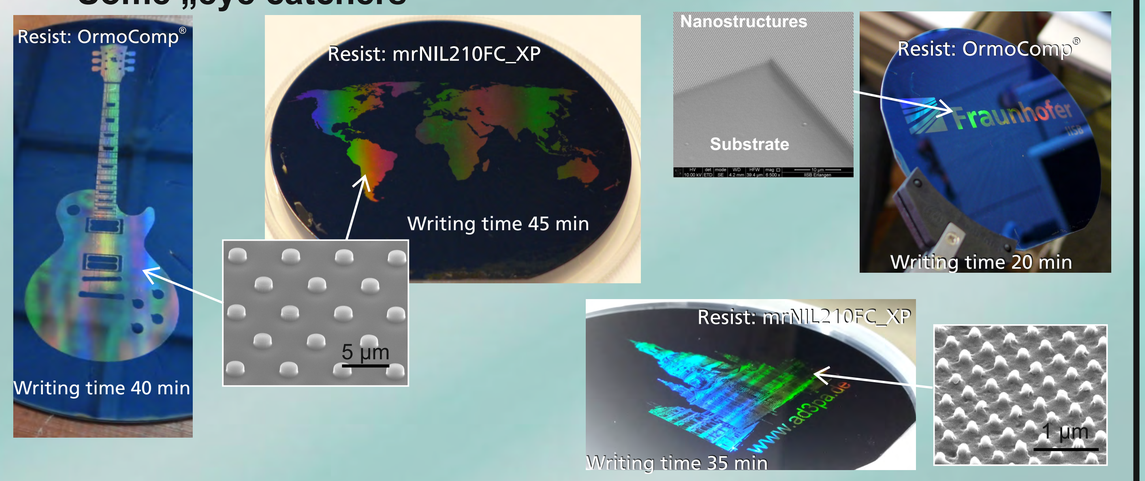
UV-SCIL imprint with nano-structured mold is performed on full wafer ahead of the DLW process, leading to the sketched topography (also see SEM images) and a strongly increased WCA.

Bragg gratings



OrmoComp®-waveguide with a DLW written surface Bragg grating (period: 530 nm). (a) SEM image (tilt angle 52°) (b) AFM image of the grating topography. (c) Reflection spectrum of a DLW written surface relief Bragg grating, with a narrow-banded Bragg peak at λ=1553.9nm.

Some „eye catchers“



Camera and SEM images of 100 mm wafers showing the variety and flexibility of structuring, in order to give an idea of process times and process area.

Summary and Outlook

Hydrophobic structures:

- Geometrical and DLW parameters influence the water contact angle
- Reduction of proximity effects with increasing structure pitch
- Pre-structured substrates further increase the hydrophobicity

Bragg gratings:

- A functional sensor with hierarchical structures was successfully fabricated

Next steps:

- Combination of nanostructures from different molds on one substrate
- Replication of hierarchical structures with PDMS
- Further alternative materials to OrmoComp®
- Optimization of process parameters for fully vertical micro pillars

[1] Liao, Y. et al., Lab Chip 12, 746-9 (2012).
[2] Warren-Smith, S. C., Opt. Express 24, 378-87 (2016)
[3] Rumler et al., Proc. SPIE 10032 (2016)

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