Developments, Applications and Challenges for the Industrial Implementation of Nanoimprint Lithography

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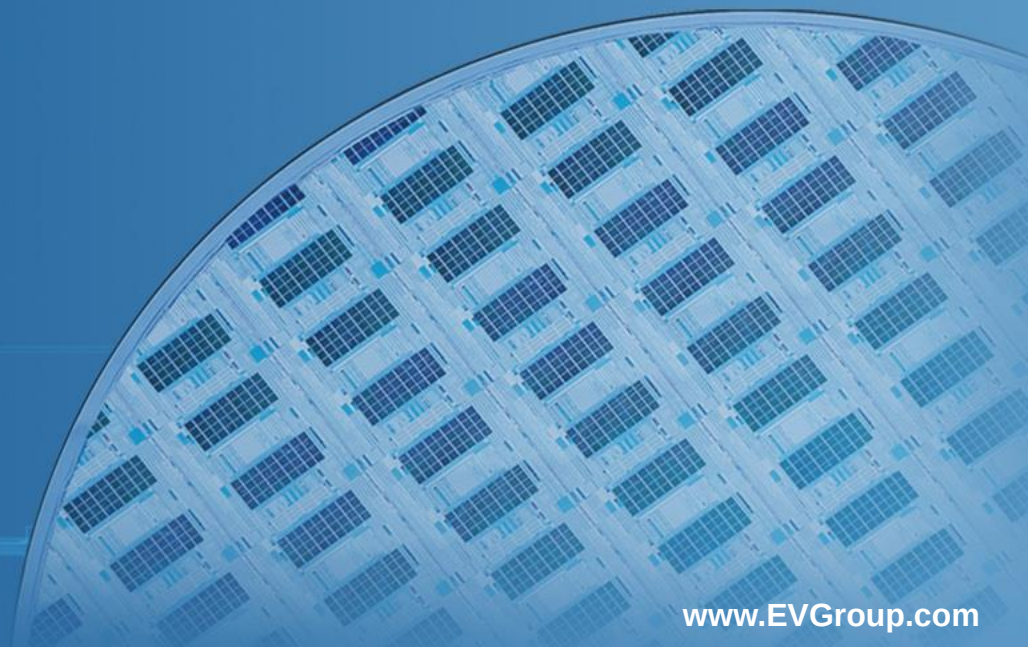


Outline

- Introduction Imprint Lithography
- Wafer Level Optics
- Applications
- SmartNIL™Technology
- EVG® Hercules®NIL
- Summary

Introduction

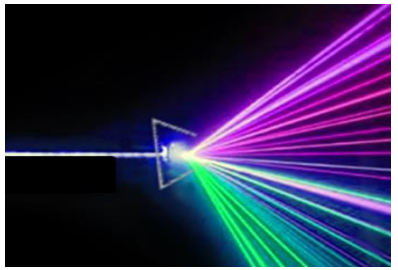
Nanoimprint Lithography

General Explanation – UV-Nano Imprint Lithography

Why ?

- Novel device concepts need alternative lithography solutions
- Complexity of pattern design should not add to manufacturing costs

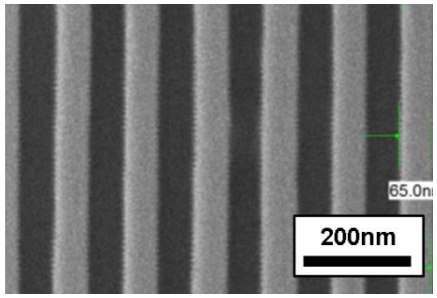
Biotechnology



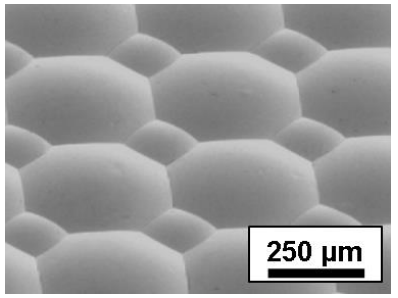
Photonics

How ?

- Nanoimprint lithography enables simple replication of various kind of structures, shapes and sizes
- Nanoscale structures can be achieved without sophisticated and expensive optics



Nanostructures



Microlenses

What?

- EVG equipment portfolio covers all common imprinting techniques on volume proven systems
- NILPhotonics™ Compentence Center to link equipment and process know-how for innovative products

EVG®620

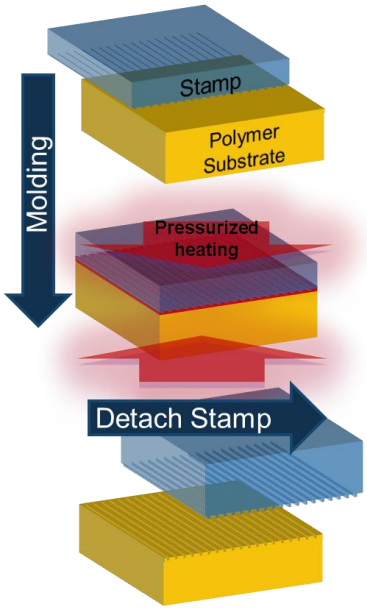
EVG® Hercules®NIL

Nanoimprint Lithography at a Glance

Hot Embossing

Hard Stamp

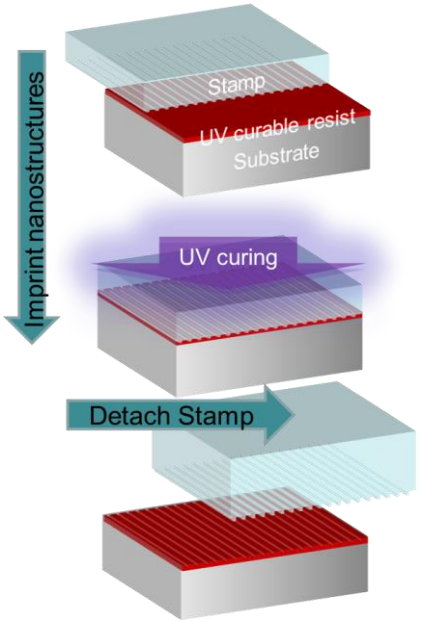
Polymer Soft Stamp



UV-Nanoimprint Lithography (UV-NIL)

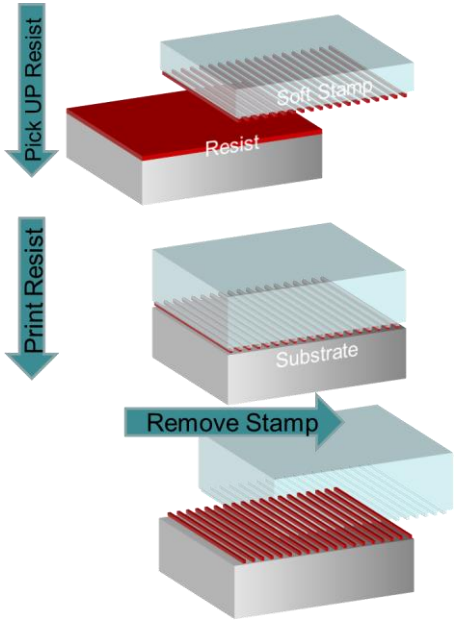
Transparent Hard Stamp

Polymer Soft Stamp



Micro Contact Printing (µCP) Soft Lithography

Polymer Soft Stamp



Nanoimprint Lithography at a Glance

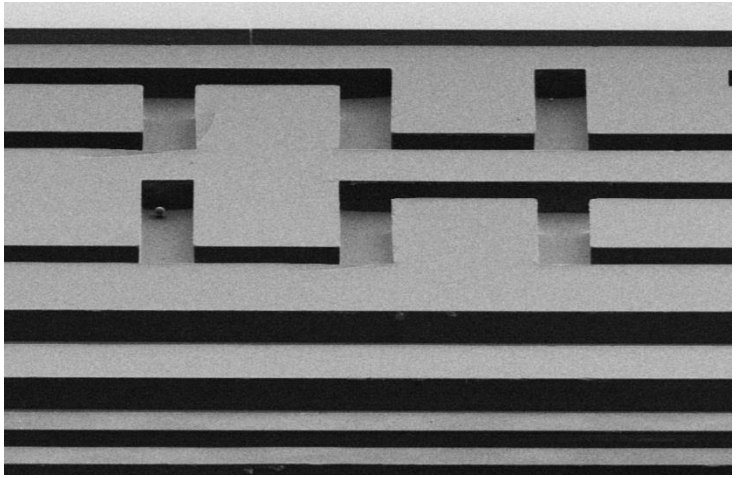
Hot Embossing

UV-Nanoimprint Lithography (UV-NIL)

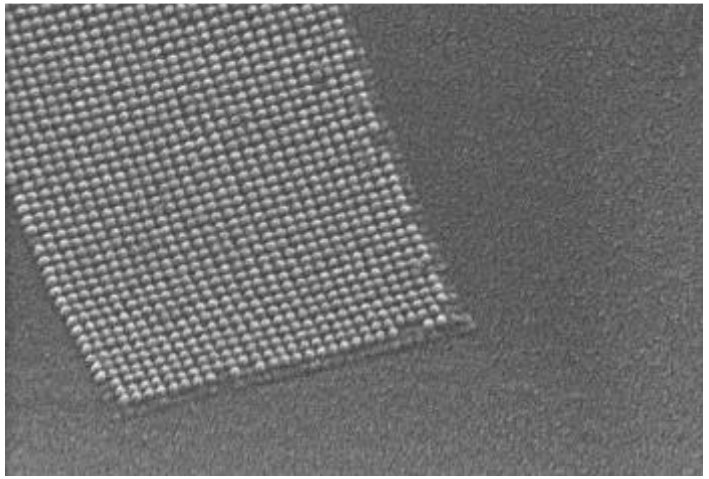
Micro Contact Printing (µCP)Soft Lithography

Resolution capabilities from micro- to nanometer.

Microfluidic structures (x 100 µm)

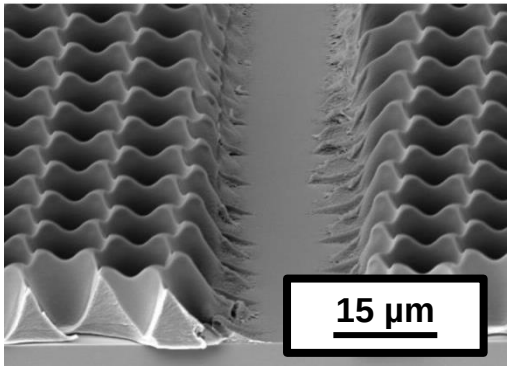


12.5 nm dots

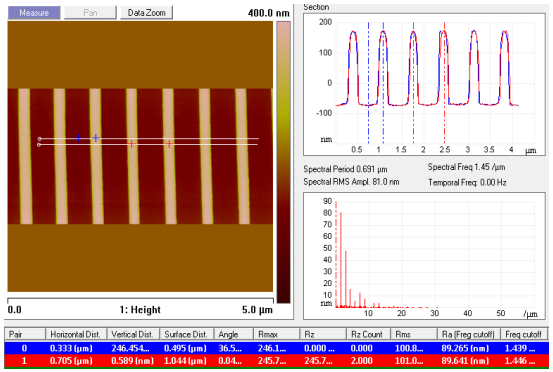


Nanoimprint Lithography Results

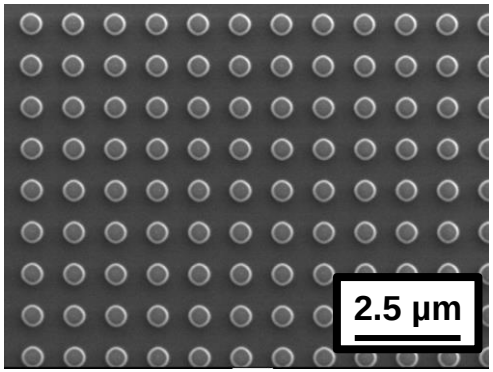
Micro- & Nano structuring by NIL is applicable in any field of photonics.



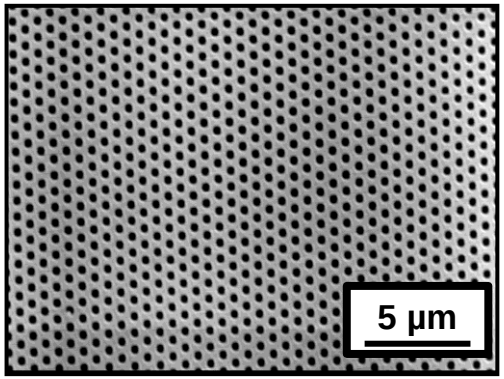
Honeycomb Texturing for Photovoltaics



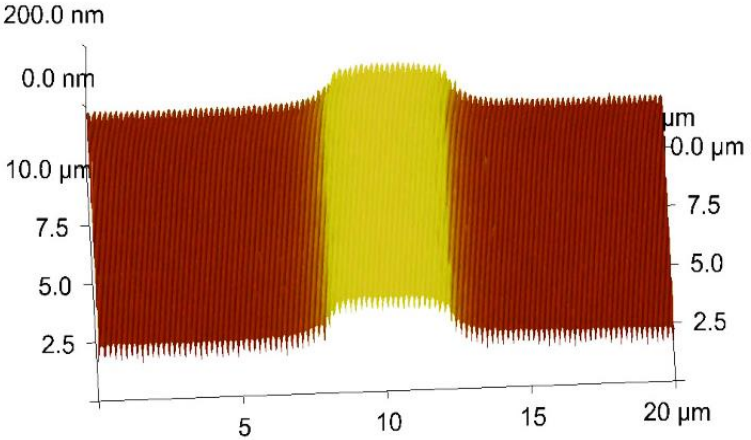
Gratings for distributed feedback lasers



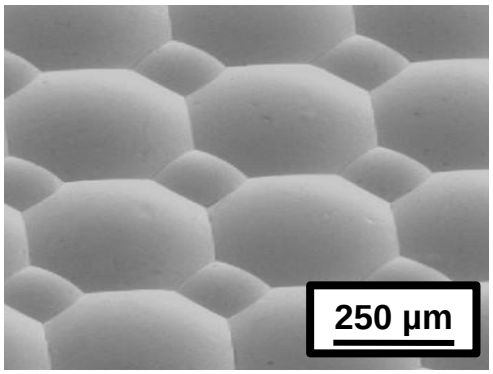
Nano-patterend Sapphire Substrates for LED growth



Photonic Crystals for light extraction of LEDs



Gratings on topography



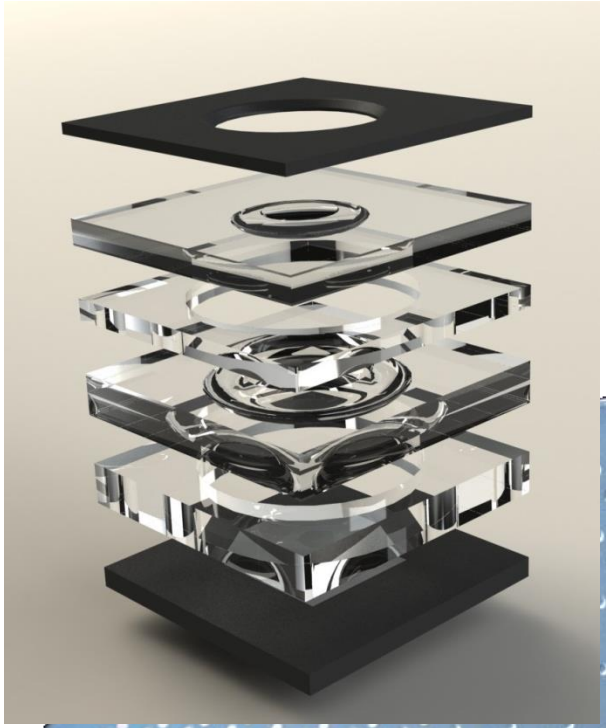
3D shaped optical elements

Wafer Level Optics

Micron and Submicron Imprinting

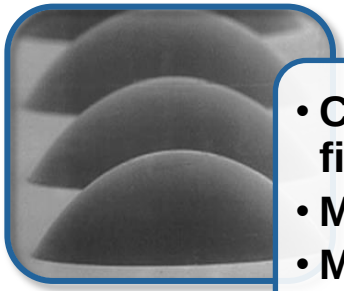
Wafer Level Optics

- **High volume manufacturing of precise optical elements**
- **Parallel processing of hundreds or thousands lenses**
- **High clarity due to turbulence free and precise processing**
- **Complete mold fill even for complex structures**
- **Enables wafer level packaging of optical modules**
- **Smallest form factors**

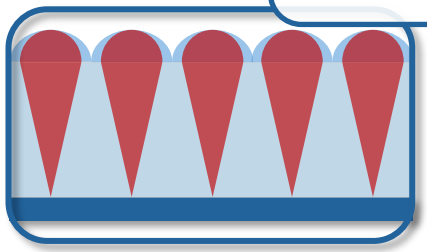


Wafer-scale miniaturized optical systems

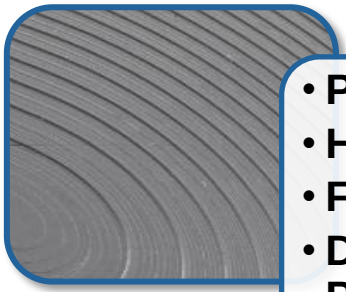
Refractive Optics



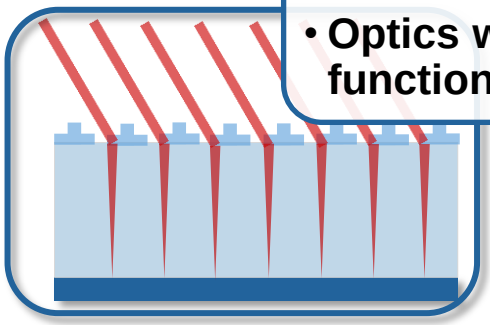
- Collimators for laser, fibers, sensors
- Multi aperture Imaging
- Microlens arrays
- Customized Microoptics



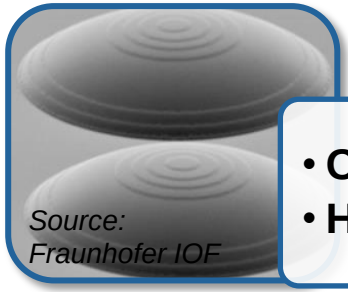
Diffractive Optics



- Pattern Projection
- Holography
- Fresnel Lenses
- Diffractive Filters or Polarizers
- Optics with complex functionality



Alternative Microoptics

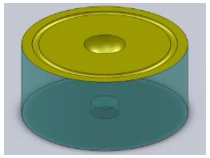


Source: Fraunhofer IOF

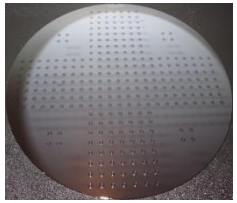
- Optics on CMOS
- Hybrid refractive/diffractive

Process Examples for Wafer Level Optics

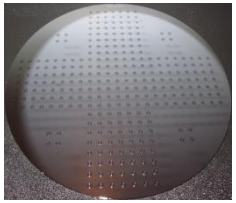
Single lens pin



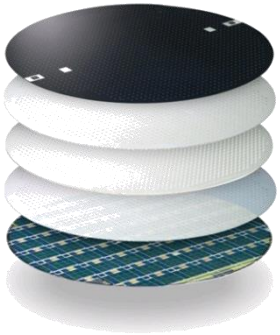
S&R master stamp



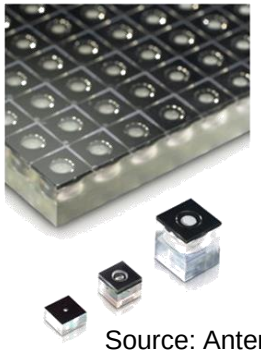
Working stamp



Lens wafers

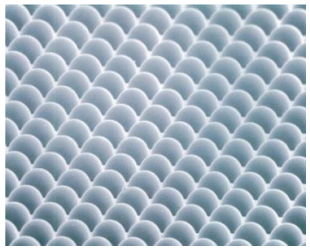


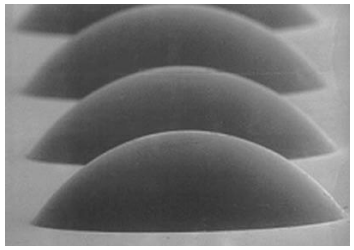
Wafer-level camera module



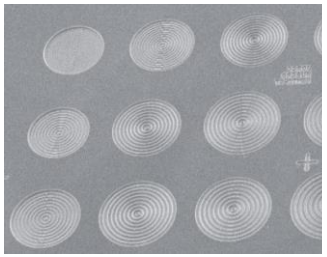
Source: Anteryon

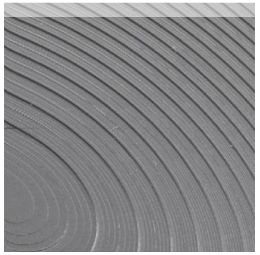
Microlens arrays



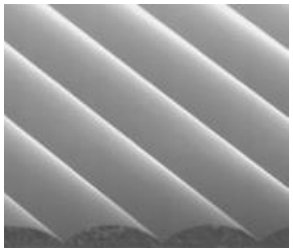


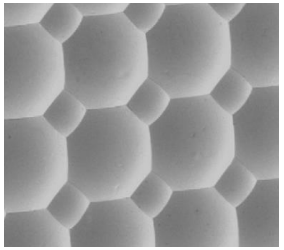
Diffractive optical elements

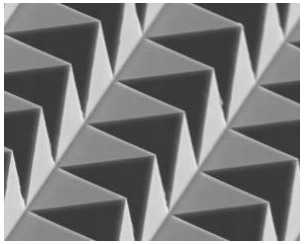




Functional optical films.







WLO in (Volume) Manufacturing

EVG®770 NIL Stepper

- Step & Repeat Master Stamp Fabrication

EVG IQ Aligner®

- Working stamp fabrication
- Lens molding & stacking
- Smart lens fabrication

Nanoimprint Lithography

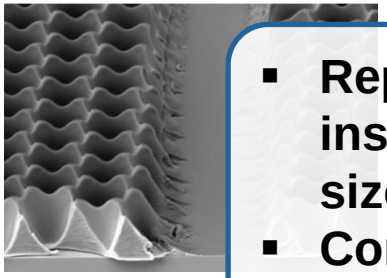
Applications

NIL Unique Benefits

Large Area Nanopatterning

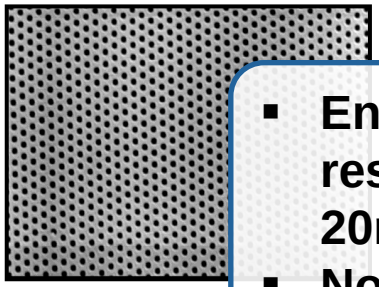
- Wafer level processing of nanostructures without stitching
- Scalable technology which not limited by an optical system

3D Pattering



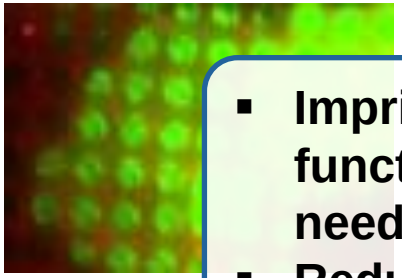
- Replication process is insensitive to shape, size & structure
- Complexity does not add manufacturing costs

Resolution << Alignment



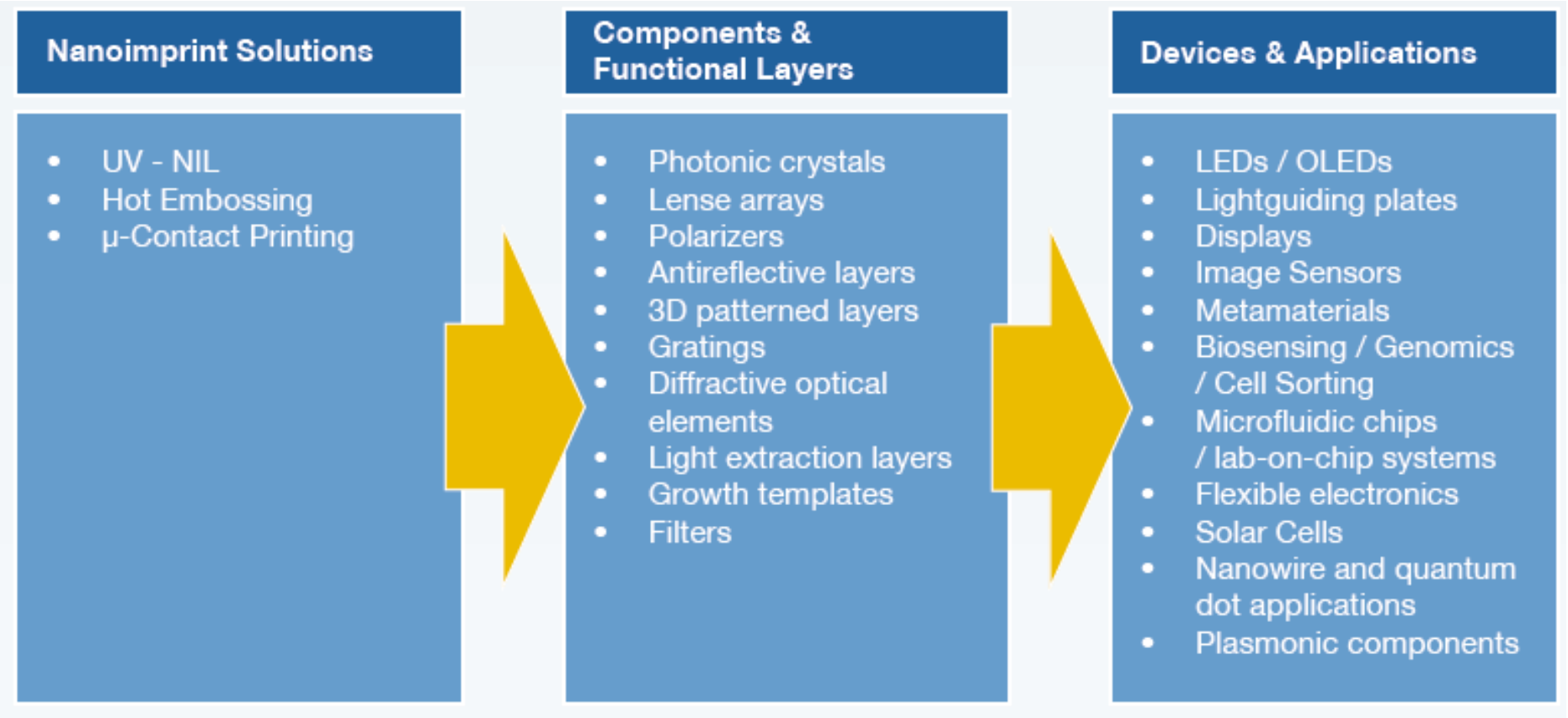
- Enables highest resolution down to 20nm and less
- No expensive precision alignment optics

Direct Patterning



- Imprint materials can be functionalized to needed properties
- Reduces process steps significantly

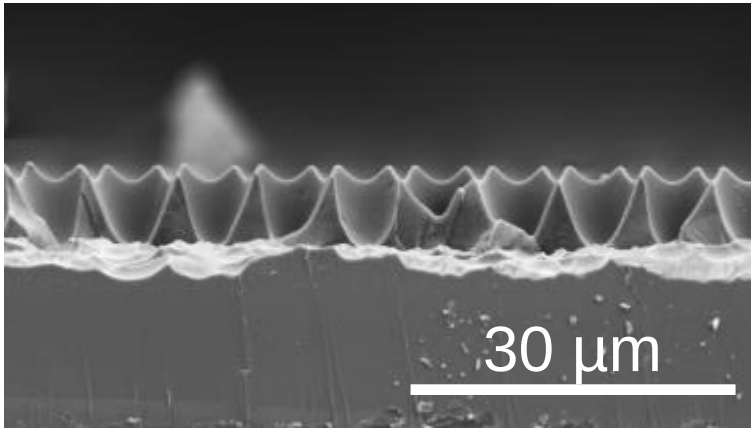
From Imprinting to Devices

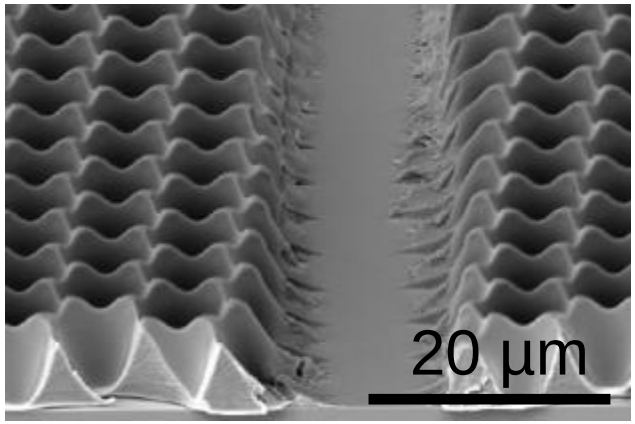


Honeycomb Texturing of Multicrystalline Silicon (mc-Si)

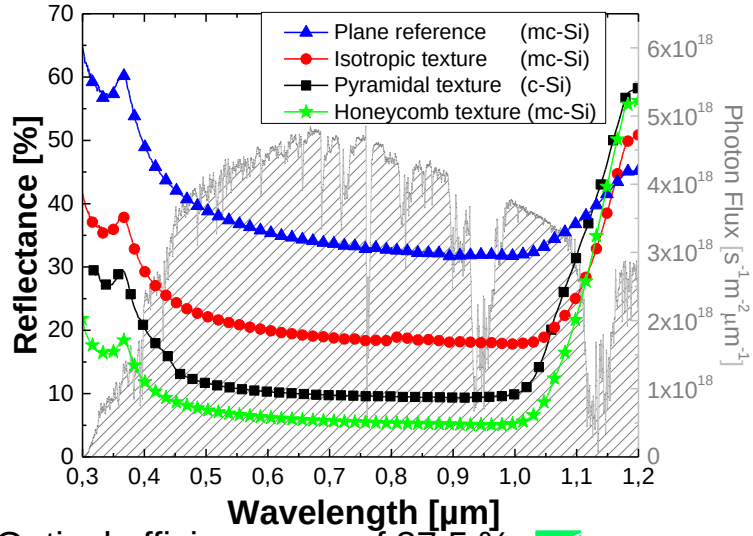
- **Mastering using three-beam IL (hexagonal pattern, 8 µm period)**
- **NIL using PDMS stamps on**
  - **Rough, brittle and thin (~180 µm)**
  - **Large area (156 x 156 mm²) mc-Si substrates**
- **Plasma etching and subsequent wet chemical post-treatment**

➔ **Excellent optical performance even outperforming pyramidal shapes**





H. Hauser, et.al., Development of NIL processes for PV applications; Proceedings of SPIE; 2015; in press.

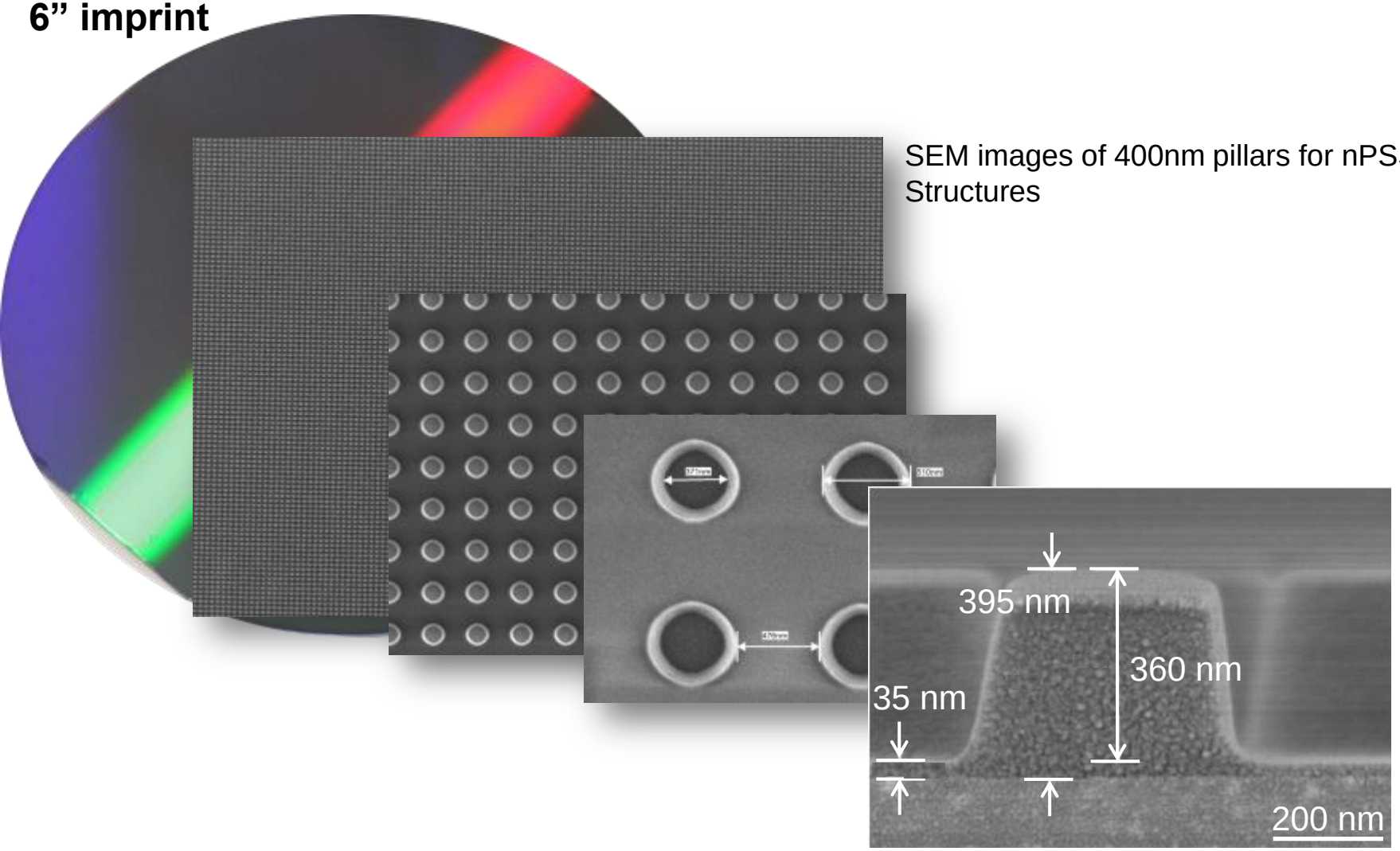


Optical efficiency η_{opt} of 87.5 %
(electrons out / photons in)

Fraunhofer ISE

nPSS Fabricated by SmartNIL™

6” imprint

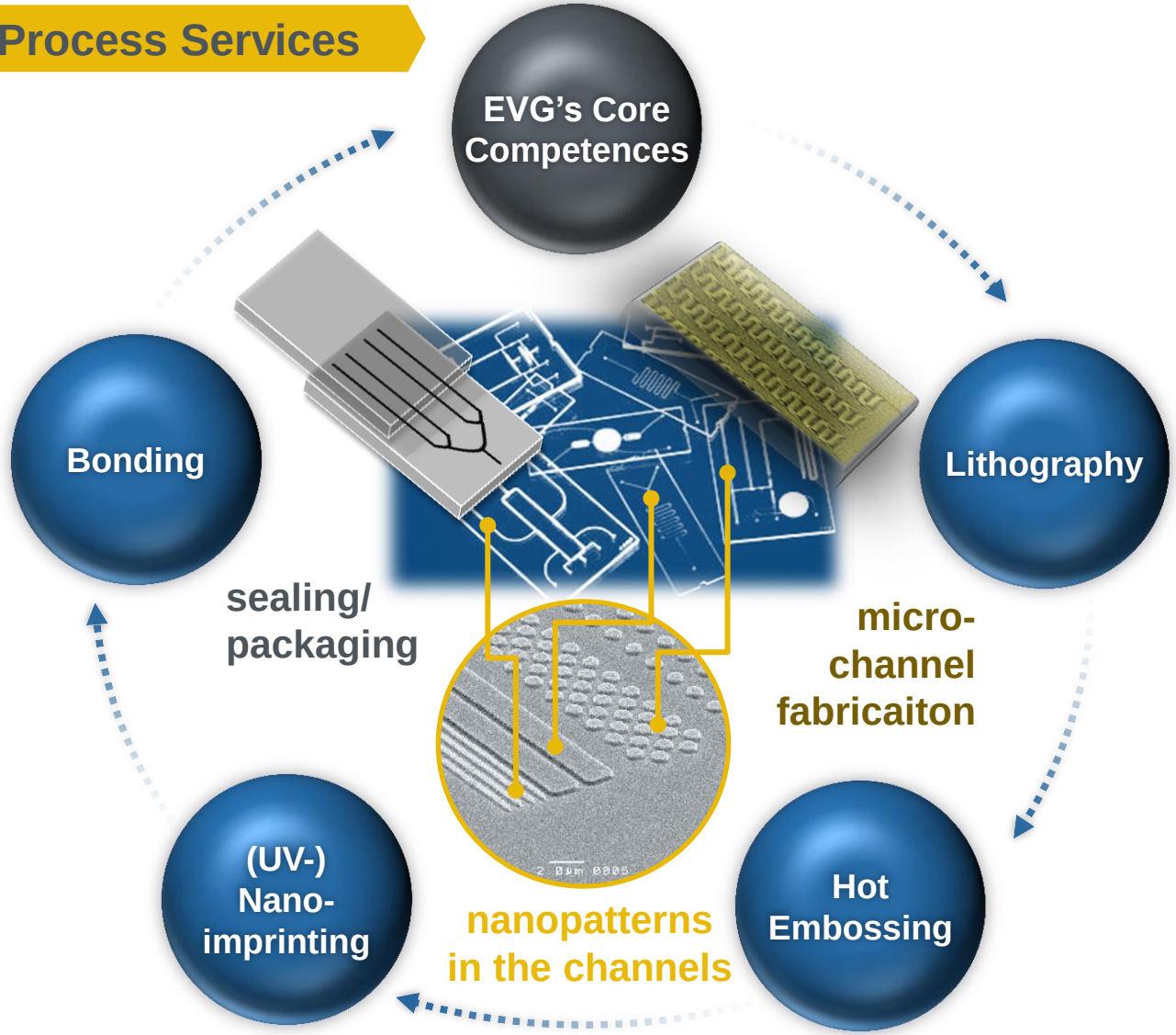


SEM images of 400nm pillars for nPSS Structures

Solutions for Microfluidics

R&D | Pilot Line | HVM

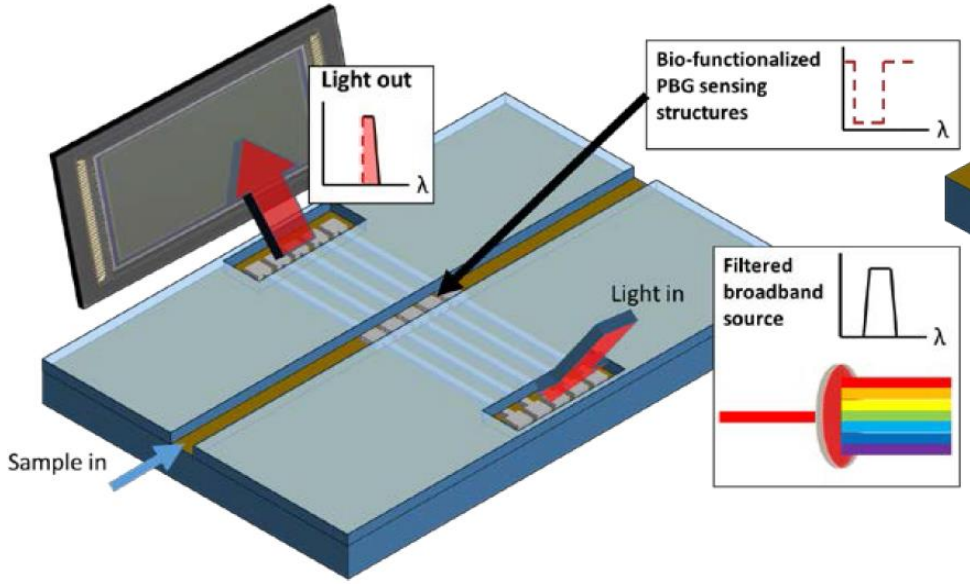
Process Services

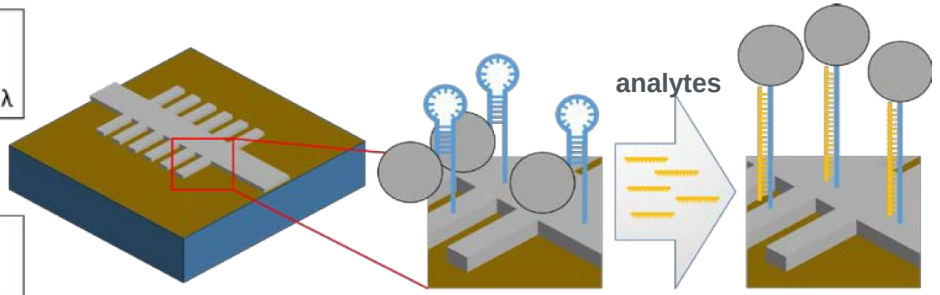


Saphely Project

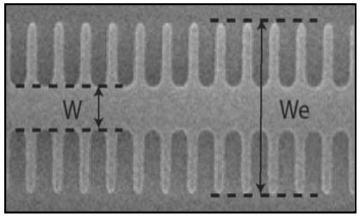
Self amplfied photonic biosensing platform for micro RNA-based early diagnosis of deseases

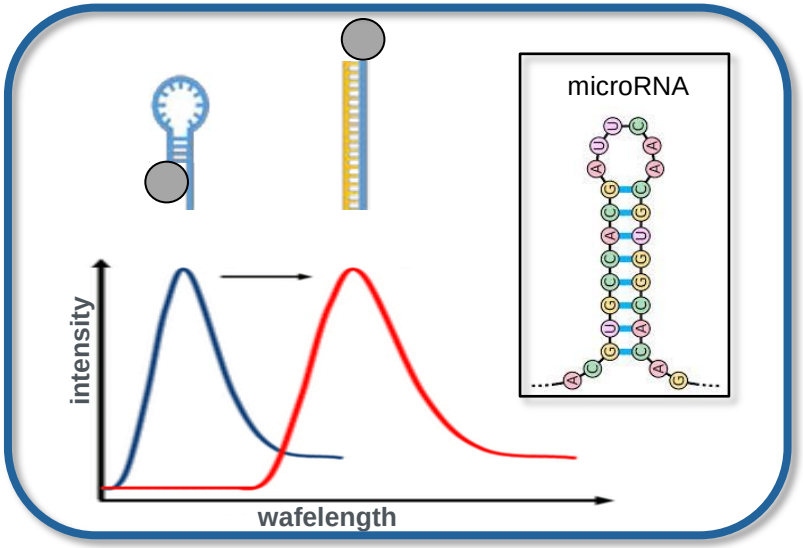
Photonic Bandgap Sensor



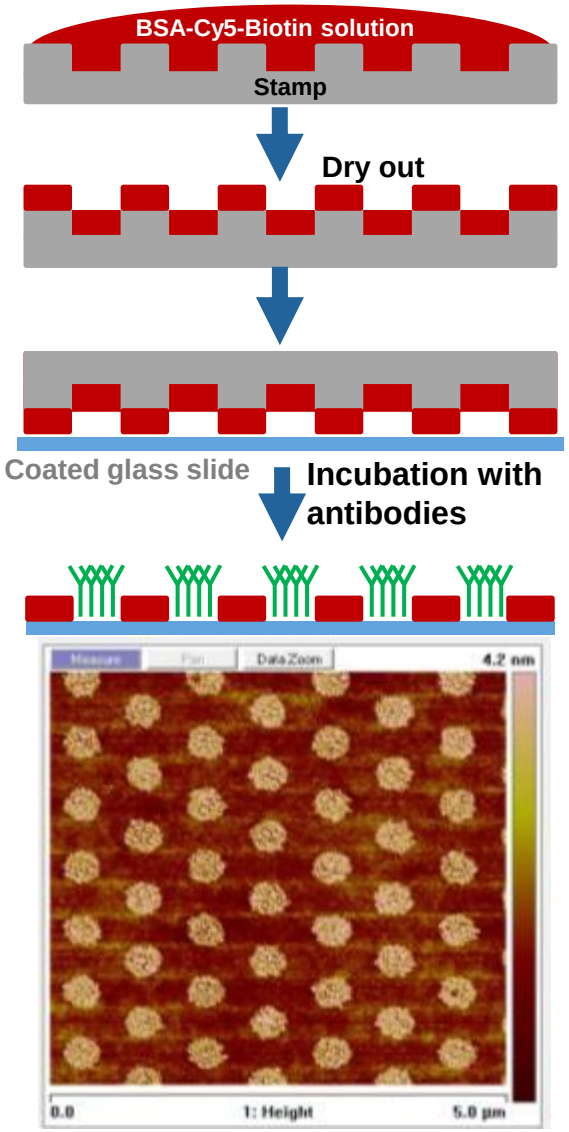


Gratings manufactured with SmartNIL!



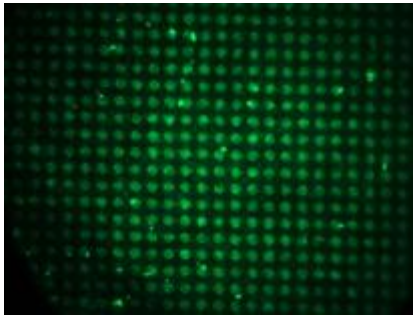


SmartNIL™ for Bio-functionalization

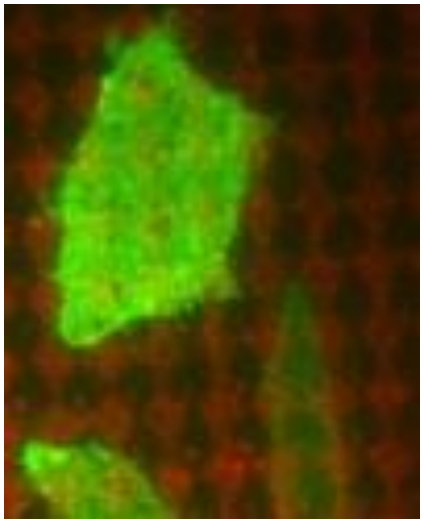


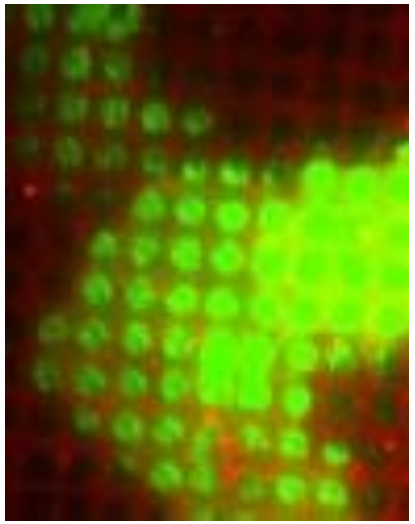
AFM measurement of antibodies

BSA-Cy5 grid



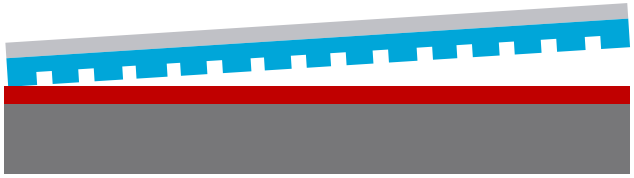
FITC-antibody





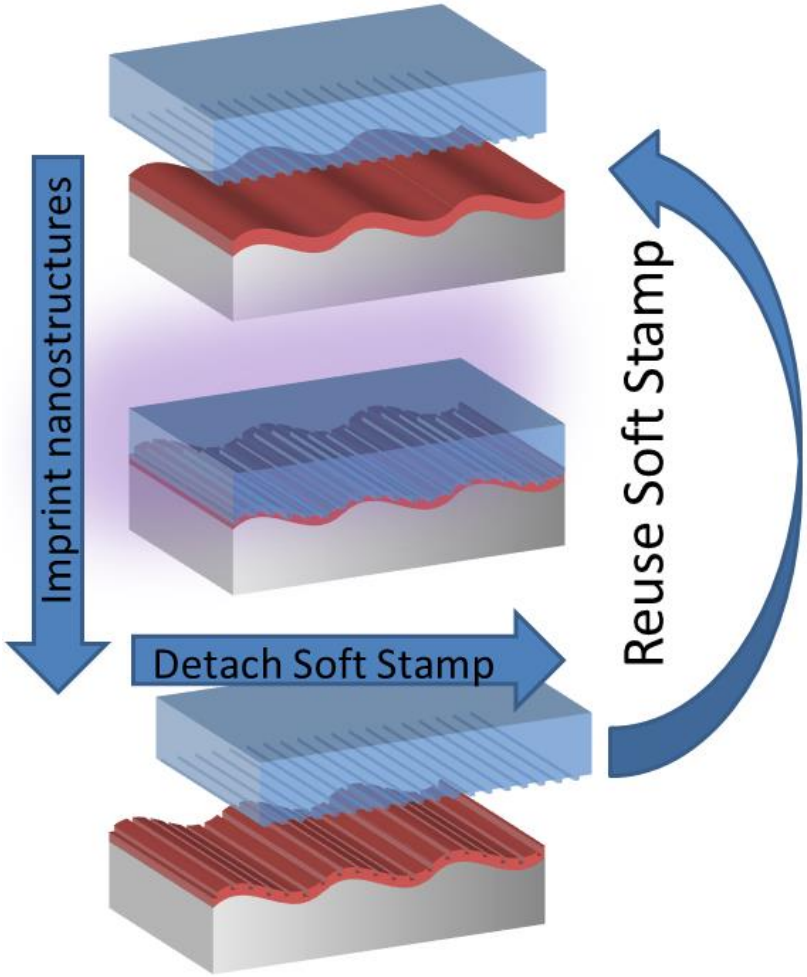
Bio-functionalization of µ-arrays

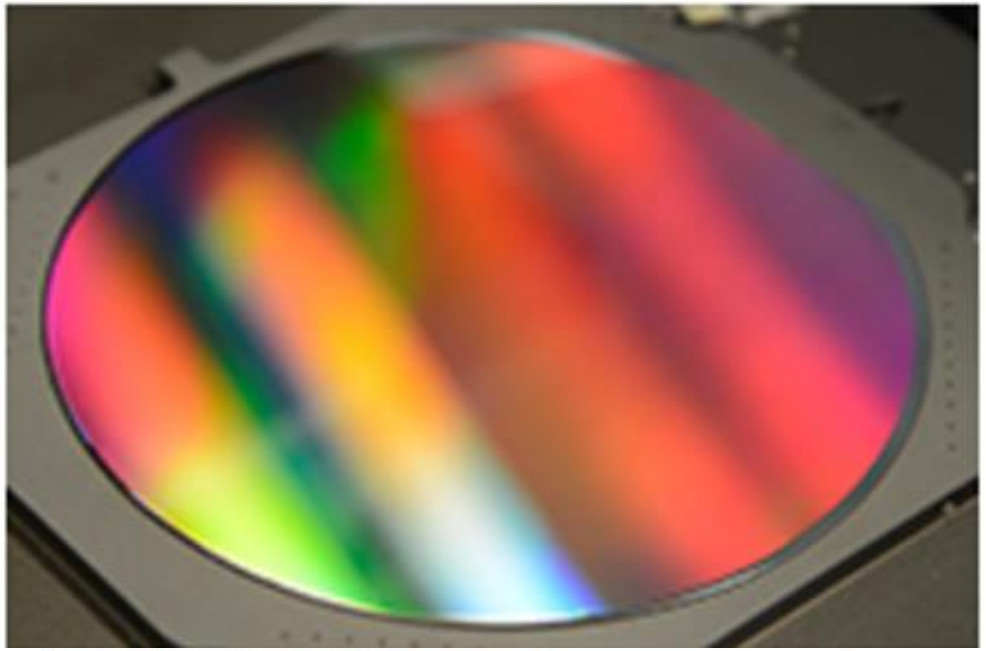
Schwarzenbacher *et* al., 2008. **Nature Methods**. Weghuber *et* al., 2010. **Methods in Enzymology**. Lanzerstorfer *et* al.**,** 2013**. Basic Methods in Protein Purification and Analysis.**



SmartNIL™ Technology

SmartNIL™ – Large Area Imprint





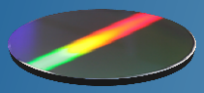
Basic elements of the technique:

Flexible UV-transparent molds
Proprietary imprint tooling → **SmartNIL™**

Allows large area conformal imprints

Soft UV-NIL Improves Cost of Ownership (CoO)

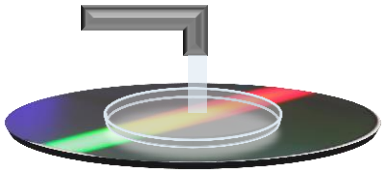
Master



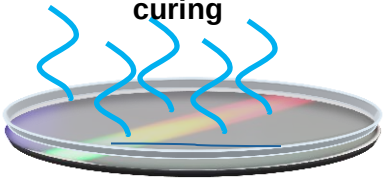
Made by e-beam-lithography, …

Master stamp

Spin coat working stamp material on master



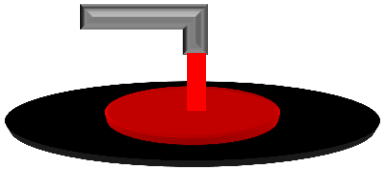
curing



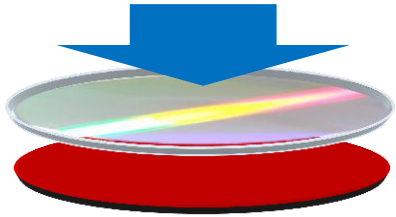
Release working stamp from master

Multi replicated working stamps

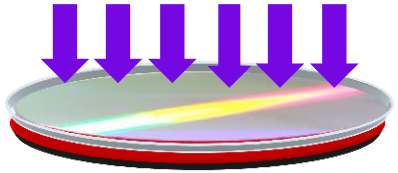
Spin coat imprint resist



Bring working stamp in contact with substrate

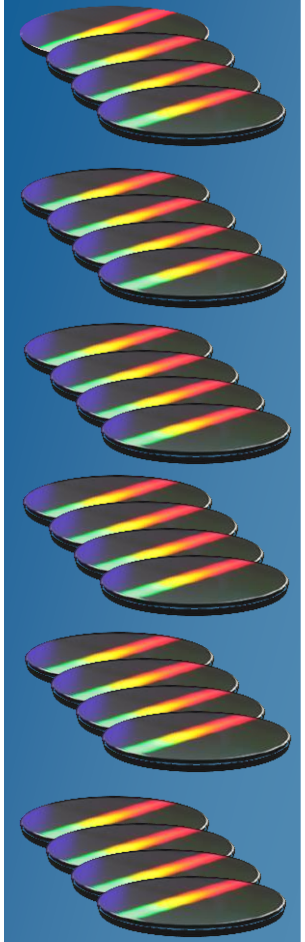


UV exposure

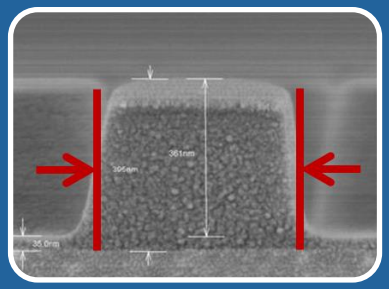


Seperation of working stamp and wafer

Multi imprints per working stamp

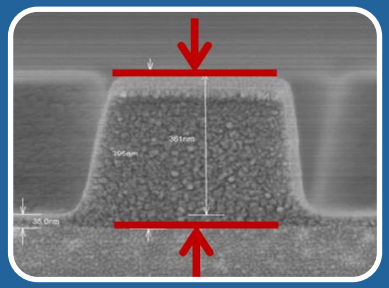


SmartNIL™ – Pattern Fidelity



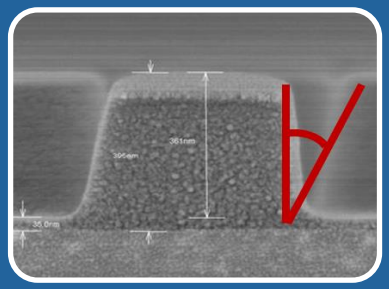
Mean Critical Dimension

- Superior mean critical dimension variation of **< 10 nm @ 3δ over all 50** imprinted substrates using the same polymer stamp.



Height

- Height variation of only **< 20 nm @ 3δ over all 50** imprinted substrates using the same polymer stamp



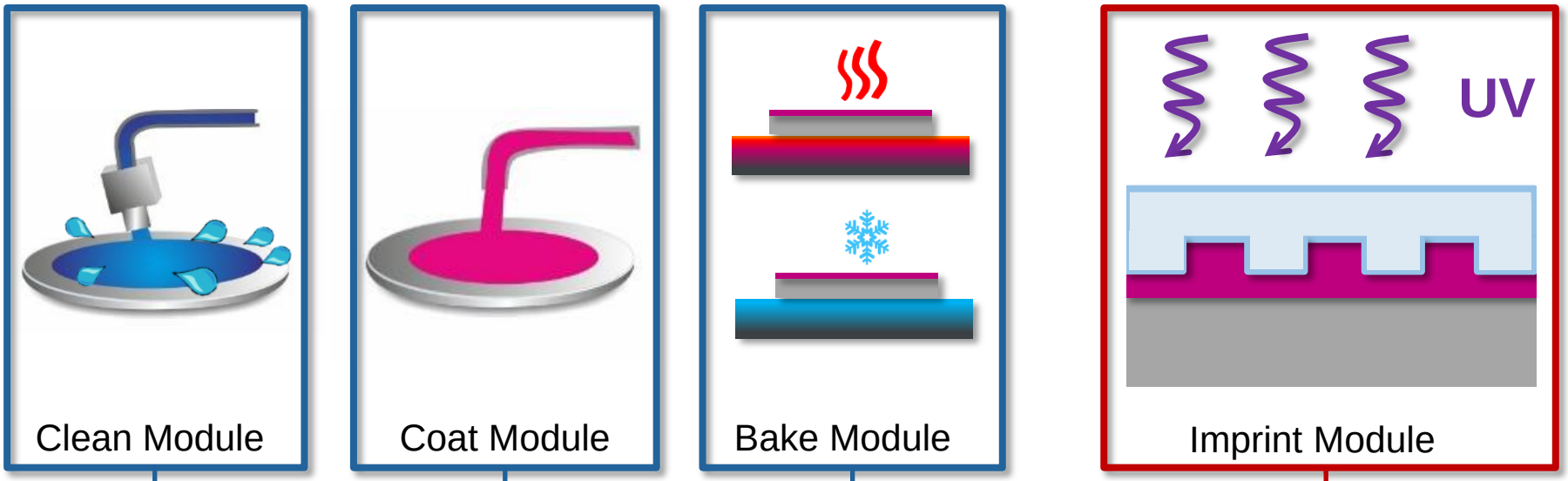
Side Wall Angle

- Side wall angle variation of only **< 2.5° @ 3δ over all 50** imprinted substrates using the same polymer stamp.

EVG® Hercules®NIL

Fully-integrated UV-Nanoimprint Lithography System

HERCULES®NIL



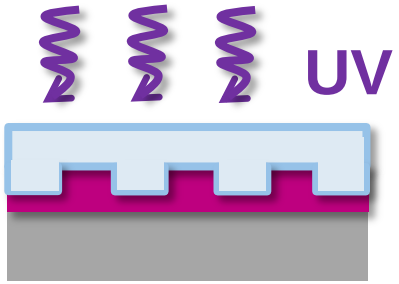
Preprocessing modules

The SmartNIL™ module is the heart of the HERCULES® NIL

Nanoimprint Module

SmartNIL™ tooling

- **Volume-proven** imprinting technology with **superior replication fidelity**
- Uniform **large area imprint** with high process flexibility
- Fully-automated imprinting and controlled low-force detachment for **maximum working stamp reusability**



Cleaning Module

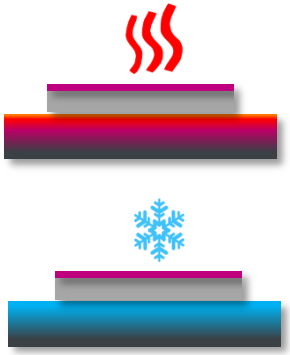
- **Excellent cleaning results** for critical particle sizes

Coating Module

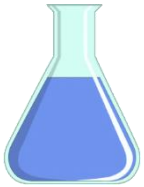
- **High uniformity** spin coat module with **precise thickness control** for minimum residual layer thickness
- Optimized bowl design and flow dynamics for **low resist consumption**

Additional Features

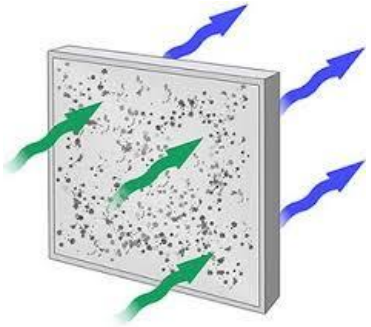
Advanced bake / chill modules
with topside heating and high solvent exhaust



Internal chemical cabinet & external chemical cabinet
for high coating uniformity due to equal temperature of resist and wafer



Optional mini-environment and climate control
for minimum particle contamination as well as best process stability and yield for sensitive processes or chemicals



Summary

NILPhotonics™ Competence Center

Master Templates

- SU-8 Mastering
- Wide Network of stamp suppliers
- S&R Mastering

Metrology Infrastructure

- SEM, AFM,
- Interferometry
- Wide network of metrology providers

Process Development

Definition and development of customized processes

- UV-NIL
- Hot Embossing
- Micro-contact Printing

Materials Know-How

Based on its extensive process related know-how, EVG offers optimization of soft-stamp and imprint resin interaction to meet:

- Applications requirements
- Layout requirements
- Productivity and low Cost of Ownership (CoO)

Pilot Line Production

For seamless transition from R&D to production, EVG offers pilot line production services as well as process transfer to customer designated volume manufacturing sites

Sample Processing

EVG offers:

- Manufacturability Demonstrations
- Small production run imprint services
- Scale-up to pilot line production

Thank You!