SPIE AR/VR/MR 2022

SCIL Production Solutions
Turning your surfaces into functions

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TeraNova

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SCIL booth: 210

SCIL
Nanoimprint solutions

Contents

- SCIL: our nanoimprint solution
- 300mm platform
- Functional optical materials for nano-photonic applications
- Quality control for nanophotonic applications
- Conclusions

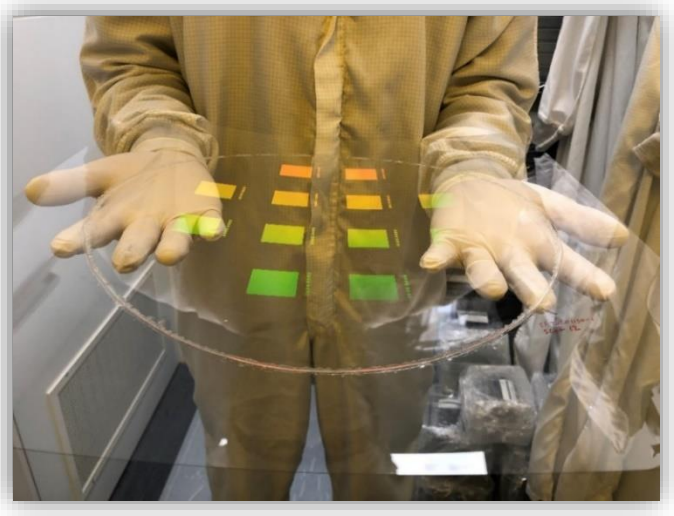
Substrate Conformal Imprint Lithography

The only wafer scale conformal imprint technology

Substrate Conformal Imprint Lithography

The only wafer scale conformal imprint technology

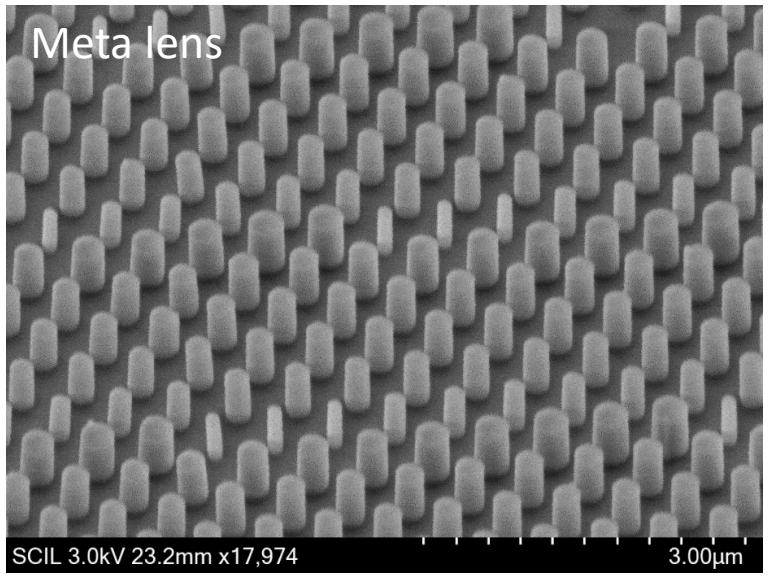
- SCIL Nanoimprint solutions **for wafer scale nano-patterning**
- Customer specific SCIL processes + ramp up to volume production
- Fully tuned imprint process (resist, stamp)

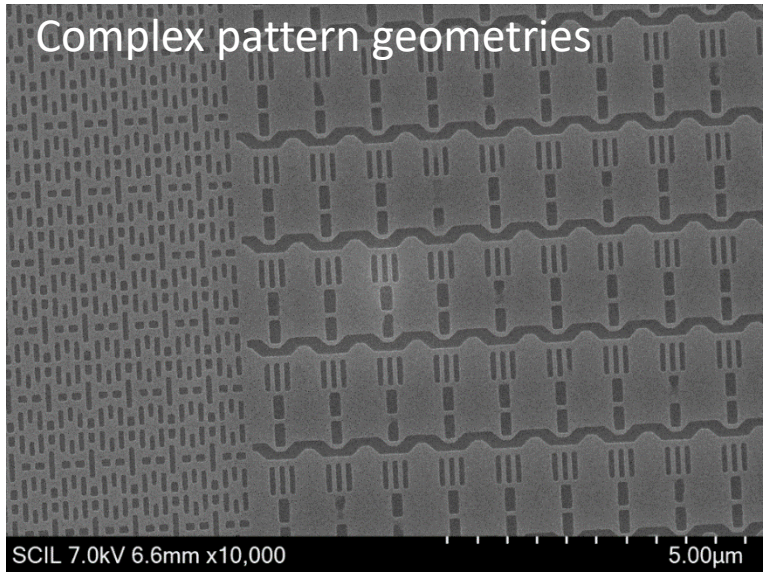


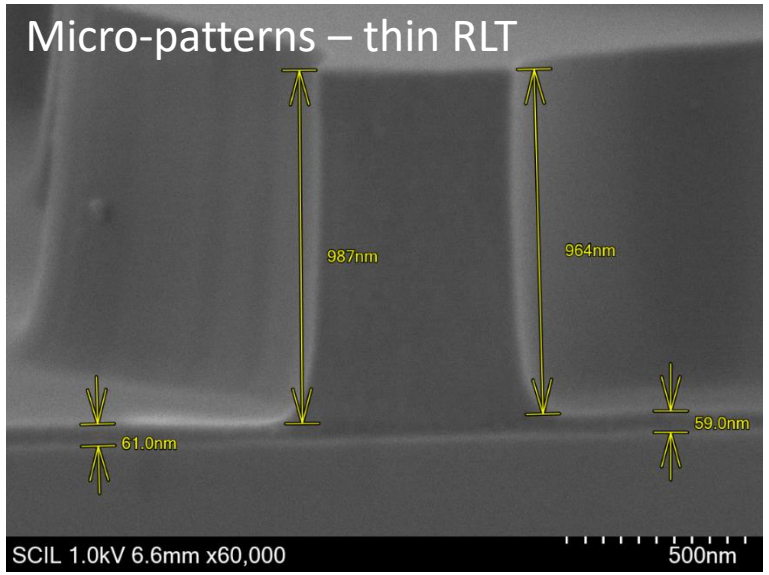
- Full inorganic imprint resist (NanoGlass®)
- X-PDMS hard rubber, flexible on the micro-scale
  - Sub-6nm resolution
- Industry leading stamp lifetime: 500+
- Resist options: open to industry available

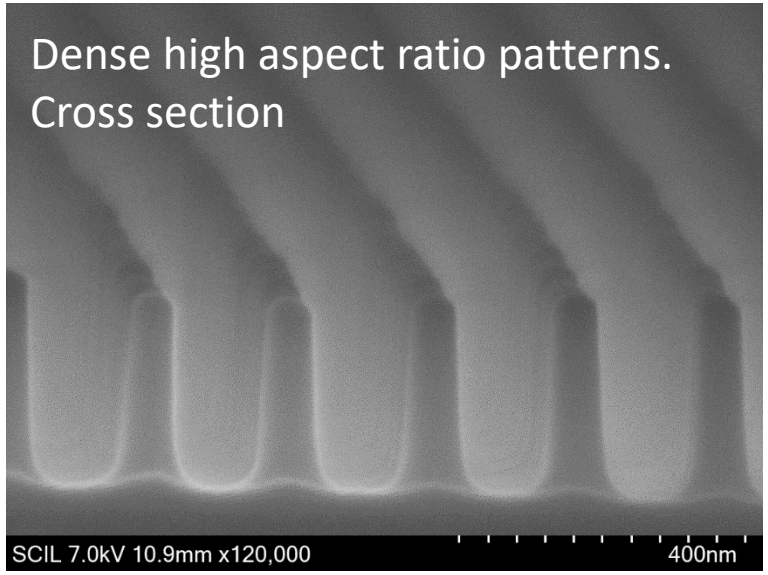
SCIL Nanoimprint solutions

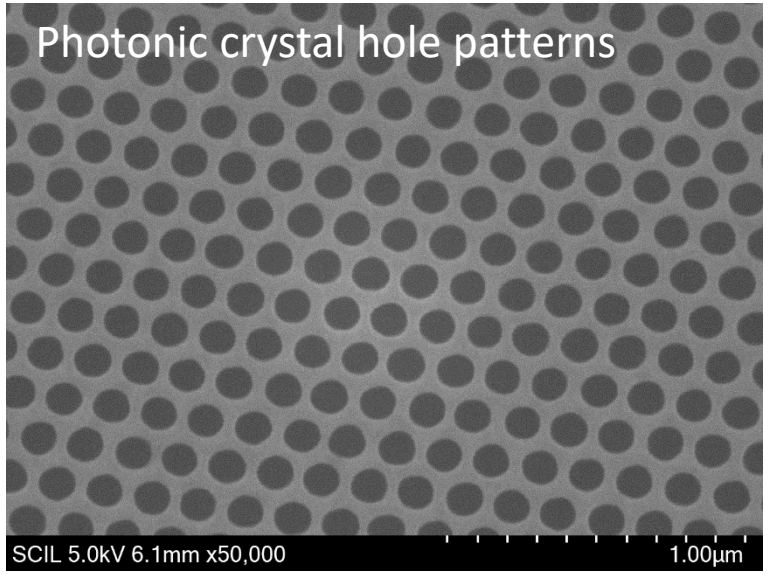
Variety of patterns, direct replication into NanoGlass resist

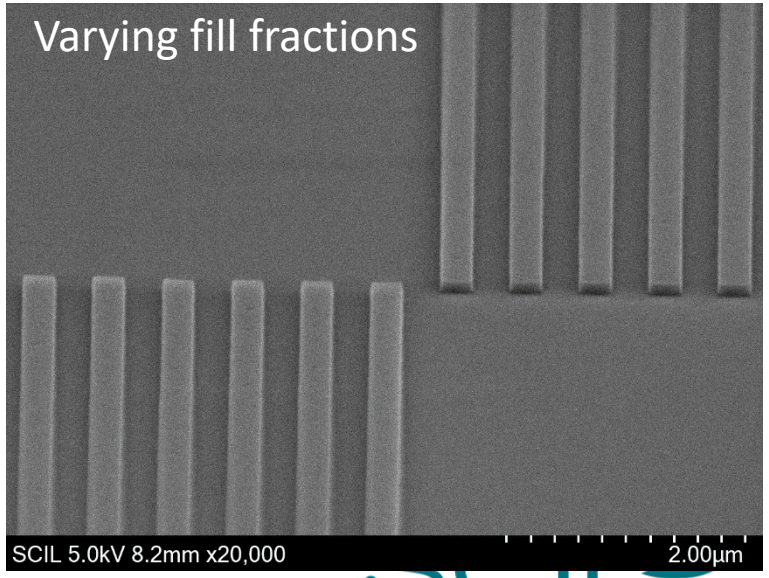




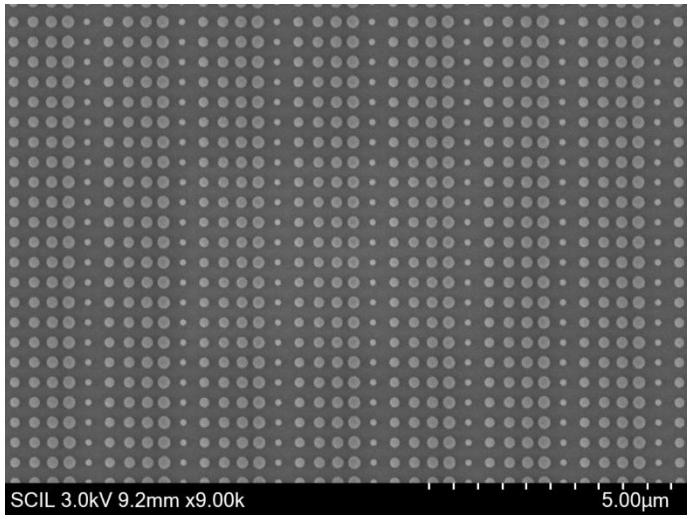


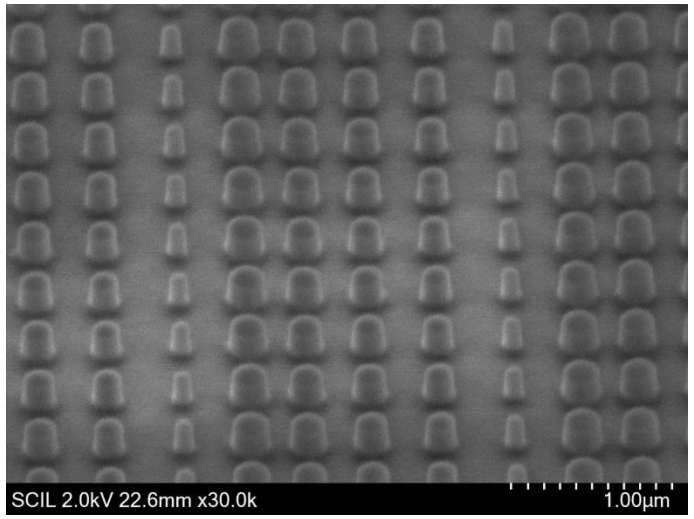


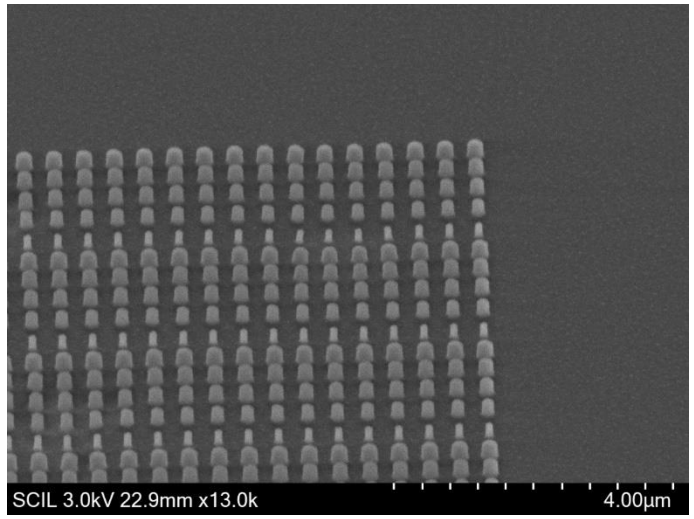


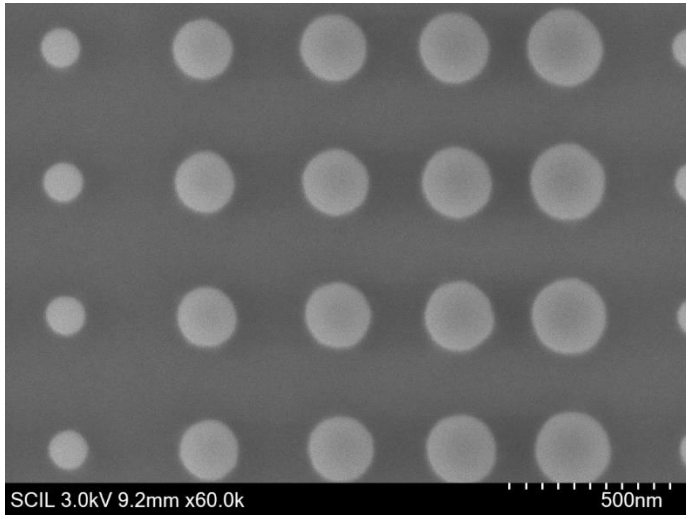


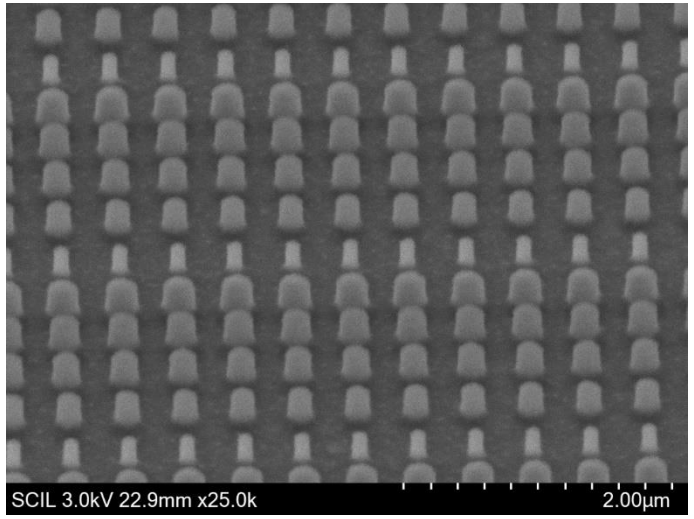
Meta-lens wafer scale test patterns – 1D lensing

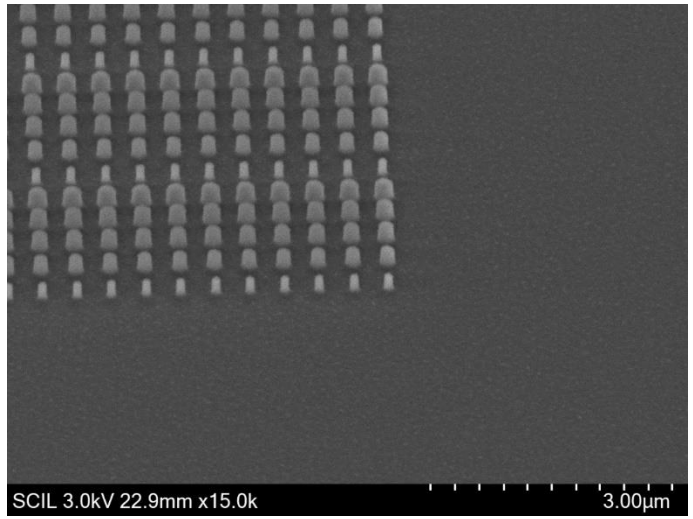












SCIL Nanoimprint solutions

SCIL nanoimprint tooling, from pilot to fab-integrated

LabSCIL

- Full SCIL functionality incl. overlay
- 100, 150 and 200mm wafers
- (Double side) overlay alignment

AutoSCIL

- Integrated tool: centering, coating, overlay, imprint, post-bake
- 100, 150 and 200mm wafers
- Automatic overlay alignment
- (Double side) overlay alignment

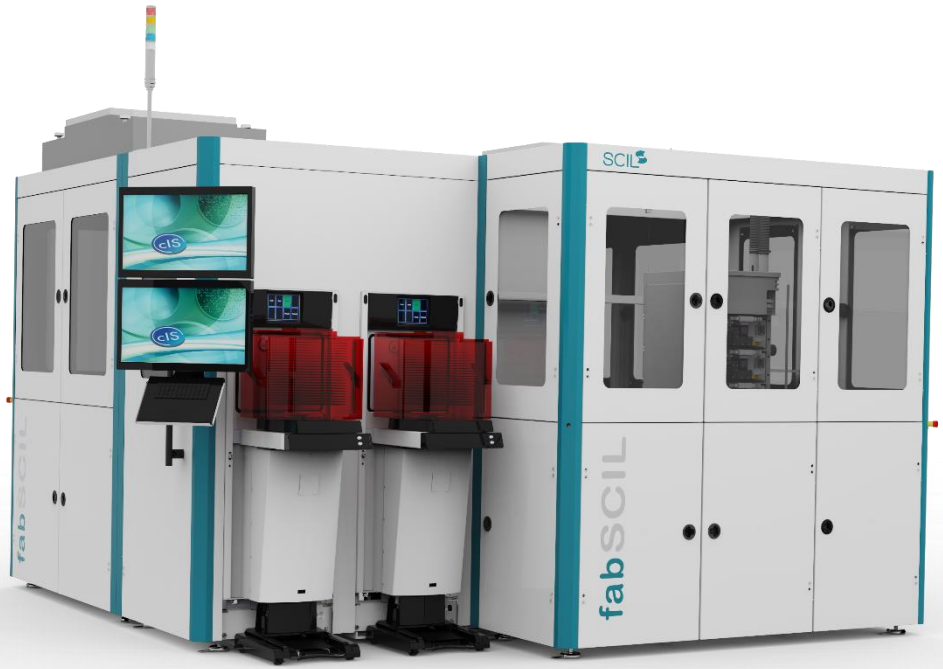
FabSCIL

- Cluster design, freely confinable
- 200 and 300mm wafers
- Automatic overlay alignment
- (Double side) overlay alignment

SCIL Nanoimprint solutions

FabSCIL system - Cluster tool with 2 FabSCIL modules

Multiple configurations possible



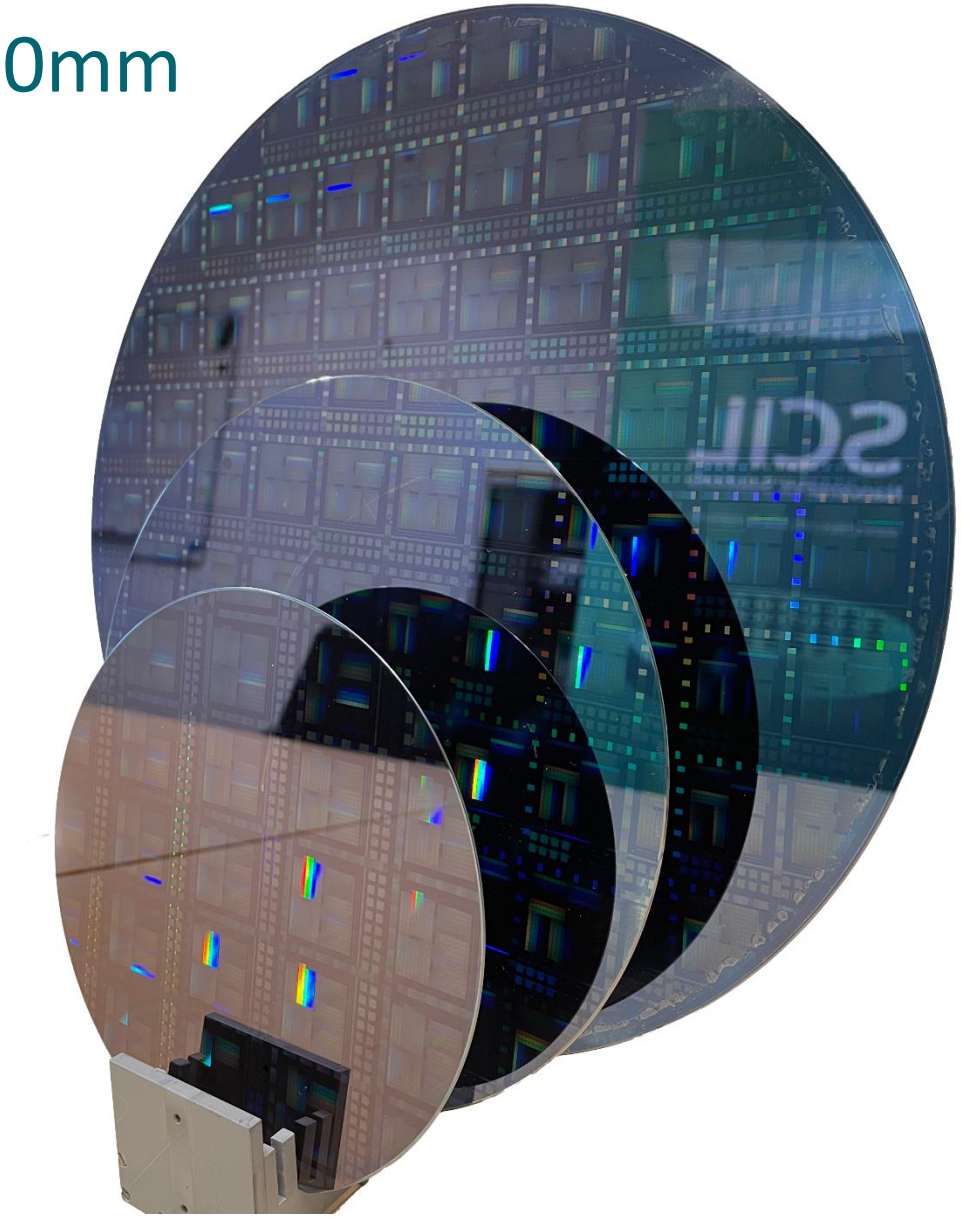
Wafer size capability 100,150,200 & 300mm

AutoSCIL platform

- 100, 150, 200mm
- Overlay alignment 1 µm X,Y, rotation error < 6 µRad
- UV cure, thermodynamic cure, RT processing
- Fully automatic processing and overlay alignment
- Front-to-Front alignment and Front-to-Back(side)

FabSCIL platform

- 200mm and 300mm
- Overlay alignment 1 µm X,Y, rotation error < 5 µRad
- UV cure, thermodynamic cure, RT processing
- Fully automatic processing and overlay alignment
- Front-to-Front alignment and Front-to-Back(side)



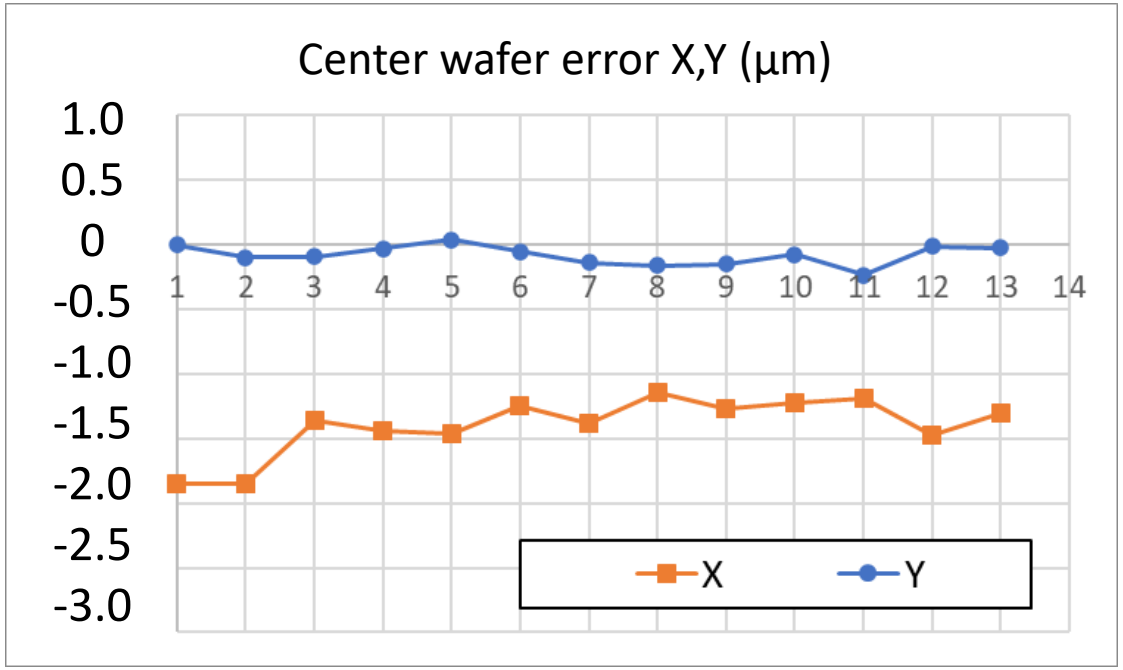
SCIL Nanoimprint solutions

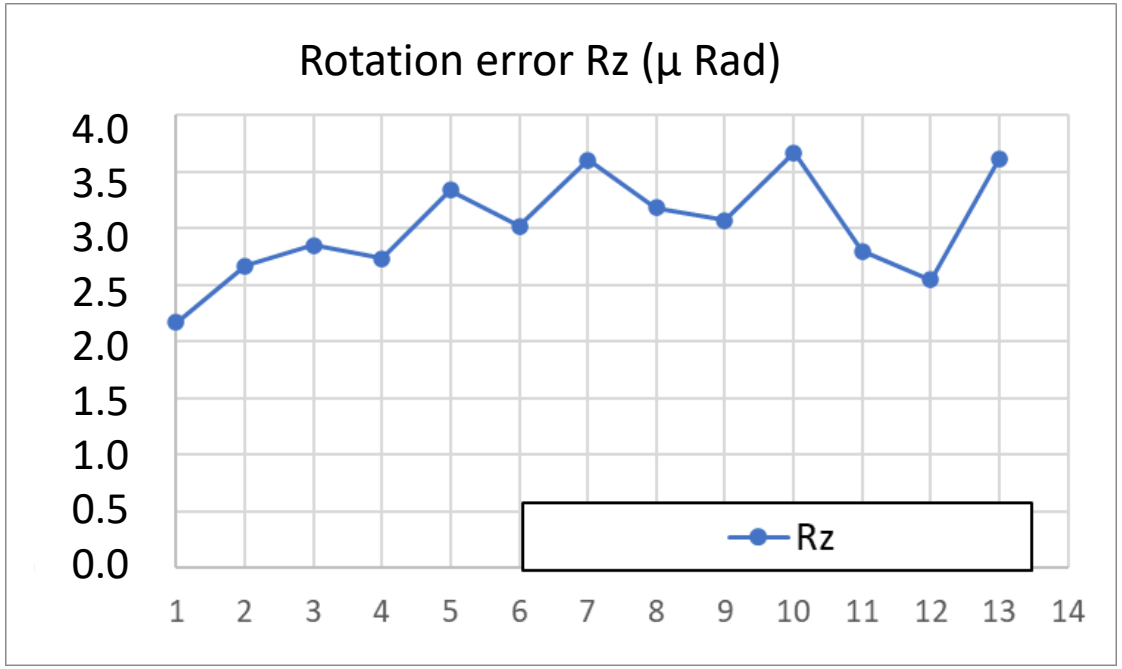
Overlay results 300mm wafers Front-to-Back alignment

Imprint glass wafer, flip, rotate 45°, align to backside, imprint

- No offset corrections used in these runs
- 300mm **300mu** thickness high index glass

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





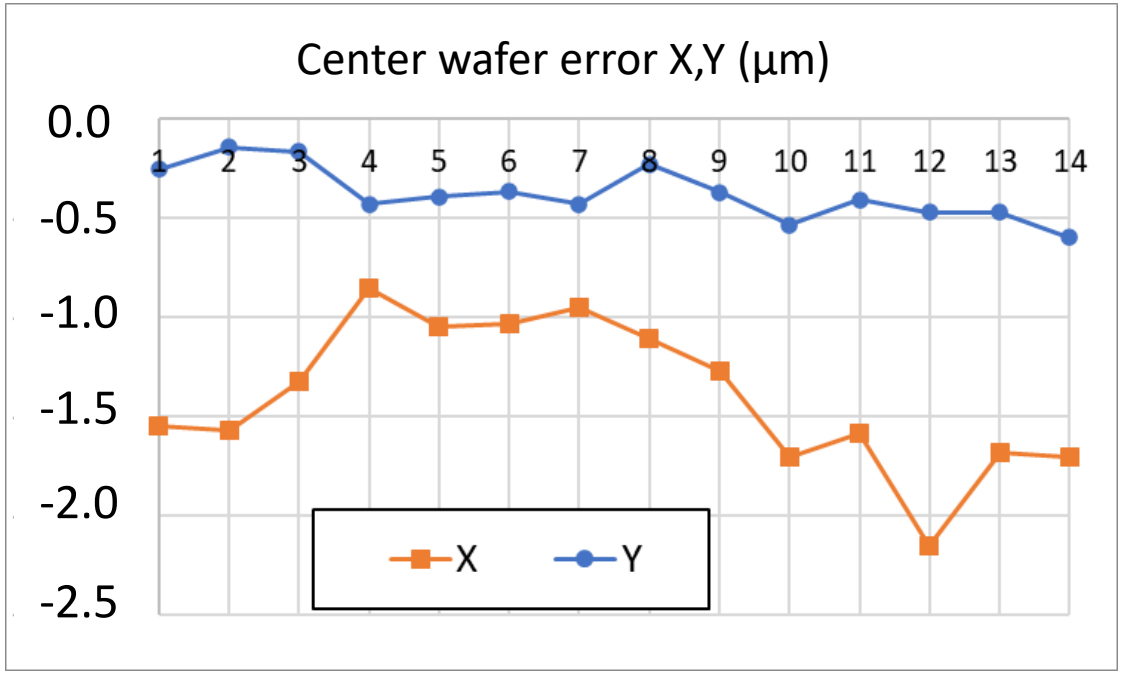
SCIL Nanoimprint solutions

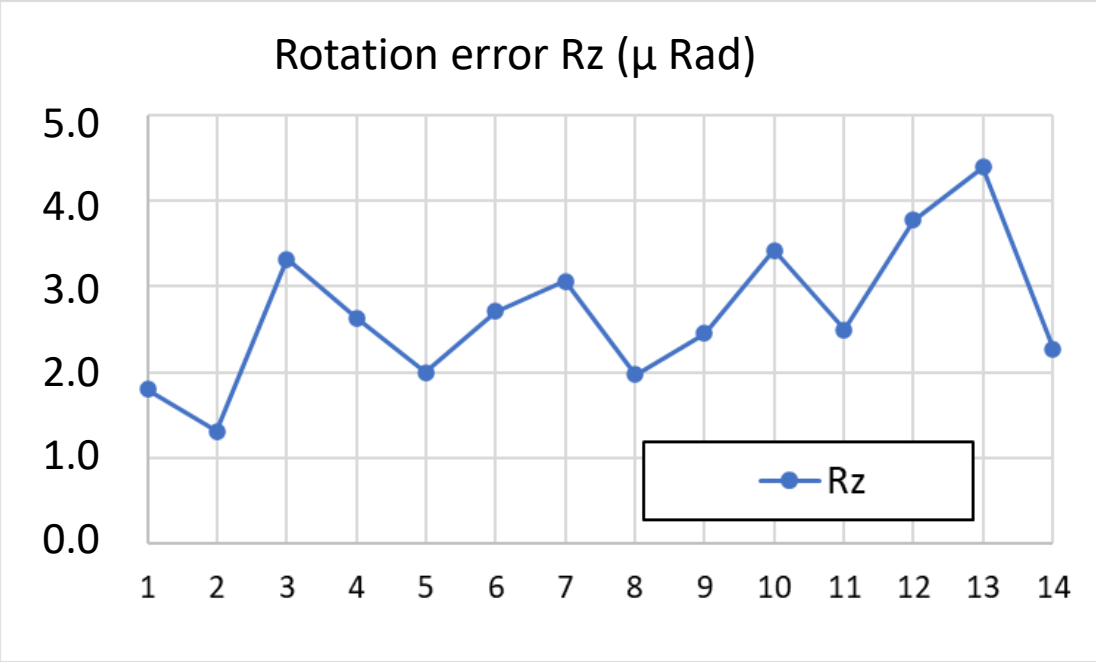
Overlay results 300mm wafers Front-to-Back alignment

Imprint glass wafer, flip, rotate 45°, align to backside, imprint

- No offset corrections used in these runs
- 300mm **800mu** thickness high index glass

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



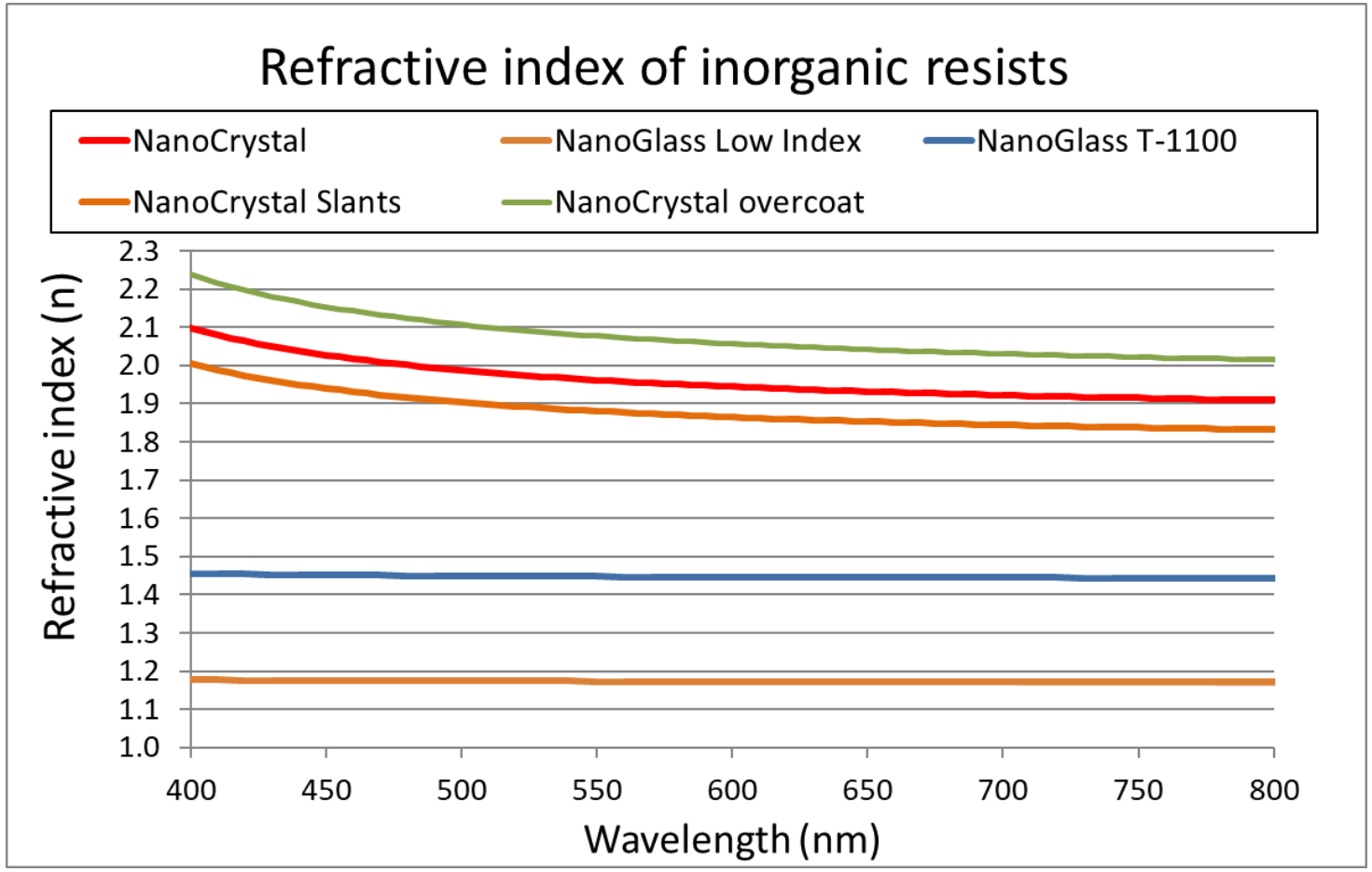


SCIL Nanoimprint solutions

Applications of inorganic functional optical materials

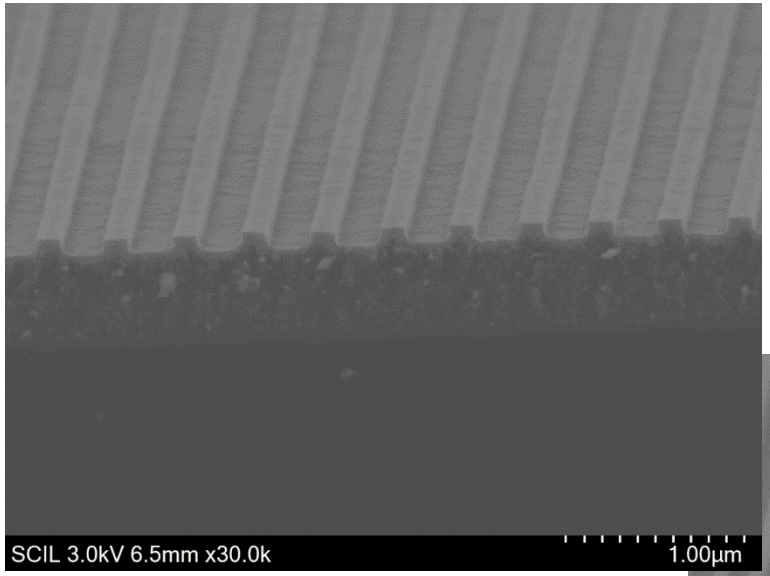
Directly patterning optical materials
full range in refractive index

- Saves 9 – 11 process steps
- All resist types are fully inorganic
  - Index range n=1.17 to **2.2**
  - **Increased slant index with 0.1**
  - High index planarizing overcoat material
  - Robust
  - Non-absorbing down to λ~**360**nm
  - Temperature stable >400°C
- Low shrinkage <10%
- Applications:
  - Augmented Reality
  - Meta-surfaces
  - Flat lenses
- Key figure or merit:
  nm-reproducible features



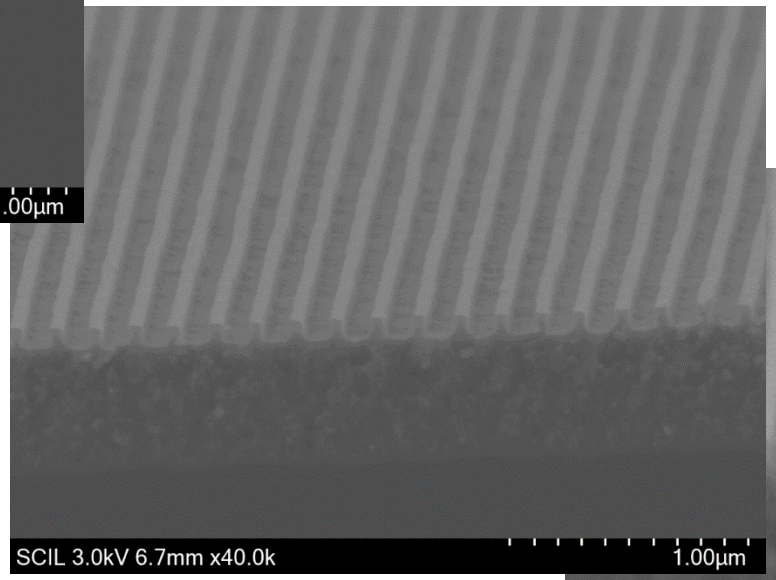
SCIL Nanoimprint solutions

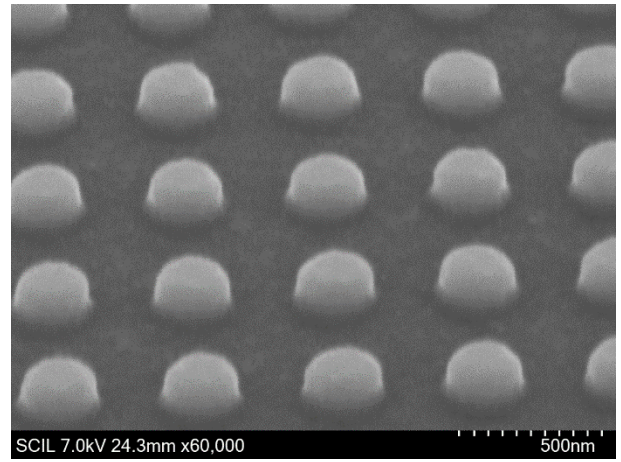
Binary gratings in NanoCrystal high index (n=1.96, 100% inorganic)



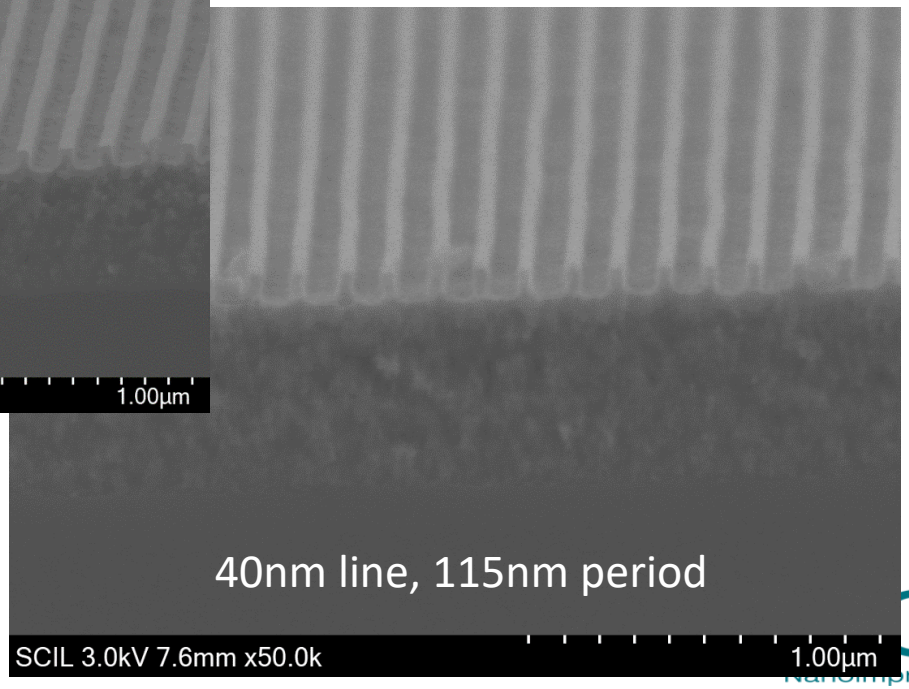
400nm period

170nm period



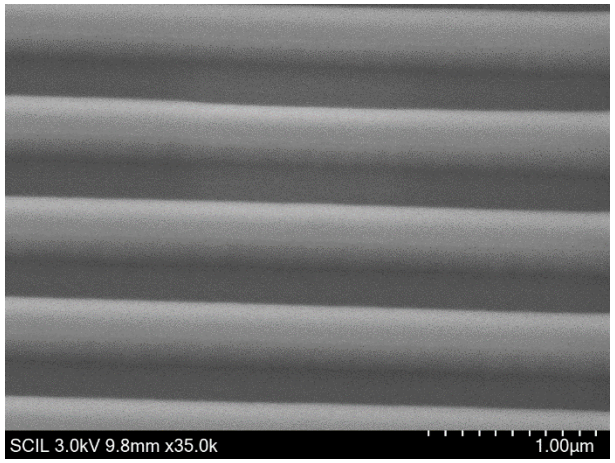


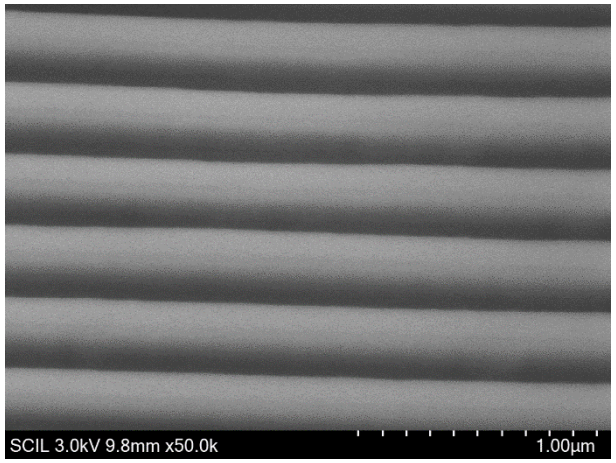
200C anneal

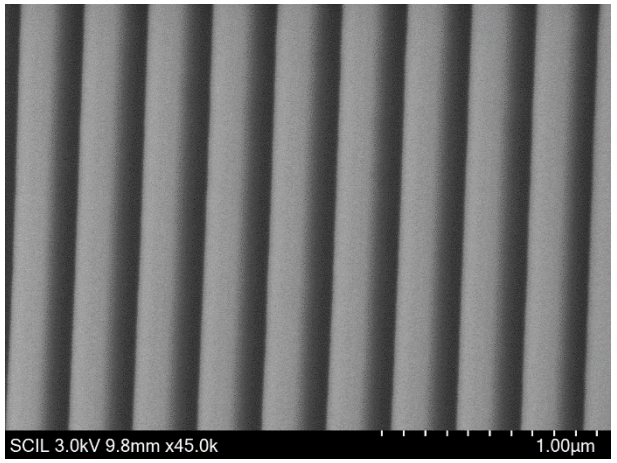


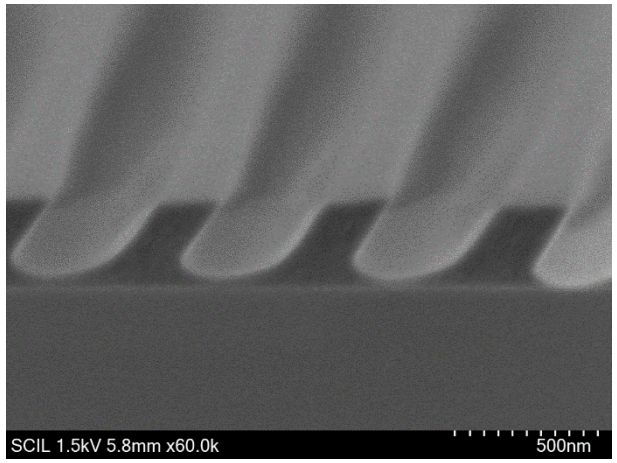
- All imprinted @ RT
- 40nm lines, aspect ratio 2

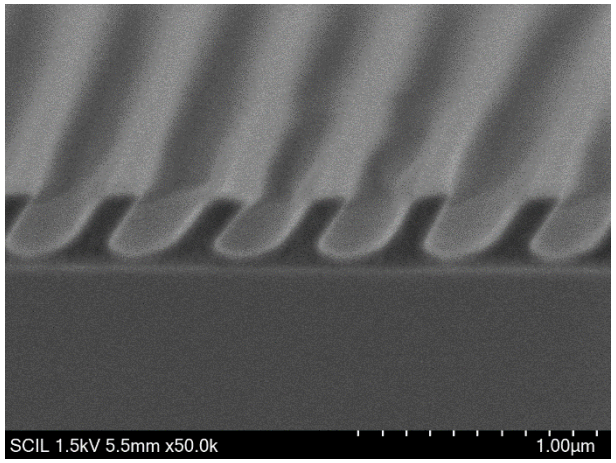
Slanted grating imprint in NanoGlass T-1250

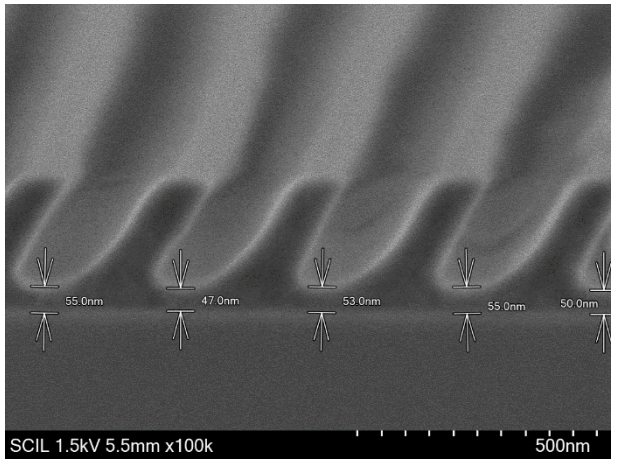












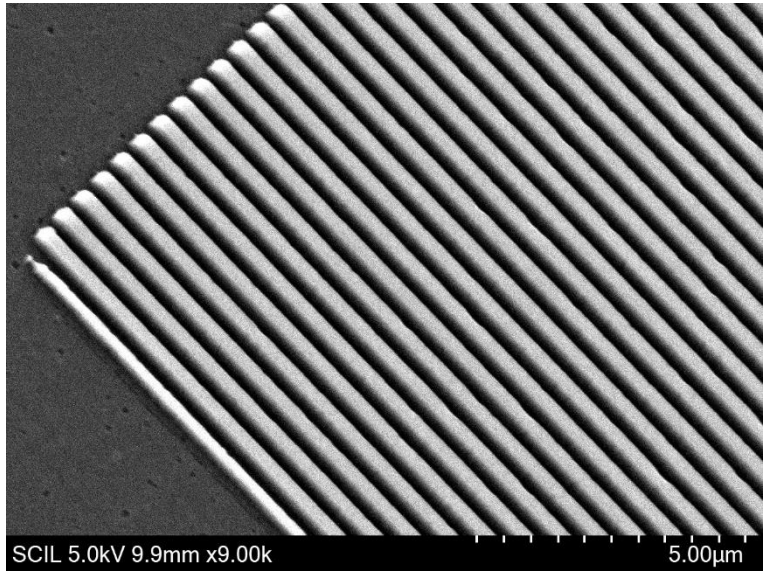
Period: 600nm 450nm 300nm

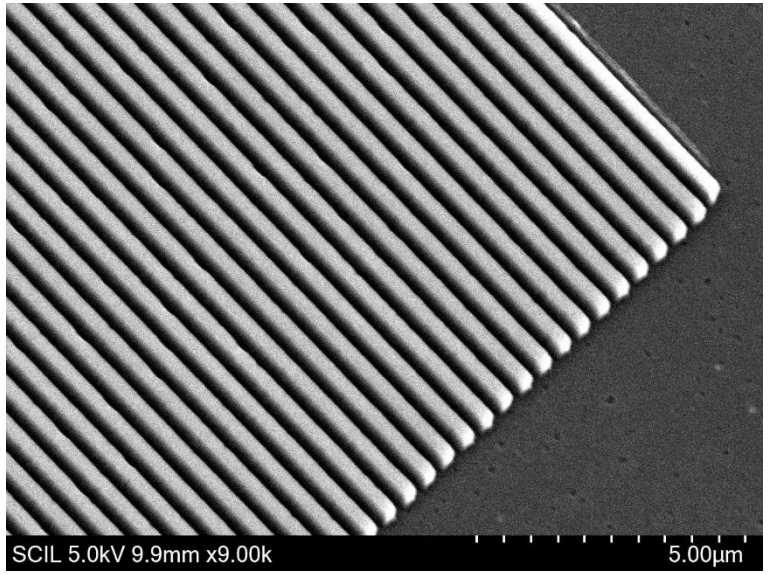
- Slanted gratings
- Slant angle ~35deg off normal
- Vertical: ~260nm

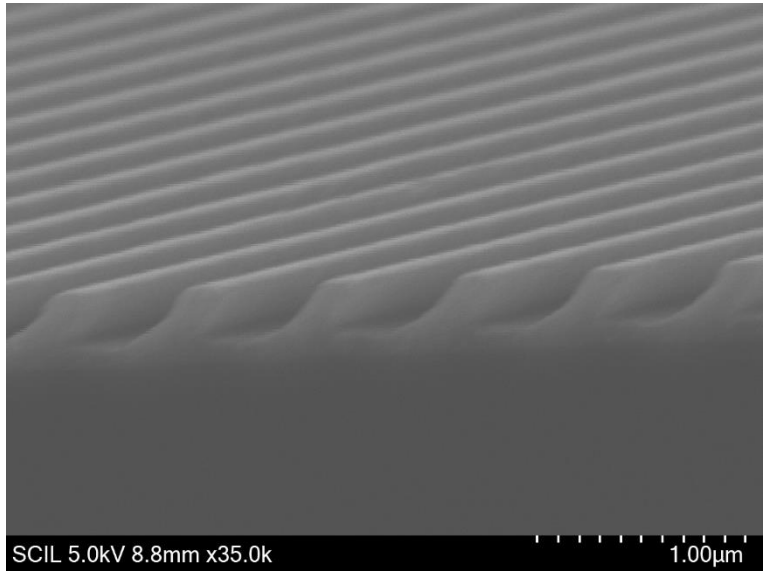
- Master provided by NIL Technology Denmark

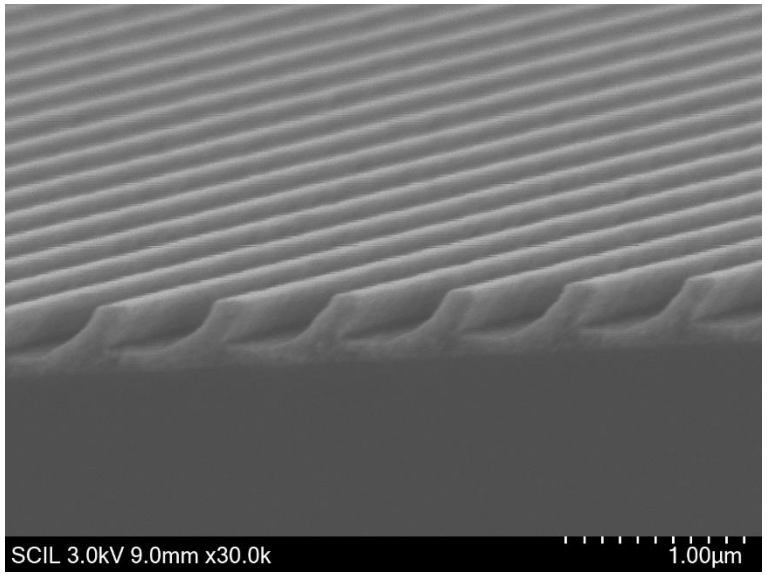
Stamp lifetime > 250 imprints proven. Expect to reach same as binary ~500

Slanted grating imprint in NanoCrystal Slant (100% inorganic)









NIL TECHNOLOGY

- Slanted gratings
- Slant angle ~35deg off normal
- Vertical: ~260nm

- Master provided by NIL Technology Denmark

SCIL Nanoimprint solutions

Pattern uniformity evaluation

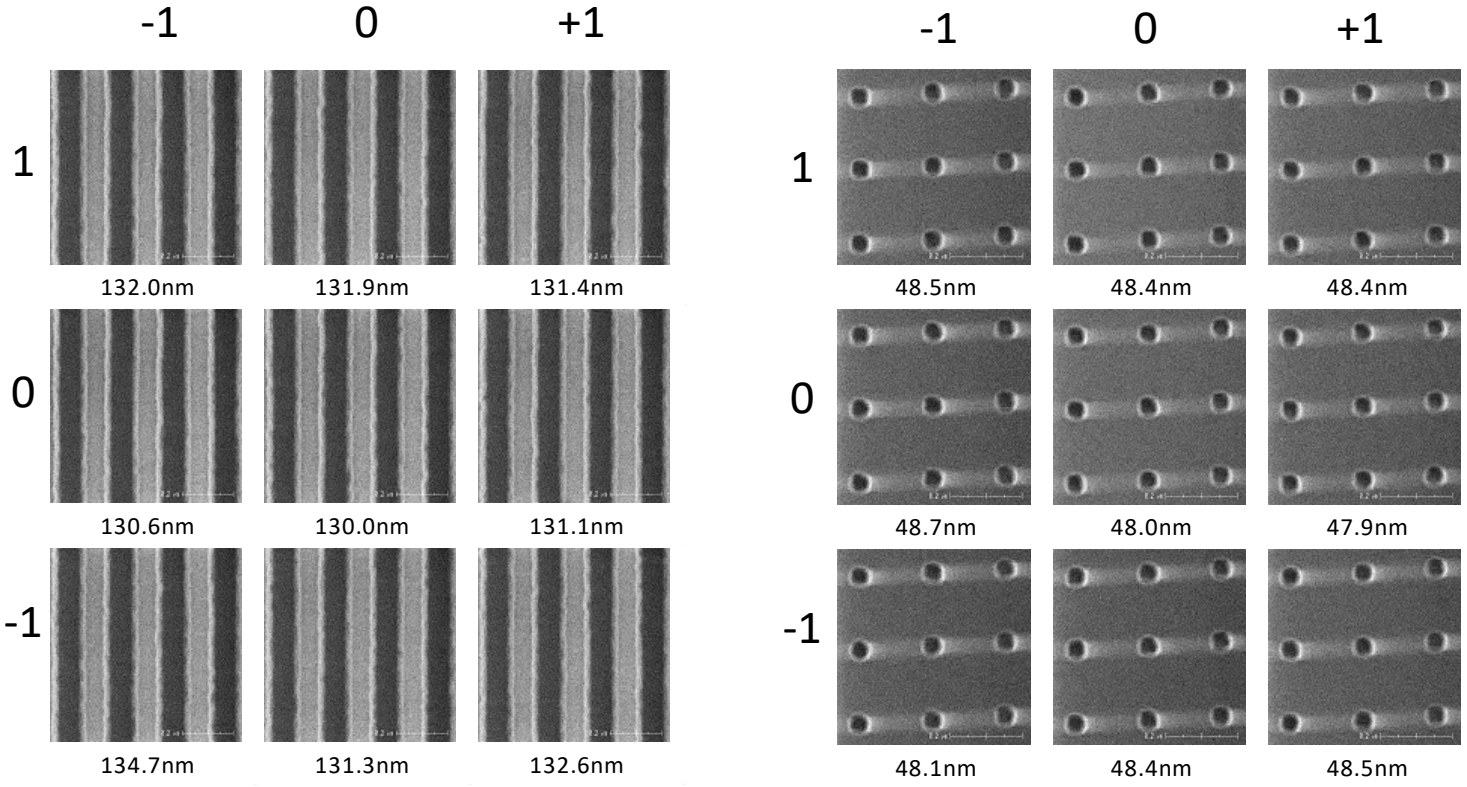
Nano photonic applications require absolute size control on the single nm

- Meta-surfaces $\pm$ 1nm
- Augmented reality waveguide combiners < 3nm

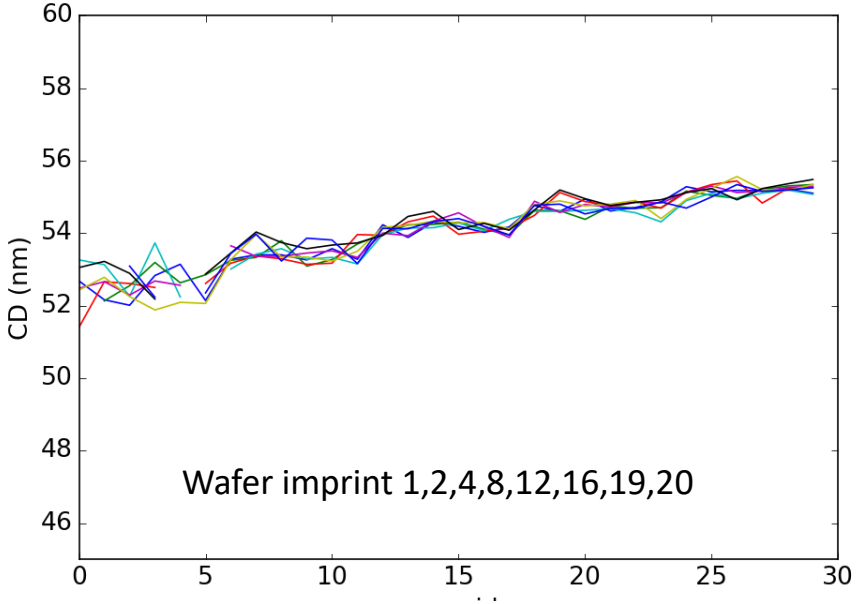
CD-SEM pattern evaluation in cooperation with CEA / Leti

- Variety of single, dense, ~40nm to microns, optical lithography bias tuning
- Hole arrays 52nm diameter, 120nm deep
- Imprints 1 through 20 of 3^{e} X-PDMS stamp from the master → ~1nm variations

SEMs of the imprints



Hole diameters comparison

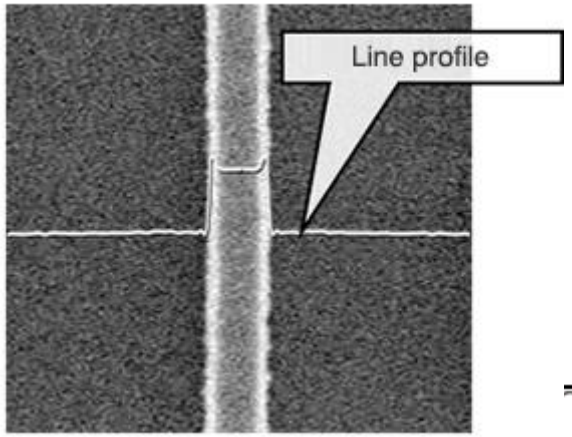


29 different hole diameters on the master

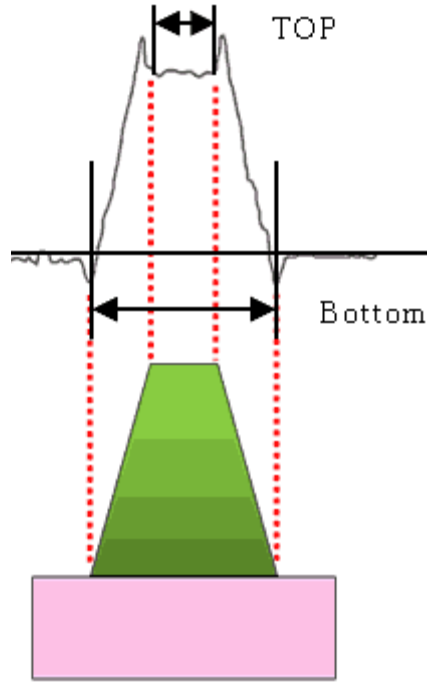
SCIL Nanoimprint solutions

CD-SEM for slanted or high aspect ratio patterns?

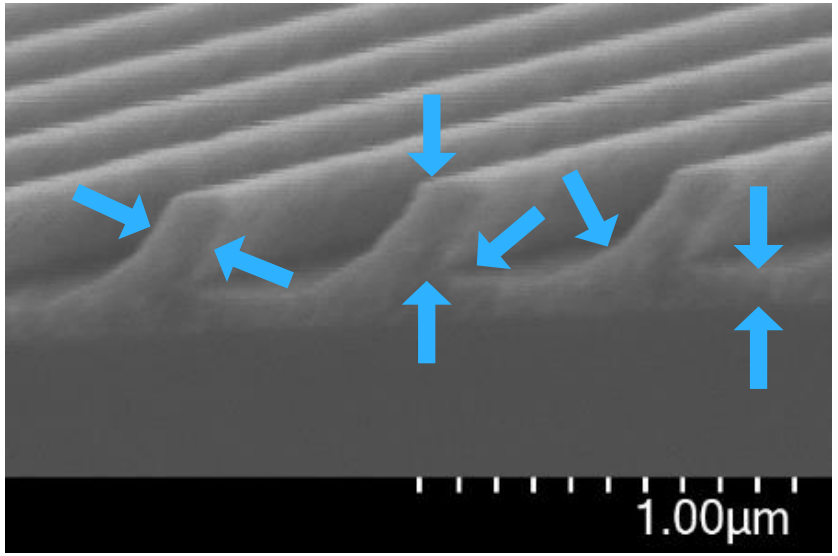
- CD-SEM can only infer a sidewall with known height
  - But lacking LRT, height and for slanted forward and backward angle



Line profile *



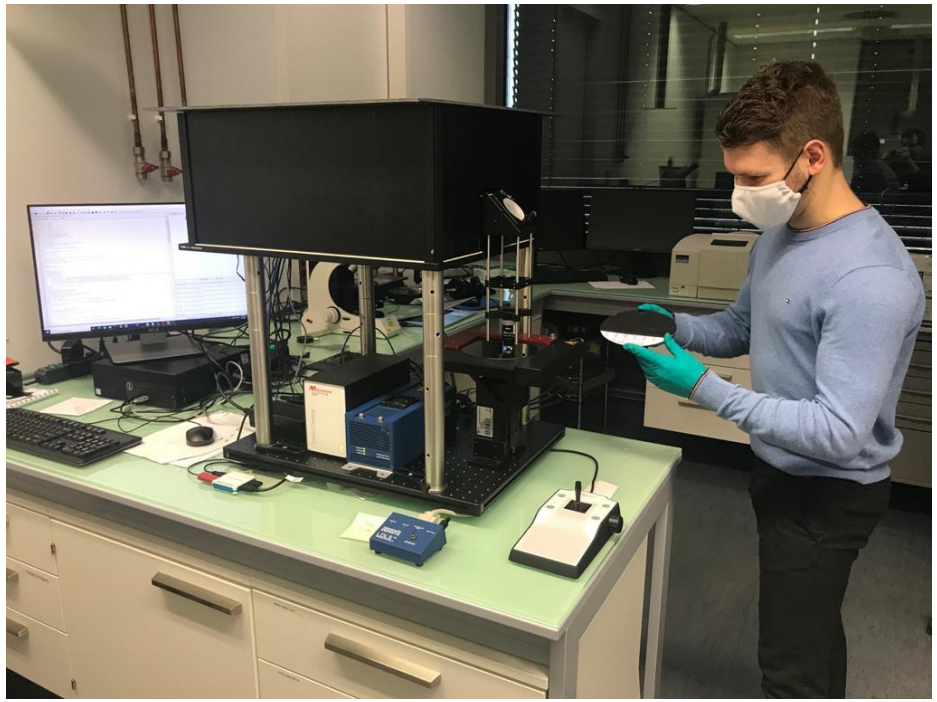
A schematic cross-sectional view

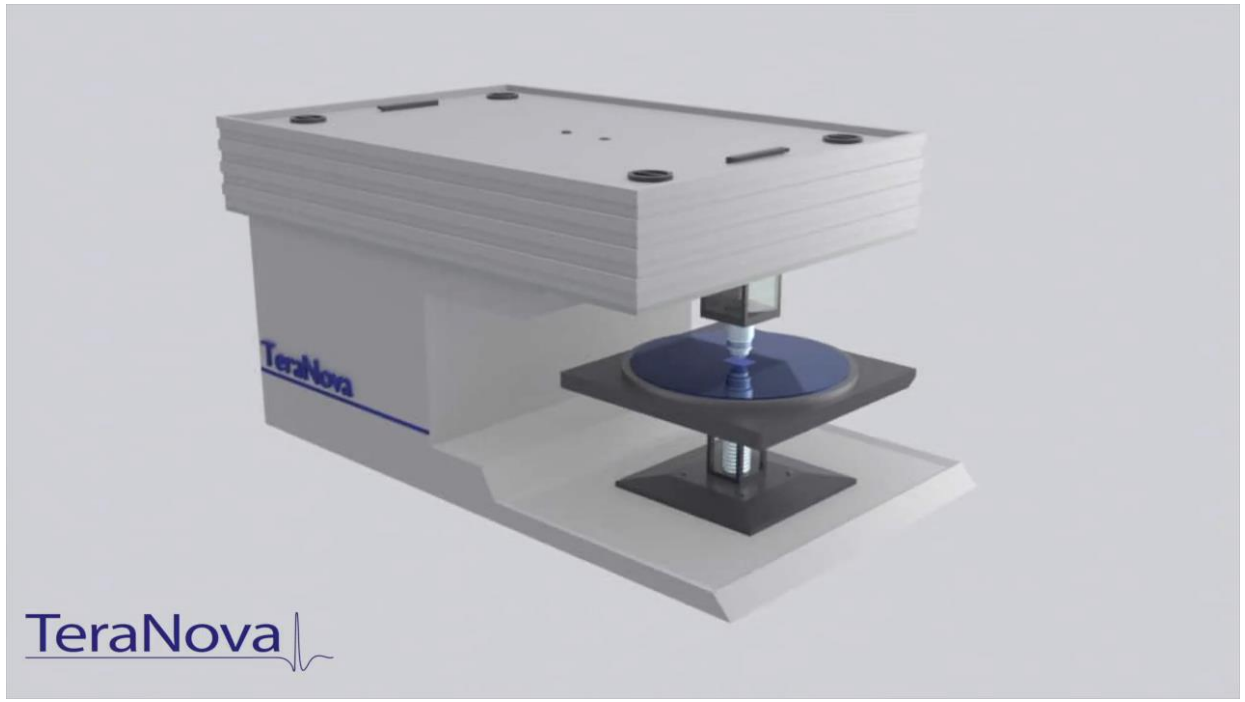


* Hitachi

SCIL Nanoimprint solutions

The Instrument: Fourier based scatterometry by TeraNova



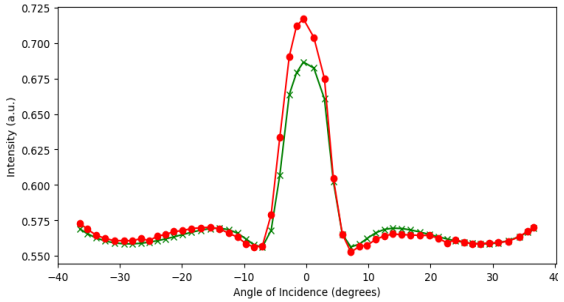


- Affordable, compact table-top tool – first proto operational and available for testing @ SCIL
- Incident angle scan and simultaneous reflection + diffraction order capture (angle + intensity data)
- Scatterometry tool will be integrated in the AutoSCIL and FabSCIL platforms for in-line QC

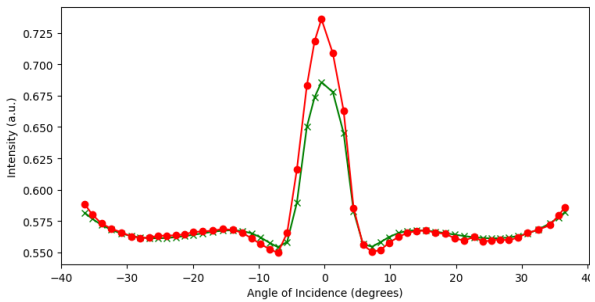
Extracting nano-pattern geometry via RCWA simulations

385nm line grating 90°C post imprint cure

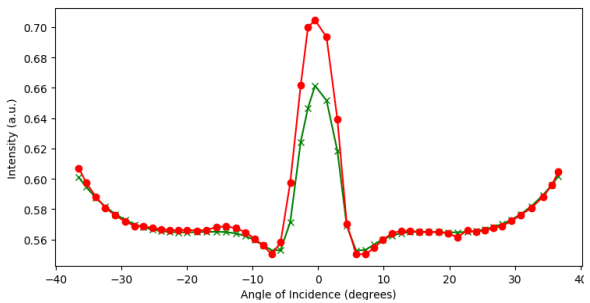
1500 rpm



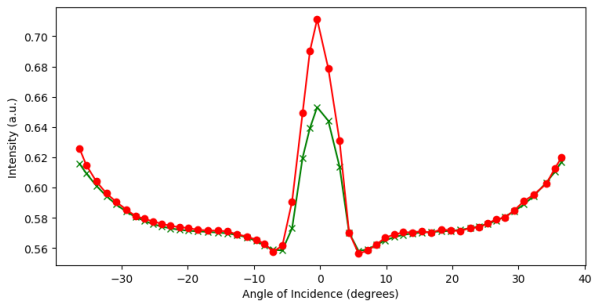
2000 rpm



2500 rpm



3000 rpm



Measurements — Simulations (RCWA)

Geometrical parameters extracted from RCWA fit to measurements + SEM, AFM, ellipsometry

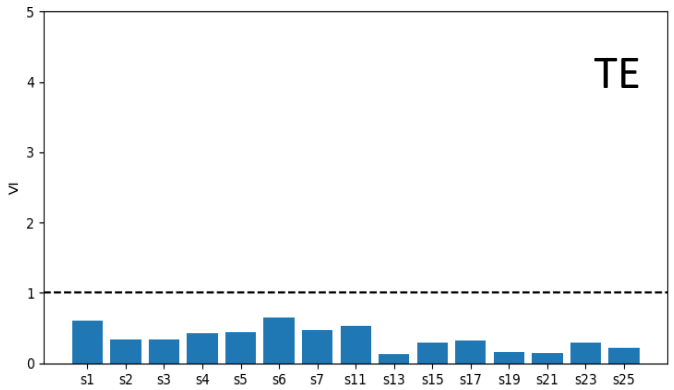
Sample	1500 rpm	2000 rpm	2500 rpm	3000 rpm
Height (nm)	95	94	90	89
Duty Cycle (%)	43	43	43	43
Residual Layer Thickness (nm)	43	34	27	23
Expected Δ in RLT from flat layers	-	**- 10**	**- 6**	**- 5**

Batch in batch repro – AutoSCIL tool 150mm Si wafers

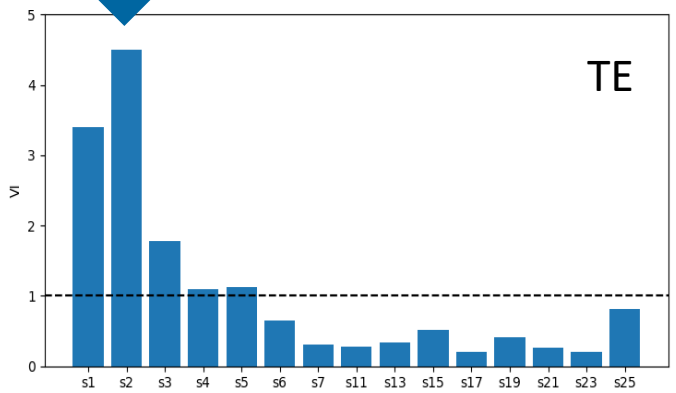
- Imprinted 2 batches of 25 wafers one week apart
- NanoGlass T-1100
- 150°C post bake hot-plate

- In 2nd run, first 2 wafers ran different process, then switched to process of batch 1
- From tool gage R&R, crosse checked with AFM, SEM. The dotted line corresponds to ~ 1nm over variation in RLT, height, width

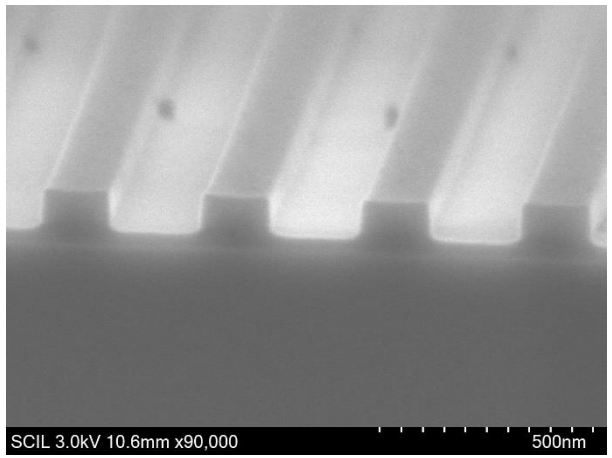
1st run – 25 wafers

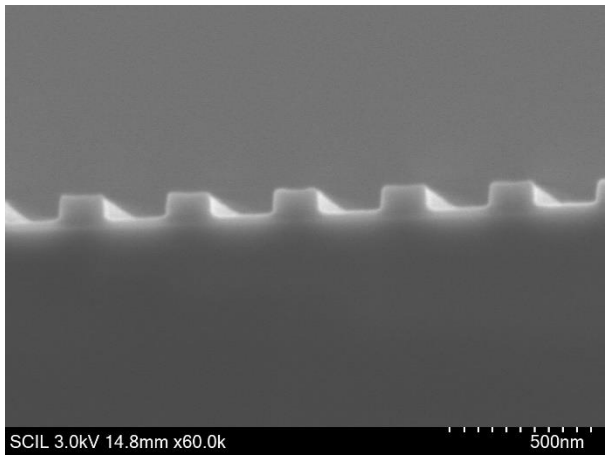


2nd run – 25 wafers



Results compared to average of slots 7 - 25 per run





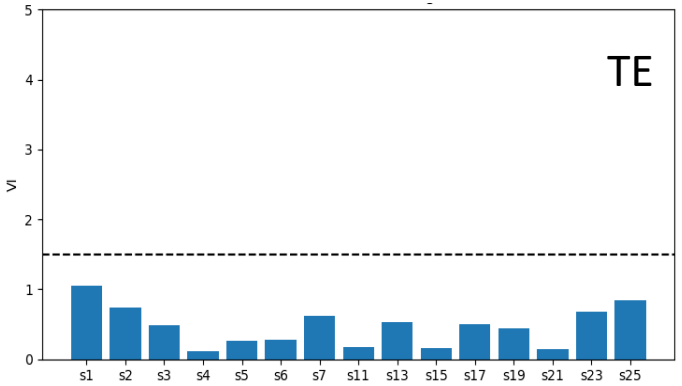
Batch to batch repro

- Imprinted 2 batches of 25 wafers one week apart
- NanoGlass T-1100
- 150°C post bake hot-plate

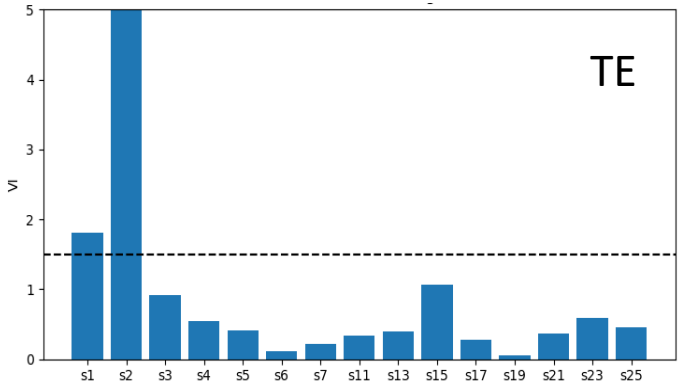
- In 2nd run, first 2 wafers ran different process, then switched to process of batch 1
- From tool gage R&R, crosse checked with AFM, SEM. The dotted line corresponds to ~ 1nm over variation in RLT, height, width

- **Batch to batch variation is < 1nm**

1st run – 25 wafers



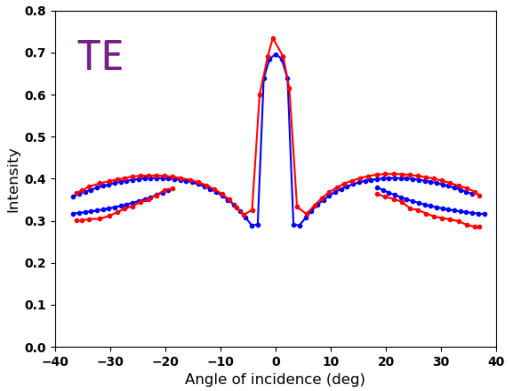
2nd run – 25 wafers

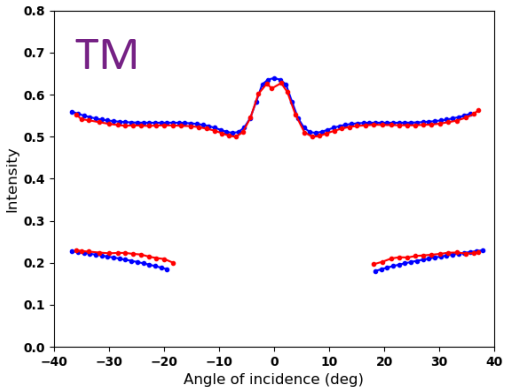


Results compared to average of slots 7 - 25 of the **OTHER** run

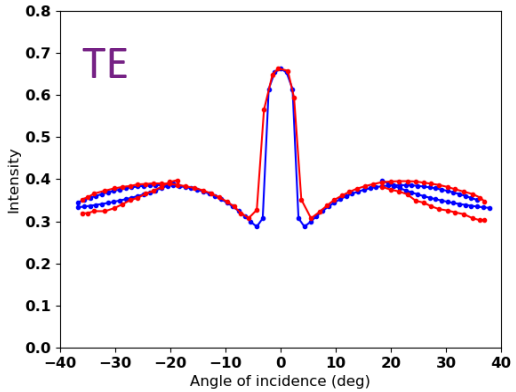
Parameter extraction via RCW simulations

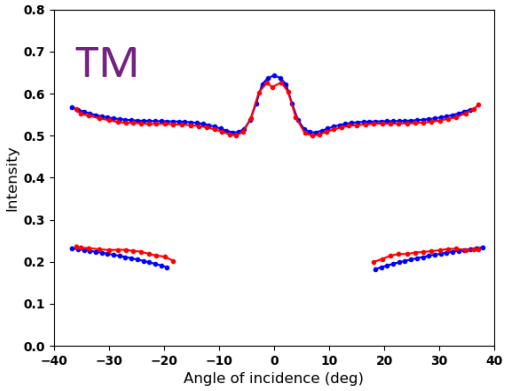
Sample 2

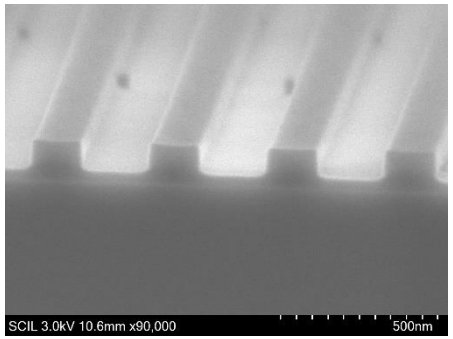


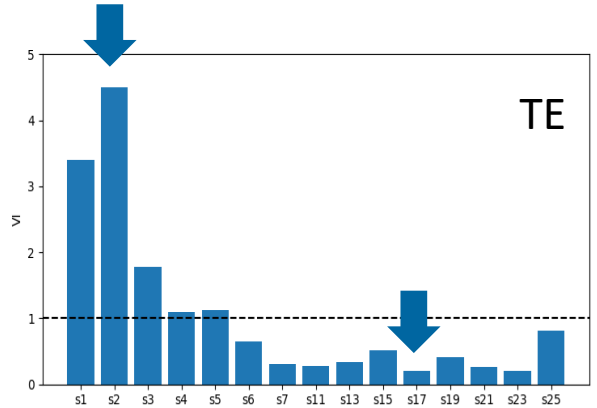


Sample 17









Batch 2 comparison - process change

Parameter	Sample 2	Sample 17
Height (nm)	85	85
RLT (nm)	44	40
Alpha (deg)	6	6
DC	0.42	0.42
Pitch (nm)	385	385
n resist	1.45	1.45

Conclusions

- SCIL provides NIL based high volume production solutions up to 300mm
- Cost effective solution due to optimized combination of tool, process and materials
- Direct replication of complex sub-micron patterns in inorganic optical materials is key enabler for nano-photonics – from low to high index
- Fast inspection that provides 3D geometry information is required for (in-line) QC
- We work with customers from: proof of concept to pilot-volumes and transfer to high volume production

SCIL booth: 210

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