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Defined area polymer working stamp manufacture for S&R UV-NIL by direct laser writing

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Introduction

- Hybrid polymer working stamps for UV-NIL have become a common alternative to quartz molds [1-3]
- Defined area working stamps are of great interest for e.g. seamless step & repeat UV-NIL [3]
- Direct Laser Writing (DLW) could be an interesting option for the fabrication of the intended hybrid polymer molds (freedom of design, no mask needed)

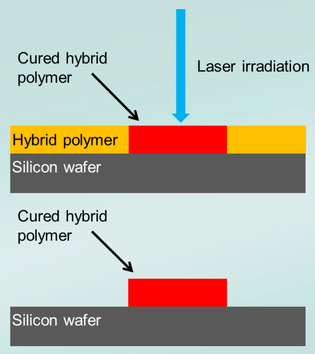
Challenges

- Identification of process window for DLW on hybrid polymers [4]
  → First exposure experiments in air, curing feasible?
- Fabrication of defined mesa-structures (sufficient height, steep sidewalls)
- Faithful replication of master structures into hybrid polymer

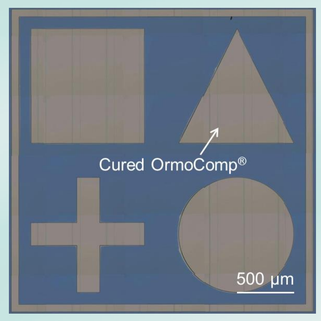
Experimental setup

- Spin-coating of hybrid polymers OrmoStamp® and OrmoComp ® @5000 rpm for 30 s
- Exposure @405 nm using Heidelberg DWL66+
- Development in OrmoDev for 2 min @RT
- Characterization using optical microscope, AFM and SEM

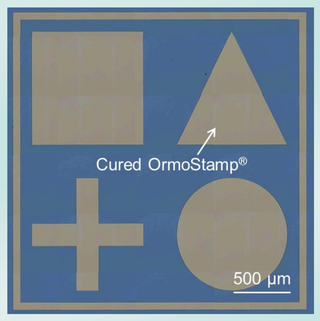
Feasibility tests in air



Process scheme

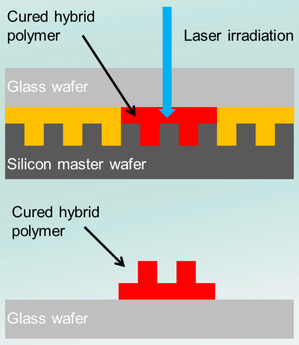


Approx. dose: 830 mJ/cm²

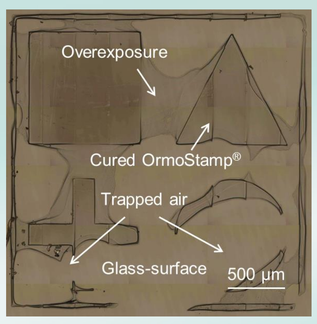


Approx. dose: 2220 mJ/cm²

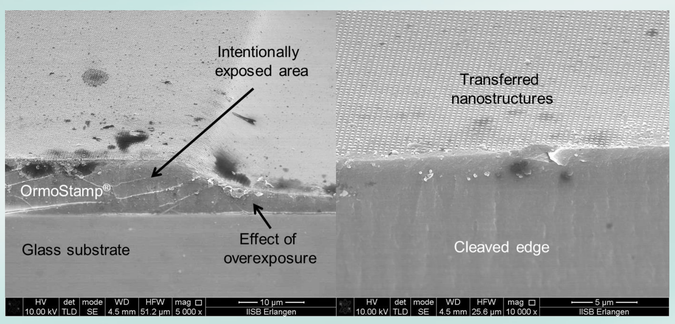
DLW Exposure under glass



Process scheme



Approx. dose: 665 mJ/cm²

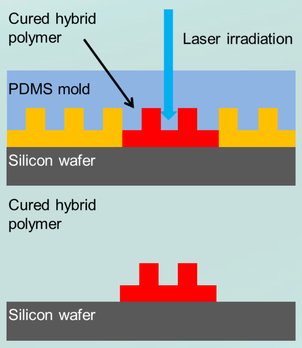


SEM cross section showing widening of OrmoStamp® mesa structure

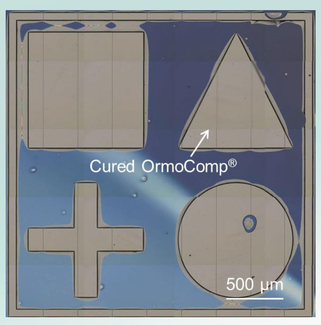
- ✓ Transfer of master structures successful
- \- Trapped air due to non-conformal contact
- \- Severe overexposure due to shift in process window compared to exposure in air
- • Enhanced polymerization due to oxygen exclusion?
- • Light scattering by master structures?

→ Use of PDMS-mold as master

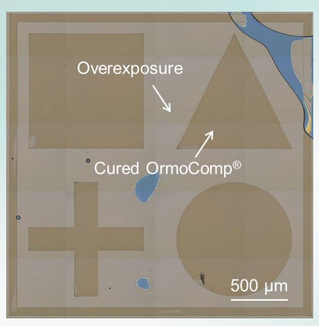
DLW Exposure under PDMS mold



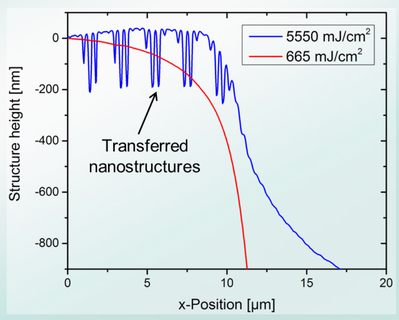
Process scheme



Approx. dose: 665 mJ/cm²



Approx. dose: 5550 mJ/cm²

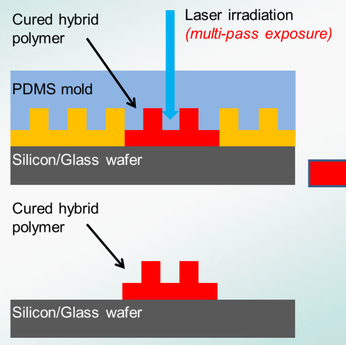


Mesa edges formed by approx. doses of 665 and 5550 mJ/cm²

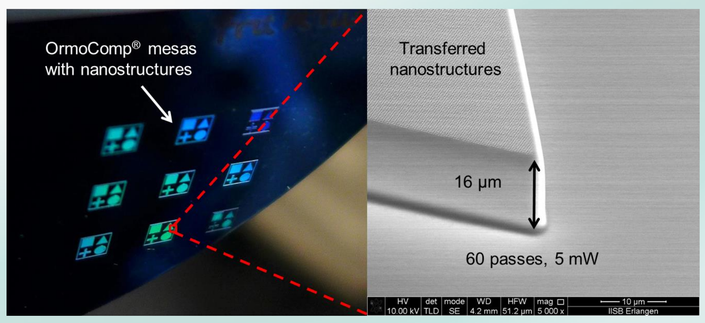
- ✓ Transfer of master structures successful
- ✓ Less air traps
- \- Problems with overexposure remain
- \- Influence of heat transfer?

→ Multi-pass exposure

Results on silicon substrate

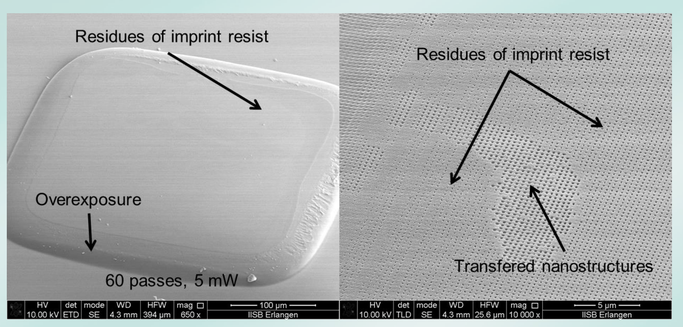


Process scheme



Photograph and SEM image of OrmoComp® mesa structures formed by multi-pass exposure, approx. dose: 10750 mJ/cm²

Results on glass substrate



SEM images of OrmoComp® mesa structure on glass substrate after failed test imprint, approx. dose: 10750 mJ/cm²

- ✓ Vertical sidewalls on Si substrate
- \- Slight overexposure on glass substrate
- \- Test imprint failed due to ASL problem

→ Further experiments on glass necessary

Conclusions

- Successful fabrication of hybrid polymer mesas containing nanostructures by DLW
- Multi-pass exposure with reduced laser power leads to vertical sidewall formation

Outlook

- Investigate influence of post exposure bake (decrease of UV dose possible?)
- Identify tolerable sidewall angle for S&R mesa structures (decrease of process time)

[1] A. Kuklowska et al., Microelectron. Eng. 4-6 (2009), 697.
[2] M. Mühlberger et al., Microelectron. Eng. 4-6 (2009), 691.
[3] A. Schleunitz et al., J. Vac. Sci. Technol. B 28 (2010) C6M37.
[4] A. Singh et al., Micromachines 5 (2014), 472.

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