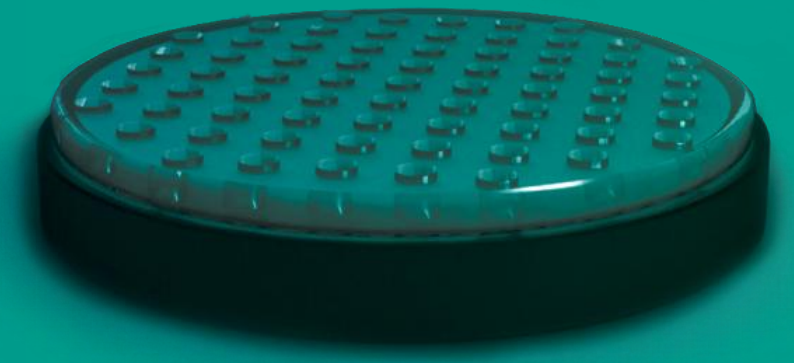
Micro-optics
SUMMIT & EXPO

SCIL
Nanoimprint solutions

High-precision nanoimprint lithography for scalable AR waveguide production



Marc Verschuuren, Gert-Jan Hurxkens

SCIL Nanoimprint Solutions

3 December. 2024

SCIL at a glance

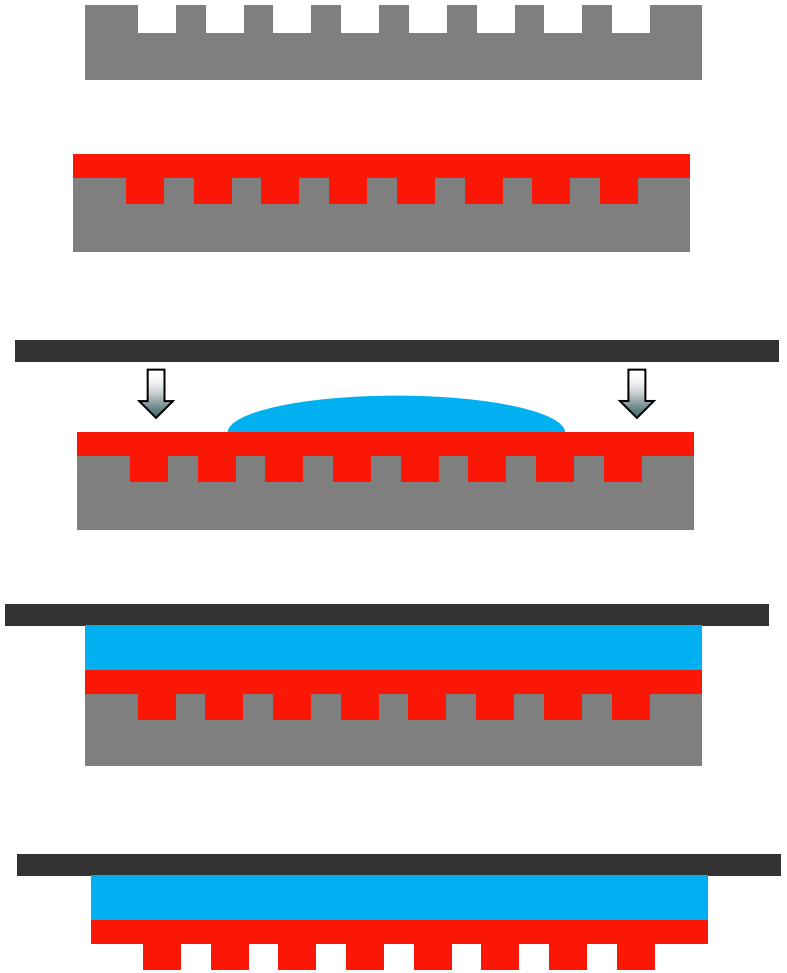
Start-up with strong financial partners

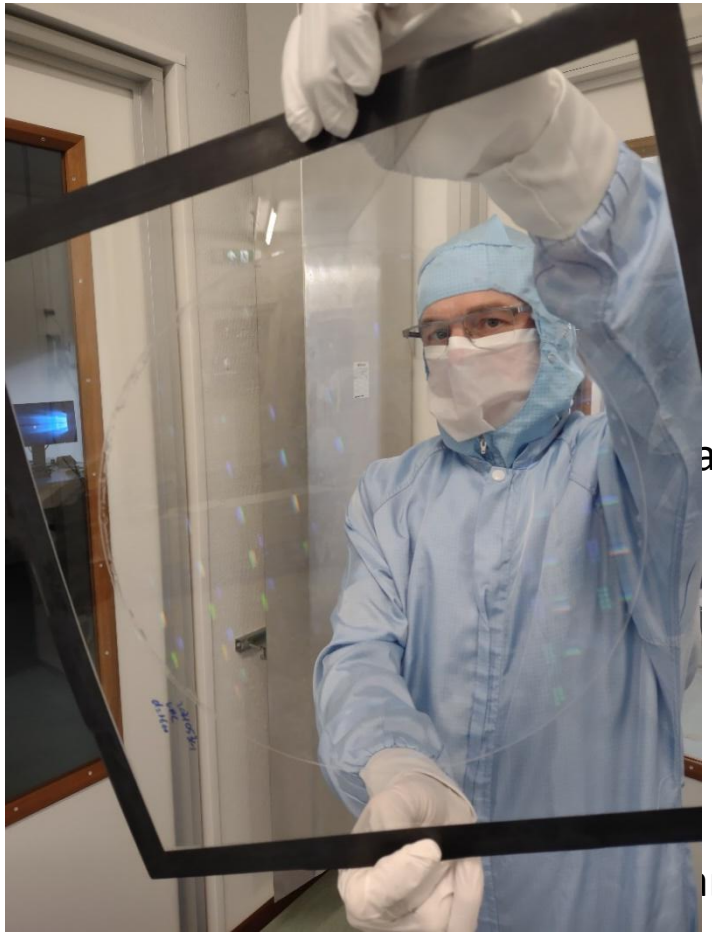
Solutions for volume production

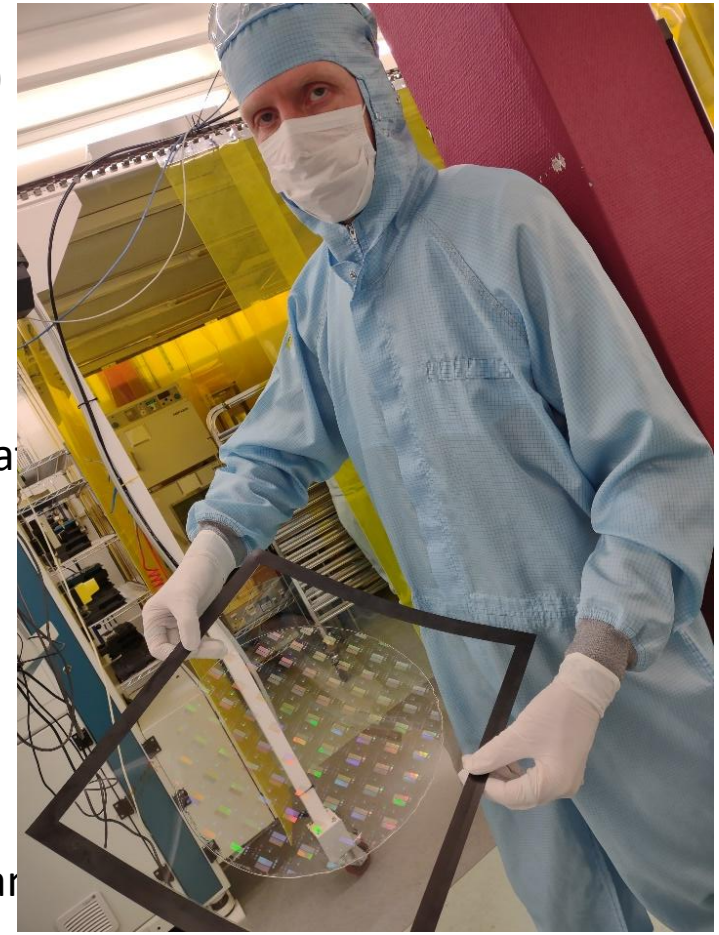
Proven world-class technology

Building customer success - Together

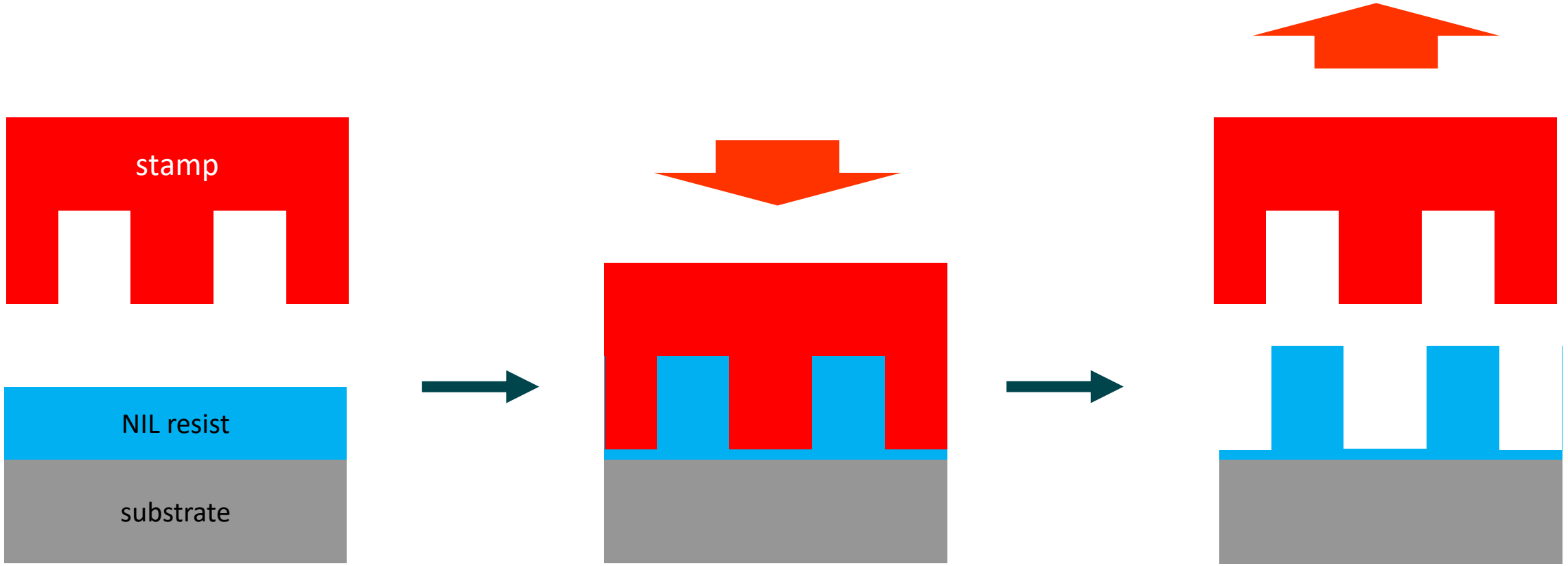
Wafer scale composite rubber stamps







Nano Imprint Lithography (NIL) method

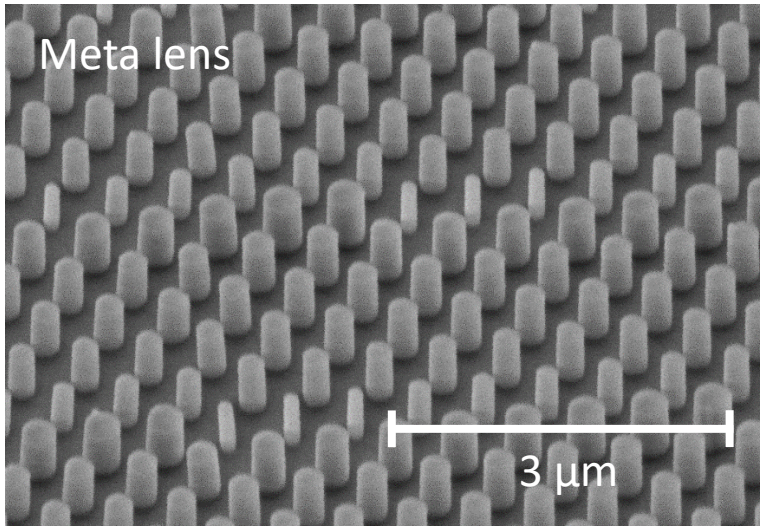


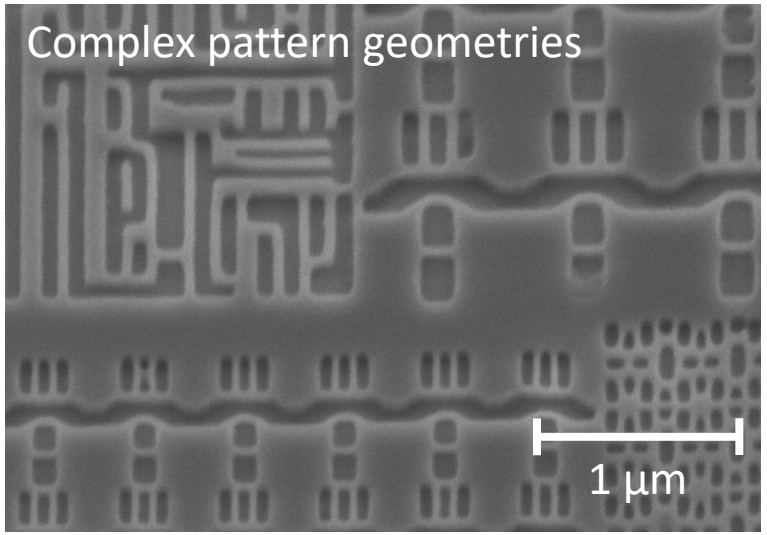
Imprint resist applied to substrate

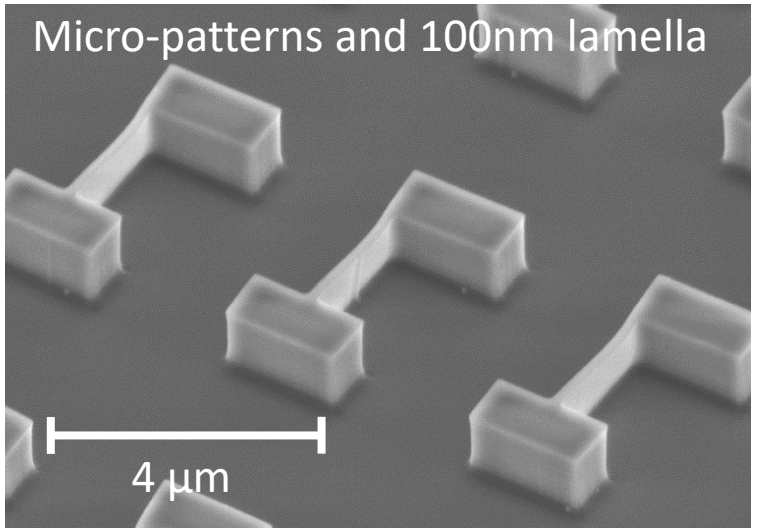
Press stamp into resist and cure

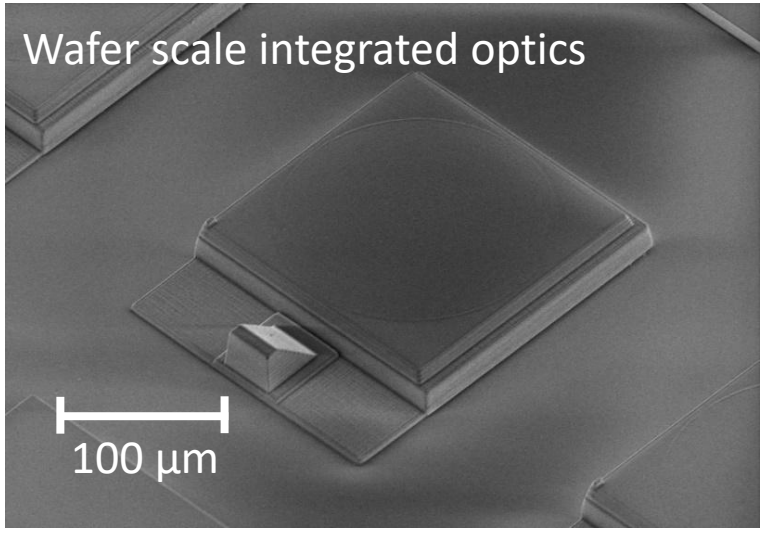
Release stamp
→ 500 imprints / stamp

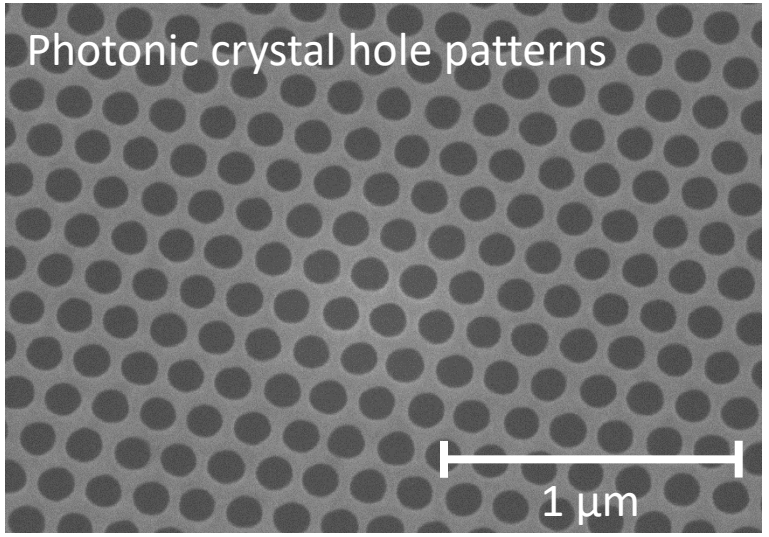
Direct replication into NanoGlass resist

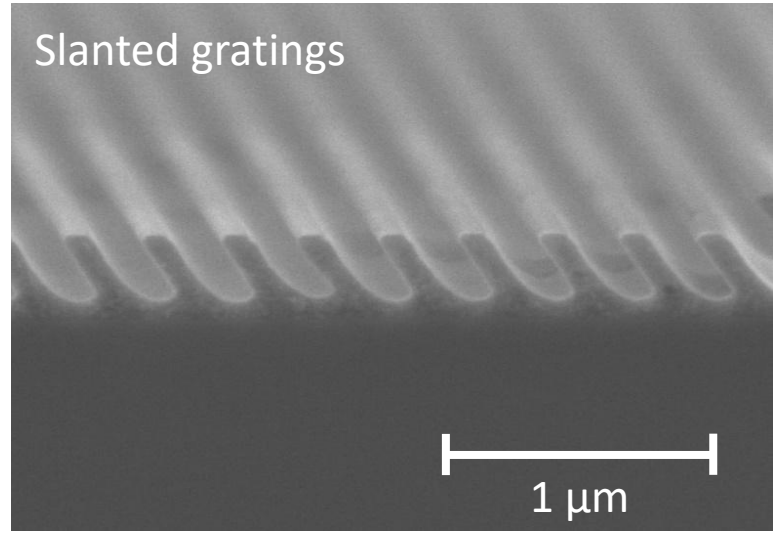












Master→ 250+ stamps→ 500+ imprints→ 120K+ product wafers

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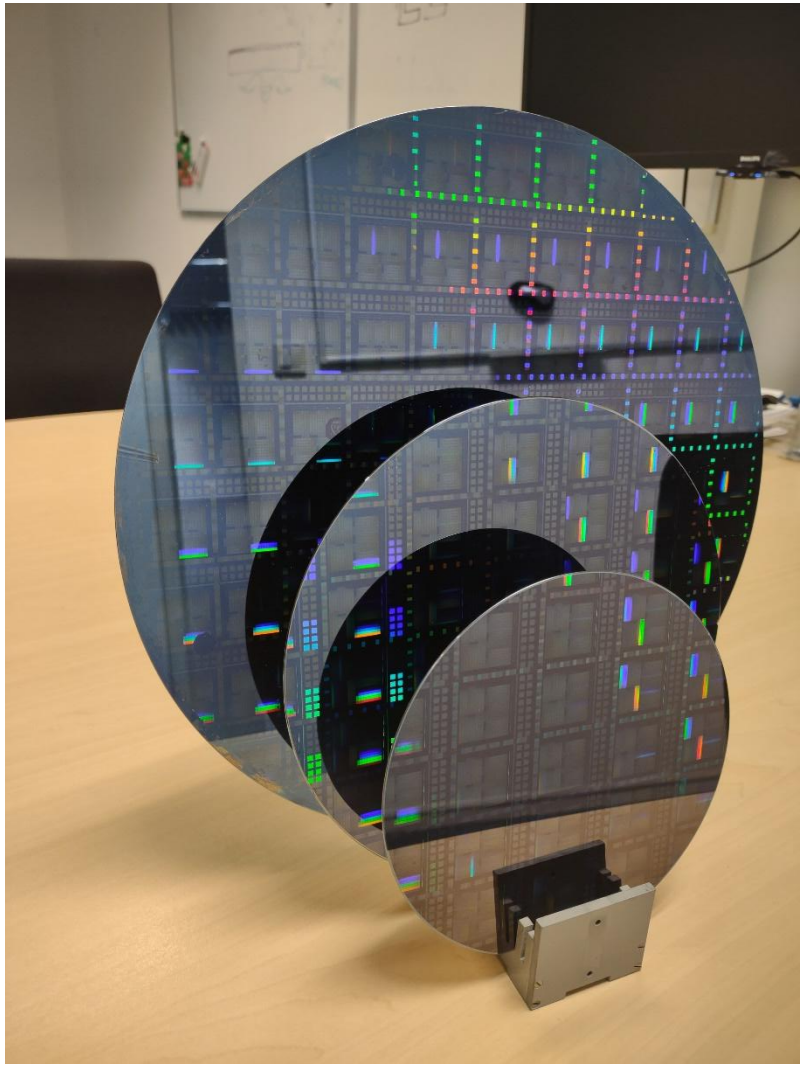
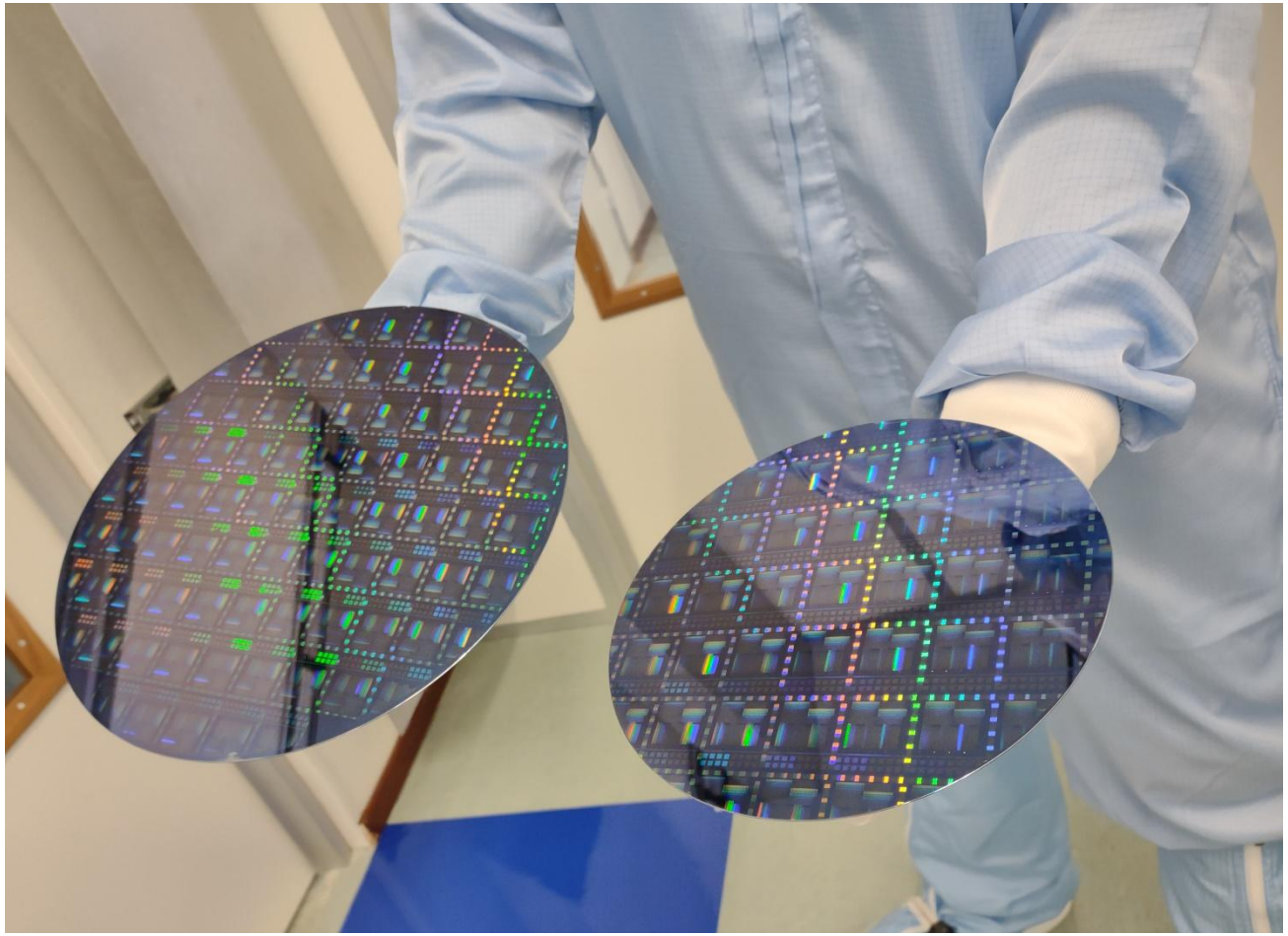




Requirements: Augmented Reality Waveguide Combiner

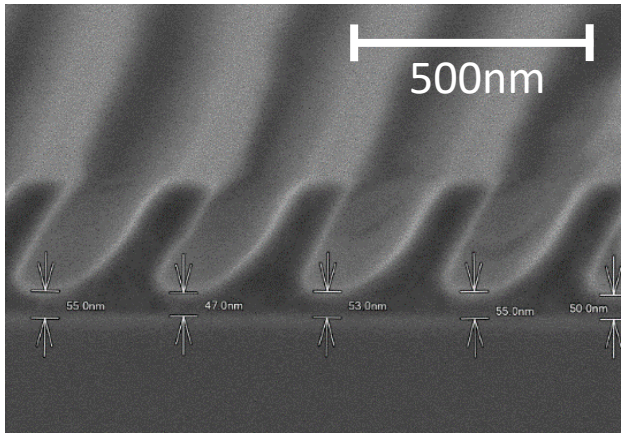
SCIL Nanoimprint solutions

Material / process

- High refractive index → Matching to high index glass for FOV & efficiency
- No primer needed → No efficiency loss (from low index adhesion layer)
- **100% inorganic** → **Device stability / lifetime (temperature + UV stability)**
- Binary- , blazed- & slanted-grating patterns → Efficiency & freedom of design
- Slanted gratings in all directions and orientations → 1 step replication & freedom of design
- No (very low) haze → Low optical loss
- **Reproducible replication with <2nm variations** → **Yield**
- Minimal residual layer thickness (RLT) → High efficiency by enhanced coupling
- X-PDMS stamps have shown >300 full wafer slanted → No release layer required, no plastic deformation imprints

Device geometry

- Processing on thin wafers → light weight / user comfort
- **Double sided aligned processing** → **Efficiency, FOV, low weight**



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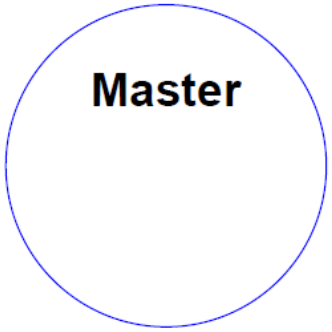
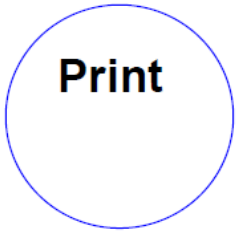
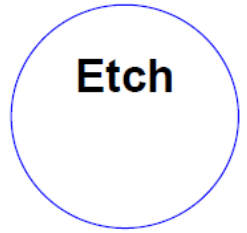
Master Replication with Precision

MOXTEK



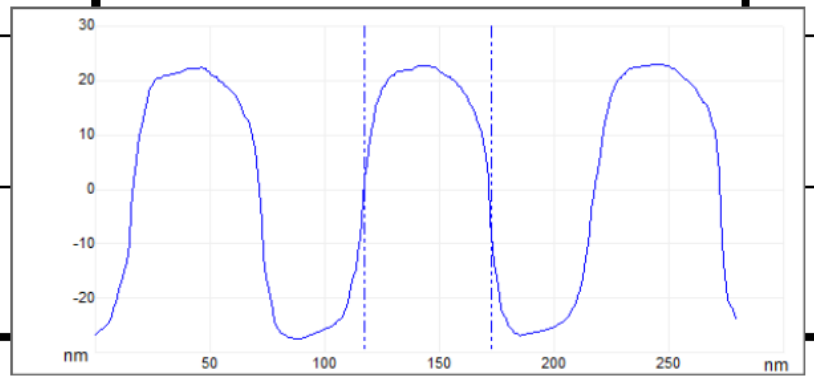


Post Etch CD Bias is etch process dependent



CD Data in nm

$\bar{x}$	47.64	45.19
σ	2.19	1.12
n	13	229



$\bar{x}$	53.94
σ	2.07
n	15

Test pattern imprint in n=1.88 (@550nm)

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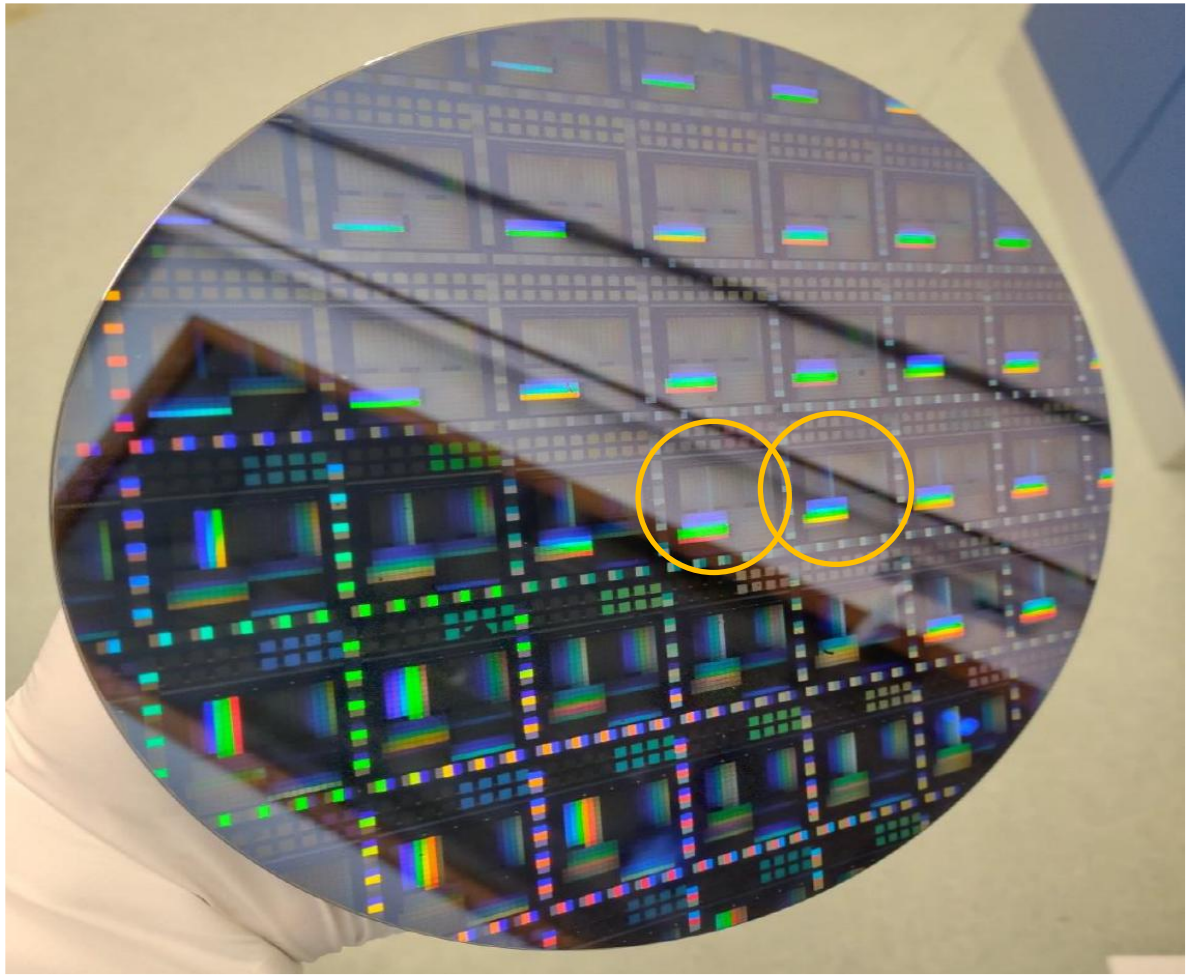
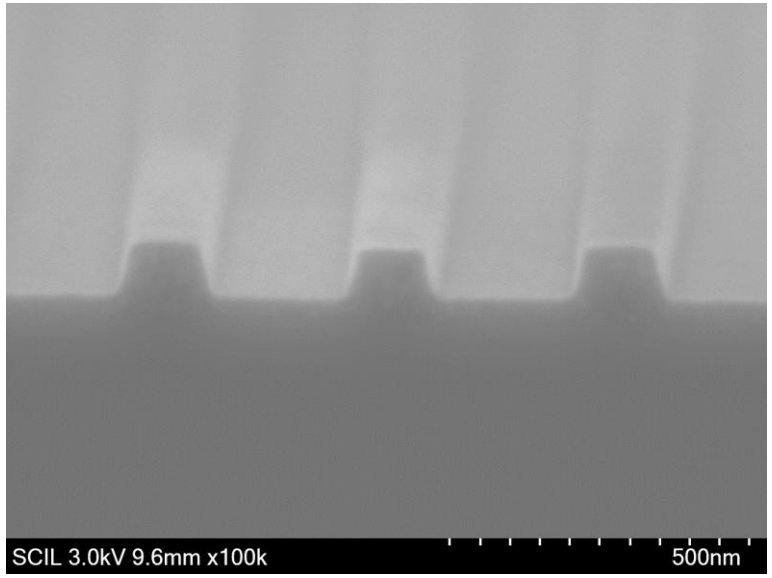
TeraNova

- Demonstrated >100 imprints with one stamp





Comparison position 1 and 2 on the same wafer

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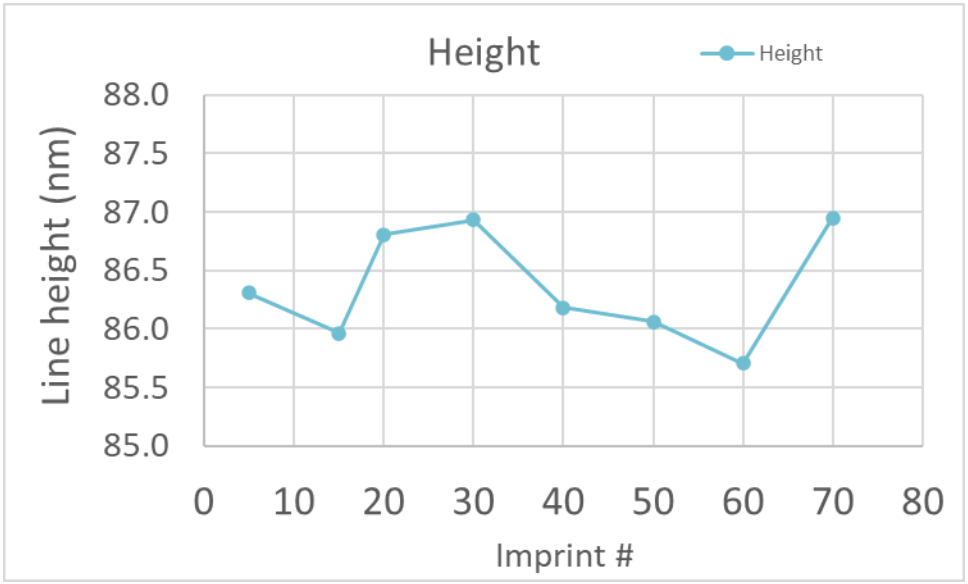
TeraNova

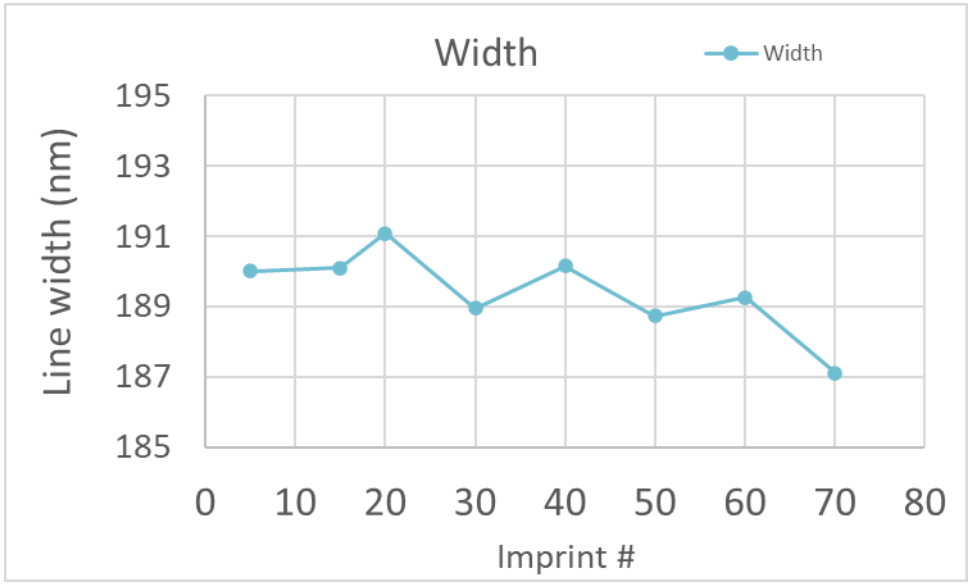
Position 1	Residual Layer	Refractive Index	Pitch	Grating Height	Duty Cycle (nm)	Side Wall Angle
Average	37,23	1,958	378,10	95,34	183,33	3,49
Std	0,20	0,005	0,60	0,68	0,67	0,04

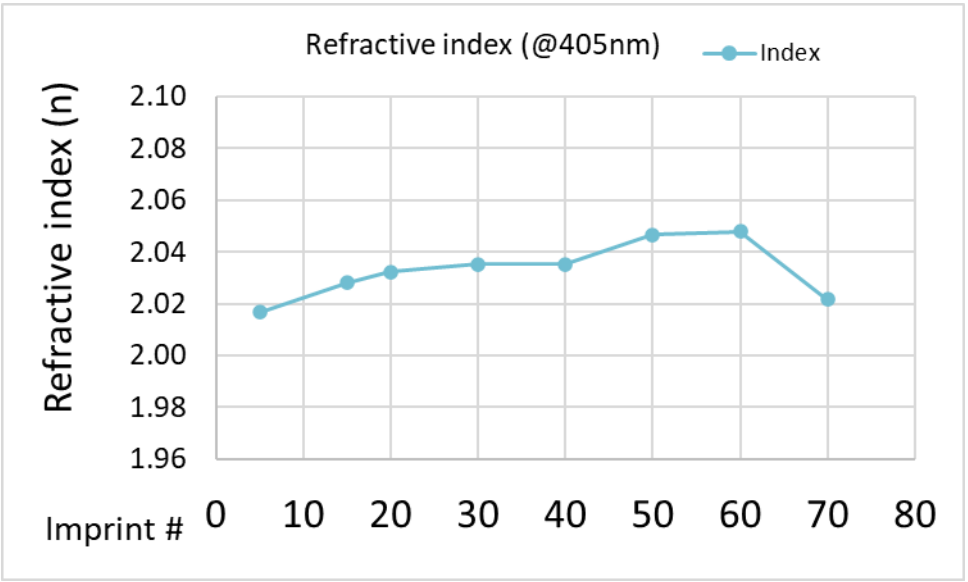
Position 2	Residual Layer	Refractive Index	Pitch	Grating Height	Duty Cycle (nm)	Side Wall Angle
Average	37,24	1,959	378,06	95,34	183,27	3,50
Std	0,15	0,004	0,48	0,57	0,55	0,04

Schematic of grating

Imprint run n=1.88 : wafer 5 through 70







Standard deviations on run:

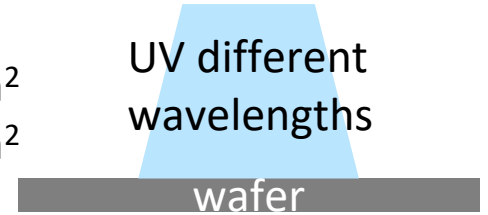
- Height: 0.44 nm (=0.5%)
- Width: 1.23 nm (=0.6%)
- Index (n) : 0.010 (=0.5%)

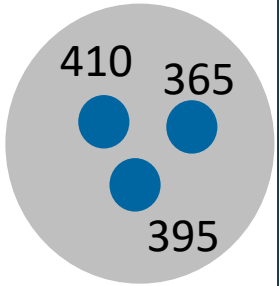
Schematic of grating

UV / light material stability – accelerated lifetime

Light intensity = ~ 5000 – 10.000x QSUN

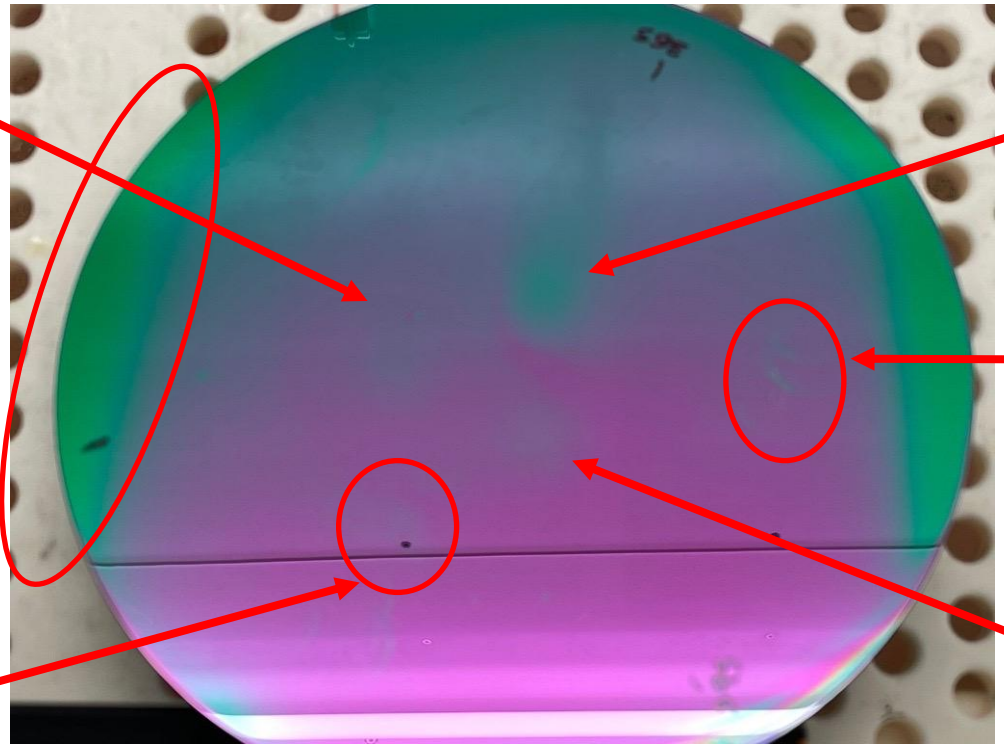
UV intensity (365) > 1 W/cm^2
UV intensity (395) ≈ 2.3 W/cm^2
UV intensity (410) ≈ 2.6 W/cm^2
Passive cooling





410nm

365nm



Changes in thickness in the edges

Device feet

Commercial mat. A.
After 1 h exposure

Device feet

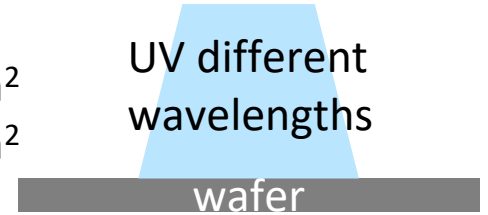
395nm

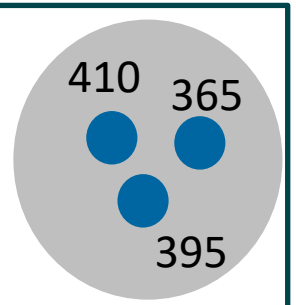
- sfs

UV / light material stability – accelerated lifetime

Light intensity = ~ 5000 – 10.000x QSUN

UV intensity (365) > 1 W/cm²
UV intensity (395) ≈ 2.3 W/cm²
UV intensity (410) ≈ 2.6 W/cm²
Passive cooling





Exposure (nm)→ 60 min ΔLT (%)	365	395	410
SCIL 1.70	-0.28	-0.43	-0.05
SCIL 1.87	-2.90	-1.18	-1.02
SCIL 1.95	-9.10	-2.94	-1.11
UV mat. A 1.9	-6.81	-4.55	-2.85
UV mat. B 1.9	-4.60	-3.82	-2.70

Layer thickness change (%)

Exposure (nm)→ 60 min ΔRI	365	395	410
SCIL 1.70	0.0027	0.0007	0.0007
SCIL 1.87	0.007	0.004	0.0017
SCIL 1.95	0.0185	0.010	0.0068
UV mat. A 1.9	0.0239	0.0176	0.0123
UV mat. B 1.9	0.032284	0.024386	0.022599

Δ refractive index (n)

- Inorganic materials show least change, by far.
- Influence of " post " anneal due to high energy input → improvements in the works

Front to backside alignment, 2 imprinted patterns

- 300mm 300µm thickness high index glass
- 300mm 800µm thickness high index glass
- 200mm 700µm thickness “normal” glass

- Stage & system has <100nm accuracy
- Sub-400nm overlay reproducibility

Front-to-Backside center wafer error

	X (µm)	Y(µm)	Rz (µRad)
Average	-1.4	-0.086	3.0
Stdev	0.23	0.077	0.45

	X(µm)	Y(µm)	Rz(µRad)
Average	-1.4	-0.38	2.7
Stdev.	0.37	0.13	0.84

	X(µm)	Y(µm)	Rz(µRad)
Average	-2.6	-0.099	2.2
Stdev.	0.17	0.13	0.53

Overlay results 300mm wafers Front-to-Back alignment
Imprint glass wafer→ flip wafer → directly align to backside → imprint

From R&D to HVM – tools, materials, process

LabSCIL

- R&D
- 100, 150 and 200mm wafers

AutoSCIL

- Integrated tool
- 100, 150 and 200mm wafers

FabSCIL

- Cluster design, freely confinable
- 150, 200 and 300mm wafers

All tools capable of:

- Automatic (double side) overlay alignment
- Proprietary SCIL imprint process (seamless scaling)

SCIL

Nanoimprint solutions

Cooperative way of working

Design → Qualify → Build → Volume production

- Structure design
- Mastering
- Material
- Manufactu-ring process

- Sample runs
- Testing
- Modify
- Pilot runs

- Imprint tools
- Stamp making tools
- Automation
- Deposition & etching

- Installation & start-up
- Material supply
- Process support
- Service

SCIL Application Development Center