New production technologies for printed electronics

Thomas Kolbusch, Vice President

Summary

Introduction	Our markets	Equipment	R&D
The printed electronics market	Bridging the gap	Technologies & Processes	Summary

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Overview

Quality
made in Germany

Part of the ATH Holding

Working widths
from 100 mm
up to 5,400 mm

Innovations

Coating

Printing

Laminating

Bespoke
equipment

Founded
1974

PrintedElectronics
Medicine
Membranes
Pharmaceutics
Renewables
Prepreg
Textile

From Lab2Fab

R&D
projects & network

Worldwide
service

Group of Companies

ATH – ALTONAER TECHNOLOGIE HOLDING

KROENERT

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

DRYTEC

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

Coatema® Coating Machinery GmbH

- ✓ Foundation 1974
- ✓ Approx. 45 employees
- ✓ Located in Dormagen

ZAE® ANTRIEBS SYSTEME

- ✓ Foundation 1919
- ✓ Approx. 140 employees
- ✓ Located in Hamburg

Represented Worldwide

Headquarter in Dormagen

1. Hauptverwaltung
2. Technikum
3. Endmontage
4. Lager / Warenannahme
- P Besucherparkplätze

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 10.000qm

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

ATH ALTONAER TECHNOLOGIE HOLDING

Vision – From Lab2Fab

Lab → **Pilot** → **Production**

Coatema equipment platform strategy for Lab2Fab

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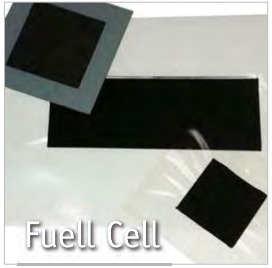
Our markets

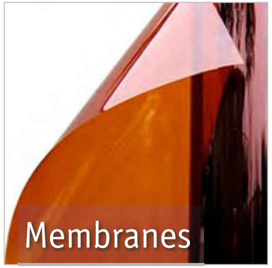

Solar


Fuell Cell

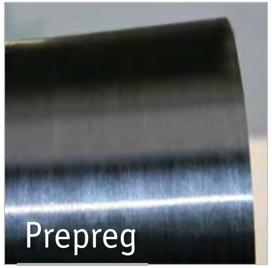

Battery


Pharmaceutics


Printed
Electronics


Membranes


Medical

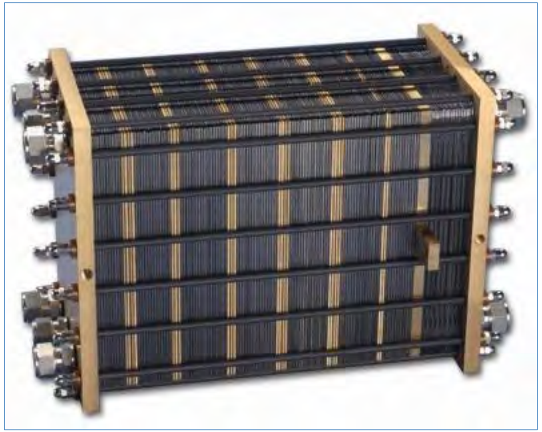

Prepreg


Textile

Renewables

Markets:

- ✓ Battery
- ✓ Fuel Cell
- ✓ Solar



Printed Electronics

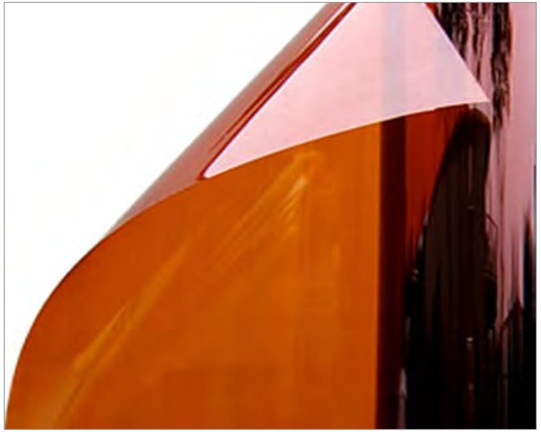
Markets:

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

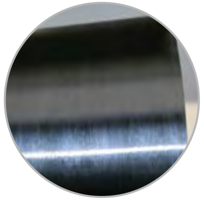
Membranes

Markets:

✓ Reverse Osmosis ✓ Water purification ✓ Medical filtration ✓ Gas Filtration ✓ Nanofiltration

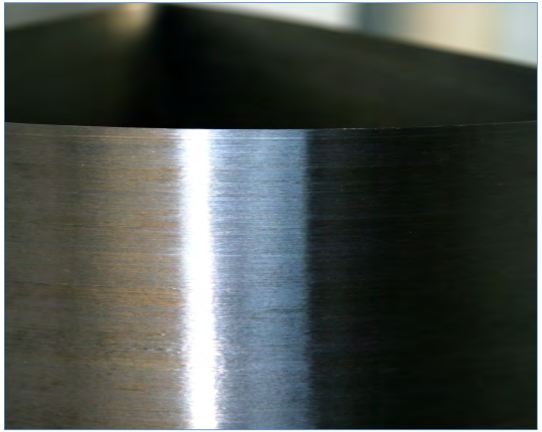


Prepreg



Markets:

✓ Automotive ✓ Aerospace ✓ Construction



Medical applications

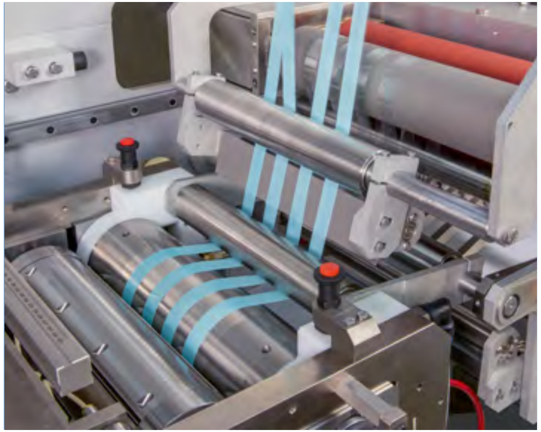
Markets:

✓ Silicone Gels ✓ Hydrogels ✓ Plaster ✓ Surgical materials

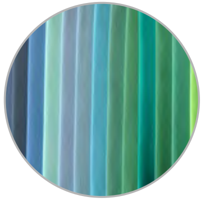
Pharmaceutics

Markets:

- ✓ ODF (Oral Dispersible Film)
- ✓ Transdermal Systems

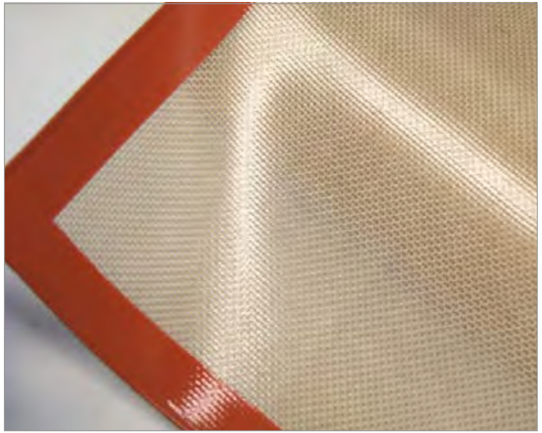


Textil



Markets:

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



Summary

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Lab units

Lab

Test Solution S2S

Easycoater

Test Solution R2R

Pilot lines

Pilot

Click & Coat™

Smartcoater

Basecoater 3rd Generation

Pilot lines

Pilot

Deskcoater

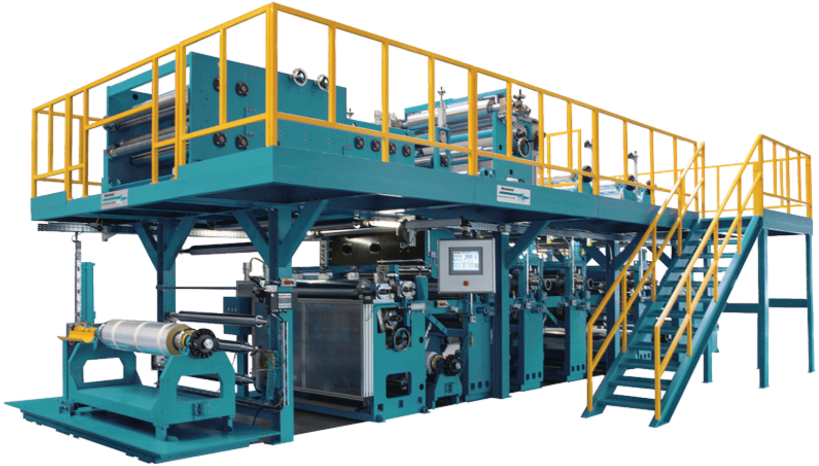
Linecoater

Verticoater

Production lines

Production

Production Lines

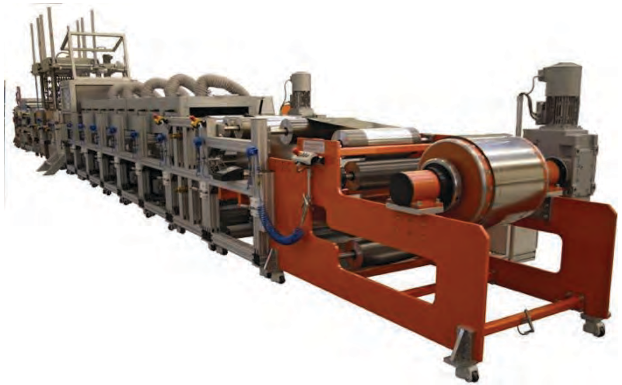


Prepreg Plant

Bespoke equipment

Custom made

Printed Oleds

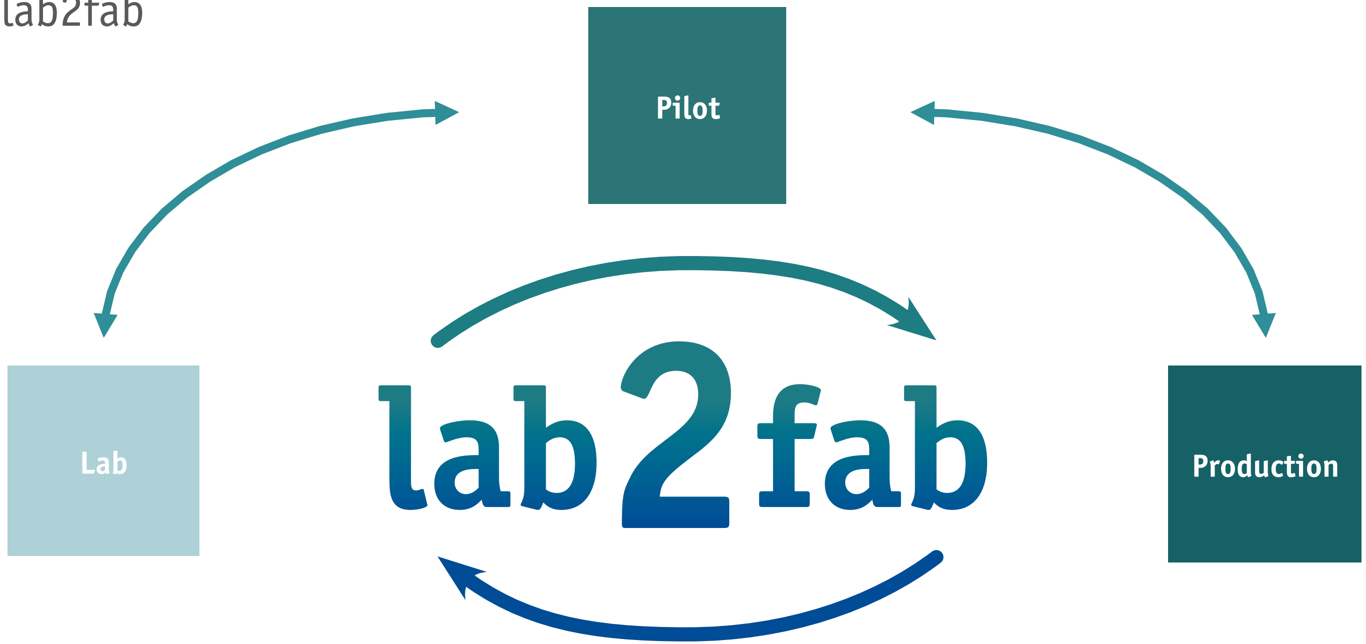


Battery

Composite Fibres

Scaling up new technologies

Tools for lab2fab



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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

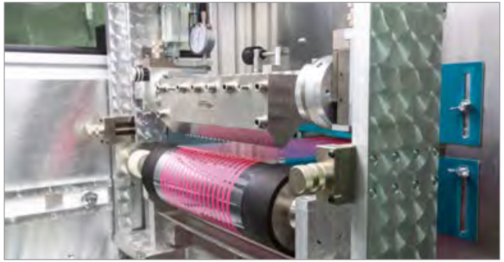
Product portfolio:

- ✓ Basic research, Process- and Productdevelopment
- ✓ Product improvement
- ✓ Trainings and Conferences

R&D Centre KROENERT & DRYTEC

R&D Centre Coatema

Coatema R&D 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 projects

TECHNISCHE UNIVERSITÄT DRESDEN
DKI Deutsches Kunststoff-Institut
SIMTech
The University of Arizona
UNSW Sydney
Queen Mary University of London
Aristotle University of Thessaloniki
TTRI Taiwan Textile Research Institute
ITA Institut für Textiltechnik und Lehrstuhl für Textilmaschinenbau
RWTH Aachen University
NREL National Renewable Energy Laboratory
Ruhr Universität Bochum RUB
Technical University of Liberec www.tul.cz
ITM
hochschule hof University of Applied Sciences
DTNW
SITF
CeNTI Centre for Nanotechnology and Smart Materials
cea
Fachhochschule Kiel University of Applied Sciences
FILK
Hochschule Niederrhein University of Applied Sciences
Heriot Watt University
Neue Materialien Würzburg
Joanneum Research
Georgia Institute of Technology
ZSW
Holst Centre
VTT
Forschungszentrum Jülich
ITC
eurecat Centre Tecnològic de Catalunya
National University Mongolia 1942
TNO
ITCF Denkendorf
KITECH
IMM Institut für Mikrotechnik Mainz GmbH
Hochschule Reutlingen Reutlingen University
KIT Karlsruhe Institute of Technology
Fraunhofer IAP
Fraunhofer IAF
Fraunhofer ILT
Fraunhofer IFAM
Fraunhofer ISC
Fraunhofer FEP
Fraunhofer IVV
Fraunhofer ISE
Fraunhofer ICT
Fraunhofer PYCO
Fraunhofer IPT
Fraunhofer IWM

R&D projects – projects overviews

Coatema® Coating Machinery GmbH

PI-SCALE

3D LIGHT TRANS

Diginova

fabrigen

iCoat

thime®

SolGel PV

REGAC

HEA2D
Herstellung
Eigenschaften
Anwendungen von 2D-Materialien

INTRES

EELICON
SMART LIGHT TRANSMITTANCE CONTROL

INNOSHADE
INNOVATIVE SHADING DEVICES

Flex-G

CLEAN4YIELD
DETECTION • CLEANING • PREVENTION • REPAIR

Facess

smartonics

GreenSense

ProLiBat

Supersmart

FlexEnSys

PowderSizing

FLEXLAS

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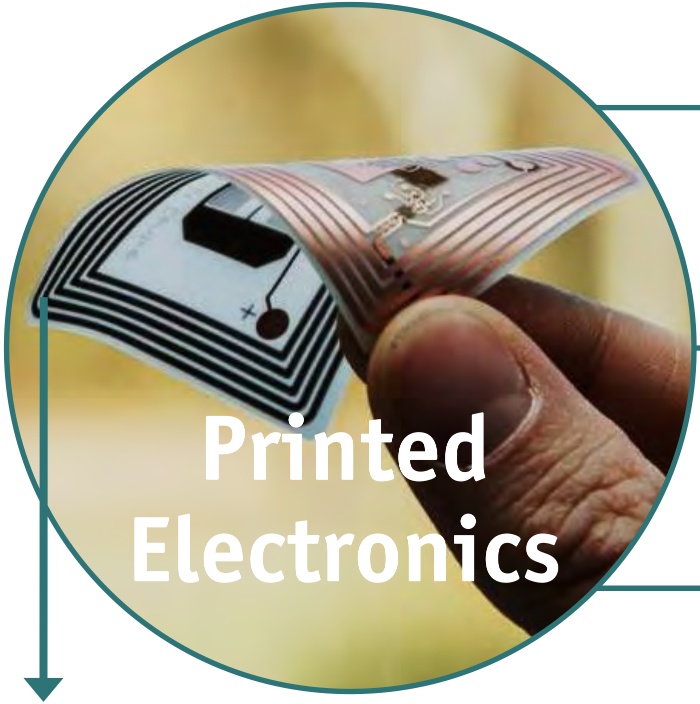
The future market



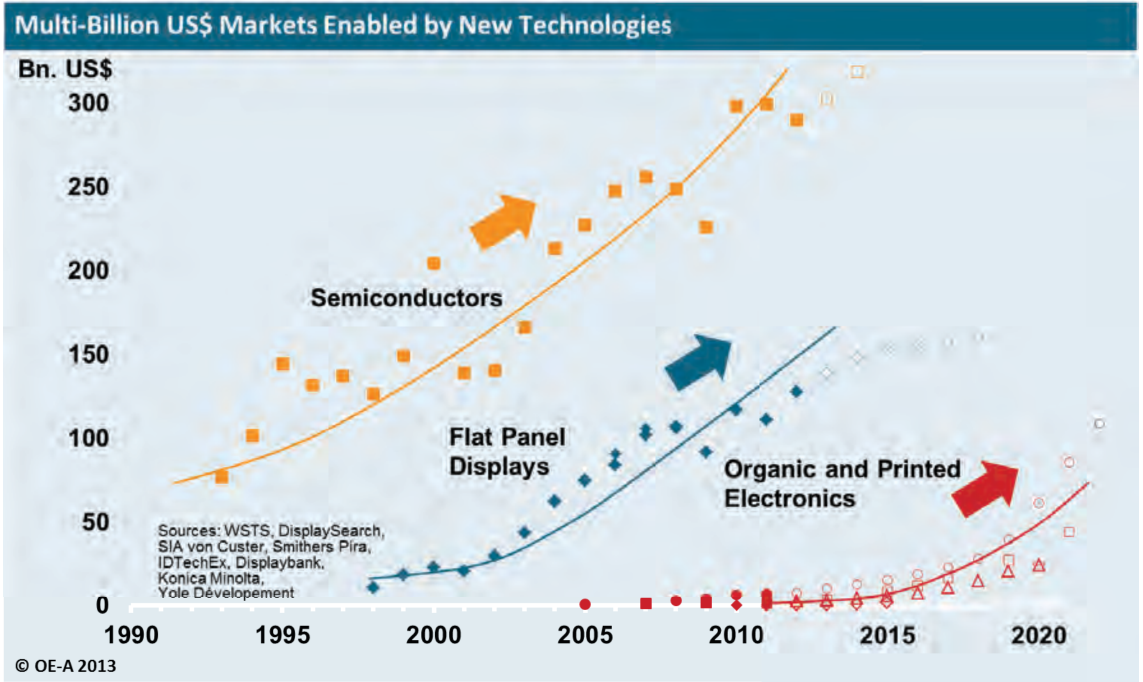
Printing
Coating
Deposition

Chemistry

Microelectronics

flexible – thin – robust – lightweight – stretchable

The future market

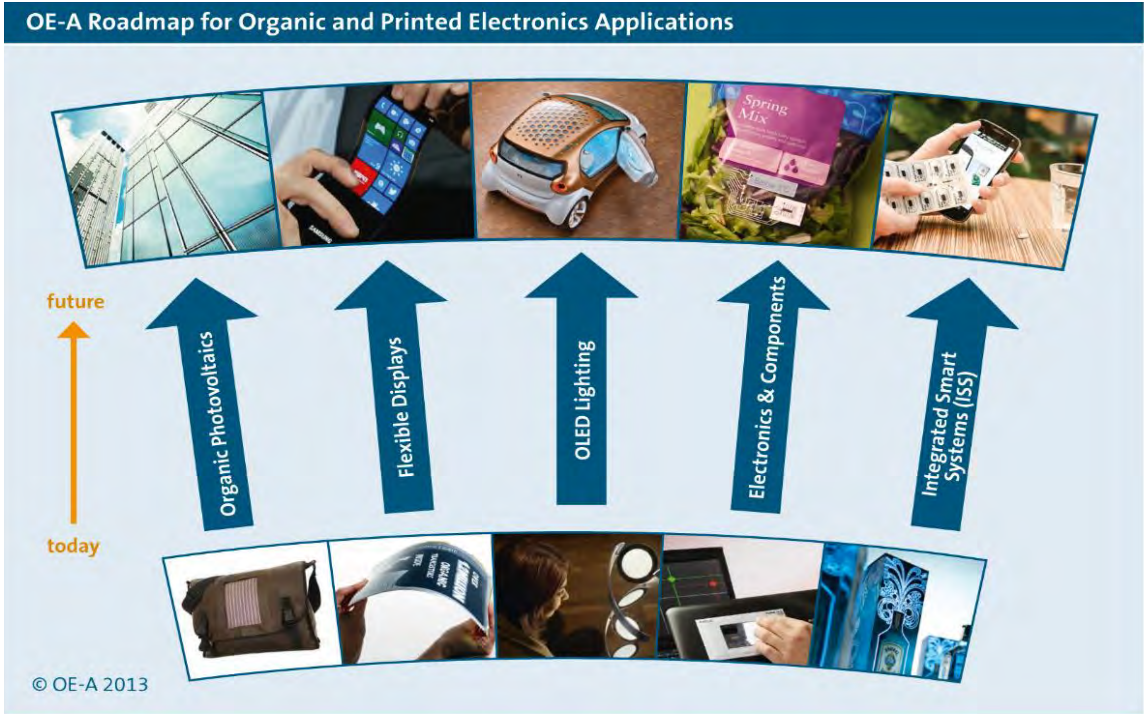


2010
2 Billion US$
predominantly by OLED displays

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



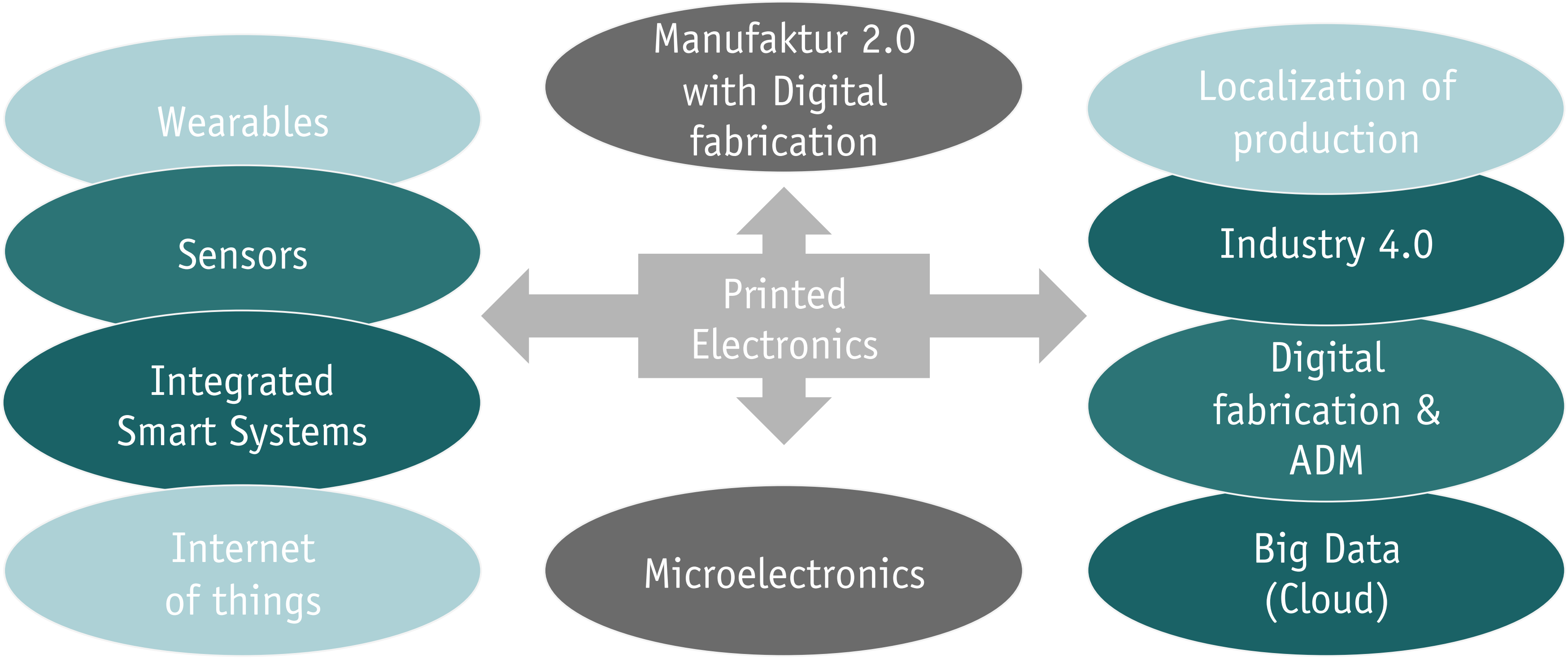
Digital fabrication

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!


Wearables
Sensors
Integrated Smart Systems
Internet of things
Manufaktur 2.0 with Digital fabrication
Printed Electronics
Microelectronics
Localization of production
Industry 4.0
Digital fabrication & ADM
Big Data (Cloud)

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

Sustainibility

Produced at place of use

Low carbon footprint

„Die digitale Manufaktur 2.0“

Digital

From globalization to localization of production

Personalized Products

Produced On demand

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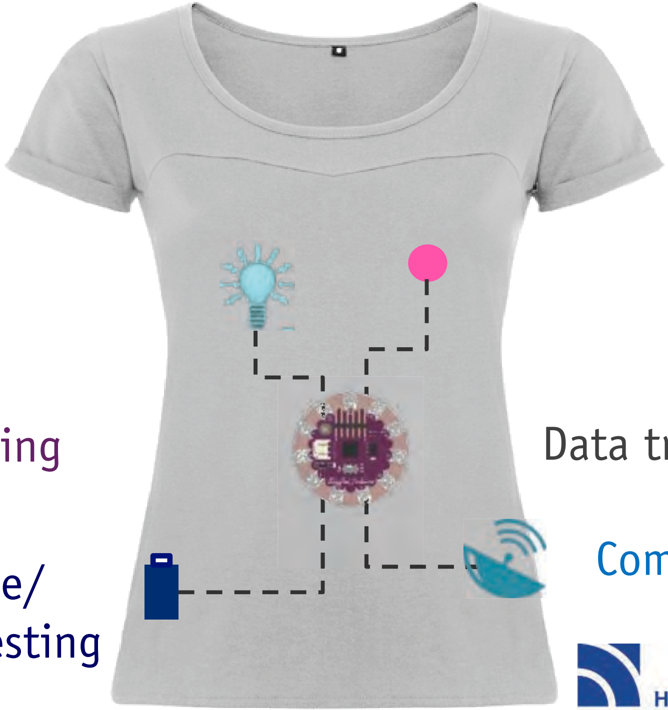
Coatema®
Coating Machinery GmbH

From 2008 till today – PE as the flexible bridge

Actuator

Data processing

Energy source/
Energy harvesting



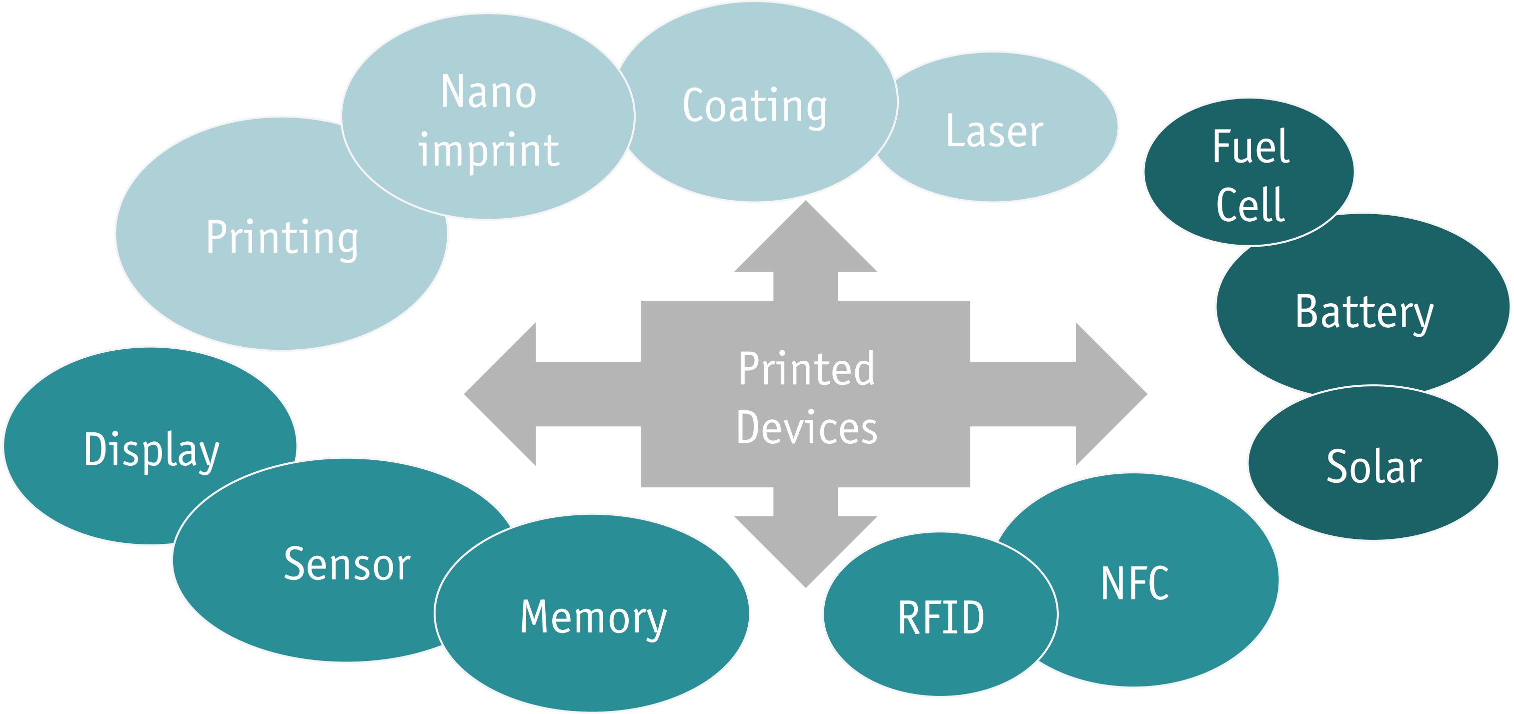
Sensor

Data transmission

Communication

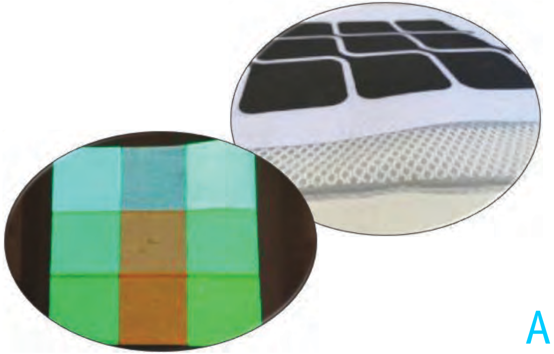
Hochschule Niederrhein
University of Applied Sciences

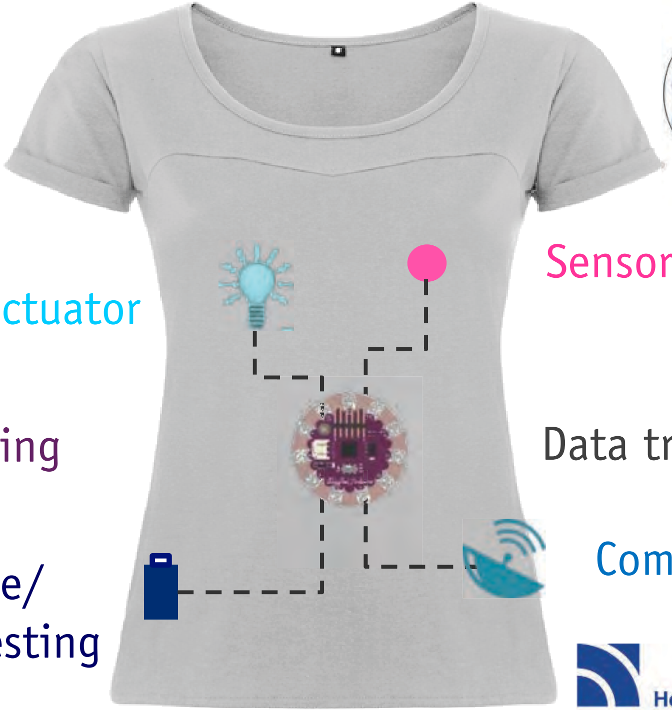
Printed electronics – Bridging the gap



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

From 2008 till today – PE as the flexible bridge





Actuator

Sensor

Data processing

Data transmission

Energy source/
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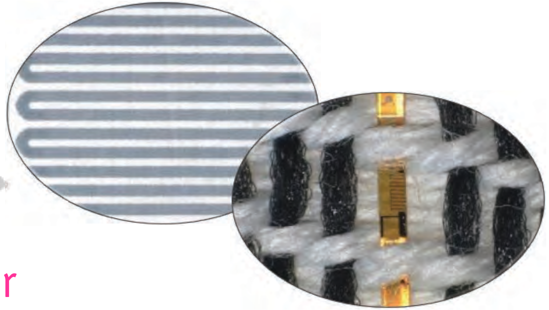
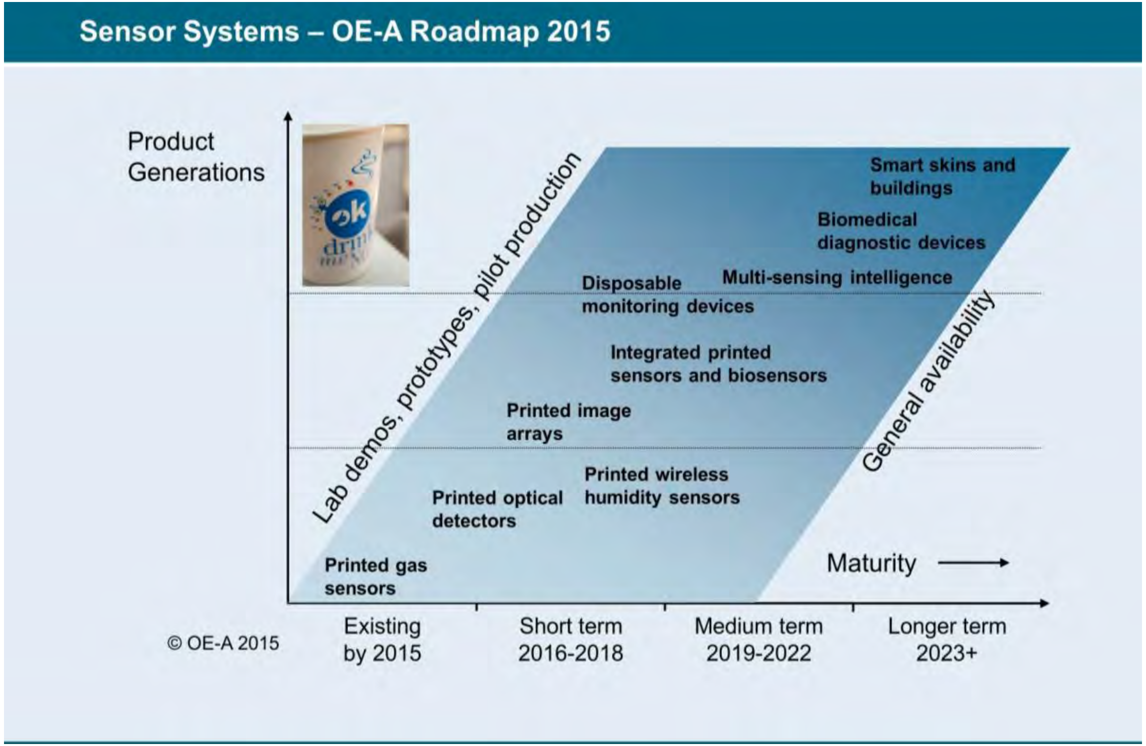
Communication



Hochschule Niederrhein
University of Applied Sciences

Sensor Systems – Roadmap 2015



Coatema® Coating Machinery GmbH

Case Study – Design principles

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

Figure 1. Printed temperature sensor and layout

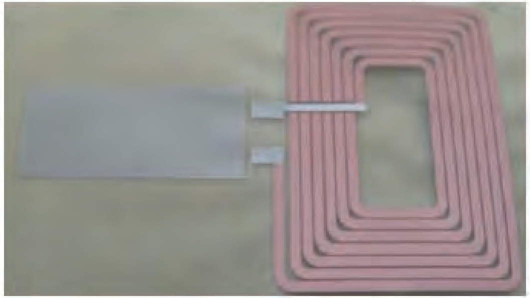
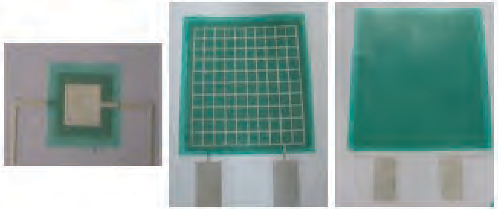


Figure 2. A remote readable RH sensor.

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



(a) (b) (c)

Figure 1. Printed capacitive humidity sensor structures

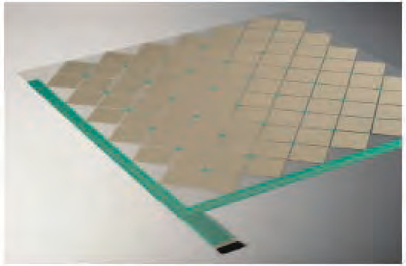


Figure 1. Capacitive touch sensor

Figure 1. Electrochemical biosensor

Authors: Elina Jansson, Jukka Hast, VTT

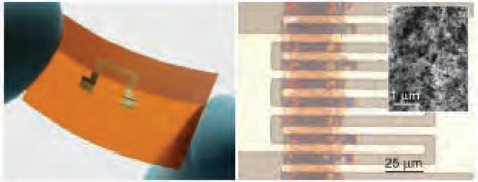
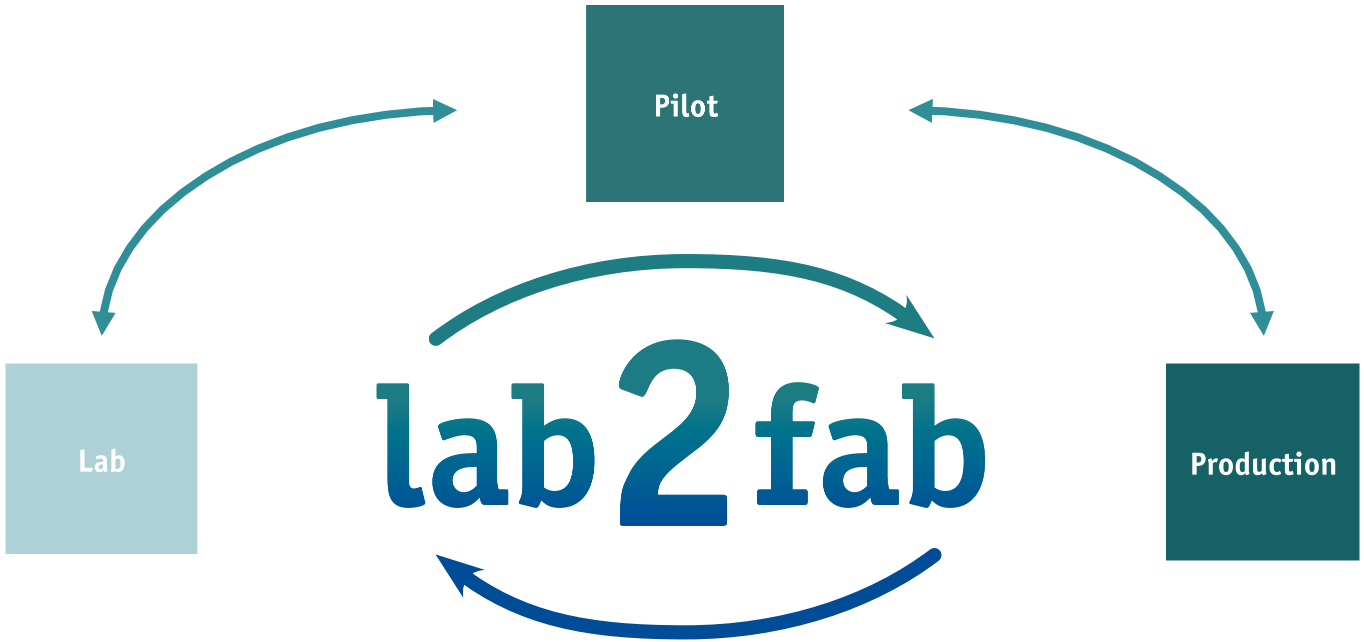


Figure 1. Printed gas sensors

PrintoCent

Designer's Handbook 2014

Tools for Lab2Fab



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Coating Parameters

Coating Chemistry
- ✓ Rheology
- ✓ Viscosity
- ✓ Viscoelasticity
- ✓ Type of solvents
- ✓ Amount of solids
- ✓ Van der Waals force
- ✓ Sheer ratio
- ✓ Adhesion/Cohesion

Coating Processes
- ✓ Coating systems
- ✓ Single or Multilayer coatings
- ✓ Direct coatings
- ✓ Transfer (indirect) coatings
- ✓ Substrate speed
- ✓ Layer Thickness
- ✓ Coating accuracy

Process control
- ✓ Process layout
- ✓ Tension control system
- ✓ Material guiding system
- ✓ Inline parameter control
- ✓ Quality control

Drying
- ✓ Convection drying
- ✓ Contact drying
- ✓ Infrared drying
- ✓ Sintering
- ✓ NIR
- ✓ High Frequency
- ✓ UV crosslinking systems

Substrate
- ✓ Surface tension
- ✓ Dimension stability
- ✓ Surface structure
- ✓ Contact angle

Pretreatment
- ✓ Corona
- ✓ Plasma
- ✓ Cleaning

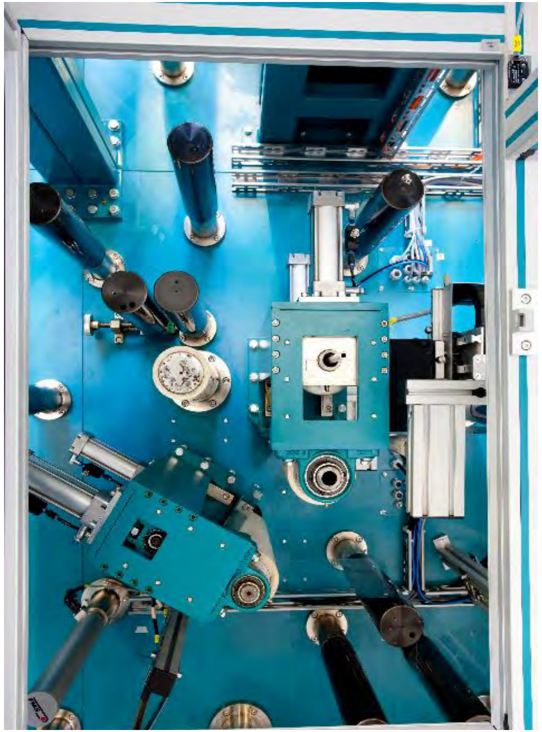
Environment
- ✓ Humidity
- ✓ Temperature
- ✓ Inert Conditions

Finishing
- ✓ Calendaring
- ✓ Embossing
- ✓ Slitting

Processes

Surface treatment	Printing	Coating	Digital Fabrication Inkjet Laser Patterning
Nano imprint	Lamination	Encapsulation	Pick & place

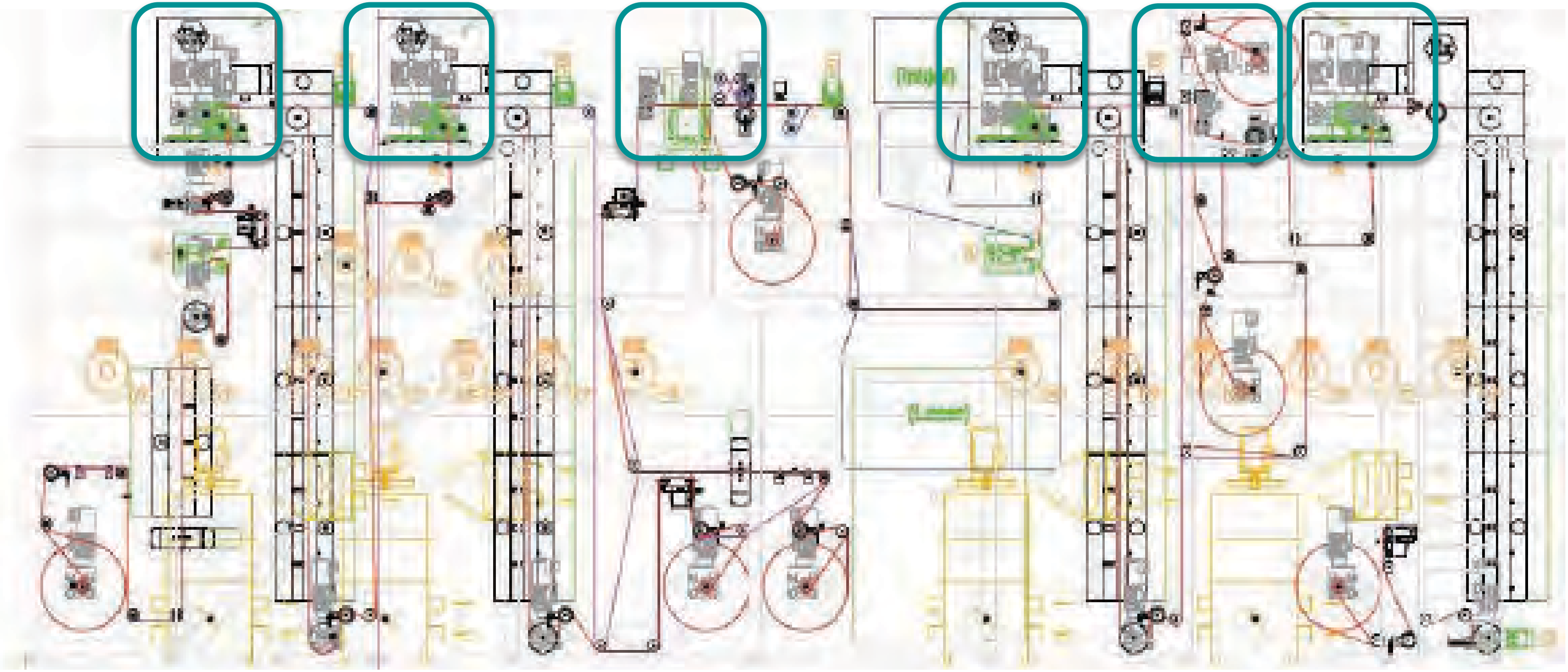
Upscaling from Lab2Fab – Going to Fab-Technologies



From Lab2Fab

PrintoCent

PrintoCent Pilot Factory



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

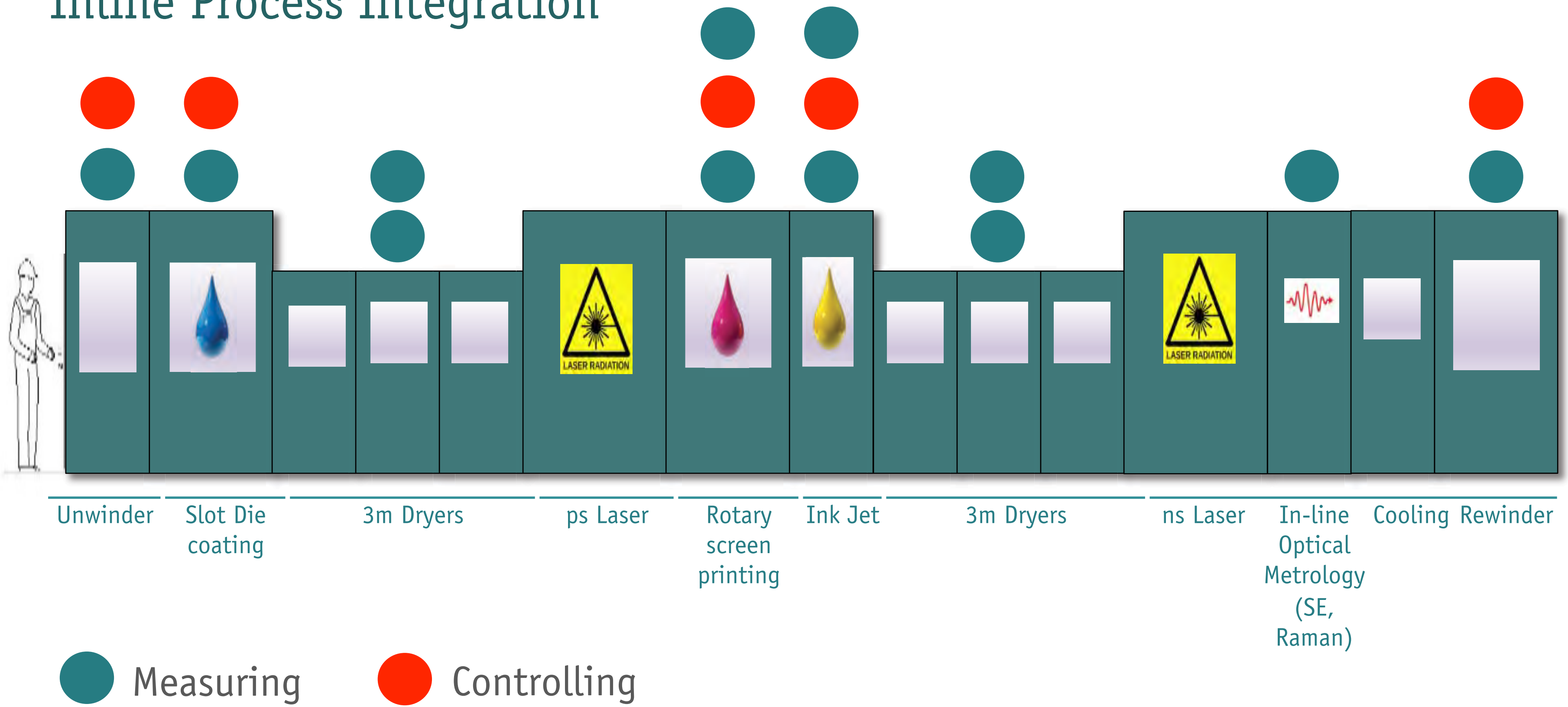
- ✓ Camera
- ✓ Fiber optic
- ✓ Design of drives

Process analysis

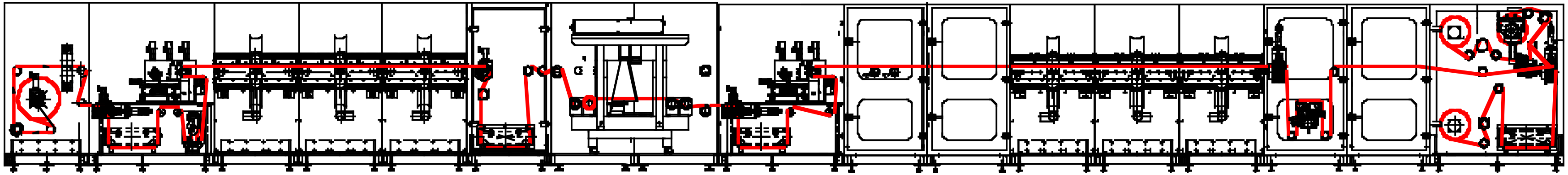
- ✓ Statistic parameters
- ✓ Product flow analysis
- ✓ Yield
- ✓ Cost of ownership

Inline Process Integration

Inline Process Integration



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

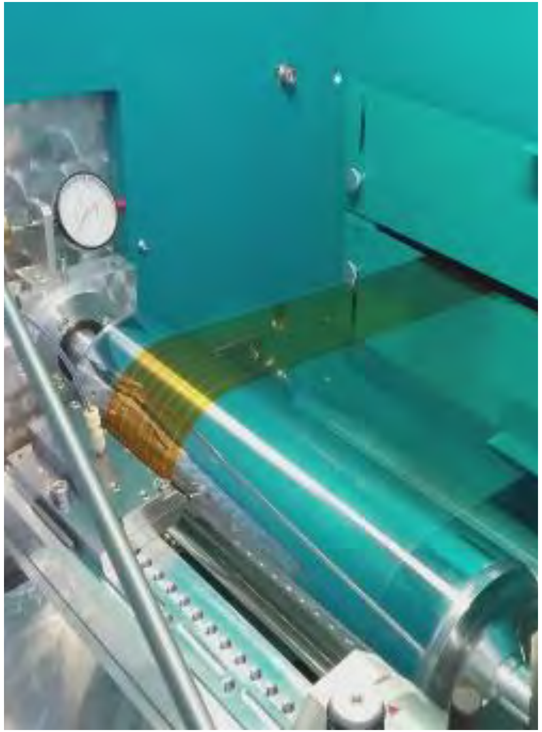
1st Printing

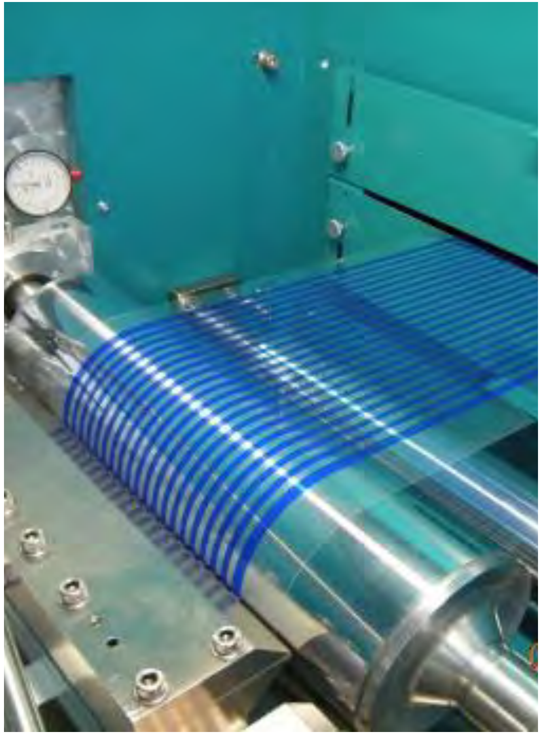
- ✓ Web surface activation with Plasma Treatment

Dryer 1

- ✓ 3 meter Dryers
- ✓ Hot Air and heated nitrogen
- ✓ Temperatures up to 230°C

Slot die coating

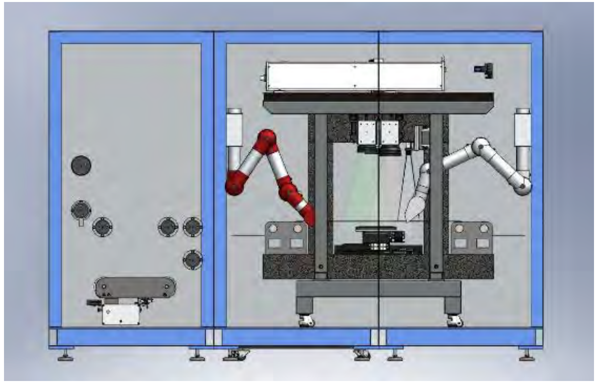




Slot-die coating station compatible for materials used in OEs

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

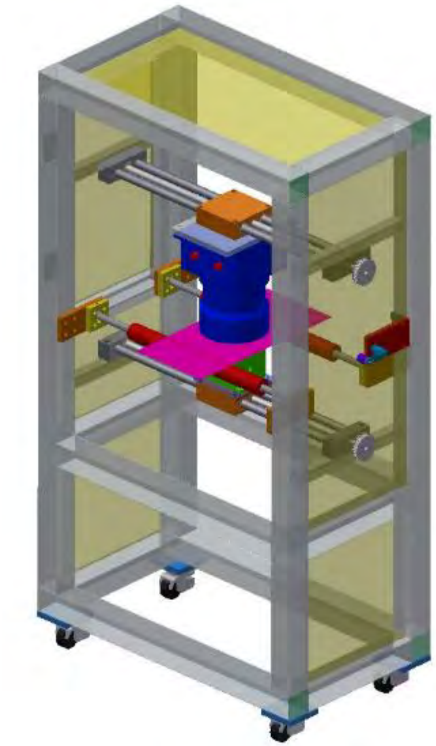
Laser Patterning



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

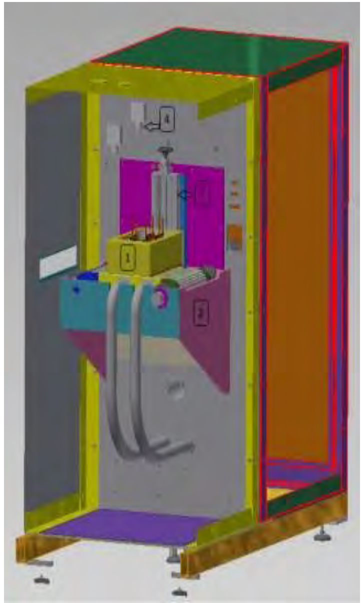
- ✓ Rotary screen printing
- ✓ Coating width of 300mm
- ✓ Lateral accuracy ±5%

Dryer 2

- ✓ 3 meters Dryers
- ✓ Hot Air and heated nitrogen
- ✓ Temperatures up to 230°C

Inline Process Integration

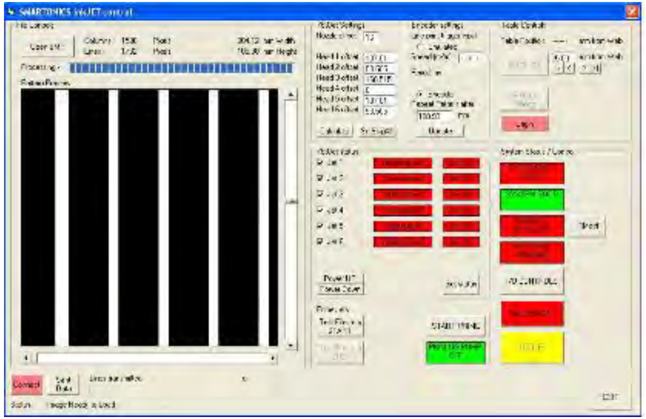
Inkjet station



Inkjet station

System

Coatema Software



Already integrated:
Fujifilm Dimatix

Encapsulation

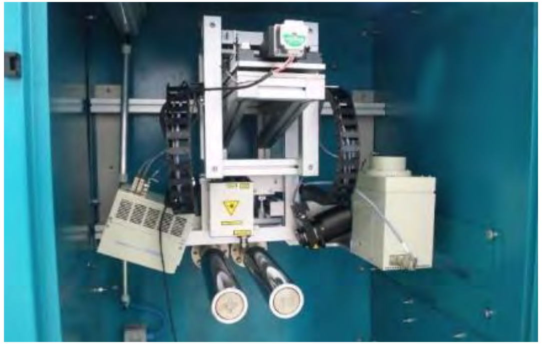
Rewinding station

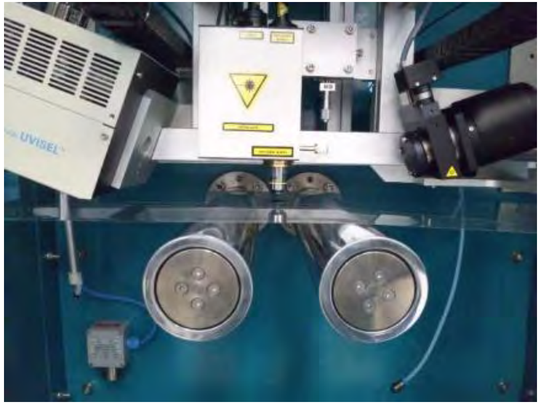
- ✓ The rewinding station has a retaining roller
- ✓ Identical specs to the unwinding station
  - ✓ 3 inch core rolls
  - ✓ Automated forward and reverse movement of the web
  - ✓ Speed of 1 – 20 m/min.
  - ✓ Tension control and Edge guide system

Lamination/delamination station

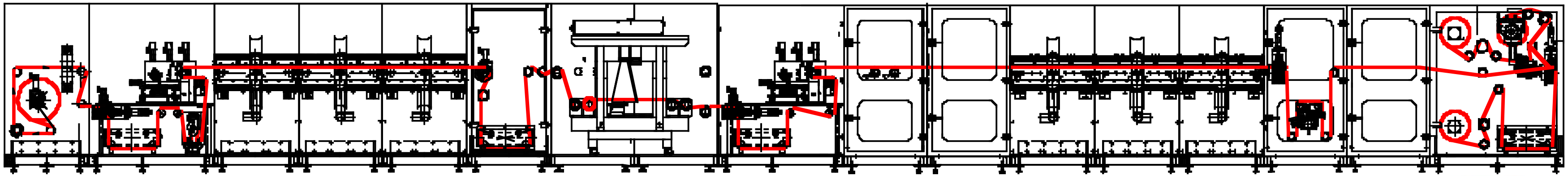
- ✓ Compatible with 300 mm web width
- ✓ Web Control with Edge guide system
- ✓ Lateral accuracy of ±100 µm / 20 µm

Inline Quality control – Ellipsiometry and inline Raman by Horiba





Summary



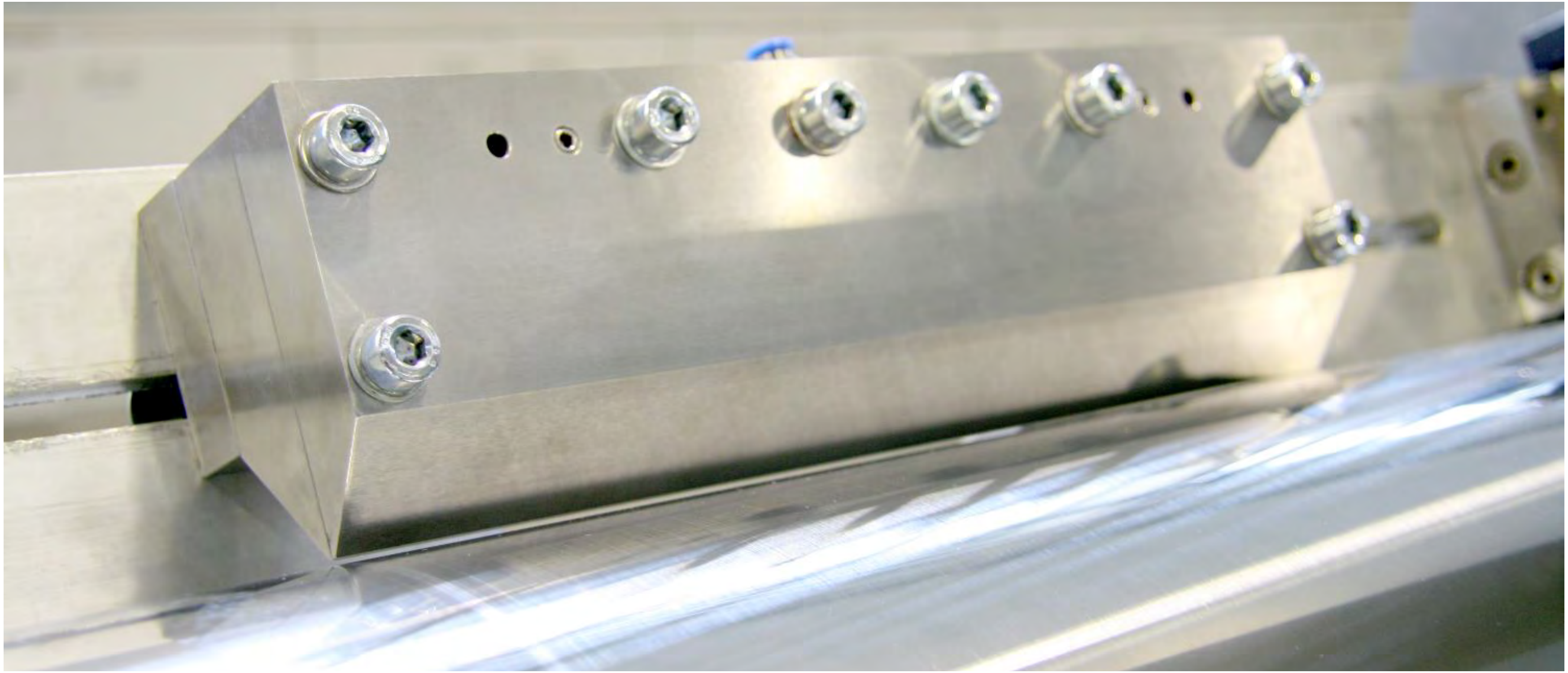
- ✓ 19 m in length
- ✓ 300 mm working width
- ✓ 30 m/min. per minutes production speed
- ✓ 3 print stations
- ✓ Plasma treatment
- ✓ 6.000 mm nitrogen dryers in 500 mm sections
- ✓ Registration control
- ✓ Laminating station

New design principle

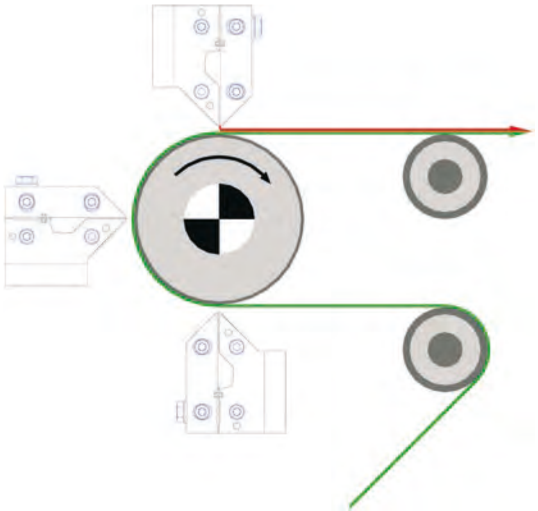
New design principle


TEMICOAT
Nanoimprint

Slot Die system



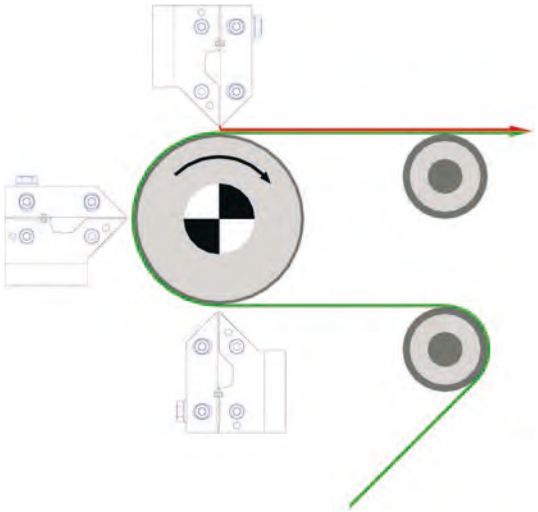
Basics of Slot Die coating – Characteristics of Slot Dies



- ✓ 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.

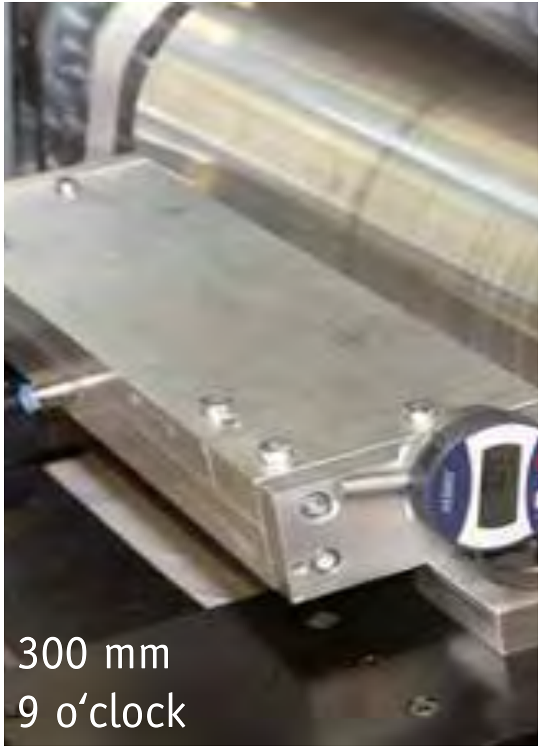
Basics of Slot Die coating – Range of parameters

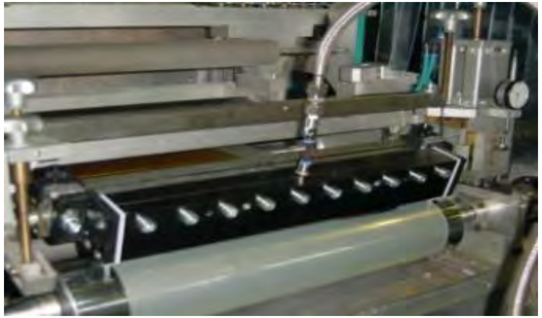


✓ Printing Speed (m/min)	0.1 – >1000
✓ Ink viscosity (mPa s)	1 – 30.000
✓ Layer Thickness	0,1 – >200µm
✓ Coating accuracy	<1% (2 – 5%)
✓ Coating width	up to approx. 3 m

Basics of Slot Die coating – Slot Die examples

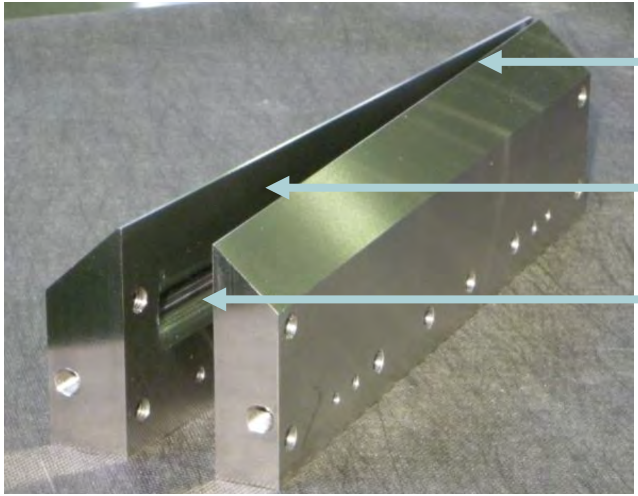

100 mm
11 o‘clock


300 mm
9 o‘clock


500 mm, slightly, tilted


300 mm, double sided

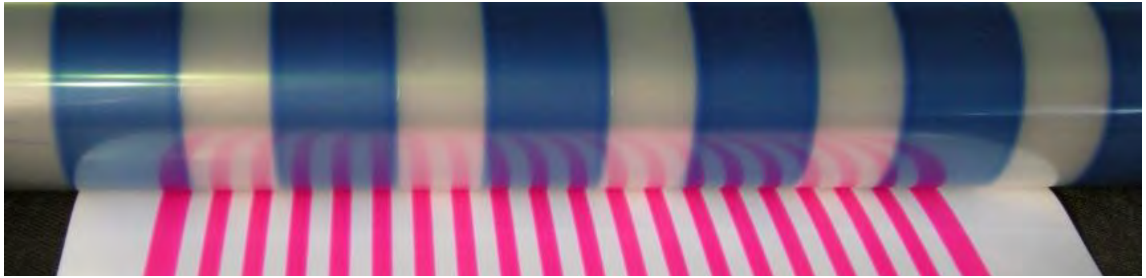
Basics of Slot Die coating – Coatema standard layout

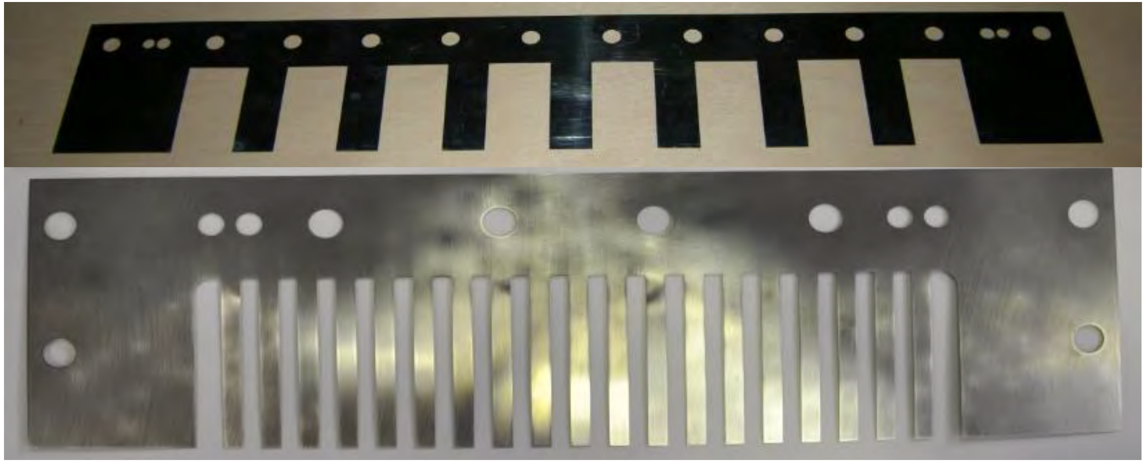


Structured coating – Levels of complexity

		Current status
1	full area, homogeneous	requirements are met, thickness profile variation of 0.5 %
2	stripes downweb	requirements are met, good edge definition
3	stripes crossweb (intermittent coating)	requirements are partially met, edge definition of 0.5 – 1 mm depending on liquid
4	arbitrary patterns	requirements are not met, concepts for realization exist, research project is going on

Structured coating – Downweb stripes

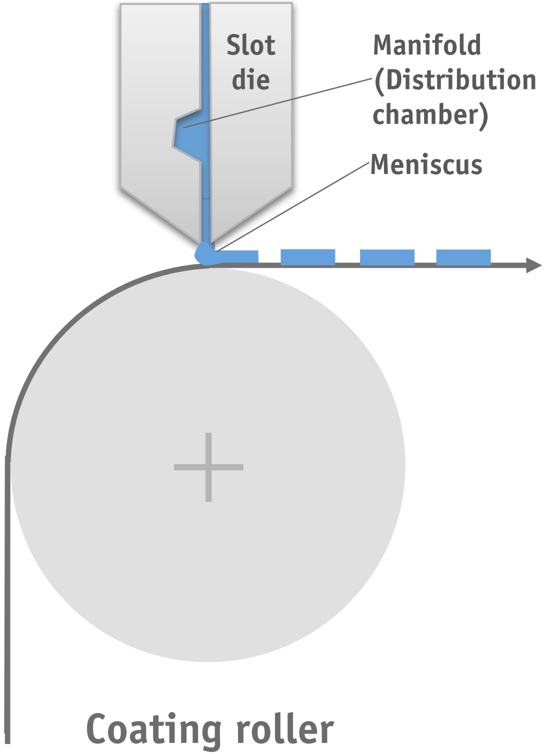




Downweb stripes of different width …

… 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.

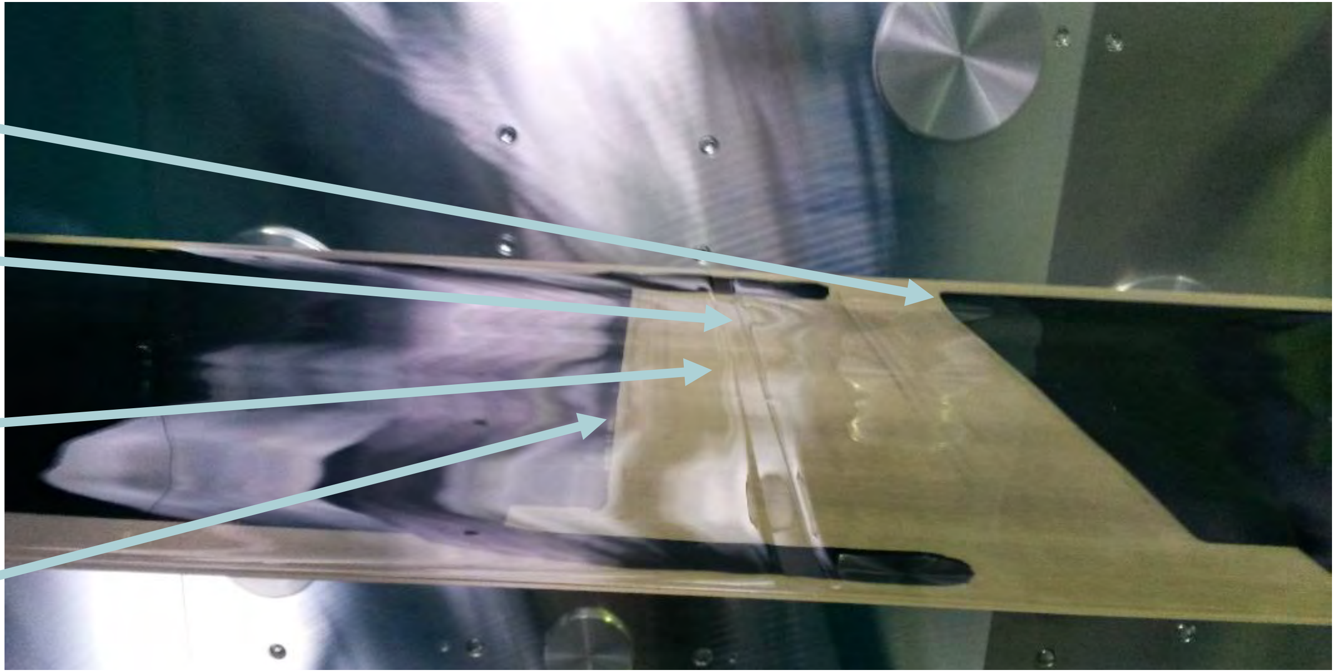
Structured coating – well defined edges at high viscosity

Leading edge
Battery paste

Leading edge
Silicone

Trailing edge
Silicone

Trailing edge
Battery paste

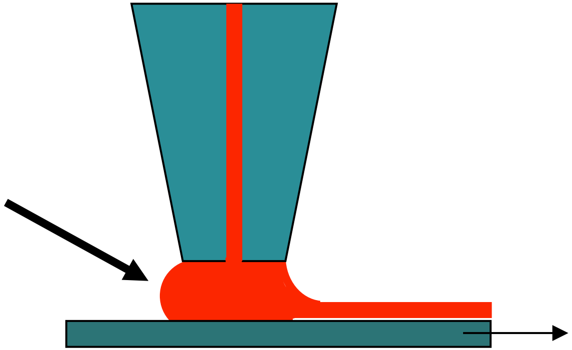


Two different stripe patterns, one on top of the other

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 edge .

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



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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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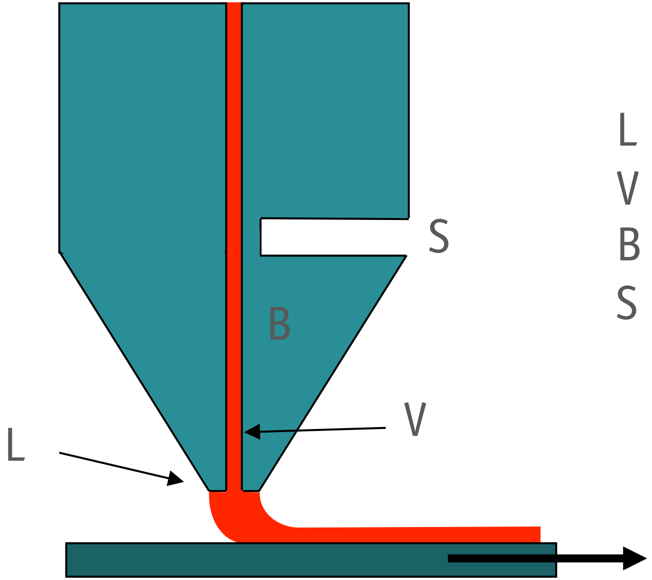
Structured coating – The switching slot die lip

Slot die with movable lips:
coating mode

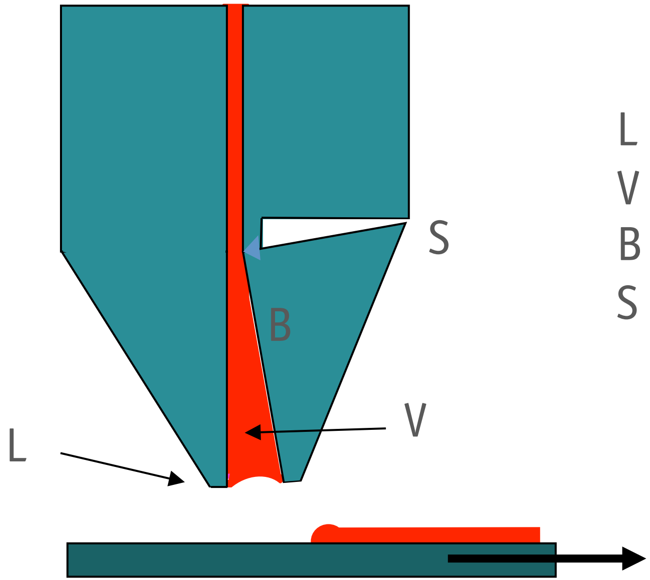


L lip
V slot volume
B bendable lip
S bending slot

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

Member B flips open
Volume V increases and
sucks away the meniscus

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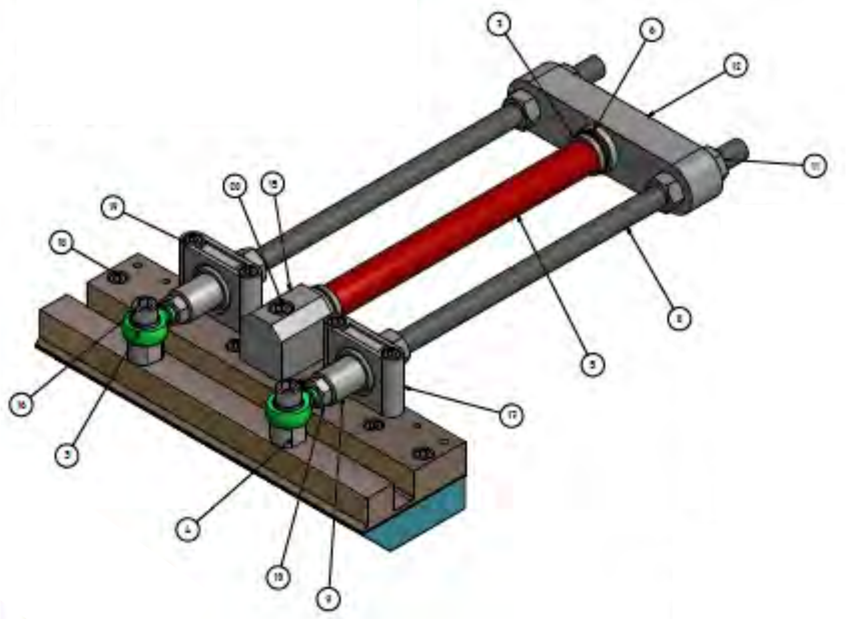
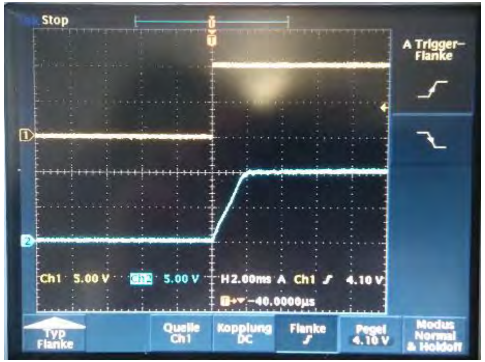
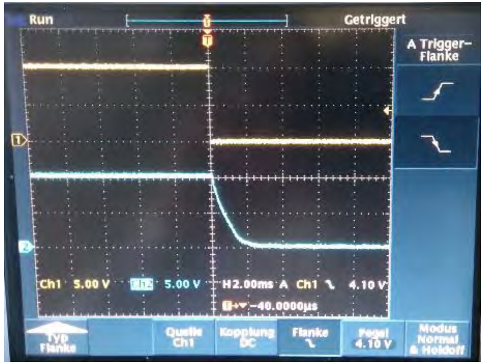
Structured coating – technical realisation with Piezo-Drive



Control Voltage

Piezo Response





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

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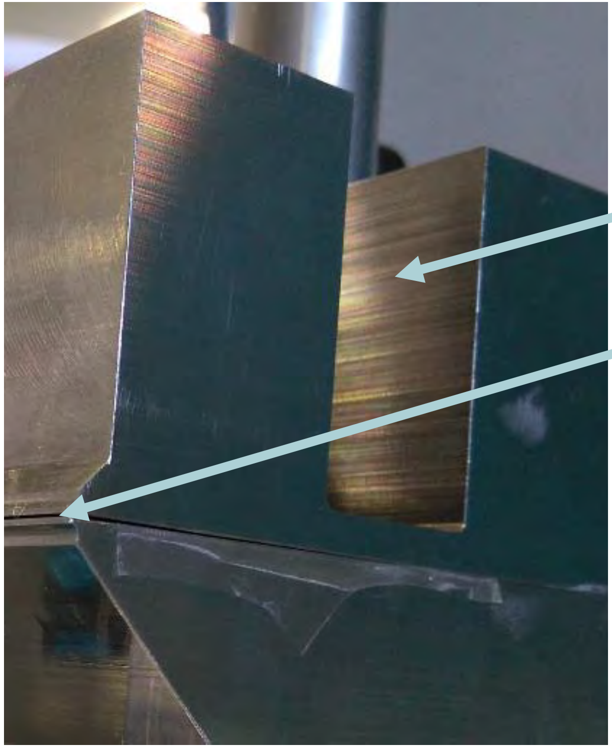
Structured coating – technical realisation with bendable lips

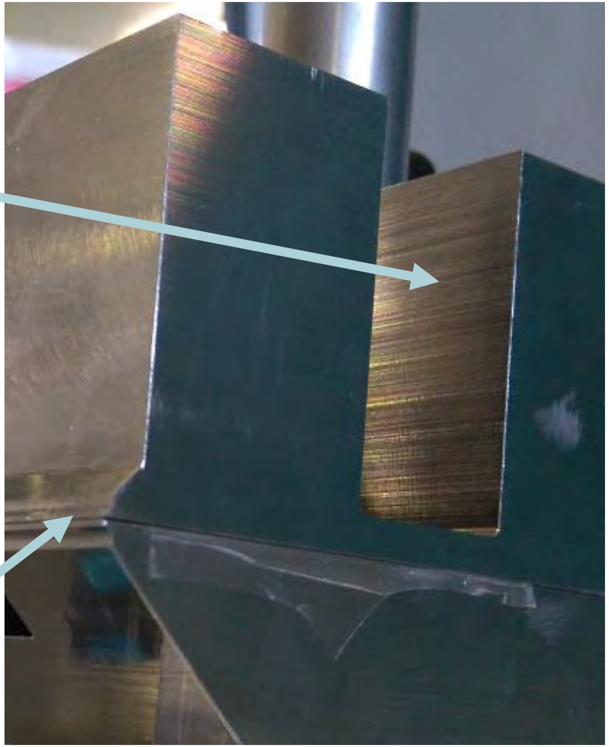


Bending slot

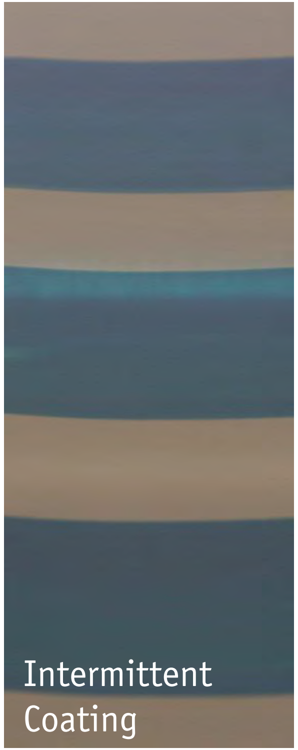
Lips open

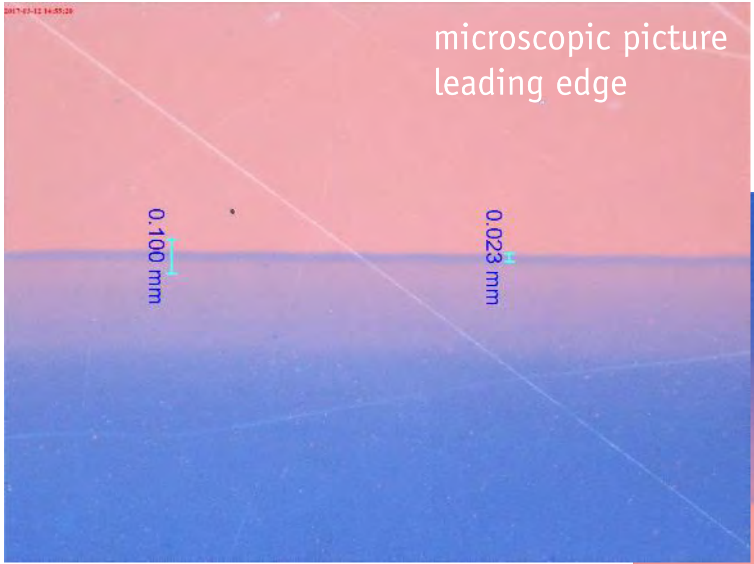
Difference is 300 µm only

Lips closed

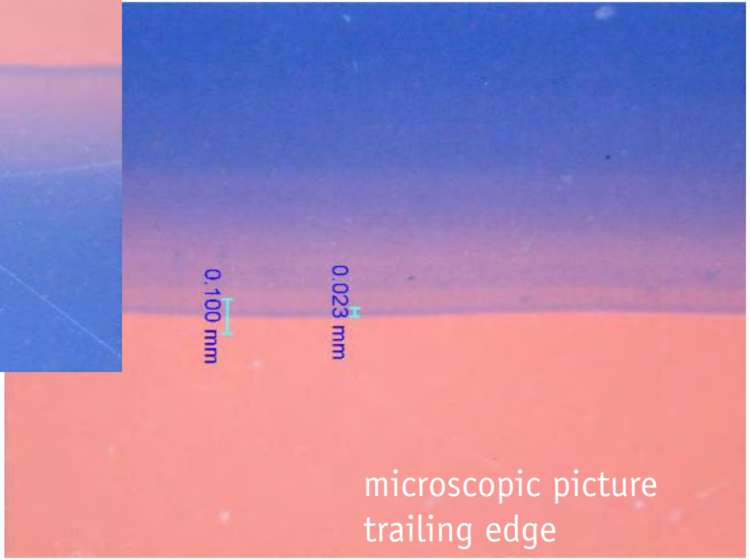


Structured coating – switching Slot Die: first results

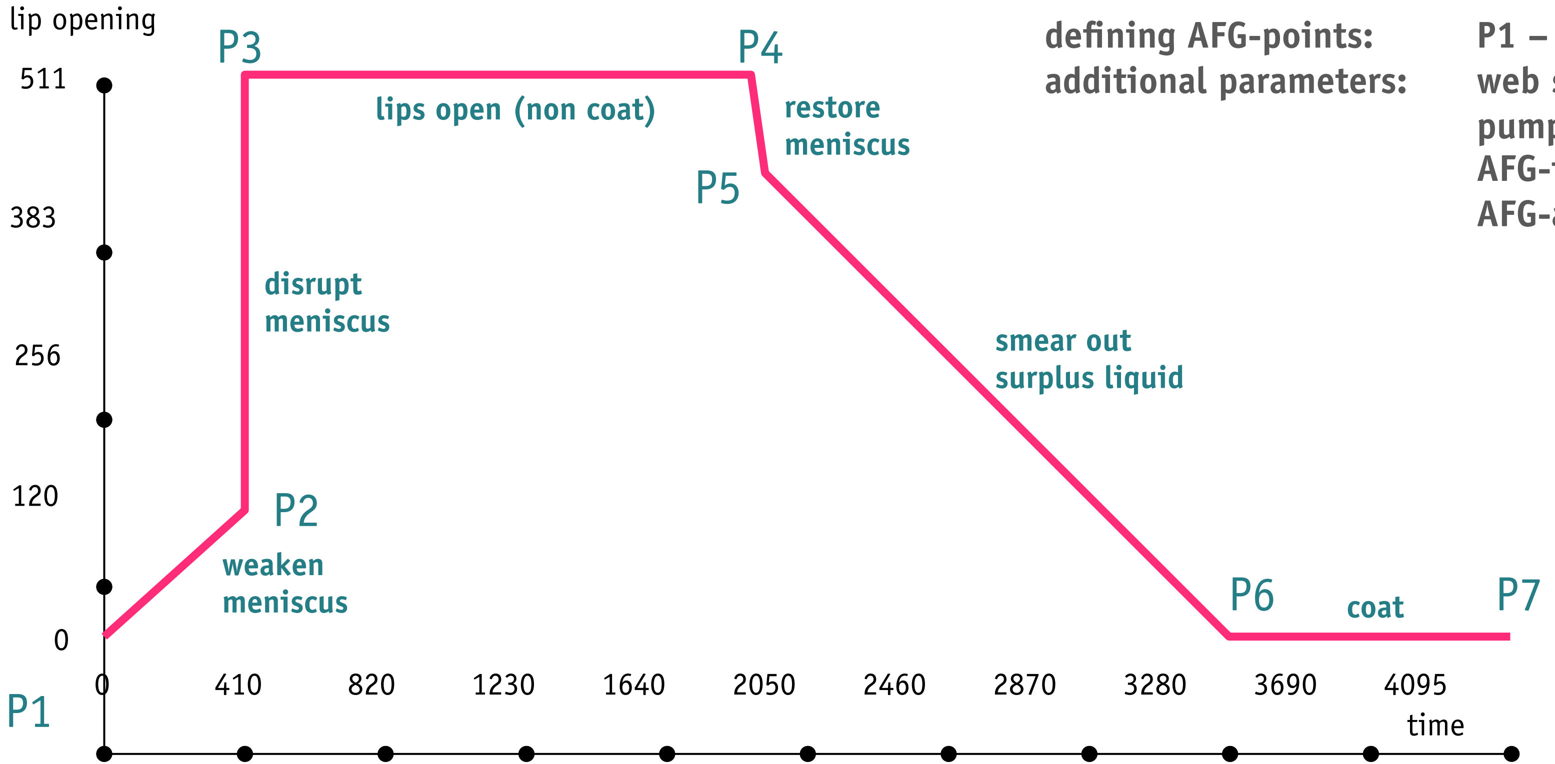




Straight edges well defined within 20 µm



Structured coating – course of lip motion



defining AFG-points: P1 – P7

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

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

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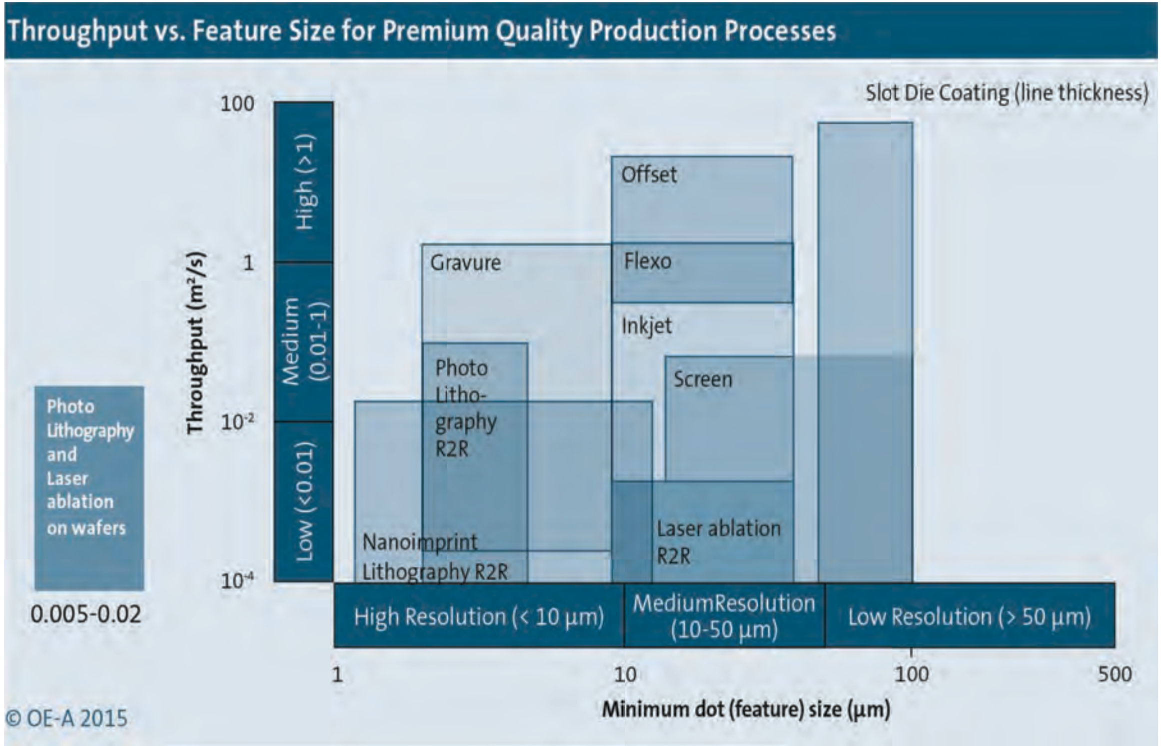
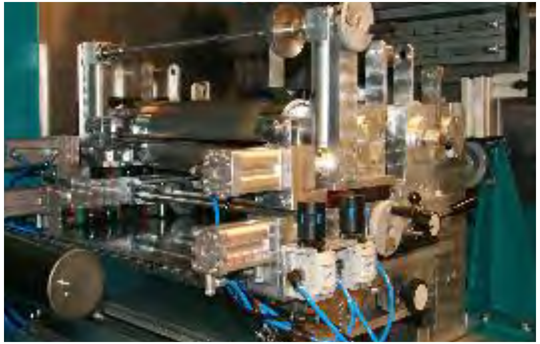
Printing Parameters



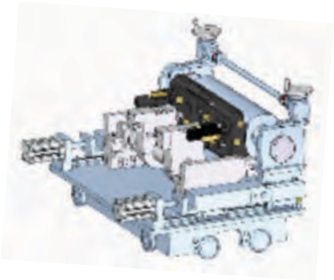
Printing Parameters

Printing method	Printing speed (m/s)	Nip pressure (MPa)	Ink viscosity (Pa·s)	Layer thickness (µm)	Feature size (µm)	Regis-tration (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

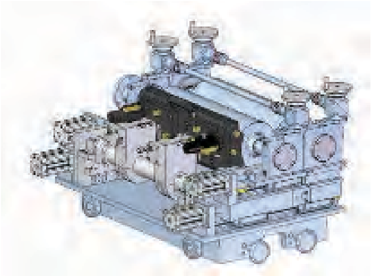
Printing Systems



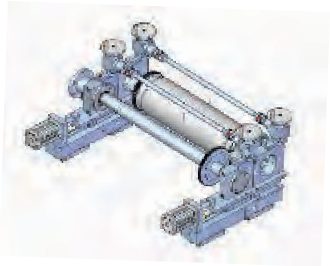
Gravure printing



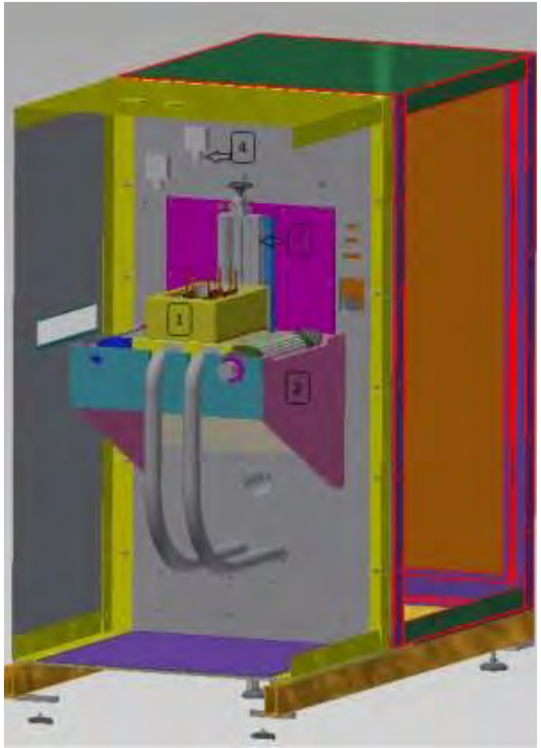
Flexo printing



Screen printing

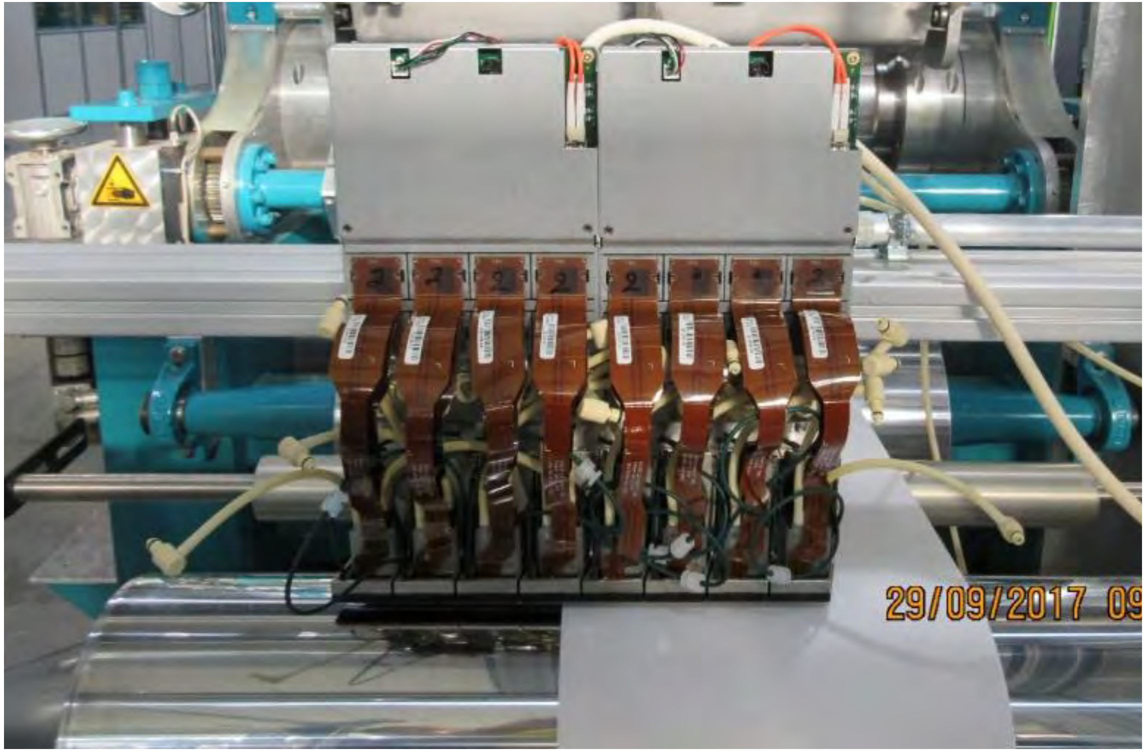


Inkjet Printing



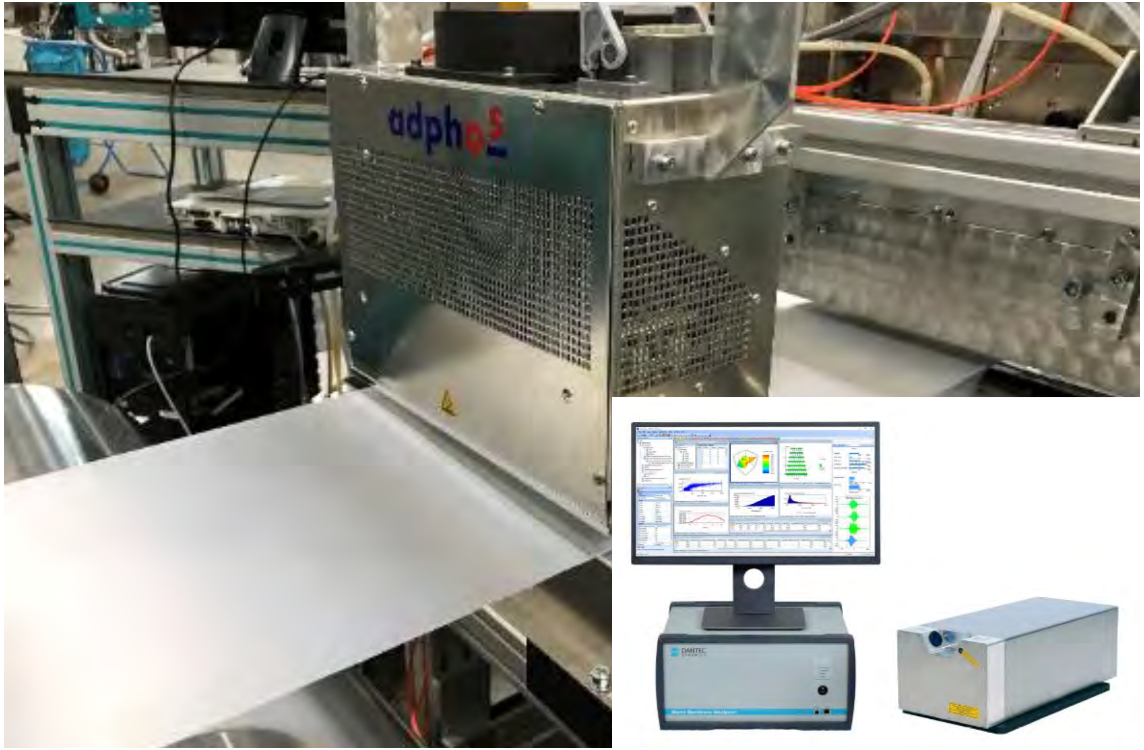
Inkjet Printing

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

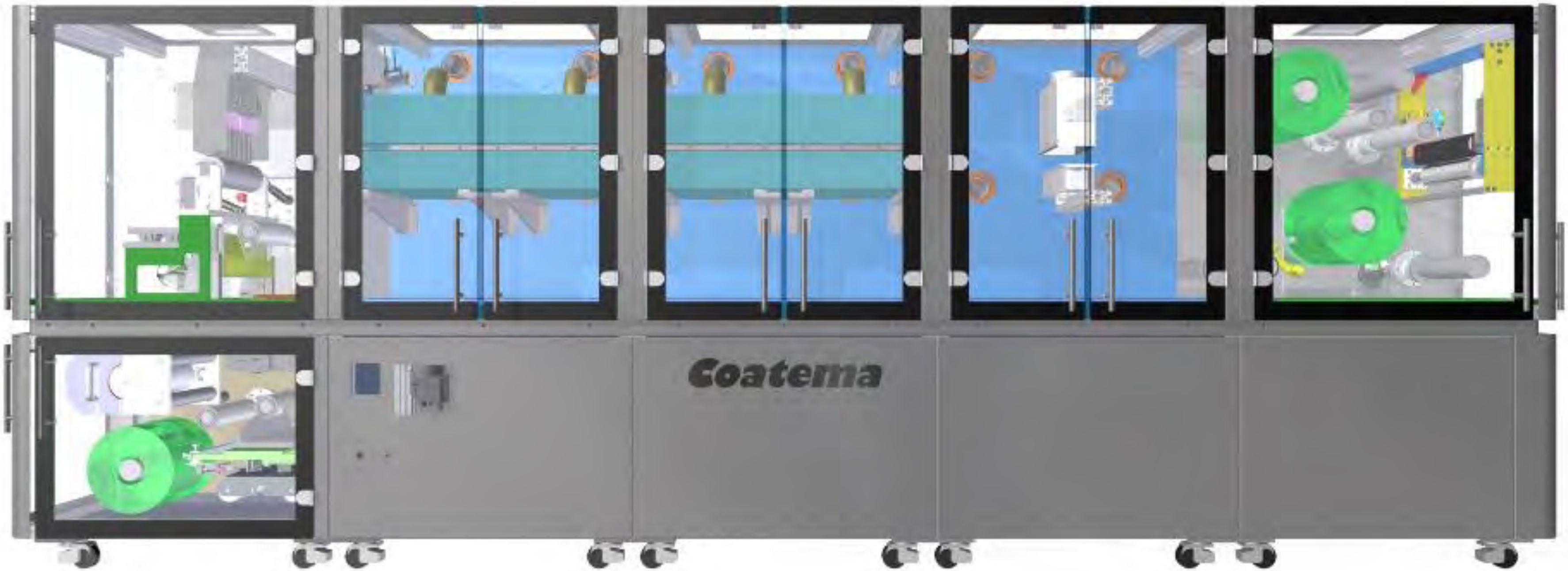


- ✓ Dantex dynamics "dropwatching"
- ✓ Velocity
- ✓ Size
- ✓ Sphericity
- ✓ Drying / Sintering
- ✓ Adphos NIR
- ✓ IR lamp
- ✓ Photonic sintering
- ✓ Hot Air dryer

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

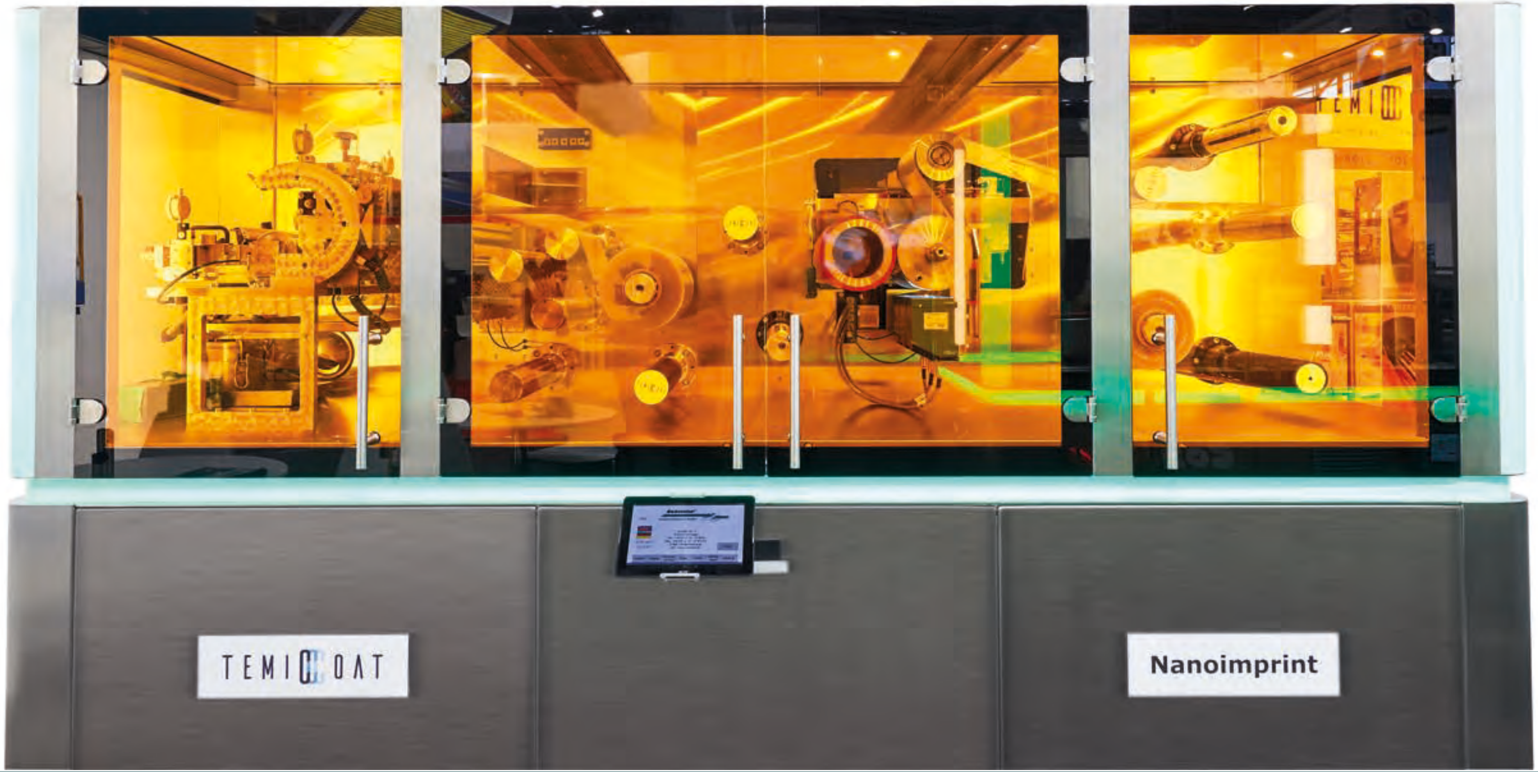


Integration – Machine layout

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



TEMICOAT NANOIMPRINT TECHNOLOGIES

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Nanoimprint technology

NIL – Nano imprint lithography

- **R2R** – roll-to-roll
- **R2P** – roll-to-plate
- **P2P** – plate-to-plate

Ultra Violet NIL

- UV-curable lacquer/ resin
- Short process time
- Processing at room temperature
- Hard or soft molds
- Low imprint pressure
- High replication resolution
- Low material shrinkage

Thermal NIL

- Thermoplastic substrate/ resin
- Long process time
- Processing above T_G
- Hard molds
- High imprint pressure
- One-component system
- High material shrinkage

Hard mold

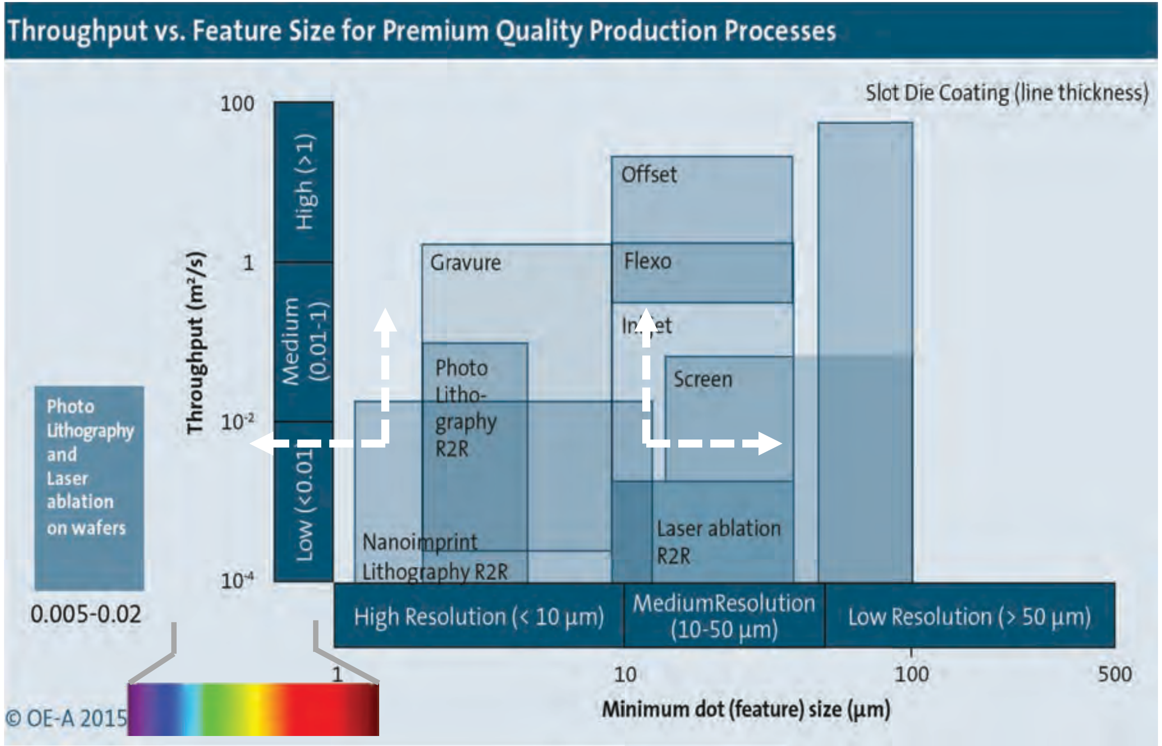
+ wear behaviour
+ life time of replication mold
+ resolution

Soft mold

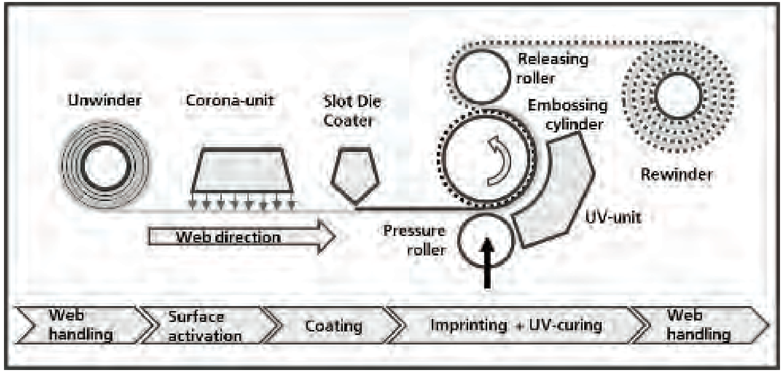
+ imprint pressure
+ life time of master mold
+ flexibilty

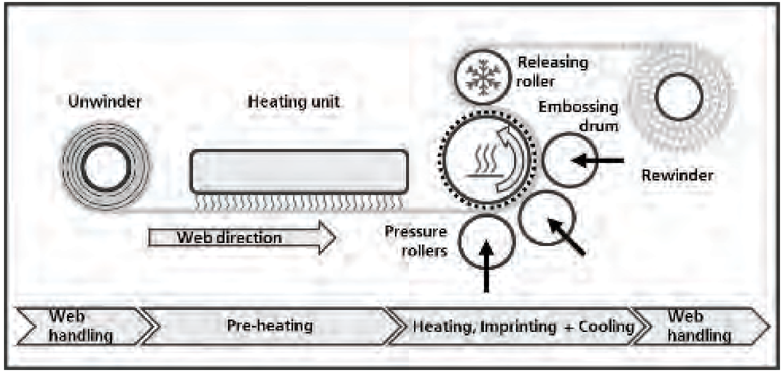
Fraunhofer IPT

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

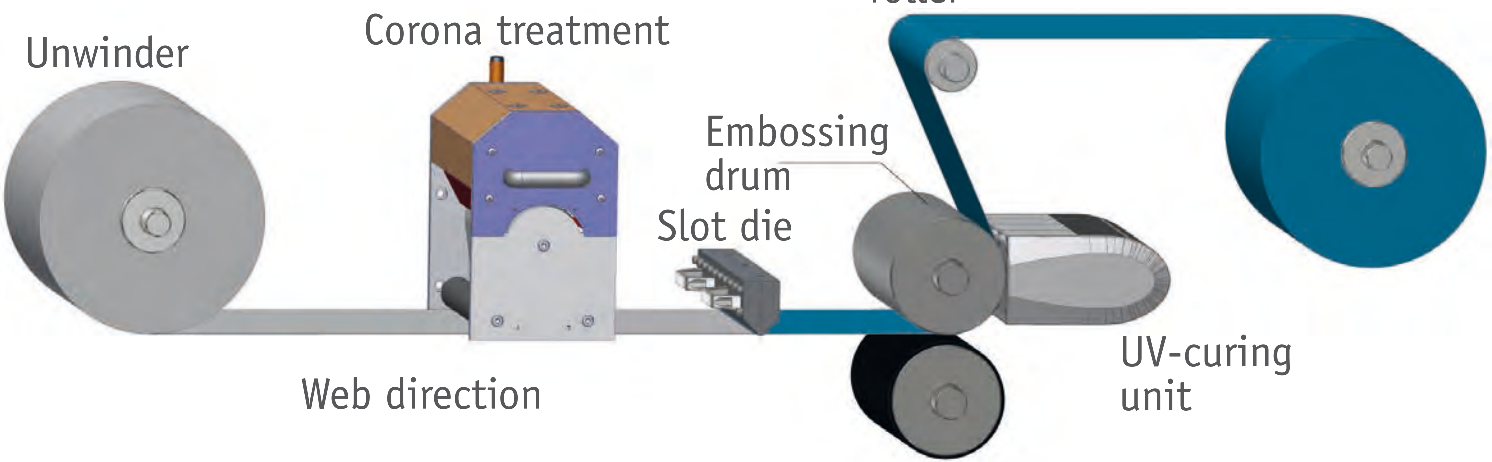
Nanoimprint Lithography

Fraunhofer IPT

Process parameters (selection):

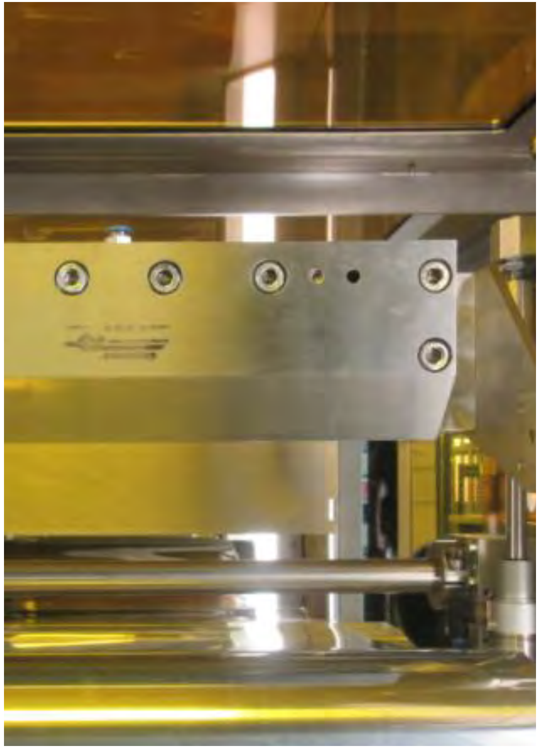
- ✓ Resist
  - ✓ Chem. Formulation
  - ✓ Viscosity / Rheology
- ✓ Film
  - ✓ Chem. Formulation
  - ✓ Chemical / mechanical pre-treatment
- ✓ Tool
  - ✓ Hard / soft mold
  - ✓ Anti-adhesion layer
- ✓ UV-source
  - ✓ Spectral distribution
  - ✓ LED- / conventional source
- ✓ Production system
  - ✓ Web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

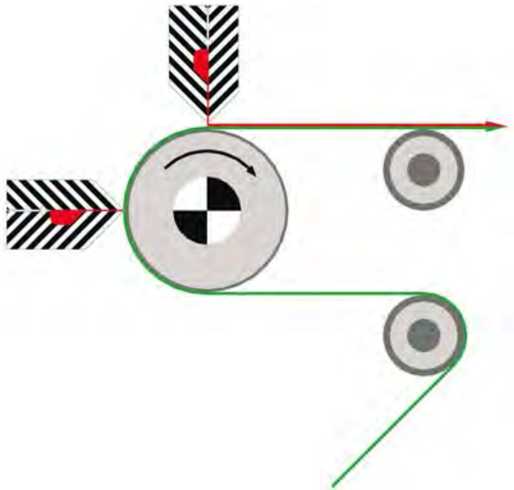
Nanoimprint Lithography



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

Coating and Printing for NIL – Nanoimprint Lithography

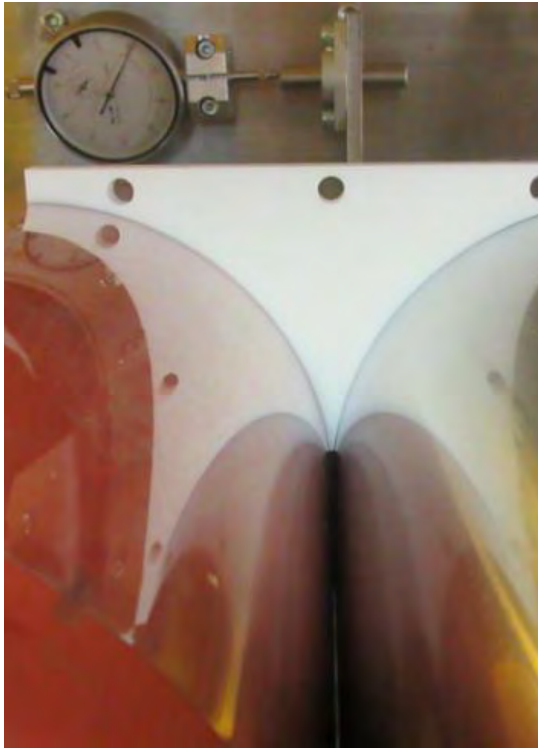


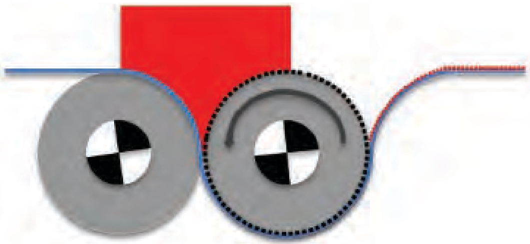


Slot Die coating for pre-metered film coating

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

Coating and Printing for NIL – Nanoimprint Lithography

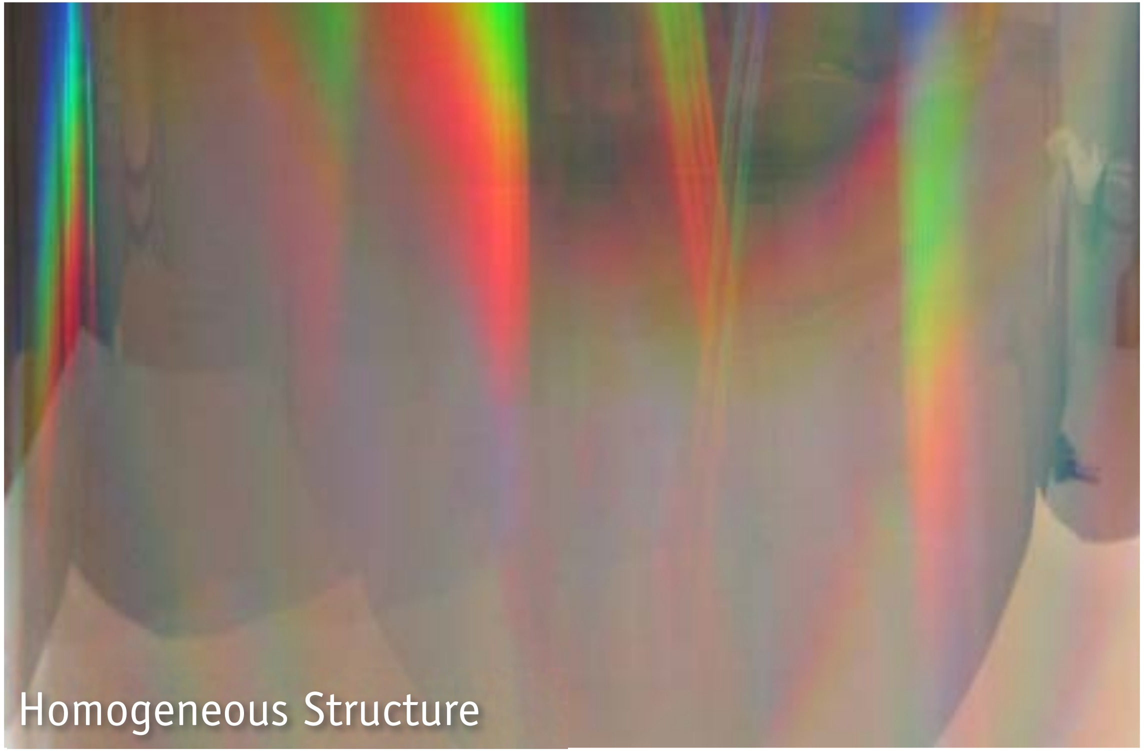




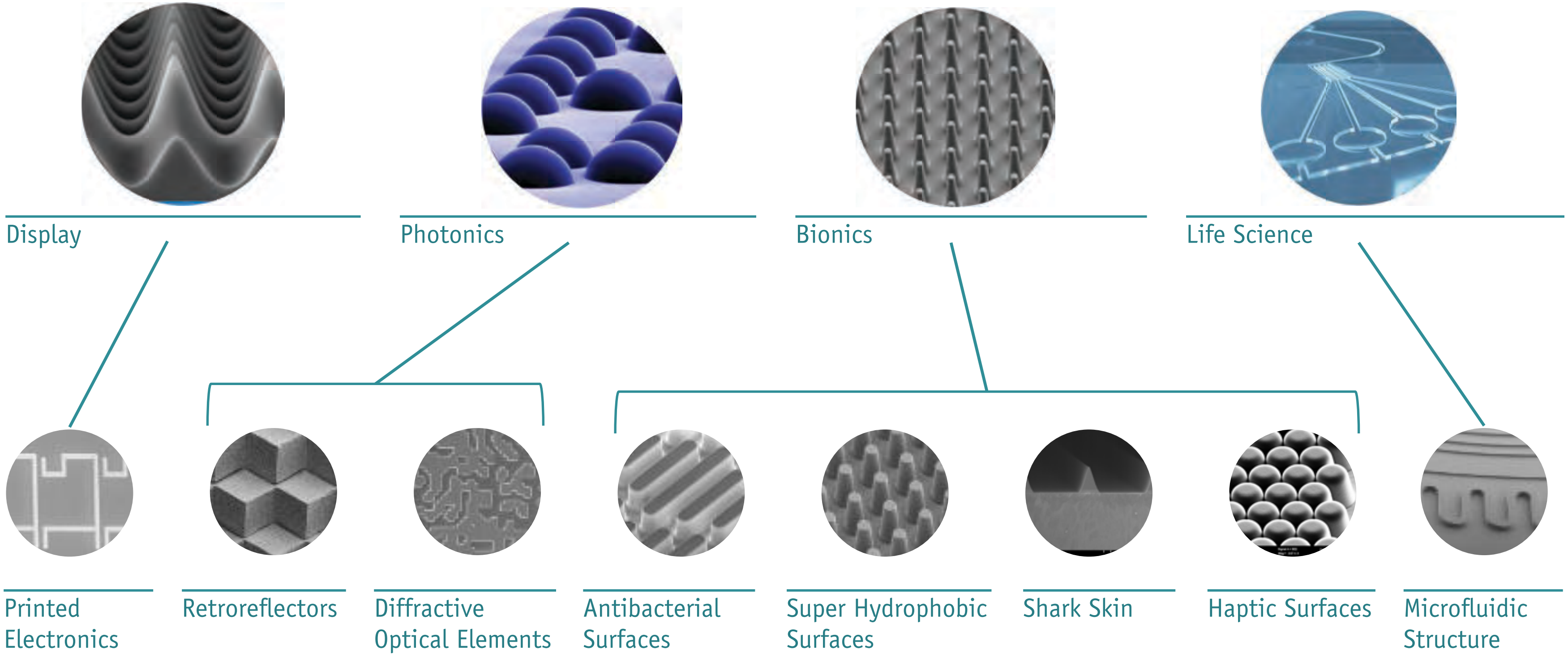
Nip coating

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

Coating and Printing for NIL – Nanoimprint Lithography

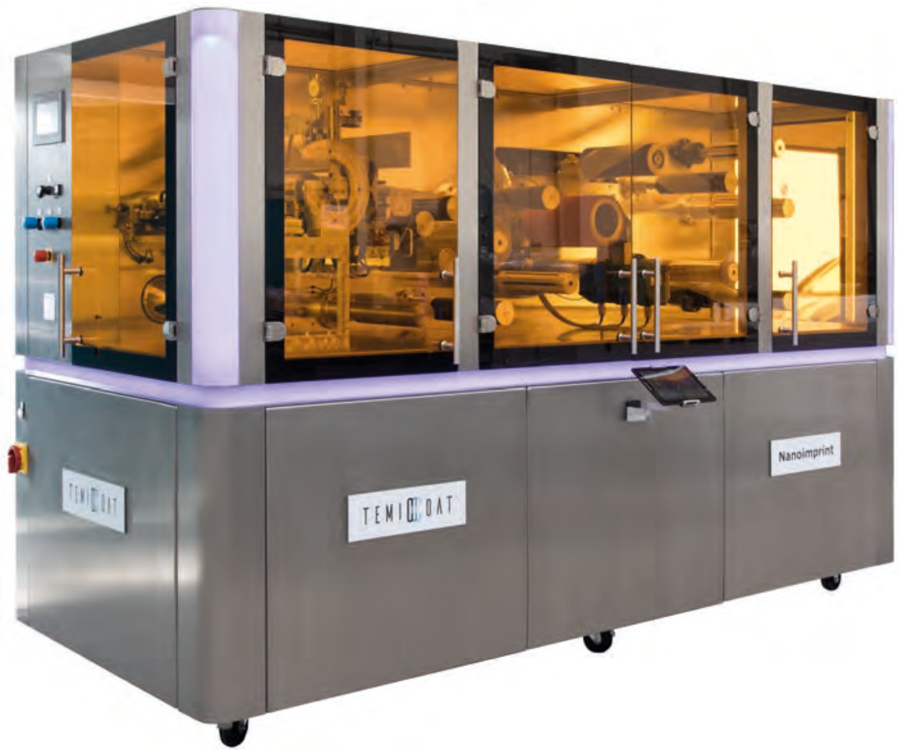


Applications

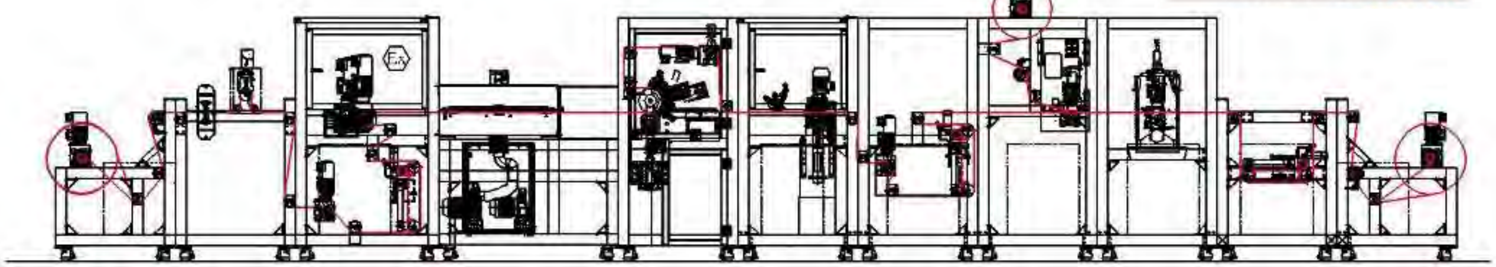


UV / NIL – Machines for Lab2Fab – R2R

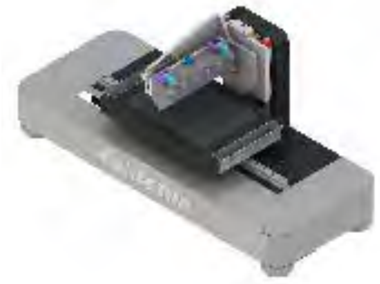
UV / NIL – Machines for Lab2Fab – R2R

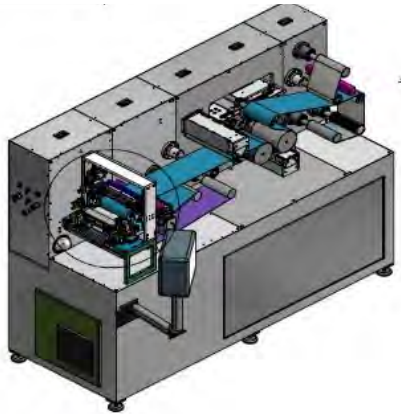


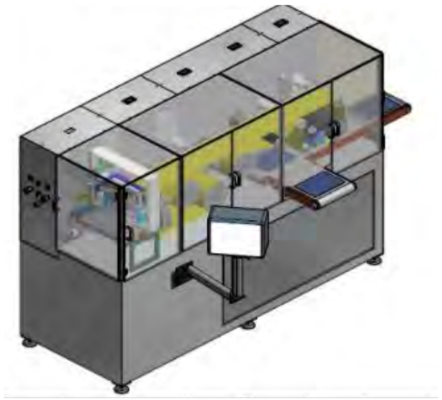
Nanoimprinting Combi System



UV / NIL – Lab2Fab – 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?

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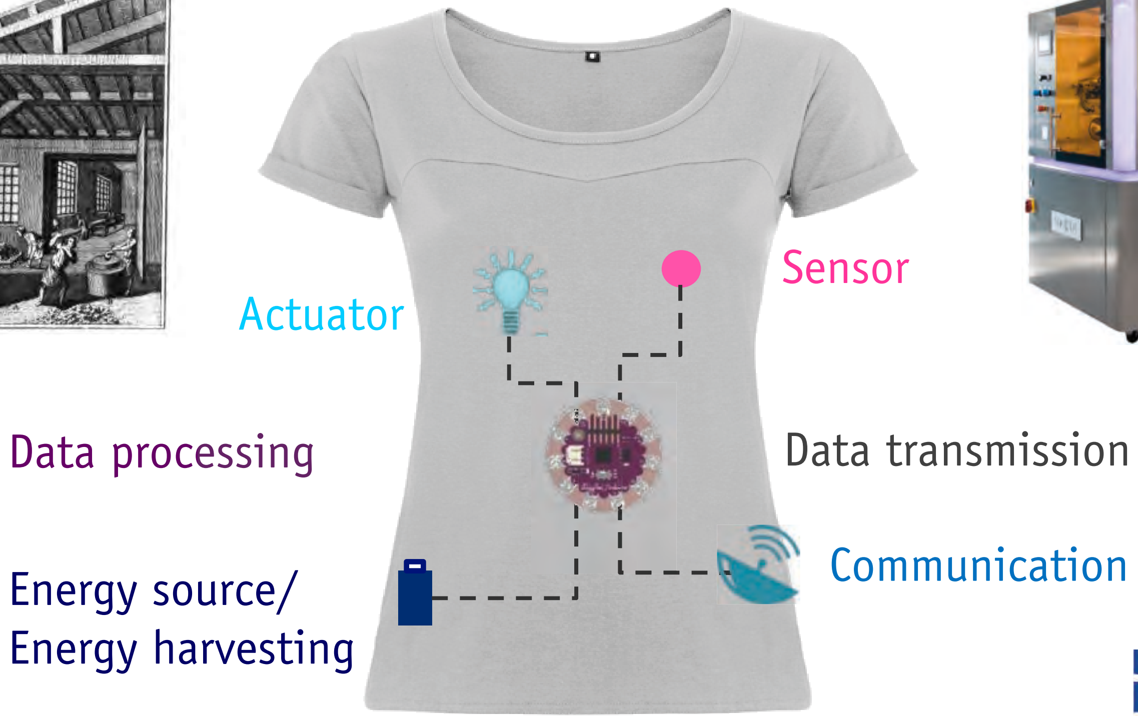
Bridging the gap



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