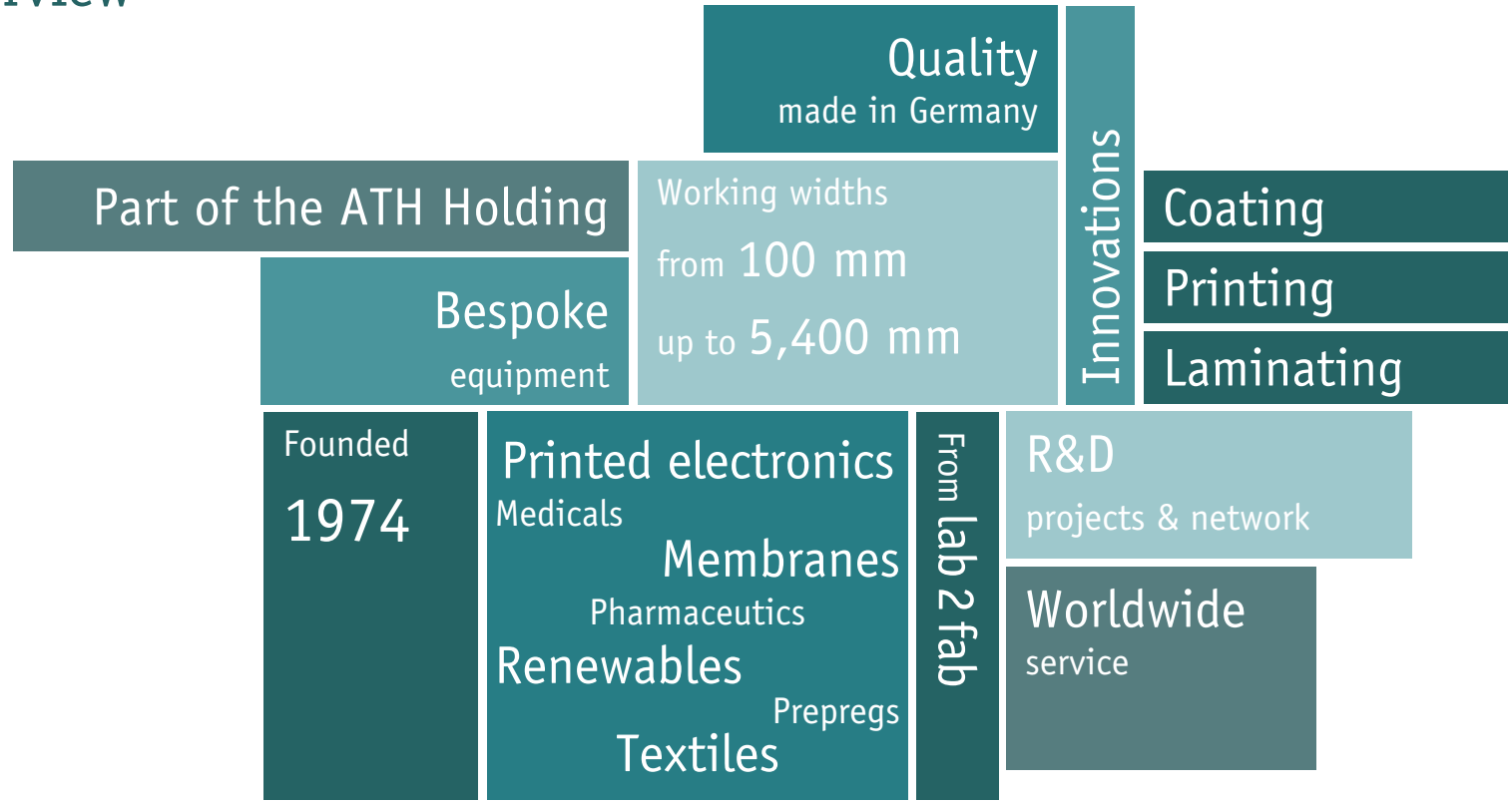
Coatema®
Coating Machinery GmbH

New production technologies for printed electronics

Summary

Summary

Overview

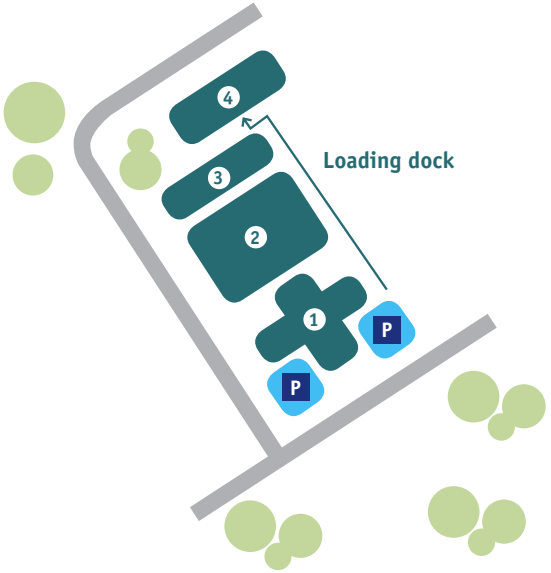


Group of companies

KROENERT	DRYTEC	Coatema® Coating Machinery GmbH	ZAE ANTRIEBSSYSTEME
✓ Founded 1903	✓ Founded 1995	✓ Founded 1974	✓ Founded 1919
✓ Approx. 200 employees	✓ Approx. 50 employees	✓ Approx. 50 employees	✓ Approx. 140 employees
✓ Located in Hamburg	✓ Located in Norderstedt	✓ Located in Dormagen	✓ Located in Hamburg

Represented worldwide

Headquarter in Dormagen



1. Head office
2. R&D centre
3. Assembly
4. Loading dock

P Visitor parking

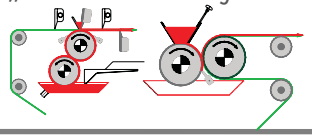
Milestones

1974
Foundation

2000
First Coatema Symposium

2001
New company site with a centre for research and development

2003
Patent „Doublesided coating system“ and „Indirect knife system“



2006
New company site, expansion to 10,000 qm

2007
Opening R&D housed in an area of 1,200 square meters

2007
Click&Coat registred as Trademark

2011
IDTechEx award „Technical Development: Manufacturing Europe & USA“

2013
New corporate design

2018
KROENERT and Coatema under one umbrella company

Vision – from lab 2 fab

Lab → **Pilot** → **Production**

Coatema equipment platform strategy for lab 2 fab

Our work in associations – global networking

oe-a

PrintoCent

NMWP.NRW
Cluster NanoMikroWerkstoffePhotonik

HOPE-A
Hellenic Organic & Printed Electronics Association

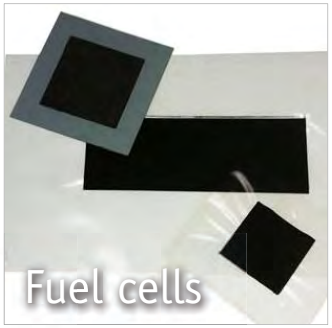
Board Member:
OE-A

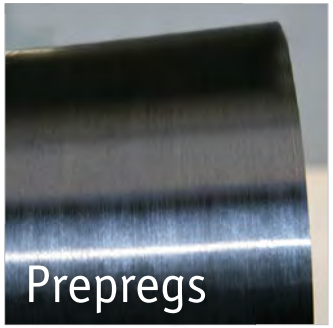
Advisory Board:
Fraunhofer ITA

Coatema customers

Summary

Our markets

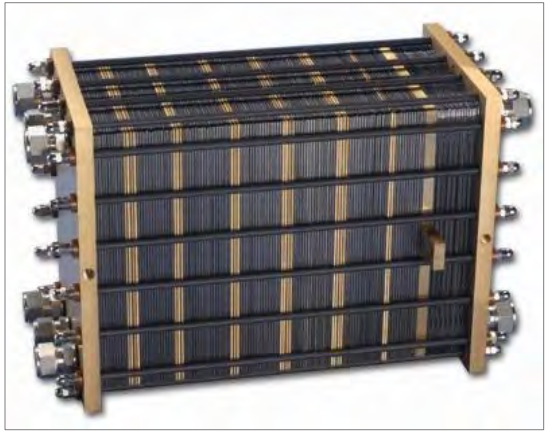




Renewables

Markets:

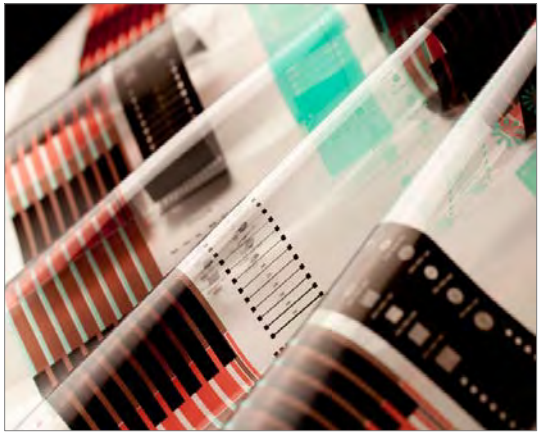
- ✓ Batteries
- ✓ Fuel cells
- ✓ Solar



Printed electronics

Markets:

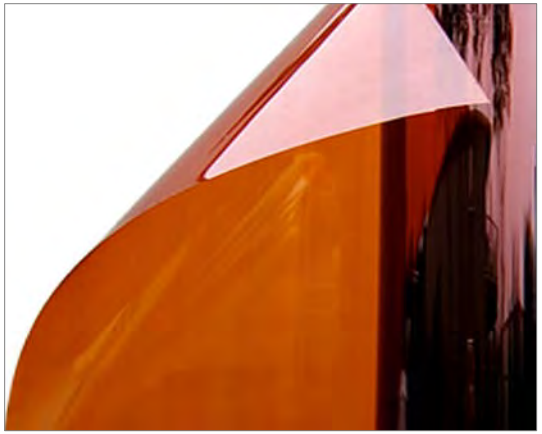
✓ Conductive coatings ✓ Smart systems ✓ Displays ✓ RFID ✓ OLED ✓ OPV ✓ Electronics



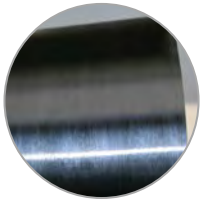
Membranes

Markets:

✓Reverse osmosis ✓Water purification ✓Medical filtration ✓Gas filtration ✓Nanofiltration



Prepregs

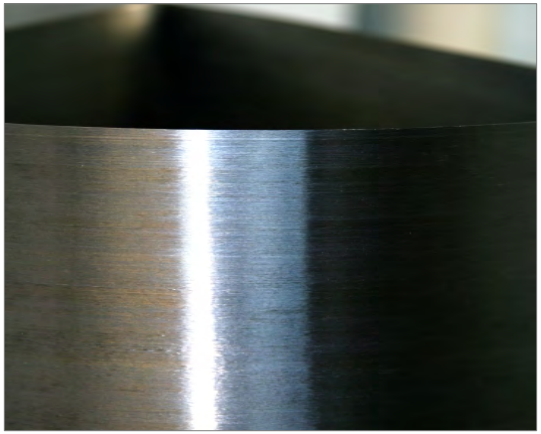


Markets:

✓ Automotives

✓ Aerospaces

✓ Constructions



Medical applications

Markets:

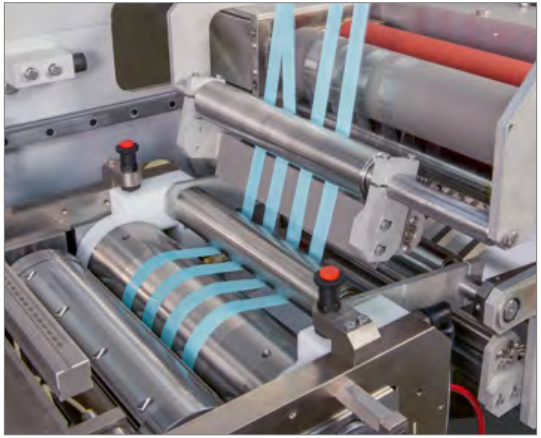
✓ Silicone gels ✓ Hydrogels ✓ Plaster ✓ Surgical materials

Pharmaceutics

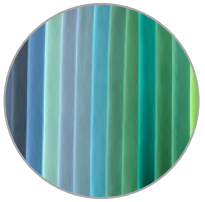
Markets:

✓ ODF (Oral Dispersible Film)

✓ Transdermal systems

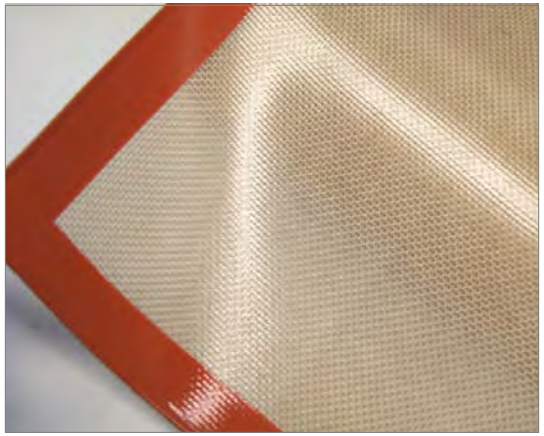


Textiles



Markets:

✓Technical textiles ✓Construction textiles ✓Medical textiles ✓Geotextiles ✓Home textiles



Summary

Lab units

Lab

Test Solution S2S

Easycoater

Test Solution R2R

Pilot lines

Pilot

Click&Coat™

Smartcoater

Basecoater 3rd Generation

Pilot lines

Pilot

Deskcoater

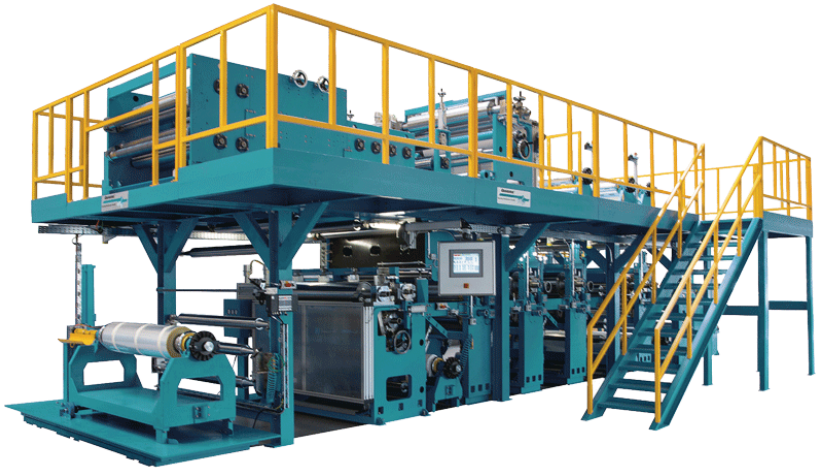
Linecoater

Verticoater

Production lines

Production

Production lines



Prepreg plants

Bespoke equipment

Custom made

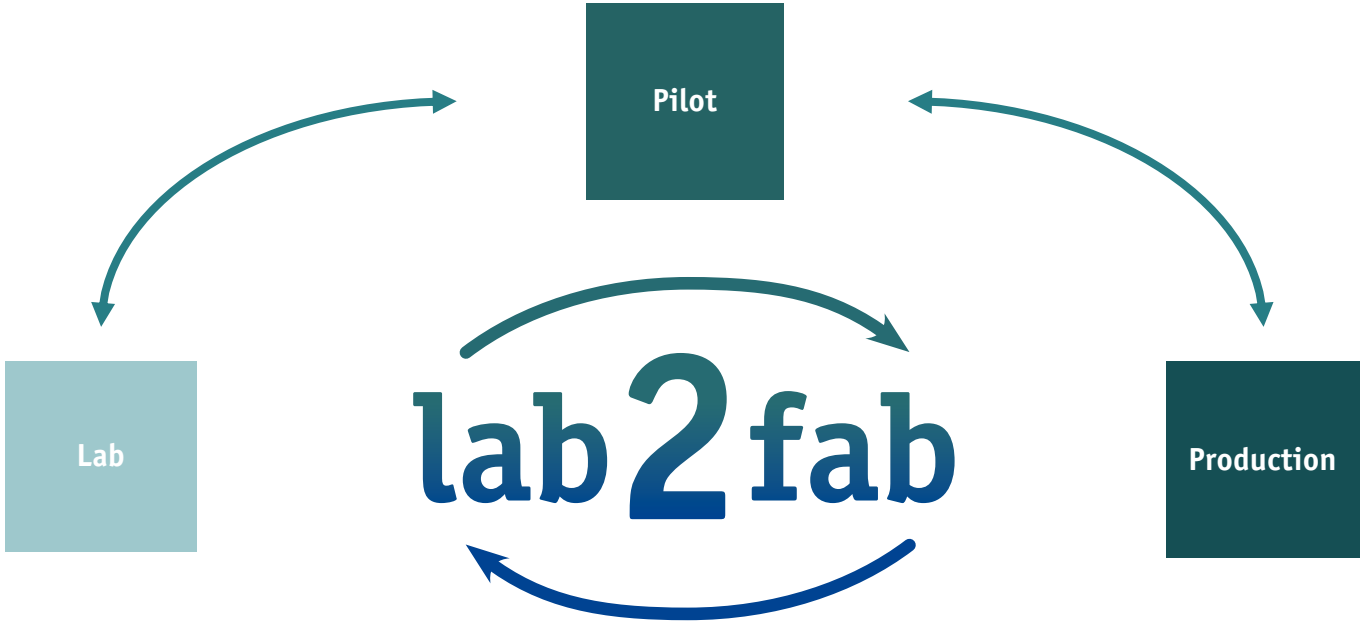
Printed oleds

Batteries

Composite fibres

Scaling up new technologies

Tools for lab2fab



Summary

R&D power house

KROENERT – Drytec – Coatema

- ✓ R&D space: 2,000 m²
- ✓ R&D units: 15
- ✓ From R2R to S2S
- ✓ Working width: 100 mm to 1,300 mm
- ✓ Operation speed: 0.1 to 1,610 m/min
- ✓ 15 parallel public funded R&D projects
- ✓ R&D staff: 25

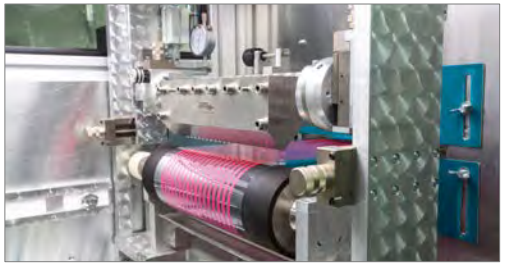
R&D centre KROENERT & DRYTEC

R&D centre Coatema

Product portfolio:

- ✓ Basic research, process- and product development
- ✓ Product improvement
- ✓ Trainings and conferences

Use of the Coatema research & development centre



Technologies
Coating, printing, laminating, imprinting, pretreatment, drying, curing, cross linking, cutting

Number of units available
10 – 12 units on 1 200 sqm

Sheet-to-Sheet – S2S
up to 300 mm x 500 mm

Roll-to-Roll – R2R
up to 500 mm width

Operation speed
0.1 to 100 m/min

Product portfolio

Process development

- ✓ Feasibility study
- ✓ Ink – process study
- ✓ Process analysis
- ✓ Proof of concept
- ✓ Smale scale prototype

Test production

- ✓ Prototyping
- ✓ Near to market testing
- ✓ TRL evaluation
- ✓ Training of staff

Education

- ✓ Coatema conference
- ✓ Training of customers
- ✓ Education of students

After sales service and ramp up of processes

- ✓ of Coatema units

Development of custom made design for equipment

- ✓ Prototyping
- ✓ Proof of concept

Funded research projects

- ✓ German funded
- ✓ Horizon 2020
- ✓ Global 2+2 projects
- ✓ B2B projects

R&D services

R&D customers

R&D projects overview 2020

PowderSizing

FLEX-G

GREEN SENSE

SUPERSMART

ENP

SOLID

Oled Solar

EI-FIB
ELECTROLUMINESCENCE for FLAGS, INTERIOR and BANNERS

PEPcat

E-Nanoprint Pro

EffiLayers

REAL NANO

FLEX FUNCTION 2 SUSTAIN

SolGel PV

Summary

Introduction

Equipment

Our markets

R&D

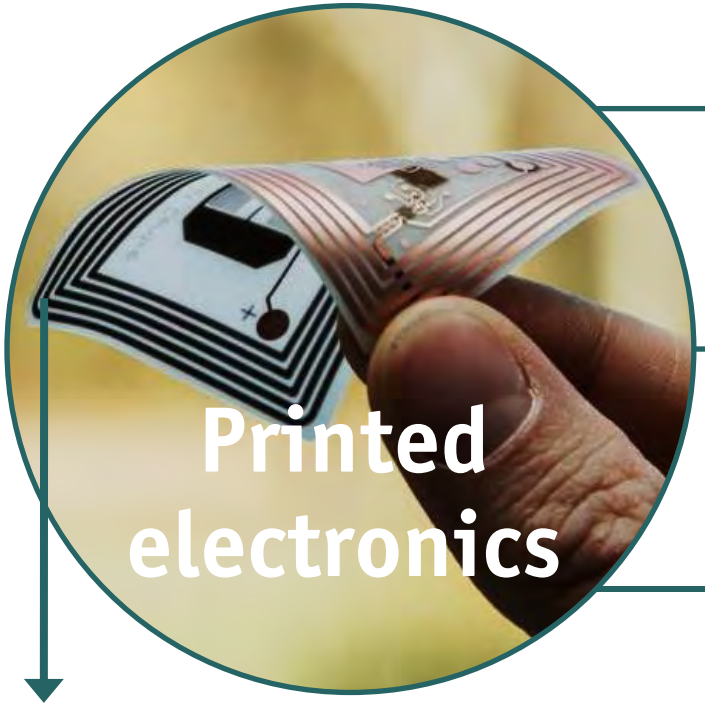
The printed electronics market

Bridging the gap

Technologies & processes

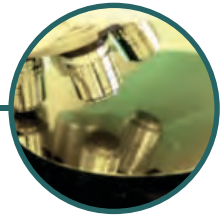
Summary

The future market



Printing
Coating
Deposition

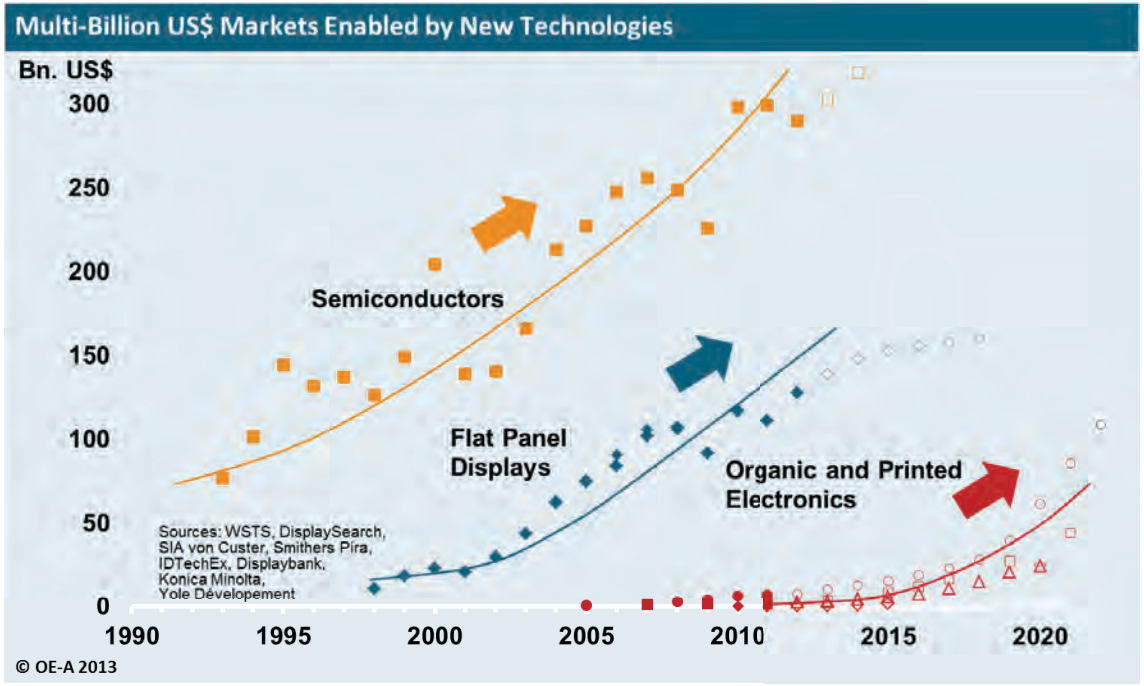
Chemistry



Microelectronics

flexible – thin – robust – lightweight – stretchable

The future market

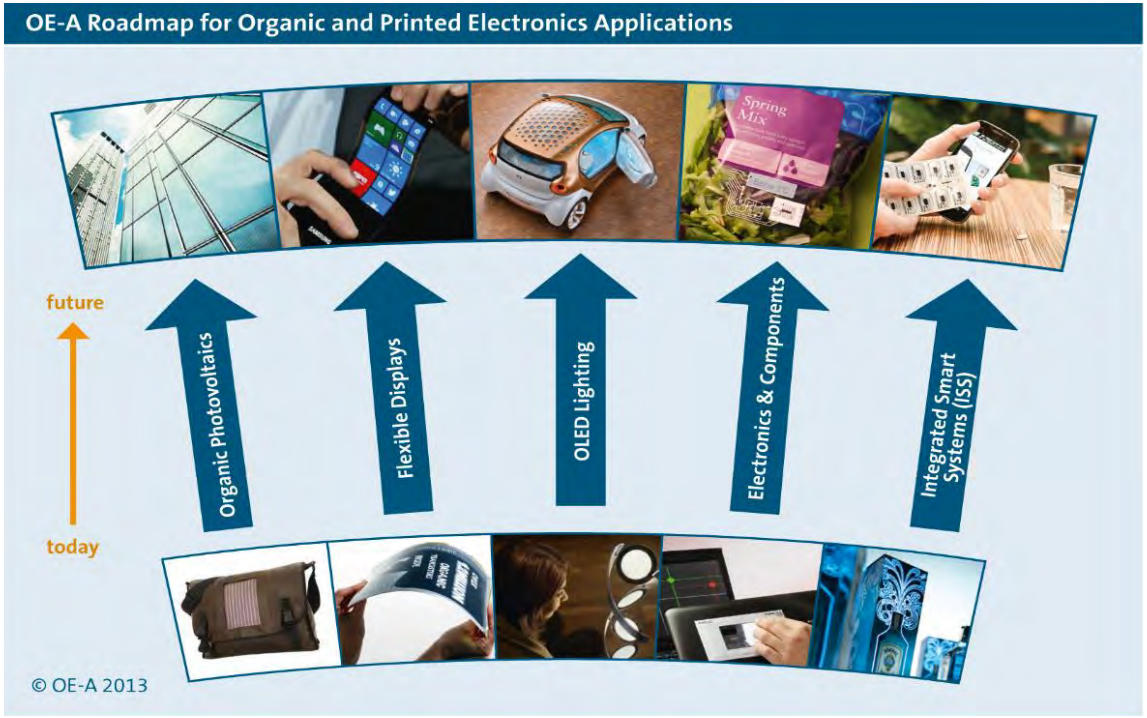


2010
2 Billion US$
predominantly by OLED displays

2012
8 Billion US$
predominantly by OLED displays

Potential
for a 50 Billion US$ market within the next 10 years driven by
OPV, lighting, displays, logic, memory/RFID, sensors

The future market



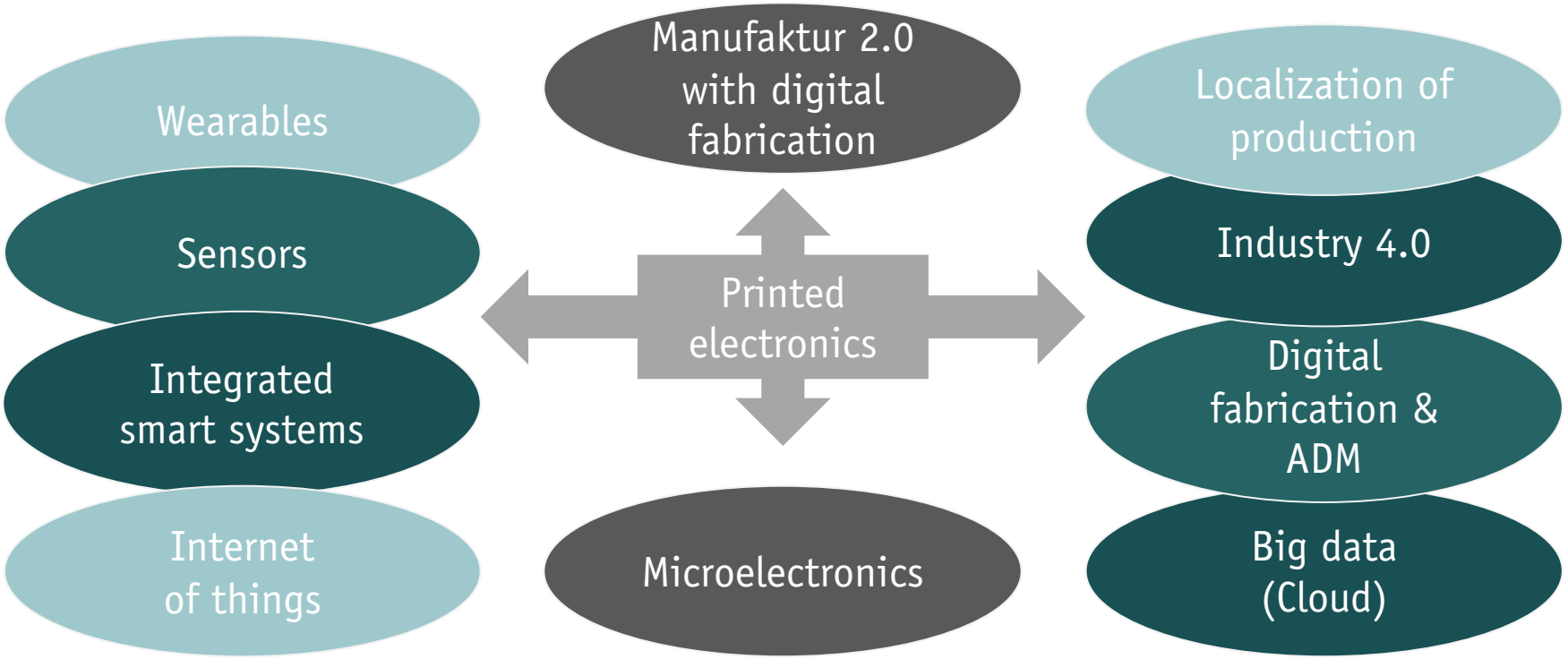
Digital fabrication

Digital fabrication is happening – lot size 1 is real

Why now?

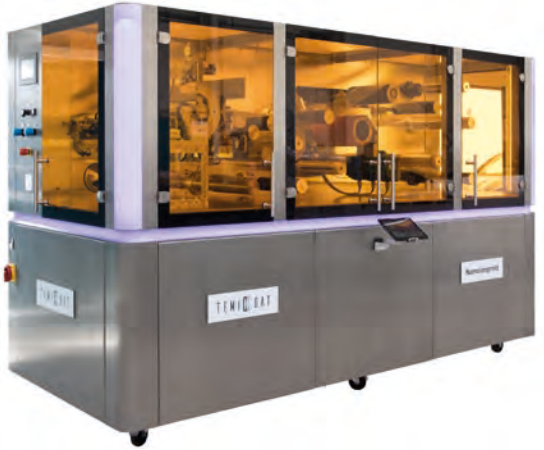
Digital fabrication and additive manufacturing will disruptively change the world of manufacturing we know today!

Disruptive!

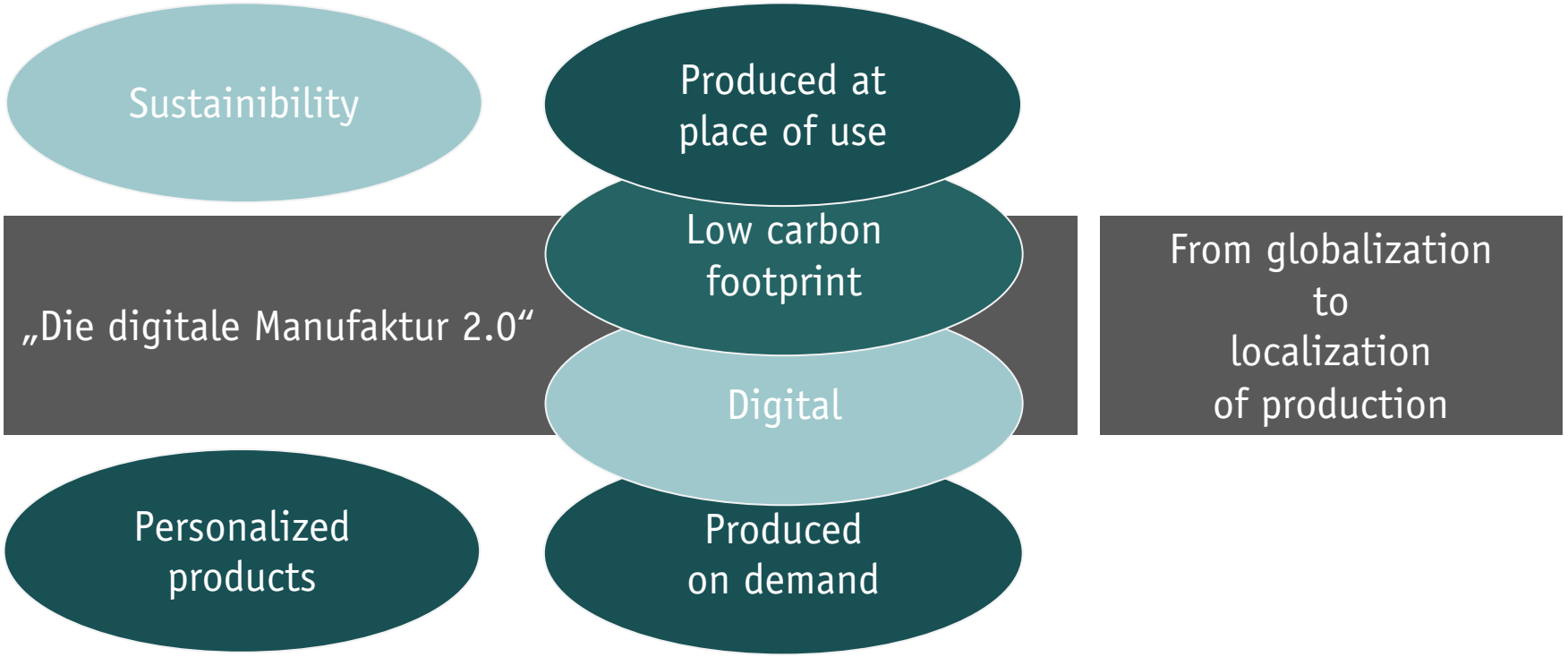


The „4th“ industrial revolution

- ✓ Digital fabrication means to have the abillity to produce lot size one for the same cost as for lot size million
- ✓ Manufacturing at the site with personalized design for each customer
- ✓ It will change global manufacturing to local manufacturing
- ✓ Productivity boost for the old economies and Europe, the real 4th revolution
- ✓ The „Manufaktur“ will come back – as the „digitale Manufaktur 2.0“



Disruptive



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From 2008 till today – PE as the flexible bridge

Actuator

Data processing

Energy source/
Energy harvesting

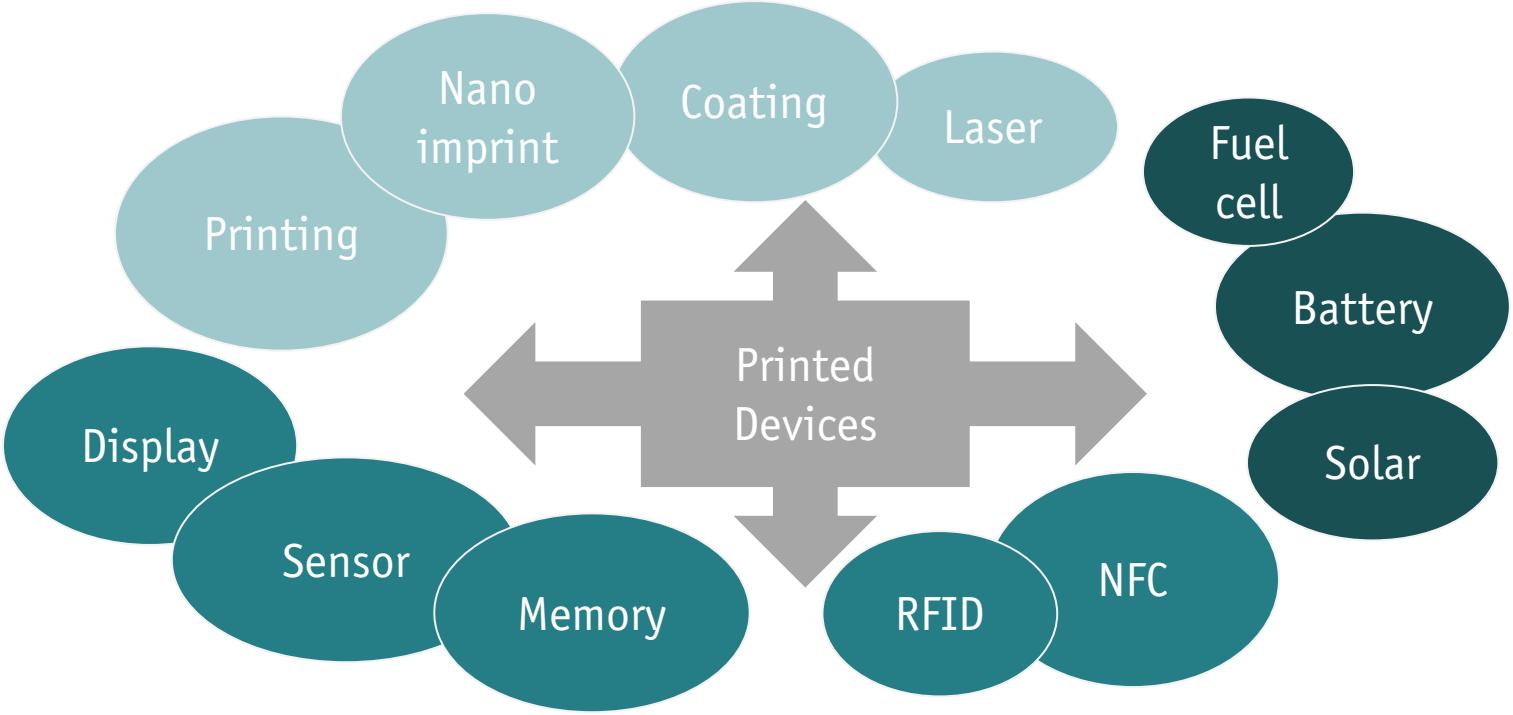
Sensor

Data transmission

Communication

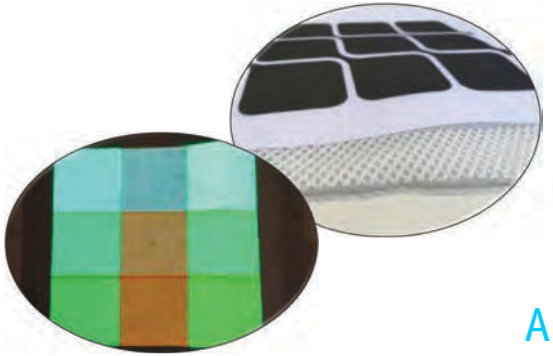
Hochschule Niederrhein
University of Applied Sciences

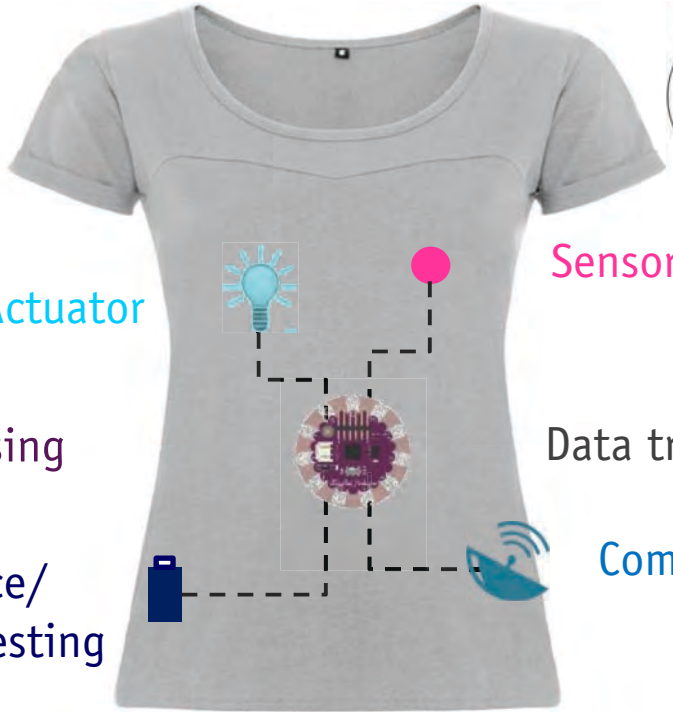
Printed electronics – bridging the gap

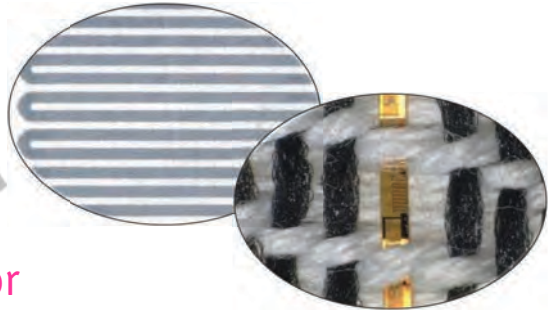


What could be the pathway on to textiles or also integrated into textiles?

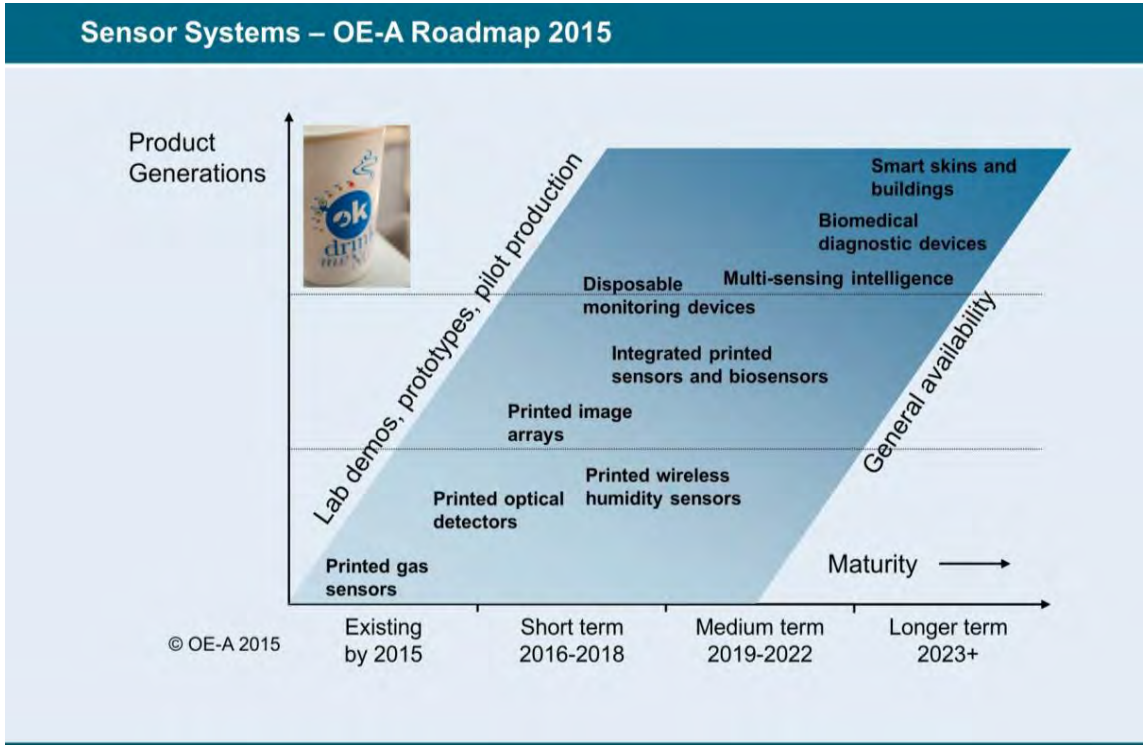
From 2008 till today – PE as the flexible bridge







Sensor systems – roadmap 2015

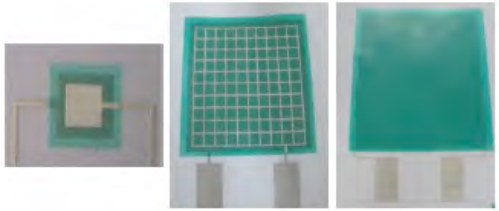


Case study – design principles

Authors: Juha-Veikko Voutilainen, Tuomas Happonen, University of Oulu

Figure 1. Printed temperature sensor and layout

Authors: Tuomas Happonen, Juha-Veikko Voutilainen, University of Oulu



(a) (b) (c)

Figure 1. Printed capacitive humidity sensor structures

Figure 1. Electrochemical biosensor

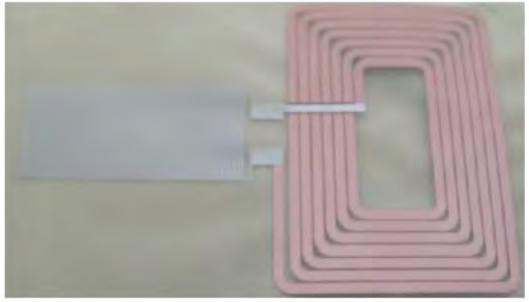


Figure 2. A remote readable RH sensor.

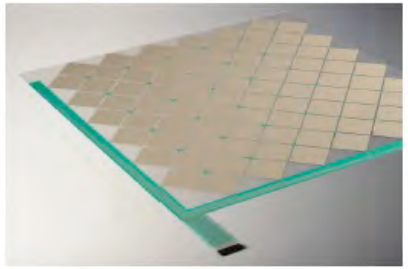


Figure 1. Capacitive touch sensor

Authors: Elina Jansson, Jukka Hast, VTT

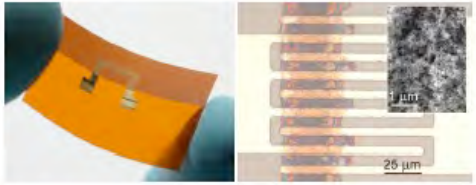
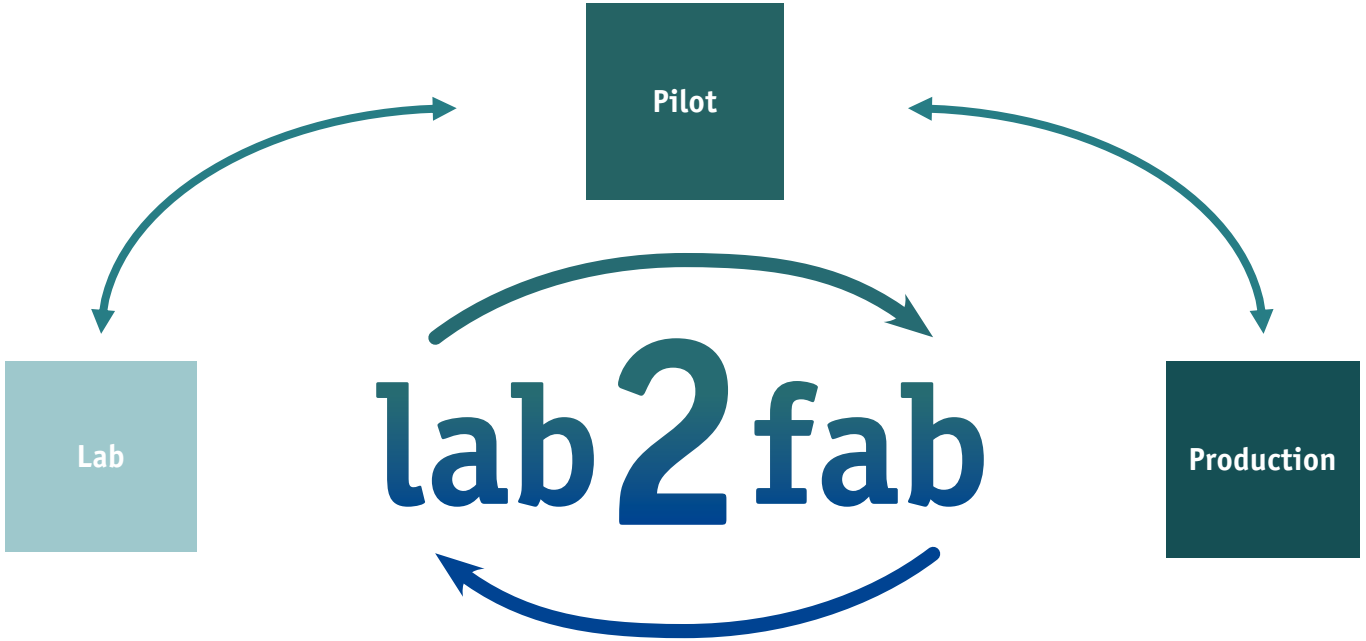


Figure 1. Printed gas sensors

PrintoCent

Designer's Handbook 2014

Tools for lab 2 fab



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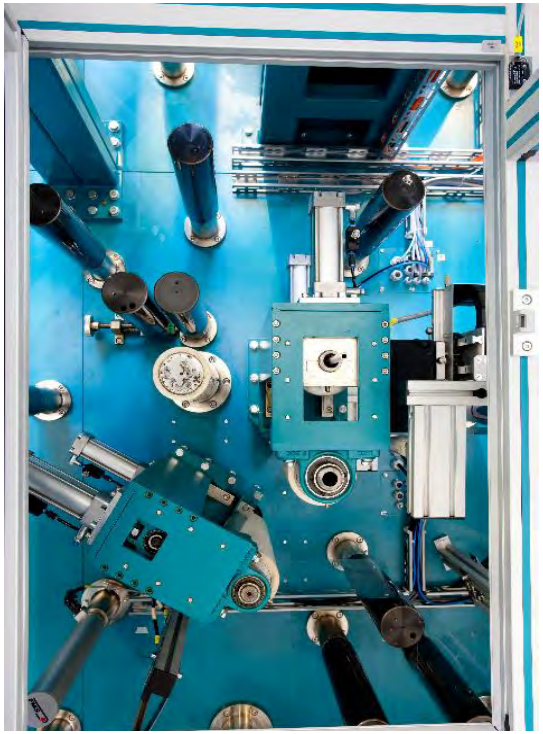
Coating parameters

Coating chemistry	Coating processes	Process control	Drying
✓ Rheology	✓ Coating systems	✓ Process layout	✓ Convection drying
✓ Viscosity	✓ Single or multilayer coatings	✓ Tension control system	✓ Contact drying
✓ Viscoelasticity	✓ Direct coatings	✓ Material guiding system	✓ Infrared drying
✓ Type of solvents	✓ Transfer (indirect) coatings	✓ Inline parameter control	✓ Sintering
✓ Amount of solids	✓ Substrate speed	✓ Quality control	✓ NIR
✓ Van der Waals force	✓ Layer thickness		✓ High frequency
✓ Sheer ratio	✓ Coating accuracy		✓ UV crosslinking systems
✓ Adhesion/Cohesion			

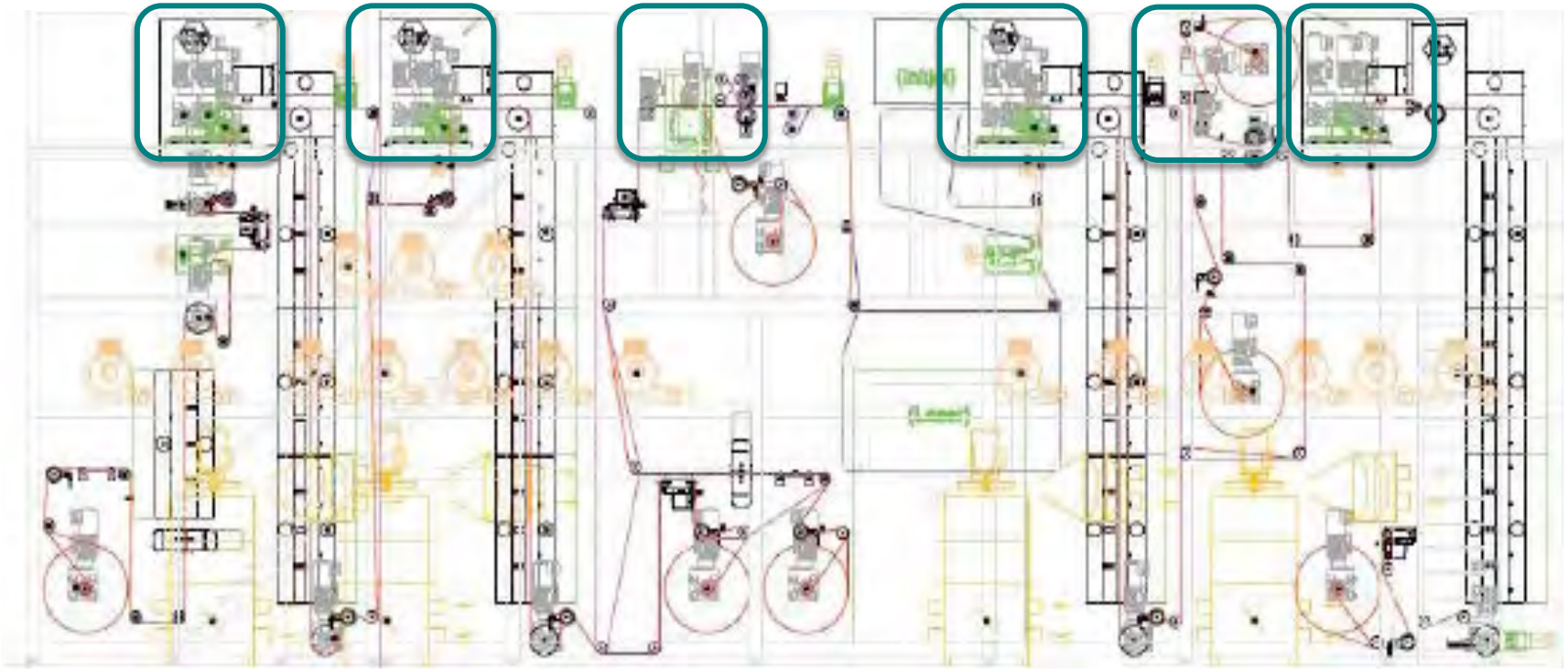
Substrate	Pretreatment	Environment	Finishing
✓ Surface tension	✓ Corona	✓ Humidity	✓ Calendaring
✓ Dimension stability	✓ Plasma	✓ Temperature	✓ Embossing
✓ Surface structure	✓ Cleaning	✓ Inert conditions	✓ Slitting
✓ Contact angle			

Processes

Upscaling from lab 2 fab – going to fab-technologies



From lab 2 fab



Process parameters

Process parameters are:

- ✓ Operation speed
- ✓ Rheology of coating and printing inks
- ✓ Substrate condition
- ✓ Tension control MD / CD
- ✓ Edge control
- ✓ Resolution and registration accuracy of printing / laminating systems
- ✓ Precision of coating operations
- ✓ Curing / drying / crosslinking

Inline process integration

Tension control

- ✓ Load cell
- ✓ Dancer
- ✓ Pulling devices
- ✓ Design of drives

Edge guide control

- ✓ Different sensors
- ✓ Mechanical stress

Quality control

- ✓ Particle contamination analysis
- ✓ Defect detection
- ✓ Thickness control
- ✓ Function control of the device or layer

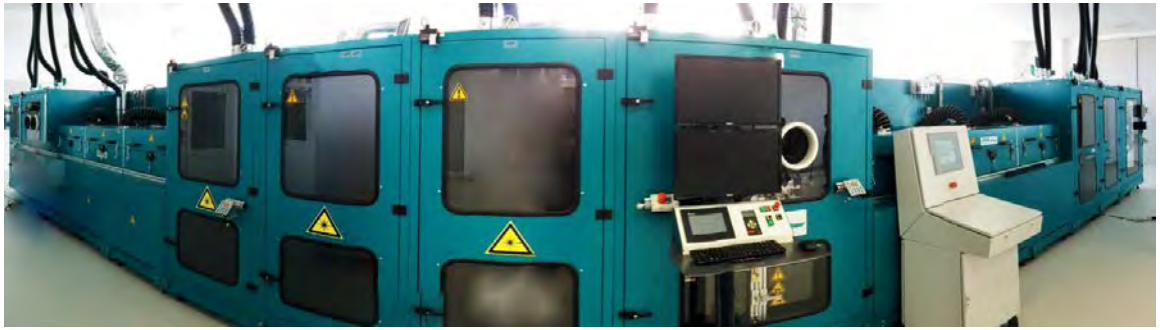
Registration control

- ✓ Camera
- ✓ Fiber optic
- ✓ Design of drives

Process analysis

- ✓ Statistic parameters
- ✓ Product flow analysis
- ✓ Yield
- ✓ Cost of ownership

Inline process integration



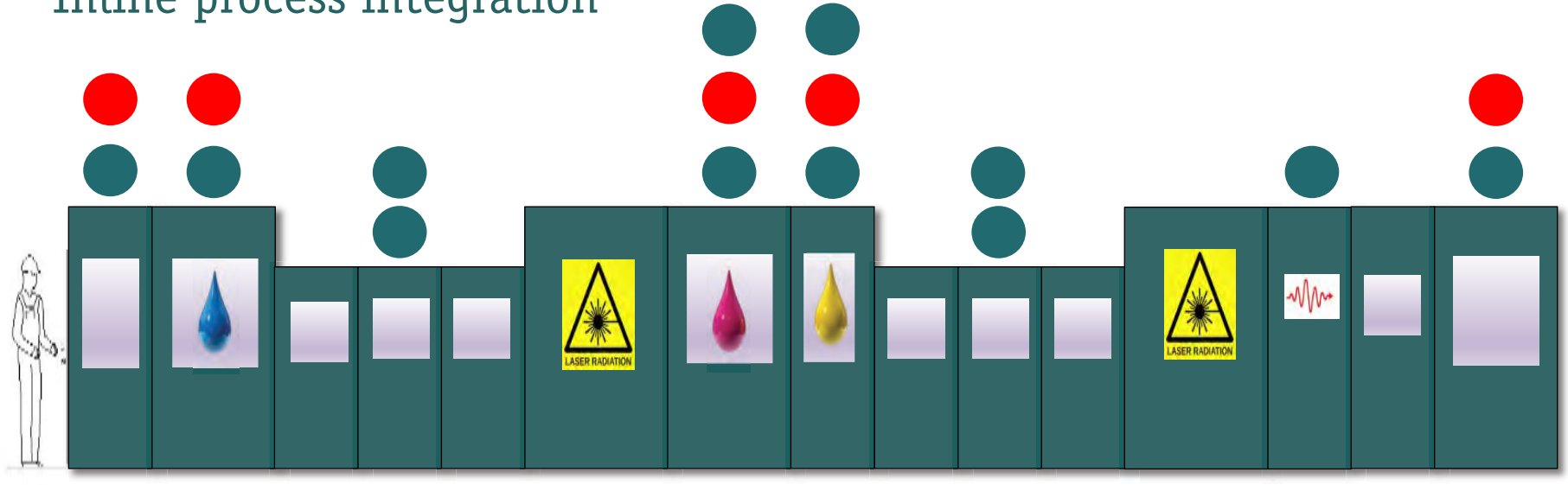
smartonics

Development of smart machines, tools and processes for the precision synthesis of nanomaterials with tailored properties for Organic Electronics

This project is funded by the European Union

The project SMARTONICS receives funding form the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no 310229.

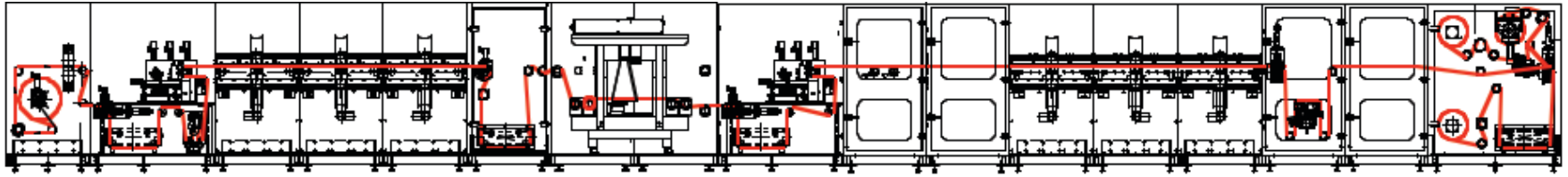
Inline process integration



Unwinder | Slot die coating | 3m dryers | ps laser | Rotary screen printing | Ink jet | 3m dryers | ns laser | In-line optical metrology (SE, Raman) | Cooling | Rewinder

Measuring Controlling

Inline process integration



Winding / cleaning

Unwinding cabinet

- ✓ Can receive rolls with core of 3 inch
- ✓ Max diameter of 500 mm
- ✓ Max weight 50 kg
- ✓ Web width of 300 mm
- ✓ Automated forward and reverse movement of the web
- ✓ Speed of 1 – 20 m/min.
- ✓ Tension control of the web within the range of 5 – 250 N

Web cleaning system

- ✓ Contact cleaning rollers for particles of >1µm diameter

Inline process integration

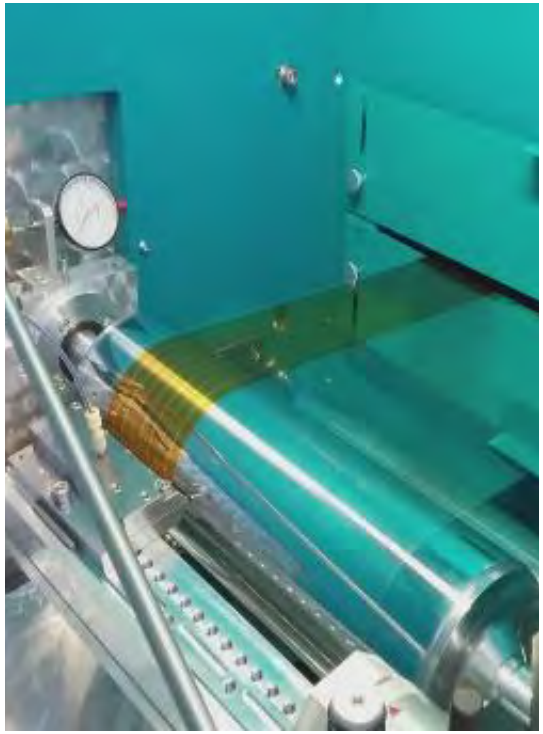
1st Printing

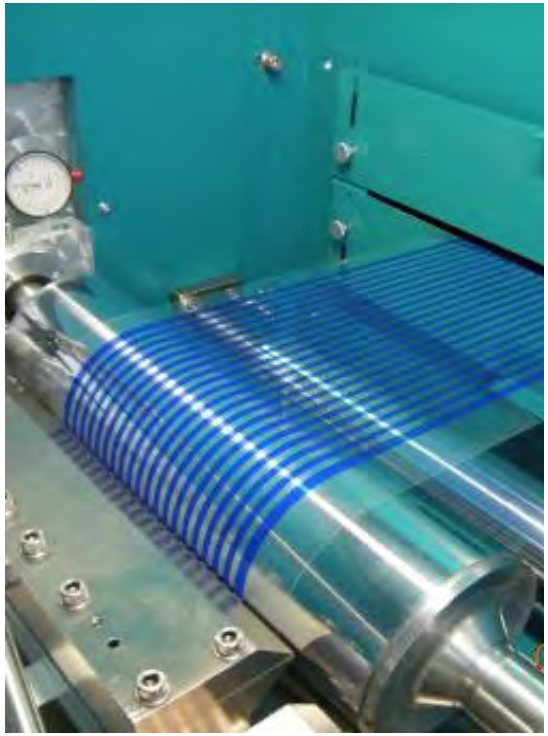
- ✓ Web surface activation with Plasma Treatment

Dryer 1

- ✓ 3 meter dryers
- ✓ Hot air and heated nitrogen
- ✓ Temperatures up to 230°C

Slot die coating

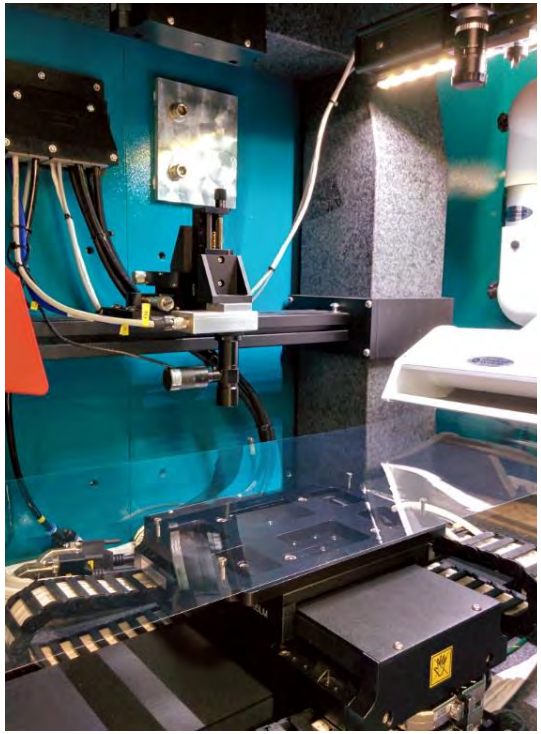


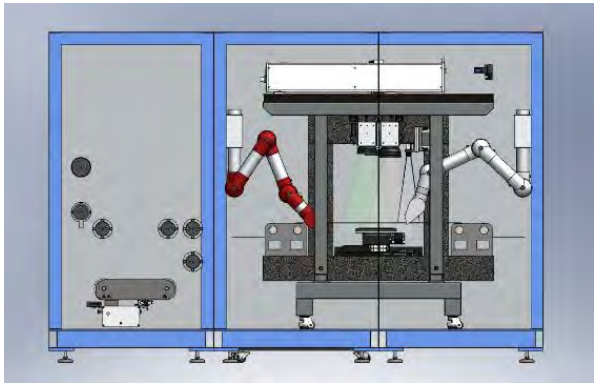


Slot die coating station compatible for materials used in OEs

- ✓ Print solutions with viscosity range of 10 – 1000 mPas
- ✓ The above range can lead to layer thickness range of 10 – 1000 nm
- ✓ Lateral accuracy of ±1%

Laser patterning

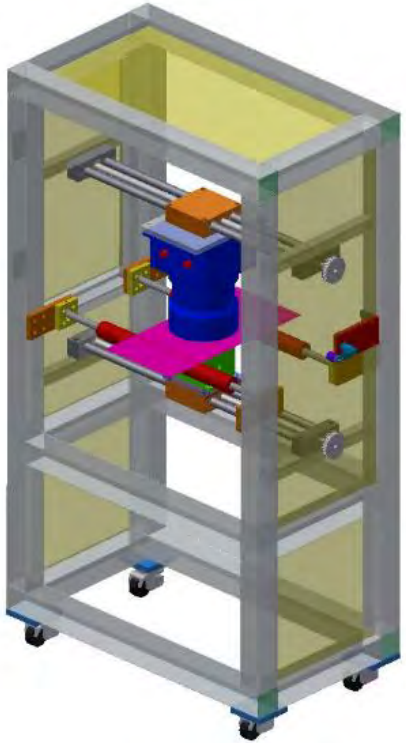




Laser scribing/patterning

- ✓ Picosecond laser for patterning OE materials
- ✓ 3 meters cabinets
- ✓ Tension and driving web control
- ✓ System ±100 µm of accuracy

Module for the registration camera



Technical specifications:

- ✓ Measurement accuracy = +/-20 µm
- ✓ ATEX proof
- ✓ 300 mm roller width
- ✓ Web speed: 1 – 20 m/min; optimum speed is 3 – 20 m/min.
- ✓ PLC-driven correction adjustment system
- ✓ Module to be operated under N_2

Rotary screen printing

2nd printing station

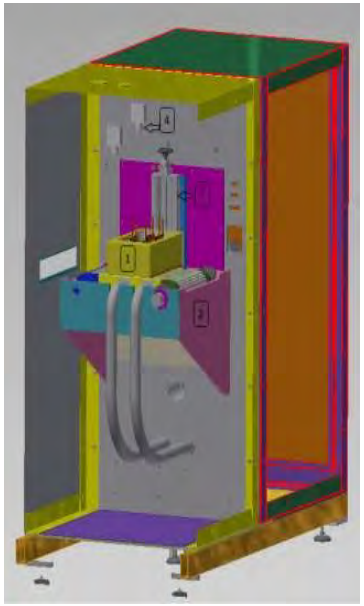
- ✓ Rotary screen printing
- ✓ Coating width of 300mm
- ✓ Lateral accuracy ±5%

Dryer 2

- ✓ 3 meters dryers
- ✓ Hot air and heated nitrogen
- ✓ Temperatures up to 230°C

Inline process integration

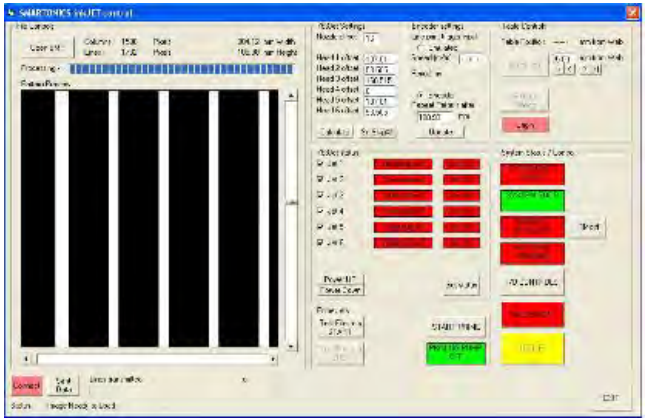
Inkjet station



Inkjet station

System

Coatema software



Already integrated:
Fujifilm Dimatix

Encapsulation

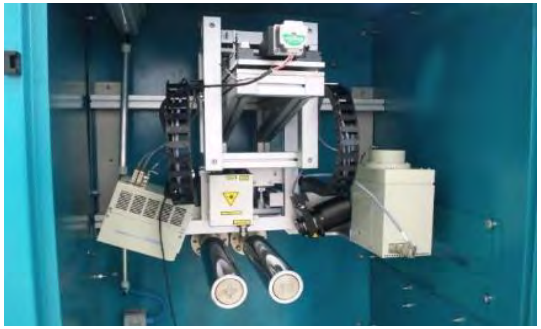
Rewinding station

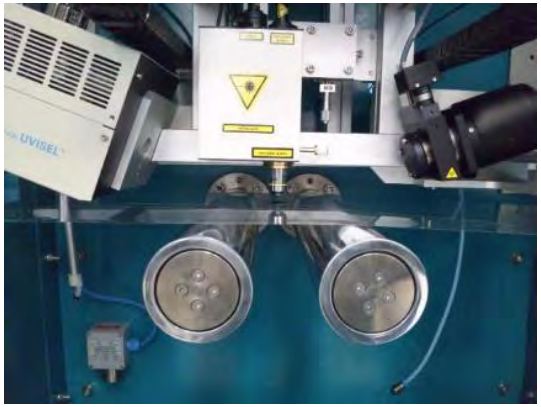
- ✓ The rewinding station has a retaining roller
- ✓ Identical specs to the unwinding station
  - ✓ 3 inch core rolls
  - ✓ Automated forward and reverse movement of the web
  - ✓ Speed of 1 – 20 m/min.
  - ✓ Tension control and edge guide system

Lamination / delamination station

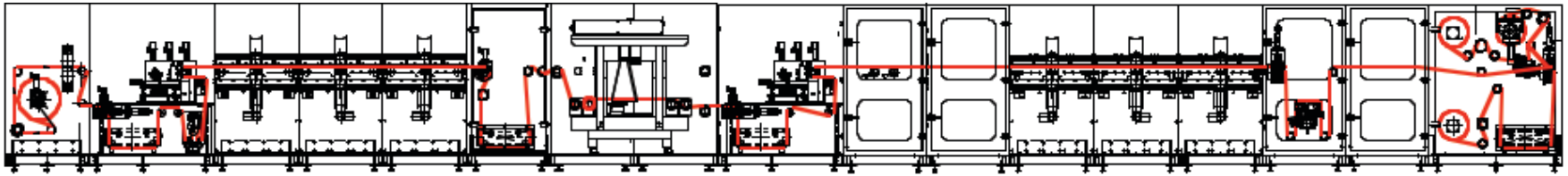
- ✓ Compatible with 300 mm web width
- ✓ Web control with edge guide system
- ✓ Lateral accuracy of ±100 µm / 20 µm

Inline quality control – Ellipsiometry and inline Raman by Horiba





Summary

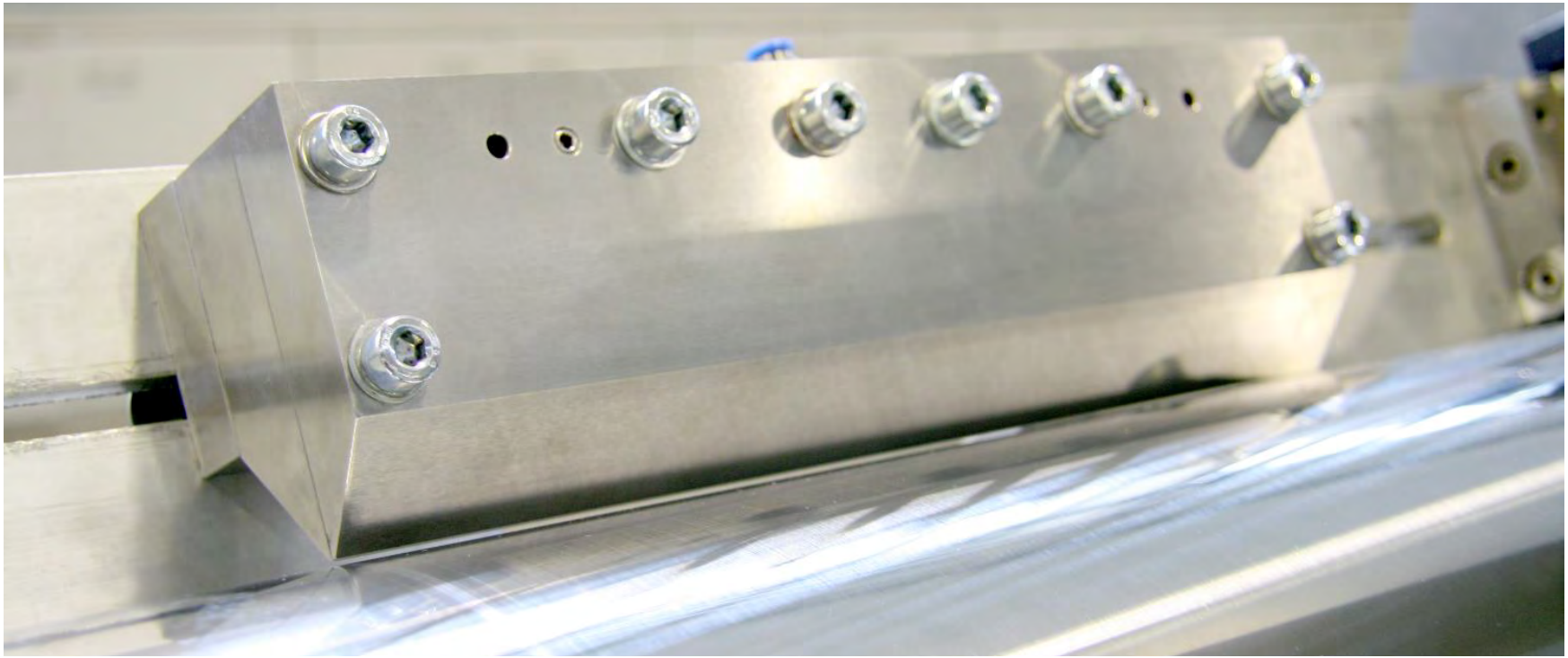


- ✓ 19 m in length
- ✓ 300 mm working width
- ✓ 30 m/min. per minutes production speed
- ✓ 3 print stations
- ✓ Plasma treatment
- ✓ 6.000 mm nitrogen dryers in 500 mm sections
- ✓ Registration control
- ✓ Laminating station

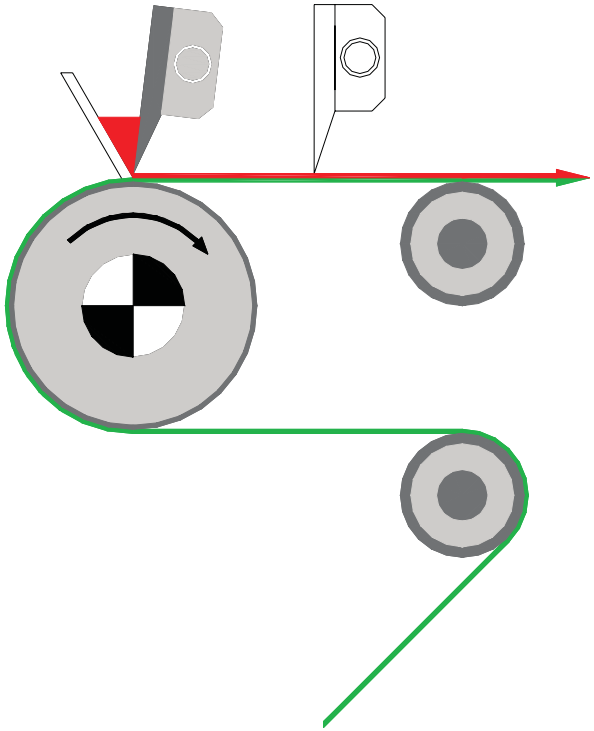
New design principle

New design principle

Slot die system



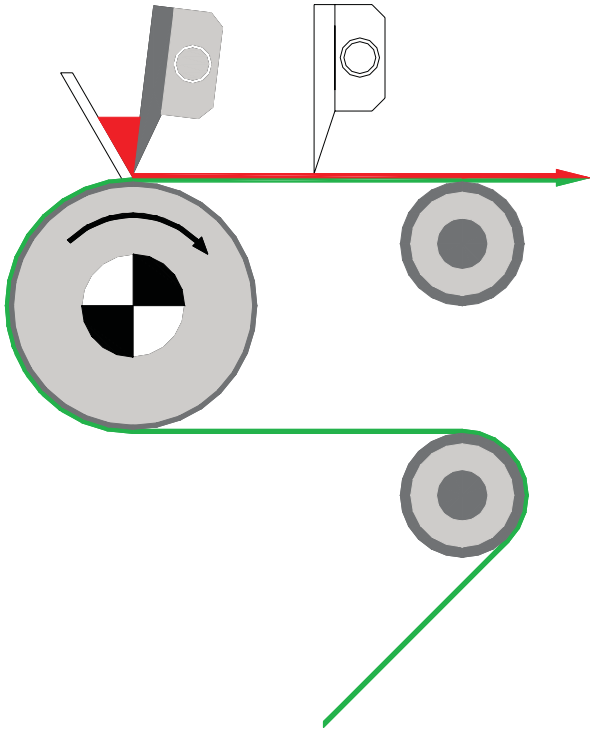
Basics of slot die coating – characteristics of slot dies



- ✓ Homogeneous, thin layers
- ✓ Dosing (metering) system
- ✓ Touchfree
  (except in impregnation mode)
- ✓ Closed system (no evaporation of solvents)
- ✓ Full area non stop coating or intermittent

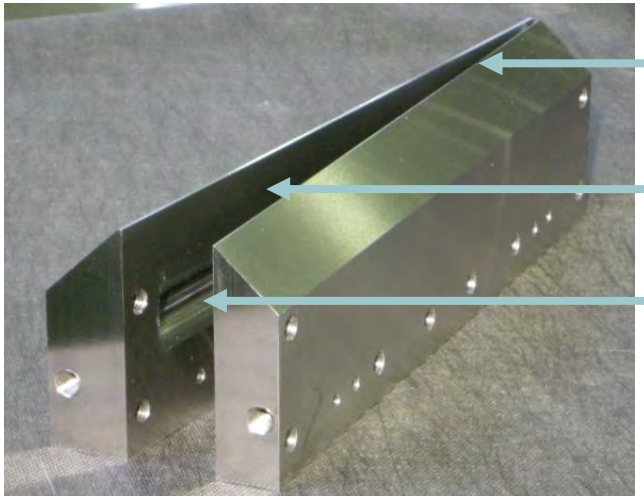
The slot die is the only system, that combines all these features.

Basics of slot die coating – range of parameters



- ✓ Printing speed
  0.1 – >1000 m/min
- ✓ Ink viscosity
  1 – 30 000 mPas
- ✓ Layer thickness
  0,1 – >200 µm
- ✓ Coating accuracy
  <1% (2 – 5%)
- ✓ Coating width
  up to approx. 3 m

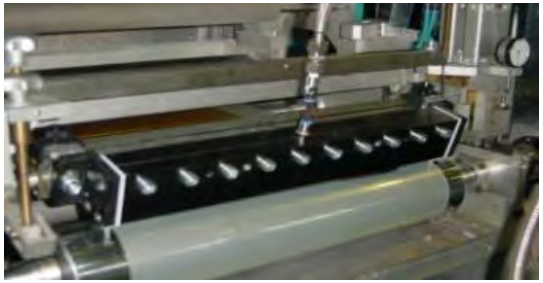
Basics of slot die coating – Coatema standard layout



Basics of slot die coating – slot die examples

100 mm, 11 o‘clock

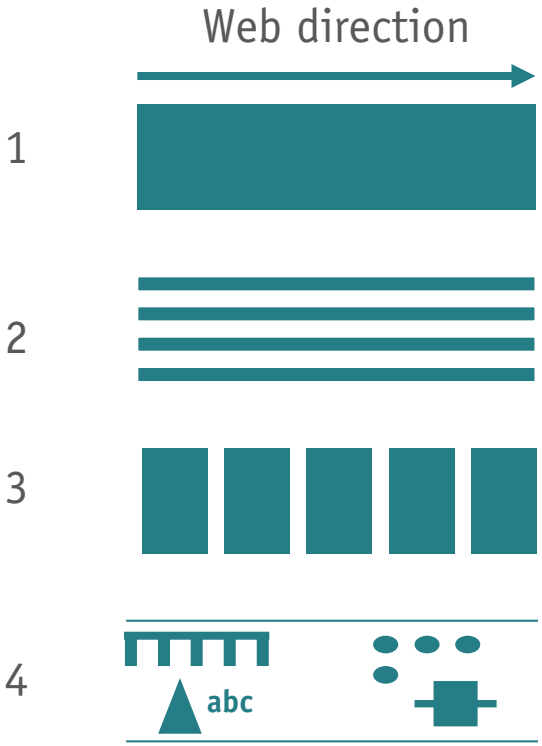
300 mm, 9 o‘clock



500 mm, slightly tilted

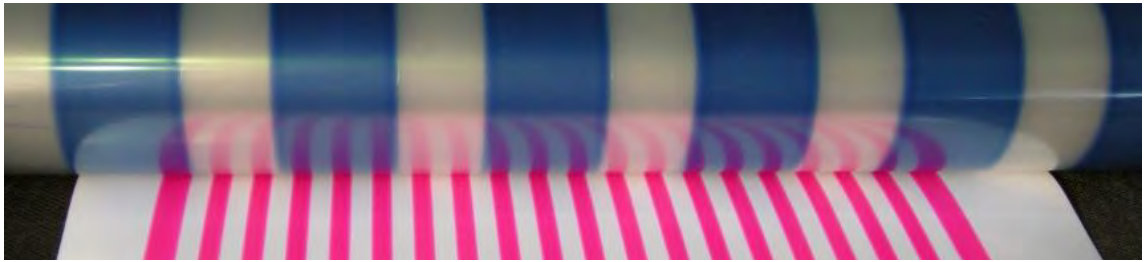
300 mm, double sided

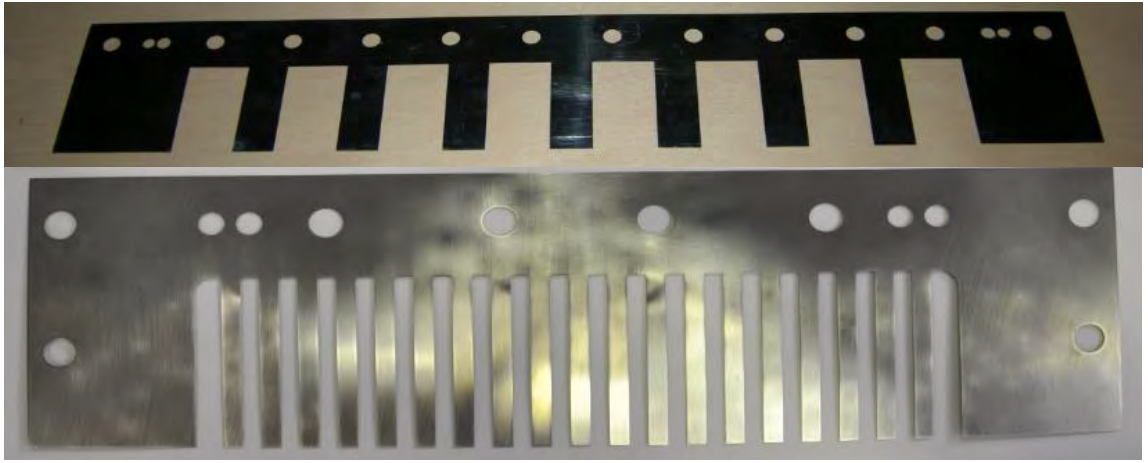
Structured coating – levels of complexity



	Current status
Full area, homogeneous	Requirements are met, thickness profile variation of 0.5 %
Stripes downweb	Requirements are met, good edge definition
Stripes crossweb (intermittent coating)	Requirements are partially met, edge definition of 0.5 – 1 mm depending on liquid
Arbitrary patterns	Requirements are not met, concepts for realization exist, research project is going on

Structured coating – downweb stripes

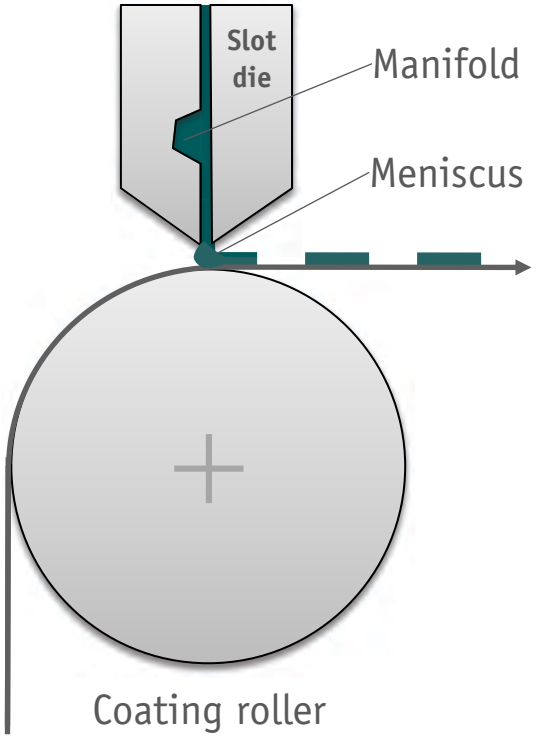




Downweb stripes of different width …

… are made by appropriate shims, lasercut from steel or kapton

Structured coating – crossweb stripes (intermittent)



Intermittent coating requires sudden start / stop of the fluid flow.

Different methods are available.

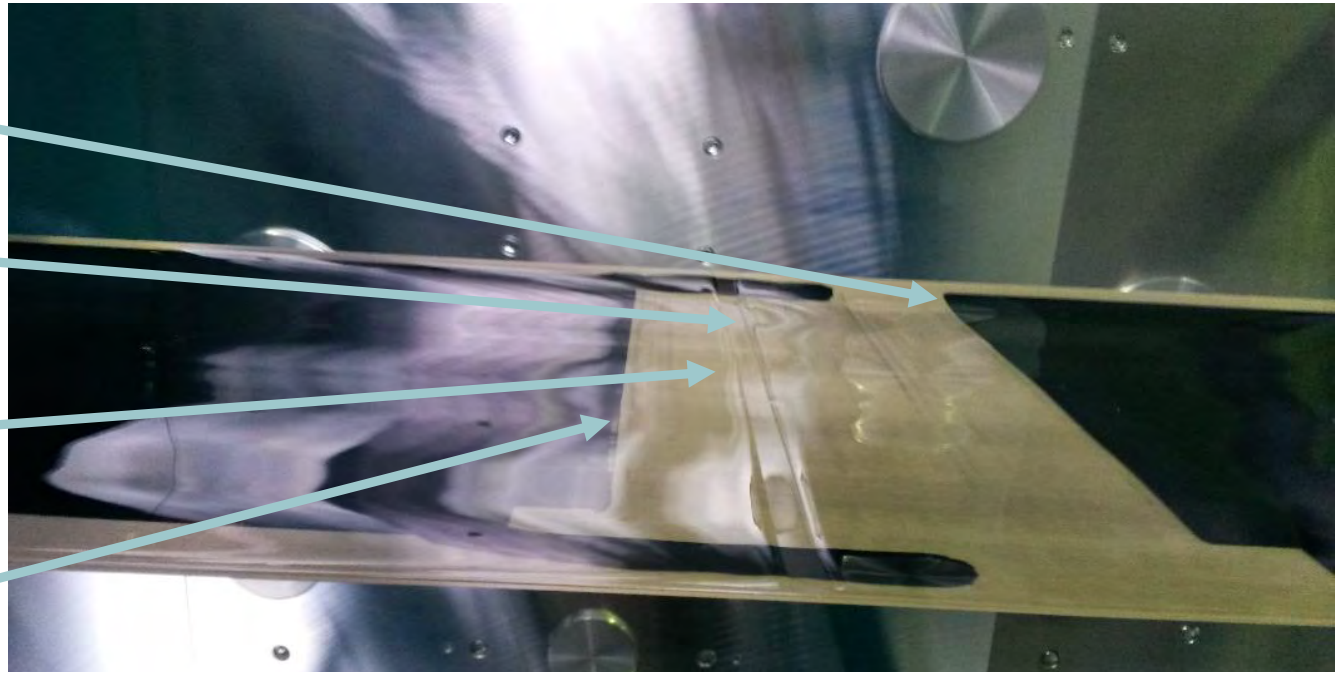
Structured coating – well defined edges at high viscosity

Leading edge battery paste

Leading edge silicone

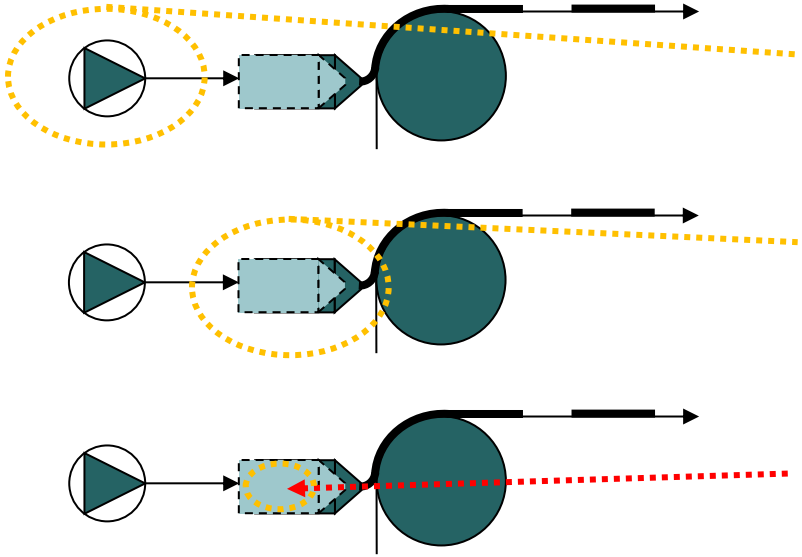
Trailing edge silicone

Trailing edge battery paste



Two different stripe patterns, one on top of the other

Standard techniques for intermittent coating



Pump:
stop – reverse – restart

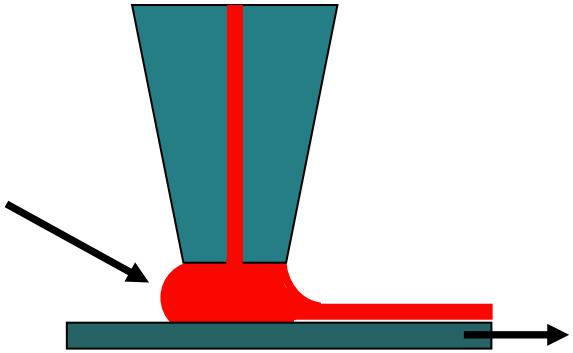
Slot die body:
move back – move forth to minimum gap – move back to working gap (wedge procedure)

Slot die internal:
stop and redirect the flow by shutters and valves. Pump flow continues, die flow stops.

All 3 techniques (single or in combination) work quite well, if the viscosity is rather high and the required edge defintion is not more precise than around 1 mm. All techniques may be combined with a vacuum pump upstream to stabilize the meniscus and suck away residual liquid.

Structured coating – reason for bad edges at low viscosity

The mensicus volume between the slot die and the substrate has to be interrupted. Low viscous liquids do not break along a straight line. So the meniscus has to be sucked back and restored as fast as possible to achieve a clear defined edge.



If the viscosity is too low, all of the three before mentioned methods are too slow and too indirect to do this.

Structured coating – new concepts for low viscosity liquids

Two new concepts allow to interrupt and restore the meniscus much faster:

- ✓ Double chamber slot die
  with modified chamber geometry and Piezo driven suck back pump

- ✓ Switching lip slot die
  with a Piezo driven lip opening mechanism
  that sucks back the meniscus right where it is

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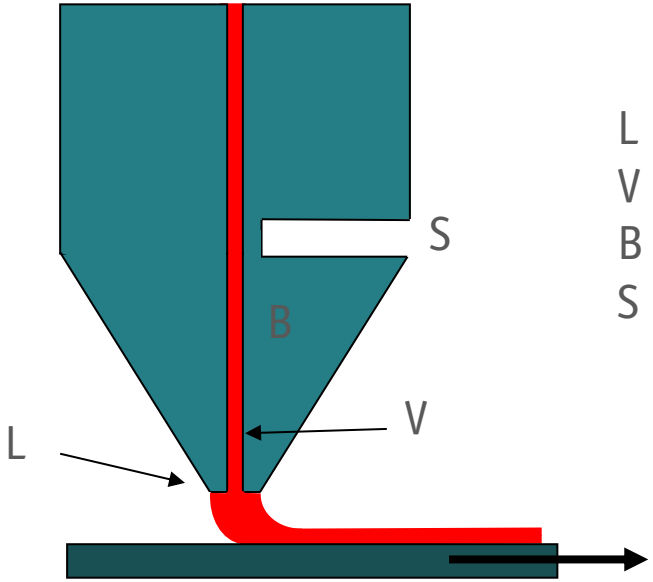
Structured coating – the switching slot die lip

Slot die with movable lips:
coating mode

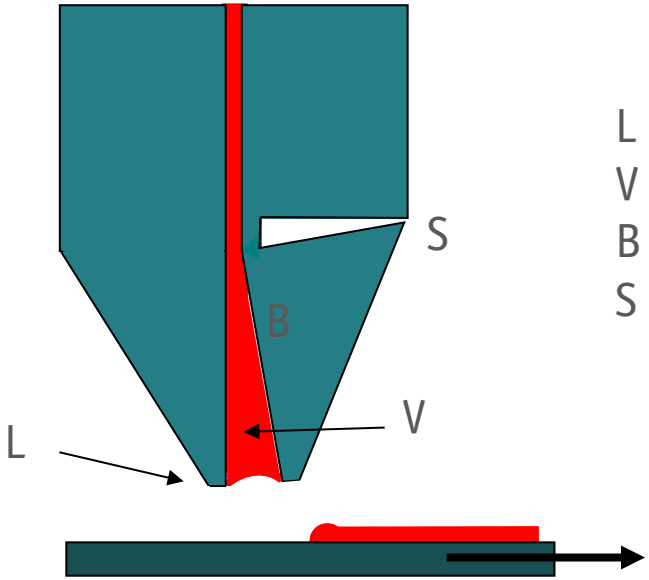


L lip
V slot volume
B bendable lip
S bending slot

coating works as usual

Structured coating – the switching slot die lip

Slot die with movable lips:
stop mode



L lip
V slot volume
B bendable lip
S bending slot

Bendable lip B flips open
Volume V increases and
sucks away the meniscus

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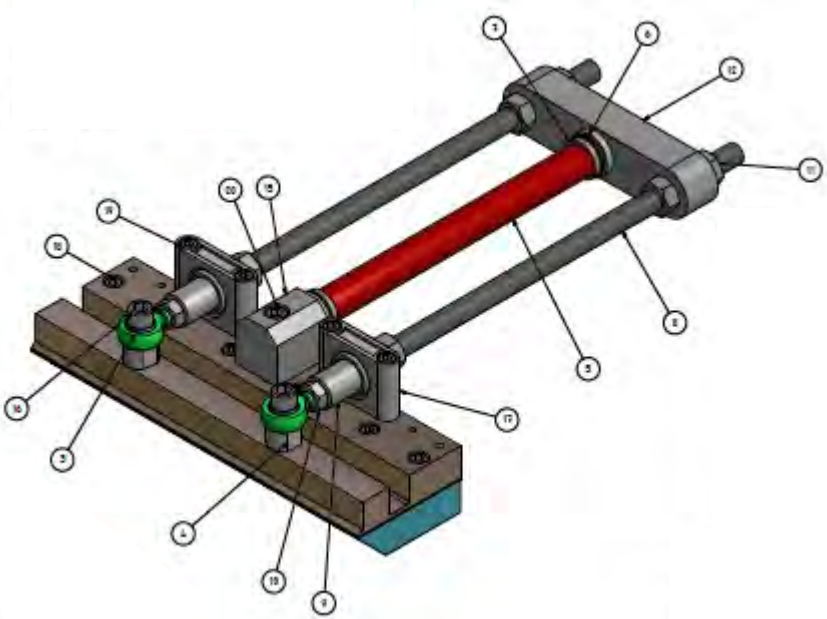
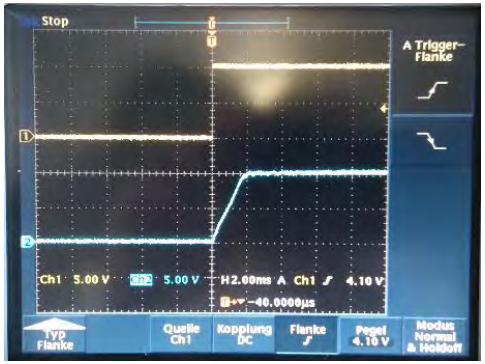
Structured coating – technical implementation with Piezo-Drive

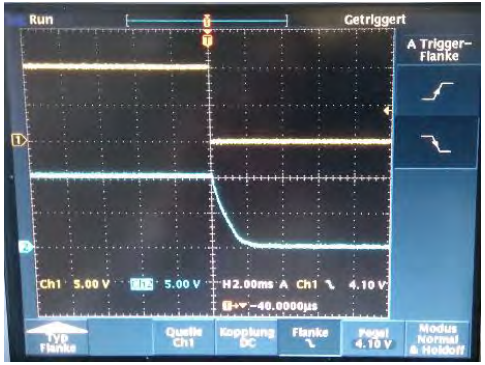


Extremely fast action:
within few ms from coating to stop mode and vice versa

Control Voltage

Piezo Response





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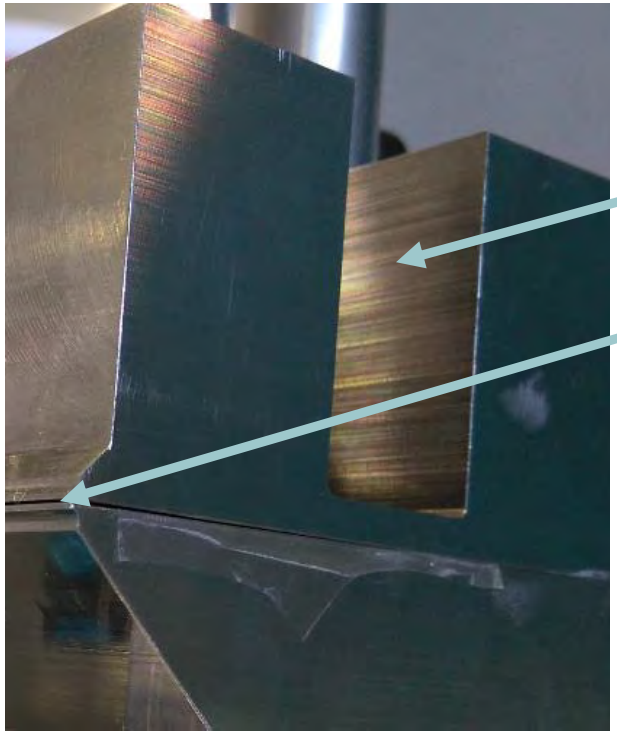
Structured coating – technical implementation with bendable lips

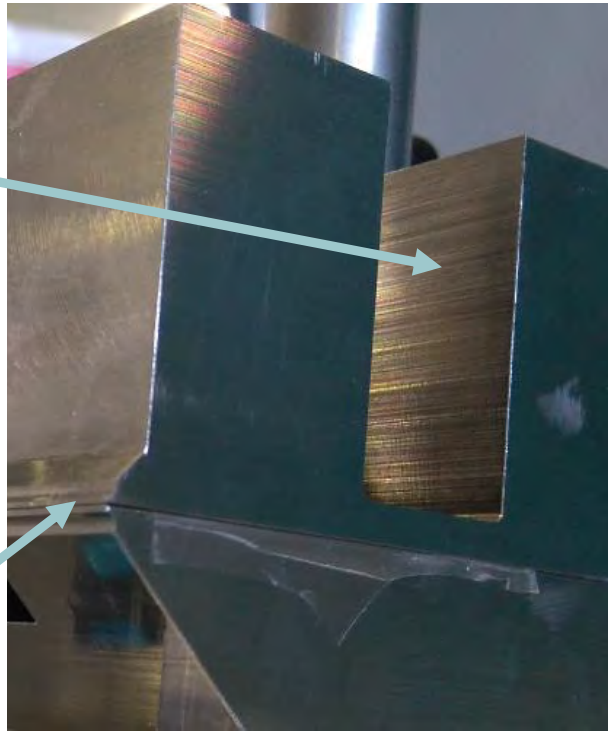


Bending slot

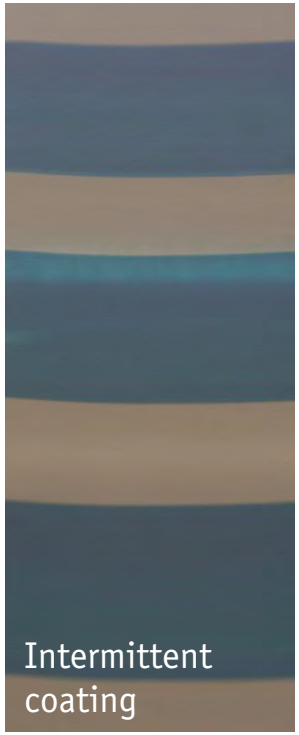
Lips open

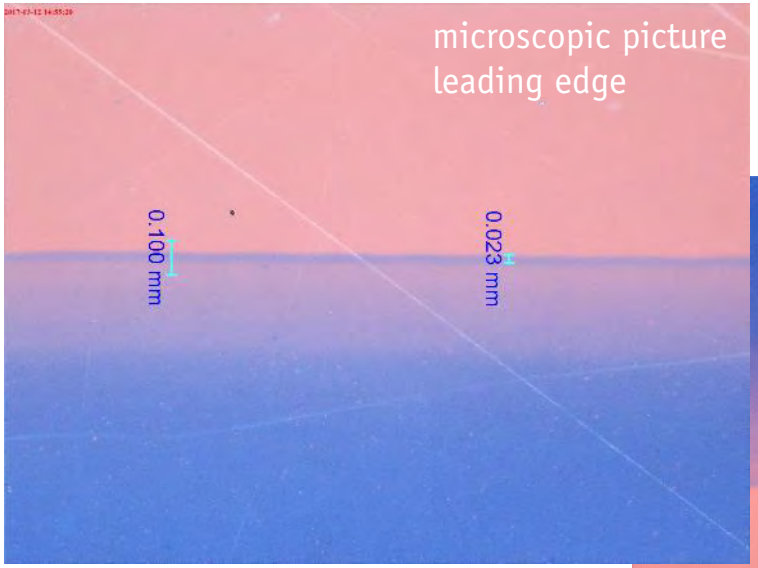
Difference is 300 µm only

Lips closed

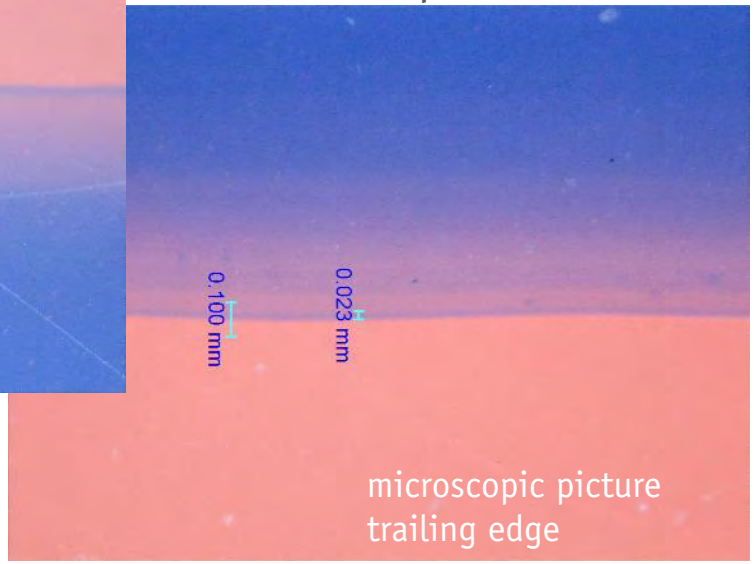


Structured coating – switching slot die: first results

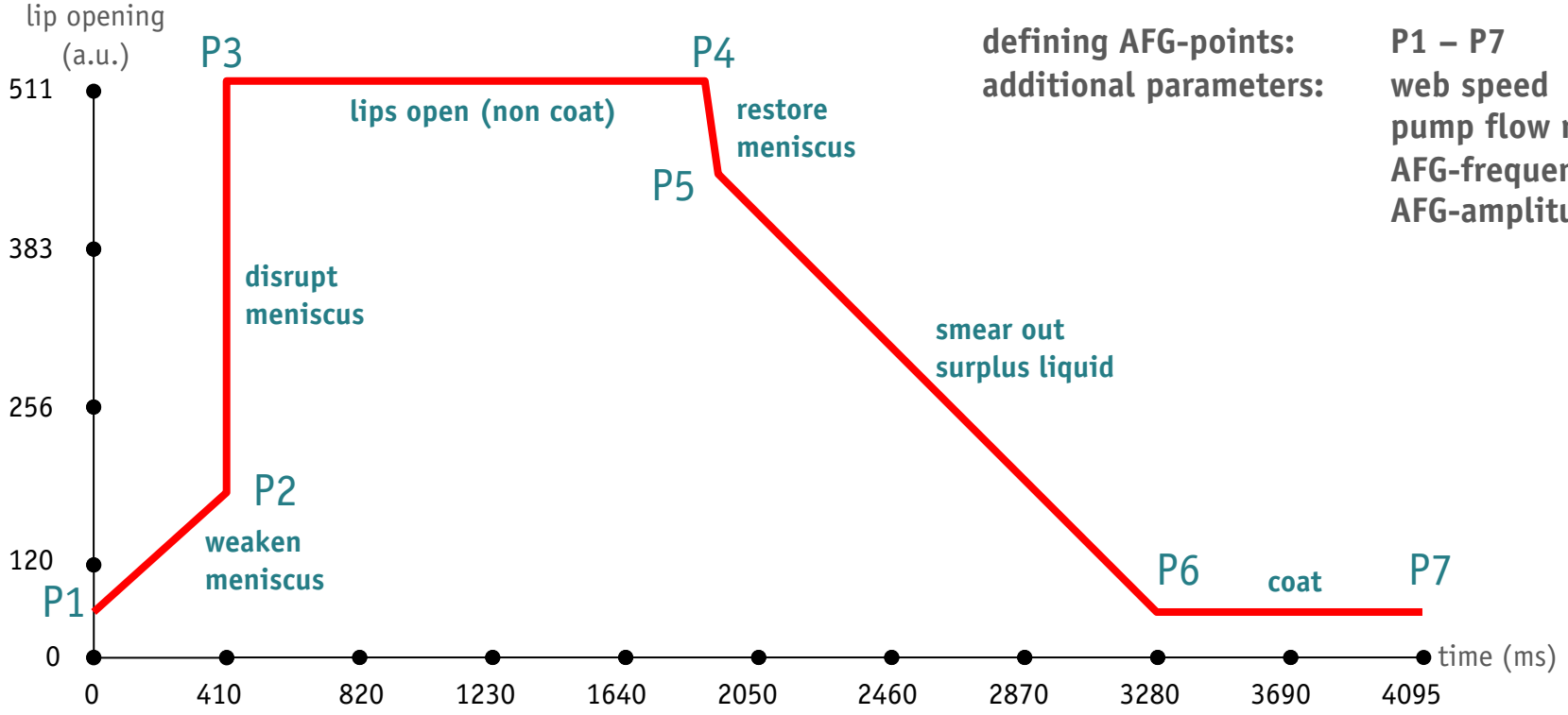




Straight edges well
defined
within 20 µm



Structured coating – stages of lip motion



defining AFG-points: P1 – P7

additional parameters:
- web speed
- pump flow rate
- AFG-frequency
- AFG-amplitude

Structured coating – ongoing trials: stripe coating of fuel cell paste

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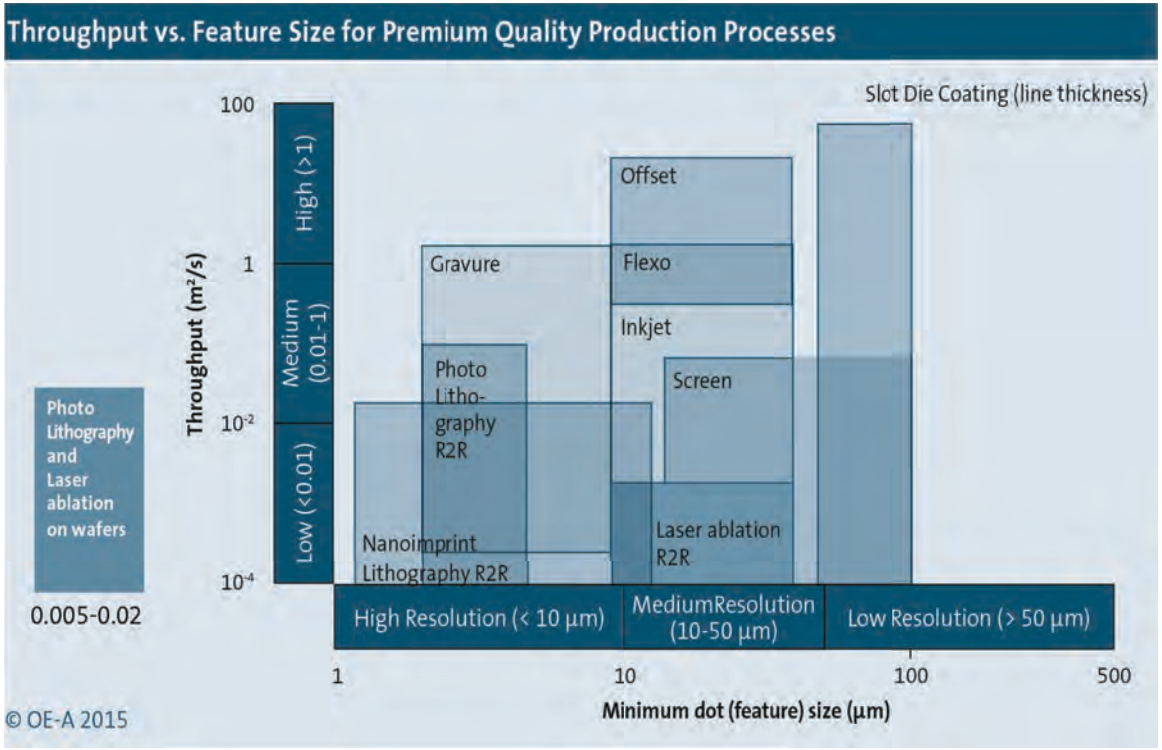
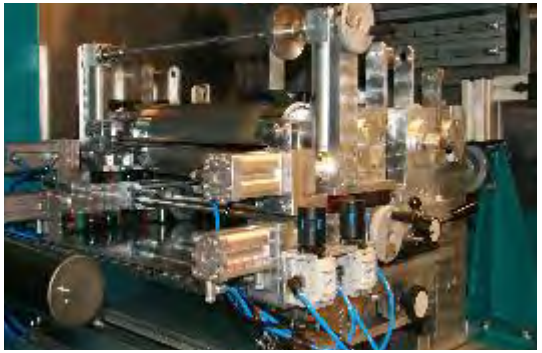
Printing parameters



Printing parameters

Printing method	Printing speed (m/s)	Nip pressure (MPa)	Ink viscosity (Pas)	Layer thickness (µm)	Feature size (µm)	Registration (µm)
Flexography	3 – 10	0.1 – 0,5	0.01 – 0.5	0.04 – 8	40 – 80	20 – 200
Gravure	10 – 16	1.5 – 5	0.01 – 0.2	0.1 – 12	20 – 75	>10
Offset	8 – 15	0.8 – 2	1 – 100	0.5 – 3	25 – 50	>10
Screen printing	2	–	0.1 – 50	3 – 100	75 – 100	>25
Inkjet	1 – 5	–	0.001 – 0.03	0.01 – 0.5 20 (UV)	10 – 50	<10

Printing systems

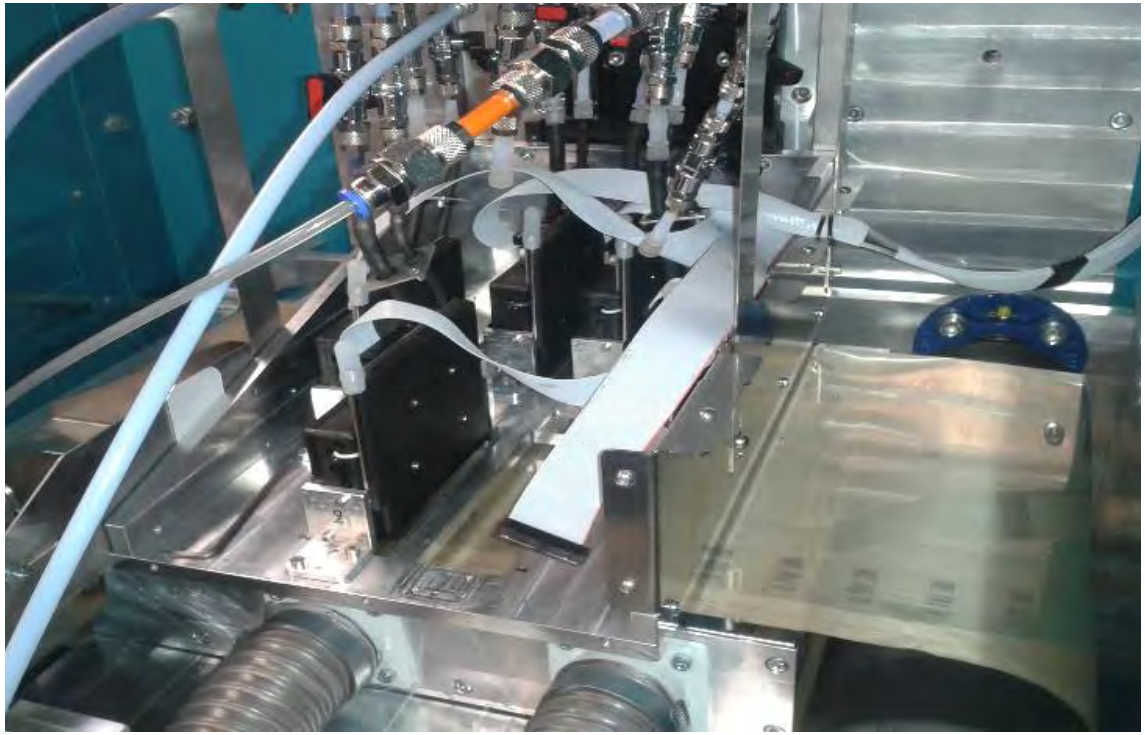


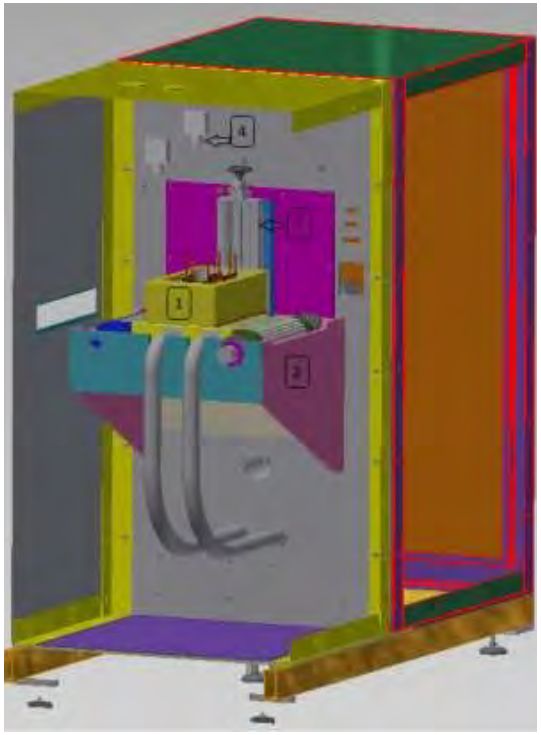
Gravure printing

Flexo printing

Screen printing

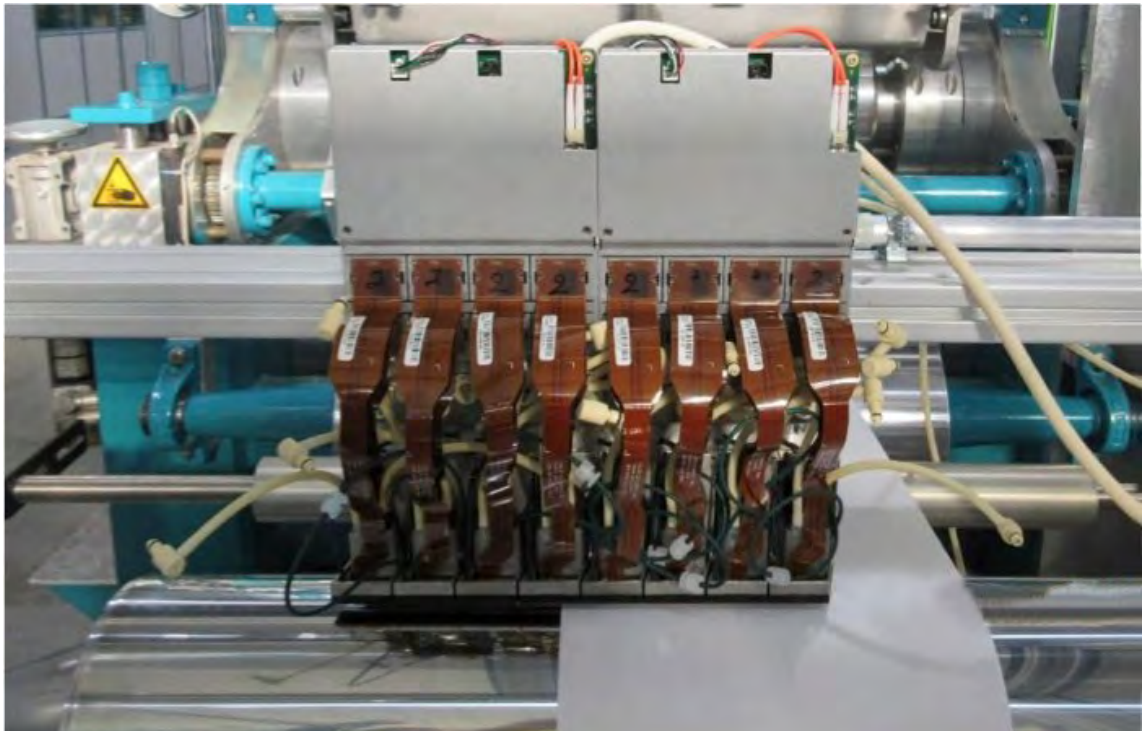
Inkjet printing





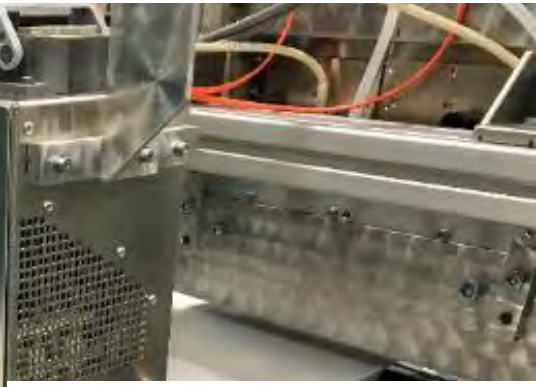
Inkjet printing

Integration of the „inking“ system – current status



- ✓ Printing head and mounting (Fujifilm Dimatix Samba)
- ✓ Fluid recirculation system
- ✓ Power supply
- ✓ Computer

Integration of analysis and sintering units – current status

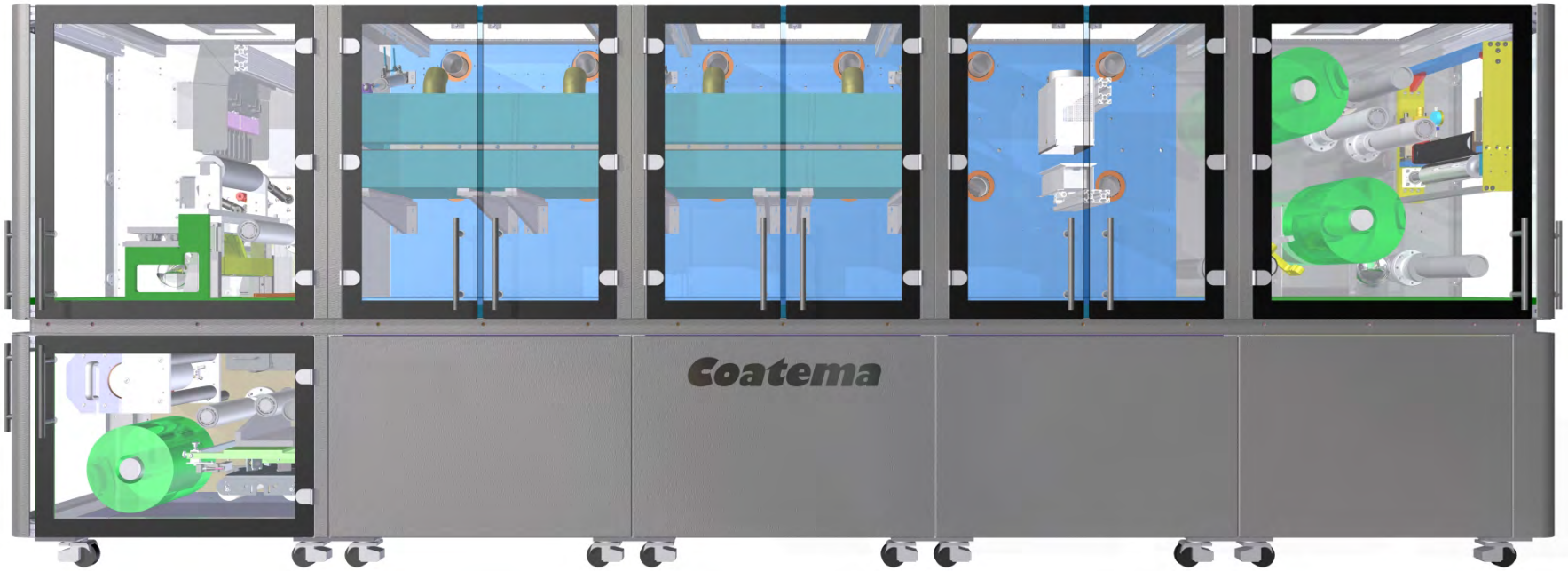


- ✓ Dantex dynamics „dropwatching"
- ✓ Velocity
- ✓ Size
- ✓ Sphericity
- ✓ Drying / Sintering
- ✓ Adphos NIR
- ✓ IR lamp
- ✓ Photonic sintering
- ✓ Hot air dryer

Integration – current status

- ✓ Combination of print heads with high precision granit stone
- ✓ Several sintering methods possible
  - ✓ Hot air dryer to remove solvents (LEL)
  - ✓ NIR / IR / Photonic sintering for conductivity
- ✓ Droplet analysis
- ✓ Possibility to combine inkjet with NIL

Integration – machine layout

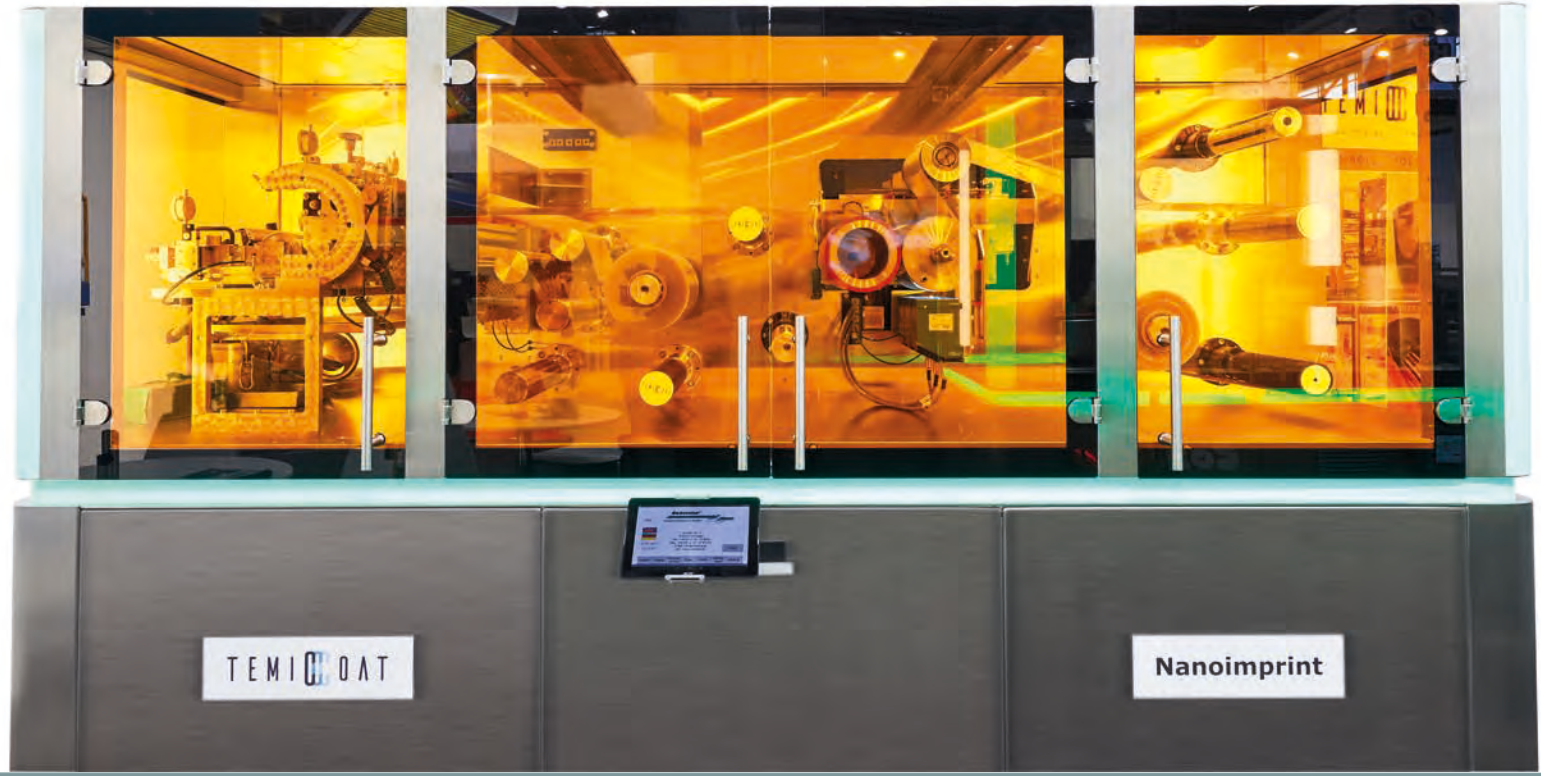


Integration – machine layout

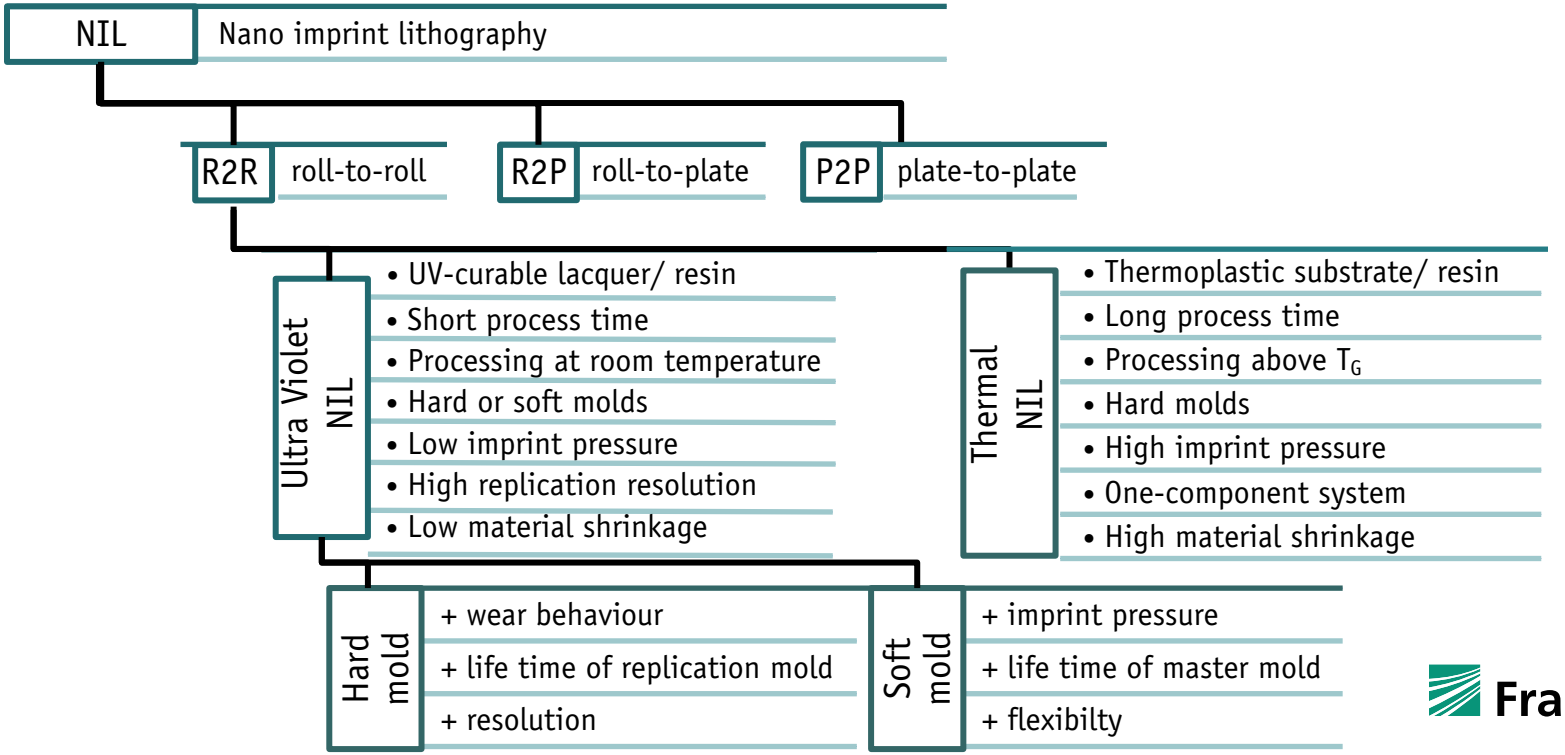
Summary

- ✓ Inkjet provides a step towards a more flexible and customizable production
- ✓ Inkjet is successfully integrated in a R2R process on 300 mm width
- ✓ Width is scalable
- ✓ Speeds up to 10 m/min were tested
- ✓ Different curing / drying systems were tested
- ✓ A layout for a inkjet dedicated machine is available

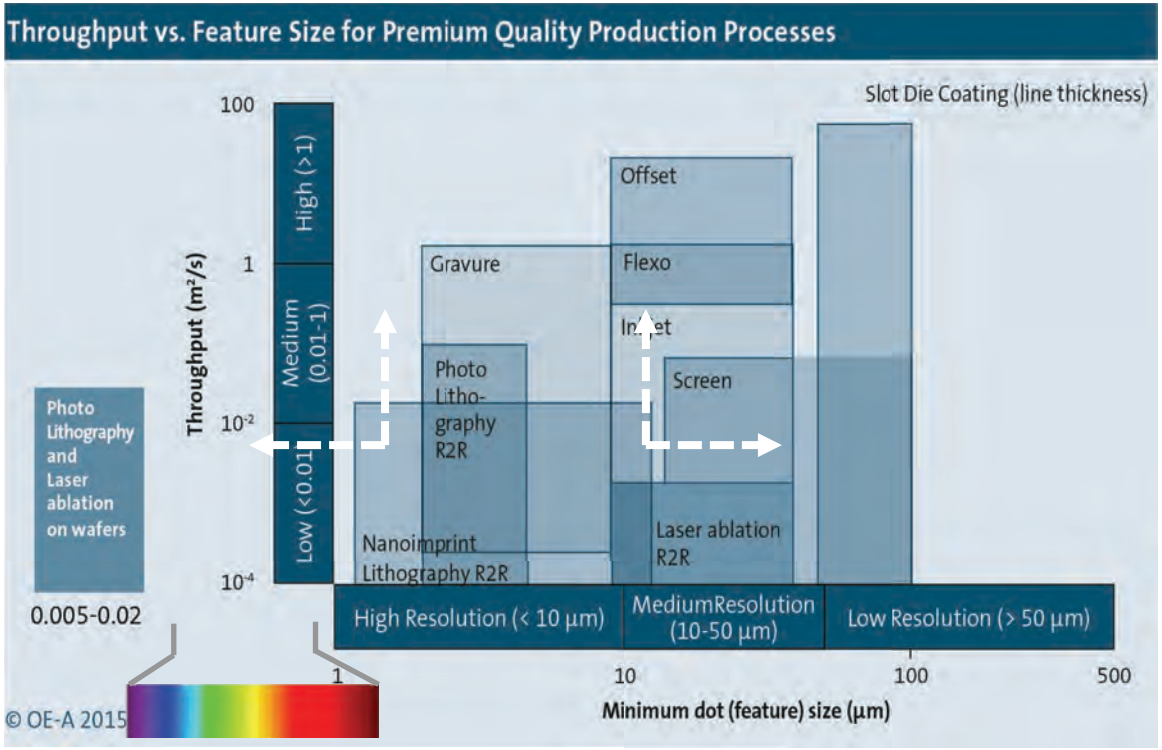
Nanoimprint technology



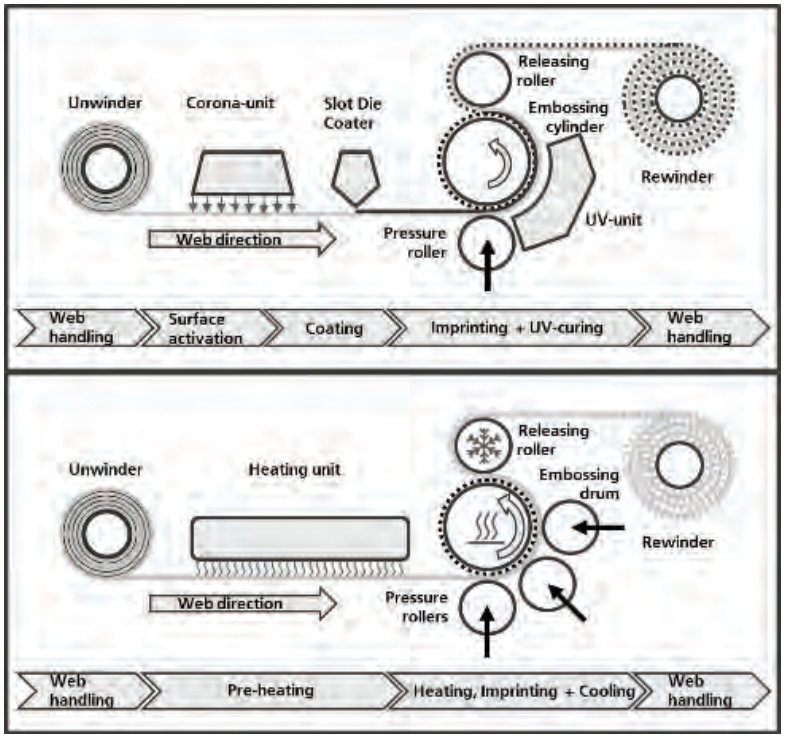
Nanoimprint technology



Introduction – comparison of printing processes



Nanoimprint lithography



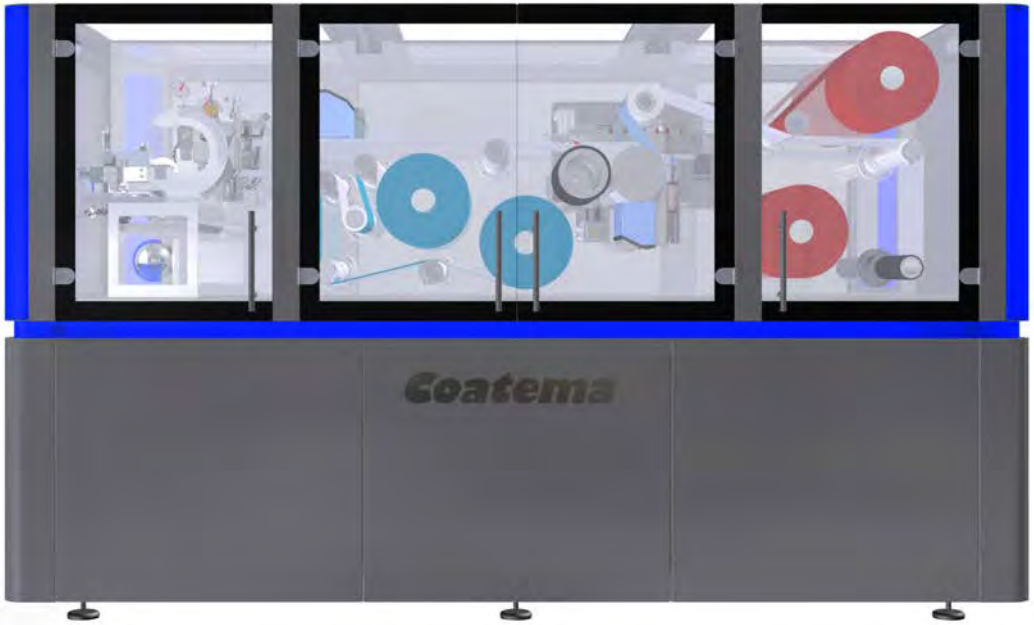
UV-NIL system designs:

- ✓ 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

Nanoimprint lithography

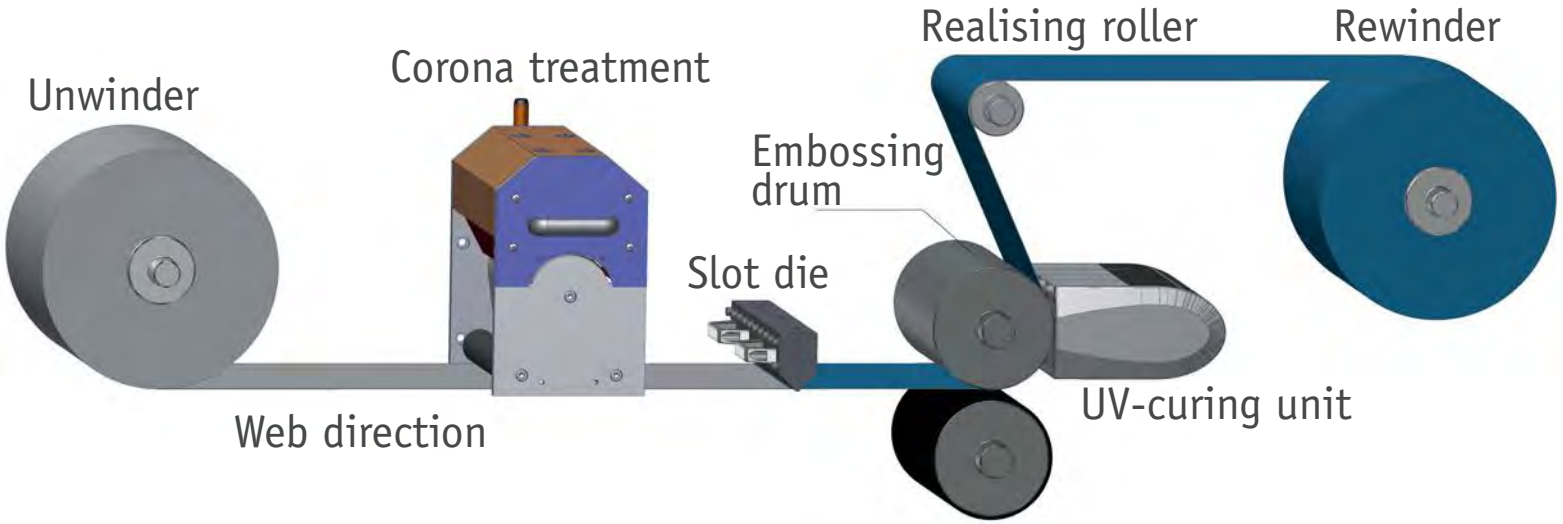


Fraunhofer IPT

Process parameters (selection):

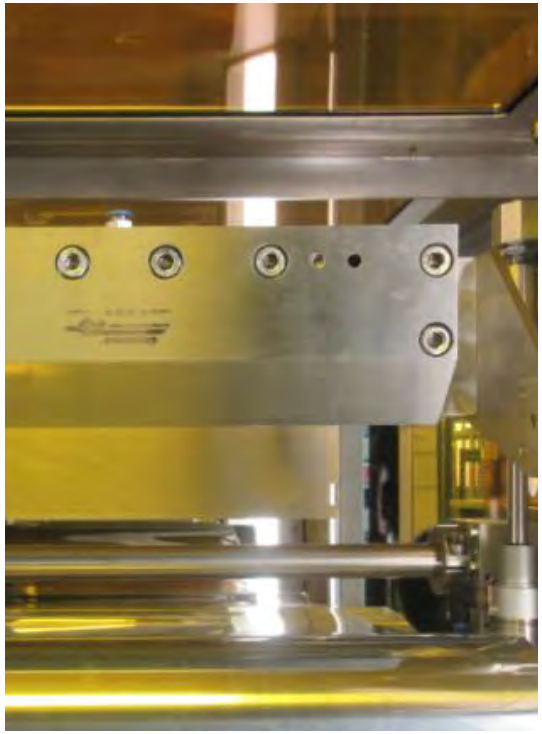
- ✓ Resist
  - ✓ Chem. formulation
  - ✓ Viscosity / Rheology
- ✓ Film
  - ✓ Chem. formulation
  - ✓ Chemical / mechanical pre-treatment
- ✓ Tool
  - ✓ Hard / soft mold
  - ✓ Anti-adhesion layer
- ✓ UV-source
  - ✓ Spectral distribution
  - ✓ LED- / conventional source
- ✓ Production system
  - ✓ Web (tension) control
  - ✓ Process specific sub-assemblies

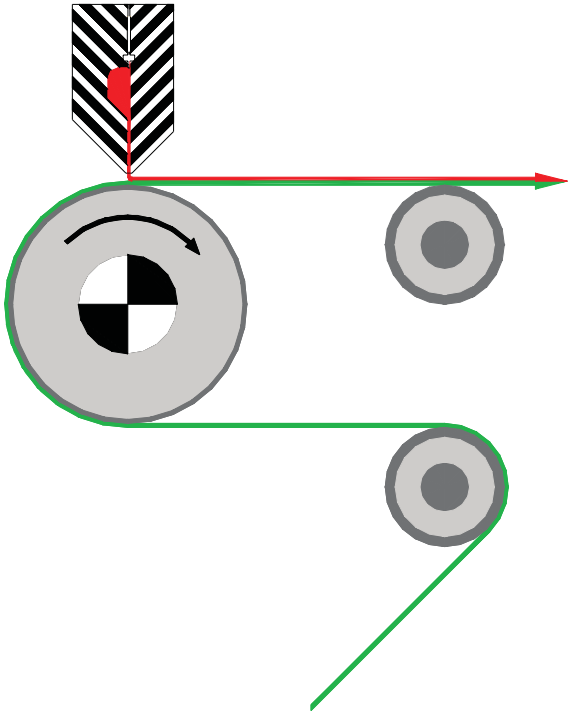
Nanoimprint lithography



web handling → surface activation → coating → imprint + UV-curing → web handling

Coating and printing for NIL – Nanoimprint lithography

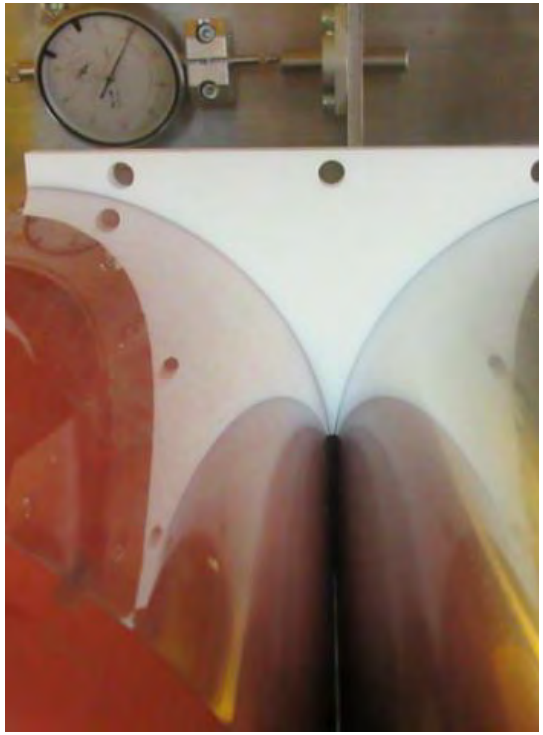


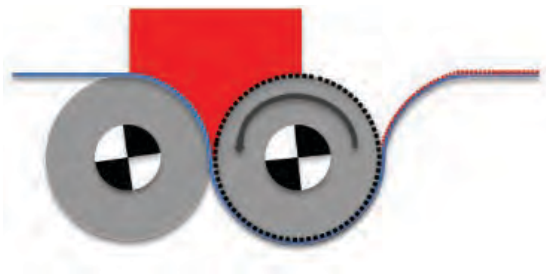


Slot die coating for pre-metered film coating

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

Coating and printing for NIL – Nanoimprint lithography

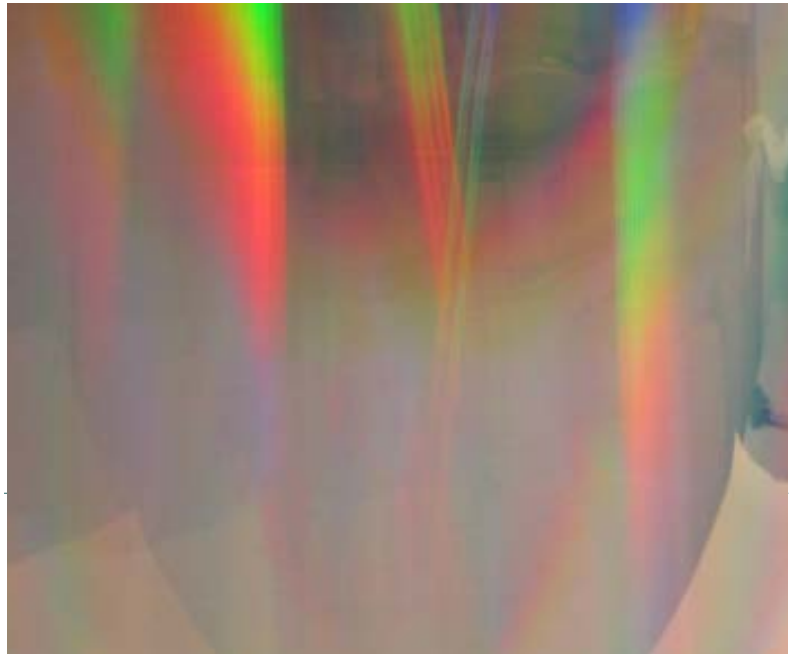




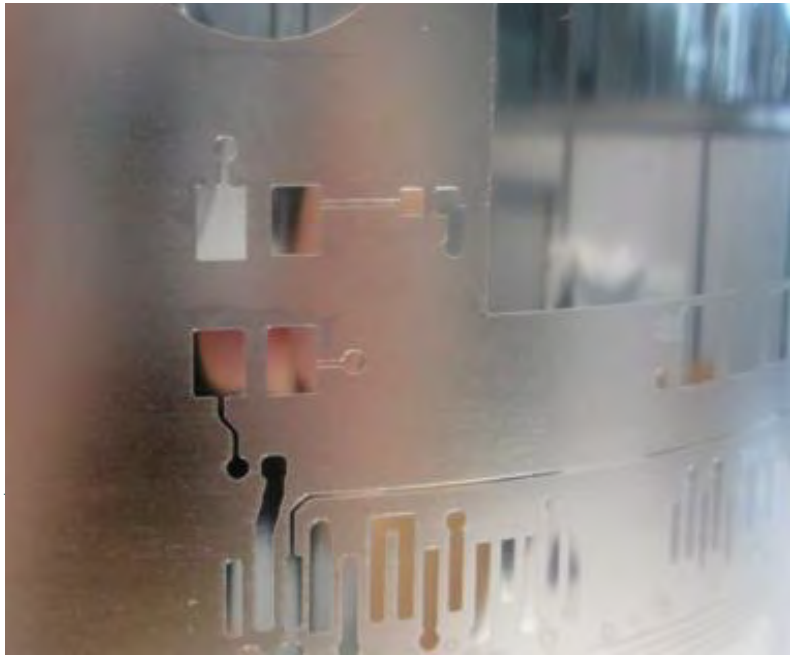
Nip coating

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

Coating and printing for NIL – Nanoimprint lithography

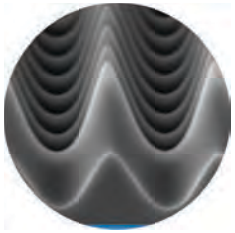


Homogeneous structure



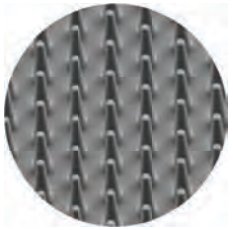
Inhomogeneous structure

Applications



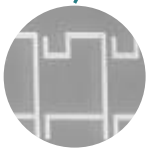
Display

Photonics



Bionics

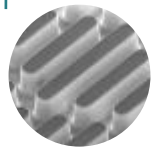
Life science



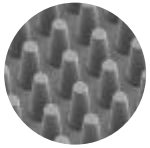
Printed electronics

Retroreflectors

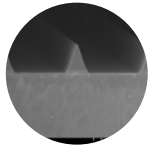
Diffractive optical elements



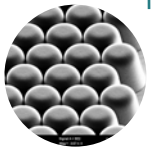
Antibacterial surfaces



Super hydrophobic surfaces



Shark skin



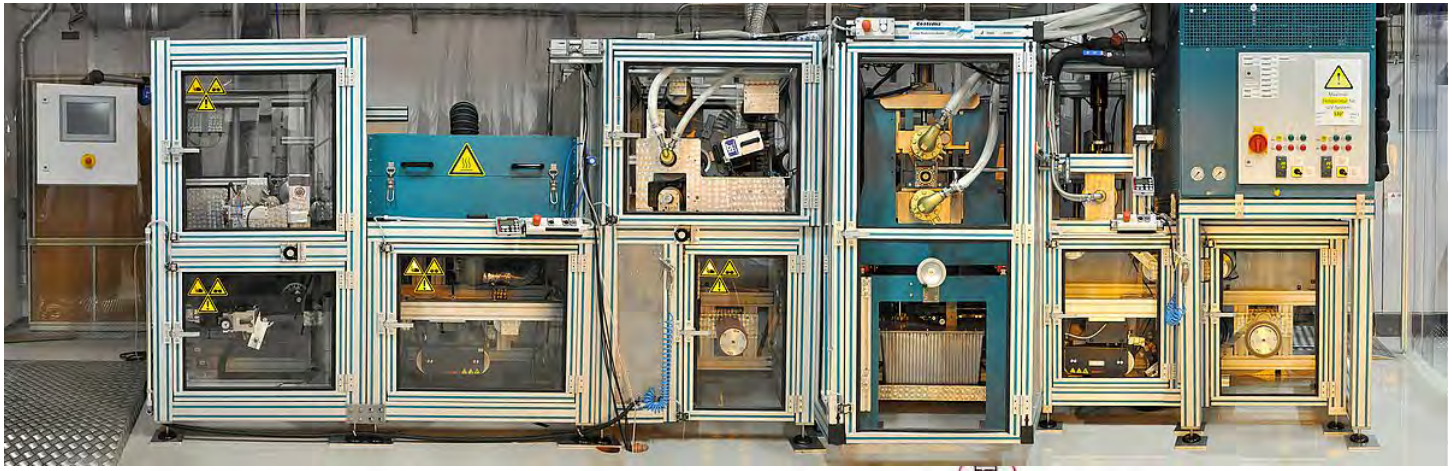
Haptic surfaces

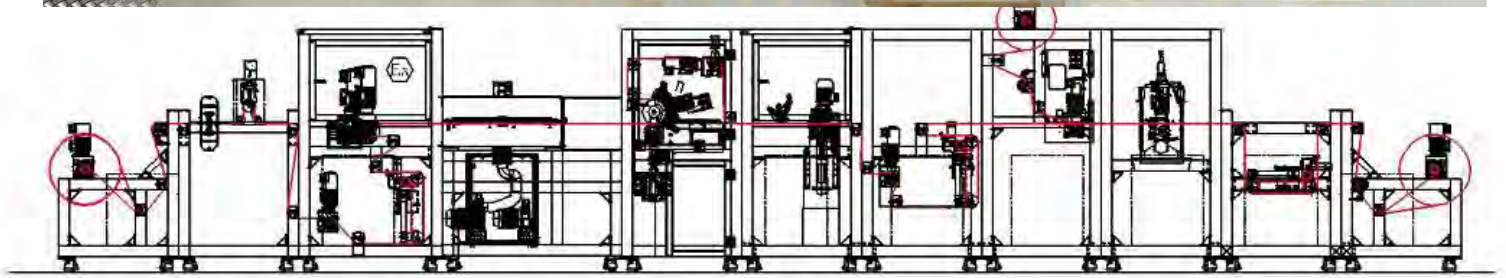
Microfluidic structure

UV / NIL – machines for lab 2 fab – R2R

UV / NIL – machines for lab 2 fab – R2R

Nanoimprinting combi system

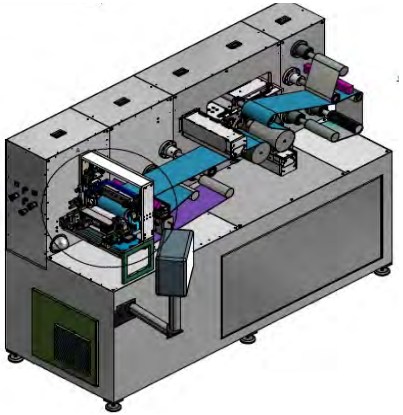




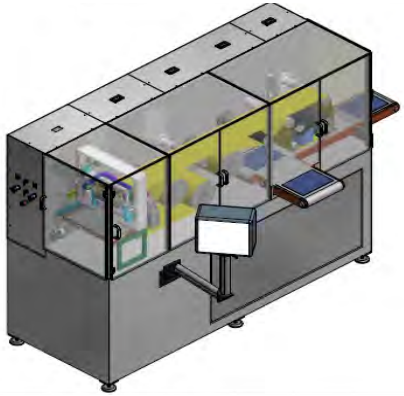
UV / NIL – lab 2 fab – R2R & R2P

Temicoat
Test Solution S2S

Temicoat
Test Solution R2R



Temicoat
NIL 300 R2R



Temicoat
NIL 300 R2P

Summary

Introduction

Equipment

Our markets

R&D

The printed electronics market

Bridging the gap

Technologies & processes

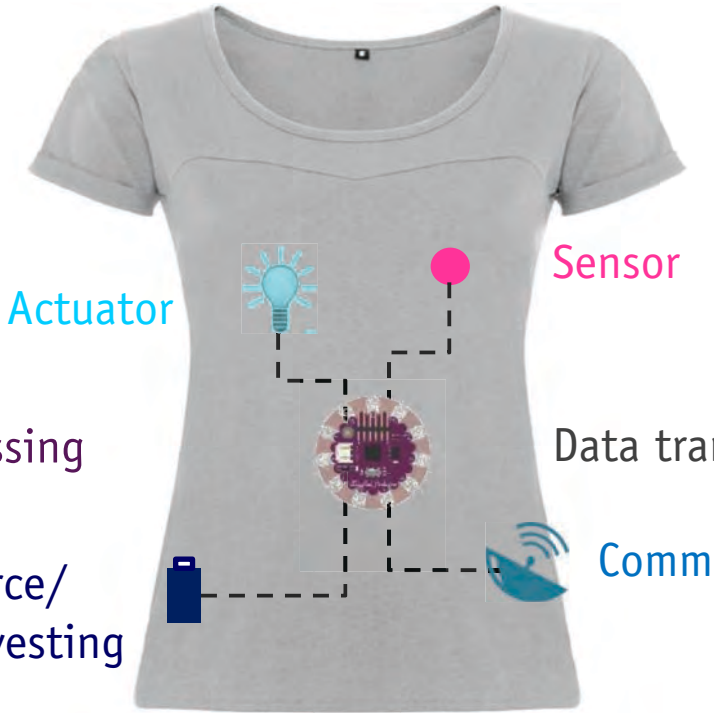
Summary

Bridging the gap

Needed for success:

- ✓ Reproducible results in every step of scale?
- ✓ Reality check if the approach is really scalable?
- ✓ Is the approach an approach for the real life production environment or is it rocket science?
- ✓ Are economies of scale reachable and when?
- ✓ Is durability really needed?
- ✓ Standardization of device manufacturing is the key for the industry
- ✓ Maybe small is the new big?

Bridging the gap



Hochschule Niederrhein
University of Applied Sciences

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.

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