

EPIC Technology Meeting on Microelectronics & Photonics – Two Sides of One Coin

# Nanoimprint Lithography for Silicon Photonics

Dr. Anton Alexeev, Business Development Manager

Leading supplier of wafer processing equipment for the nanotechnology, MEMS and semiconductor markets

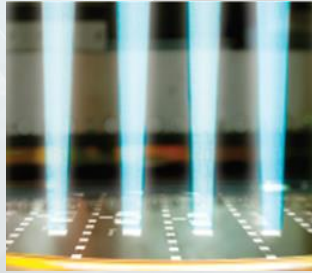
Founded in 1980 by DI Erich and Aya Maria Thallner. More than 1000 employees worldwide

Headquarters in Austria, with fully owned subsidiaries in the USA, Japan, South Korea, China and Taiwan

## Recent Developments



**GEMINI® FB**  
Hybrid Bonding



**EVG® MLE™**  
Maskless Exposure  
Technology



**EVG® HERCULES® NIL**  
SmartNIL® HVM  
Up to 300 mm



**EVG® 770 NT**  
S&R NIL System



**EVG® 7300**  
SmartNIL® and WLO  
Up to 300 mm

## Nanoimprint Lithography (NIL) Developments

**NIL is a cost-effective and flexible technology to enable nanostructured surfaces as well microstructures on wafer-level**

- Volume-proven wafer level imprinting technology (= replication)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- Enables highest resolution at low cost
- Insensitive to shapes, sizes and structures

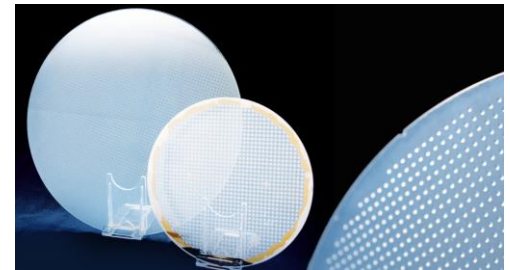
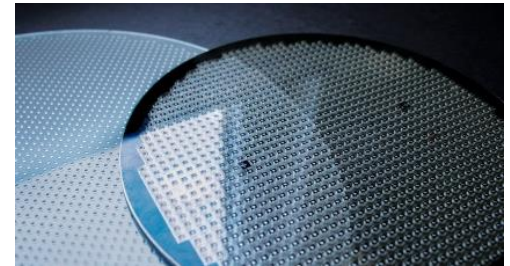
## **EVG NIL equipment and dedicated process capabilities**

- Step-and-Repeat Mastering
  - SmartNIL®
  - Lens Molding
- Tools from R&D to fully automated HVM



## **EVG NIL Photonics Competence Center → Innovation Incubator**

- Helping to ramp up
- 1.300 m<sup>2</sup> class 10 – 100 cleanroom space & application labs



# Agenda



- NIL Structures Examples
- NIL Processes
  - Step and Repeat
  - Stamp
- Process Results
- NIL Photonics® Competence Center

# NIL Structure Examples | Broad Range of Possibilities

Diffractive Optical Elements

Holographic Optical Elements

Lightguides

Light Coupling

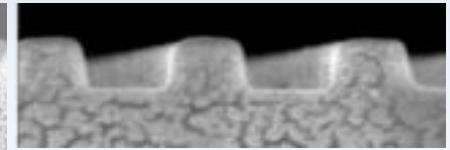
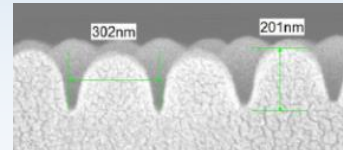
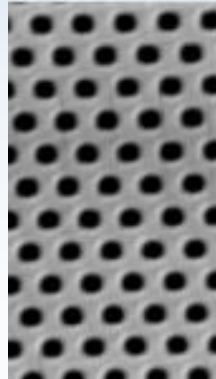
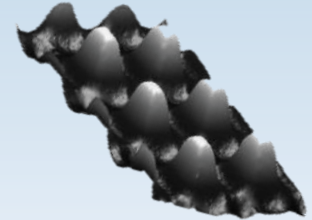
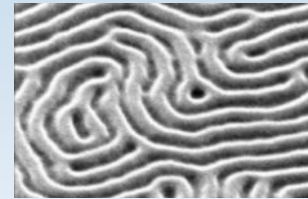
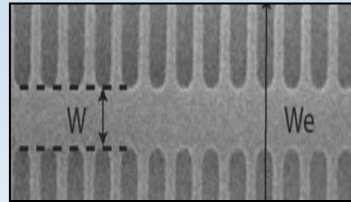
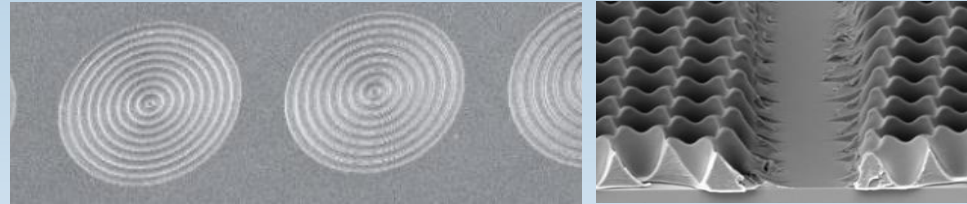
Optical Gratings

Diffusor Optics

Photonic Crystals

Anti Reflective Structures

Plasmonic Structures



SmartNIL<sup>®</sup> is shape insensitive and allows efficient replication of complex structures

Arbitrary 3D Structure

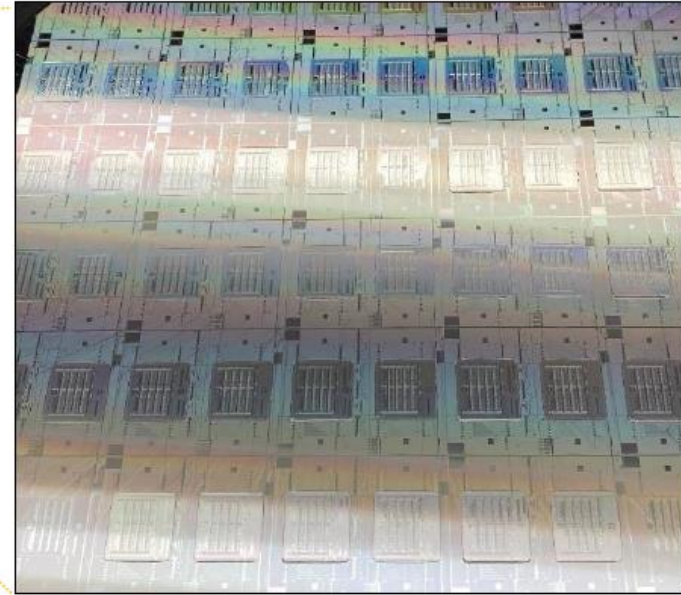
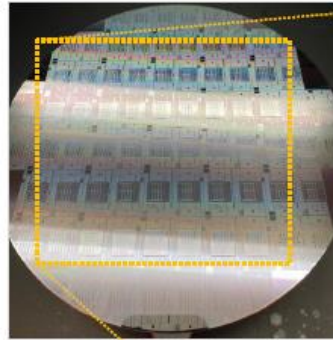
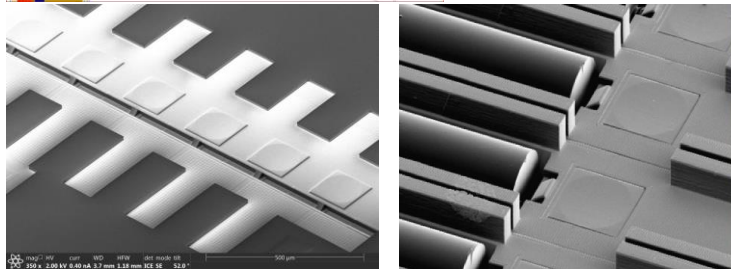
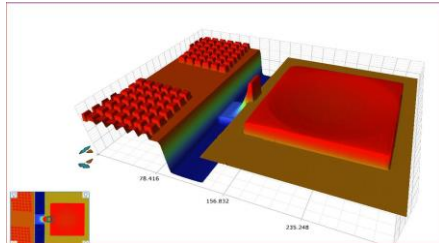
## Bridging the gap in SiPh packaging towards wafer level HVM

### Teramonts PhotonicPlug und PhotonicBump: Done by NIL

→ Nanoimprint of complex optical microstructures like lenses or mirrors on SiPh wafers

#### Important

- Pattern fidelity and repeatable → scalability
- Highest alignment accuracy
- Residual layer control → thin and uniform
- Fiber trenches perfectly aligned to the mirrors



*PhotonicBump – Imprint inside 20µm on 8" SiPh wafer*



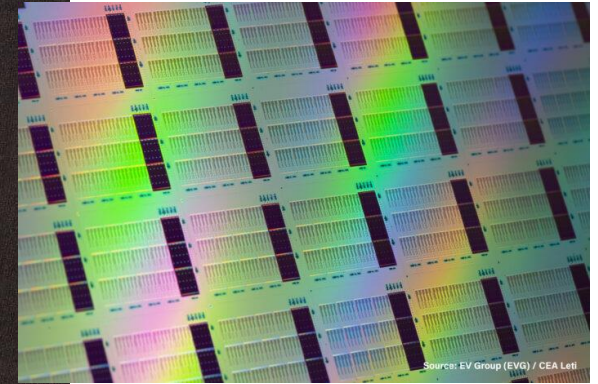
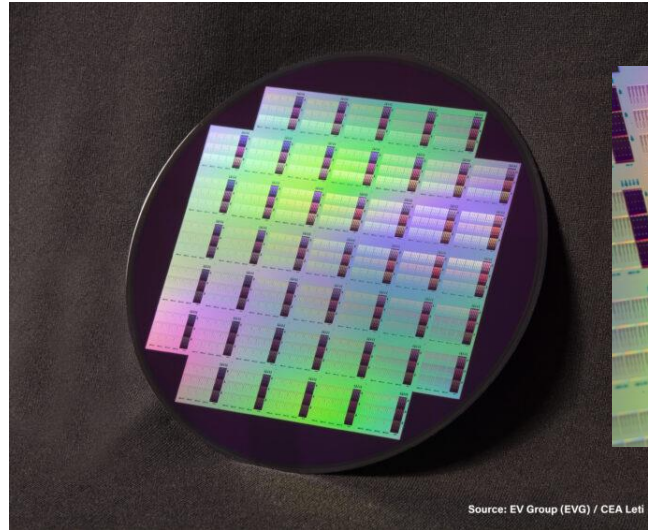
Grant Agreement No. 958472

LiDAR is required for self / autonomous driving cars

Automotive industry needs

- Lower weight
- Better power consumption
- Lowered sensor size and costs

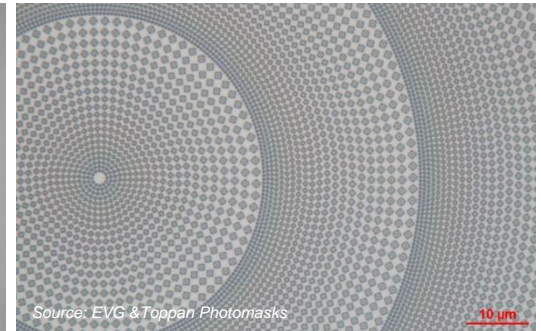
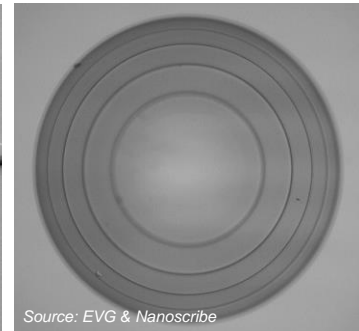
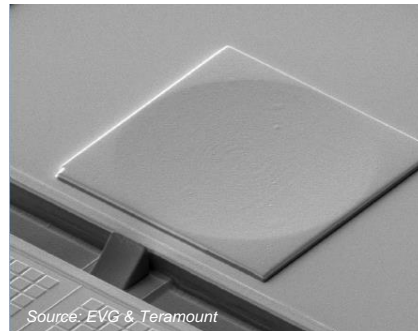
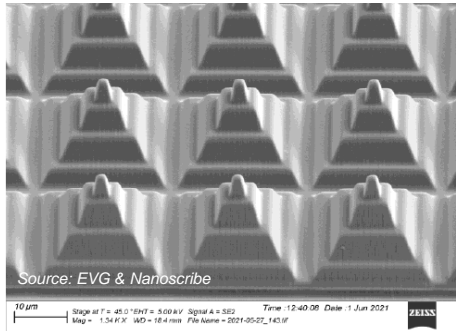
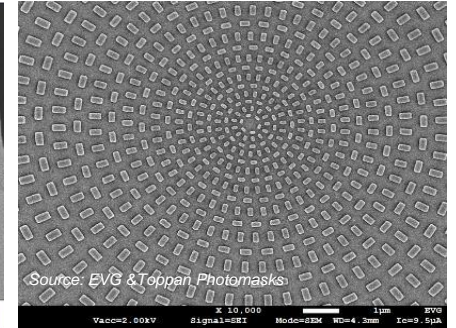
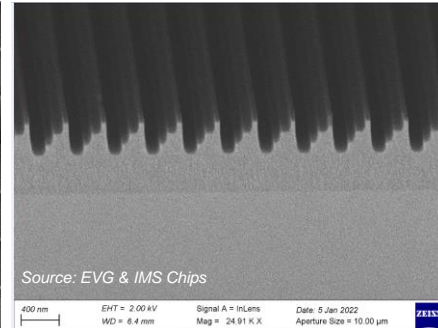
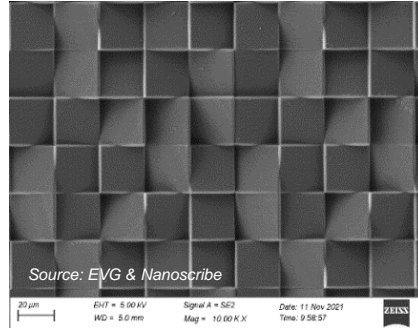
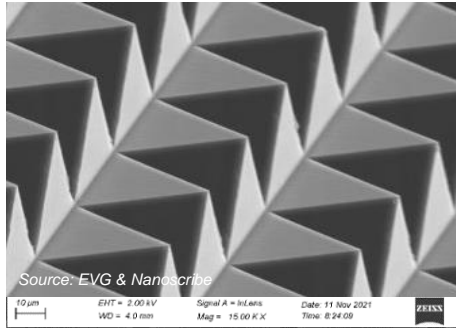
→ Goal miniaturize the device and improve power consumption



Source: EVG, master provided by CEA Leti

→ NIL enabled more complex design and miniaturized the system further

# NIL Structure Examples | Broad Range of Possibilities



Process capability for nano- and microstructures, also for complex shaped structures - in a single step!

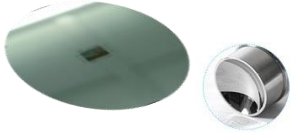


# Nanoimprint Lithography | From Master Template to Multiple Imprints



S&R process

Single DIE Master



EVG<sup>®</sup>770 S&R System



Cure imprint polymer and de-emboss template



Move to next DIE and imprint again



S&R Master

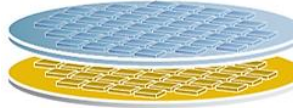


NIL imprint process

Working Stamp



Multiple Imprints



EVG<sup>®</sup>7300



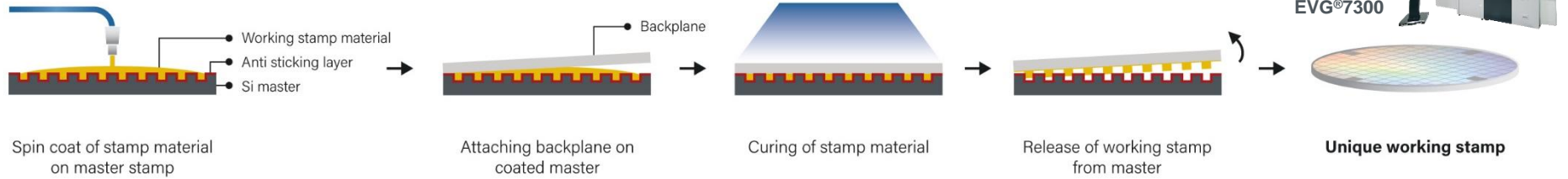
HERCULES<sup>®</sup> NIL



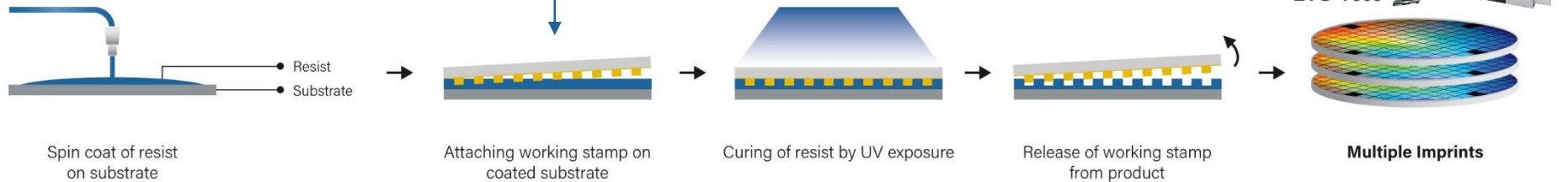
# Nanoimprint Lithography | From Master Template to Multiple Imprints



## SmartNIL® - Stamp fabrication



## SmartNIL® - Imprint



→ Working stamp manufacturing and imprinting is performed in the same equipment

## Process Results

# S&R and SmartNIL<sup>®</sup> Results | Process Chain



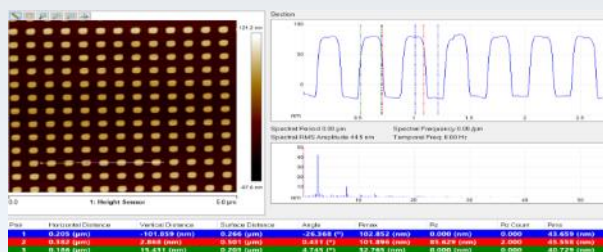
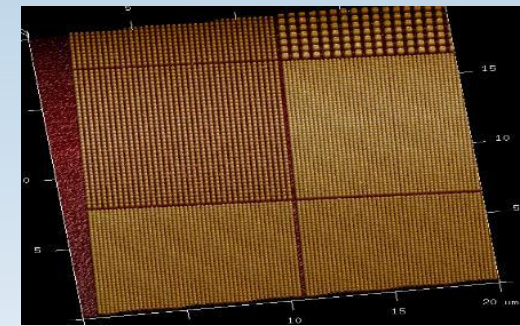
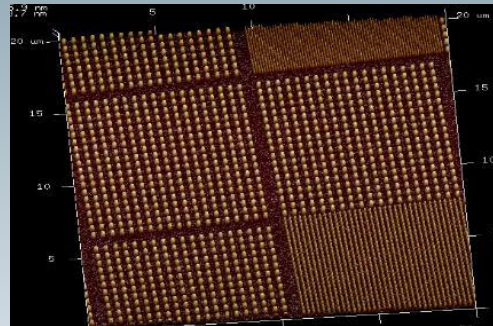
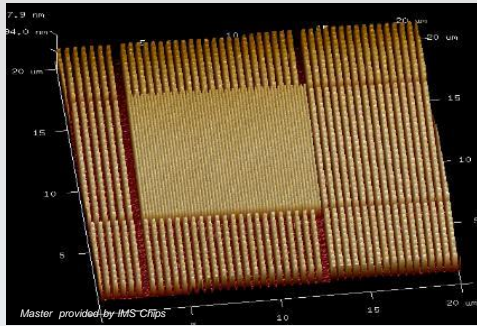
## Master Template



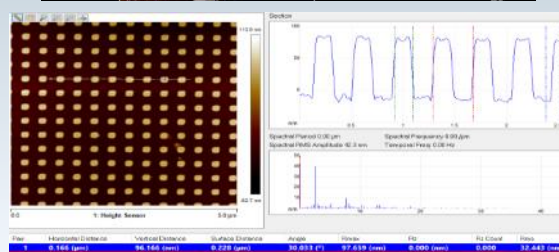
## Step & Repeat



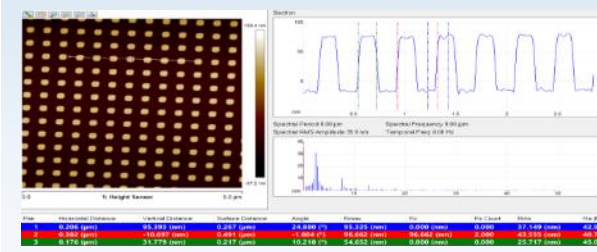
## Final Imprint



Pillar height: 101nm  
Pillar Diameter: 186nm  
Pitch: 382nm



Pillar height: 96nm  
Pillar Diameter: 176nm  
Pitch: 382nm

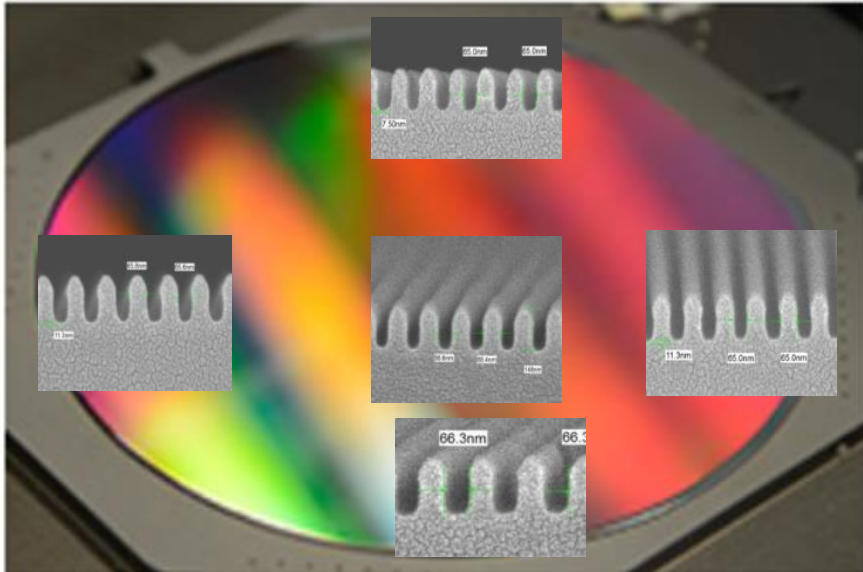


Pillar height: 95nm  
Pillar Diameter: 176nm  
Pitch: 382nm



Stable pattern fidelity over the whole process chain → highly reproducible NIL replications & proven HVM capability





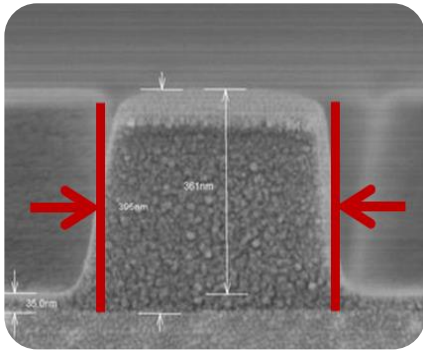
**8" Full Area Imprint With Lines and Spaces**  
(Source EVG)



**Excellent CD Uniformity over 8"**  
**Minimum residual layer thickness and variation**

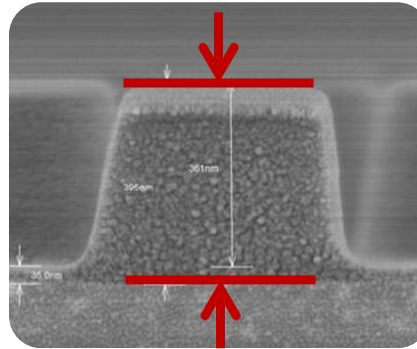
Position	Height	L/S	RLT
Center	179nm	78nm/77nm	10.7nm
12:00	182nm	75nm/75nm	11.7nm
3:00	182nm	75nm/75nm	13.5nm
6:00	181nm	76nm/76nm	8.0nm
9:00	181nm	76nm/76nm	13.5nm

## Mean Critical Dimension



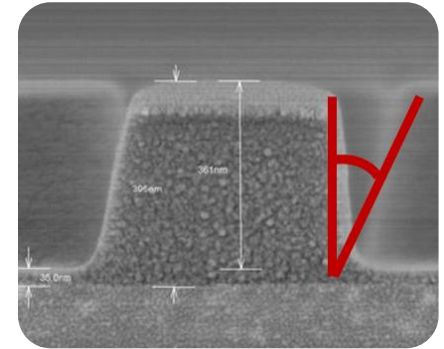
Mean critical dimension  
< 10nm @ 3 $\sigma$  over all 50  
using the same polymer stamp

## Height



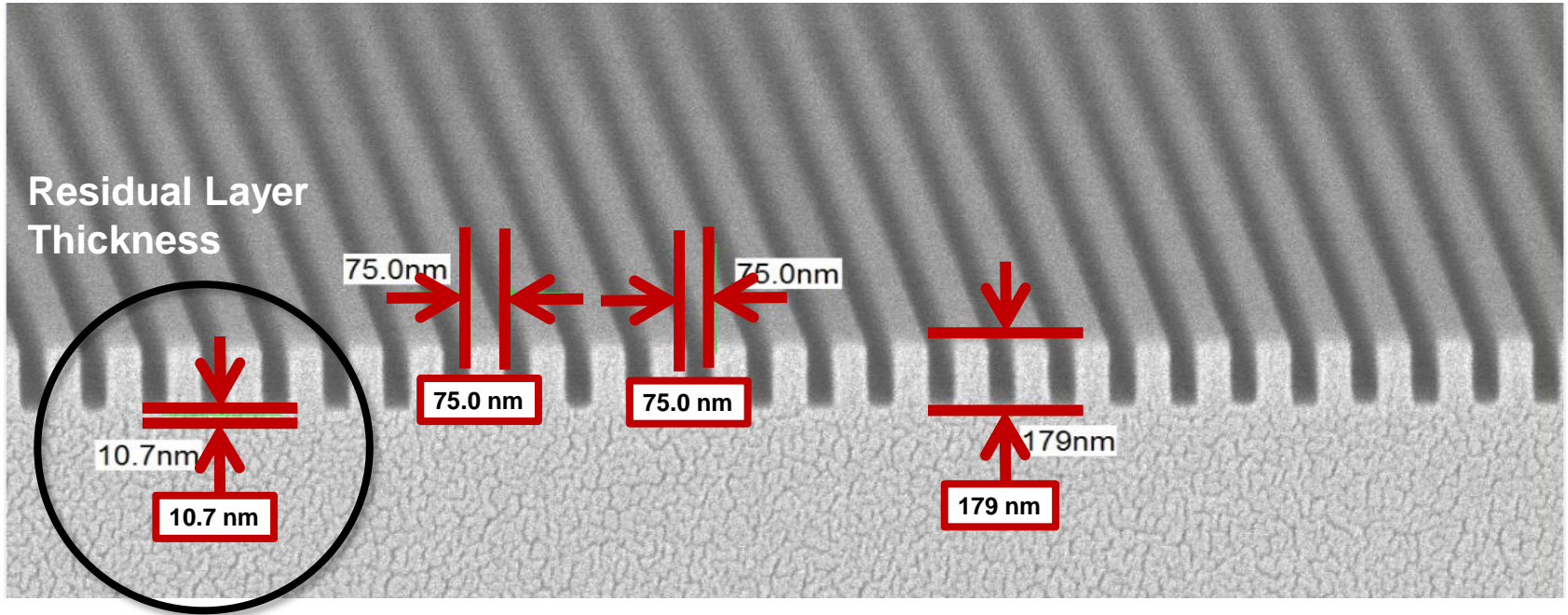
Height variation of  
< 20nm @ 3 $\sigma$  over all 50  
using the same polymer stamp

## Side Wall Angle



Side wall angle variation  
< 2,5° @ 3 $\sigma$  over all 50  
using the same polymer stamp

12" master stamp; full area pattern



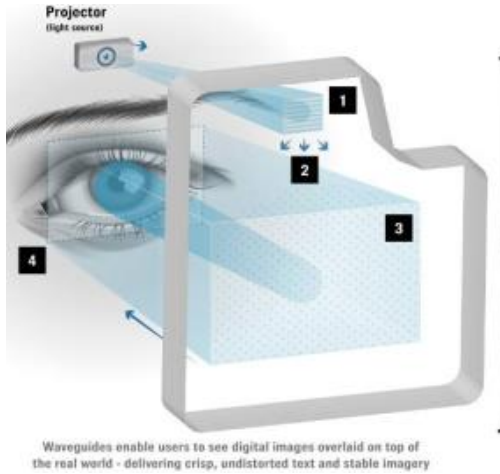
75 nm lines  
150 nm pitch  
180 nm height

**Aspect ratio: 1:2.4**  
**Residual layer thickness: 10.7 nm**



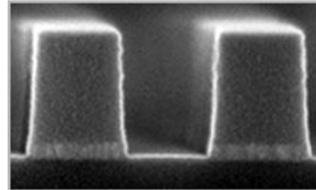
**Very small residual layer compared to imprinted structure**  
**No/Minor influence of the residual layer on etching**

# NIL Applications & Trends | Waveguides for Augmented Reality



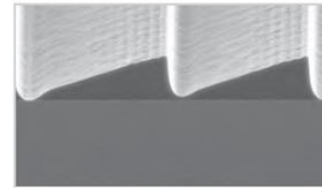
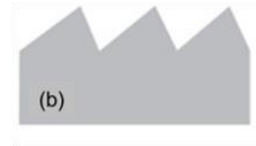
Source: Waveoptics

Binary Grating



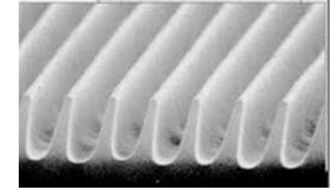
Source: IMS Chips

Blazed Grating



Source: IMS Chips

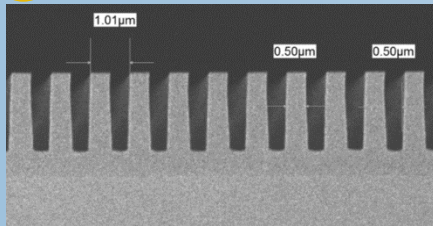
Slanted Grating



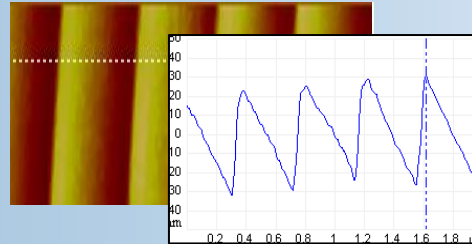
Source: Yole



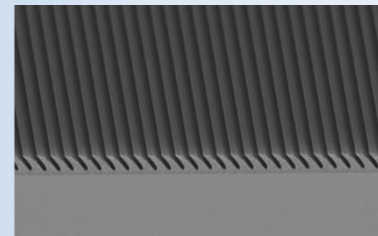
## SmartNIL® Results



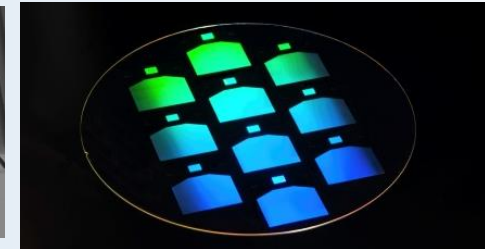
Source: EVG



Source: EVG



Source: EVG and NILT



Courtesy of Waveoptics





# NIL Photonics<sup>®</sup> Competence Center

**“All in one cleanroom”  
Competence Center at EVG HQ**

- R&D and HVM NIL Tools
- S&R Mastering Service
- R&D and Process Development
- Customer Sampling and Demo
- Pilot Line Production
- Supplier Guidance (e.g. Materials, Masters, Substrates)
- Metrology Infrastructure

Over 1.300 m<sup>2</sup>  
cleanroom area (class  
10 – 100) and  
application labs



Cleanroom space for  
rent → quick  
turnarounds



High quality  
standards, ISO  
certified, full  
documentary and  
reporting



**Helping customers to ramp up their ideas!**

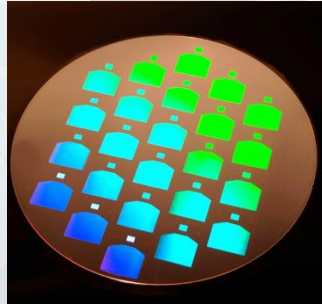
**NILPhotonics® Competence Center – A smart way to collaborate for success**

**Establish decisive manufacturing steps in close collaboration with process and equipment experts**

**Bridging the gap between photonics R&D and volume manufacturing**



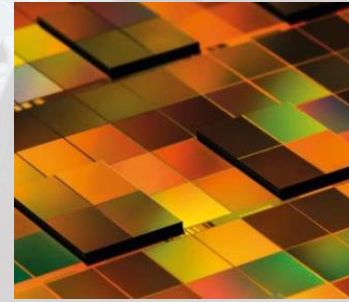
**Wafer Level Optics & Photonics Packaging**



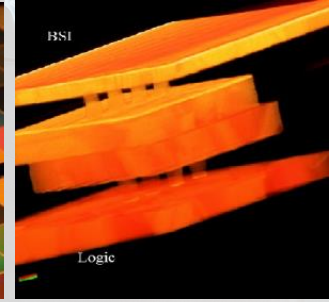
**Nanoimprint & S&R Mastering**



**Advanced Resist Processing**



**Heterogeneous Integration**



**3D Integration & Hybrid Bonding**