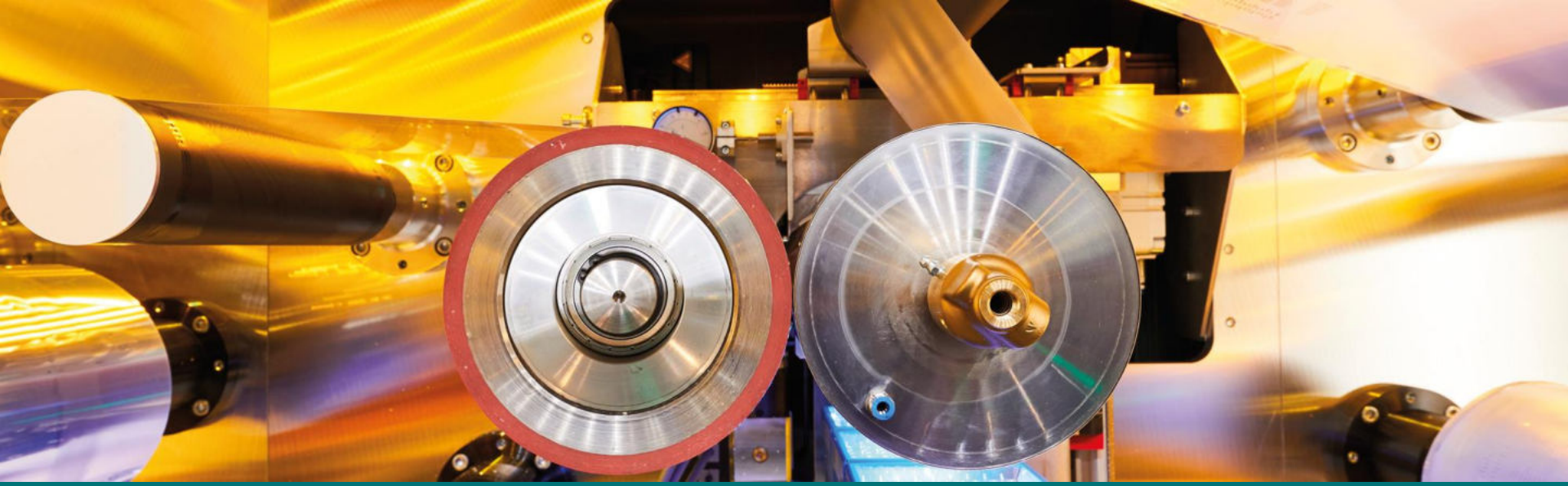


Nanoimprint lithography technology

Coatema

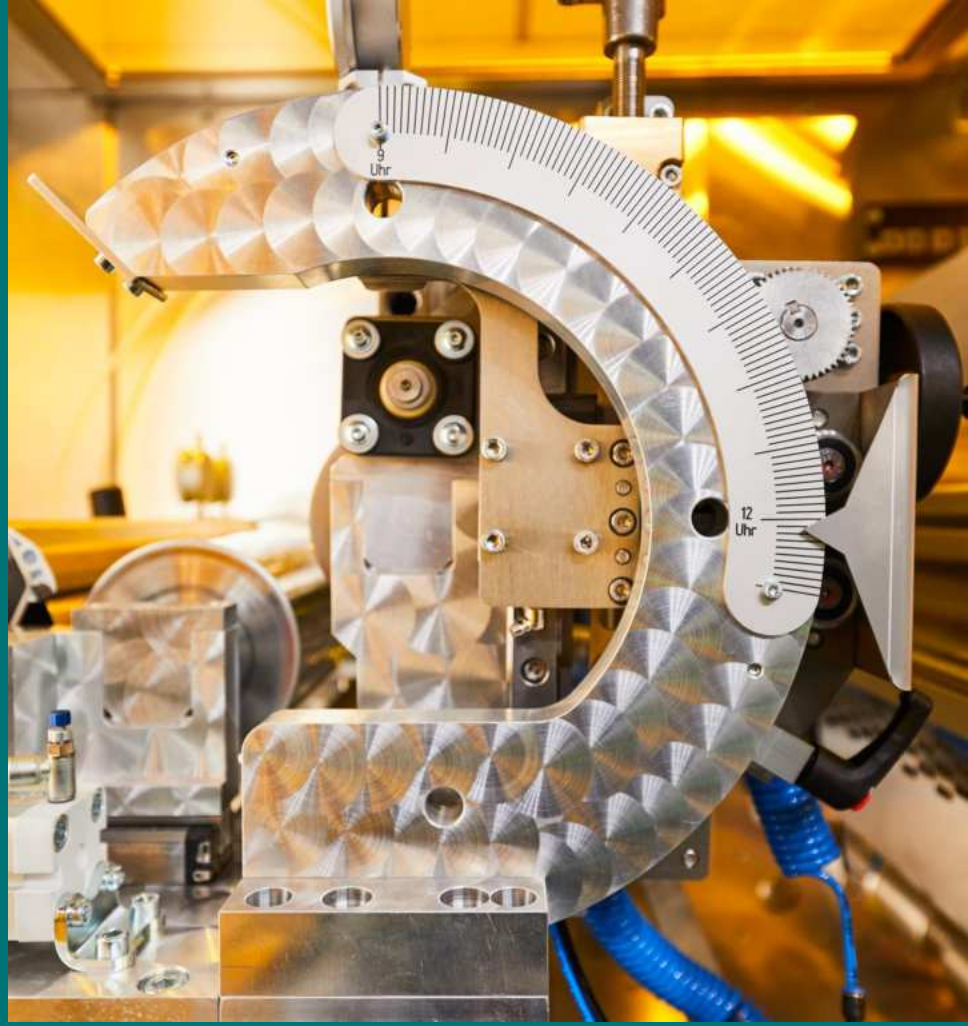
28/04/25

MEMBER OF ATH

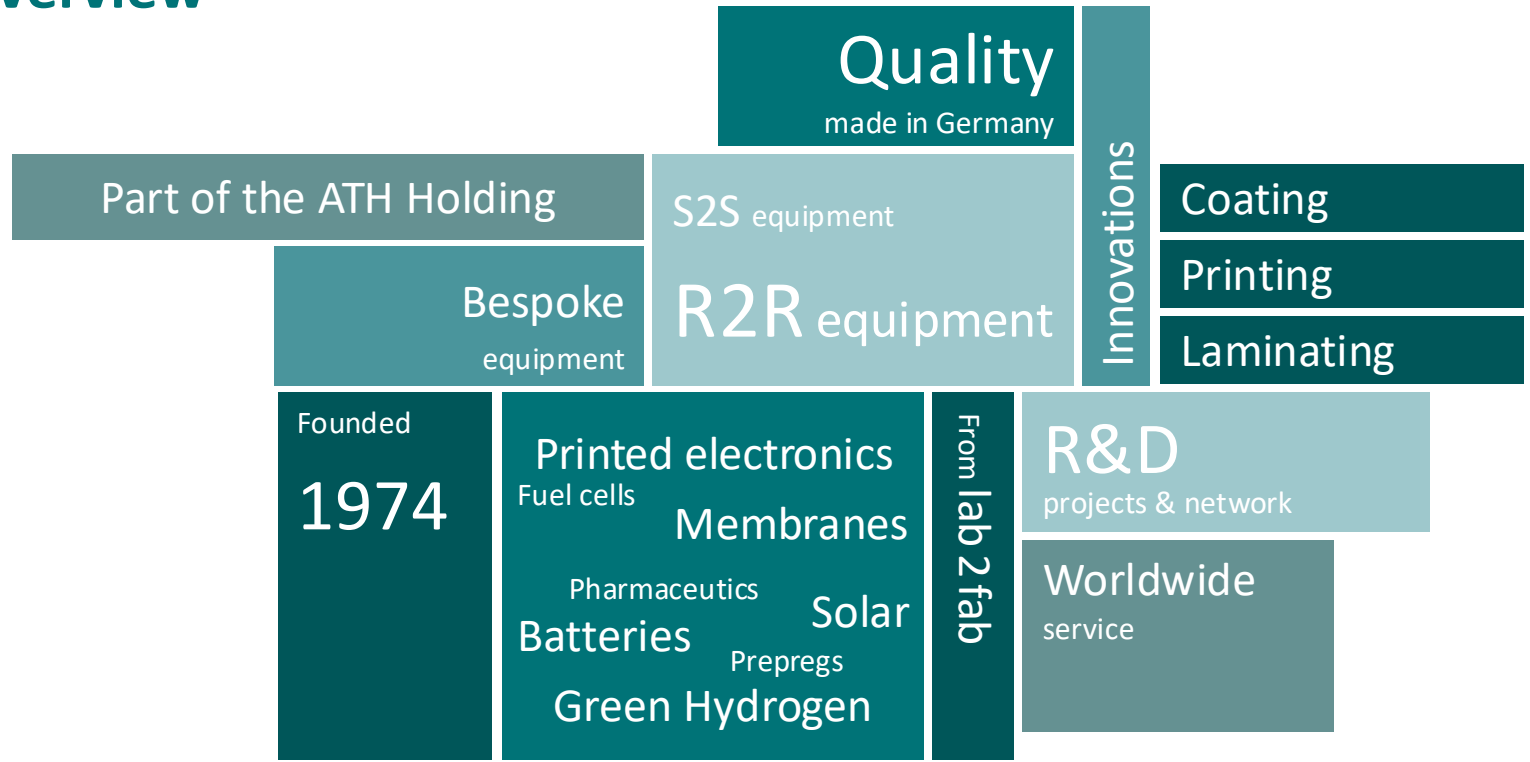
1. Introduction
2. Technologies and processes
3. Products
4. Equipment
5. Summary

1.

Introduction



Overview


Quality
made in Germany
Innovations
Part of the ATH Holding
S2S equipment
R2R equipment
Bespoke
equipment
Coating
Printing
Laminating
Founded
1974
Printed electronics
Fuel cells
Membranes
Pharmaceutics
Solar
Batteries
Prepregs
Green Hydrogen
From lab 2 fab
R&D
projects & network
Worldwide
service

Group of companies

ALTONAER
TECHNOLOGIE
HOLDING

KROENERT

- ✓ Founded 1903
- ✓ Approx. 200 employees
- ✓ Located in Hamburg

DRYTEC

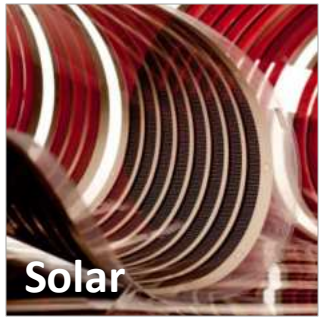
- ✓ Founded 1995
- ✓ Approx. 50 employees
- ✓ Located in Norderstedt

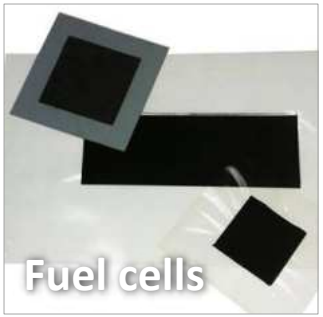
Coatema®
Coating Machinery GmbH

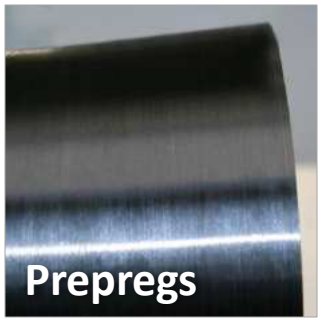
- ✓ Founded 1974
- ✓ Approx. 50 employees
- ✓ Located in Dormagen

Represented worldwide

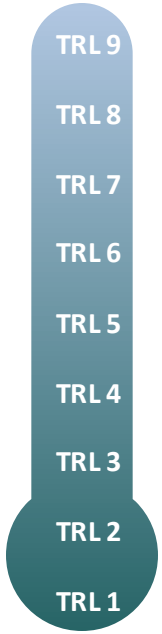
Our markets







Actual system proven in operational environment



Basic principles observed

Coatema equipment platform strategy for lab2fab

Lab

- ✓ State-of-the-art research and development equipment
- ✓ Sheet-to-sheet to roll-to-roll systems

Pilot Production

- ✓ Proven electrolyzer and fuel cell coating and laminating equipment
- ✓ Highest-quality pilot product lines enable stable pilot production and reduce cost
- ✓ Scaling laboratory equipment to enable pilot production

Production

- ✓ Full-scale production line for electolyzers
- ✓ Elevating our in-depth roll-to-roll equipment to fully scale production and further reduce adoption cost

Coatema focus areas

- Green hydrogen
- Fuel cells
- Batteries
- Solar

- Sustainability
- Digital fabrication
- Printed electronics
- The next thing

Coatema services as an overview

The Coatema R&D centre

Accelerate your innovation in our dedicated pilot facility with advanced lab & pilot lines and expert guidance – bridging the gap from #lab2fab.

The Coatema international Coating Symposium

Join the global network of coating experts at our annual event, where cutting-edge developments meet industry collaboration for next-level innovation.

The Coatema Slot Die Coating Masterclass

Master precision coating in our hands-on training program, led by industry specialists to optimize slot-die performance and product excellence.

Our work in associations – global networking

oe-a

NMWP.NRW
Cluster NanoMikroWerkstoffePhotonik

HOPE-A
Hellenic Organic & Printed Electronics Association

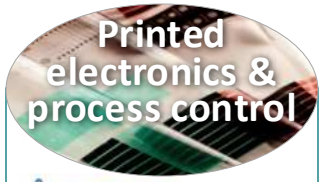
Board Member:
OE-A

Advisory Board:
Fraunhofer ITA

Coatema customers

R&D customers

R&D projects overview 2022 – 2025

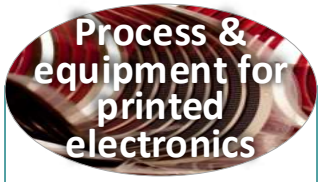


REAL NANO

In-line and real-time digital nano-characterization for flexible organic electronics

NOUVEAU

The NOUVEAU project will develop solid oxide cells (SOCs) with innovative La- and PMG-free electrode materials



FLEX2ENERGY
AUTOMATED MANUFACTURING PRODUCTION LINE FOR IPVS

R2R production line for OPV solar with integrated backend

FLEX-G 4.0

Upscaling and development of EC based switchable films to decrease energy use in buildings

IDEEL

Implementation of laser drying processes for lithium-ion battery production

SOLiD

R2R process optimization for solid state batteries

pepLAT

Plasmonically enhanced photocatalysis for wastewater treatment

ROLL 2 SOL

R2R nanostructuring of functional films

WATER PROOF

The WaterProof project aims at developing an electrochemical process that converts CO_2 emission

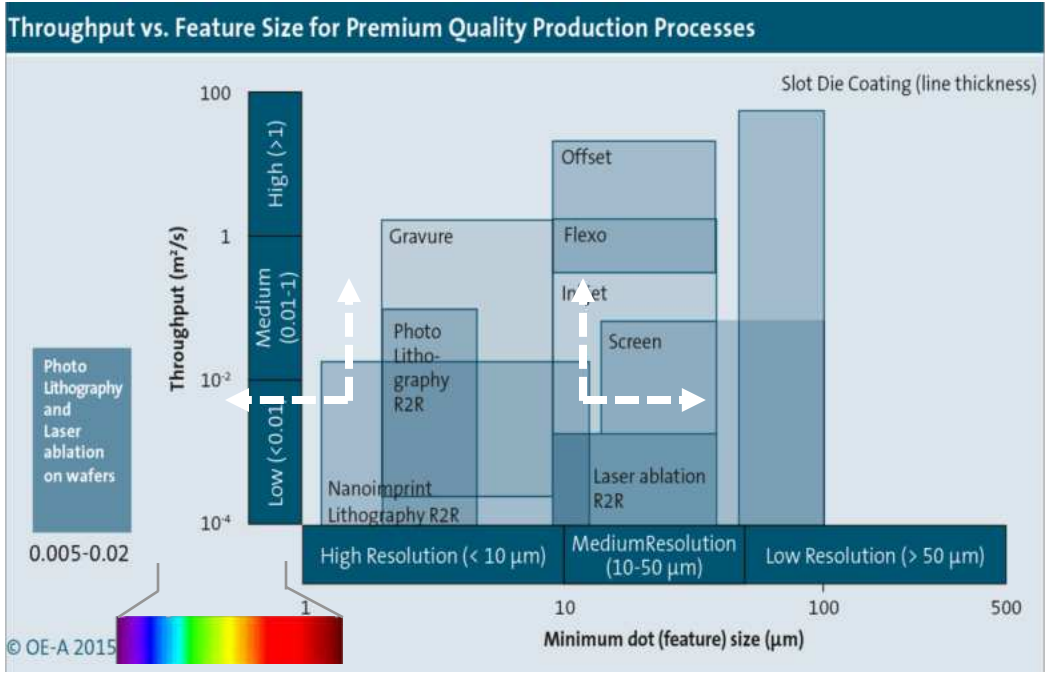
FLEX FUNCTION 2 SUSTAIN

Creating an open-innovation testbed for sustainable packaging

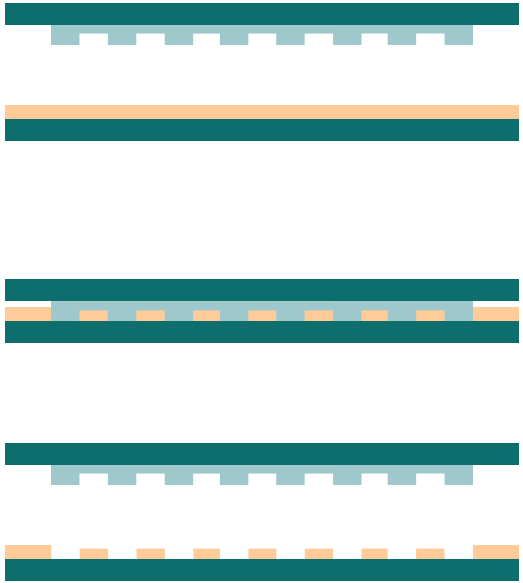
2.

Technologies and processes

Why is nanoimprint lithography relevant?

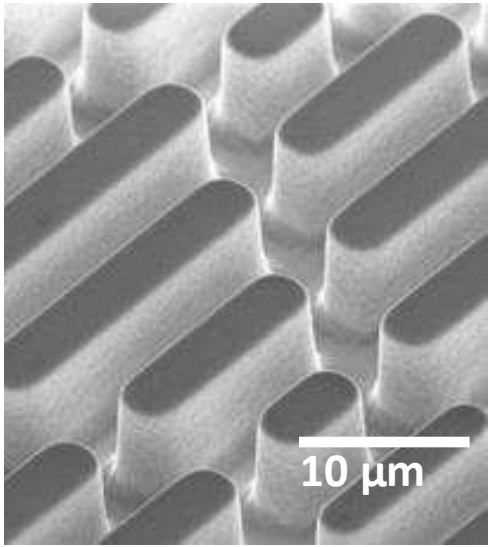


Basic principle of nanoimprint lithography



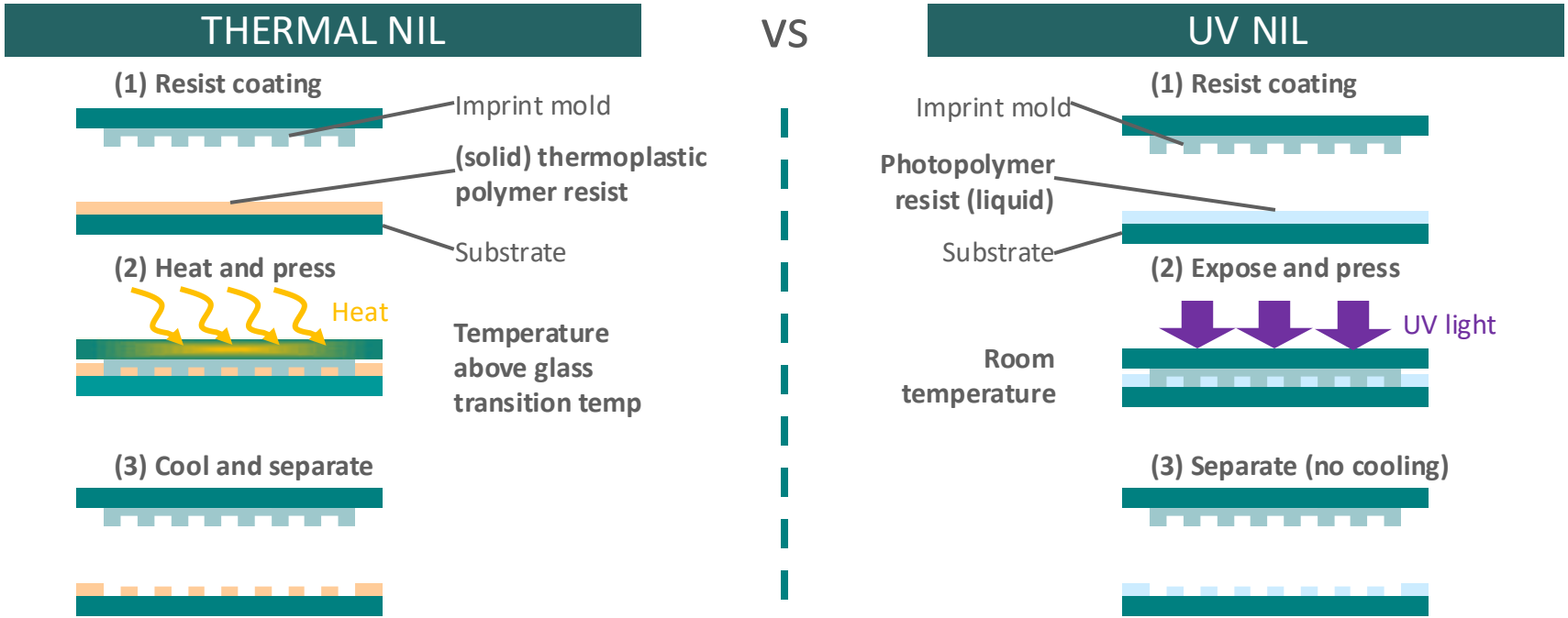
Principle

Ancient days



Modern days

Basic principle of nanoimprint lithography



Basic principle of nanoimprint lithography

THERMAL NIL	VS	UV NIL
✓ **Imprint into substrate possible**		✓ **(faster)**
✓ **Great depths possible**		✓ **Uniformity**
✓ (slower)		✓ **Less viscous resists (less pressure)**
✓ heat distribution		✓ **Soft molds possible**
✓ Thermal conductive mold		✓ UV resists (Transparent substrate or mold)
✓ Thermal expansion of mold and resist		
✓ Cooling		
✓ Higher pressure		

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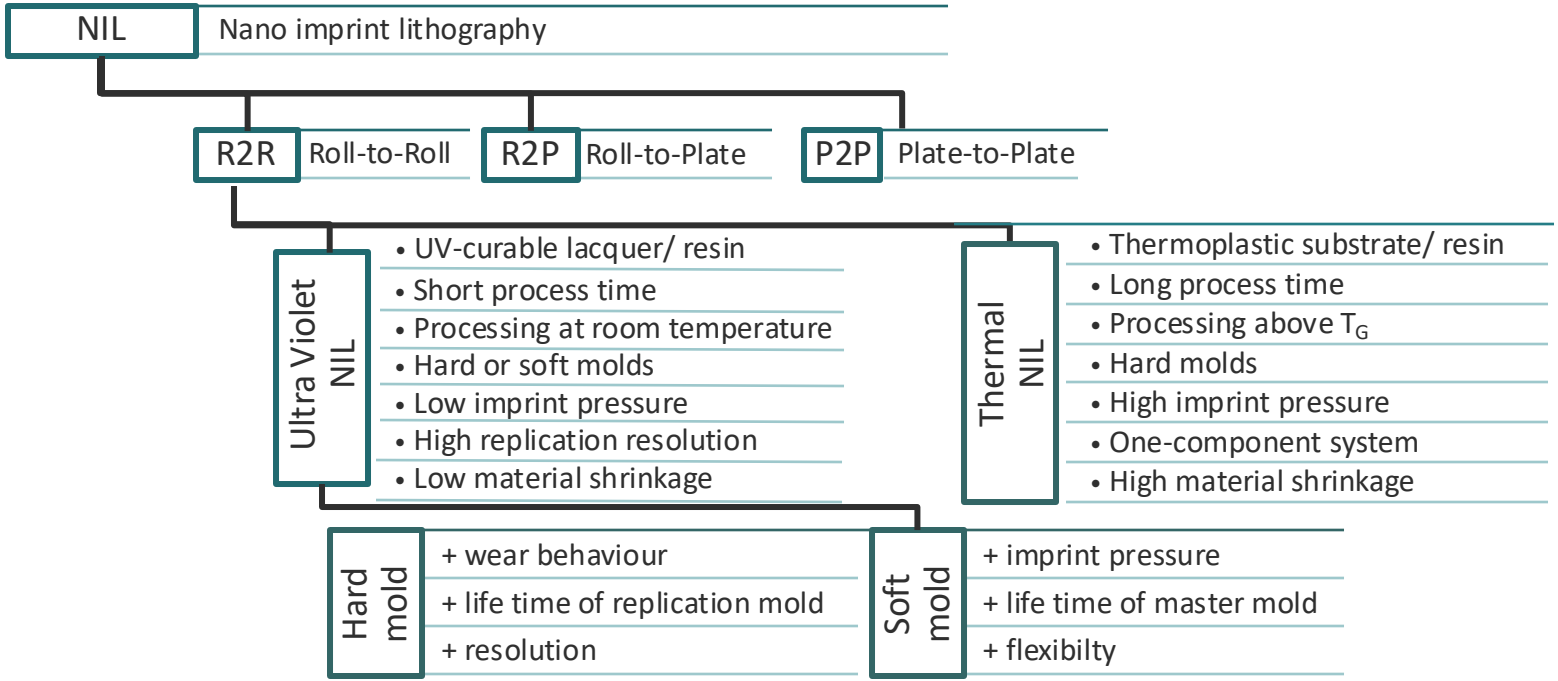
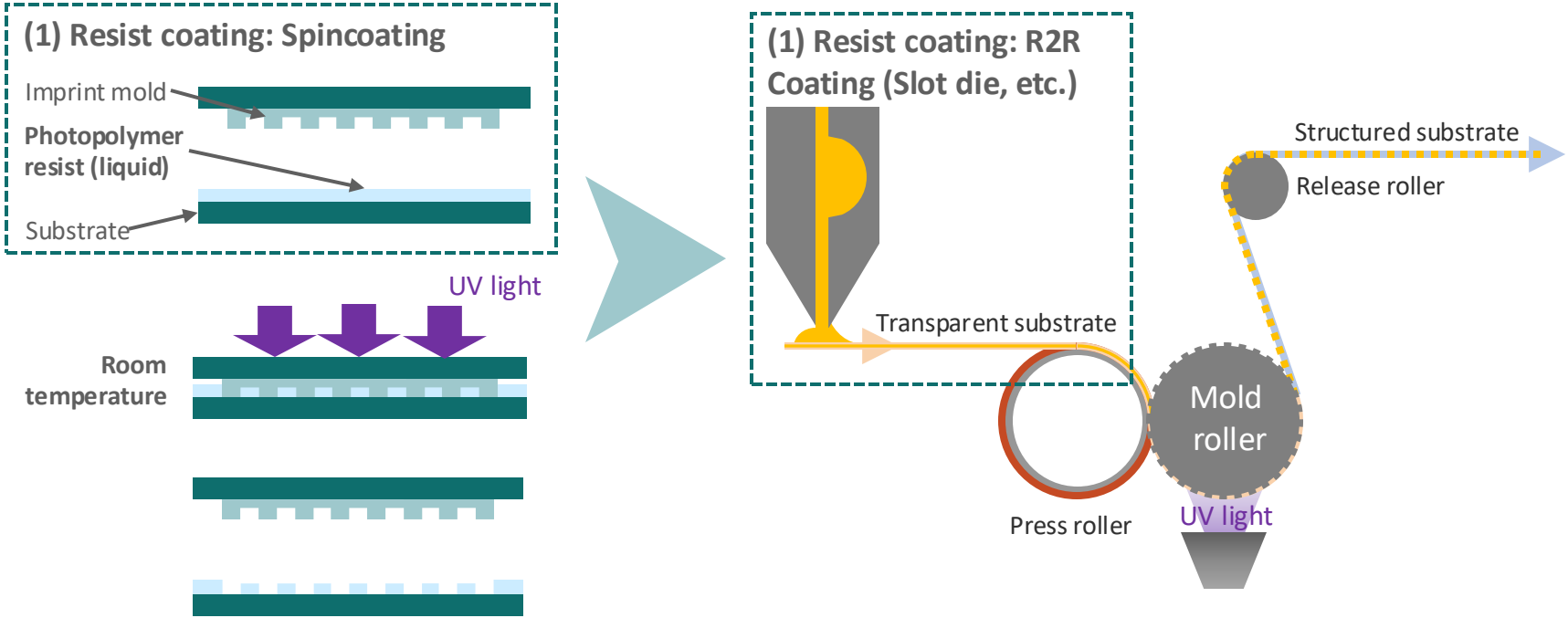
Overview of nanoimprint lithography technologies and processes

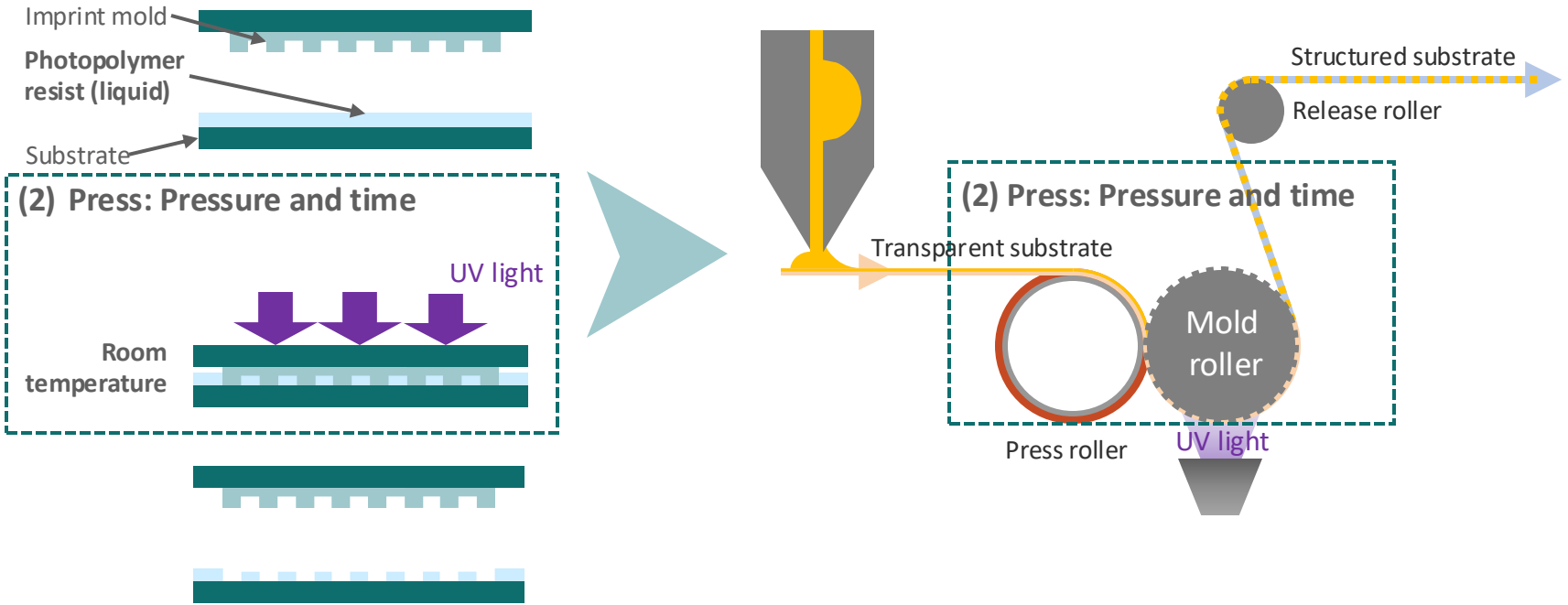


Source: Fraunhofer IPT

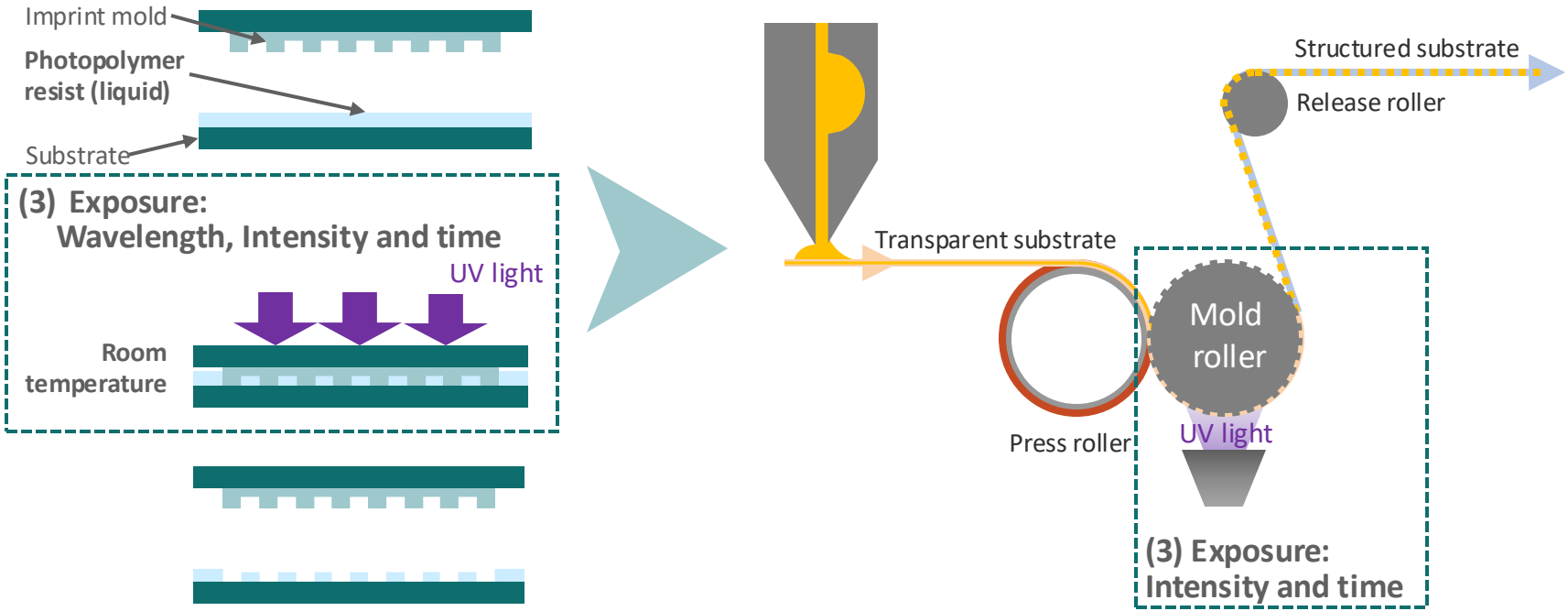
Translating from P2P to R2R



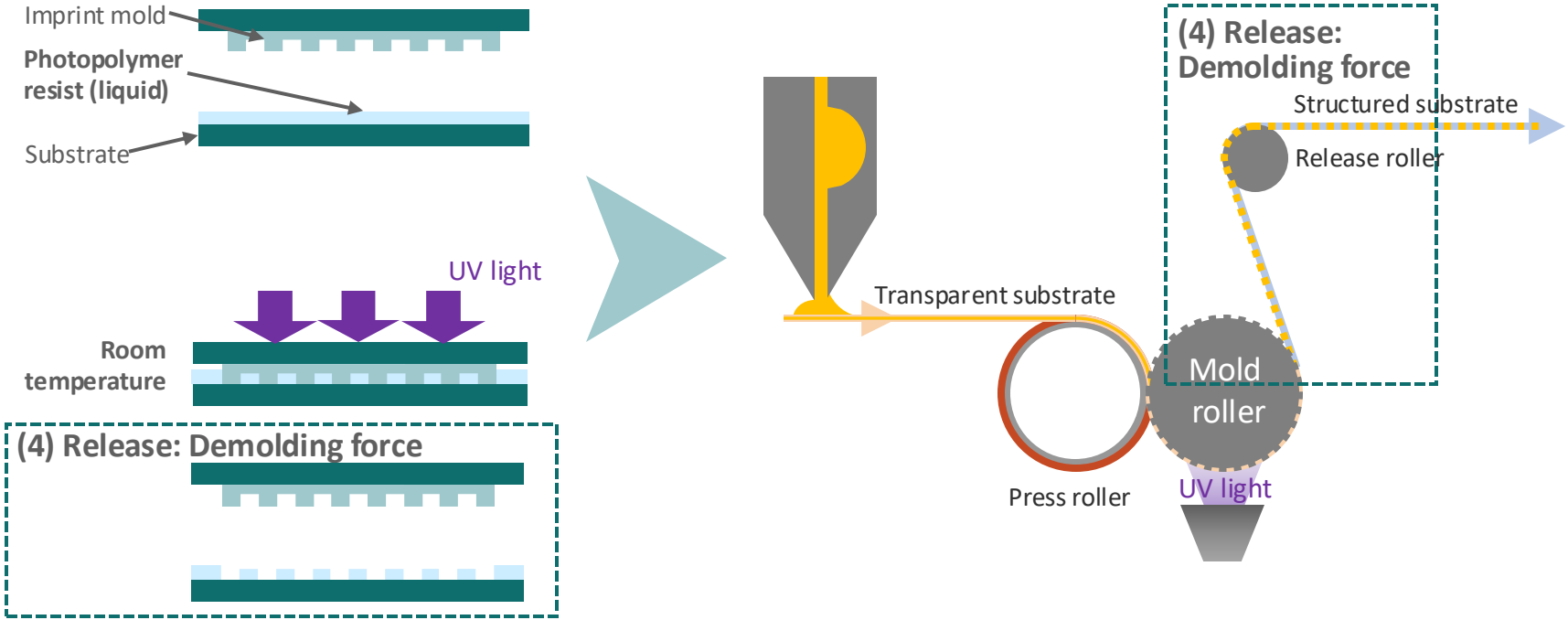
Translating from P2P to R2R



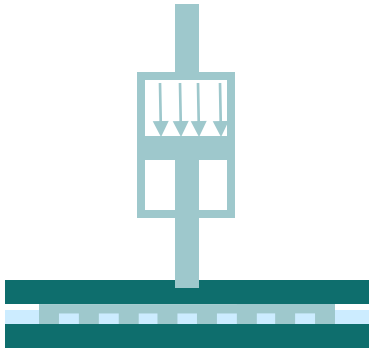
Translating from P2P to R2R

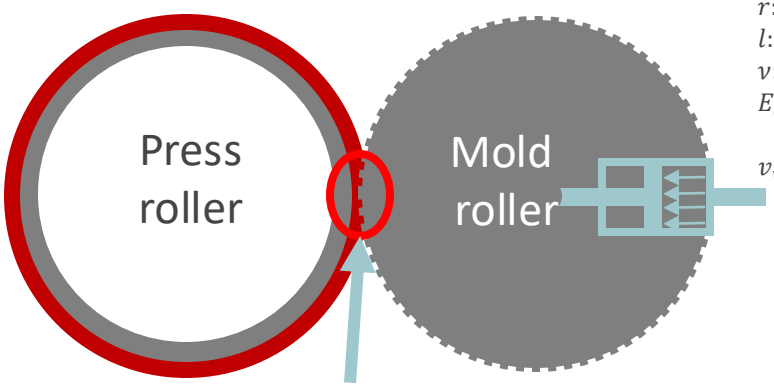


Translating from P2P to R2R



Translating from P2P to R2R





F: Force mold roller
r: Radius press roller
l: length press roller
ν: Poisson's number
E_{comb}: Combined modulus
v_{web}: Webspeed

$$p_{\text{press}} = p_{\text{cylinder}} \cdot \frac{A_{\text{cylinder}}}{A_{\text{imprint}}}$$

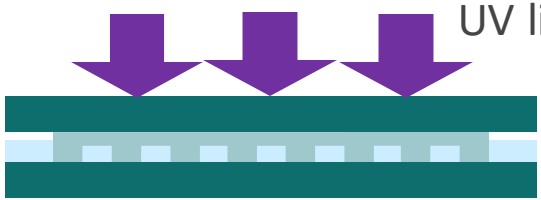
$$t_{\text{press}} = variable$$

Hertzian deformation:

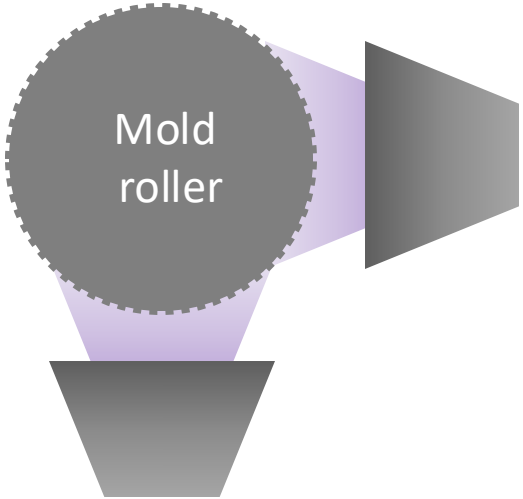
$$p_{\max} = \sqrt{\frac{F}{2\pi r l} \cdot \frac{E_{\text{comb}}}{1-\nu^2}}$$

$$t_{\text{press}} = 2 \cdot \arccos\left(1 - \sqrt{\frac{F}{2\pi r l E_{\text{comb}}} \cdot \frac{1}{1-\nu^2}}\right) \cdot \frac{r}{V_{\text{web}}}$$

Translating from P2P to R2R



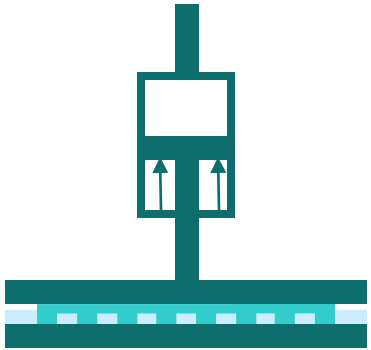
$$t_{\text{expo}} = variable$$
$$I = I_0 \cdot e^{-\alpha \cdot d_{\text{resist}}}$$

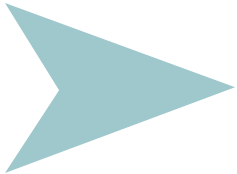


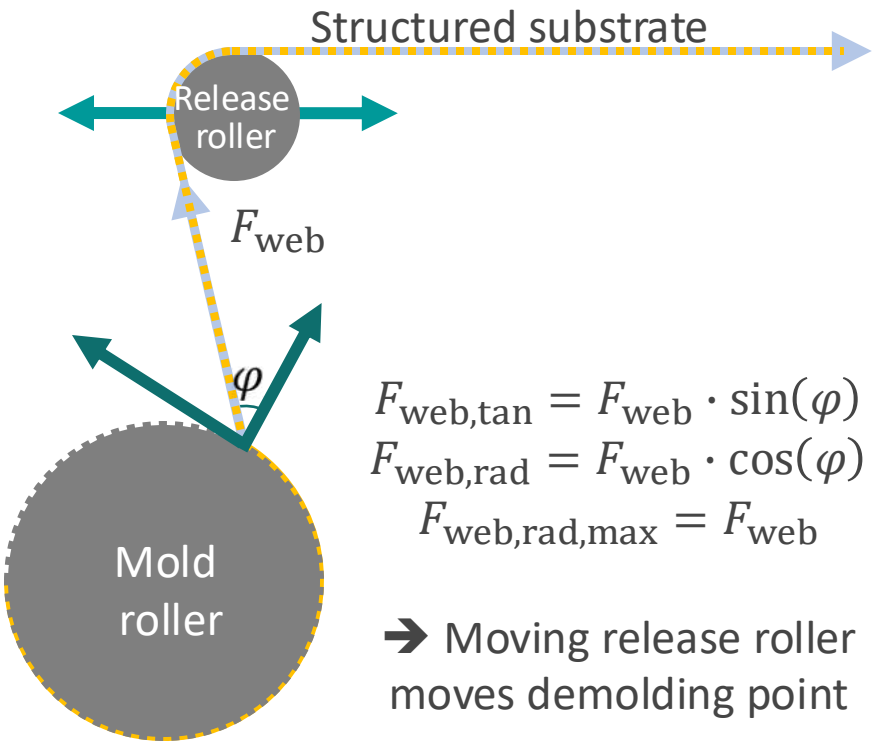
$$t_{\text{expo}} = \frac{2r}{v_{\text{web}}} \cdot \arcsin\left(\frac{w_{\text{lamp}}}{2r}\right)$$
$$I = I_0 \cdot e^{-\alpha \cdot d'_{\text{resist}}}$$
$$\text{with } d' = \sqrt{(r+d)^2 - x^2} - \sqrt{r^2 - x^2}$$

Translating from P2P to R2R

$$p_{\text{release}} = p_{\text{cylinder}} \cdot \frac{A_{\text{cylinder}}}{A_{\text{imprint}}}$$







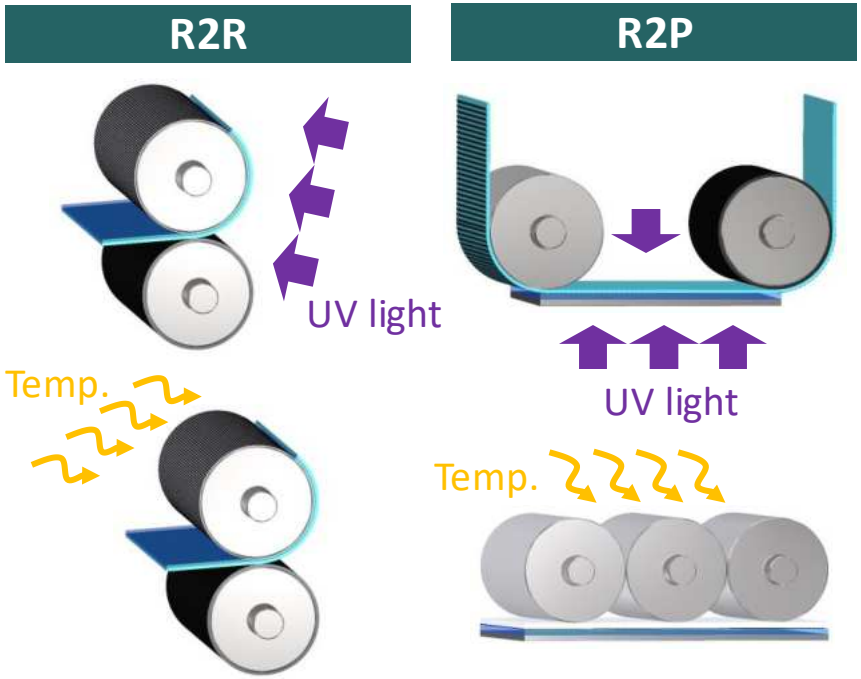
$$F_{\text{web,tan}} = F_{\text{web}} \cdot \sin(\varphi)$$
$$F_{\text{web,rad}} = F_{\text{web}} \cdot \cos(\varphi)$$
$$F_{\text{web,rad,max}} = F_{\text{web}}$$

➔ Moving release roller moves demolding point

Translating from P2P to R2R

Parameter	P2P (lab)	R2R (1 m/min)
Coating thickness	5 µm (Spin coating)	5 µm (Slot die)
Dimensions	25 x 25 mm²	250 mm
Press pressure	1 bar	Up to 3.6 bar
Press time	2 s	~3 s (increase with softer press roller)
Exposure time	4 s	~6.4 s (1 lamp)
Release force	15 N	~120 N
Release angle to normal	0°	53° (@200 N)
Tensile force	-	Up to 250 N
Throughput	3 samples/minute (0.001875 m²/min)	0,25 m²/min Factor >120

Technologies and processes



UV NIL system designs:

- ✓ Surface activation
  Corona, plasma, chemical treatment
- ✓ Coating
  Slot die, knife, roller coater …
- ✓ UV curing
  Mercury, LED UV radiator

NIL system designs:

- ✓ Heating
- ✓ IR/ NIR, inductive, laser heating or heated fluids in embossing drum

Replication mold:

- ✓ Drum, endless belt, film
- ✓ One-/ Multi-Temperature zones

Source: Fraunhofer IPT

Technologies and processes

Process parameters (selection):

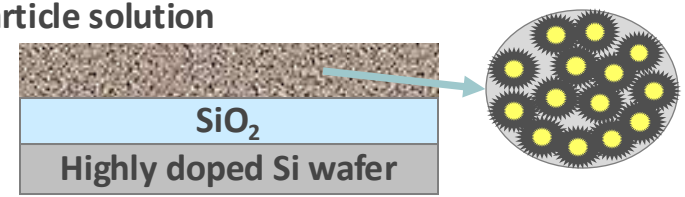
- ✓ Resist
  - ✓ Chem. formulation
  - ✓ Viscosity / rheology
- ✓ Film
  - ✓ Chem. formulation
  - ✓ Chemical / mechanical pre-treatment
- ✓ Tool
  - ✓ Hard / soft mold
  - ✓ Anti-adhesion layer
- ✓ UV-source
  - ✓ Spectral distribution
  - ✓ LED- / conventional source

Source: Fraunhofer IPT

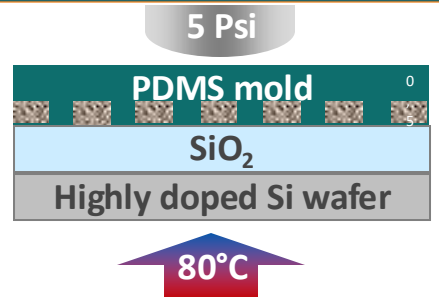
Innovative coating of gold contacts:

A. Coating of substrate

Nanoparticle solution

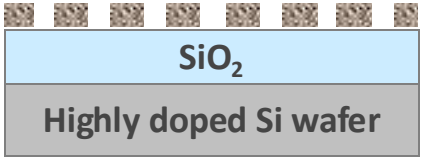


B. Thermal imprint

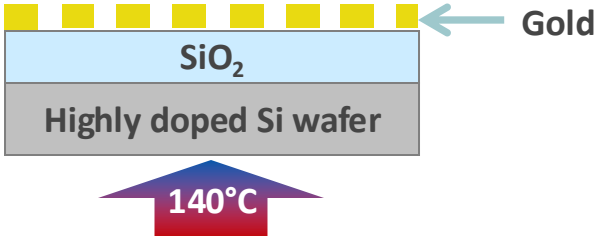


C. Imprinted structure

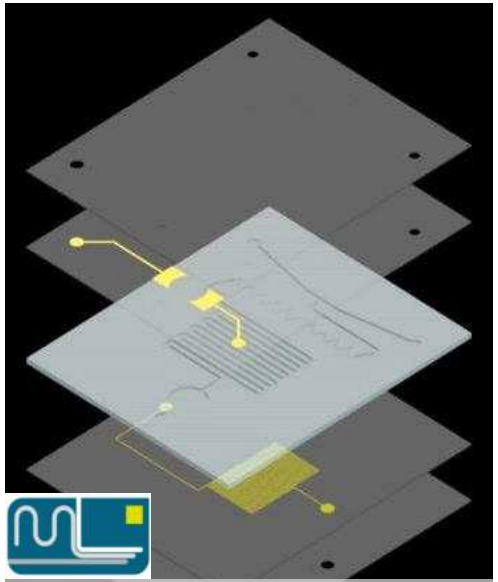
Dried nanoparticles



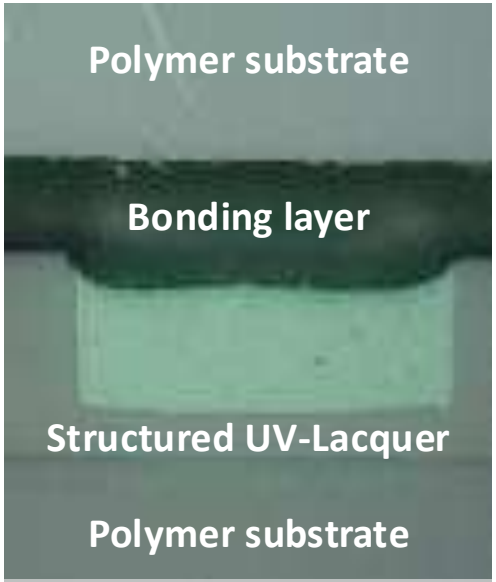
D. Sintering of gold NP to gold-contacts



Technologies and processes



Vertical combination of functional layers



Sealed microfluidic channels

1. Top sealing layer
2. Optical layer
   - ✓ light guide for fluorescence detection
3. Microfluidic layer
   - ✓ Fluid input, mixer, serpentine channel, detection well

2 stacked imprint structures

4. Electrical layer
   - ✓ Heaters for two temperature zones
5. Bottom sealing layer

Source: EU FP7, coordinated by Fraunhofer IPT www.ml2.eu/

Technologies and processes

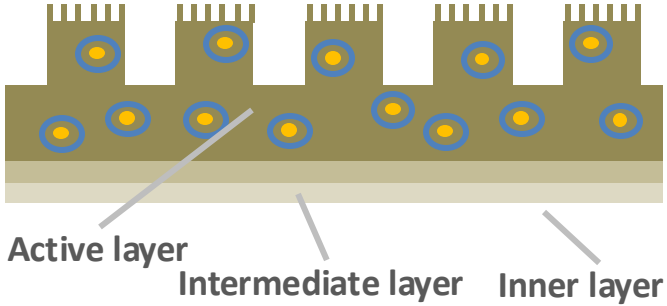
Micro pillars:

✓ Anti-sticking properties

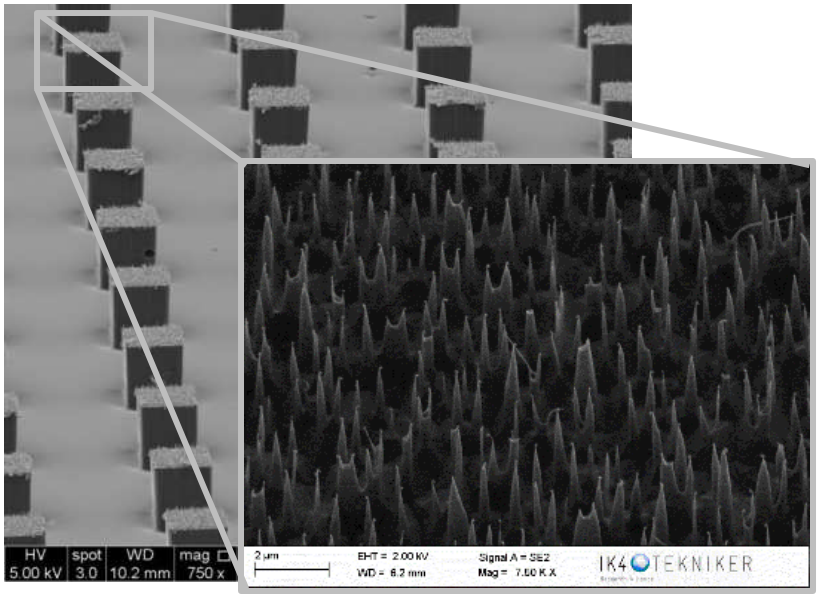
Nanospikes:

✓ Perforation

3-layered antimicrobial film

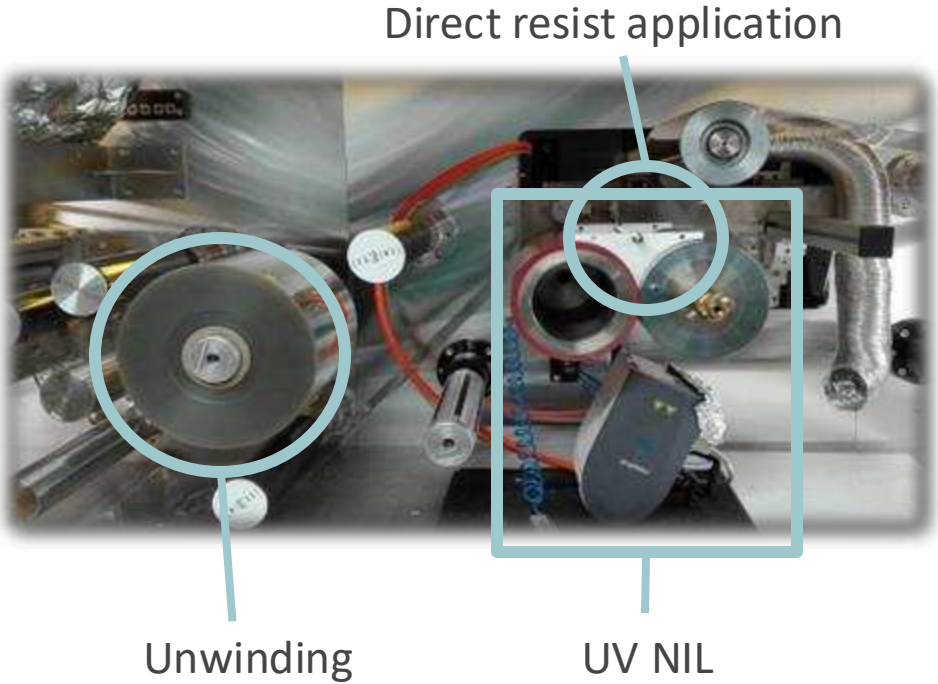


Hierarchical micro-/ nano structures



Source: Fraunhofer IPT

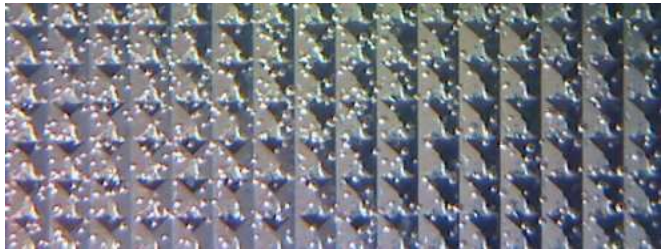
Technologies and processes



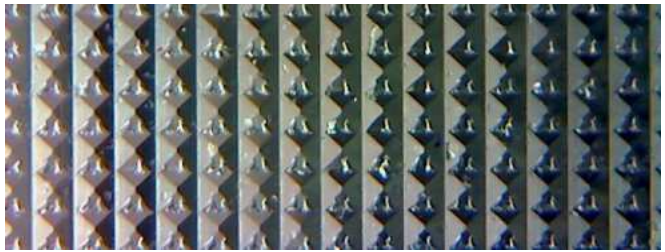
How to not do UV NIL:

- ✓ Too much resist
- ✓ Too little UV
- ✓ Too fast substrate speeds

Technologies and processes



Bubble enclosures



Geometrical defects

Influences on the quality mainly result from

Substrate:
- ✓ Impurities / Dust

Wetting behaviour

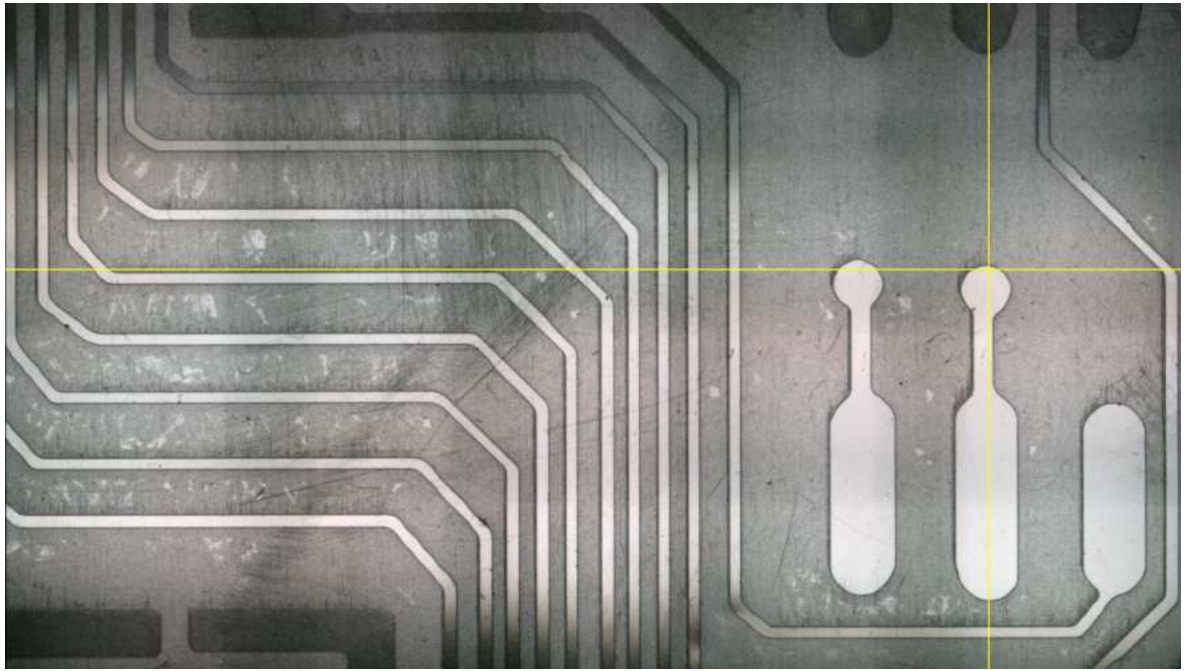
Embossing drum:
- ✓ Machining errors (e.g. badly joint sleeves)
- ✓ Wear

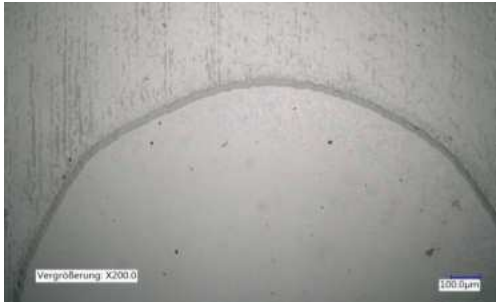
Partial / total lacquer adhesion

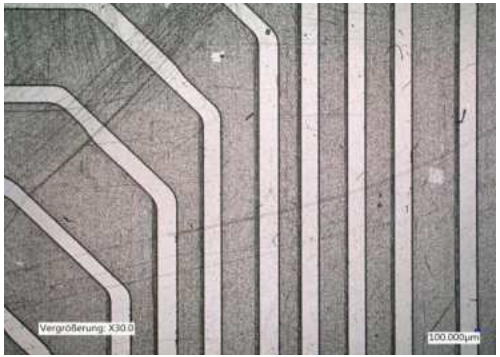
Resist:
- ✓ Impurities / Dust
- ✓ Bubbles / Foam
- ✓ Coating homogeneity

Source: Fraunhofer IPT

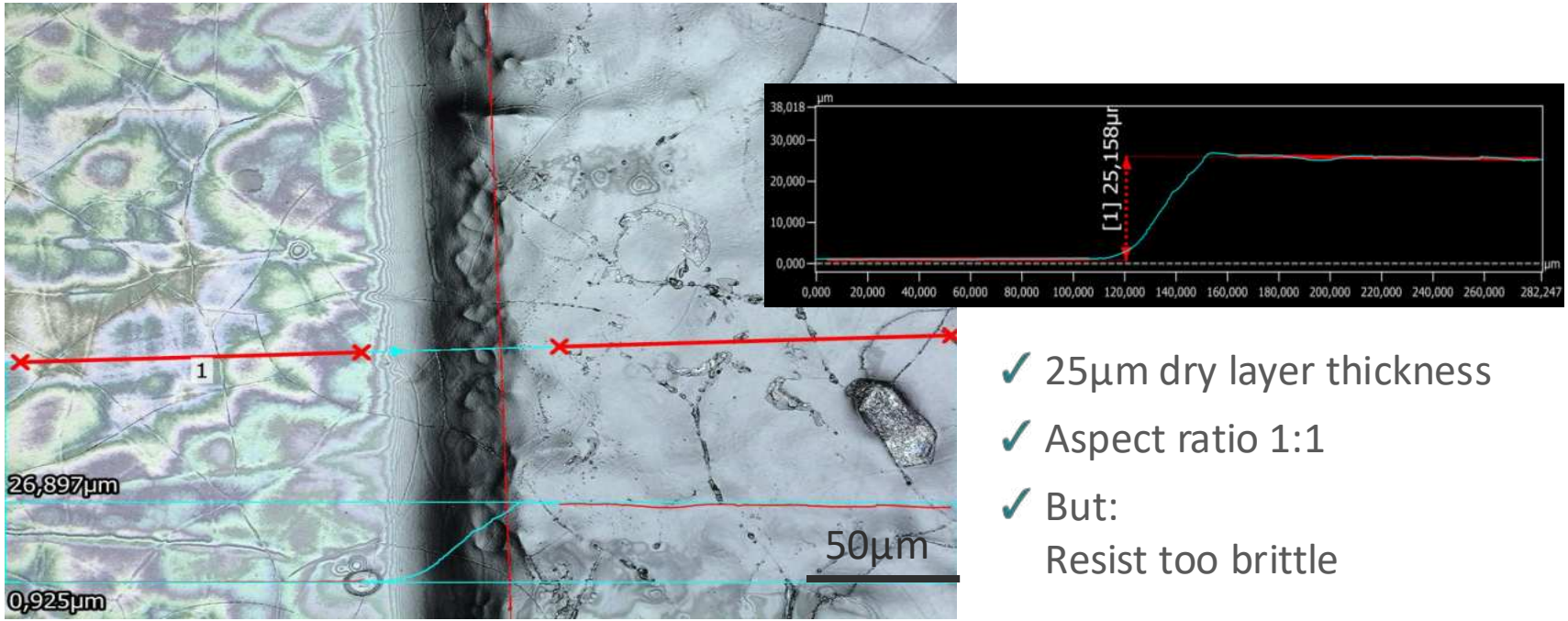
Successful imprint several mm down to 40µm feature size





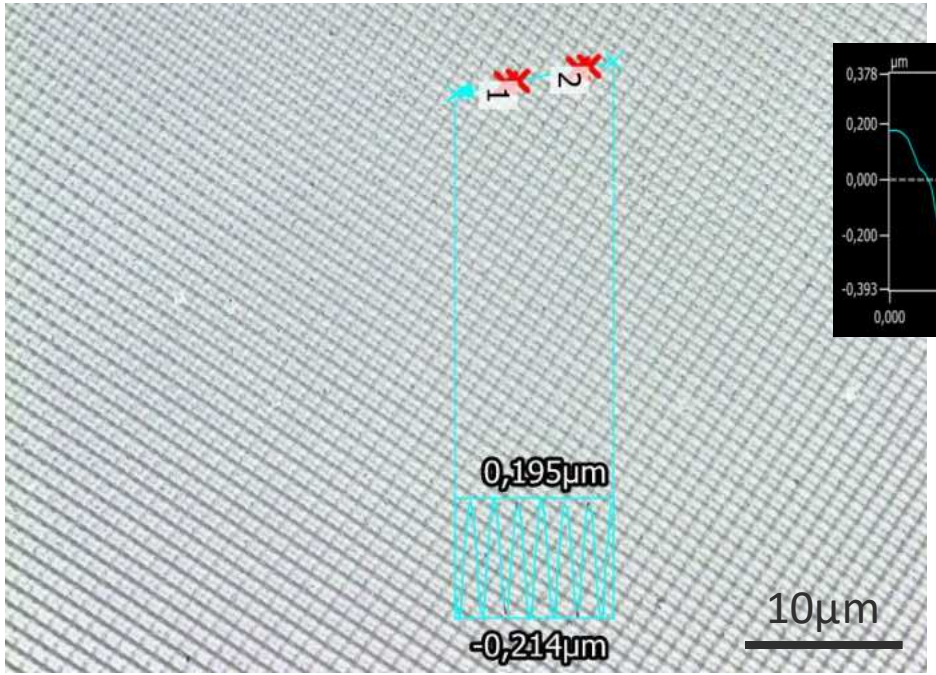


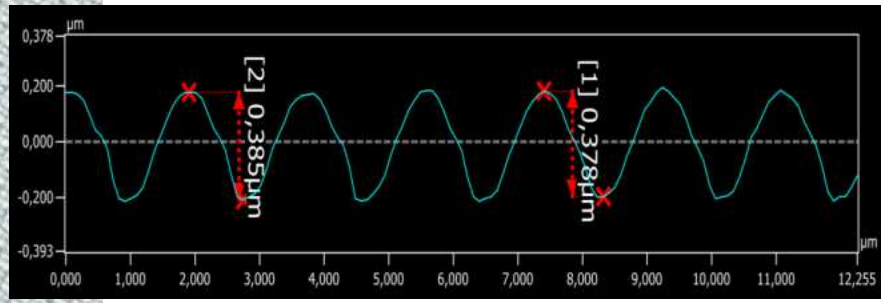
Technologies and processes



- ✓ 25µm dry layer thickness
- ✓ Aspect ratio 1:1
- ✓ But:
  Resist too brittle

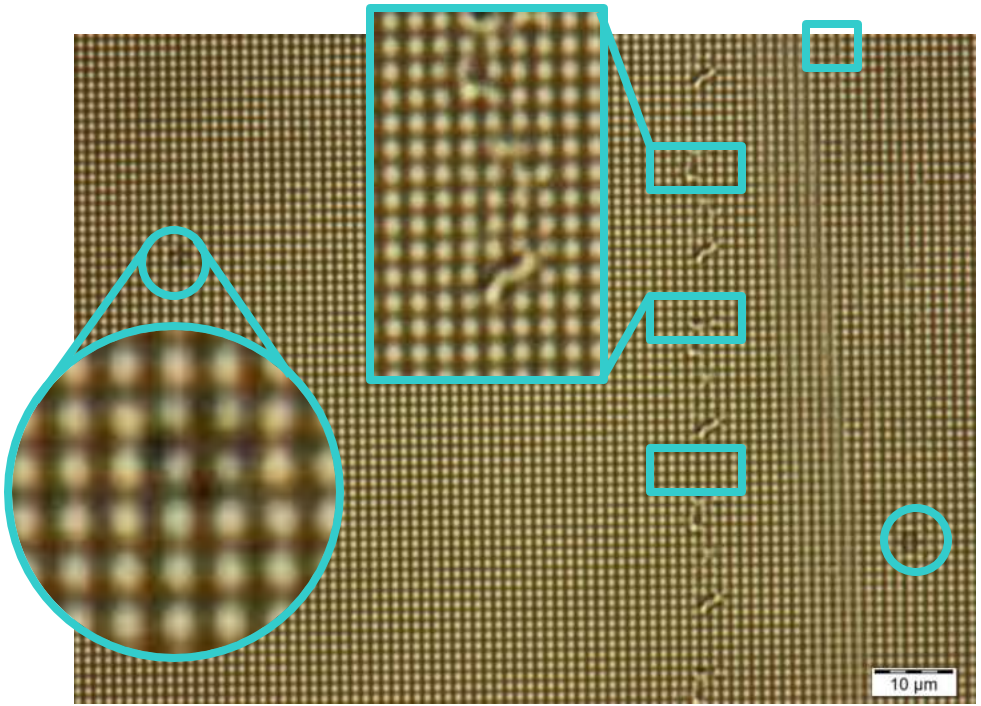
Technologies and processes





- ✓ 380nm feature size
- ✓ Aspect ratio 2:1
- ✓ Low density of defects

Technologies and processes



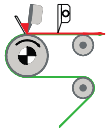
Imprint defects:

1. Surface scratches

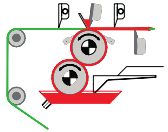
2. Point defects
   → No effect on optical purpose

3. Damages in sleeve
   → Periodic damage in optical structure

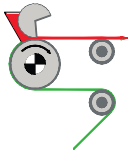
Coating systems



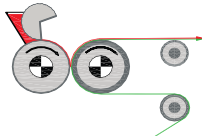
Knife system



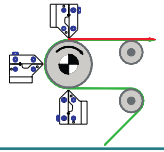
Double side coating system



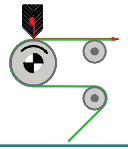
Commabar system



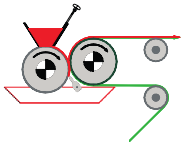
Reverse commabar system



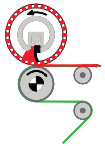
Slot die system



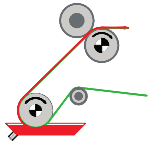
Curtain coating system



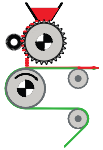
Case knife system



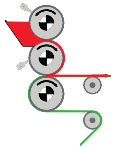
Rotary screen system



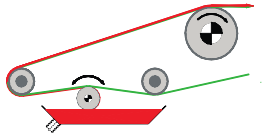
Dipping system (Foulard)



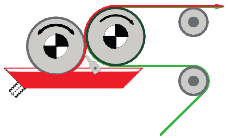
Powder scattering system



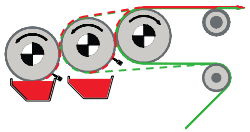
Reverse roll coating system



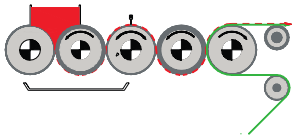
Micro roller coating system



2-roller coating system

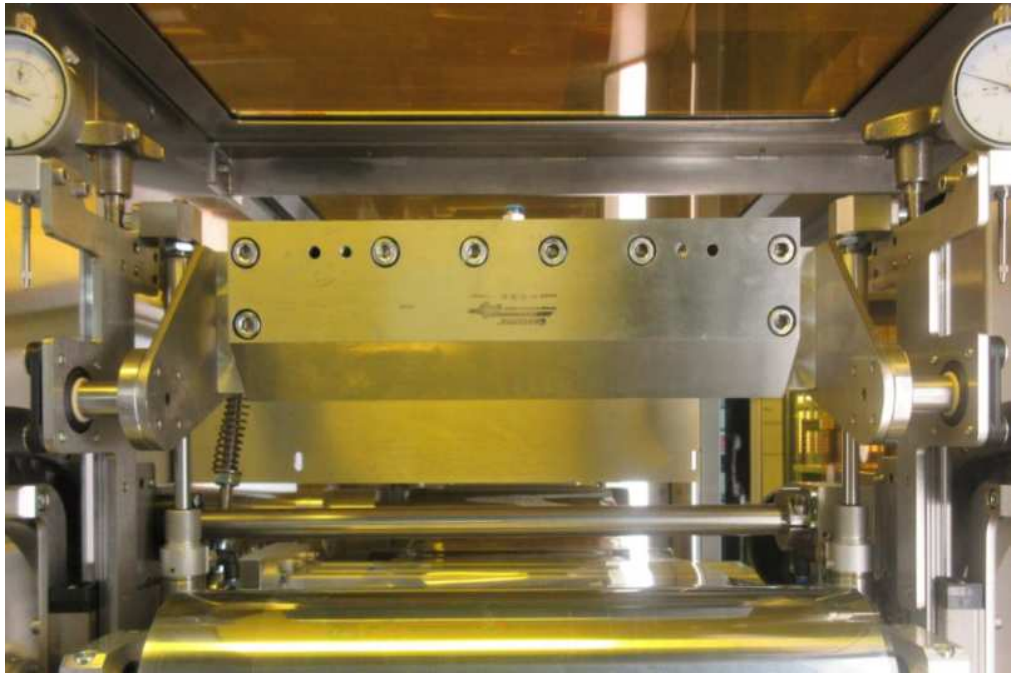


3-roller combi coating system

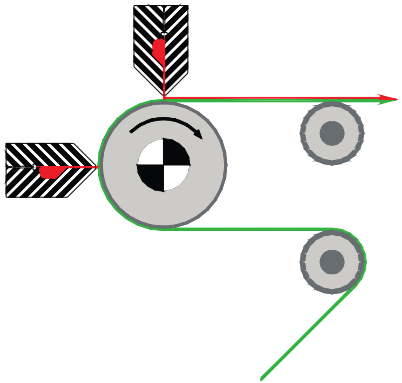


5-roller coating system

Coating and printing for nanoimprint lithography



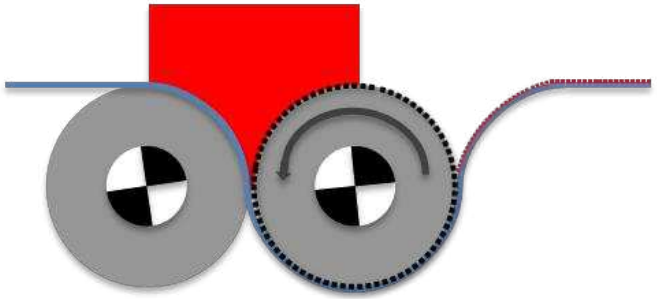
Slot die coating for
pre-metered film coating



- ✓ Layer control
- ✓ Level control in the nip
- ✓ 12/9” position

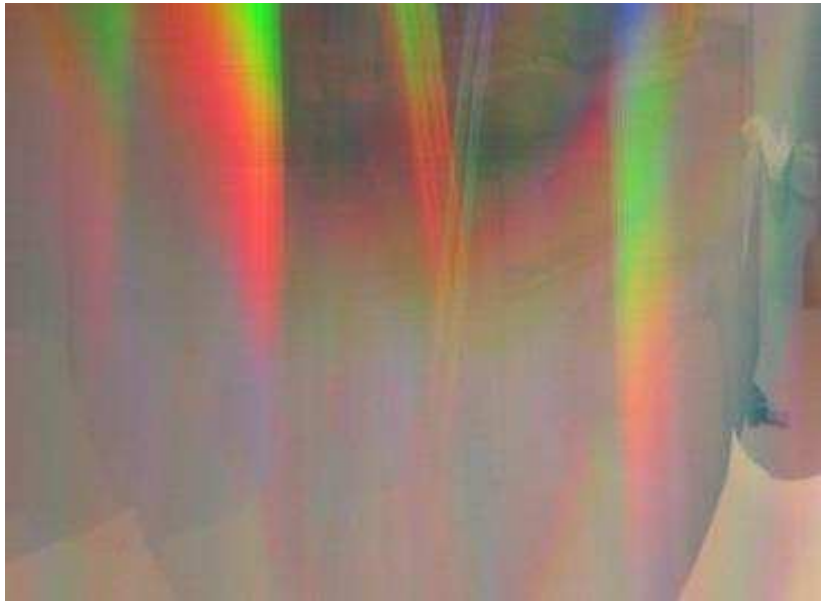
Coating and printing for nanoimprint lithography

Nip coating

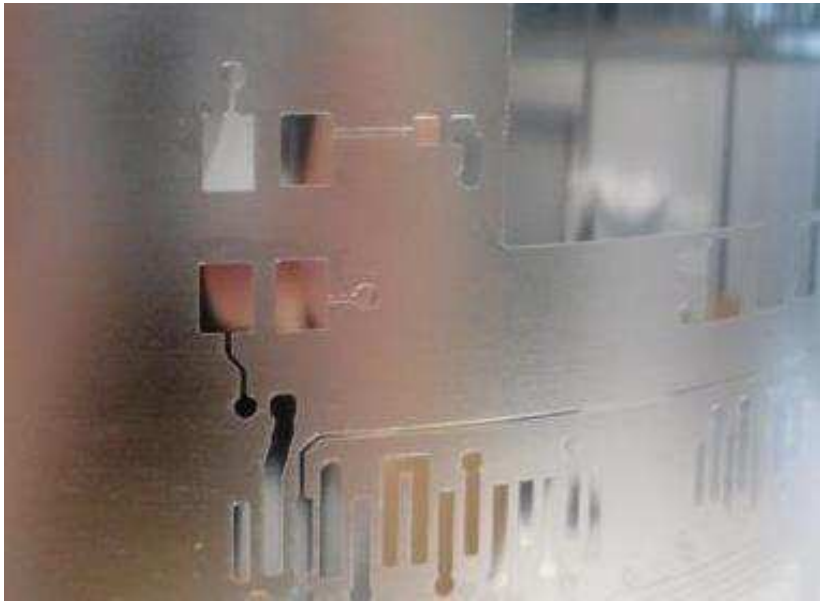


- ✓ Layer control by gap
- ✓ Level control in the nip
- ✓ Compact process

Coating and printing for nanoimprint lithography



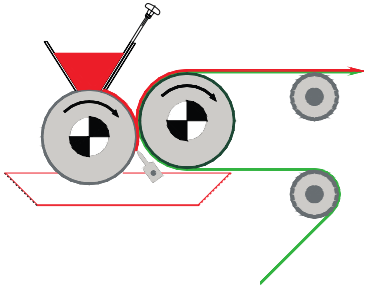
Homogeneous structure



Inhomogeneous structure

Coating and printing for nanoimprint lithography

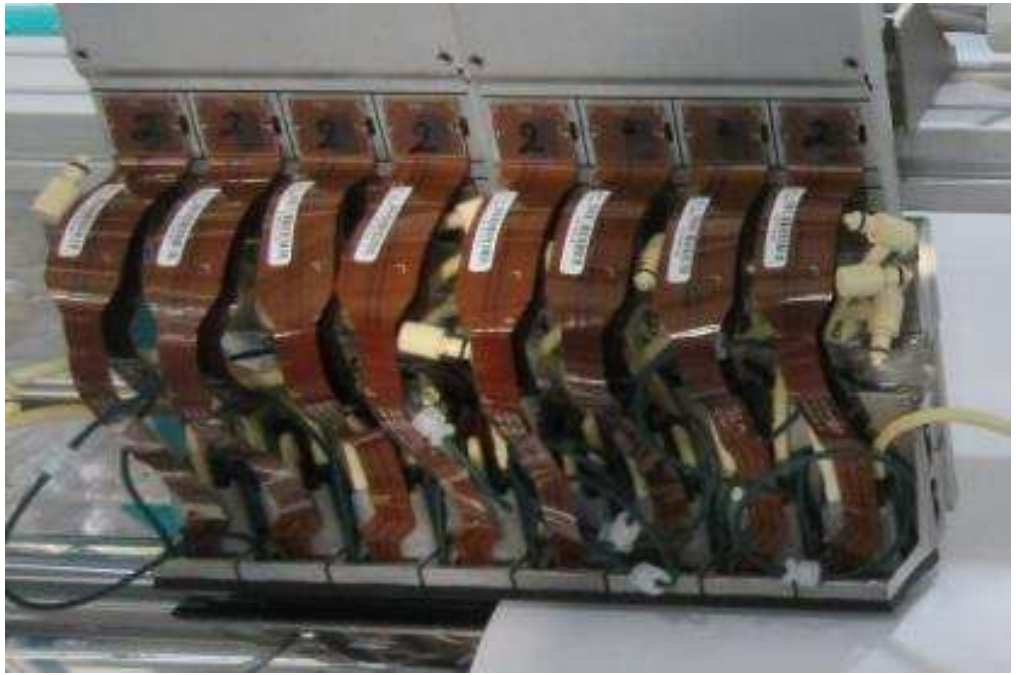
Printing for inhomogeneous structures?



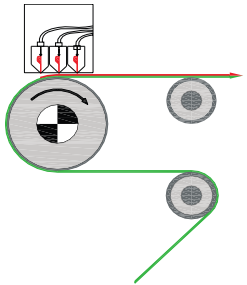
Case knife

- ✓ Layer control „inhomogeneous“
- ✓ Matched level control in the nip
- ✓ Nip material fits „sleeve consumption“

Coating and printing for nanoimprint lithography



Printing for inhomogeneous structures?



Inkjet

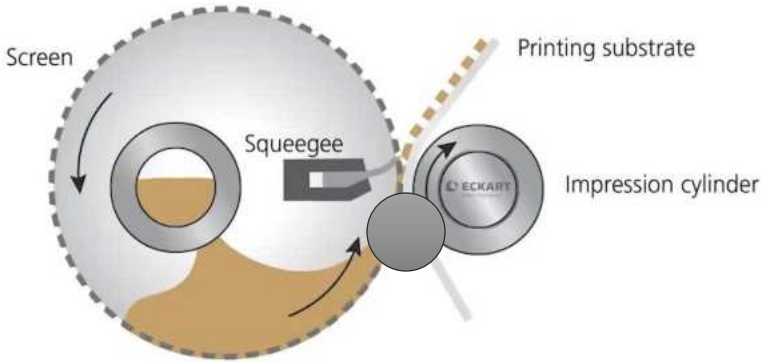
- ✓ Layer control „inhomogeneous“
- ✓ Matched level control in the nip
- ✓ Nip material fits „sleeve consumption“

Coating and printing for nanoimprint lithography

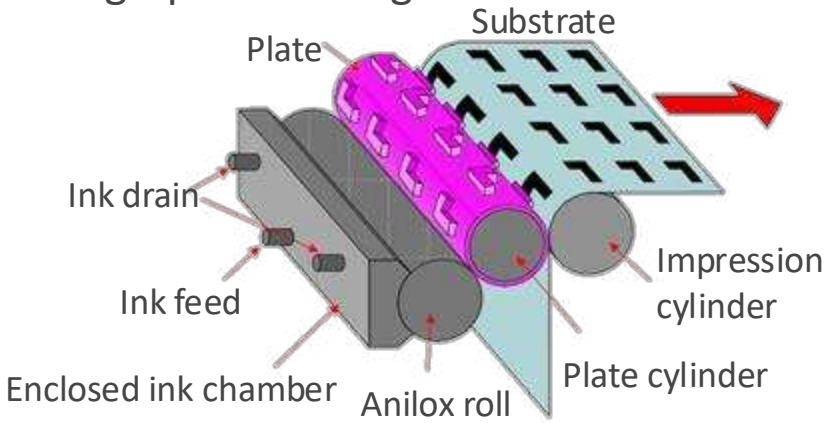
Printing for inhomogeneous structures?

- ✓ Layer control „inhomogeneous“
- ✓ Matched level control in the nip
- ✓ Nip material fits „sleeve consumption“

Rotary Screen Printing



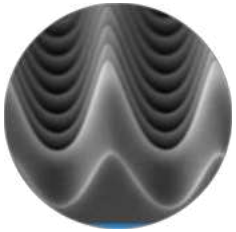
Flexographic Printing



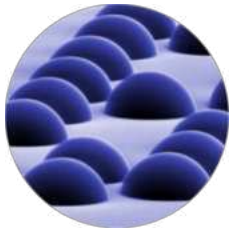
3.

Products

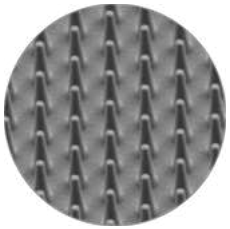
Applications



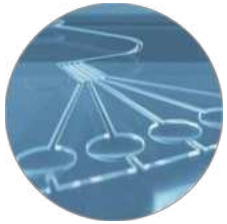
Display



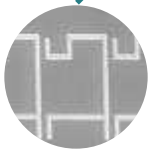
Photonics



Bionics



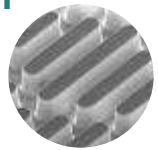
Life science



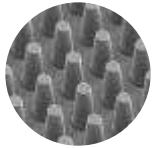
Printed electronics

Retroreflectors

Diffractive optical elements



Antibacterial surfaces



Super hydrophobic surfaces

Shark skin

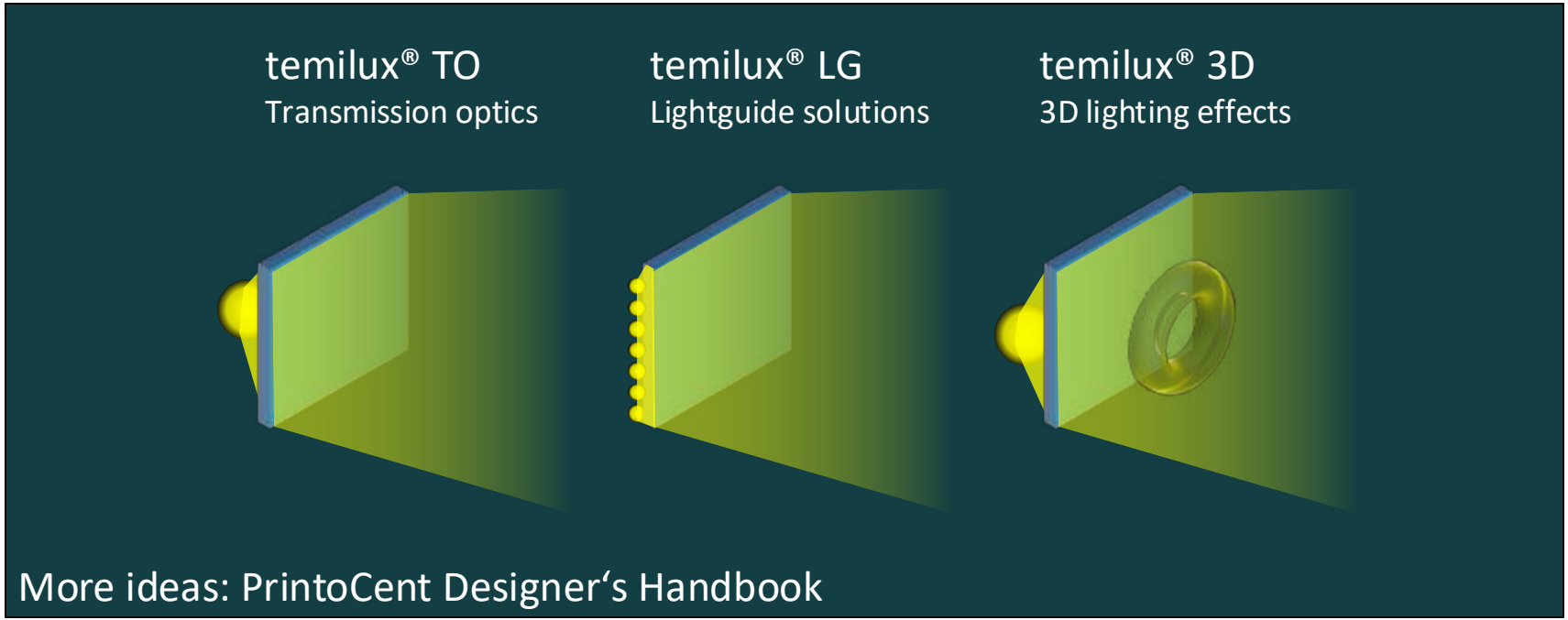
Haptic surfaces

Microfluidic structure

Products

Source: temicon

Products



Source: temicon

4.

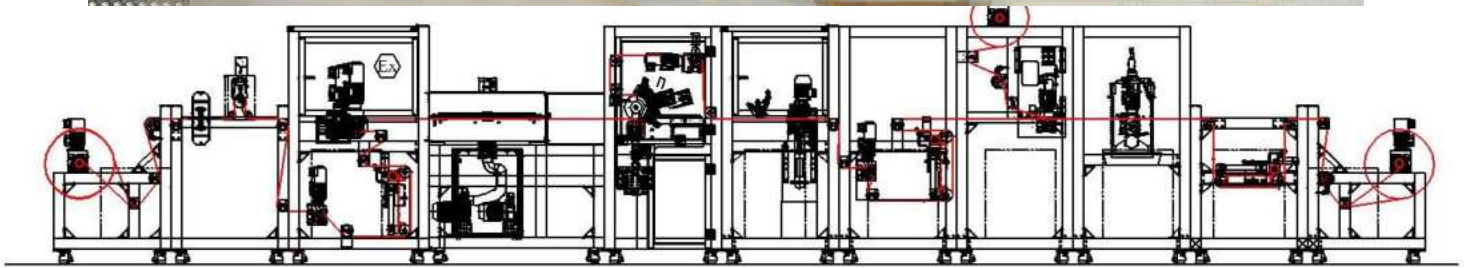
Equipment

Equipment

Coating Unit:

- ✓ Knife coating
- ✓ Slot die coating
- ✓ Inkjet
- ✓ Flexographic printing
- ✓ Rotary screen printing

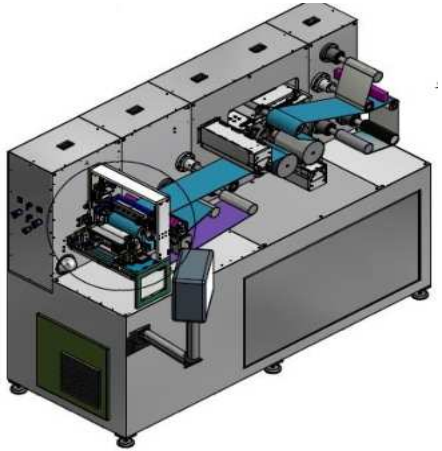
Equipment



Equipment

Test Solution S2S

Test Solution R2R

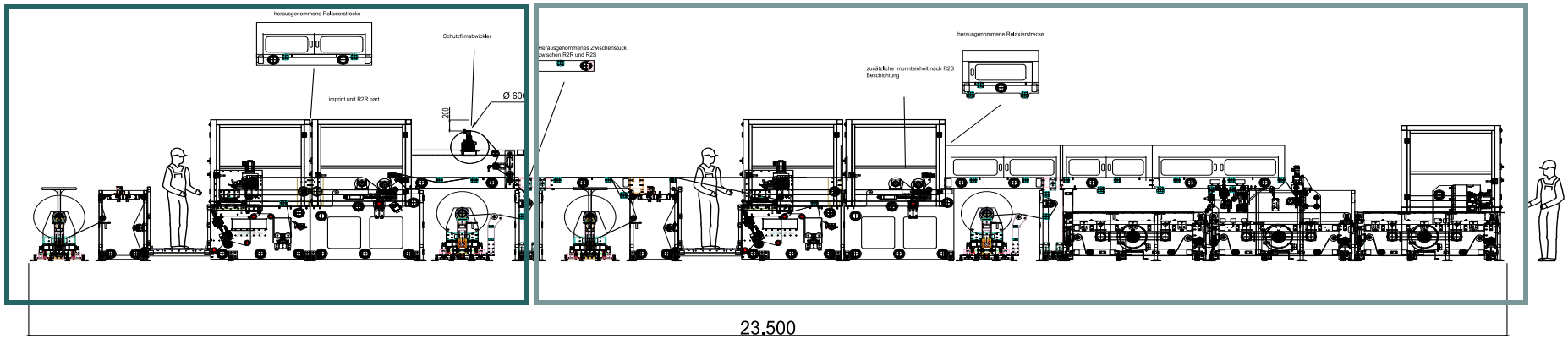


NIL 300 R2R

Equipment

R2R + R2P-Machine

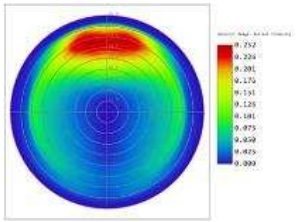
Specs:
Working width R2R: 1100 mm
Dimensions R2P: 1000 mm x 1600 mm
Speeds: 6 – 60 m/min
Coating unit: Slot die coating

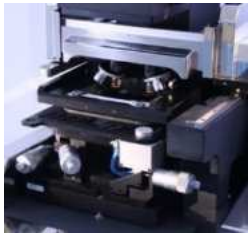


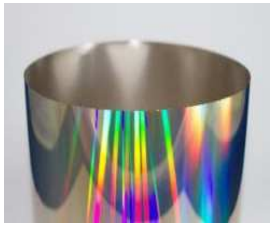
5.

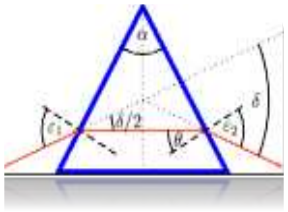
Summary

Summary









Simulation

Origination

Tooling

Replication

Do not hesitate to contact us!

Anything missing?

Let us know and we will make it happen!

Our R&D centre is worldwide the most versatile centre for coating, printing and laminating.

Sales department:
sales@coatema.de

Download
broschures & presentations

Thank you

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T +49 21 33 97 84 - 0 ▪ info@coatema.de

www.coatema.com

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