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

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

What?
- EVG equipment portfolio covers all common imprinting techniques on volume proven systems
- NILPhotonics™ Competence Center to link equipment and process know-how for innovative products
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-patterned 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**
- Optics on CMOS
- Hybrid refractive/diffractive

Source: Fraunhofer IOF
Process Examples for Wafer Level Optics

- **Microlens arrays**
- **Diffractive optical elements**
- **Functional optical films.**

Source: Anteryon
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 Patterning**
- 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

**Nanoimprint Solutions**
- UV - NIL
- Hot Embossing
- $\mu$-Contact Printing

**Components & Functional Layers**
- Photonic crystals
- Lense arrays
- Polarizers
- Antireflective layers
- 3D patterned layers
- Gratings
- Diffractive optical elements
- Light extraction layers
- Growth templates
- Filters

**Devices & Applications**
- LEDs / OLEDs
- Lightguiding plates
- Displays
- Image Sensors
- Metamaterials
- Biosensing / Genomics / Cell Sorting
- Microfluidic chips / lab-on-chip systems
- Flexible electronics
- Solar Cells
- Nanowire and quantum dot applications
- Plasmonic components
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.
nPSS Fabricated by SmartNIL™

6” imprint

SEM images of 400nm pillars for nPSS Structures

395 nm
360 nm
35 nm
200 nm
Solutions for Microfluidics

EVG’s Core Competences

- Bonding
- Lithography
- (UV-) Nano-imprinting
- Hot Embossing
- Sealing/packaging
- Micro-channel fabricaiton
- Nanopatterns in the channels

Process Services

R&D | Pilot Line | HVM
Saphely Project

Self amplified photonic biosensing platform for micro RNA-based early diagnosis of diseases

Photonic Bandgap Sensor

Gratings manufactured with SmartNIL!
SmartNIL™ for Bio-functionalization

BSA-Cy5-Biotin solution

Stamp

Dry out

Coated glass slide

Incubation with antibodies

BSA-Cy5 grid

FITC-antibody

Bio-functionalization of μ-arrays

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 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
Separation of working stamp and wafer

Multi imprints per working stamp

Master stamp

Made by e-beam-lithography,...
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

Clean Module

Coat Module

Bake Module

Imprint Module

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

Preprocessing modules
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

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

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)

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

Process Development
Definition and development of customized processes
- UV-NIL
- Hot Embossing
- Micro-contact Printing

Sample Processing
EVG offers:
- Manufacturability Demonstrations
- Small production run imprint services
- Scale-up to pilot line production

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
Thank You!