SCIL technology for direct patterning of functional optics

EPIC meeting Neuchatel 2019

Marc Verschuuren,
Rob Voorkamp, SCIL team

November 7, 2019

marc.verschuuren@philips.com

SCIL
Nanoimprint solutions

Contents

- SCIL Nanoimprint Solutions
- SCIL technology and materials
- Tooling and roadmap
- Pattern uniformity
- Conclusions

SCIL Nanoimprint solutions

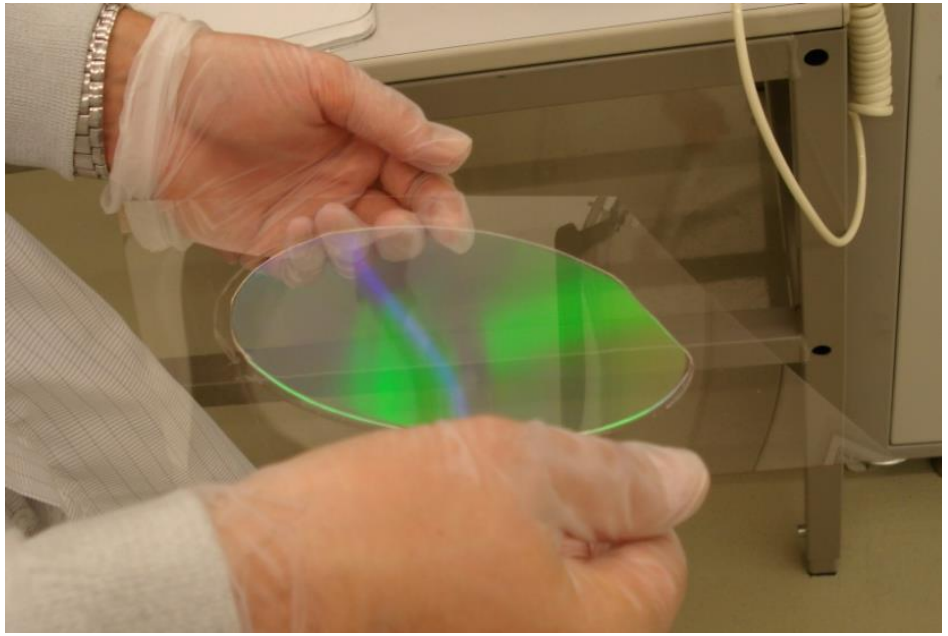
SCIL Nanoimprint solutions

- Developed in Philips research from 2001, SCIL venture start in 2015
- SCIL is a unique and proprietary technology for **nanoprint and nanoimprint lithography**
- SCIL Nanoimprint solutions **for wafer scale nano patterning**
  - Imprint tools for low and high volume production
  - Stamp materials or ready-to-use stamps
  - NanoGlass® resists
  - Customer specific SCIL processes
- This enables our customers to **increase performance and lower costs** of their products
- Our customers include manufacturers of LEDs, lasers, optical components, solar cells, bio-sensors and many others

SCIL
Nanoimprint solutions

Substrate Conformal Imprint Lithography (SCIL)

- Substrate conformal NIL solution
  - The only real conformal imprint technology
- Composite stamp sub-10nm resolution
  - Flexible enough to follow substrate non-flatness
  - Hard enough to achieve nano structures
- Unique Imprint process
  - Sequential low pressure imprint cycle. Capillary force driven
  - ~1.5µm overlay alignment over 200mm wafer
- Full inorganic imprint resist (NanoGlass®)
  - Good etch resistance, thermal stability, optical transparent and UV stable
  - Stamp lifetime > 500 imprints for sub-50nm patterns



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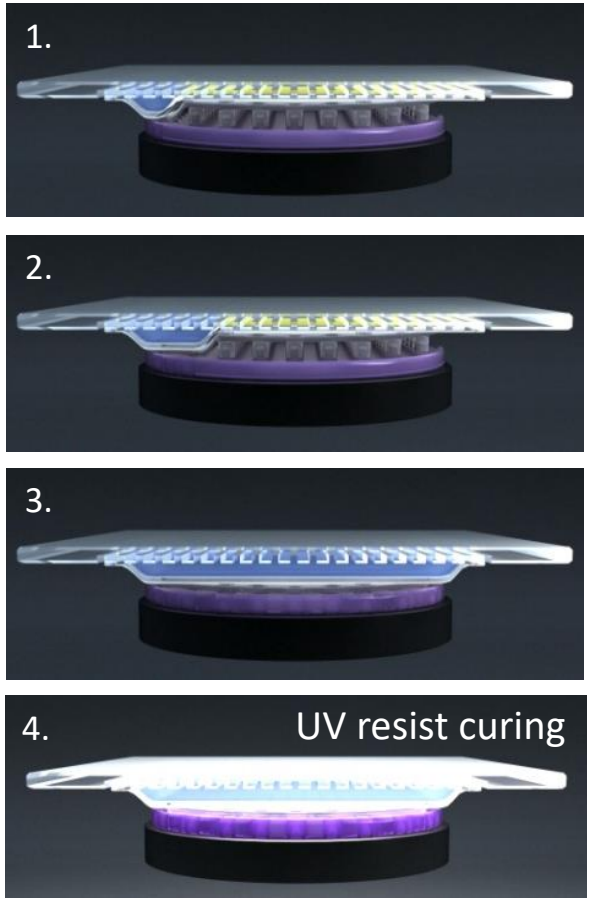
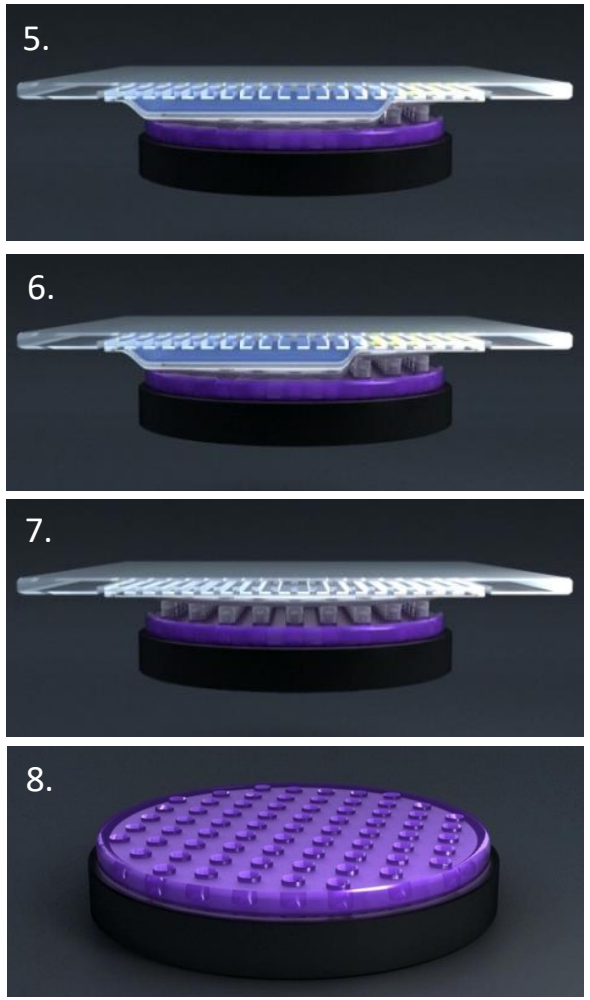
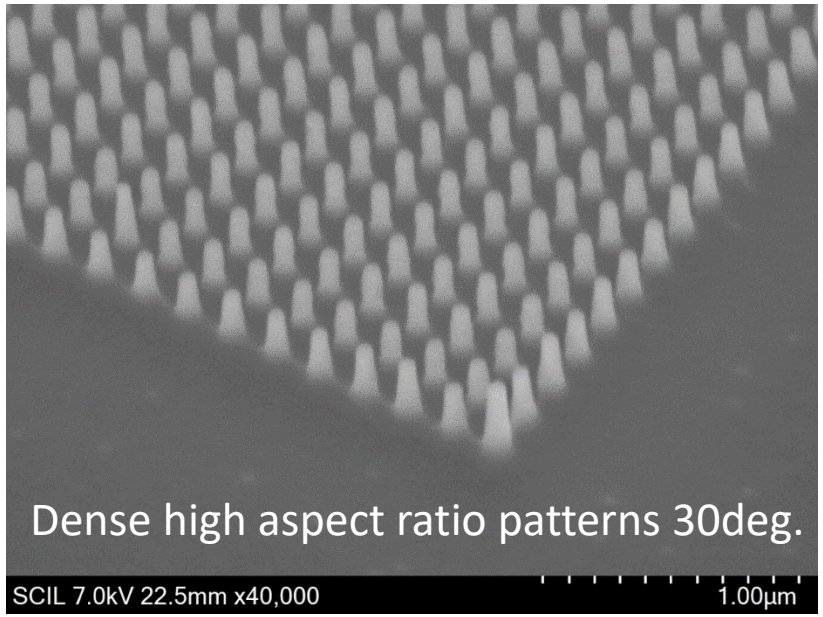
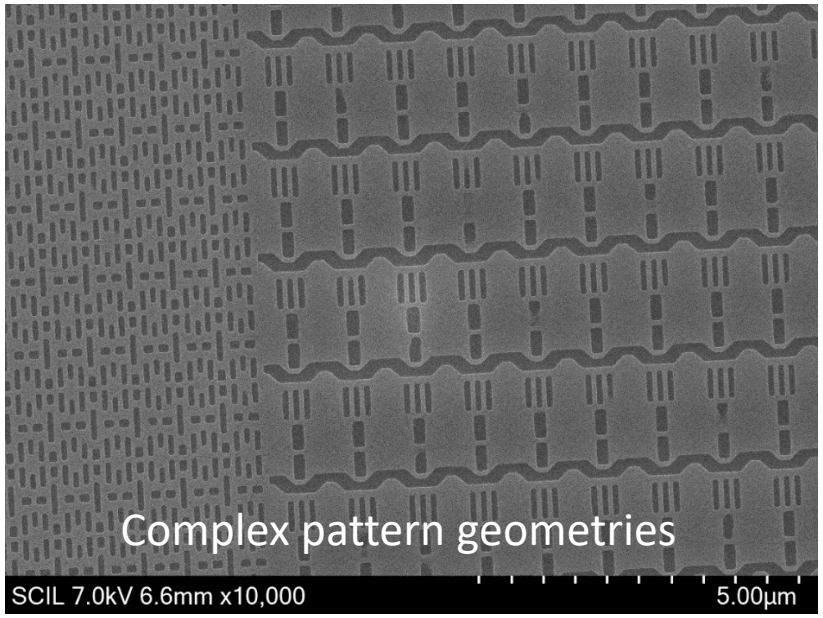


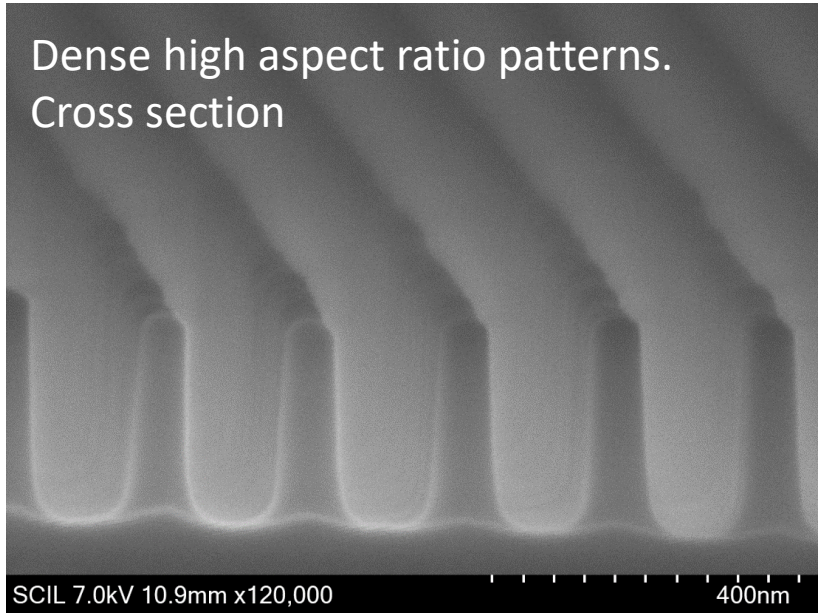


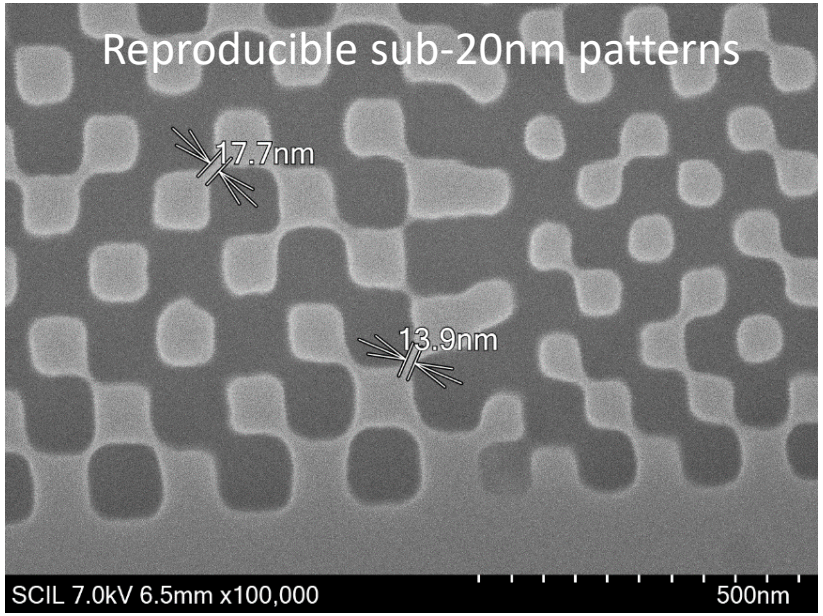
SCIL Nanoimprint solutions

Variety of patterns









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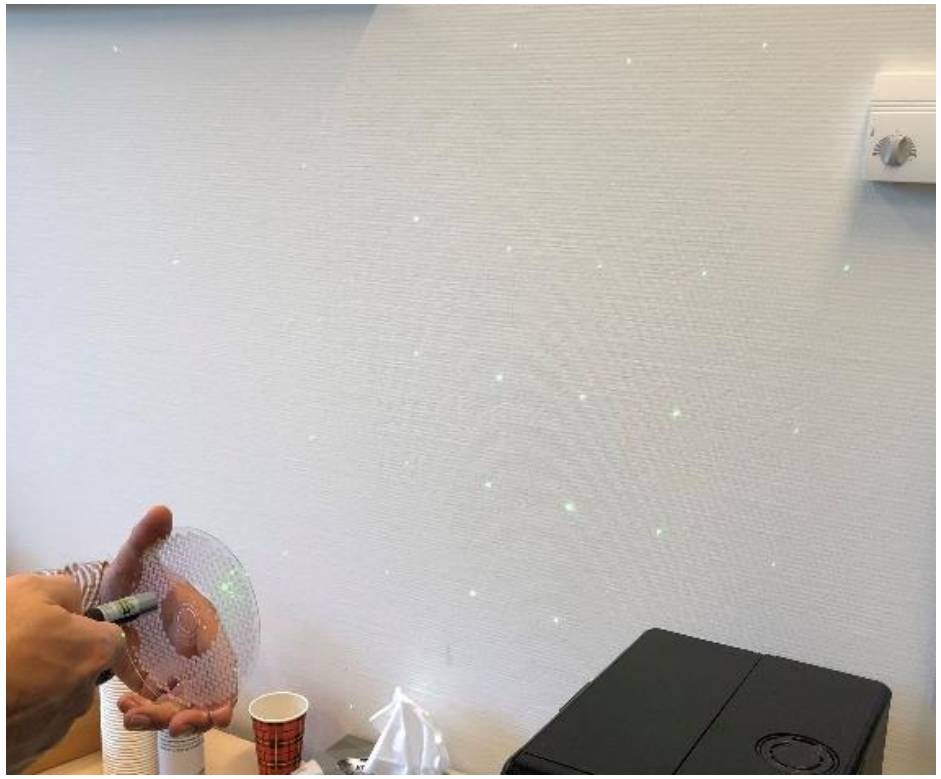
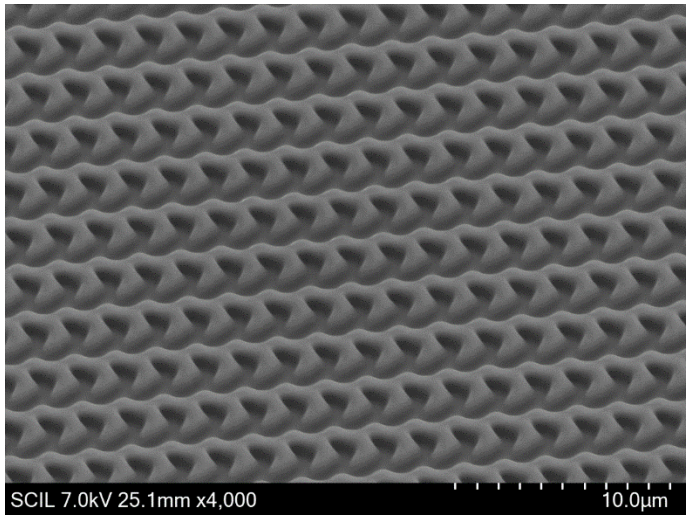
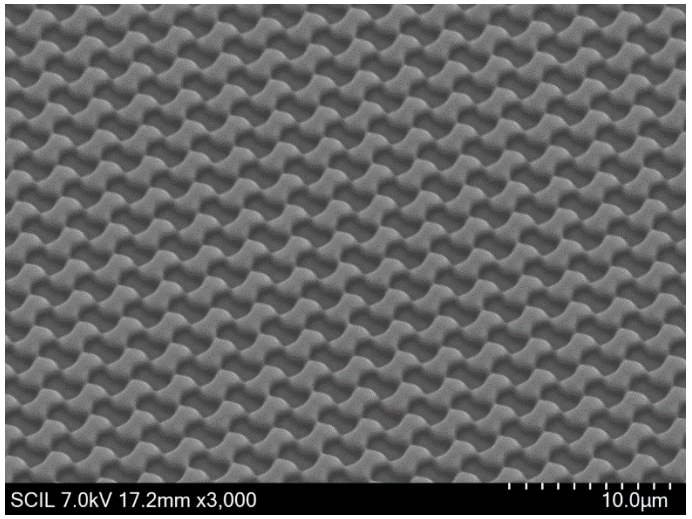
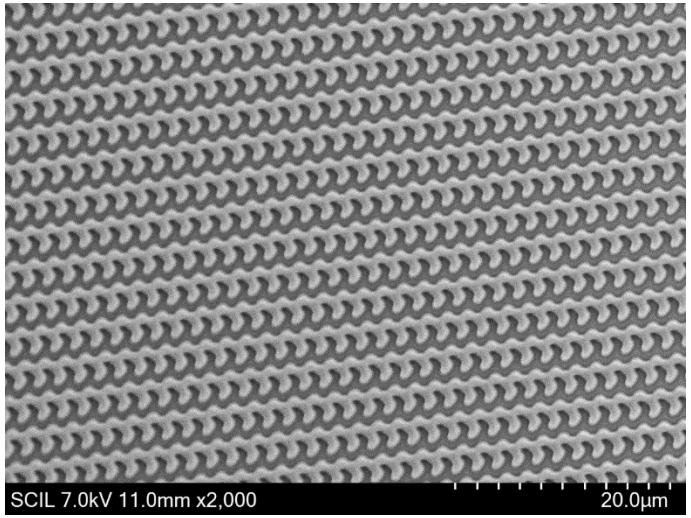
DOEs on glass and COP

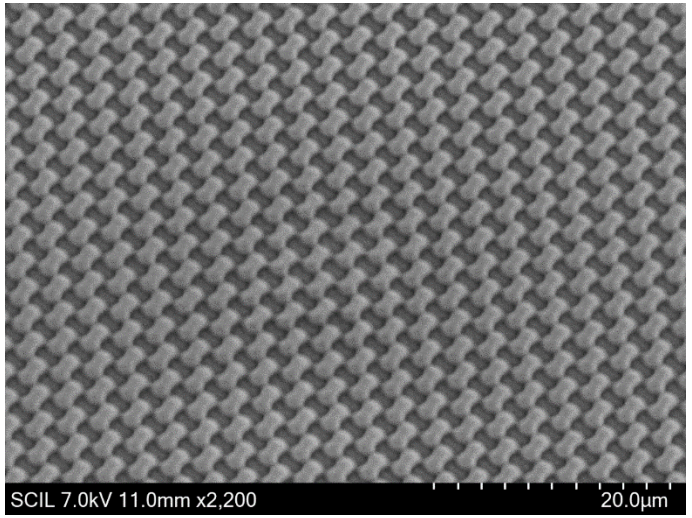
- Dot pattern generation
- Tape test passed on COP and glass
- ~1 micron high patterns
- Curtesy to CDA GmbH – Germany











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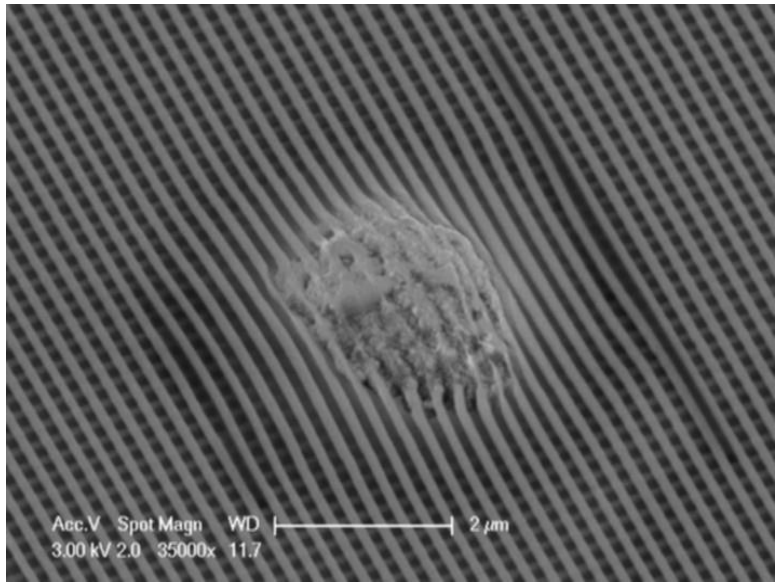
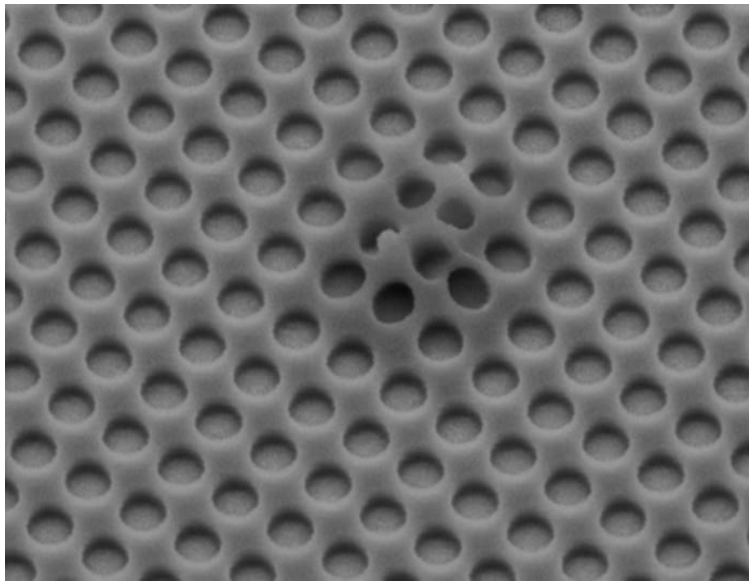
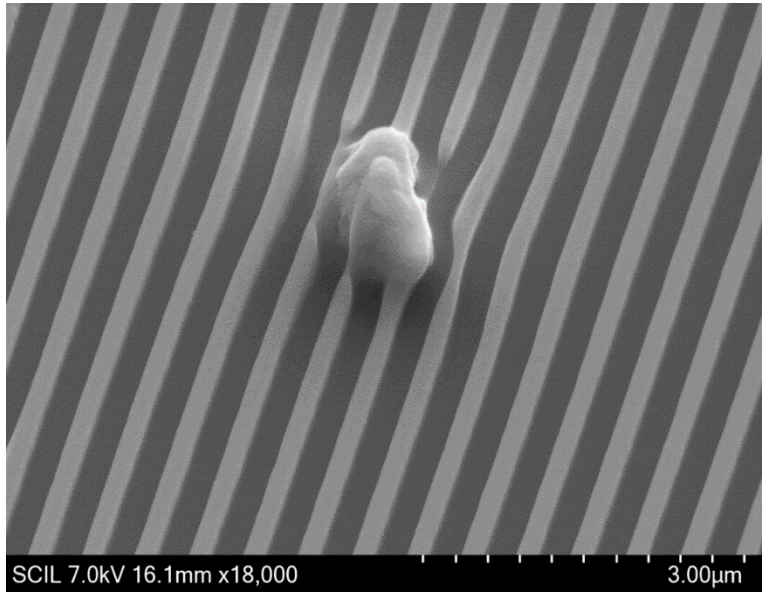
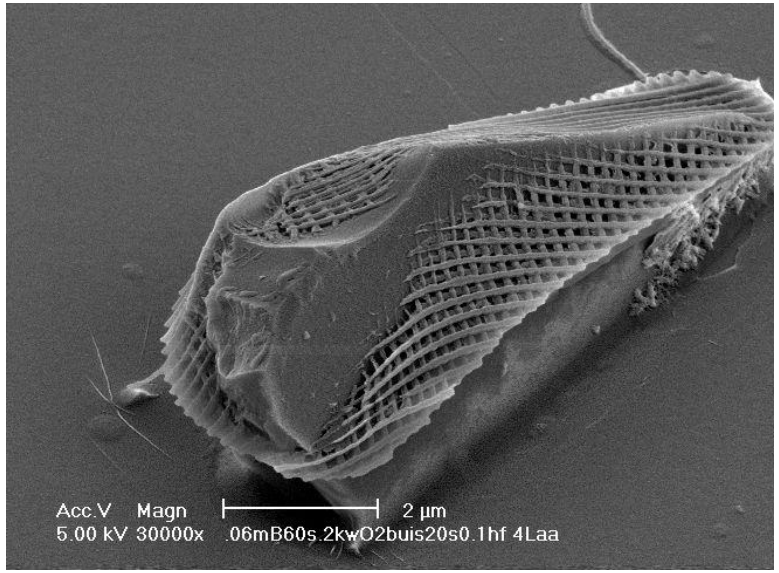
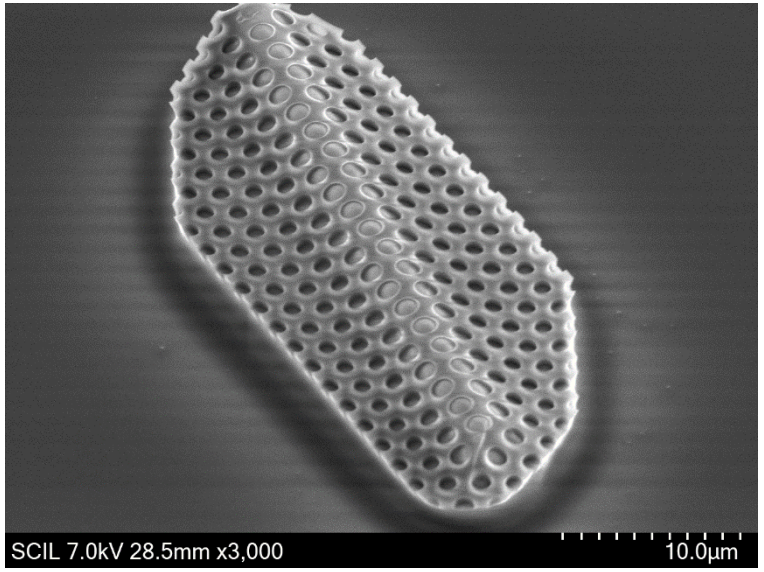
Substrate Conformal, self cleaning, stamp lifetime >500 imprints

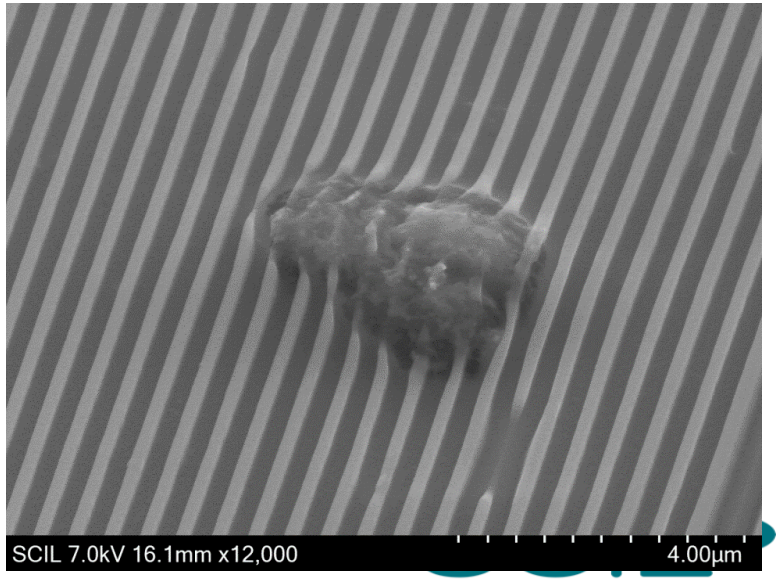












Nanoimprint solutions

SCIL Tooling

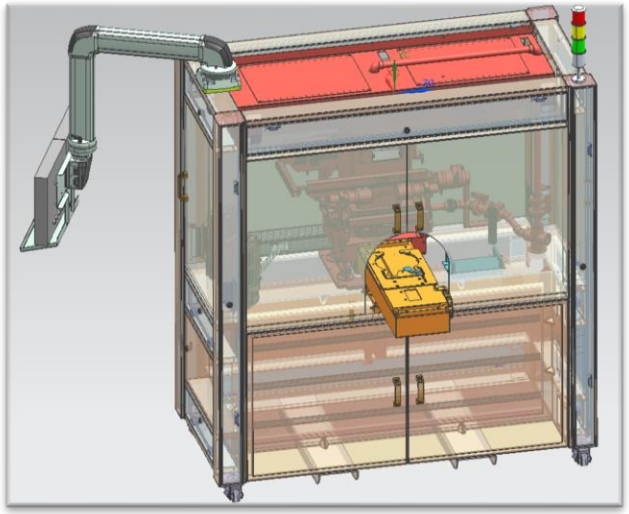
AutoSCIL

- Fully integrated system including all process steps : wafer handling, aligning, spin-coating, SCIL imprint, baking and cooling.
- Specifications:
  - 75, 100, 150, 200mm wafers
  - 30-60 waf./hr using NanoGlass UV & thermal curing
  - Wafer scale overlay alignment

LabSCIL

- Stand-alone SCIL imprint unit for R&D and low volume production

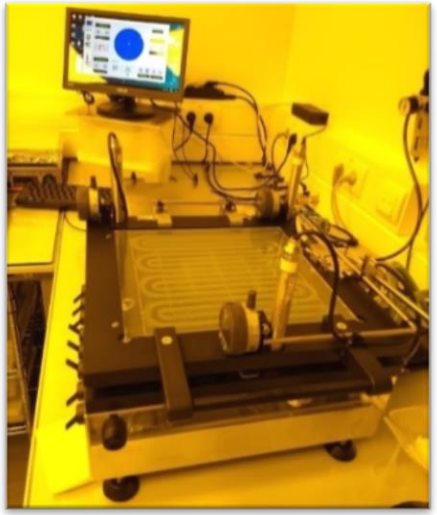
- Specifications:
  - Processing: 100, 150, 200mm wafers
  - Low volume
  - UV & thermal curing
  - Wafer scale overlay alignment



Stamp making tools

- Stamp Making Tool to make SCIL composite stamps

- Specifications:
  - Size: 2”, 3”, 100mm, 150mm, 200mm
  - Uniform heating
  - Manual and semi automatic tools available



SCIL
Nanoimprint solutions

Roadmap stamp tooling

- 300mm semi-automatic stamp making
  - Compact stand alone
  - Increased level of automation
  - Extensive logging for quality control
  - Enhanced thermal control
    - Absolute
    - Uniformity

- Fully automatic stamp making
  - 200 and 300mm stamps
  - Library of masters
  - Finished stamp in clean box out
  - ~4 stamps / h

Available in Q1 2020

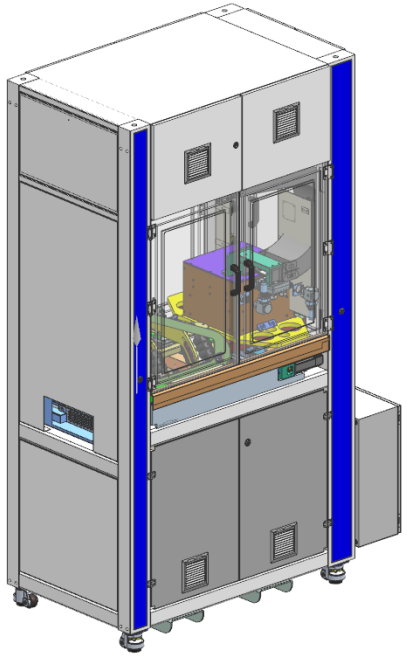
Available in 2022


(artist impression)

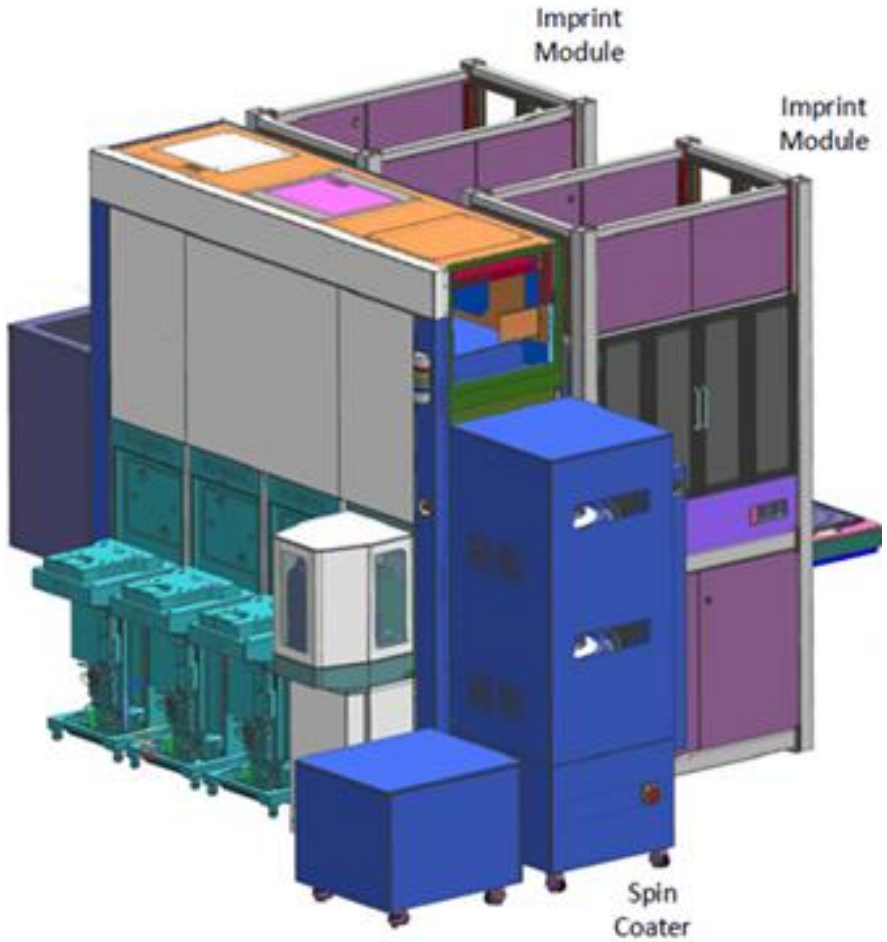
Roadmap SCIL Imprint tooling

AutoSCIL300

- 200mm & 300mm wafers
- Automatic stamp loading
- Available Q2 2020



200/300mm
imprint module



200/300mm cluster tool with two imprint modules

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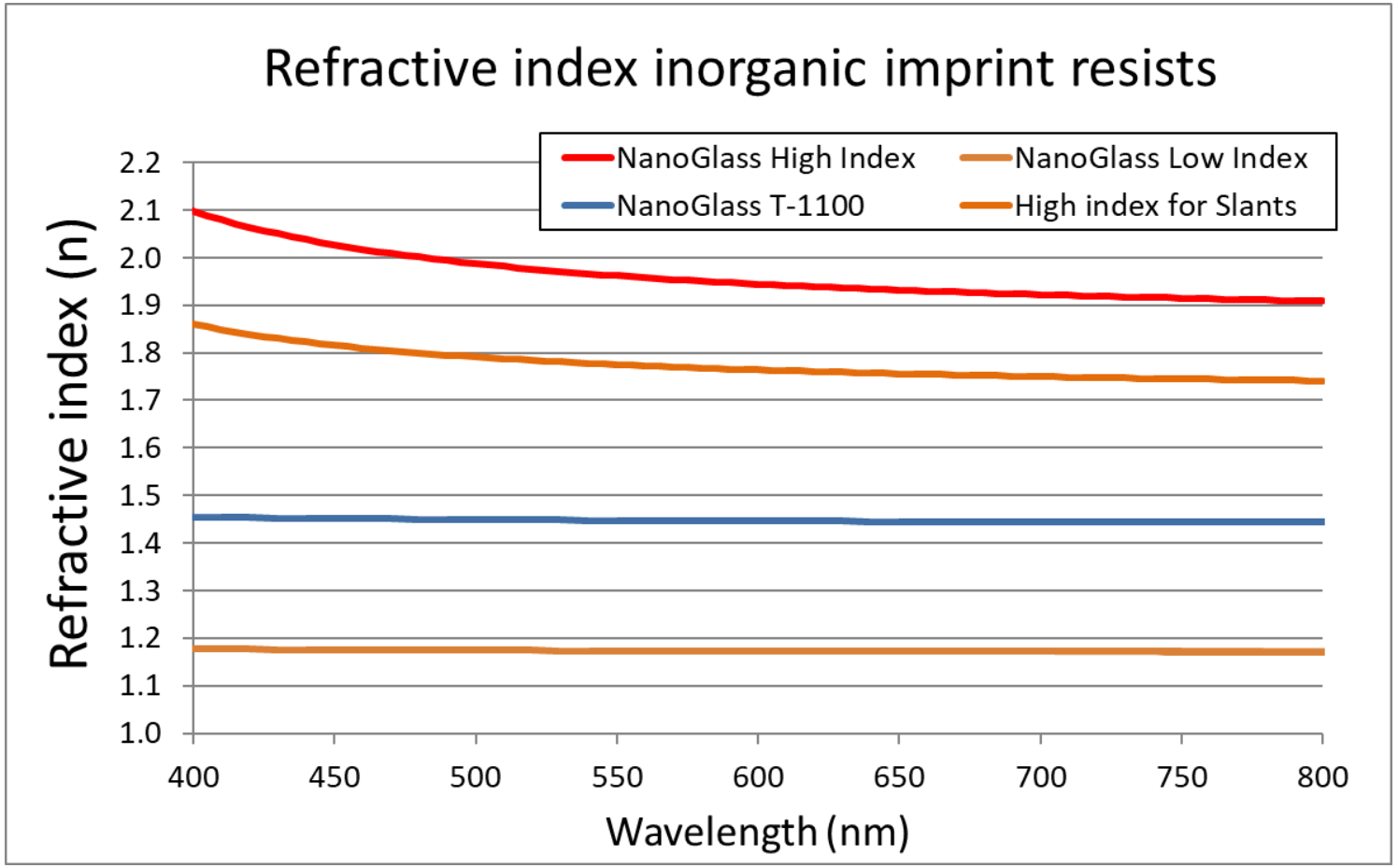
Inorganic functional optical materials

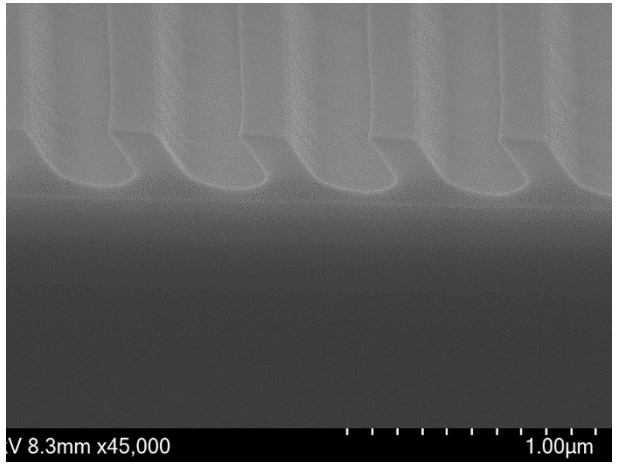
Directly patterning optical materials – new range in refractive index

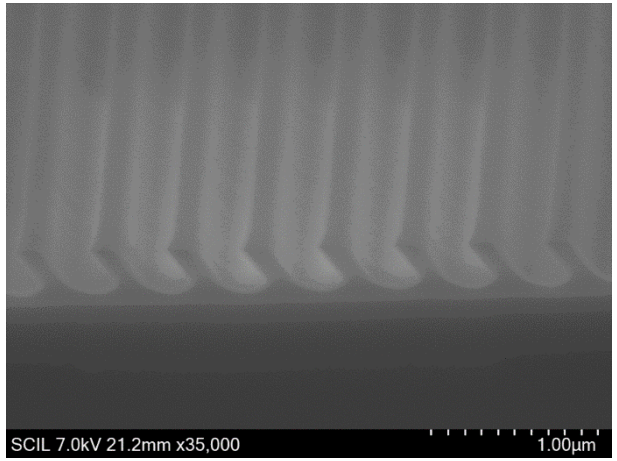
- All resist types are fully inorganic
  - Index range n=1.17 to **2.1**
  - Robust
  - Non-absorbing down to λ~**360**nm
  - Temperature stable >400°C
- Low shrinkage <10%
- For metasurfaces / flat lenses
- Key figure or merit: nm-reproducible features

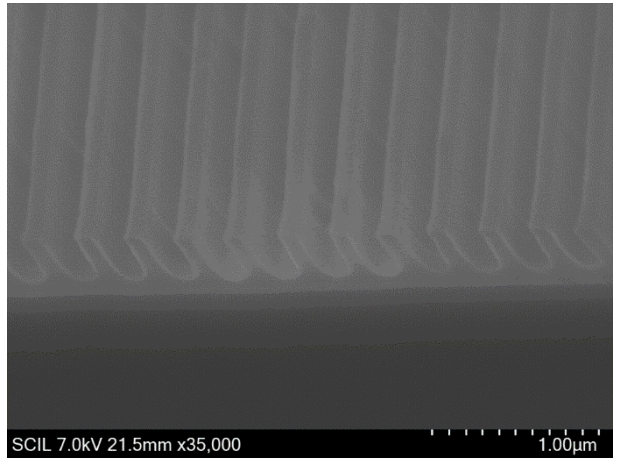


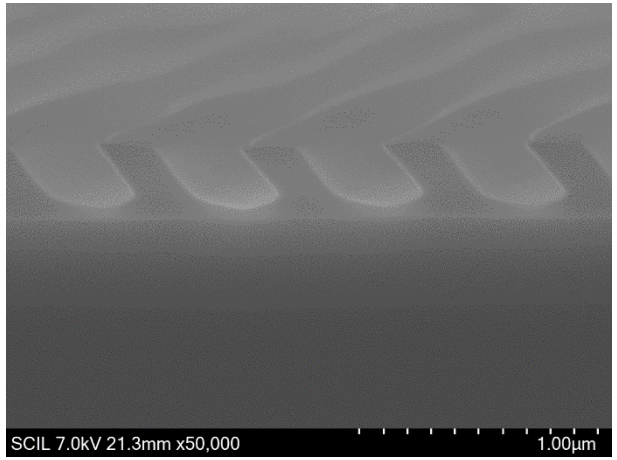
SCIL Nanoimprint solutions

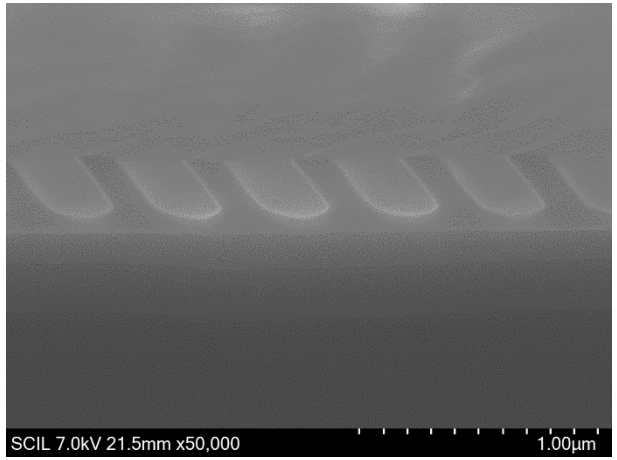
Slanted grating imprint in NanoGlass T-1250

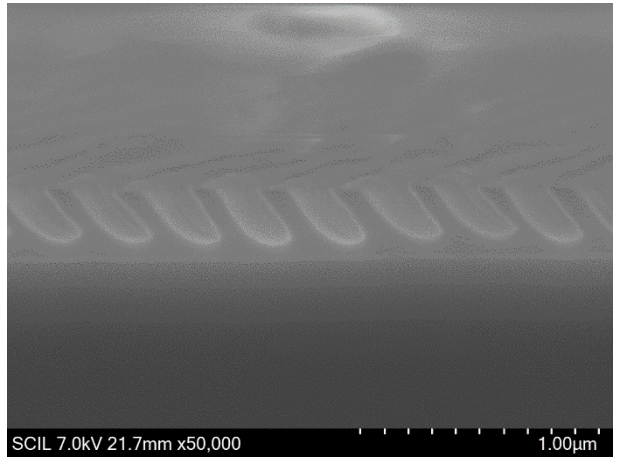












Period: 600nm 450nm 300nm

NIL TECHNOLOGY

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

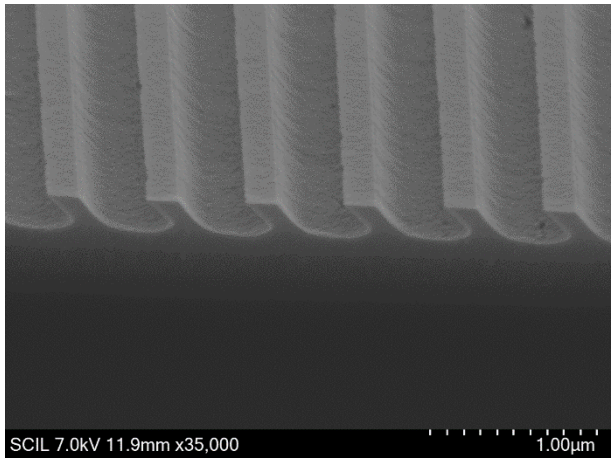
- Master provided by NIL Technology Denmark

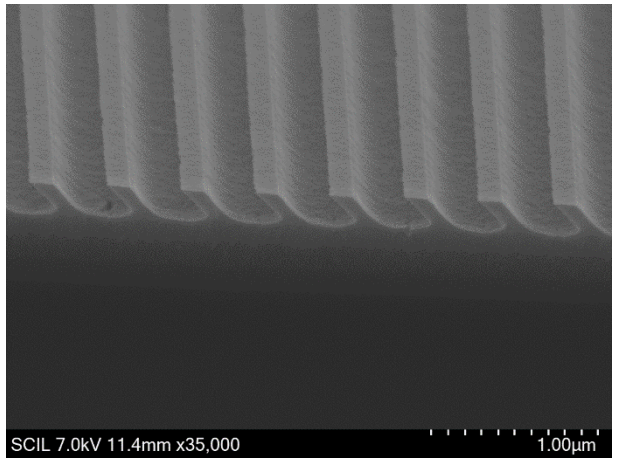
PHILIPS Technology Venture

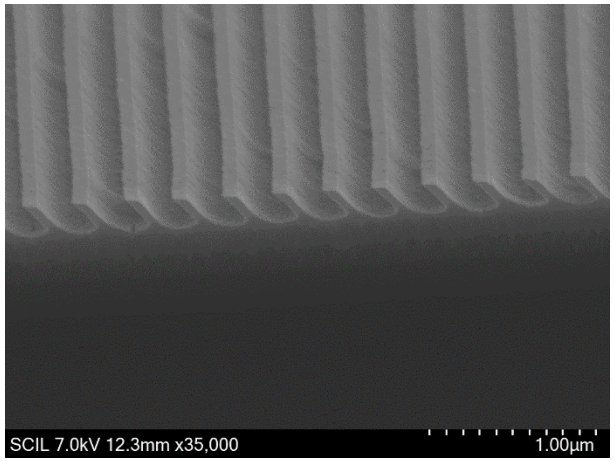
Stamp lifetime > 100 imprints proven. Expect to reach same as binary ~500

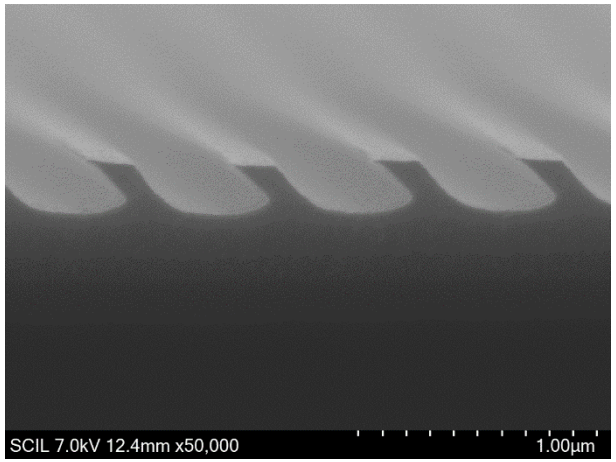
SCIL Nanoimprint solutions

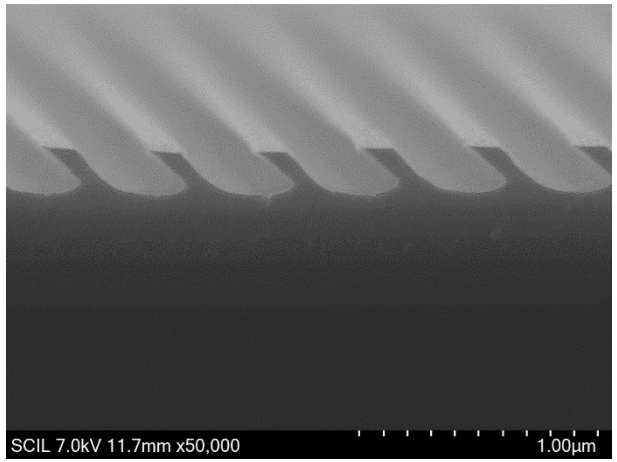
Slanted grating imprint in NanoGlass high index (n=1.8)

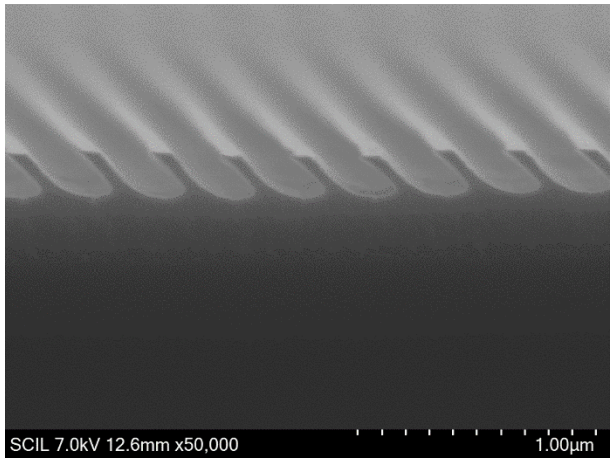












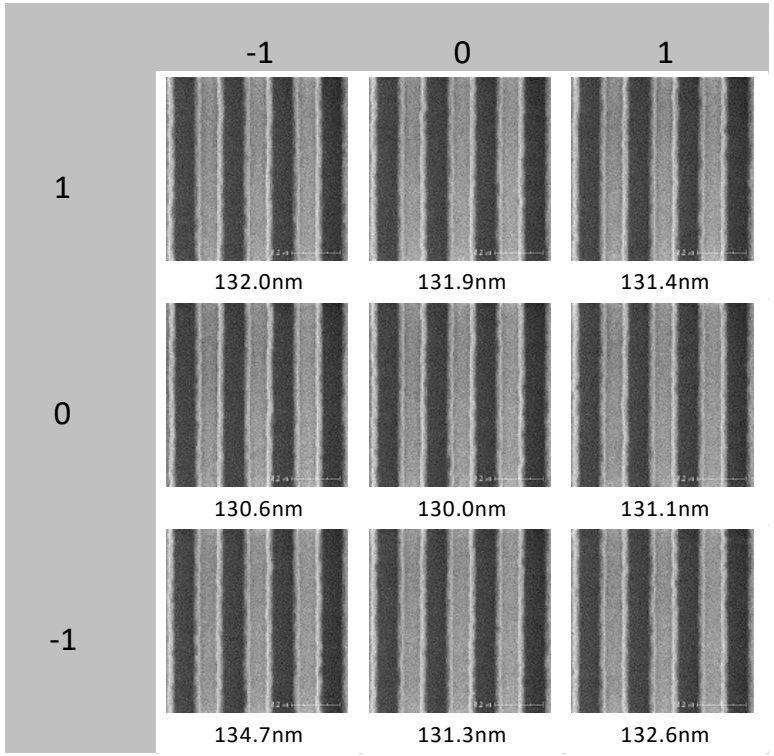
Period: 600nm 450nm 300nm

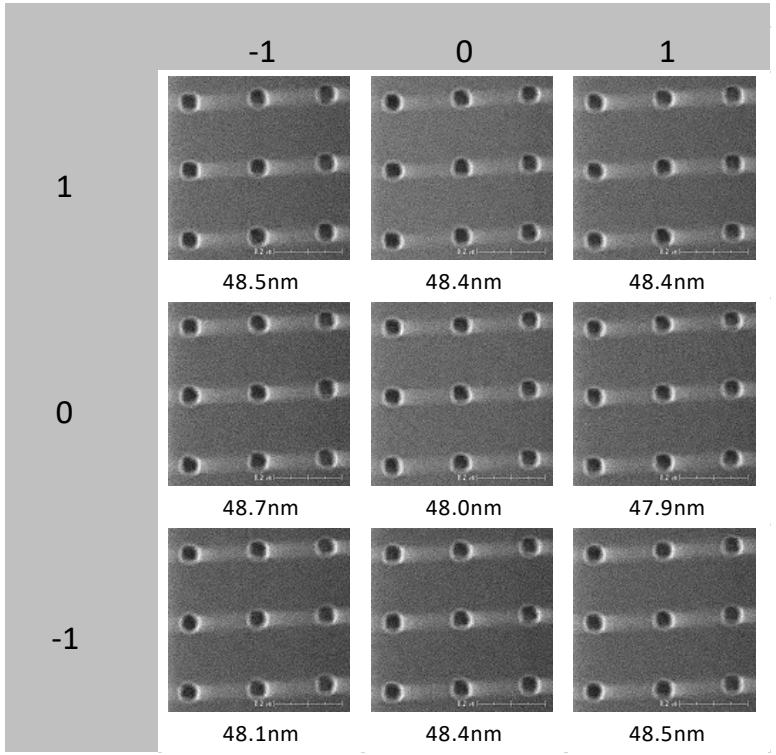
Slightly more shrinkage than T-1250, developments to reach n> 1.8

Pattern uniformity evaluation

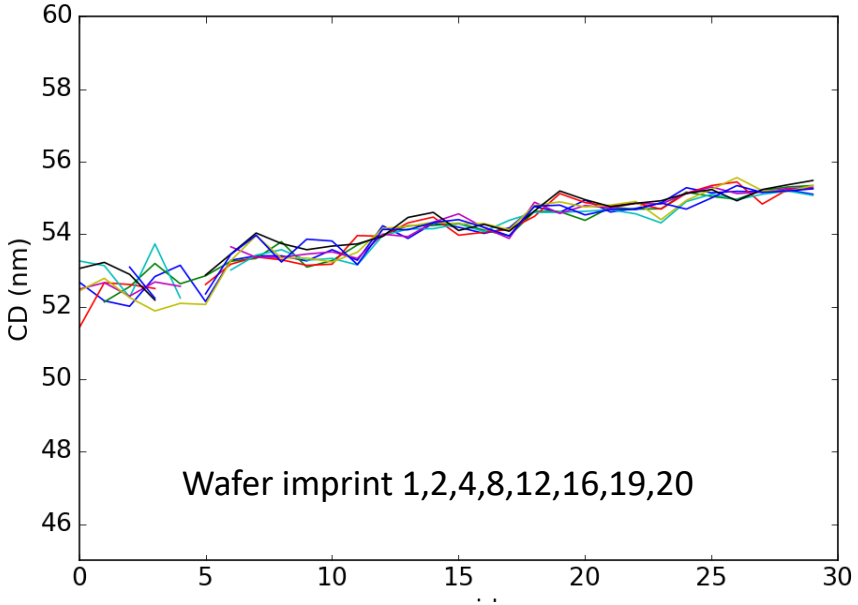
CD-SEM pattern evaluation in cooperation with CEA / Leti

- Single, dense, ~40nm to micro's
- Hole arrays 52nm diameter, 120nm deep
- Imprints 1 through 20 of 3^{e} X-PDMS stamp from the master → ~1nm variations





Hole diameters comparison



29 different hole diameters on the master

SCIL Nanoimprint solutions

Conclusions

- SCIL provides NIL based high volume production solutions up to 300mm (2020 Q2)
- 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
- We work with customers from: proof of concept to pilot-volumes and transfer to high production

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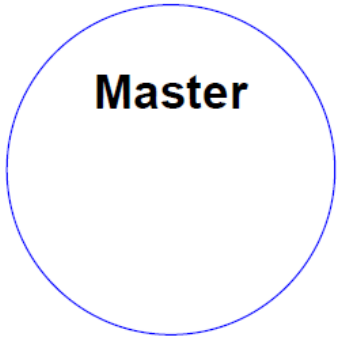
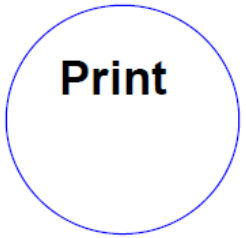
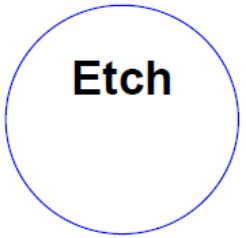
Nanoimprint solutions

Master Replication with Precision



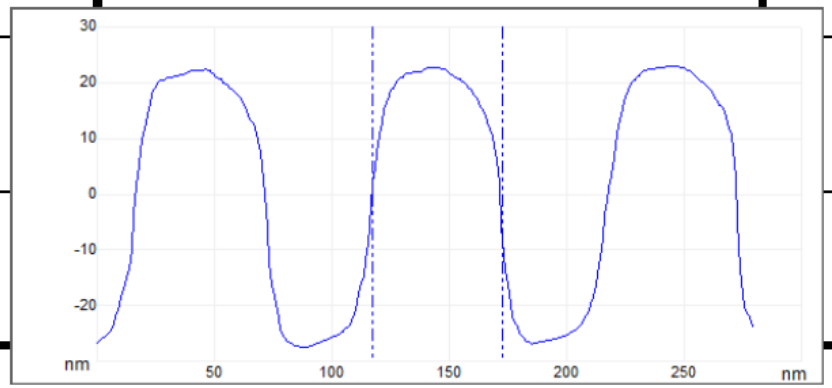


Post Etch CD Bias is etch process dependent



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

Nanoimprint solutions

Print to print variation, sub-50nm patterns

- Product performance highly sensitivity to pattern size
- There is pattern size variations in the master pattern
- We want to know the SCIL induced variation

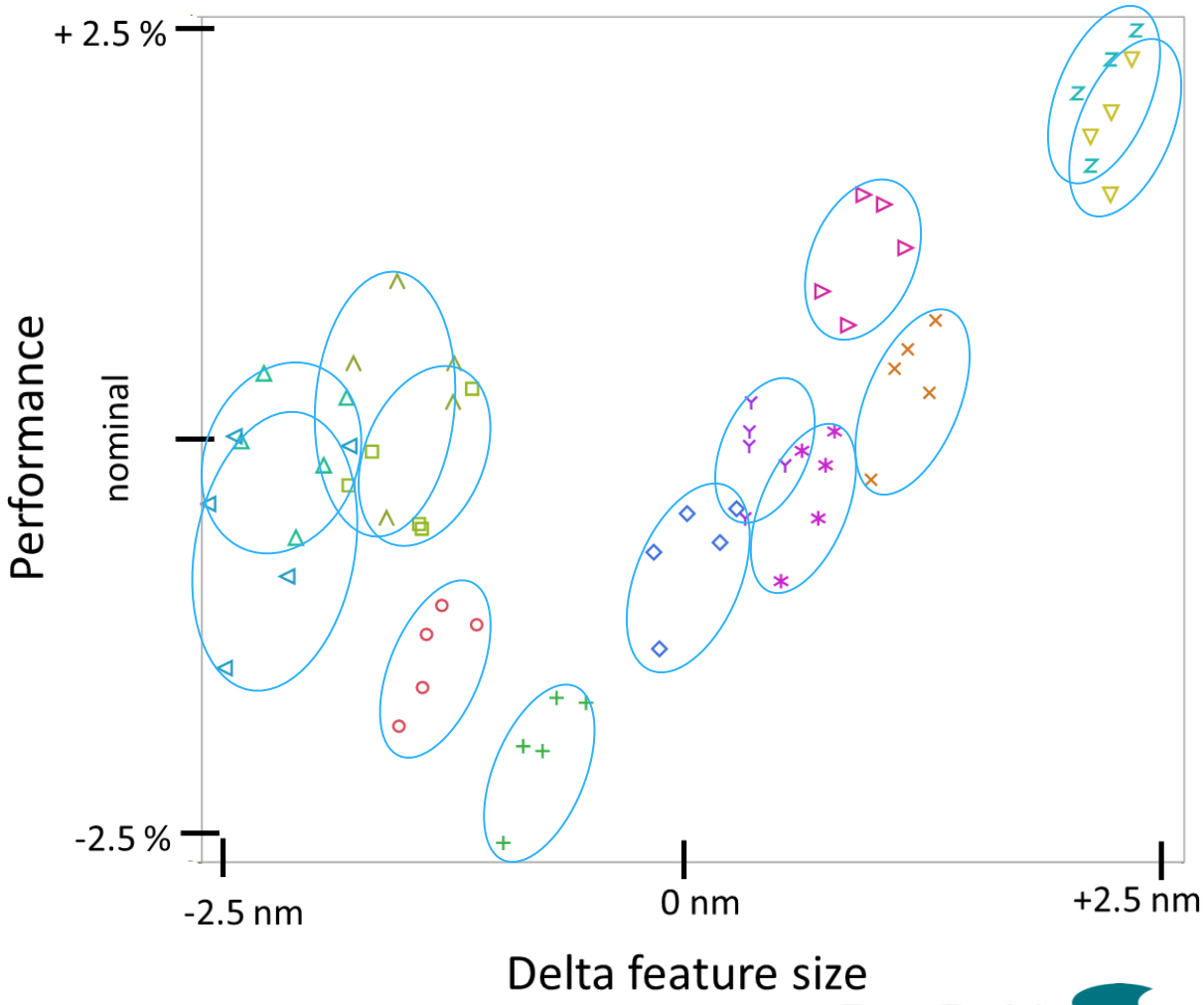
Measurements:

- 13 locations over a 200 mm wafer
- 5 imprinted wafers (from batch of 25)
- Sub-50nm patterns

Results:

- Spread is nicely grouped
- Each site is consistent
  - print to print
  - stamp to stamp

13 locations over a 200mm wafer



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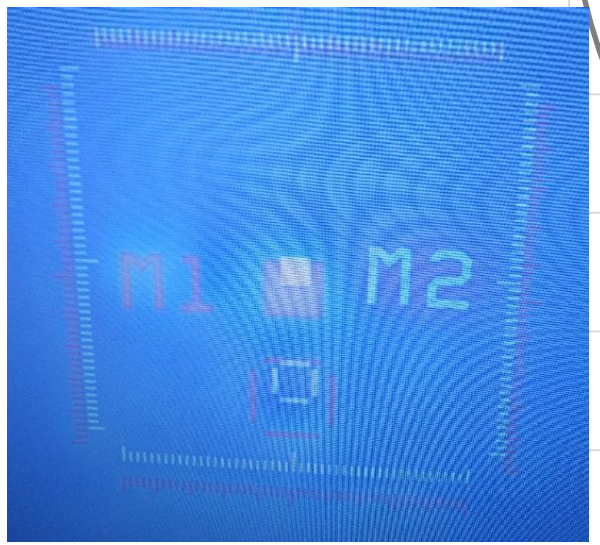
Overlay result 200mm

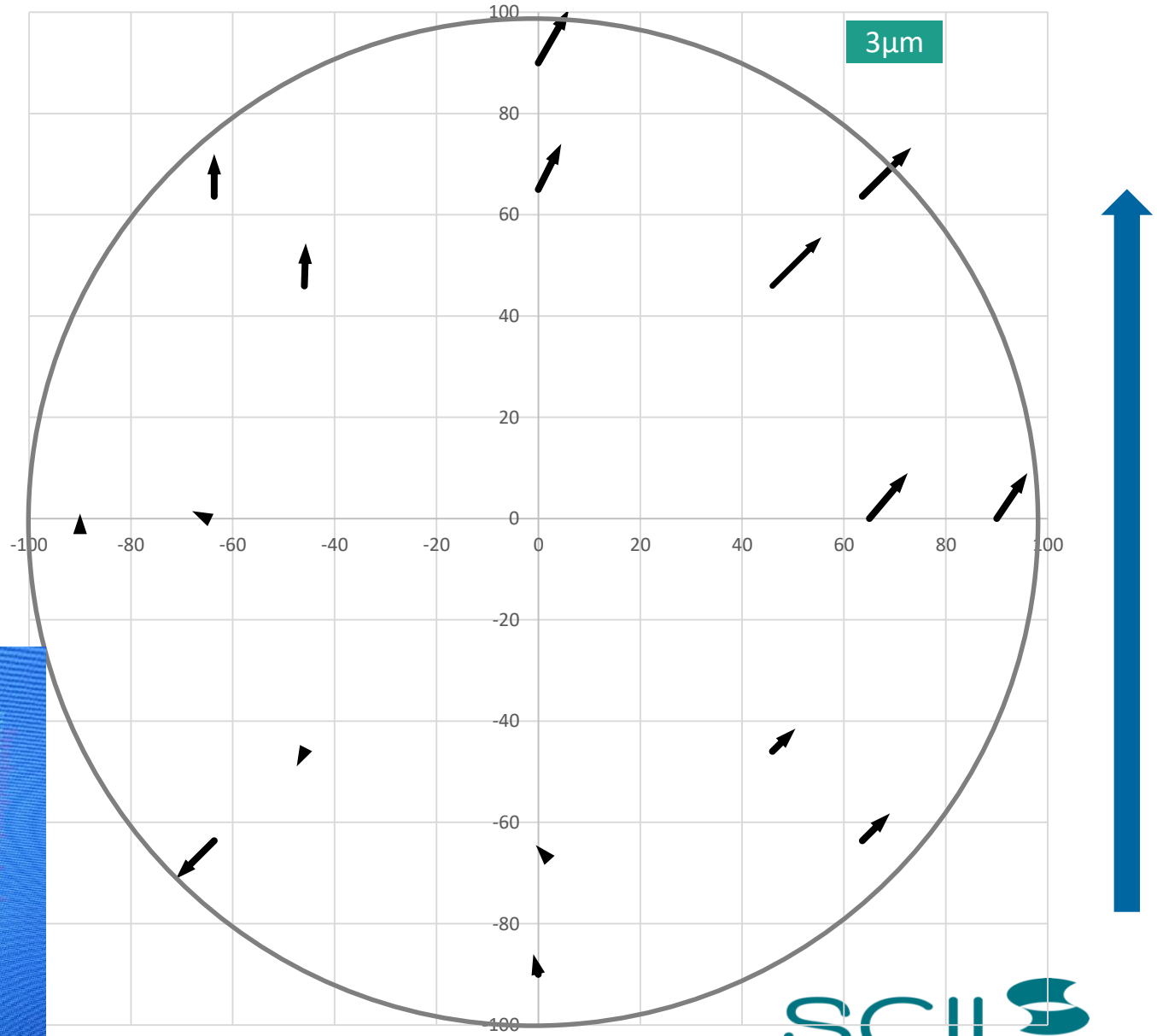
- Blank wafer
- Imprint 1st layer
- Coat with high index for contrast
- Align and imprint 2nd layer
- Used thermo cycling (worst case)

- Observation:
  - Magnification error
  - Pattern shift

- Initial results OK
- Aim to go below 1 mu

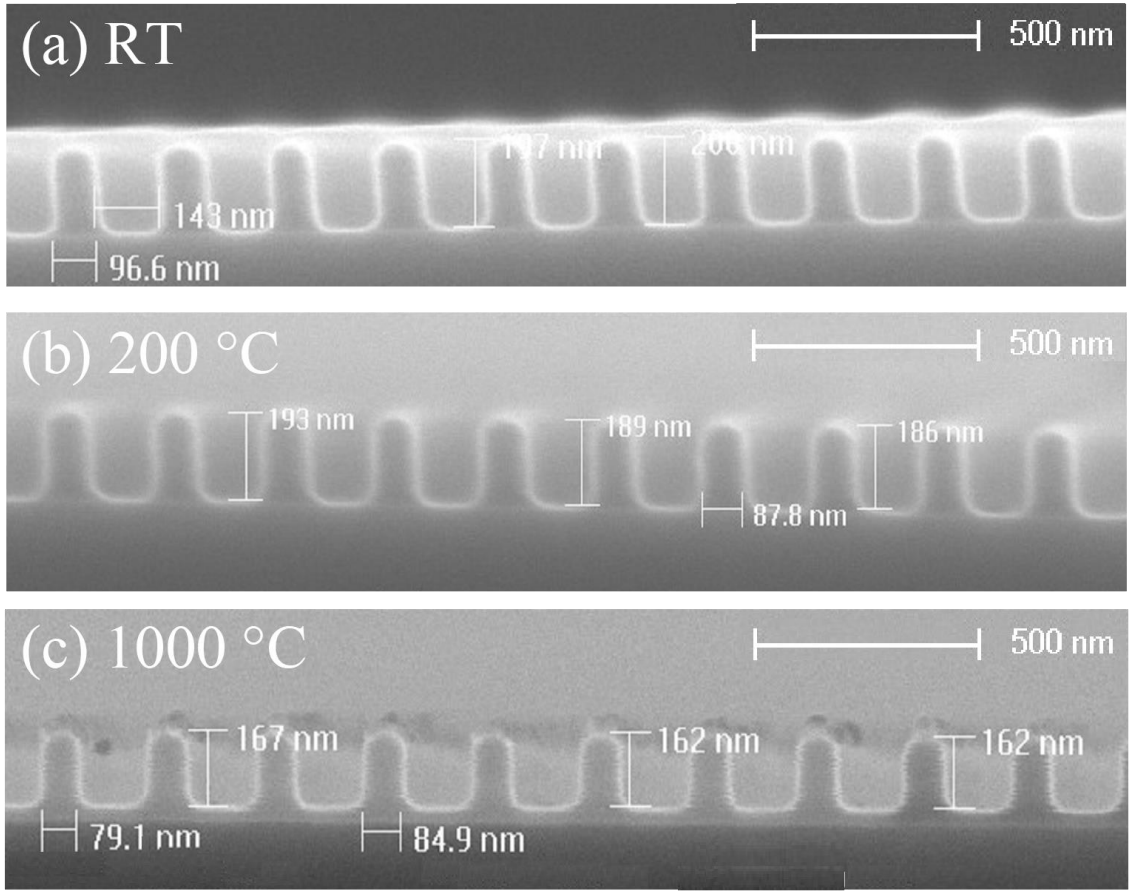


200mm wafer, 16 markers



SCIL Nanoimprint solutions

High SiO_2 density @ RT → Low shrinkage



SEM cross section of sol-gel grating on silicon

As imprinted (RT)
= 73% dense silica

200 °C =
84% dense silica

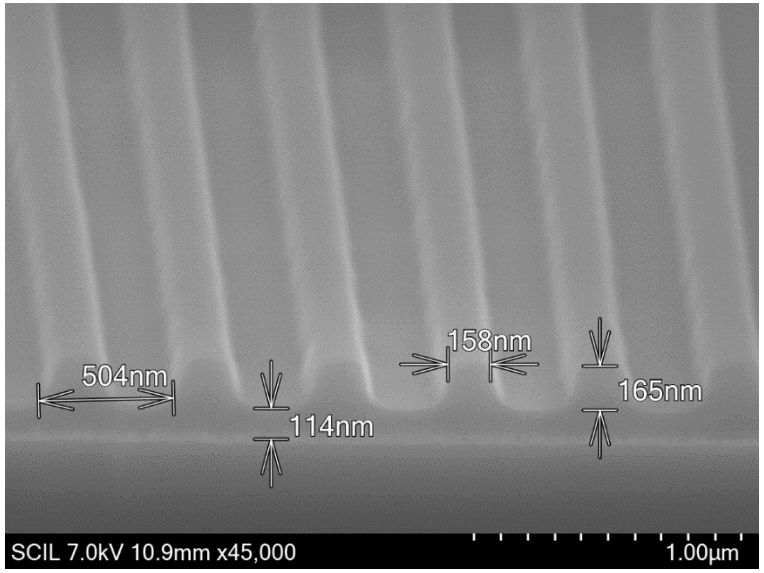
1000 °C =
100% dense silica

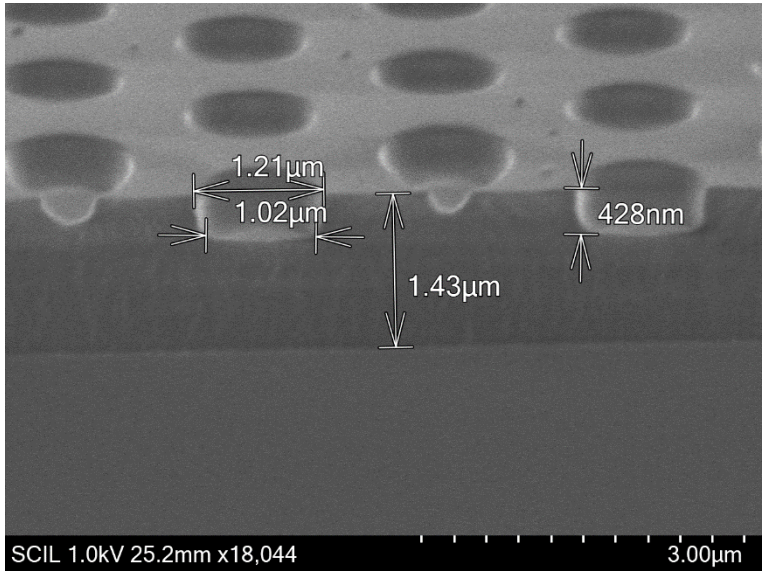
Shape retention

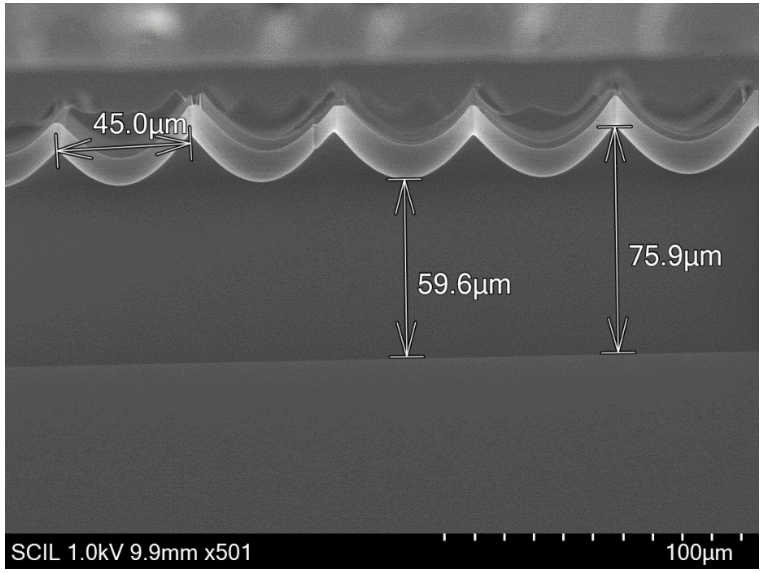
SCIL
Nanoimprint solutions

UV curing fully organic imprint resist (under development)

- Some processes require a fully organic imprint resist
- PDMS stamp compatible
- Layers from 100nm to ~50 micron
- Non-absorbing for visible light
- Refractive index ~n=1.6



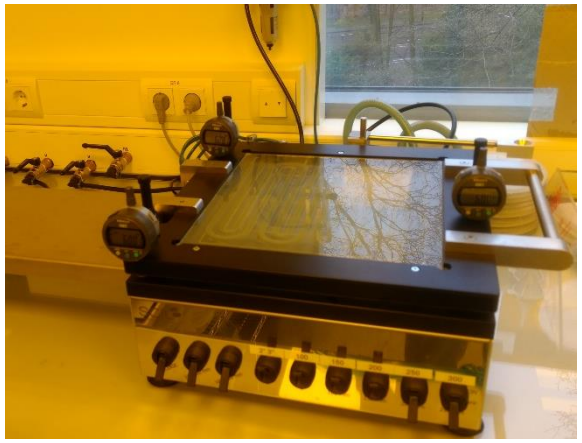


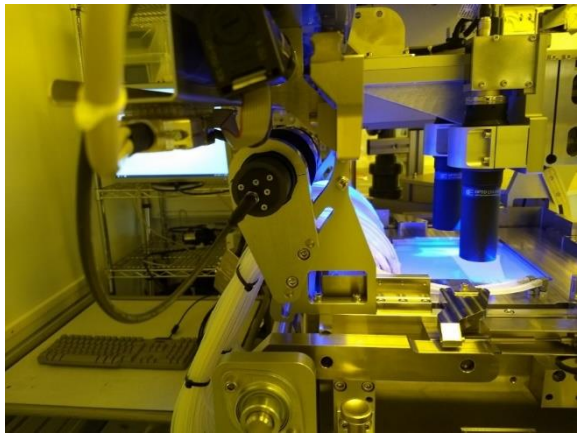


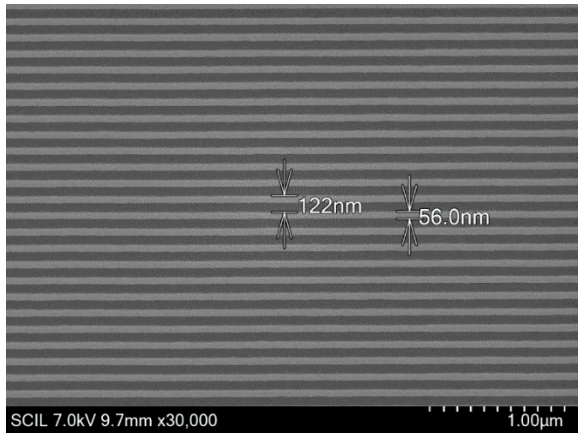
SCIL
Nanoimprint solutions

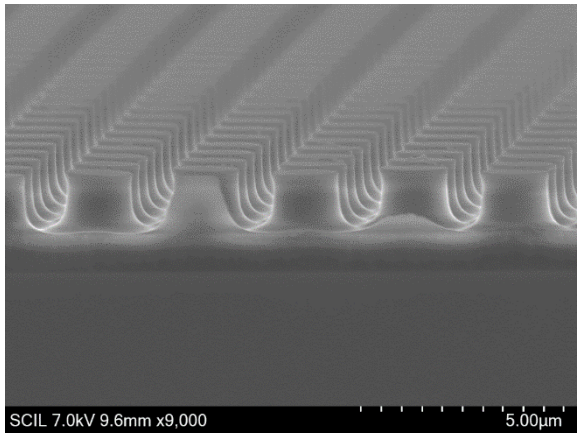
Last year achievements

- Two tools installed @ customers
  - **AutoSCIL150**: 3”, 4” and 6” wafers
  - **AutoSCIL200DS**: 200mm wafers with overlay alignment
- Equipment development:
  - **LabSCIL200**: Stand alone 200mm imprint tool
  - **AutoSCIL300**: 300mm SCIL tooling
- Stamp manufacturing
  - Semi-automatic tooling available from now
  - Started development of fully automatic tooling
- Wafer scale overlay alignment successfully introduced:
  - Initial overlay X, Y ~1 µm (3-sigma)
  - Front-to-front and front-to-back
  - < 6 sec. for fully automatic alignment
- Materials
  - Fully inorganic, light & temperature stable
  - Low & high index
  - Silica NanoGlass thickness range increased up to 2µm

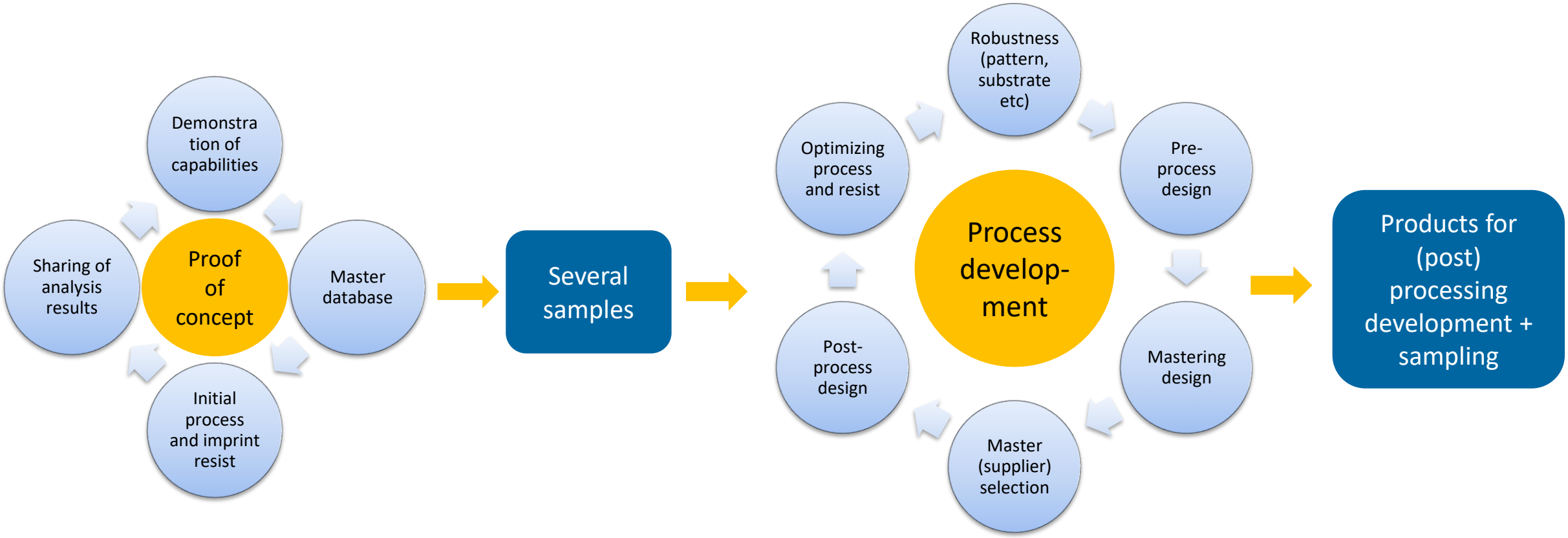








Sampling and process development



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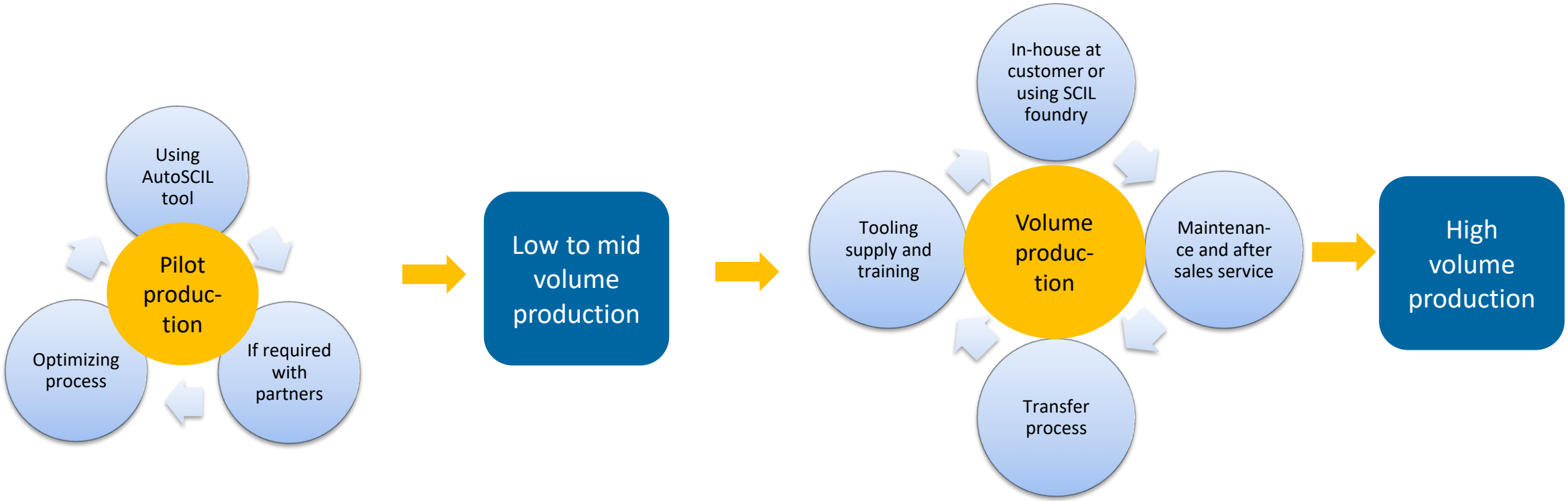
From low to high volume production



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This presentation was presented at EPIC Meeting on Wafer Level Optics 2019

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