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# Comparison of surface relief Bragg gratings fabricated by UV-SCIL and volume index Bragg gratings based on hybrid polymers

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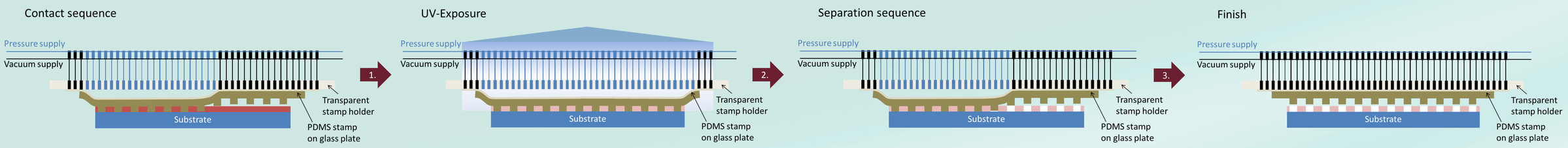
## Introduction

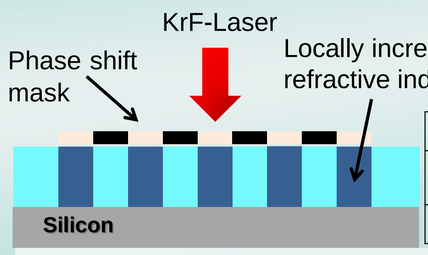
- ✓ Hybrid polymers show high potential for optical device fabrication [1].
- ✓ Viable for usage in lab-on-a-chip systems [1].
- ✓ UV-SCIL as low cost and high precision patterning technique for wafer scale solutions [2].
- ✓ Planar and surface relief Bragg gratings fabricatable in OrmoComp® by UV-SCIL.
- ✓ Planar grating type for high quality signals.
- ✓ Surface relief gratings created in silicon master by ion beam treatment for fast and flexible prototyping of specific grating periods and depths.
- ✓ Surface relief Bragg gratings enable direct structuring of optical devices including couplers, branches and sensing elements in a single step by nanoimprint.

## Scheme of the UV-SCIL-process



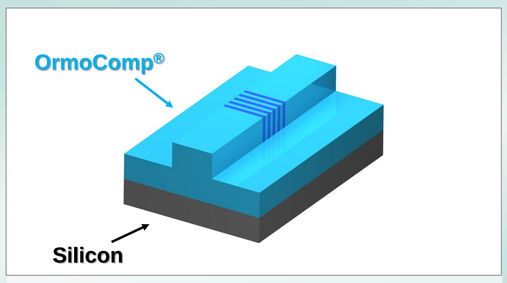

**Process flow of UV-SCIL Nanoimprint process. For both grating types a three layer hybrid stamp was used containing a X-PDMS top layer for a high aspect structure transfer.**

## Planar Bragg grating



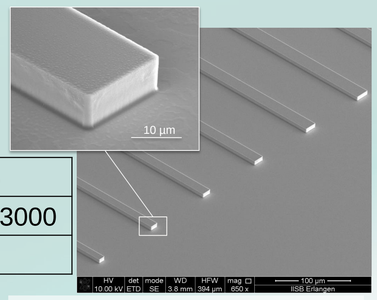

| | |
|---|---|
| Wavelength [nm] | 248 (KrF) |
| Fluence [mJ/cm²] | 16,000 |
| Mask pitch [nm] | 1036 |

**Scheme of writing process for planar Bragg grating into OrmoComp® waveguide**

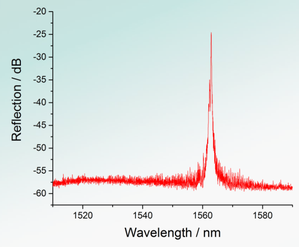



**3D-scheme of a planar Bragg grating in a rib-type waveguide**

| | |
|---|---|
| Layer thickness [µm] | 10 - 15 |
| Spin speed (90sec) [rpm] | 5000 - 3000 |
| Exposure dose [mW/cm²] | 2000 |




**SEM image of imprinted waveguides (OrmoComp®)**

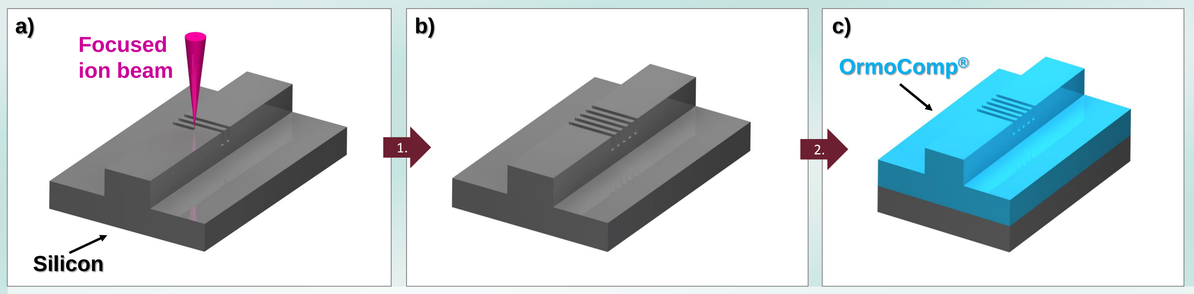



**Reflected spectrum of a Bragg grating written into OrmoComp®**

- → **Signal proves the presence of a Bragg grating written into the waveguide**
- → **Sharp signal with high S/N ratio for precise and reliable measurements.**

## Surface relief Bragg grating

### Process scheme



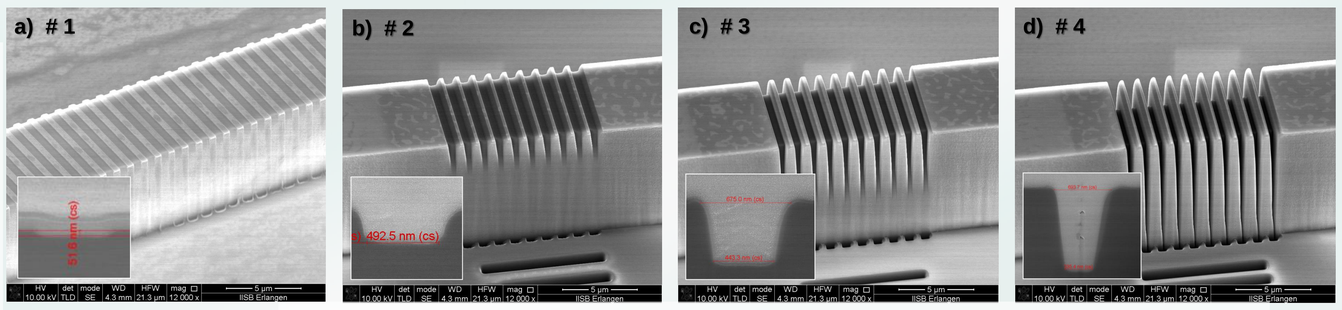

**Process scheme of the fabrication of surface relief gratings (OrmoComp®)**

**a)** FIB milling of gratings in etched silicon waveguide structures **b)** surface relief grating for stamp manufacturing **c)** transferred surface relief grating imprinted on a silicon substrate

- → **Which grating periods and aspect ratios are viable?**
- → **Capability of SCIL to transfer surface relief gratings into OrmoComp®?**

### Test pattern

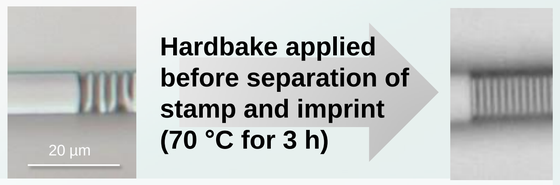
**Gratings with a pitch of 1064 nm and depths varying from 25 nm up to 2.5 µm were implemented on silicon masters using focused ion beam (FIB) milling.**




**SEM images of test patterns including cross sections shown in the inset:**
**a)** aspect ratio ~ 0.01 **b)** aspect ratio ~ 0.5 **c)** aspect ratio ~ 1 **d)** aspect ratio ~ 2

**Applied ion beam parameters**

| Pattern # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Dose [1/cm²] | 1 x 10¹⁷ | 5 x 10¹⁷ | 1 x 10¹⁸ | 2 x 10¹⁸ |
| Current [pA] | 93 | 93 | 93 | 93 |
| Aspect ratio | ~ 0.01 | ~ 0.5 | ~ 1 | ~ 2 |

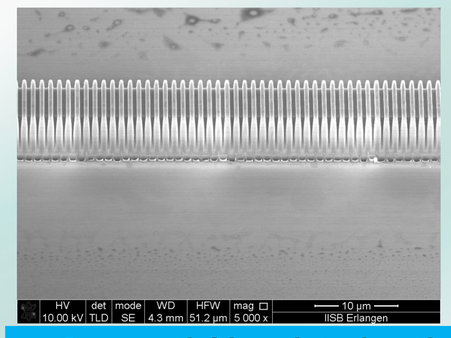



**Hardbake applied before separation of stamp and imprint (70 °C for 3 h)**

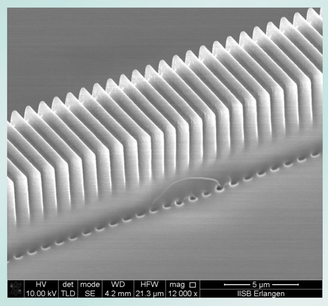
**Imprinted test patterns with and without hardbake**

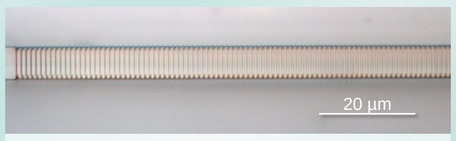
- → **Collapsing of imprinted gratings for aspect ratios > 2**
- → **Gratings stabilized by hardbake**
- → **Increased Young's modulus**

### Fabrication of Bragg gratings



**SEM image of fabricated relief gratings having pattern type # 3 and a total length of 400 µm. Manual stitching between single writing processes led to no measurable shift in the periodicity.**






**SEM (left) and optical microscope (top) image of replicated surface relief grating from pattern type # 3. No defect or structure collapse visible over the whole length.**

→ **Successful imprint of surface relief gratings with varying grating depths using UV-SCIL and OrmoComp®**

## Conclusions and Outlook

In conclusion, this work presents two concepts to produce Bragg gratings using hybrid polymers combined with UV-SCIL.

- ✓ Planar Bragg gratings: more steps needed to produce devices. Also, they are restricted to the period of the phase mask, but show a clear and high Bragg reflection.
- ✓ Surface relief Bragg gratings: are flexible in production concerning the grating period and no additional exposure step is needed after the imprint to create a device. The focused ion beam milling is connected to a high effort to achieve a sufficing length of the Bragg grating.

As an outlook, surface relief Bragg gratings will be characterized and the performance will be compared to those of planar type Bragg gratings.

## References

[1] Houbertz, R.; Domann, G.; Cronauer, C.; Schmitt, A.; Martin, H.; Park, J.-U.; Fröhlich, L.; Thin Solid Films 443 (2003) 194–200.
[2] Verschuuren, M.A.; Substrate conformal imprint lithography for nanophotonics, PhD thesis, Utrecht University, 2010.

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