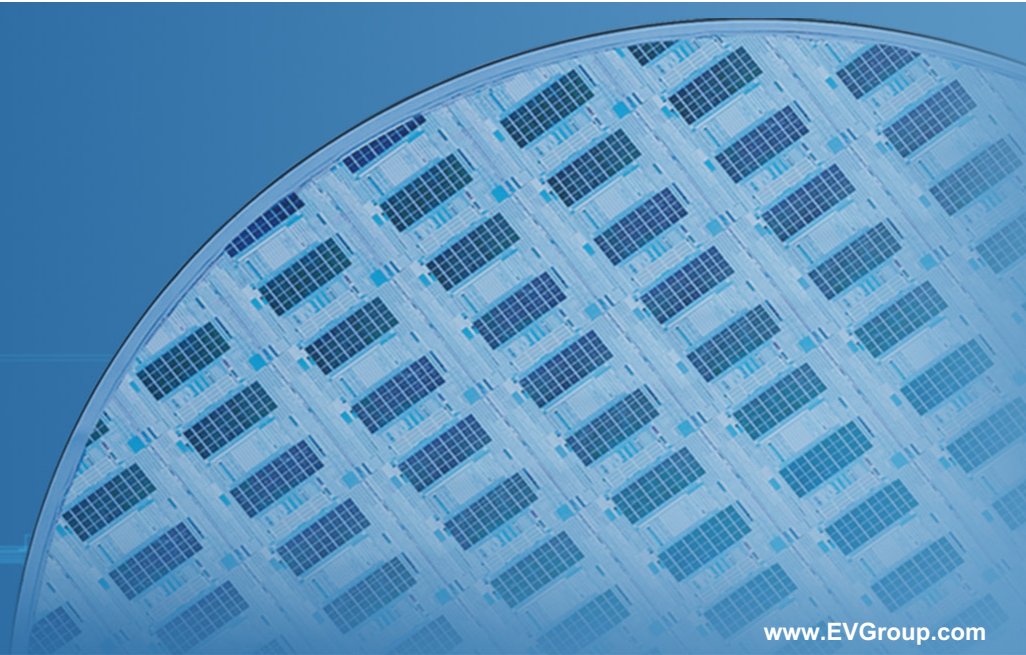
PIC INTERNATIONAL 2024

Advances in PIC Manufacturing for Sensing and Datacom Applications – All thanks to Nano Imprinting Lithography

Khan Jonas
Team Leader Process Technology NIL Development



EV Group | At A Glance

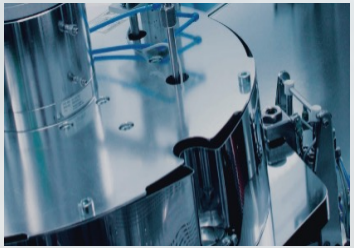
Leading supplier of wafer processing equipment for the MEMS, nanotechnology and semiconductor markets

Founded in 1980 by DI Erich and Aya Maria Thallner. More than 1300 employees worldwide

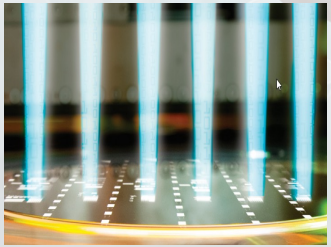
Headquarters in Austria, with fully owned subsidiaries in the USA, Japan, South Korea, China and Taiwan

EVG Core Technologies

Wafer Bonding



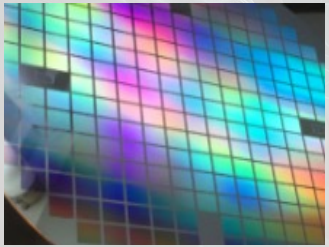
Maskless Lithography



Advanced Resist Processing

Wafer Level Optics

Nanoimprint



EV Group | At A Glance

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

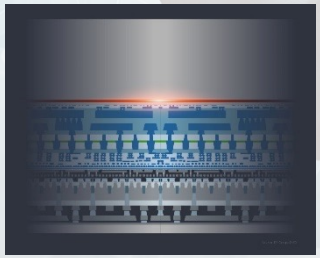
Founded in 1980 by DI Erich and Aya Maria Thallner. More than 1300 employees worldwide

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

Recent Developments

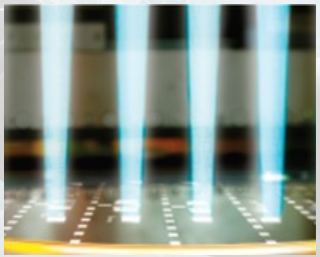
EVG® GEMINI® FB
SmartView® NT3

Hybrid Bonding



EVG® 850 DB

IR Laser Release



EVG® Lithoscale
Maskless Exposure Technology

Back-end Lithography

EVG® HERCULES® NIL
SmartNIL® HVM

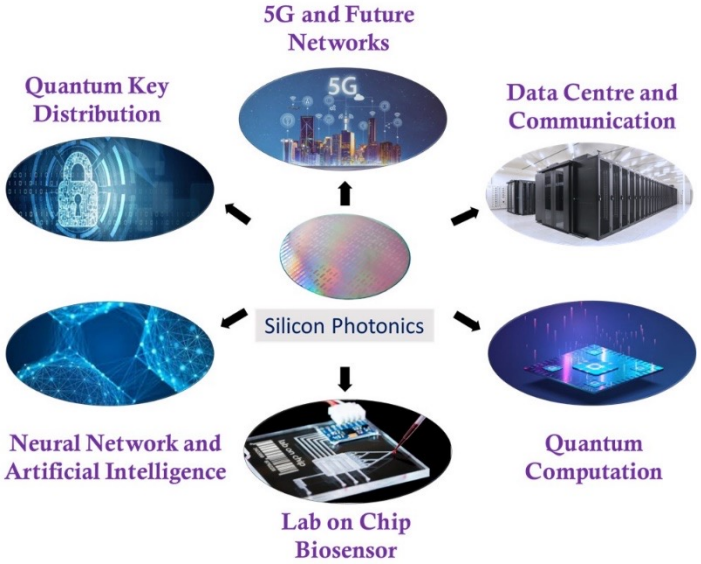
Nanoimprint Lithography

EVG® 7300
SmartNIL® and WLO

Nanoimprint Lithography

Si Photonics | Introduction and Applications

- Photonics = science of generating, manipulating and detecting light … crucial in optical communications
- Si Photonics is a material platform from which photonic integrated circuits (PICs) can be made
- SOI wafers are typically used, most of standard CMOS foundry manufacturing processes can be applied → Cost effective mass production of SiPh devices

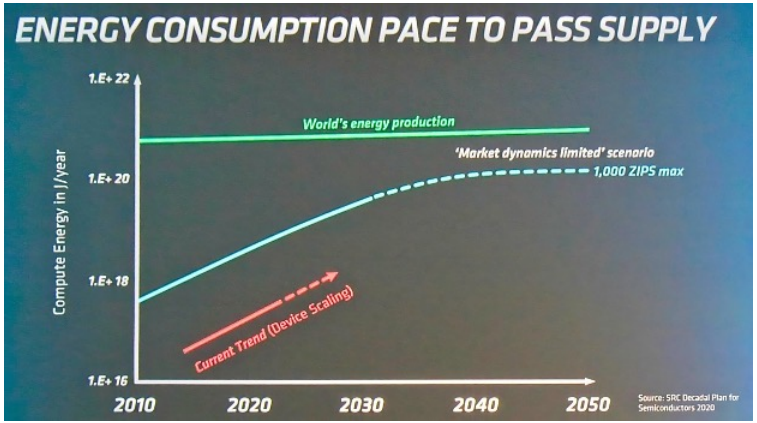


Source: Centre for Programmable Photonic Integrated Circuits and Systems

- Rapid growth of SiPh is expected over the next years
- All applications are in need of advanced / new manufacturing technologies for light management as a supplement to the existing and known advanced capabilities of semiconductor technology

Si Photonics | Introduction and Applications

- Photonics = science of generating, manipulating and detecting light … crucial in optical communications
- Si Photonics is a material platform from which photonic integrated circuits (PICs) can be made
- SOI wafers are typically used, most of standard CMOS foundry manufacturing processes can be applied → Cost effective mass production of SiPh devices



Datacenter interconnect applications: growing demand for high bandwidth while maintaining low power consumption & package footprint

Si Photonics | Building Blocks

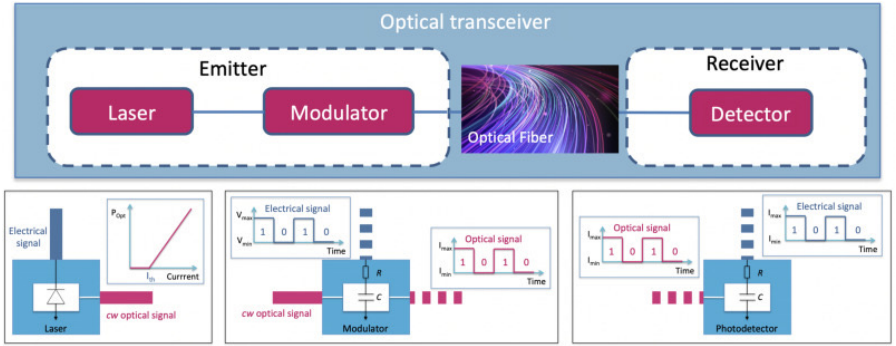
Key Components

Light source → laser
- Optical source on Si remains challenge → hybrid co-integration with III-V materials

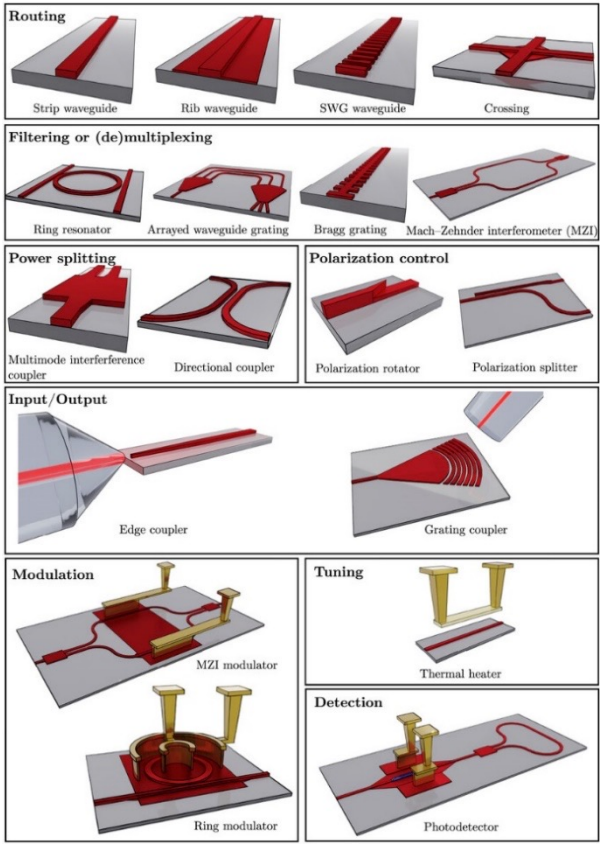
Guide
- Interconnects between photonic devices in the circuit → waveguides
- Device to device connection
- External connection

Modulate / Manipulate
- Laser light is modulated by a high-speed electrical signal
- Altering characteristics of a light wave in response to external signal
- Filtering / splitting of signals / polarisation

Detect
- Photodetectors convert incoming light into electrical signals

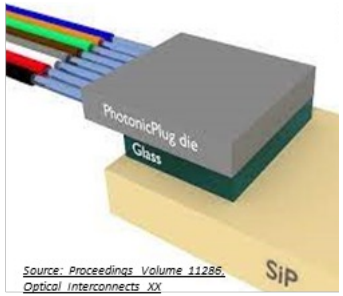


Source: Building blocks of silicon photonics, DOI:10.1016/BS.SEMSEM.2019.07.006

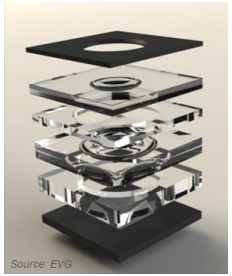


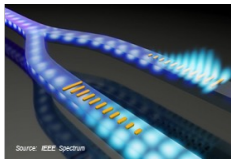
Source: Scaling capacity of fiber-optic transmission systems via silicon photonics, DOI:10.1515/nanoph-2020-0309

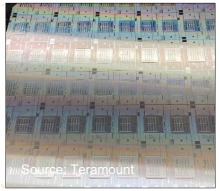
PIC Manufacturing and Packaging | Requirements



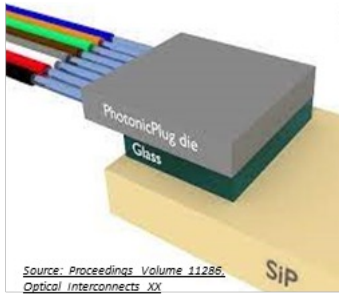
Source: Proceedings Volume 11286, Optical Interconnects XX

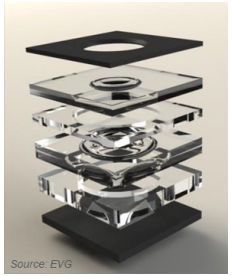

Source: EVG

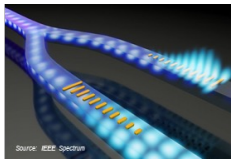

Source: IEEE Spectrum

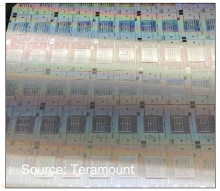

Source: Teramount

PIC Manufacturing and Packaging | Requirements





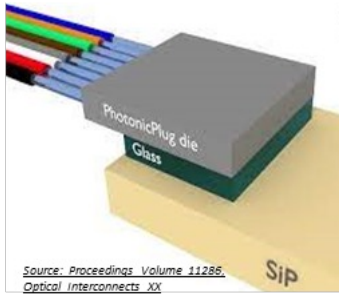


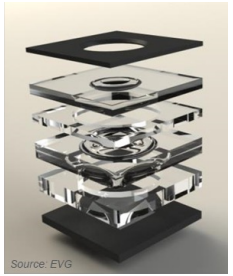


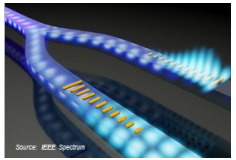
Technology

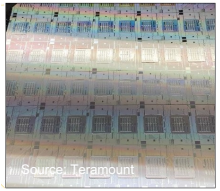
- Structuring and patterning of arbitrary geometrical shapes
- High resolution from easy to complex shapes (e.g. lenses, gratings, slopes, slants, various orientations, …)
- Repeatable fidelity all over the required area
- Scalable from small area to larger area and from low volume to large volume
- Dedicated material properties

PIC Manufacturing and Packaging | Requirements









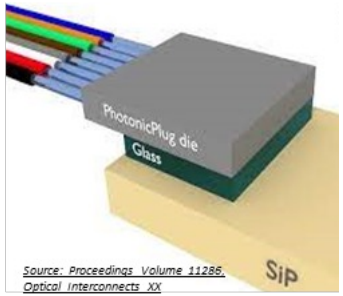
Technology

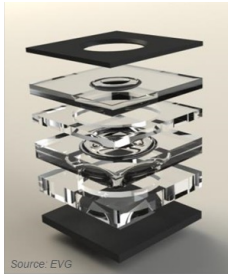
- Structuring and patterning of arbitrary geometrical shapes
- High resolution from easy to complex shapes (e.g. lenses, gratings, slopes, slants, various orientations, …)
- Repeatable fidelity all over the required area
- Scalable from small area to larger area and from low volume to large volume
- Dedicated material properties

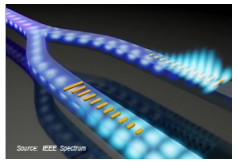
Integration

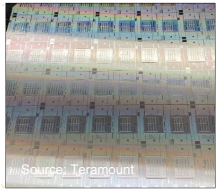
- Std. semiconductor chain compliant
- Structuring of functional wafers / full area & selective area
- Precise alignment accuracy
- Residual layer control

PIC Manufacturing and Packaging | Requirements









Technology

- Structuring and patterning of arbitrary geometrical shapes
- High resolution from easy to complex shapes (e.g. lenses, gratings, slopes, slants, various orientations, …)
- Repeatable fidelity all over the required area
- Scalable from small area to larger area and from low volume to large volume
- Dedicated material properties

Integration

- Std. semiconductor chain compliant
- Structuring of functional wafers / full area & selective area
- Precise alignment accuracy
- Residual layer control

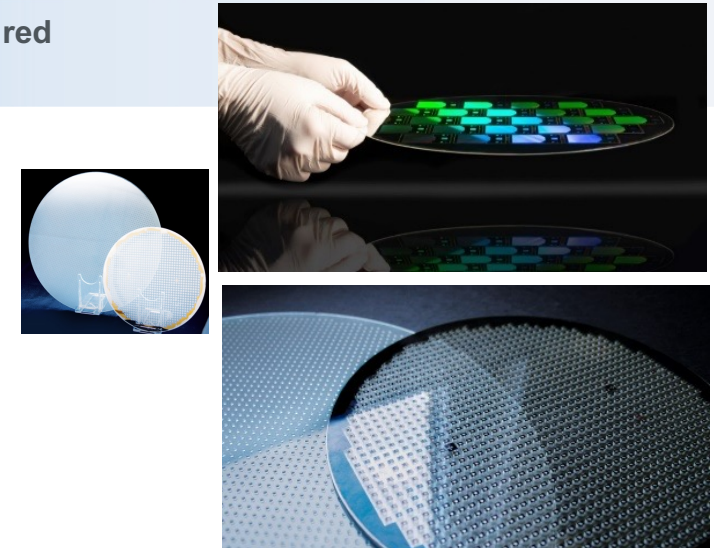
Required Know-how

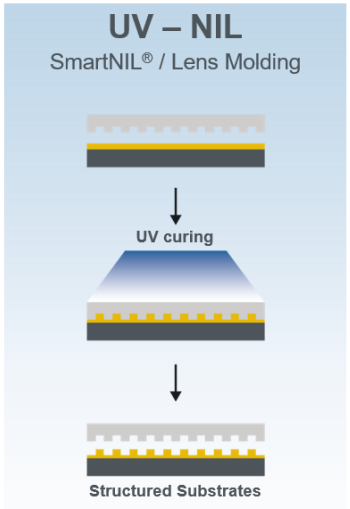
Material
Equipment
Process

Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates

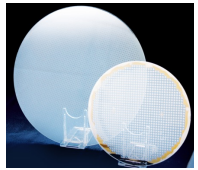


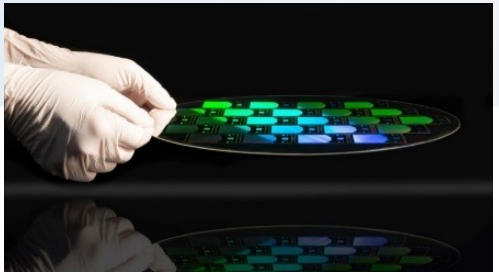


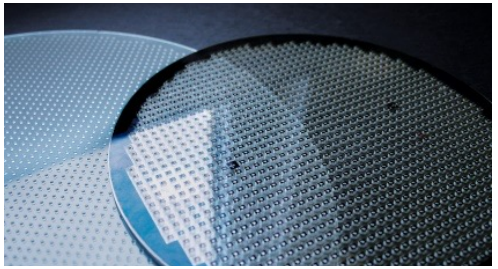
Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates





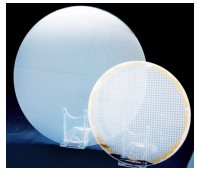


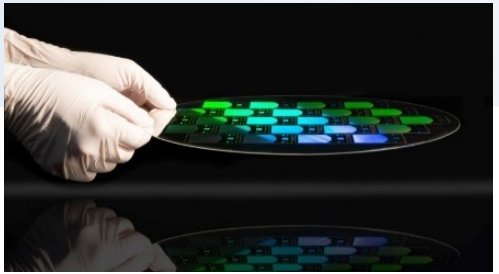
NIL Infrastructure / Ecosystem

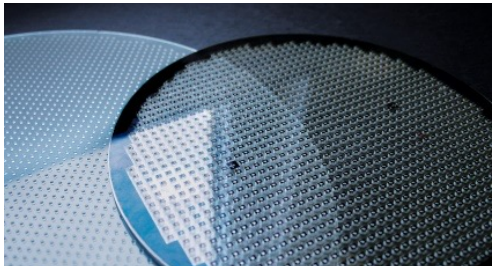
Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates







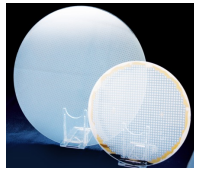
NIL Infrastructure / Ecosystem

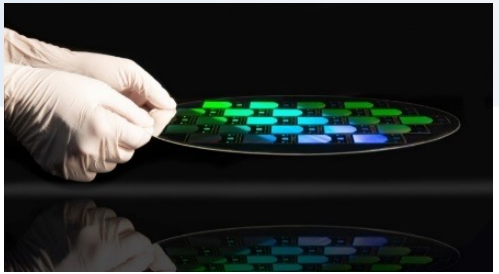
- **Design** → Close collaboration with master suppliers

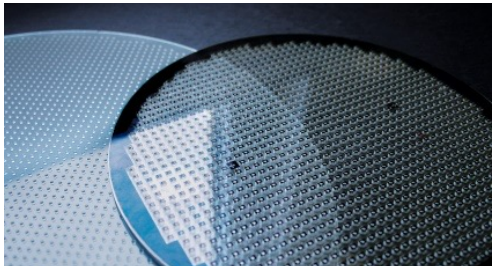
Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates







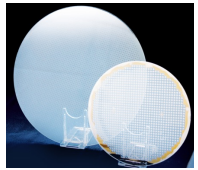
NIL Infrastructure / Ecosystem

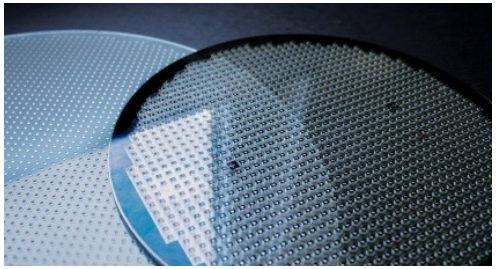
- **Design** → Close collaboration with master suppliers
- **Material** → Strong partnership with material vendors

Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates





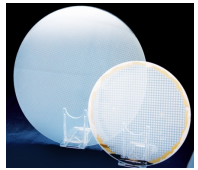
NIL Infrastructure / Ecosystem

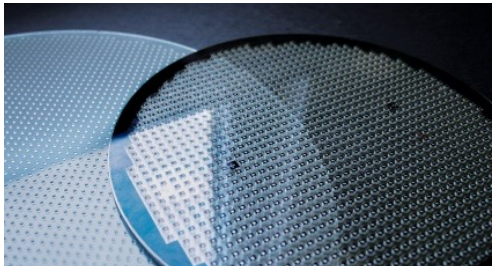
- **Design** → Close collaboration with master suppliers
- **Material** → Strong partnership with material vendors
- **Process**
  - Step-and-Repeat Mastering
  - SmartNIL®
  - Lens Molding / Wafer Level Optics
  - Lens Stacking

Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates





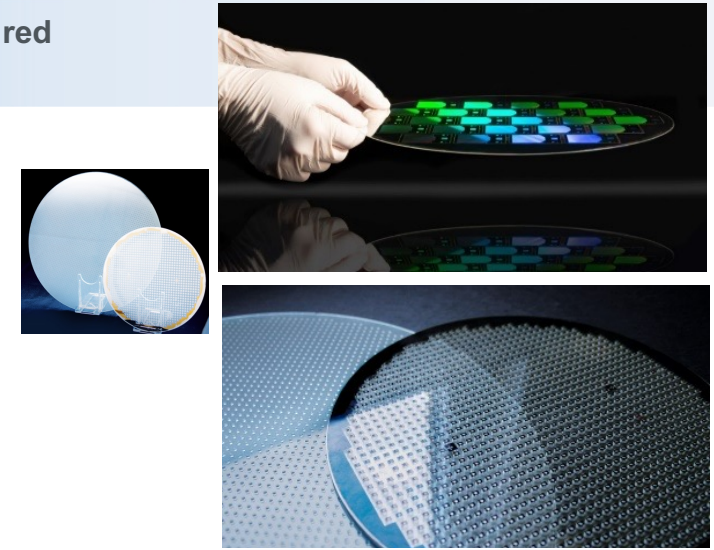
NIL Infrastructure / Ecosystem

- **Design** → Close collaboration with master suppliers
- **Material** → Strong partnership with material vendors
- **Process**
  - Step-and-Repeat Mastering
  - SmartNIL®
  - Lens Molding / Wafer Level Optics
  - Lens Stacking
- **Equipment**
  - Tools from R&D to fully automated HVM

Nano Imprint Lithography (NIL) | Focus Topic

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

- Volume-proven replication technology (= imprinting)
- Parallel processing of hundreds or thousands of micro- and nanostructures
- High degree of flexibility on replicable structures an substrates



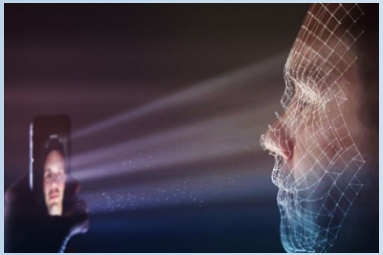
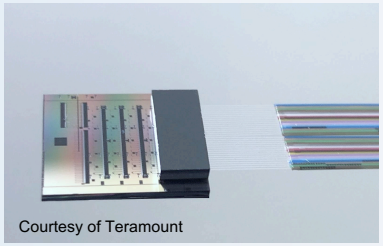
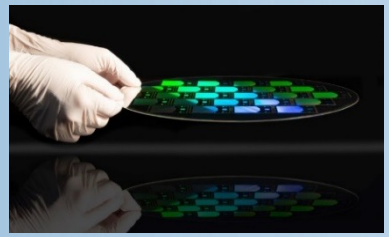
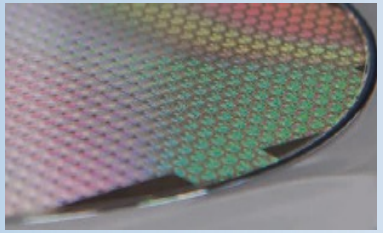
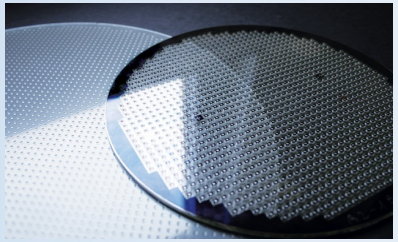
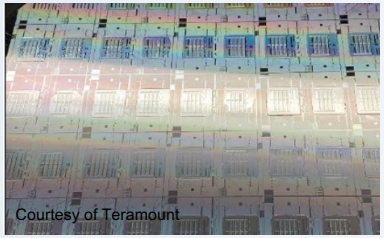
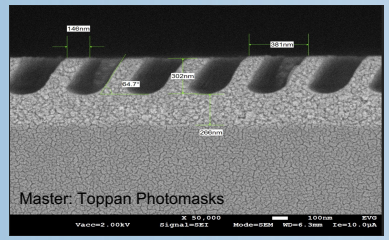
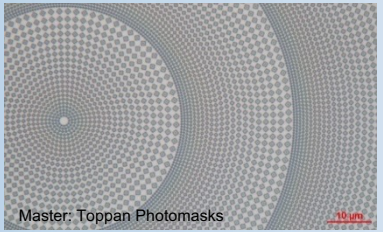
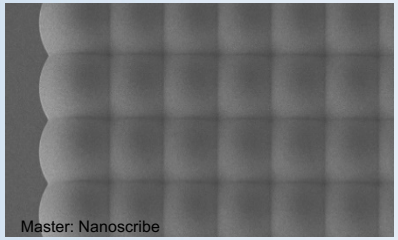
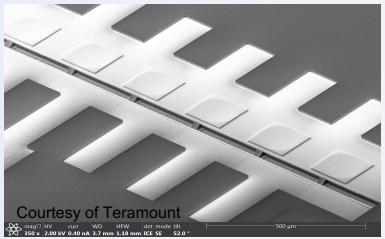
NIL Infrastructure / Ecosystem

- **Design** → Close collaboration with master suppliers
- **Material** → Strong partnership with material vendors
- **Process**
  - Step-and-Repeat Mastering
  - SmartNIL®
  - Lens Molding / Wafer Level Optics
  - Lens Stacking
- **Equipment**
  - Tools from R&D to fully automated HVM

NIL Photonics Competence Center → Innovation Incubator

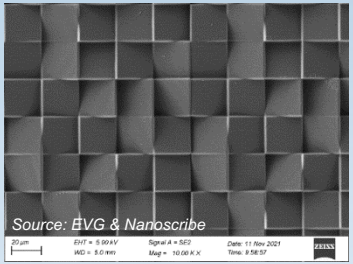
- Helping to ramp up
- Access to available network and ecosystem

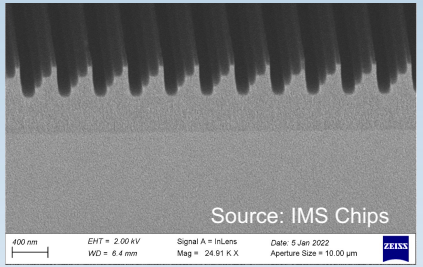
Nano Imprint Lithography | Key Markets

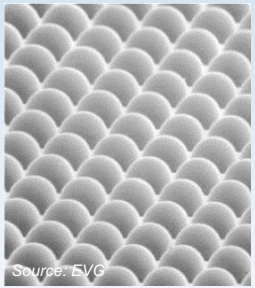
	Displays & Augmented Reality	Sensors & Wafer Level Optics	Automotive & LiDAR	Silicon Photonics / PIC
Application			 ams.com Projection lighting	 Courtesy of Teramount
Wafer				 Courtesy of Teramount
Structures	 Master: Toppan Photomasks	 Master: Toppan Photomasks	 Master: Nanoscribe	 Courtesy of Teramount

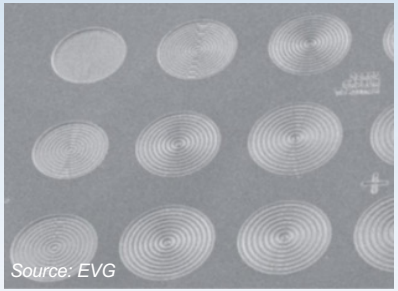
Nano Imprint Lithography | Structure Examples

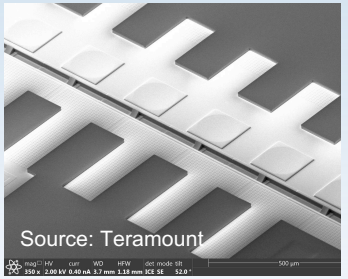
- Diffractive Optical Elements
- Holographic Optical Elements
- Waveguides
- Light Coupling / Optical Gratings
- Diffusor Optics
- Lenses & Micro Lens Arrays
- Mirror & Deflectors
- Anti Reflective Structures
- Plasmonic & Photonic Structures

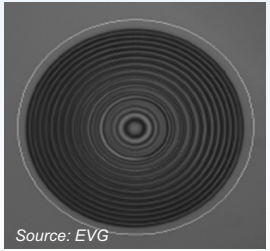


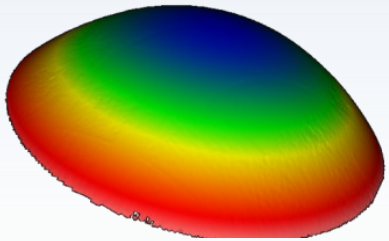




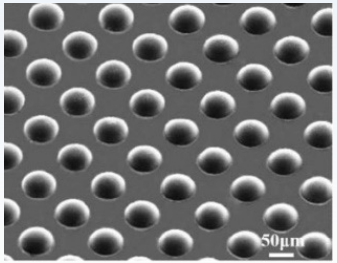








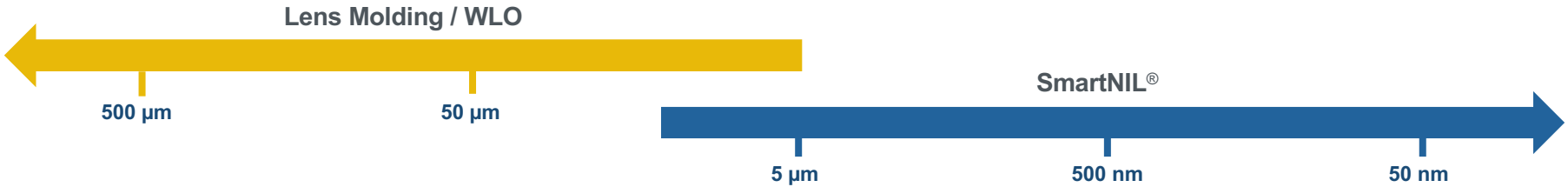
Source: EVG

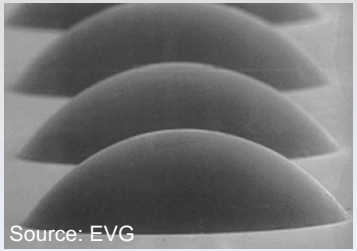


Source: University of Shanghai for Science and Technology

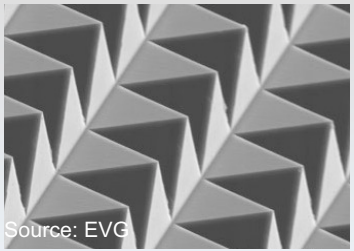
Arbitrary Structures

Nano Imprint Lithography | Resolution

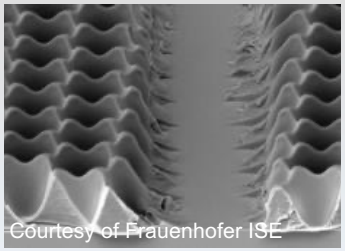




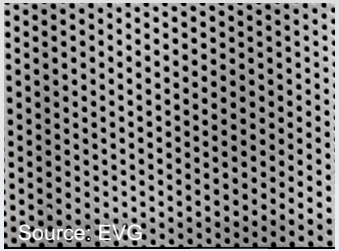
Lenses
[300 µm]



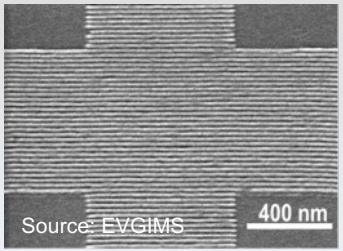
Pyramidal Structures
[50 µm]



3D Anti reflective Structures [7 µm]



Photonic Crystal
[350 nm]

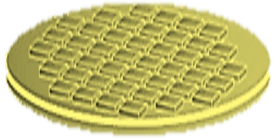


High Resolution Imprinting
[12.5 nm]

Nano Imprint Lithography | Process Flow Example

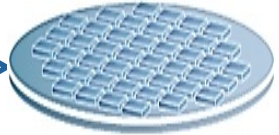
Working stamp fabrication

Master Wafer

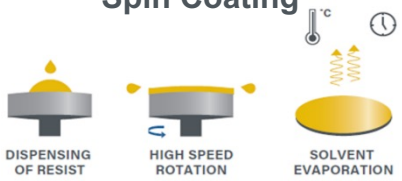


Working stamp fabrication

Re-usable Working Stamp

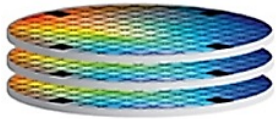


Spin Coating

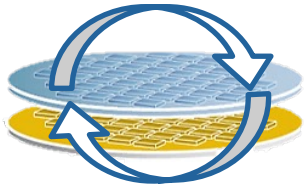


HERCULES® NIL
EVG® 7xxx

Imprinting Process



Multiple Imprints

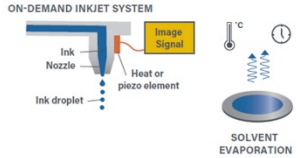


Imprinting Process

Spin Coating

1a) Spin coating

Ink Jet Coating



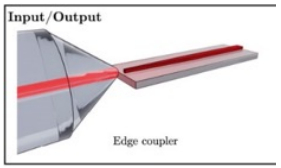
1b) Ink jet coating

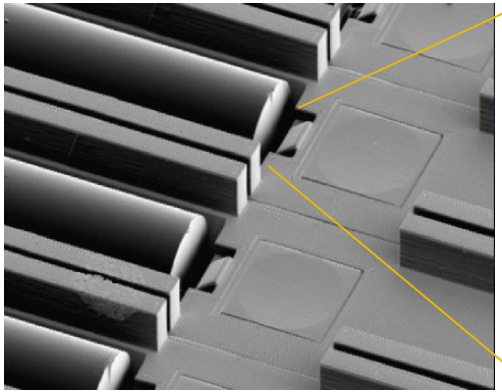
NIL for Silicon Photonics | Datacom

Bridging the gap in SiPh packaging towards wafer level HVM

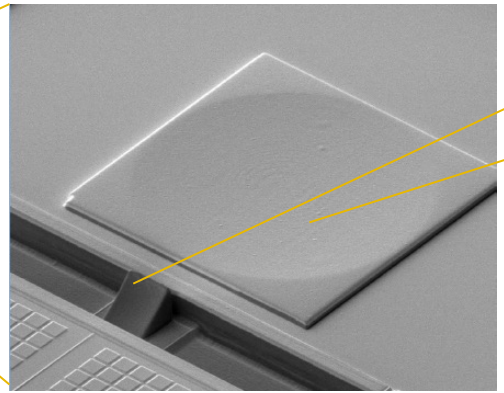
Teramounts PhotonicPlug und PhotonicBump: Done by NIL

- Imprint inside a 20µm trench (imprint in deep cavities)
- In combination with v-grooves fiber assembly
- Fiber trenches perfectly aligned to the mirrors

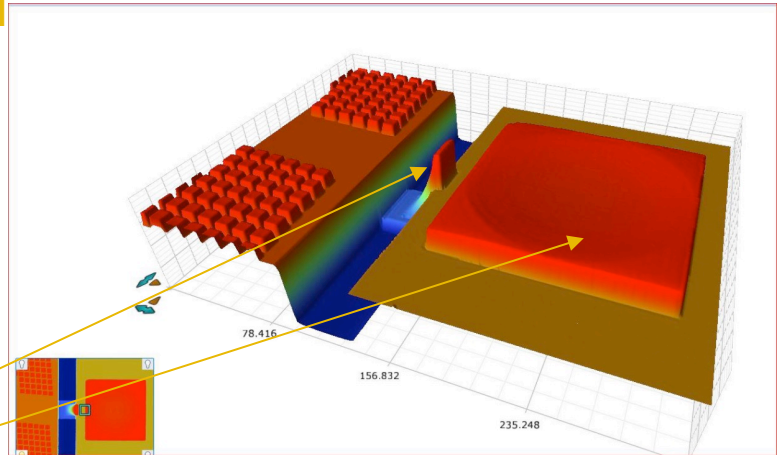




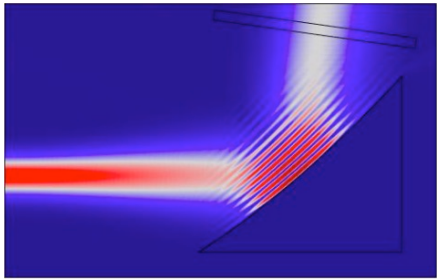
PhotonicPlug fiber connector



PhotonicBump: Beam expansion mirror and deflector/mode-match mirror



PhotonicBump imprint on a SiPh wafer at accurate placement relative to waveguide channel



Mode conversion deflector

Ideally suited for photonics industry, where light-matter interaction relies largely on shape and geometry

NIL for Silicon Photonics | Datacom

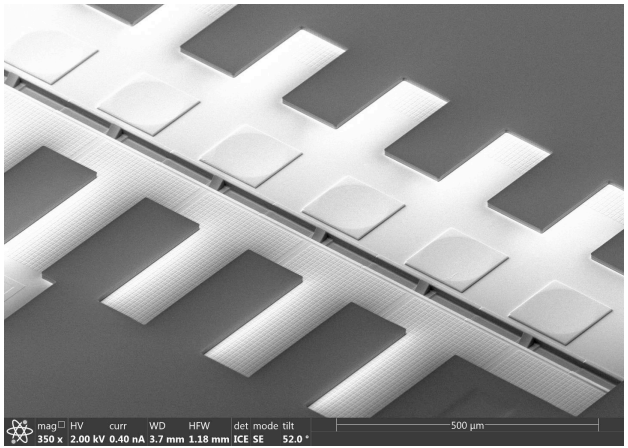
Bridging the gap in SiPh packaging towards wafer level HVM

Teramounts PhotonicPlug und PhotonicBump: Done by NIL

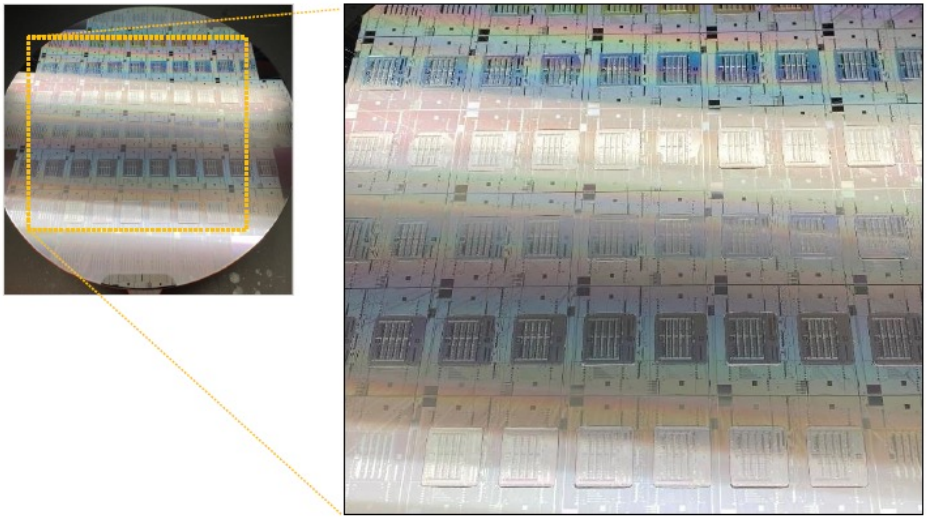
→ Imprinted complex optical microstructures (e.g. lenses or mirrors) on SiPh wafers

Important

- Pattern fidelity and repeatable → optical functionality of shape
- Highest alignment accuracy → matching to device wafer
- Residual layer control → thin and uniform
- Material → specific optical properties



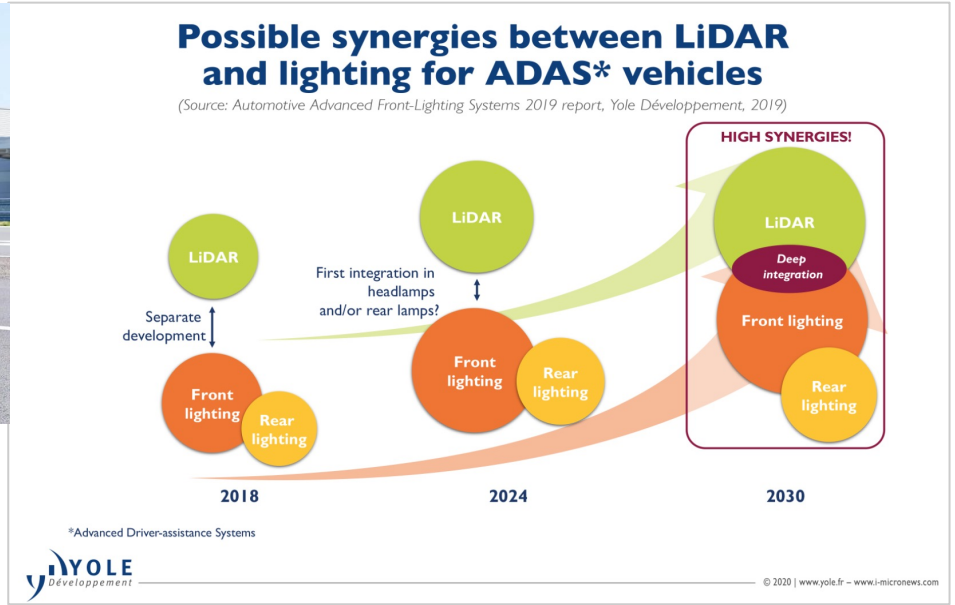
WLO for wide-band surface coupling, mode conversion and wafer level inspection.



PhotonicBump – Imprint inside 20µm on 8'' SiPh wafer

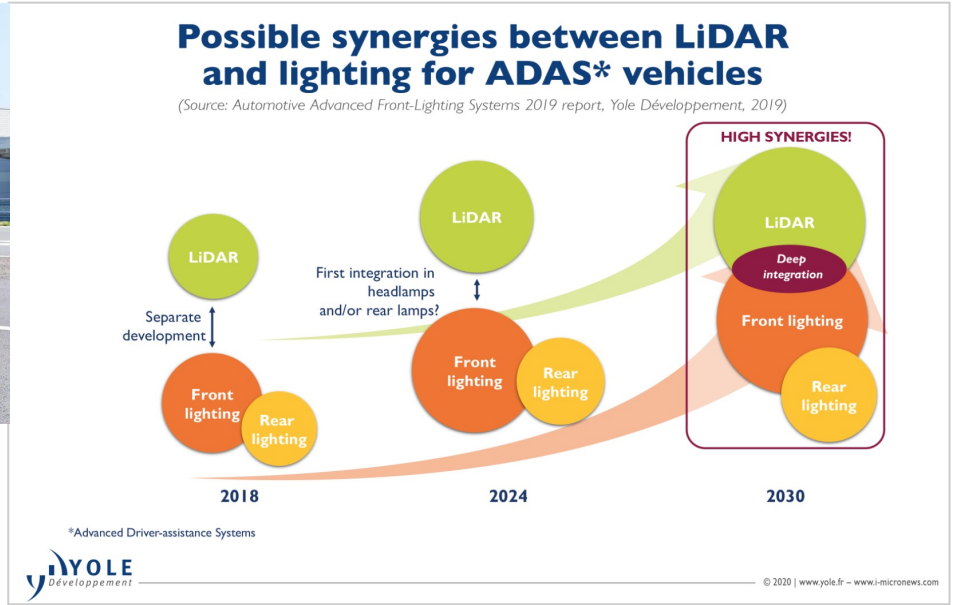
NIL for Silicon Photonics | LiDAR

Miniaturization needed to meet integration requirements from roadmap



NIL for Silicon Photonics | LiDAR

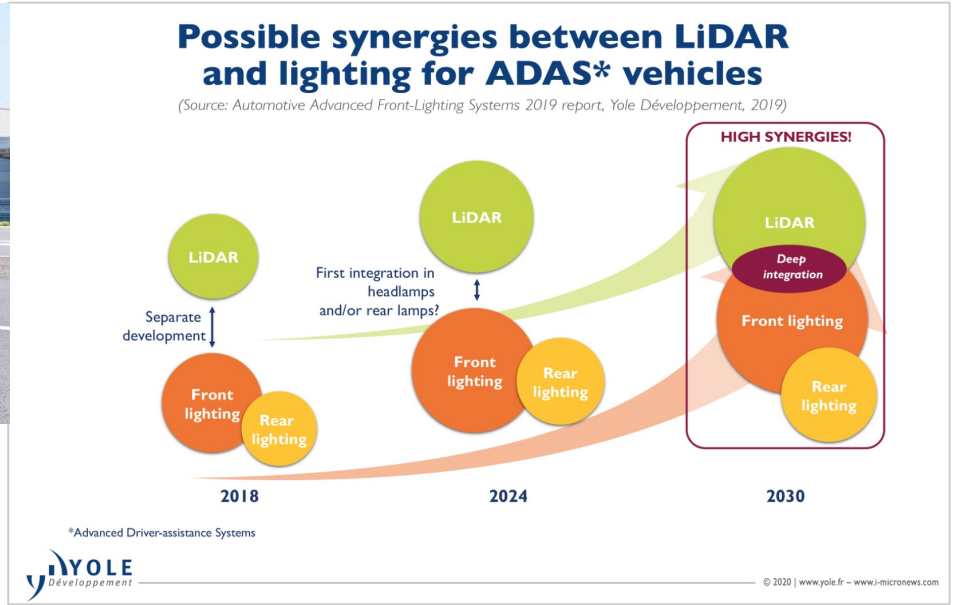
Miniaturization needed to meet integration requirements from roadmap



Automotive
Seeking for new manufacturing possibilities, enhanced functionalities, ..

NIL for Silicon Photonics | LiDAR

Miniaturization needed to meet integration requirements from roadmap

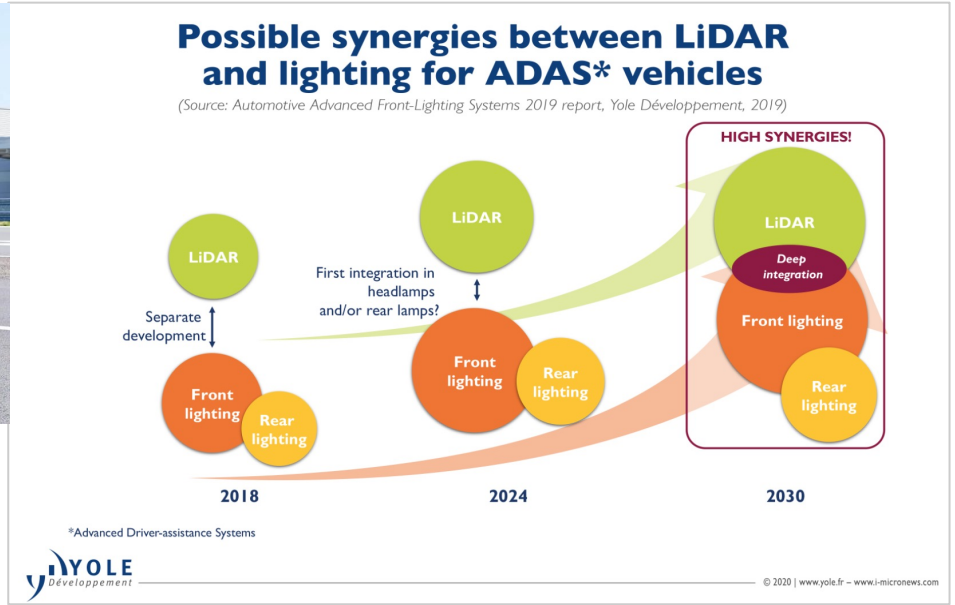


Automotive
Seeking for new manufacturing possibilities, enhanced functionalities, ..

Semiconductor
Wafer level based, miniaturizing, cost-effectiveness

NIL for Silicon Photonics | LiDAR

Miniaturization needed to meet integration requirements from roadmap



EVG NIL
Tools, Process Development, Support, ..

Automotive
Seeking for new manufacturing possibilities, enhanced functionalities, ..

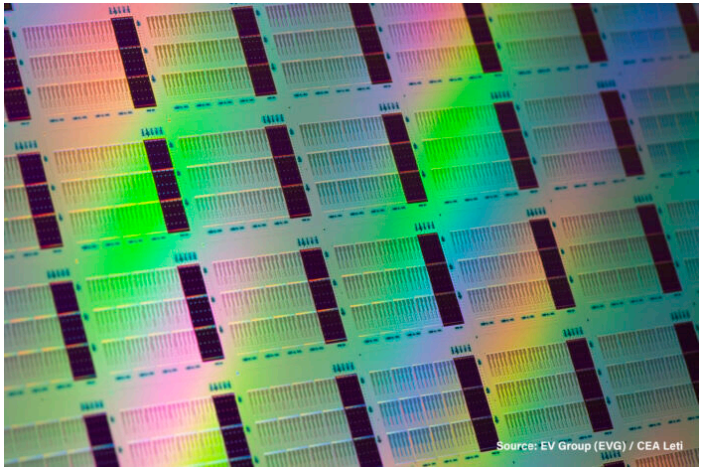
Semiconductor
Wafer level based, miniaturizing, cost-effectiveness

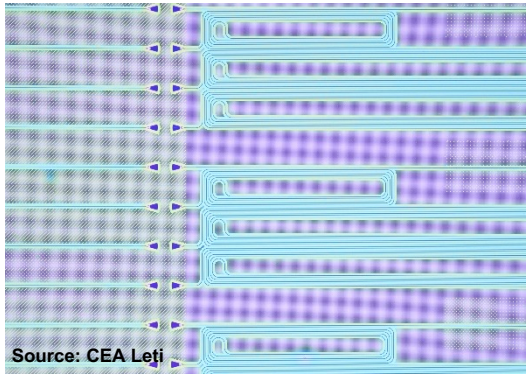
NIL for Silicon Photonics | LiDAR

EU Project: TINKER

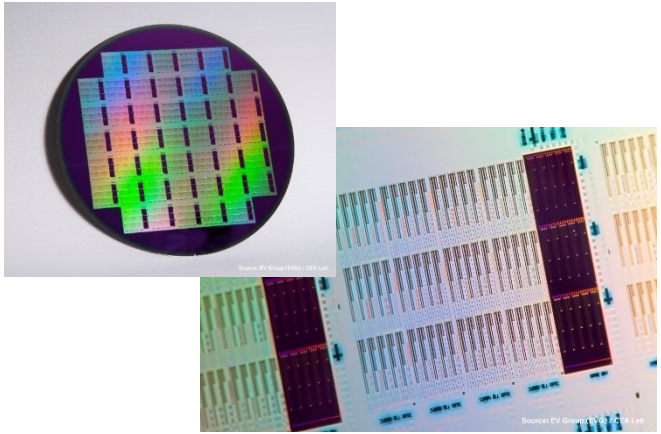
- Development received funding from the European Union's Horizon 2020 program

Light Guide structures developed by **CEA Leti**
Part of the sensors to be integrated into **Marelli's** smart headlight lamp

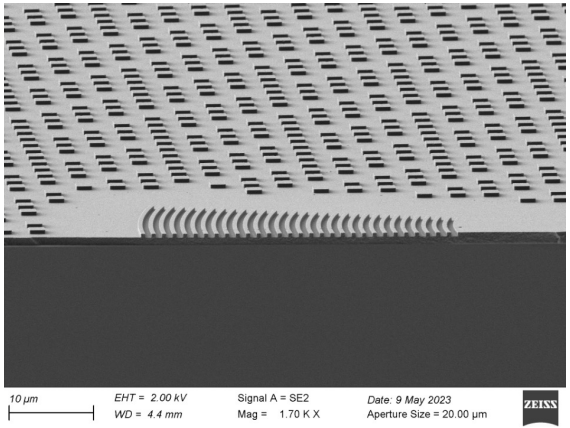




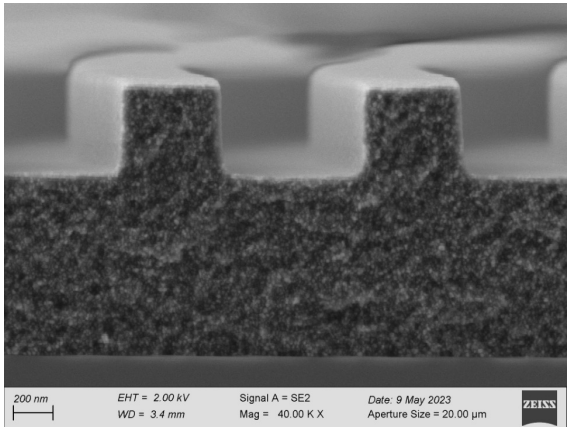
NIL for Silicon Photonics | LiDAR



Waveguides on wafer



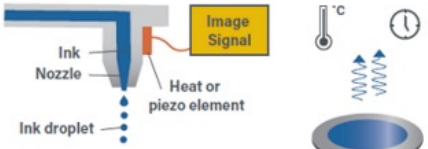
Waveguide gratings



Waveguide structures

- Direct imprinting into high refractive index material
- Complex in- and outcouple gratings possible

Inkjet coating ➔ structuring only dedicated areas on the wafer



Waveguides manufactured by SmartNIL® and inkjet coated high refractive index material

NILPhotonics® Competence Center | Innovation Incubator

NILPhotonics® Competence Center | Innovation Incubator

“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 m² cleanroom area (class 10 – 100) and application labs

NILPhotonics® Competence Center | Innovation Incubator

“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 m² cleanroom area (class 10 – 100) and application labs

Cleanroom space for rent → quick turnarounds

NILPhotonics® Competence Center | Innovation Incubator

“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 m² cleanroom area (class 10 – 100) and application labs

Cleanroom space for rent → quick turnarounds

High quality standards, ISO certified, full documentary and reporting

NILPhotonics® Competence Center | Innovation Incubator

“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 m² cleanroom area (class 10 – 100) and application labs

Cleanroom space for rent → quick turnarounds

High quality standards, ISO certified, full documentary and reporting

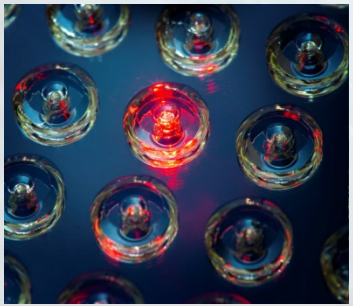
Helping customers to ramp up their ideas!

EV Group | Semiconductor Manufacturing for Photonic Devices

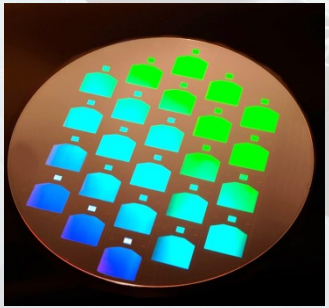
NILPhotonics® Competence Center – A smart way to collaborate for success

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

Bridging the gap between photonics R&D and volume manufacturing

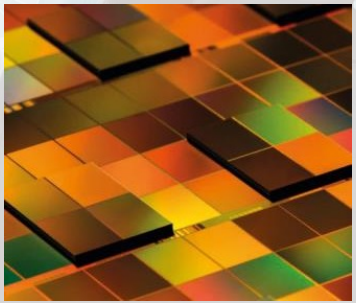


Wafer Level Optics & Photonics Packaging

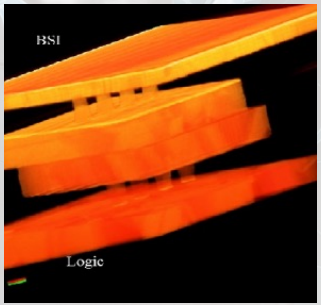


Nanoimprint & S&R Mastering

Advanced Resist Processing



Heterogeneous Integration



3D Integration & Hybrid Bonding

Thank you

Khan Jonas
Team Leader Process Technology NIL Development