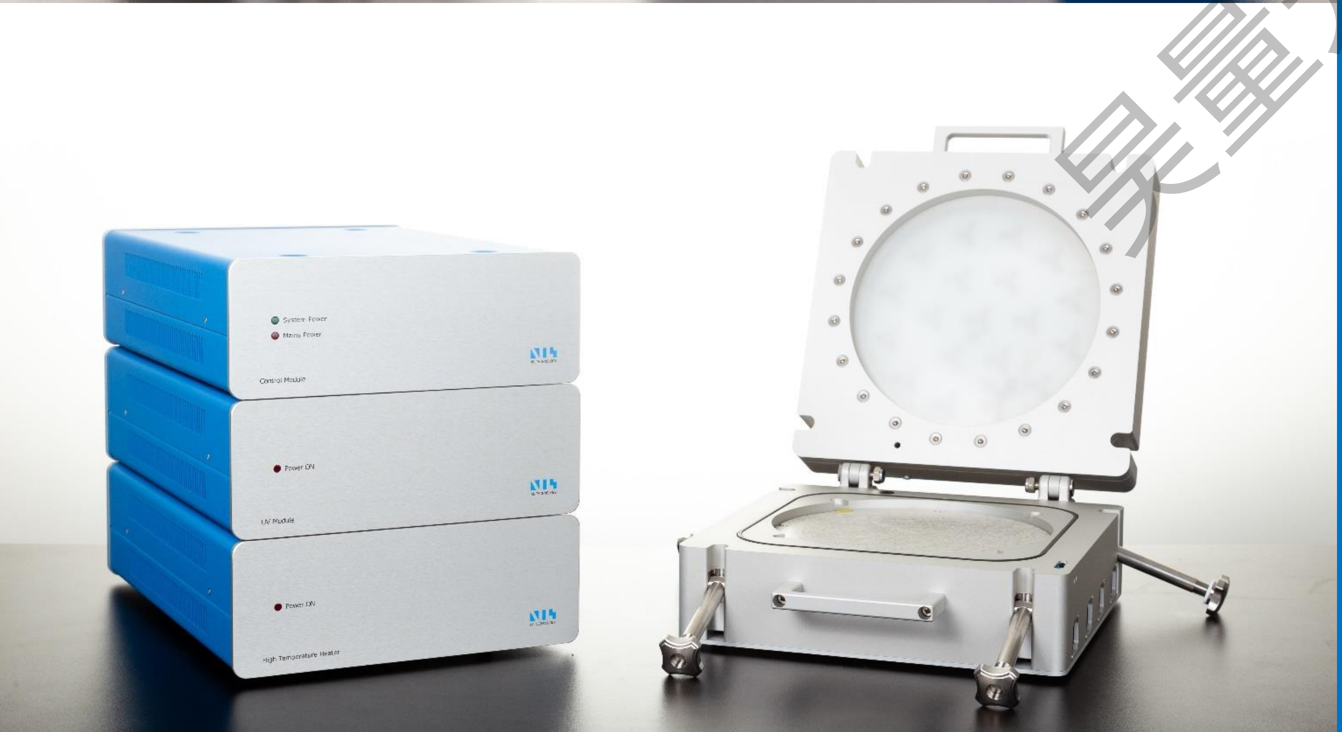

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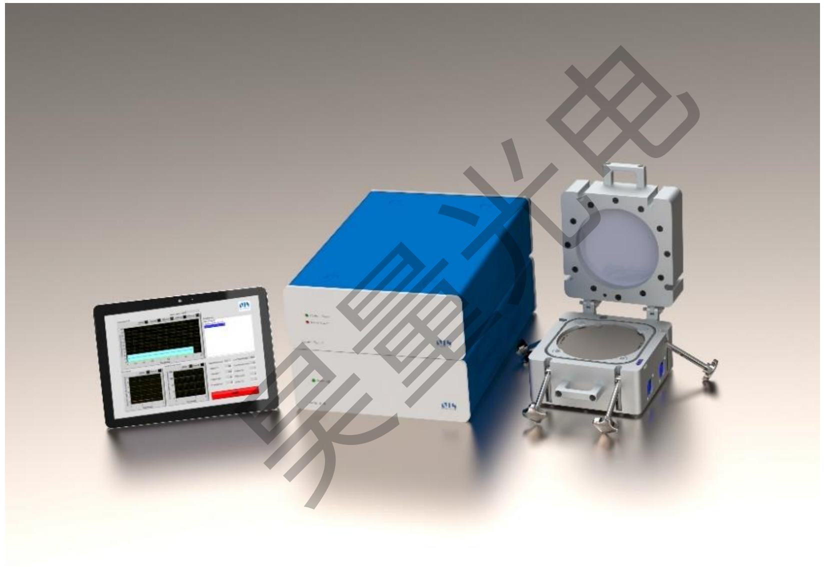
Compact Nanoimprint – CNI v3.0

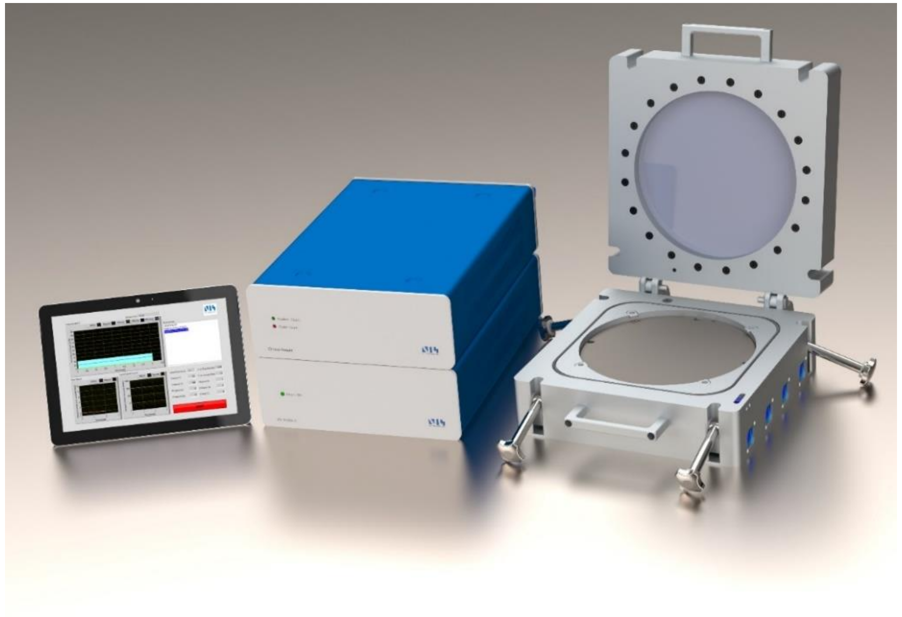
Desktop nanoimprint tool. Easy replication of micro- and nanoscale structures

CNI v3.0

Desktop nanoimprint tool. Easy replication of micro and nanoscale structures
Available chambers support up to 100 mm wafers or up to 200 mm wafers

- Nanoimprint (thermal and UV)
- Hot embossing
- Easy and intuitive operation
- Versatile usage
- Plug-and-play
- Designed for product development and R&D

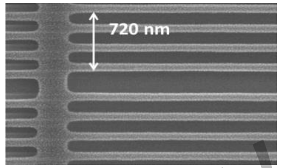
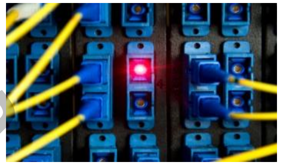
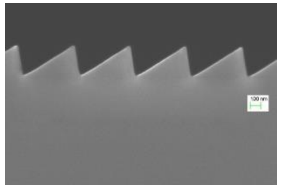
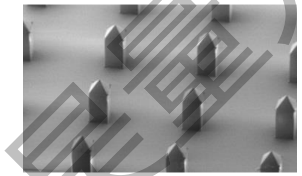
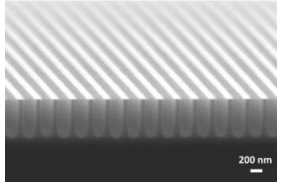
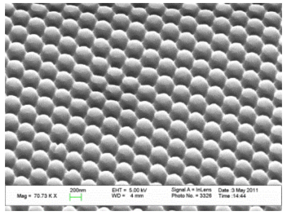




CNI tool in use (opens a youtube video)

Easy replication of micro/nanostructures

Thermal and UV imprint with no need for large and expensive tools. Due to a simple process and an intuitive user interface, operations may be carried out without any need for dedicated operating staff. Any master that fits inside the imprint chamber can be used.

Buy or make your own master/stamp	Replicate your master	Replicas with desired functionality
 Silicon stamp with 4 pillar gratings. Pitch 200-400 nm, diameter 125-275 nm.	 Replication for lithographic use.	 Lithographic structure can be used for e.g. electrical and optical devices.
 Blazed gratings - Saw tooth gratings	 Tilted SEM of 100 µm x 100 µm needles replicated in the CNI tool.	 Image of a COP film with embossed micro-needle array.
 High aspect ratio silicon stamp with 150 nm protruding lines with 150 nm gaps. The height of the lines is 1 µm.	 Tilted SEM of polymer repl. made by CNI using an intermediate flexible COP stamp.	 Image showing the functionality of the nanostructured polymer.

The starting point for nanoreplication

CNI is a desktop size tool for nanoimprint and hot embossing. It allows for replication of micro- and nanostructures from a master to a substrate. The CNI tool can perform thermal replication as well as UV replication.

The CNI tool is the perfect starting point for nanoimprint, but it also supports mature and advanced development work. The CNI tool is simple to operate, it is robust and facilitates non-standard processes and new experiments.

Easy to install	Plug and play in less than 20 minutes
Excellent	With its thermal and UV replication capabilities, in vacuum if needed, the CNI tool is unique in its offering and supports many different technologies and processes
Easy to use	Everyone can use it! (You will probably never read the manual)
Compact size	26 x 30 x 14 cm (size of 120 mm imprint chamber) 42 x 44 x 14 cm (size of 210 mm imprint chamber) 1 touch computer
Attractive offer	CNI is compact and has no need for fixed installation
High quality imprints	Capable of replicating structures from smaller than 40 nm to structures larger than 100 µm
Versatile	You can work with any size of stamp and substrates up to 210 mm (8”) round formats
Support	We assist our clients in obtaining good results, offering individual support with focus on your processing needs.

CNI v3.0 | Features

- A desktop size nanoimprint tool
- Thermal NIL up to 250°C
- UV NIL @ 365 nm (or 405 nm – custom option)
- Imprint pressure from 0.3 to 11 bar
- Imprint in vacuum (1 mbar)
- Stamp and substrate size: Up to 210 mm (8-inch) diameter
- No fixed format for stamps and substrates
- Robust and simple to use
- Manual load and unload of stamp and substrate
- Automatic process control
- Easy to operate software interface
- Logging of all recipes and processes

CNI v3.0 supports many different technologies

- Thermal nanoimprint
- UV nanoimprint
- Hot embossing
- µ-contact printing
- Polymer bonding

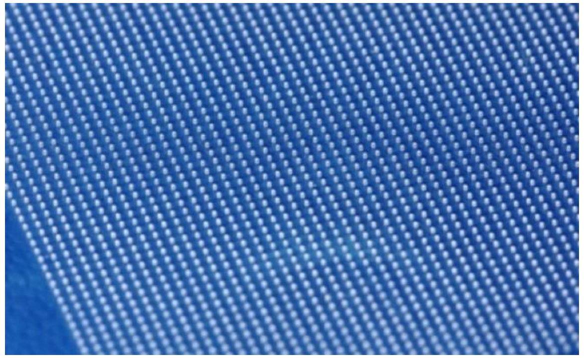
Examples of use include

- Imprint of nanostructures
- Imprint of microstructures
- Imprint of gratings with nm pitch on silicon
- Imprint on fragile substrates (e.g. III-V materials, InP)
- Production of working stamps
- Hot embossing of high aspect ratio structures
- Hot embossing of polymer sheets
- Thermal polymer bonding

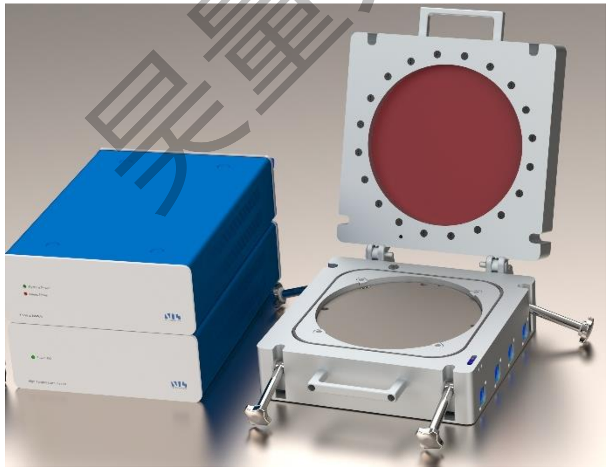
CNI v3.0 | Features

Stamps and substrates

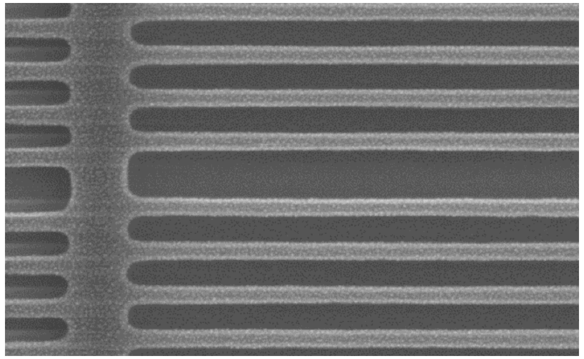
- The stamp and substrate can have any shape and size up to 210 mm (8-inch) diameter. No requirement that stamp and substrate has same size and shape.
- The stamp and substrate can have a total height of up to 20 mm.
- CNI v3.0 has been tested with many materials including: mr-I 6000, mr-I 7000, mr-I 8000, mr-I 9000 series, SU8, BCB, Topas8007,Ormostamp, DELO OM4310, DELO OM614, Topas5013, COP (Zeonex 480), polycarbonate, PEN, PET, ABS, mr-I XNIL26 (UV resist), and mrNIL210 (UV resist)



Pillar master stamp replicated in COP by CNI. 100 x 100 µm pillars.



The CNI tool



Replication of gratings for photonic applications.

CNI Modules and options

Modules

- Imprint chamber (stand alone)
- Control Module with vacuum option
- High Temperature Module
- UV Module

Auxilliary

- Touch computer with pre-installed software
- Heating Element called a Stamp Carrier (SC)
- All necessary cables and tubing
- The tool comes with standard recipes
    - Hot embossing in c
    - Thermal nanomprint in mr I-7000, mr-I 8000
    - UV nanoimprint in mr-I XNIL26, and mrNIL210
- Installation and operation manual and on-line videos

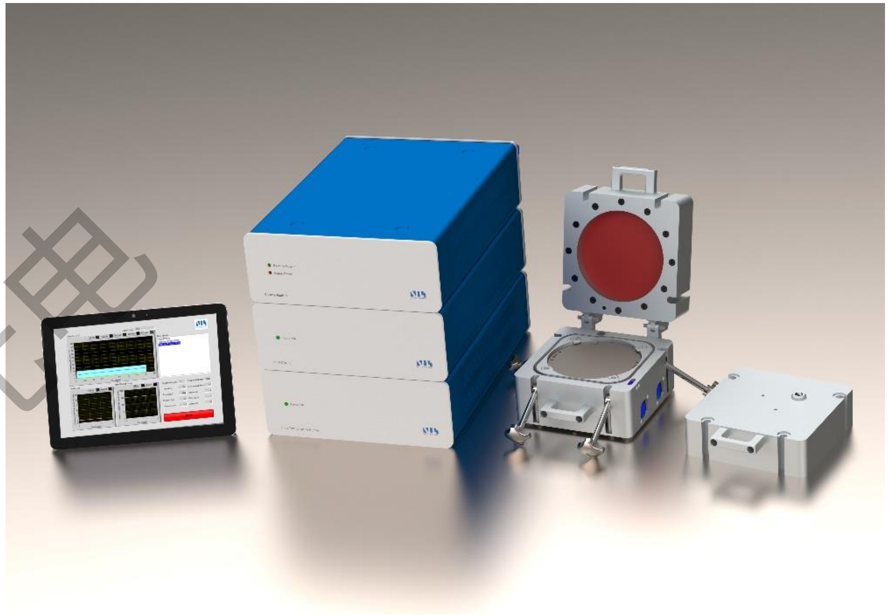
Consumables

- Topas 8007 film with thickness of 0.14 mm (10 pcs)
- Teflon (spacer) sheets with thickness of 0.1 mm (10 pcs)
- Test stamp (www.nilt.com/707/micro-test-standard-stamp) with anti-sticking coating (www.nilt.com/467/anti-sticking-coating)
- Resist starter package from micro resist technology

Custom orders may differ from our suggested starter kit

CNI v3.0 | High temperature option

- The high temperature option consists of:
  - Additional lid for the CNI chamber. The additional lid contains a high temperature membrane, which is not UV transparent.
  - Switching from the high temperature lid to the UV-transparent standard temperature lid is as easy as loosening and fastening two screws.
- The high temperature lid allows for processing up to 250˚C
  - Bonding with a wide range of polymers including BCB, PMMA, and Topas.
  - Hot embossed polymer sheets with high glass transition temperature can be used as working stamp in CNI for both UV and thermal imprint



Same compact form factor as a 200 ˚C CNI

CNI v3.0 | Configurations

A CNI for every set of needs:

- There are many options to choose from when you configure your CNI
  - Chamber size
    - 120 mm or 210 mm round
  - UV source and wavelength
    - None, 365nm, and/or 405nm
  - Heating
    - None, 200°C or 250°C maximum temperature
- NILT will happily help you choose your configuration

Different configuration options:

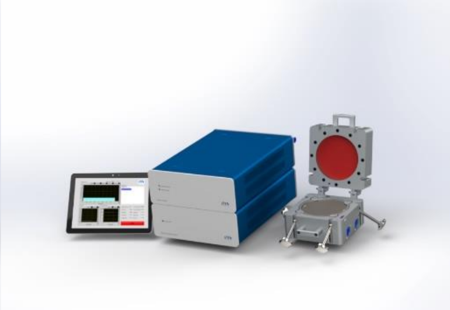
- Heater setup - 210 mm chamber and 120 mm chamber

  Consist of a touch computer, a control module, a high temperatur module and a chamber either in 210 mm or 120 mm
- UV setup – 210 mm chamber and 120 mm chamber

  Consists of a touch computer, a control module, a UV (365 or 405 nm) module and a chamber either in 210 mm or 120 mm
- Full package – 210 mm chamber or 120 mm chamber with lids for both high temperature and two different UV wavelenghts

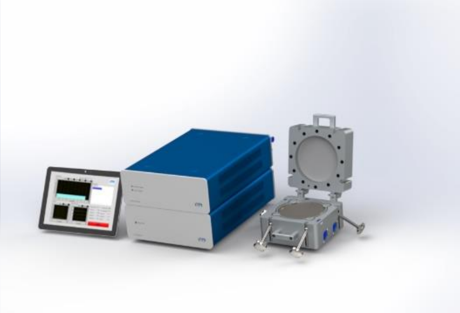
  Consists of a touch computer, a control module, a High temperatur module, a UV module, a chamber either in 210 mm or 120 mm with lids for both heater setup and two UV wavelengths

Heater setup 210 mm

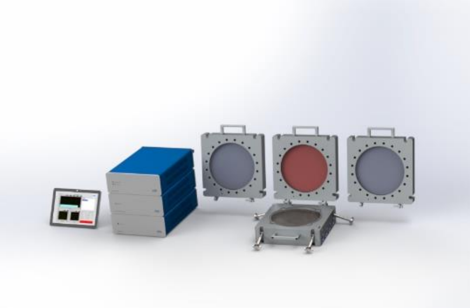


Heater setup 120 mm

UV setup 210 mm



UV setup 120 mm



Full package 210 mm

Full package 120 mm

CNI v3.0 | Consumables

Topas 8007

The Topas 8007 is 0.14 mm thick and hand cut to app. 4-inch round format. We deliver 10 pieces. This film can be used to imprint into – and it can also be used as a working stamp material

Teflon sheets

The teflon sheets have a thickness of 0.1 mm and come in a box with 10 pieces. We recommend to use the Teflon sheets between the top of your imprint stack and the membrane. The Teflon sheets can also be used between the ceramic stamp carrier (i.e. the heating element) and the bottom of the imprint stack. The general purposes of the Teflon sheet is to protect the samples from mechanical stress and avoid contaminating the membrane with resist.

CNI v3.0 | Requirements

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Technical requirements at installation site

- Compressed dry air or nitrogen pressures of 6-11 bar with outer diameter Ø 6 mm connector. Flow should be at least ½ standard L/min
- Vacuum better than 0.1 mbar in Ø10 mm outer diameter connector (if you want the full benefit of the vacuum option)
- Power of 110-240V (50-60 Hz, larger than 200 W)

Environment

- CNI shall preferably be installed in clean, dust- and particle free environment to achieve an optimal result
- Operating temperature range: 10°C to 35°C
- Operating humidity range: 30-70%

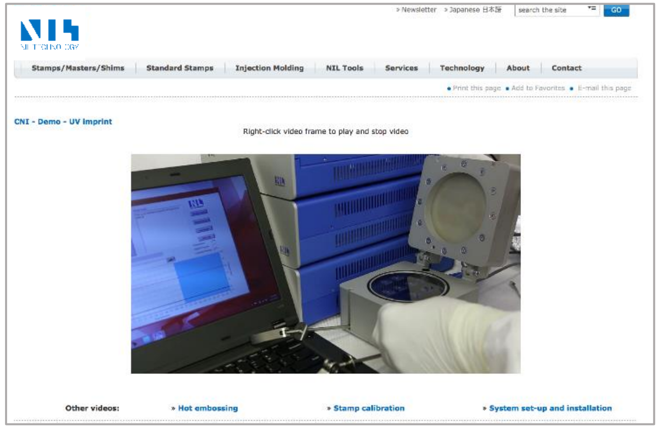
Other

- Pressure booster: If your lab cannot supply at least 6 bar of compressed air pressure, NILT can provide a pressure booster that will double 3-5 bar to 6-10 bar.
- Vacuum: NILT recommends Edwards nXDS6i dry scroll vacuum pump. Any other pump with similar or better specs should work as well.

Videos | Installation & training

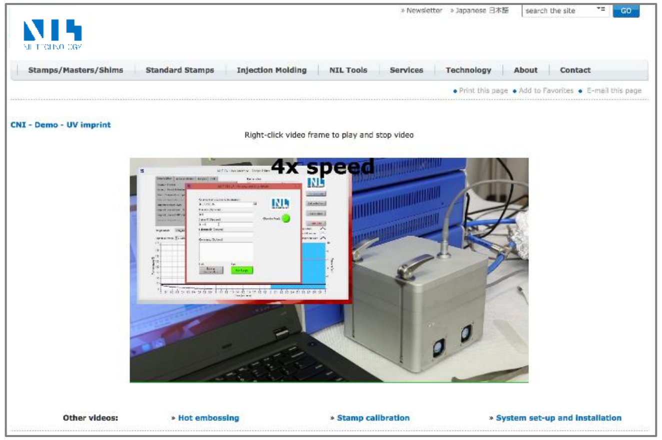
Installation

- The CNI v3.0 tool is very easy to install. Make sure to have your lab ready (see page 11) with compressed air, vacuum and electricity – and you are up and running soon after the CNI v3.0 box has arrived
- NILT supplies an on-line step-by-step installation video. You will be guided through the installation process. Of course, NILT’s dedicated team is always ready to support you before, during and after the installation
- It is possible to see the installation process video before ordering or before the tool arrive in your lab. This way you will feel comfortable with the process



Training

- We offer training videos which shows how most common imprints and maintenance tasks are performed
  - Hot embossing
  - UV imprint
  - Replacing and calibrating the stamp carrier that serves as replaceable chuck, heat element and temperature sensor



Videos are available upon request prior to ordering CNI v3.0

CNI v3.0 | Specifications

Pressure

- Imprint pressure from 0.3 - 11 bar overpressure

Temperature

- Up to 250 °C with control of +/- 1 °C

UV exposure

- UV led light with 365 and/or 405 nm wavelength and optical power of 12 W in the 120 mm chamber, ~100 mW/cm^2 or 57 W in the 210 mm chamber ~165 mW/cm^2.

Vacuum

- The imprint chamber can be evacuated down to pressures ~1 mbar

Size of imprint chamber

- Diameter of 120 mm and height of 20 mm (can be expanded up to 45 mm)
- Diameter of 210 mm and height up to 20 mm (no expansion possible)

Automated replication process

- Stamp and substrate are loaded manually
- Replication process is fully automated and controlled through CNI software

Software

- Full process control and flexibility. Everything besides loading and unloading is handled by the software

CNI customization

- CNI can be modified to meet individual requirements

On-line video instructions

- On-line video installation and operation guides

Optional

- Pressure booster to boost a lab compressed air supply from 3-5 bar to 6-10 bar
- On-site training and/or installation by NILT personnel

Technical details

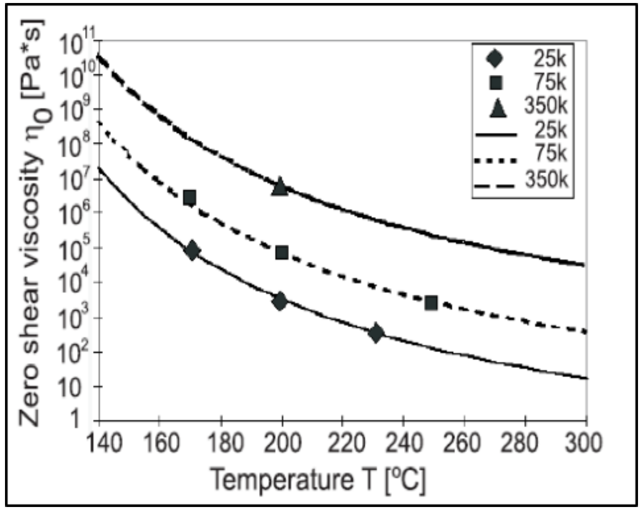
Well-understood principles

Thermal mode

- CNI supplies enough pressure to make intimate contact between stamp and substrate. We rely on accurate temperature control for controlling the imprint process
- The time it takes to imprint a cylindrically shaped protrusion with radius, R, is inversely proportional to the imprint pressure and proportional to the zero shear viscosity η_0. Viscosity decreases an order of magnitude for every 10 degree temperature increase. Therefore, temperature is a much more powerful way to control the imprint process compared to pressure

UV mode

- UV resists are typically much less viscous than thermal resists and the approach in the CNI is to flood exposure the entire chamber with UV light to cure the resist
- For the Stefan equation to the right, t_f is the imprint time, η_0 is zero-shear rate viscosity of polymer, R is protrusion radius, F_{pr} is the force on the protrusion, h_f is the final polymer thickness, and h_0 is the initial polymer thickness.



Zero shear viscosity, η_0, for PMMA at different molecular weights as function of temperature, T.

$$t_f \cong \frac{3\pi\eta_0 R^4}{4F_{pr}} \frac{1}{h_f^2}, \quad h_f \ll h_0$$

Stefan equation describing the squeeze flow of polymer in the imprint process below a cylindrically shaped protrusion.

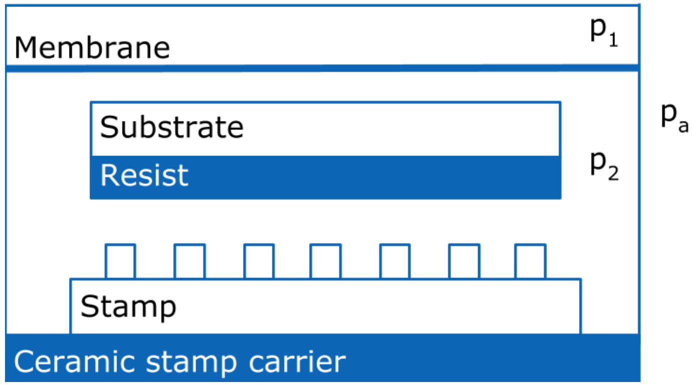
CNI v3.0 | Pressure

The CNI tool allows for accurate control of imprint pressure and gas pressure in the imprint chamber. The tool allows for imprint pressures of less than 1 bar which is unique compared to other tools.

In the CNI tool two pressures can be individually controlled:

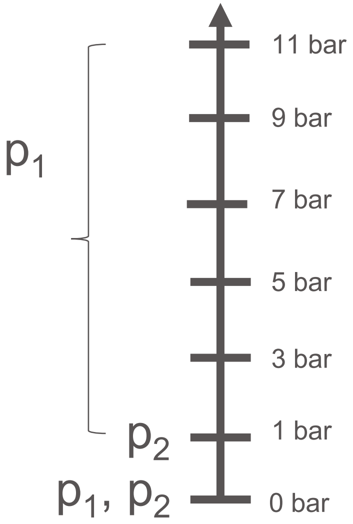
- The force pressure, p_1
- The chamber pressure, p_2
- The imprint pressure is the difference between these two

Both pressures are referred to as pressure above absolute vacuum.



- In CNI the pressure are controlled in the following manner:
- Vacuum can be on or off, so the chamber pressure is either close to 0 bar or 1 bar.
- The force pressure can be 0 or anything between 1 and 11 bar with a precision of 0.1 bar.
- With ambient pressure (1 bar) in the chamber imprint pressures between 0* and 10 bar can be obtained.
- With vacuum (~0 bar) in the chamber imprint pressures between 1 and 11 bar can be obtained.

* We recommend imprint pressures > 0.3 bar. Lower settings yield insufficient quality.



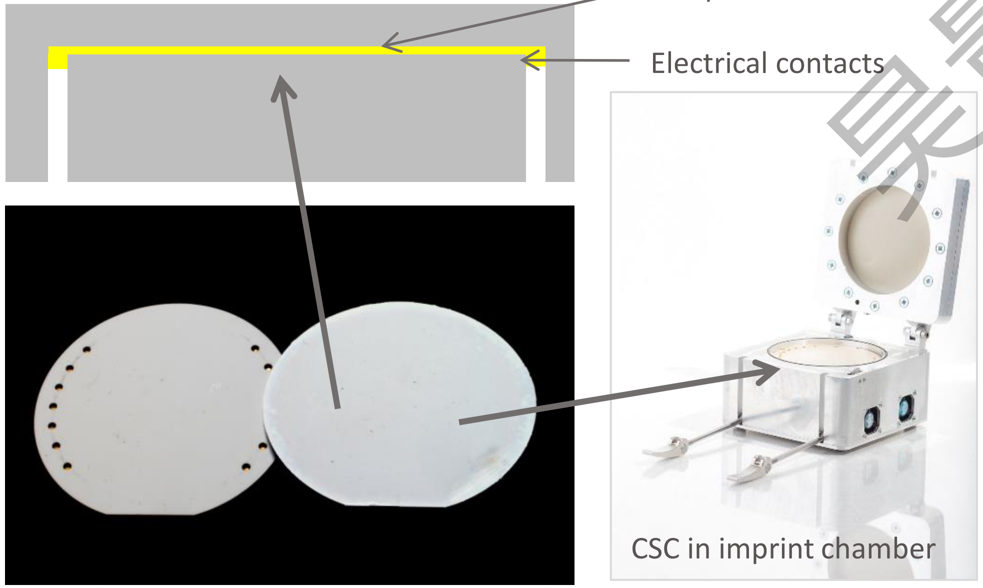
CNI v3.0 | Temperature

Temperature is controlled by use of an exchangeable heating element that provides **in-situ real temperature data** close to stamp and substrate. We call this heating element a Stamp Carrier (SC).

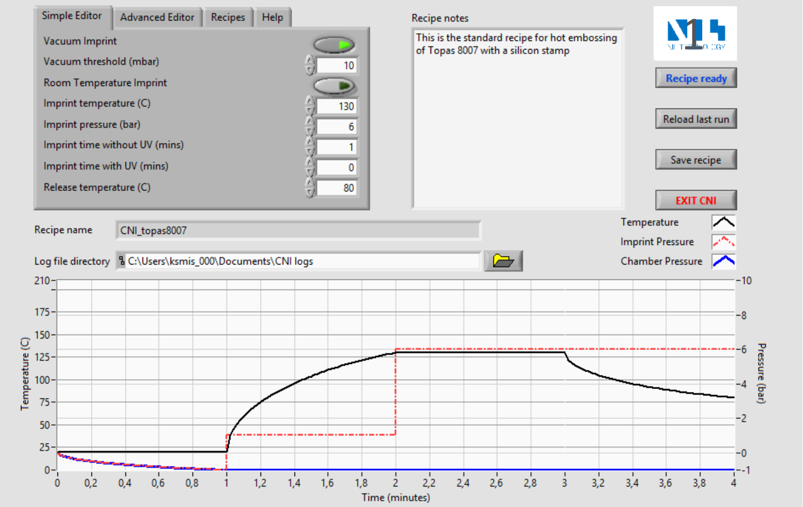
The Stamp Carrier is an integrated hotplate and temperature sensor with **very small thermal mass**. The small thermal mass of the heater ensures fast heating and cooling and the stamp carrier is designed to secure high temperature uniformity.

Over time, a heating element in any imprint tool will sustain many small damages (scratches, dents, etc.). At some point these small damages will impede the temperature distribution and negatively affect the imprint quality. **The exchangeable heating element will allow for easy replacement**, or one can even have one element reserved for critical work on one specific type of substrate and another heating element for more experimental work.

CNI stamp carrier profile sketch

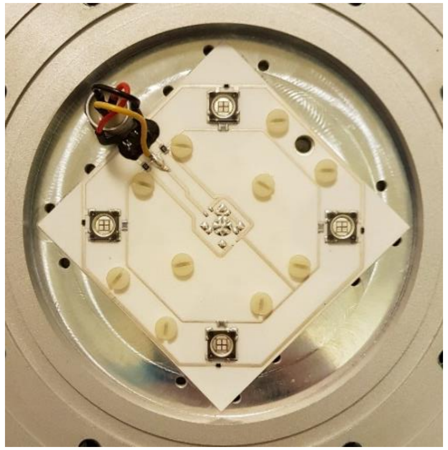


The CSC

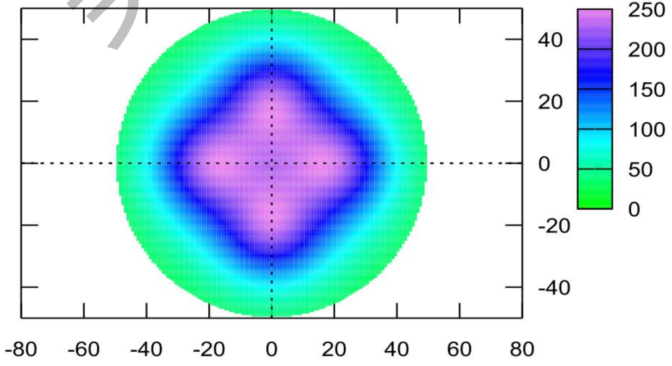


CNI v3.0 | UV exposure

- 4 LEDs with combined optical power of 11.6 W (120 mm chamber, 210 mm chamber is similar)
- The LED temperature is monitored, and over heating protection is enforced. The system automatically makes sure the exposure dose is correct, even if overheating occurs
- Peak wavelength 365 nm or 405 nm
  - Output < 10% of peak at wavelengths < 355 nm or > 385 nm for 365 nm option
- The UV power is everywhere >10% of maximum power
- The system does UV and thermal nanoimprint as well as combined UV and thermal nanoimprint
- No tool change is necessary to switch between UV and thermal nanoimprint. The tool is always ready to do both*.
  - *If you have the high temperature option, you have to switch to the high temperature lid to run high temperature recipes
- The surface plot below shows the theoretical power distribution in mW/cm2 on a Ø100 mm wafer.
- On the right is the power spectrum of the light



The UV leds are placed in the lid behind the membrane.



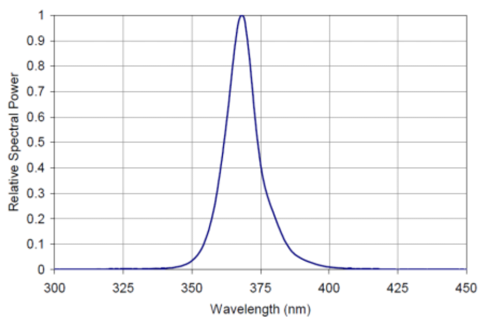
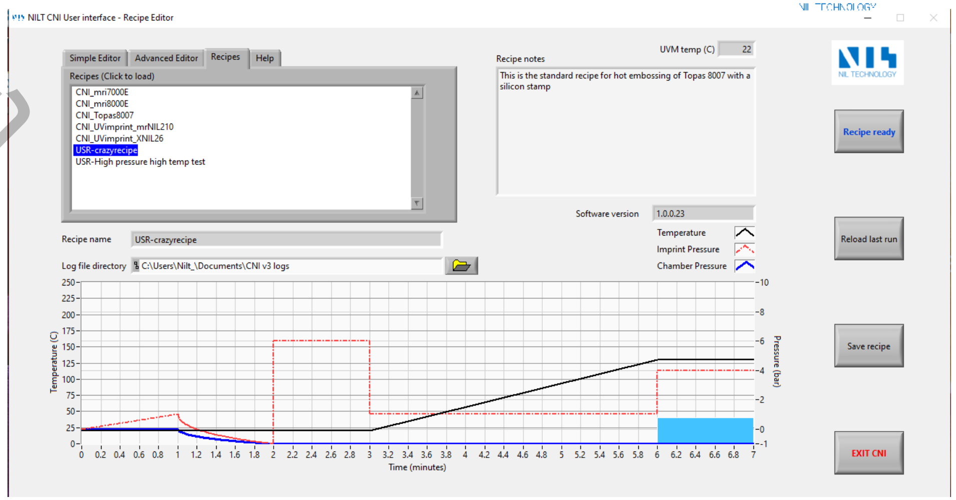


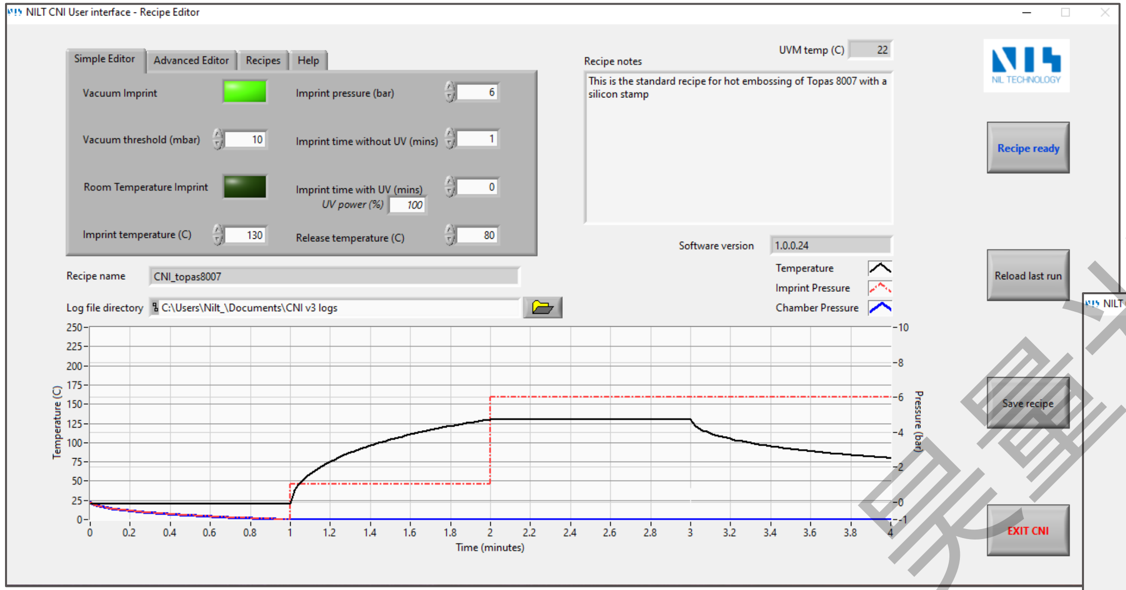
Figure 5: Relative spectral power vs. wavelength @ T_c = 25°C.

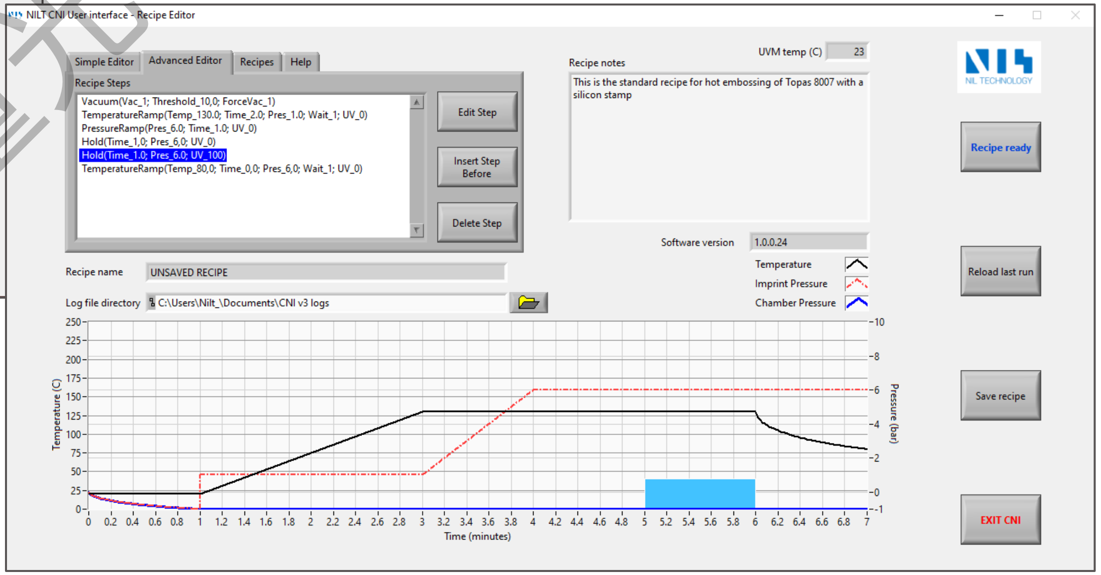
CNI v3.0 | Software

- The control software in the CNI is designed for easy and intuitive control
- The recipe editor has simple and advanced modes. Simple mode accommodates most imprint processes. Advanced mode lets the user be infinitely creative
- In the simple mode the recipes follow the structure of most common imprint recipes.
- In the advanced editor the user gets full control of all steps and parameters of the imprint process
- All recipes' data are logged in data files together with info from a "free text field" where you can put your notes
- The software controls everything in the imprint process (pressures, temperatures, UV exposure, timing)
- The process recipes (temperature, pressure and time) are easily edited and stored in CNI software
- Full control of temperature, pressure and time steps. No limitation to number of process steps
- All processing data (temperature, pressure, time) are logged via the CNI software
- Graphical illustration of imprint pressures real-time during replication process



CNI v3.0 | Software





Examples

Nanoimprint Classic

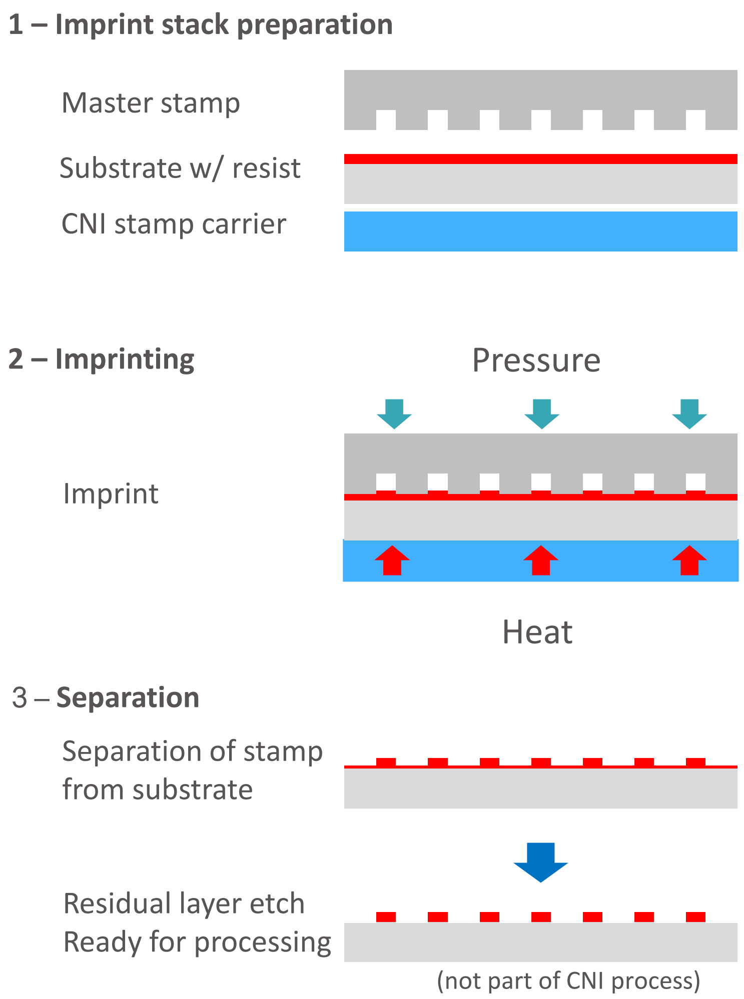
Simple and fast sample generator

As conventional photolithography reaches the feature size limits due to light diffraction and scattering effects, nanoimprint being a mechanical technique, instead relies on a 1:1 master template that is replicated in an imprinting process.

Upon acquiring your silicon, quartz, nickel, or polymer master, it can be replicated in the CNI tool using standard nanoimprint procedures:

1. Assemble the imprint stack in the tool. Stamp and substrate are put in intimate contact with each other as well as with the ceramic stamp carrier in order to get optimal thermal contact to the imprinting polymer. If substrates has different sizes we recommend placing the largest substrate in the bottom of the stack.
2. Temperature and pressure control is automatically managed during the imprint process. The flexible software interface allows for building imprint recipes with several temperature and pressure stages. Nanoimprint replicates the inverse pattern of the stamp by viscous flow of the resist due to the pressure from the protrusions. The resist will flow from beneath the protrusions into the cavities between protrusions.
3. At the end of the process, nanoimprint always leaves behind a residual layer of resist underneath the stamp protrusions. This layer must be removed before further processing (not part of CNI process).

After residual layer removal, the substrate can be further processed by regular cleanroom techniques.



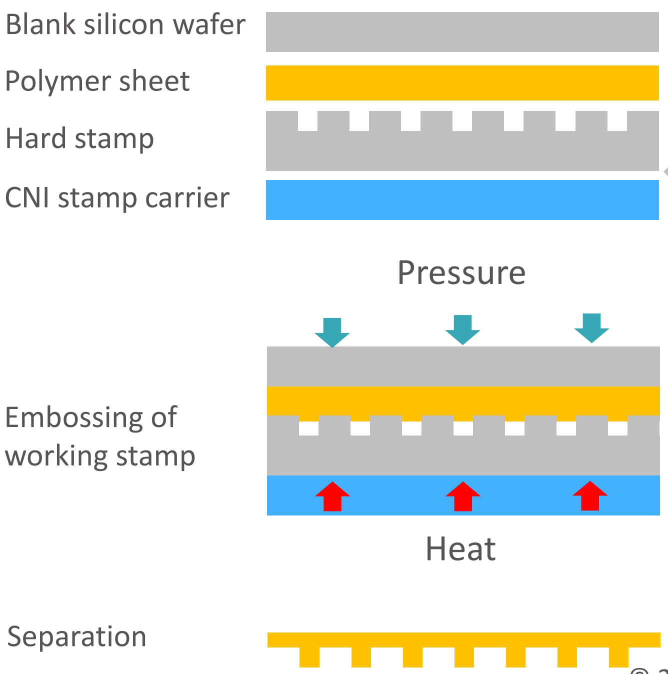
CNI core, intermediate stamps, hot embossing

Preserving the master stamp

Due to the cost associated with the fabrication of master stamps, it is often preferred to use a replica of the master in the imprint process.

The replicas are easily fabricated in the CNI tool by a hot embossing process.

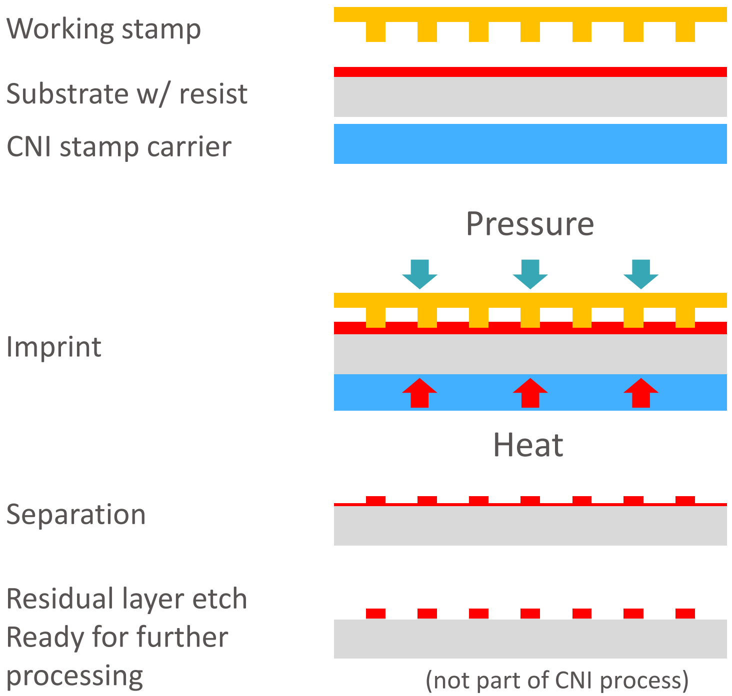
Below, a polymer sheet is simply sandwiched between a hard stamp and a blank wafer while heat and pressure are applied. After separation the polymer replica can be removed.



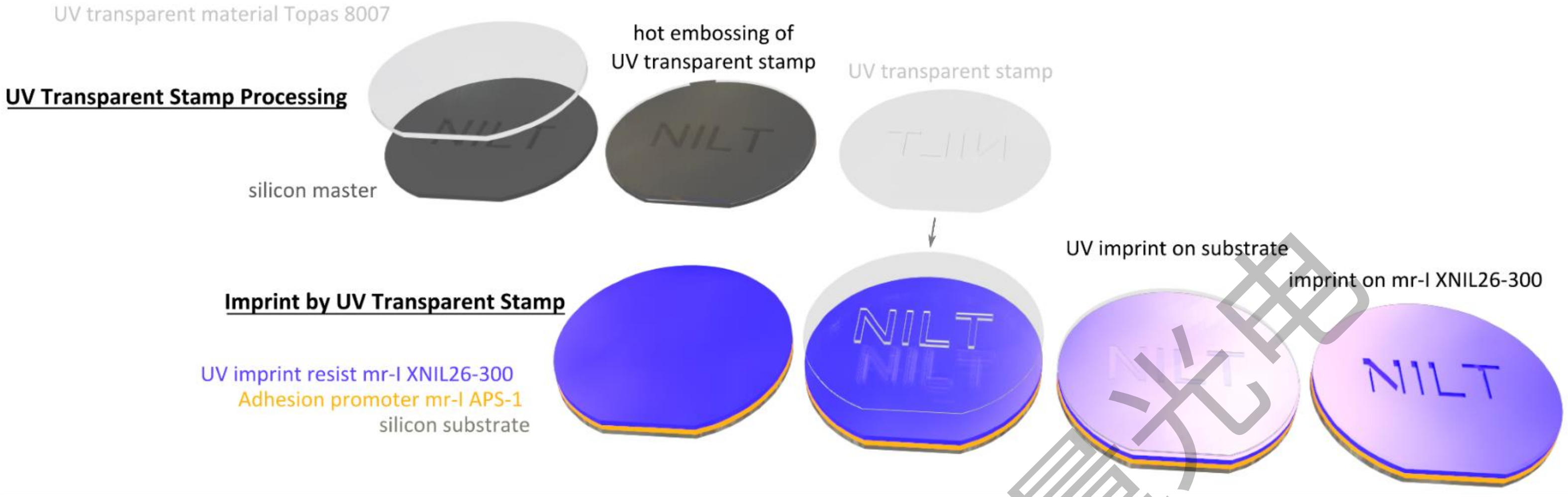
After separation you have an inverse polymer replica of the master.

The polymer replica is subsequently used for imprint processes without any risk of damaging the master.

An imprint process with a polymer replica stamp is illustrated below.



UV Imprint with polymer stamps (1:2)

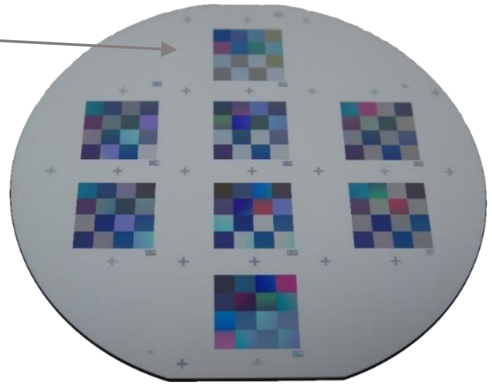


[Video of this proces
(youtube – same as slide 2)]

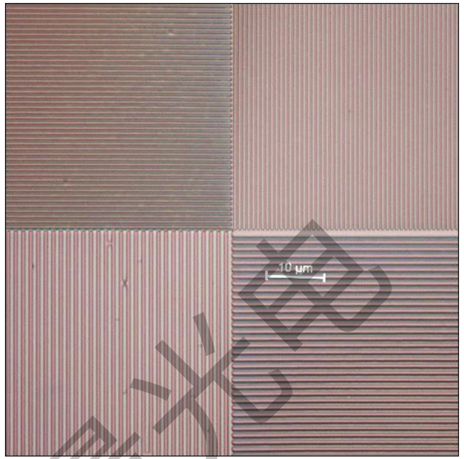
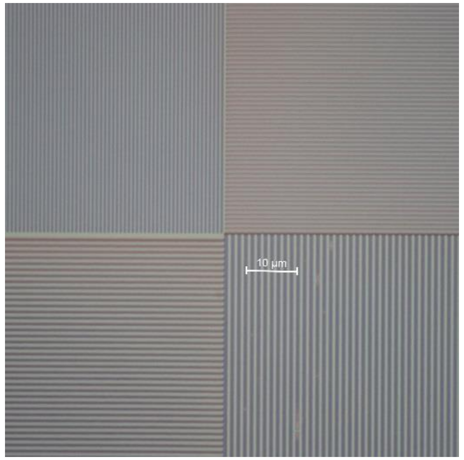
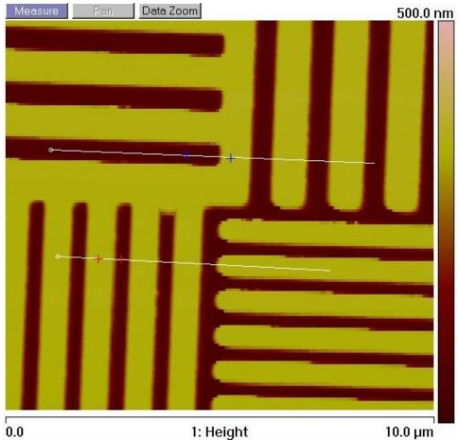
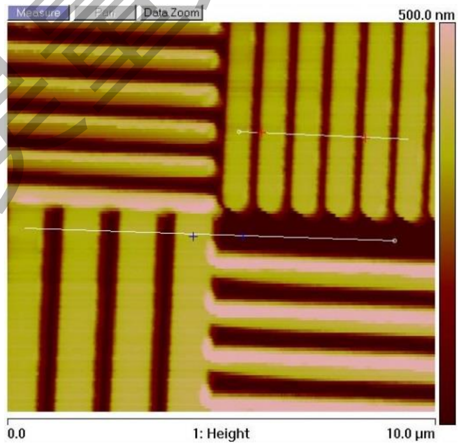
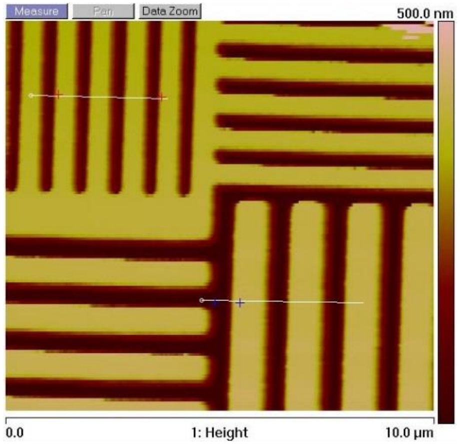
As a demonstration of the CNI tool with UV option capabilities, we perform in situ polymer working stamp fabrication from a silicon master followed by UV nanoimprint on silicon

- Silicon master with 514 nm deep half-pitch lines
  - Pitch range 700-1400 nm, line widths down to 350 nm
- Hot embossing of UV transparent working stamp
  - Stamp material Topas 8007
  - Imprint parameters: 1 min @ 120°C & 6bar → release 80°C
  - Total process time (incl. sample load/unload) < 10 minutes
- Substrate preparation
  - Spin-on mr-I APS-1 adhesion promoter
  - Spin-on mr-I XNIL26-300 nm to a thickness of 260 nm
- UV imprint on substrate
  - Imprint parameters: 5 secs @ 6 bar → 60 secs @ 6 bar with UV

  -Total process time (incl. sample load/unload) < 5 minutes



UV Imprint with polymer stamps (2:2)

	Master	Working Stamp	Substrate
Optical Microscope 100x			
AFM			

- Master depth is 514 nm, imprint depth is 503 nm.
- Perfect master to substrate replication
- Residual layer thickness < 20 nm

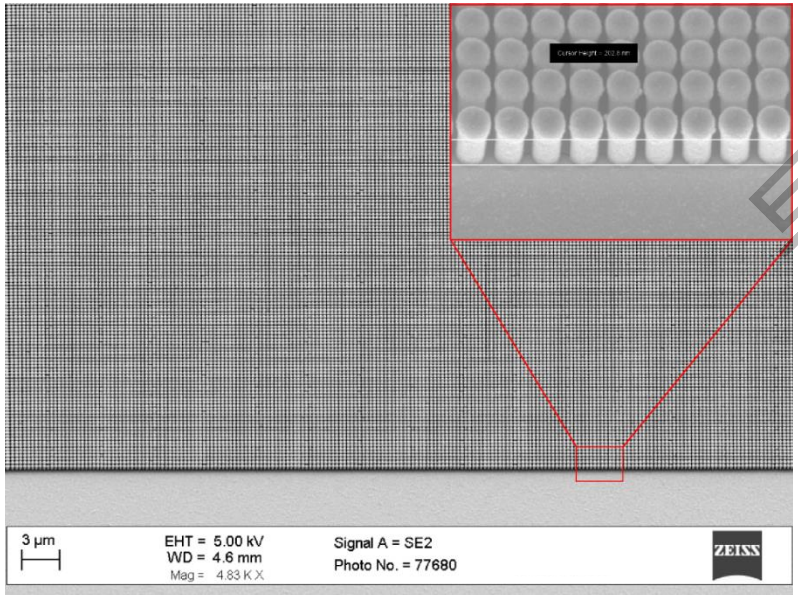
Imprint of dense pillar structures

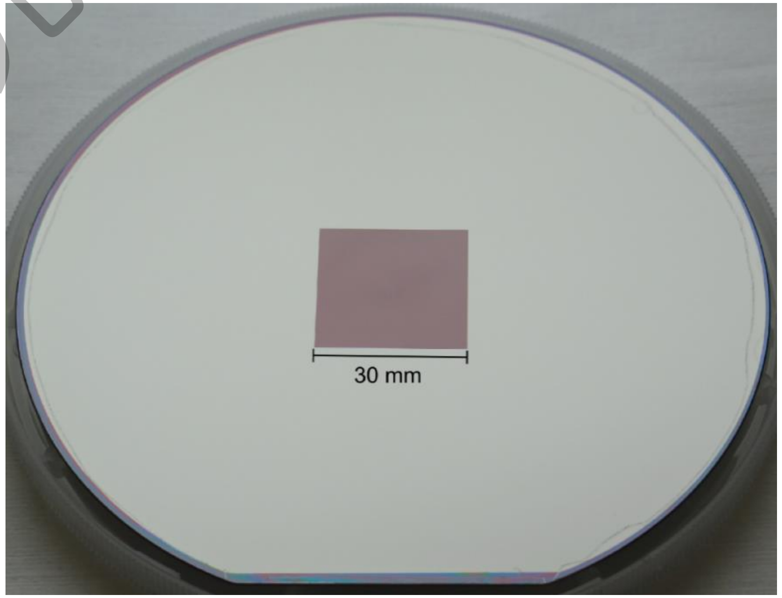
Thermal imprint

200 nm pillars, 300 nm pitch (100 nm separation) and 400 nm high fabricated in thermoplastic material on silicon using thermal NIL mode in CNI v3.0.

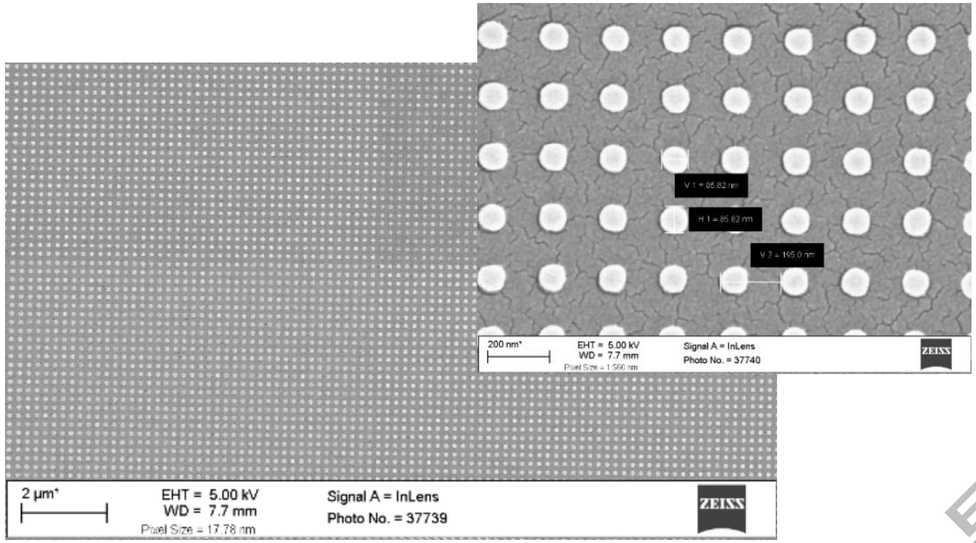
Imprint covered area of 30 mm x 30 mm and was defect free.

Both pictures below show the imprinted sample (metalized before images are taken).

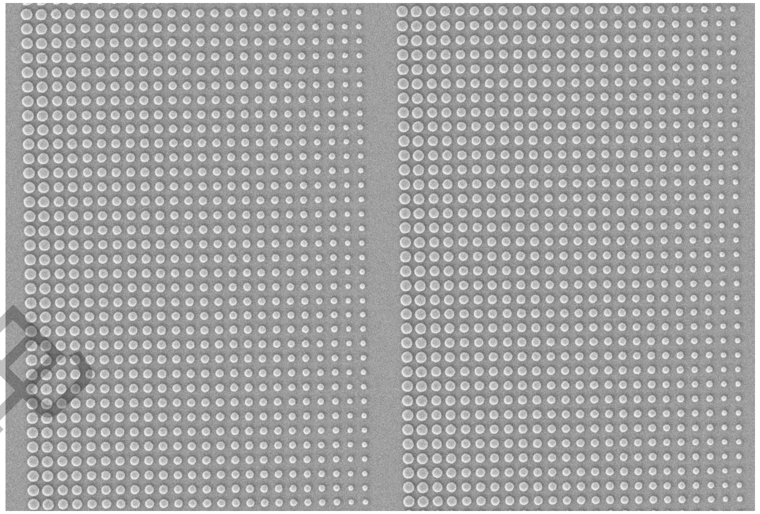




Fine structures



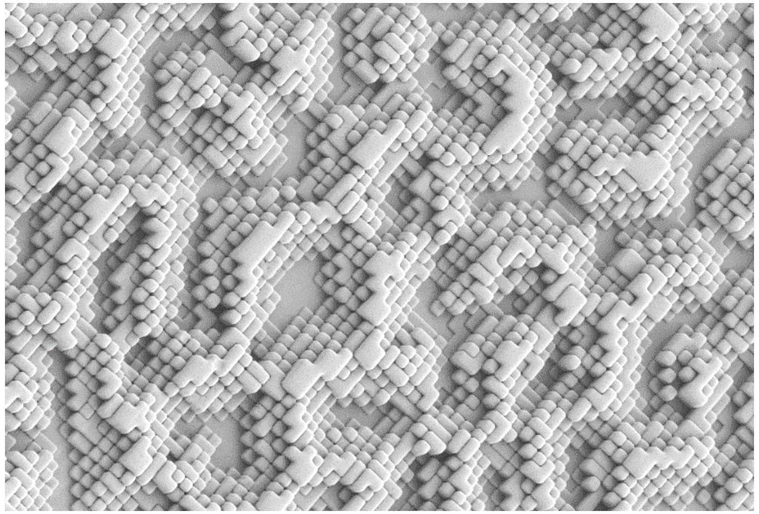
80 nm pillars, 200 nm pitch



Cr dots on Si after lift-off. The smallest dots are 100 mm diameter – Made in collaboration with Johns Hopkins University

SEM images of imprinted polymer.

The polymer is coated with a thin gold (Au) layer to facilitate the SEM investigation. The cracks visible are due to the gold deposition process (not the imprint).

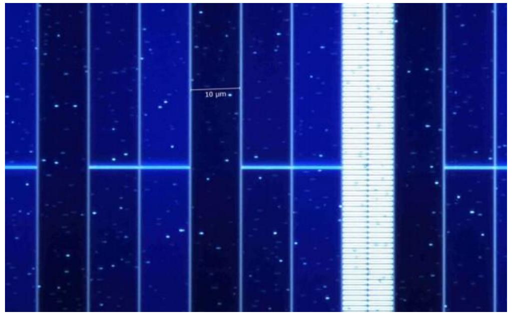


16 level DOE structure in Ormostamp with 500x500 nm pixel size

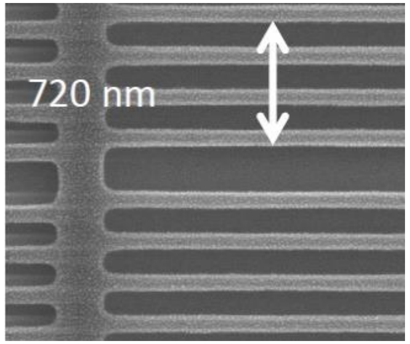
240 nm pitch gratings for laser application

Thermal imprint

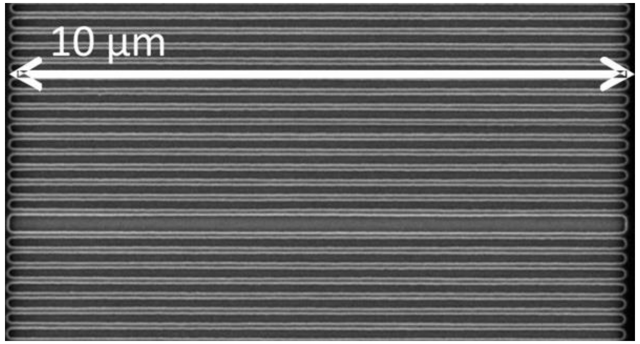
Application:	Distributed feedback laser array (DFB)
Pattern:	Gratings, pitch of 240 nm
Substrate:	Silicon and Indium Phosphide
Protrusion height:	138 nm
Protrusion density:	50%
Imprint mode:	Complete filling
Imprint time:	15 minutes

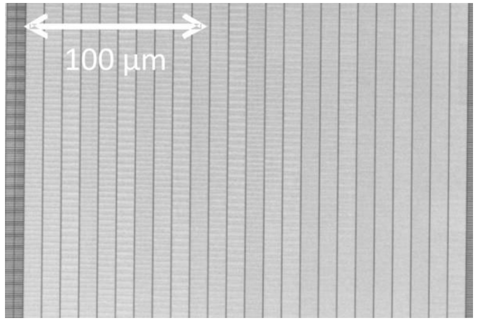


Dark Field microscope images of imprinted gratings etched into silicon. The three different grating periods are 236nm, 240 nm and 244 nm. The bright line in the middle is the lambda quarter shift.



Right: Scanning Electron Microscope image of imprinted grating. The imprinted lines are well-defined. The wide line is an imprinted lambda quarter shift.



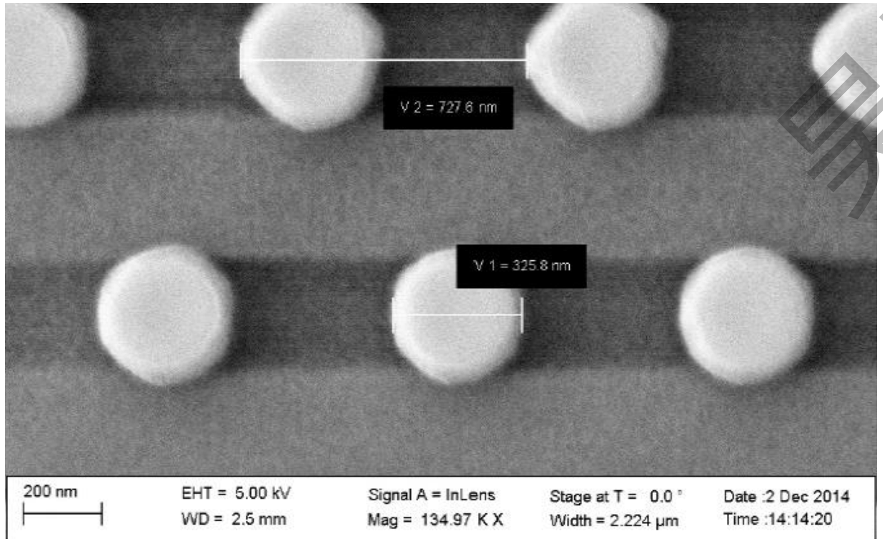


Scanning Electron Microscope image of imprinted gratings. The low magnification shows that a large area has been imprinted without defects.

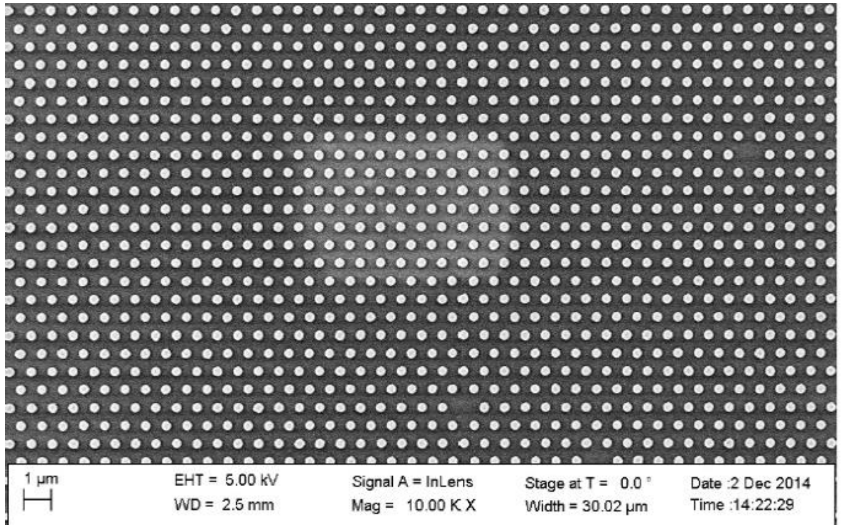
Metal dots on sapphire defined by imprint and lift-off

Imprint parameters

- Pre-print pressure: 1 bar
- Imprint pressure: 7 bar
- Imprint temperature: 120°C
- Imprint time: 10 min
- Release temperature: 45°C
- Approximately 200 nm mr-I 7020E was spin coated in the substrate.
- The imprint depth was measured to 226 nm.



The width of the structures was approximately 325.8 nm



Overview of structure. White area due to zoomed in image on the left taken before.

DTU Nanotech
Department of Micro- and Nanotechnology
GRAPHENE FLAGSHIP
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Graphene Gas Sensor

Graphene based gas sensors have received great interest in the past five years, showing down to single molecular detection. Recent studies have shown that patterning of graphene strongly increases the sensitivity compared to non-patterned layers.

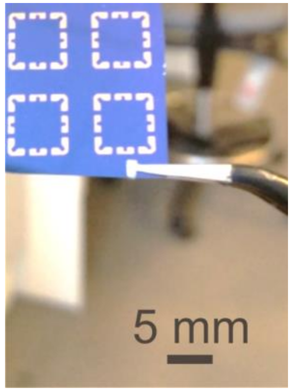
CVD graphene was grown by standard procedures and then transferred to Si/SiO2 substrates for further processing. Contacts and devices areas were defined using physical shadow masks and laser ablation as described in (Mackenzie, **2D Materials**, [http://dx.doi.org/10.1088/2053-1583/2/4/045003]).

Thermal nanoimprint lithography was performed in CNI v2.0 using a soft stamp. mr-I7010E imprint resist was imprinted at 130 °C, 6 bar pressure for ten minutes. The pressure was released at 70 °C.

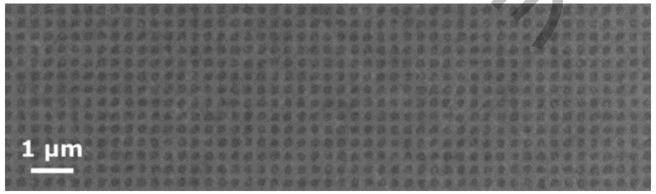
Large area patterns of holes with an edge-to-edge spacing of 120-150 nm were transferred into the graphene by reactive ion etching, and remaining resist was removed with acetone.

Devices were found to have a carrier mobility of approximately 2000 cm^2/Vs before processing, and 400 cm^2/Vs after processing, while maintaining the overall low doping level.

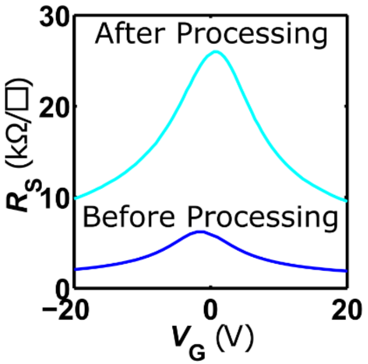
See more here: http://aip.scitation.org/doi/pdf/10.1063/1.5010923



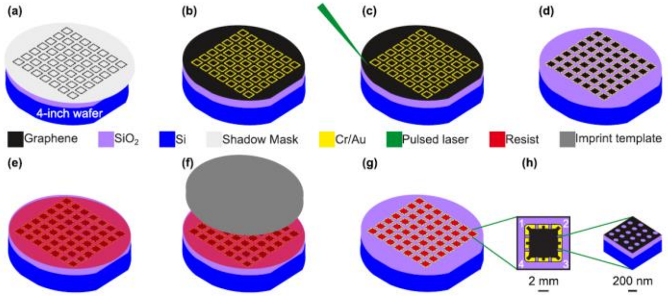
Si/SiO2 substrate with graphene and gold contacts



SEM images of graphene layer after NIL structuring



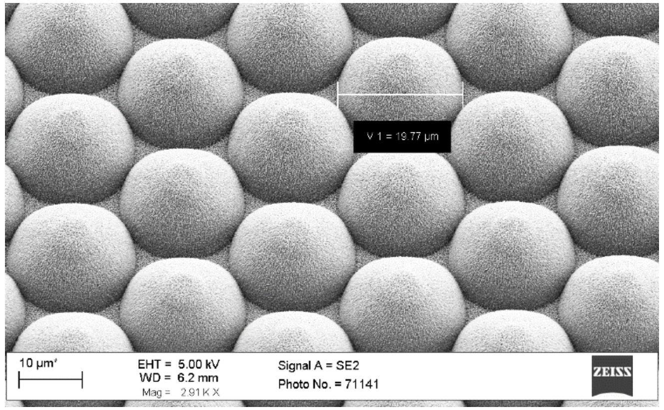
Sheet resistance measurement before and after NIL structuring



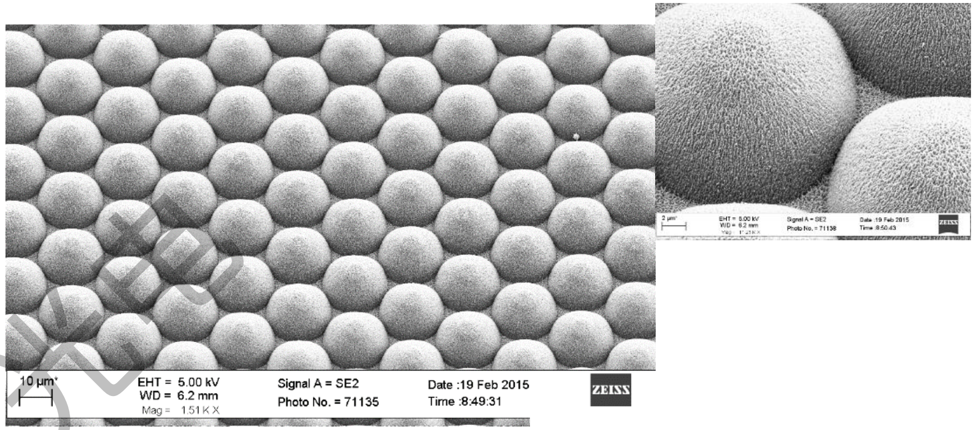
Batch fabrication of nanopatterned graphene devices via nanoimprint lithography

David M. A. Mackenzie,[1,2,a)] Kristian Smistrup,[3] Patrick R. Whelan,[1,2] Birong Luo,[4,b)] Abhay Shivayogimath,[1,2] Theodor Nielsen,[3] Dirch H. Petersen,[1,2] Sara A. Messina,[1,2] and Peter Bøggild[1,2]
[1]*Department of Micro- and Nanotechnology, Technical University of Denmark, Ørsteds Plads 345 B, 2800 Kongens Lyngby, Denmark*
[2]*Center for Nanostructured Graphene (CNG), Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark*
[3]*NIL Technology APS, Diplomvej 381, DK-2800 Kongens Lyngby, Denmark*
[4]*Cambridge Graphene Centre, Engineering Department, University of Cambridge, 9 JJ Thomson Avenue, Cambridge CB3 0FA, United Kingdom*

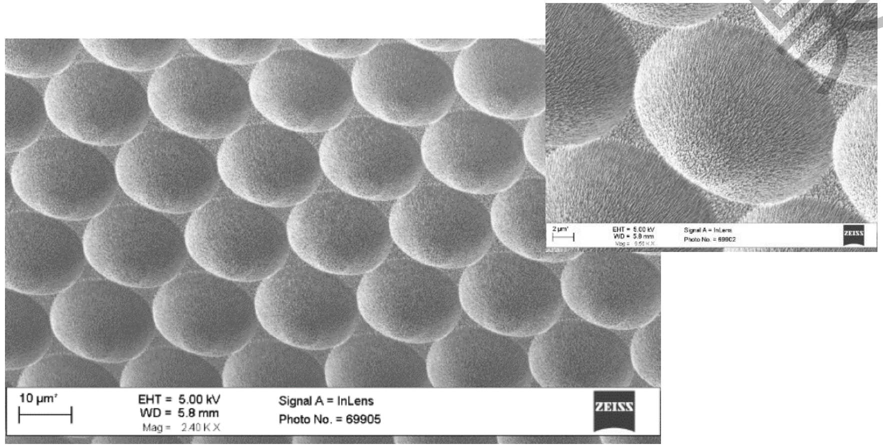
Convex MLS with nanograss in topas



SEM image of the resulting imprint.



SEM image of the resulting imprint.



SEM images of the silicon stamp used for the imprint.

Tilted SEM images of the produced micro lens array with nanograss

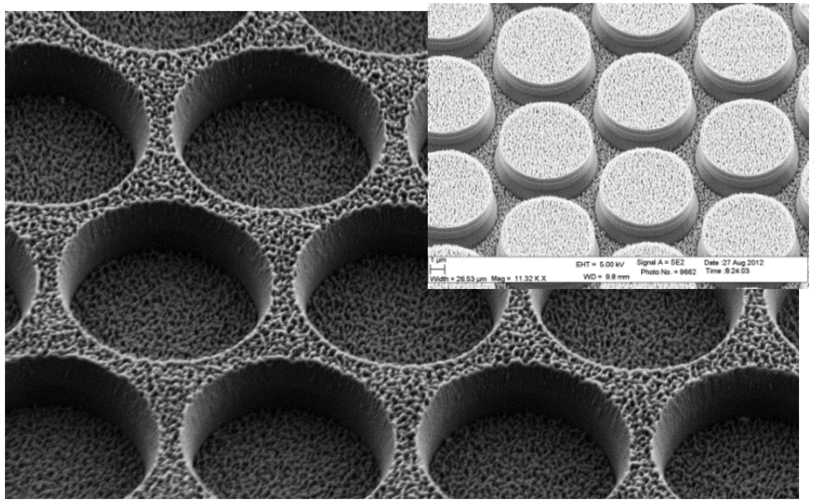
The tilt angle is 30°. The convex spherical lenses (diameter=20 µm and height=8 µm) with a carpet of nano grass are clearly visible. The arrangement of the lenses is hexagonal. The imprint was performed in the CNI tool.

Self-cleaning surfaces

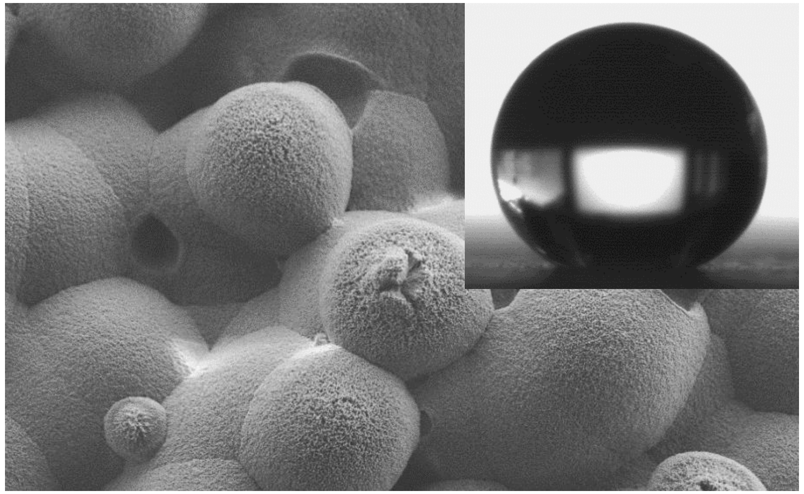
The leaf of a lotus flower has a complex surface topology that essentially makes the flower self-cleaning. NIL Technology is continuously developing stamps and masters that may be used for embossing or moulding polymers and thereby achieve an altered surface that mimics nature.

Using a combination of DUV and well-controlled ICP etching, we have made a silicon stamp with periodic microscale pillars combined with nanograss on all planar surfaces. The stamp was used for making a self-cleaning surface by CNI imprint in a biocompatible 200 µm thick polymer foil (SEM, left image).

The right image (SEM) shows another hierarchical and biomimetic structure developed and hot embossed by NILT. As a result of the fabricated structure, the surface contact angle of water on the polymer sample was increased by more than 50%.



SEM of silicon stamp with periodic microscale pillars and nanograss surface.



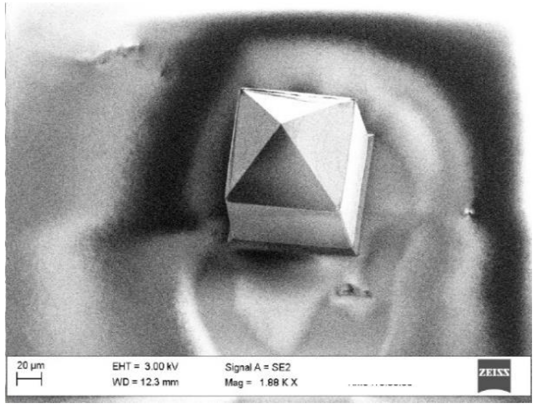
Hierarchical and biomimetic structure by hot-embossing significantly increasing the contact angle of water.

Micro needles

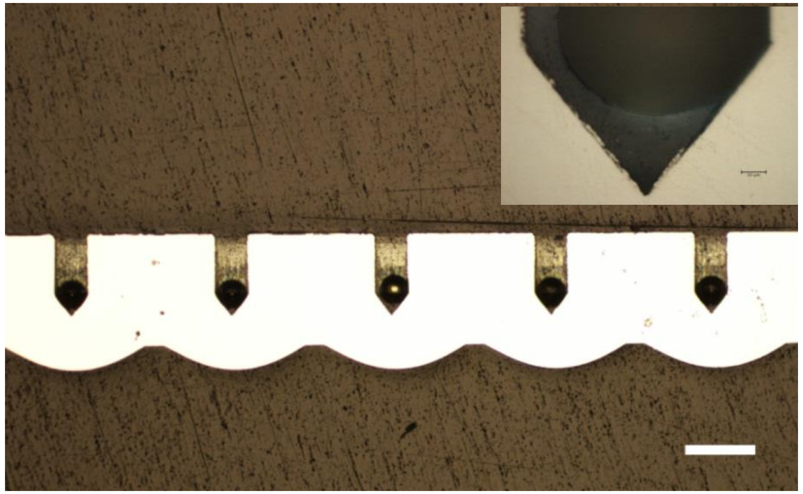
Currently there is a growing interest in polymer micro needles. NIL Technology has developed a process for making both silicon and nickel masters that allows replication of large arrays of micro needles by hot embossing or injection moulding.

The micro needles may be used for e.g. micro epilation or epidermal drug transport. The left image (scale bar=200 µm) shows a cross-sectional image of a nickel master and the insert is a magnified view at the sharp and well defined apex of the micro-hole.

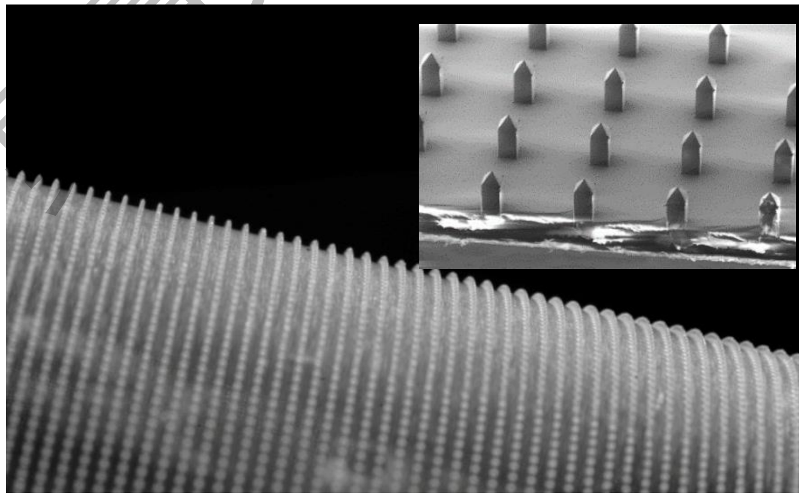
The right image is a SEM image showing a flexible polymer foil after imprint of an array of needles. The needles have a square cross section of 100x100 µm^2 and a height of 300 µm from base to tip. The sharp tips ensures that the needles easily penetrate the skin.



130°C, 6 bar, 10 minutes, release at 80°C

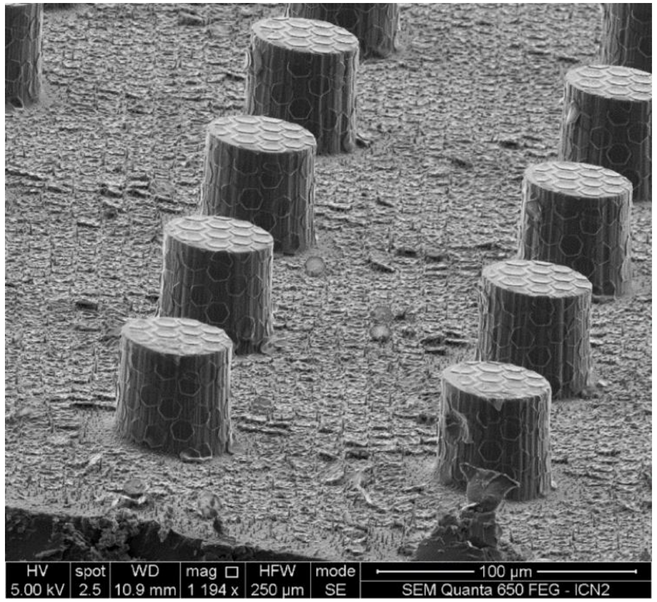


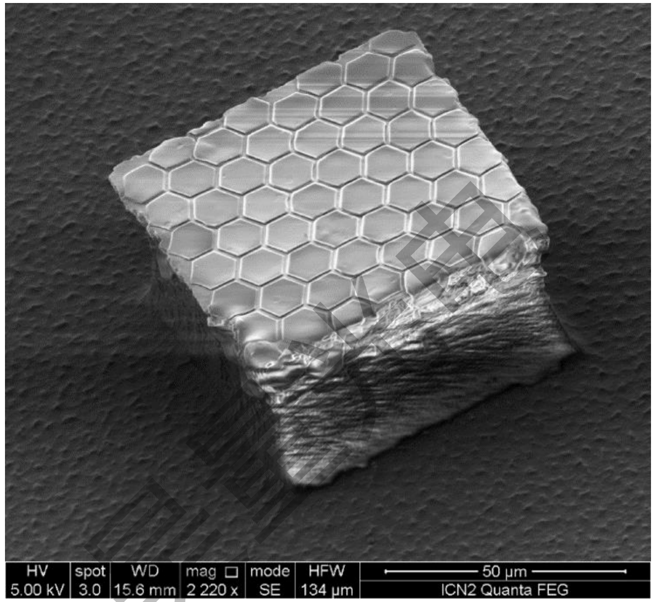
The needles are 100x100 µm at the base and 300 µm from base to tip.

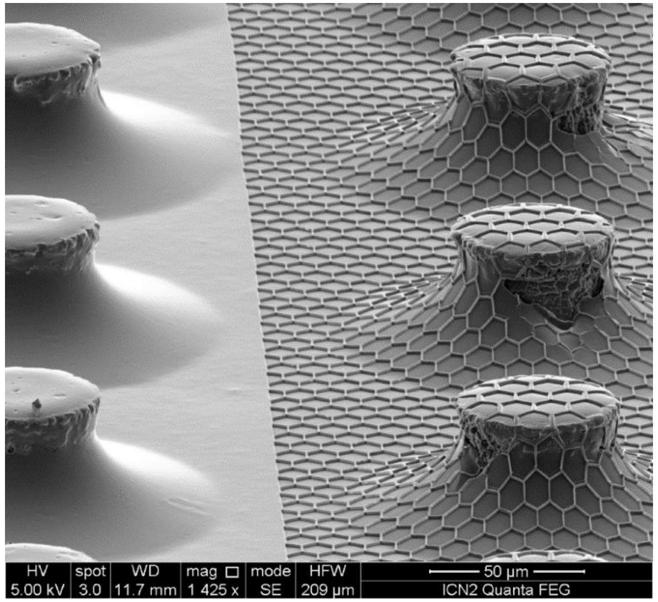


Flexible polymer foil after imprint of an array of micro needles.

Reverse NIL using PDMS stamps







The research group at INSTITUT CATALÀ DE NANOCIÈNCIA I NANOTECNOLOGIA (ICN2), www.icn.cat, lead by Dr. Nikos Kehagias has used the CNI tool to develop a reverse-NIL process (placement of polymer patterns in a surface) using PDMS stamps. The pictures reveal to what extreme the CNI can adapt to non-even surfaces – note the patterning of the micro posts sidewalls.

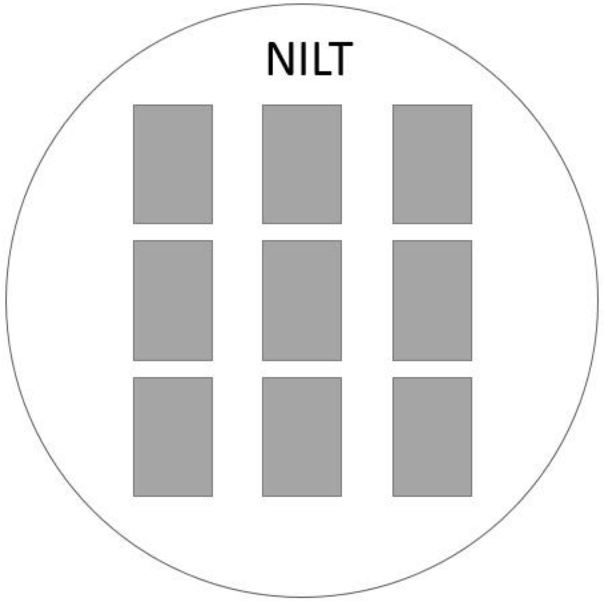
Test and process validation

A standard stamp specially designed for optimizing imprint parameters is included in the CNI starter kit.

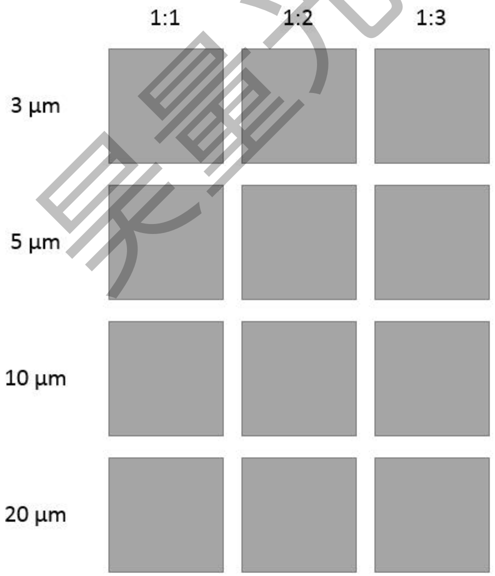
Pattern:	Arrays of line gratings
Substrate:	Silicon
Protrusion height:	300 nm
Protrusion density:	25-50 %
Imprint mode:	Complete filling

Video using this stamp
(youtube – same as slide 2)

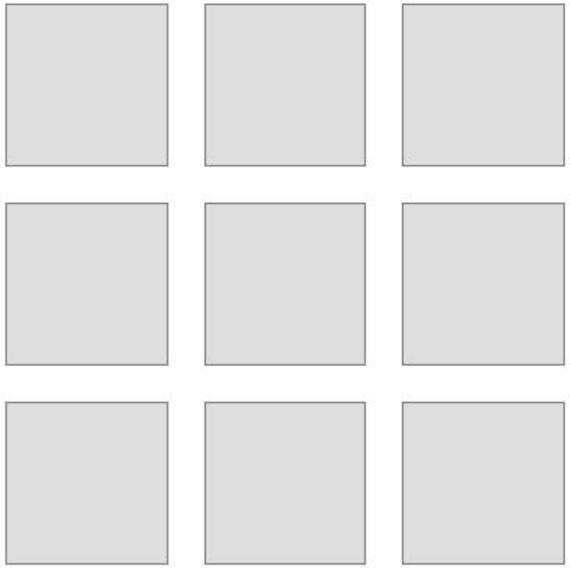
-The micro test standard stamp is ideal for evaluating and optimizing imprint parameters during NIL or even hot embossing of thin films. The structure size allows for rapid inspection by conventional microscopy.
-Structure size are 3, 5, 10 and 20 µm with protrusion coverages 25%, 33%, and 50%.



The Micro Test Standard Stamp consists of 9 identically patterned areas arranged in a 3 x 3 array.



Each of the 9 patterned areas contain line grating structures with lateral dimensions 3, 5 10 and 20 µm with line:spacing ratios of 1:1, 1:2 and 1:3 in individual patterned fields.



Each of the patterned fields are composed of 1 mm x 1 mm areas with line gratings with the specific lateral dimension and spacing. The 1 mm x 1 mm areas are arranged in a 3 x 3 array with 100 µm spacing.

CNI used for stem cell research

https://www.researchgate.net/publication/304186906_Biomechanical_Cell_Regulation_by_High_Aspect_Ratio_Nanoimprinted_Pillars

Materials Views
www.MaterialsViews.com
ADVANCED FUNCTIONAL MATERIALS
www.afm-journal.de

Biomechanical Cell Regulation by High Aspect Ratio Nanoimprinted Pillars

*Felipe Viela, Daniel Granados, Angel Ayuso-Sacido, and Isabel Rodríguez**

High aspect ratio pillared topographies provide a large number of mechanical cues that cells can sense and react to. High aspect ratio pillars have been employed effectively to promote stem cell differentiation and to probe cellular tractions. Yet, the full potential of these topographies for mechanobiology remains insufficiently characterized. Here, the response of progenitor neural stem cells to dense high aspect ratio polymer pillars in the nano- and micro-scale is investigated. Thermal nanoimprinting is utilized to fabricate with high precision well-defined pillars with high density and aspect ratio. Studies on cell viability, morphology, cell spreading, and migration are performed comparatively to a control flat substrate. The traction forces exerted by the cells on the pillar structures are probed quantitatively by a combined focused ion beam scanning electron microscopy (FIB-SEM) technique. The cell responses observed are distinctive for each dimension, following the trend that an increase in aspect ratio and feature size from nano- to micronscale results in more confined cell morphology with large cytoplasmic penetrations and nuclear deformation. Accordingly, cells seeded on the micrometer scale topography show reduced mobility, a persistent quasi-directional migration, high traction forces, and a lower rate of proliferation. Cells on the nanotopography show higher rate of proliferation, a large cell spread, high mobility with random migration altogether with lower traction forces.

and differentiation capability. During in vitro culture conditions, cells can react to synthetic surfaces with a wide way of responses that depend upon many factors, including the chemical makeup of the surface and its physical properties such as stiffness, topography feature size, and geometry. Identifying how these factors affect the SC behavior and fate and controlling them, it is crucial for the development of new regenerative medicine approaches to replace damaged cells, tissues, or even organs[2] by growing artificial tissue in vitro for further implantation into the injured site.[3]

Today, substantial research efforts in biomaterial's research are aimed at controlling material topography, mechanical properties, and surface biochemistry to understand and ultimately control the cellular response.[4] In this sense, there have been numerous approaches to develop materials with fine control of the topographical features using micro- and nanofabrication techniques.[5] These technologies enable the fabrication with

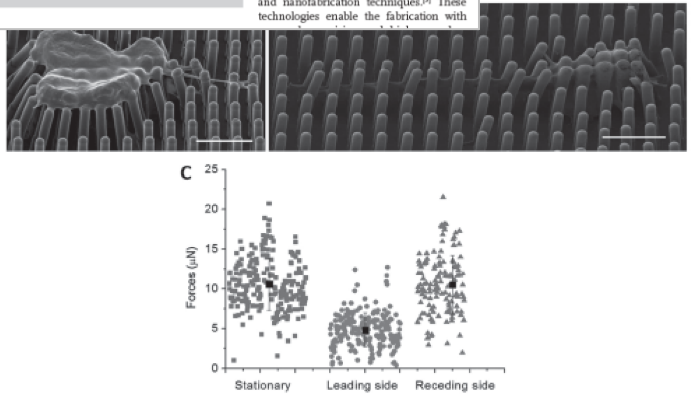
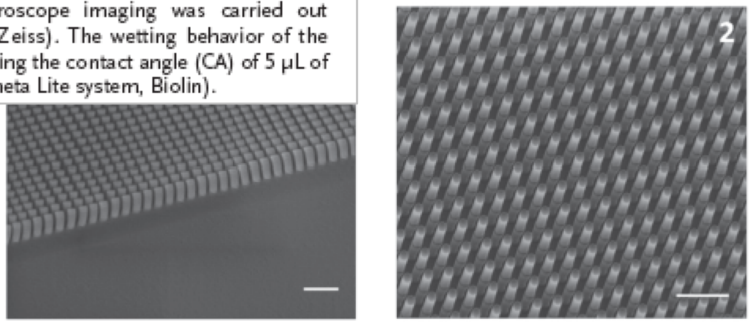


Figure 7. Traction forces for cells cultured on 2 μm HAR pillar substrates. A) SEM image of a stationary cell over 2 μm pillars. B) SEM image of a cell migrating within the 2 μm pillar topography. C) Distribution of the traction forces exert by a stationary cell at the periphery and migrating cell at the receding edge. Scale bar 10 μm.

5. Experimental Section

Patterning of HAR Topographies: HAR pillar structures were patterned by thermal nanoimprinting. The required silicon templates were fabricated through standard clean room processes of photolithography and reactive plasma etching. The templates were coated with a perfluorodecyltrichlorosilane (FDTS) (Alfa Aesar) as a release agent to facilitate the demolding process through vapor deposition. Imprinting was performed using a CNI nanoimprinter (NIL Technology). The substrates employed were polycarbonate films (Lexan 8040, Sabic) with a thickness of 175 μm. The PC films were imprinted at 180 °C and 6 Bar of pressure for 20 min. The polymer-mold assembly was allowed to cool down to 80 °C before the pressure was released and demolding was performed. Nanopillars of 500 ± 15 nm in diameter and 2 μm height and micropillars of 2 ± 0.5 μm in diameter and 10 μm in height were produced. Scanning electron microscope imaging was carried out using an Auriga FIB-SEM system (Zeiss). The wetting behavior of the substrates was evaluated by measuring the contact angle (CA) of 5 μL of water drops using a tensiometer (Theta Lite system, Biolin).



B

Substrate Pillar diameter	Aspect Ratio [Heigh:Diameter]	Density [pillars cm^{-2}]	WCA Mean [°]	WCA Mean + Gelatin [°]	Interspacing [μm]	Coverage [%]
500 nm	4	1.2x10^{8}	147.5±1.3	28.8±0.2	0.5	50
2 μm	5	7.4x10^{6}	148.9±3.4	25.2±0.4	2	50

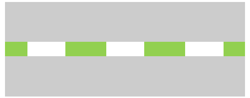
Figure 1. A) SEM images of the topographies fabricated by polymer nanoimprinting 1) 500 nm pillars and 2) 2 μm pillars. B) Summary of the physical characteristics of the patterned substrates. Scale bar 2 μm (1), 10 μm (2).

BCB wafer bonding with CNI

Spin-coating BCB

UV lithography

Wafer bonding in CNI

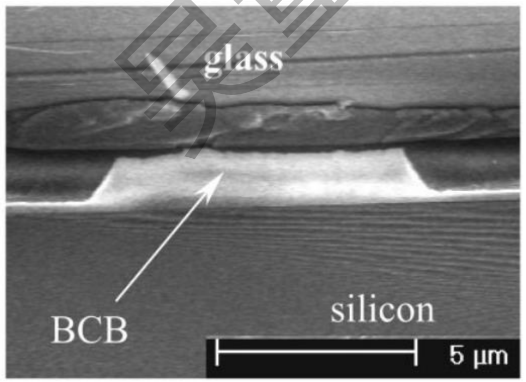


Bonding of both silicon and quartz wafers can easily be performed in the CNI tool, using benzocyclobutene (BCB) as an adhesive layer.

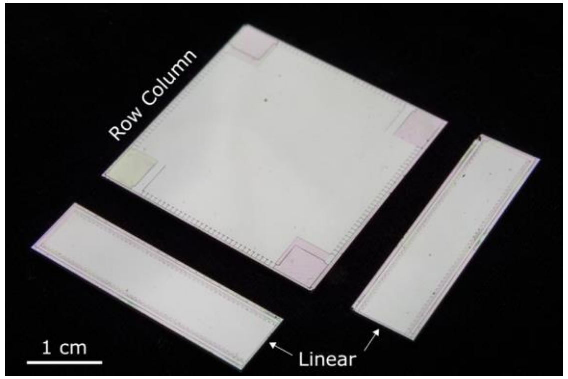
BCB can be structured with UV lithography, which combined with void free bonding allows for easy Lab On a Chip fabrication.

High adhesion strength, high breakdown strength, and precise thickness control down to 50 nm makes BCB ideal for MEMS fabrication.

BCB is all organic, making it easy to remove and etch with plasmas.



Micro channel separator fabricated with BCB, *J. Electron. Packag* 127(1), 7-11



Ultrasonic transducers for medical imaging fabricated in the CNI using BCB bonding from. http://ieeexplore.ieee.org/document/8091939/

Frequently asked questions

FAQ

What does the CNI not have?
CNI does not have any alignment capabilities. We can supply mechanical alignment features (custom made) but in general the CNI is a ‘first print’ tool.

The UV power can decrease to at least 20% from the centre to the outer edges of a 4 inch wafer? Can you explain why?
The UV source is placed in the centre of the tool. Total uniform light distribution is often not needed for UV-nanoimprint, since you just need a certain dose to cure the polymer. Over-exposure is rarely an issue. The uniformity could be improved by adding more light sources in the lid but this will also increase the cost.

What is the operating pressure range of the tool (min/max)?
The maximum imprint pressure is 11 bar. Imprint pressures can be set down to 0.1 bar (uniform imprinting on a 100 mm wafer is achieved with pressures > 1 bar). However, for reliable results we recommend to use at least 0.3 bar imprint pressure.

Can you work in inert atmosphere? Do you have any valves on the tool for inert gas supply?
There are no valves for inert gas supply as a standard. If you also choose the vacuum option, we could supply an extra valve on the vacuum line for supply of an inert gas.

What happens if my CNI tool breaks?
The CNI tool is designed for experimental work and research in general. The CNI tool consist of three control modules and the imprint chamber. Each can easily be returned to NILT for repair or replaced individually. As for the imprint chamber, all parts are easily replaced. We encourage our users to experiment with the tool!

FAQ

For the Teflon sheet, what is the use? What is the glass transition temperature/melting point temperature?
The Teflon sheets should be used for various kinds of protection. The glass temperature is beyond the capabilities of CNI.

I regret that I did not get all features when I ordered my CNI v3.0 tool. Can I add functionalities now?
Yes, heat module, vacuum modules and UV modules can be added to you CNI v3.0 tool at any time.

What should the working stamp material be made from?
Working stamp copies could be several material – If it is to be used for UV nanoimprint, we recommend making Topas8007 copies or using OrmoStamp®. PDMS and many other working stamp materials also work well

FAQ

During the cool down step, I still see some power reading at HM power(W)=0.304, is it normal? My settings are to cool down to 30°C with time = 0, need to wait for final temperature.
We measure the temperature in the tool by measuring the resistance in the Stamp Carrier, and hence we need to pass a small current through the stamp at all times. 0.3W does not really impede the cooling. Cooling to 30 degC is unnecessary. You should only cool to just below the glass temperature (or even a little bit above). This will speed up the process.

How do I prevent that the polymer melts and sticks on the membrane? How do I clean the membrane if polymer sticks on it?
The membrane can be cleaned with ethanol or IPA – not acetone. In order to avoid polymer on the membrane, one can protect the membrane with a Teflon sheet or in case of Topas 8007 embossing, one can use a blank silicon wafer with anti-sticking coating.

Can I apply more than 10 bar over pressure into the CNI in order to a higher imprint pressure?
NO! Regulators, valves and vents are not designed to handle pressures exceeding 10 bar.

FAQ

How long can the chamber membrane last? Do I need to replace this part regularly? Maybe the elasticity is not so good after used a set number of times.
There are no sort of wearing out of the membrane in the CNI tool. We have customers who have been using the same membrane for years. Typically, the reason it ruptures is because of sharp edges in the imprint stack. E.g., if one used thick glass pieces that are smaller than a 4-inch Si wafer in the tool.

Roughly, how long can the CSC be used? Where is the temperature sensor in the chamber? I guess the temperature of the bottom is higher than the top.
There are no sort of wearing out of the SC either. Again, we have customers who have been using the same SC for years and then we have customers who breaks it – we do not have a conclusive data on the circumstances when people break their SC. The temperature sensor is integrated in the SC so the temperature readout is basically the temperature on the surface of the SC.

FAQ

What's the calibration software purpose? Is it for calibrating the temperature? Should I do it after turn on the device everyday?

The stamp carrier is both our heating element and our temperature sensor. We pass current through the carrier and thereby dissipate heat in it. The Stamp Carrier contains a resistive network that is temperature dependent, so by measuring the resistance, we also measure the temperature. This is the reason, you always get a calibration file with every Stamp Carrier. The sensitivity of the temperature measurement is on the order of 40 °C/Ohm, so even a small change in the wiring resistances could influence the temperature measurement.

We compensate for this by making the Stamp Carrier to System Calibration for each Stamp Carrier on the tool, where it is going to be used. When you run the calibration routine, the routine measures the room temperature resistance, and thus compensates for any differences in wiring resistance. This calibration seems to be very robust, and there is no need to do it more than once.

When you start the tool in the morning, you should observe that the first temperature measurement corresponds to room temperature. If the first measurement in the morning starts to deviate from room temperature, it might be time to clean the contacts and maybe re-run the calibration software. But I don’t think, you will ever need it.

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