Production technologies for fuel cells

Overview

Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
Drying & curing	GDE & CCM approach	Todays equipment	Production line for MEAs	Summary

Summary

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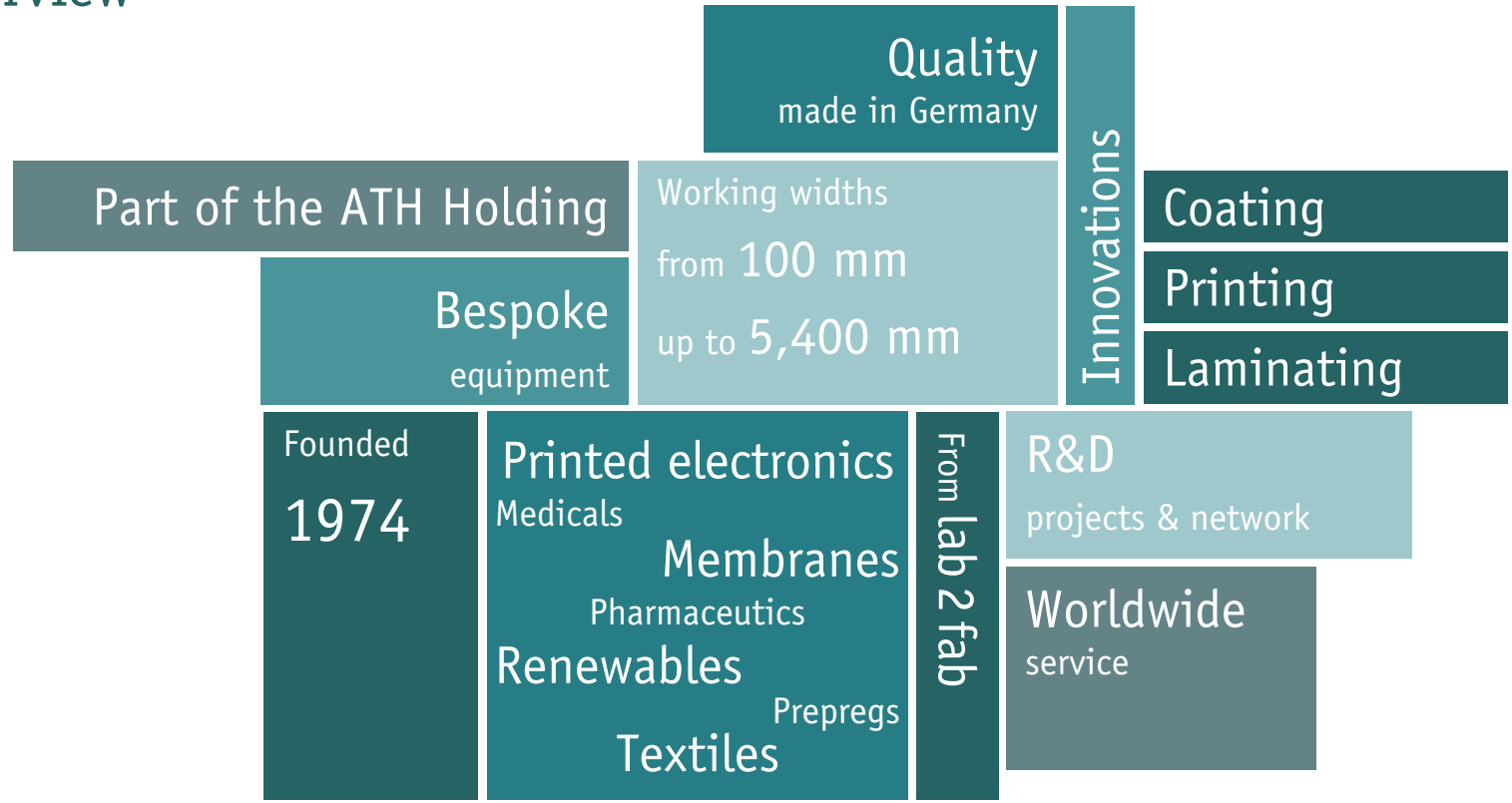
Overview



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

Vision – from lab 2 fab

Lab → **Pilot** → **Production**

Coatema equipment platform strategy for lab 2 fab

Summary

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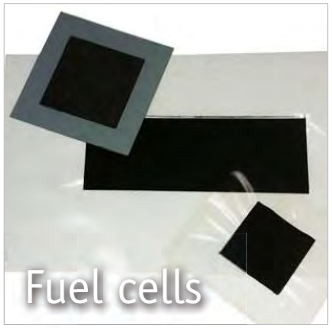
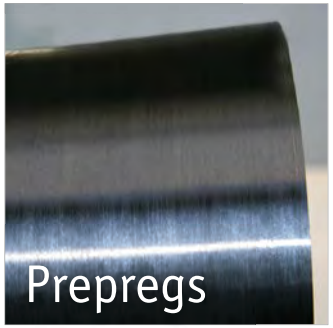
Our markets

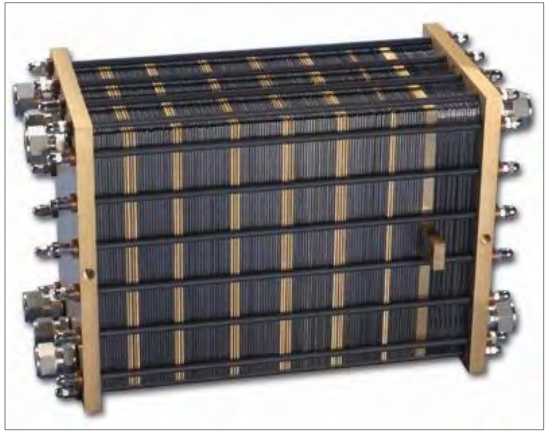




Renewables

Markets:

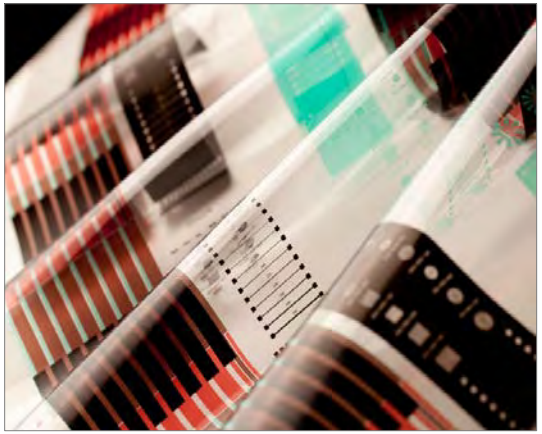
- ✓ Batteries
- ✓ Fuel cells
- ✓ Solar



Printed electronics

Markets:

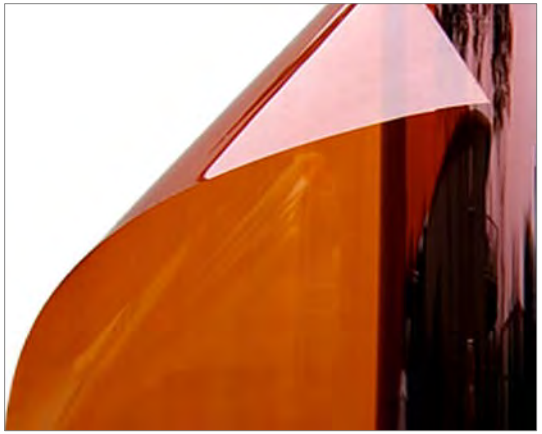
✓ Conductive coatings ✓ Smart systems ✓ Displays ✓ RFID ✓ OLED ✓ OPV ✓ Electronics



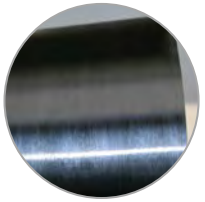
Membranes

Markets:

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



Prepregs

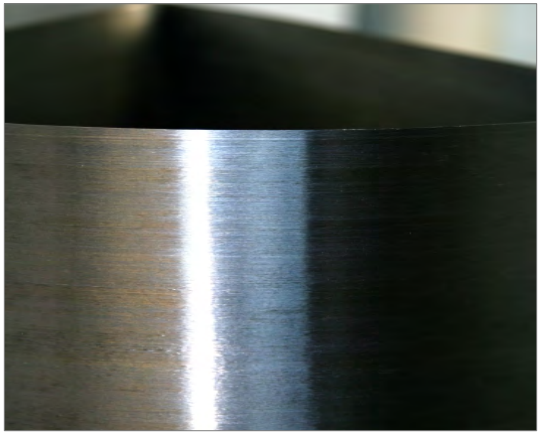


Markets:

✓ Automotives

✓ Aerospaces

✓ Constructions



Medical applications

Markets:

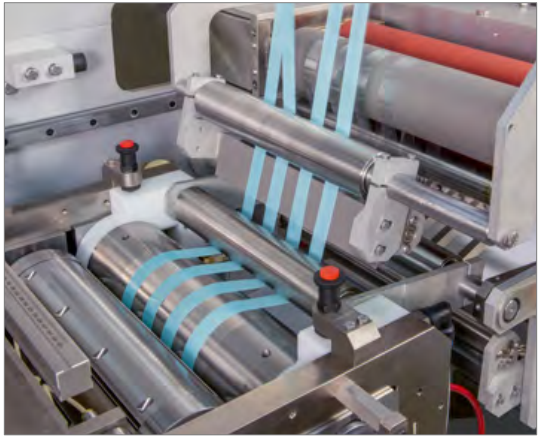
✓ Silicone gels ✓ Hydrogels ✓ Plaster ✓ Surgical materials

Pharmaceutics

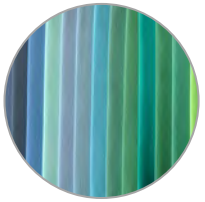
Markets:

✓ ODF (Oral Dispersible Film)

✓ Transdermal systems

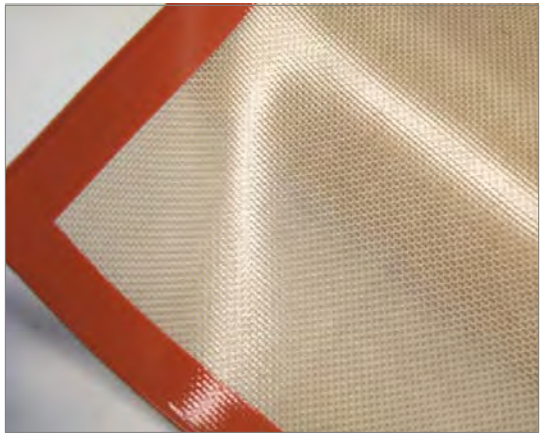


Textiles



Markets:

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



Lab units

Lab

Test Solution S2S

Easycoater

Test Solution R2R

Pilot lines

Pilot

Click&Coat™

Smartcoater

Basecoater 3rd Generation

Pilot lines

Pilot

Deskcoater

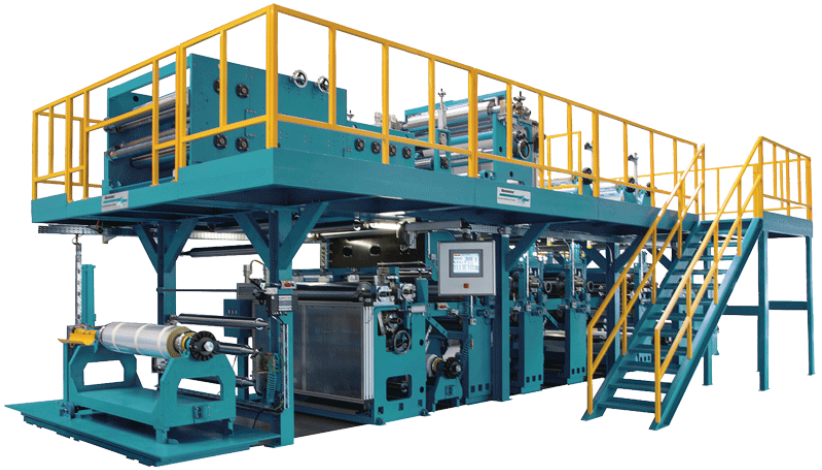
Linecoater

Verticoater

Production lines

Production

Production lines



Prepreg plants

Bespoke equipment

Custom made

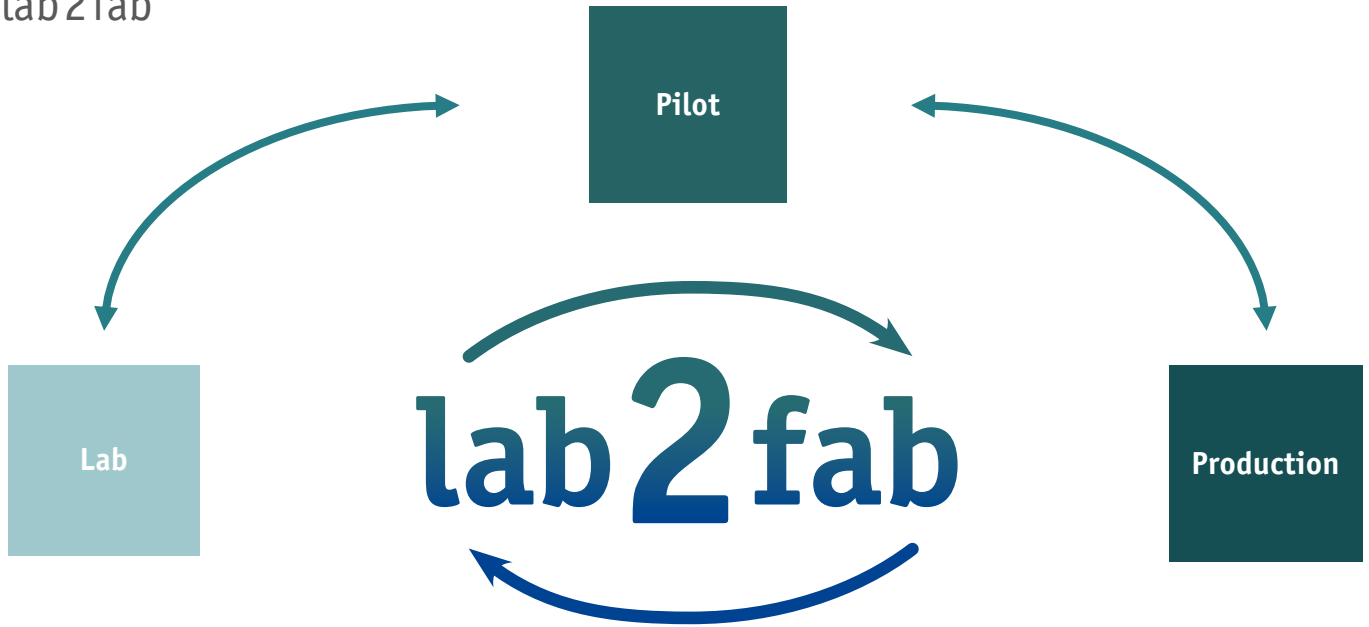
Printed oleds

Batteries

Composite fibres

Scaling up new technologies

Tools for lab2fab



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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

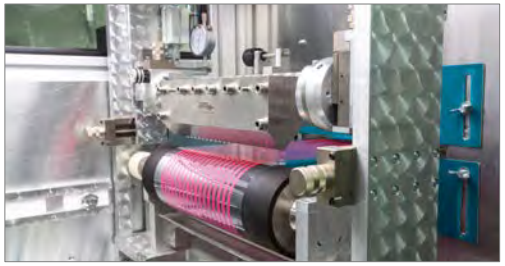
R&D centre KROENERT & DRYTEC

Product portfolio:

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

R&D centre Coatema

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

R&D projects

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 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

R&D projects 2020

PowderSizing

Bundesministerium für Wirtschaft und Energie
FKZ: ZF4099702BL6
FKZ: TF4018750BL6c

PowderSizing: Process chain for powder laminated **glass fiber** enhanced compounds. 3 years, 0.8 M€

Coatema: Developing coating rollers for improved surface coverage of fibers.

FLEX-G

Bundesministerium für Wirtschaft und Energie
FKZ: 03ET1470D

FLEX-G: Flexible **roof and facade elements.**
3 years, 2.4 M€

Coatema: Transferring the lab process to a R2R process and upscaling.

GREEN SENSE

GA No. 761000

Greensense: Sustainable **paper-based** printed electronics and **biosensing platform.** 4 years, 8.0 M€

Coatema: Engineering of machinery and process development for Nano Cellulose.

SUPERSMART

GA No. 0800645

Supersmart: Scale-Up of Printed Electronics Recyclable SMART materials.
3 years, 5.0 M€

Coatema: Subtask partner for machinery development.

SOLID

Bundesministerium für Wirtschaft und Energie
FKZ: 03XP0129C

SOLID: Innovative **solid state batteries** with Sol-Gel, Li anodes and 3D structuring.
3 years, 2.1 M€
Coatema: Upscaling of lab processes for Sol-Gel materials and integration of new concepts.

Oled Solar

GA No. 820789

OLEDSOLAR: Scale-Up of opto-electronics to production.
3 years, 7.8 M€

Coatema: Improving registration accuracy in R2R processes.

EL-FIB
ELECTROLUMINESCENCE for FLAGS, INTERIOR and BANNERS

ZIM Zentrales Innovationsprogramm Mittelstand

ZF4099704SL8

EL-FIB: Development of **electro-luminescent tapestry.**
2 years, 1.2 M€

Coatema: Upscaling of printing and coating processes**, intermittent slot die.**

PEPcat

Bundesministerium für Bildung und Forschung
FKZ: 02WCL1019C

PEPcat: Plasmonically Enhanced Photocatalysis for Waste-Water Treatment. 3 years, 3.0 M€
Coatema: Novel Easycoater Design for S&R R2P NIL; Enhancing the system accuracy to s digit micrometer range.

R&D projects 2020

E-Nanoprint Pro

Rocket-Re: -I-XXX

E-Nanoprint Pro: Nanowire printing Process development for Health-medical applications.

Coatema: Integration E-Nano printing head in R2R process equipment.

EffiLayers

EFRE-0801555

Effilayers: Flexible **organic solar-cells**. 3 years, 1.5 M€

Coatema: Process development and equipment for R2R Process.

REAL NANO

GA No. 862442

RealNano: In-line and Real-time Nano-characterization technologies for flexible OE. 3 years, 4.9 M€

Coatema: Integration of characterization tools in pilot to production line.

FLEX FUNCTION 2 SUSTAIN

GA No. 862156

FF2S: Upgrade of various **pilot lines** and connection to an open-innovation test bed (**OITB**). 4 years, 16 M€
Coatema: Upgrade of the R&D centre and of two external pilot lines; development of a R2R ALD system; execution of user and pilot cases .

Bundesministerium für Bildung und Forschung

FKZ: 0324151C

SOLGEL-PV: multipurpose **Sol-Gel films for PV.**
3 years, 2.0 Mio.€

Coatema: Upscaling of **R2R Nano-Imprint process toward Click&Coat®**

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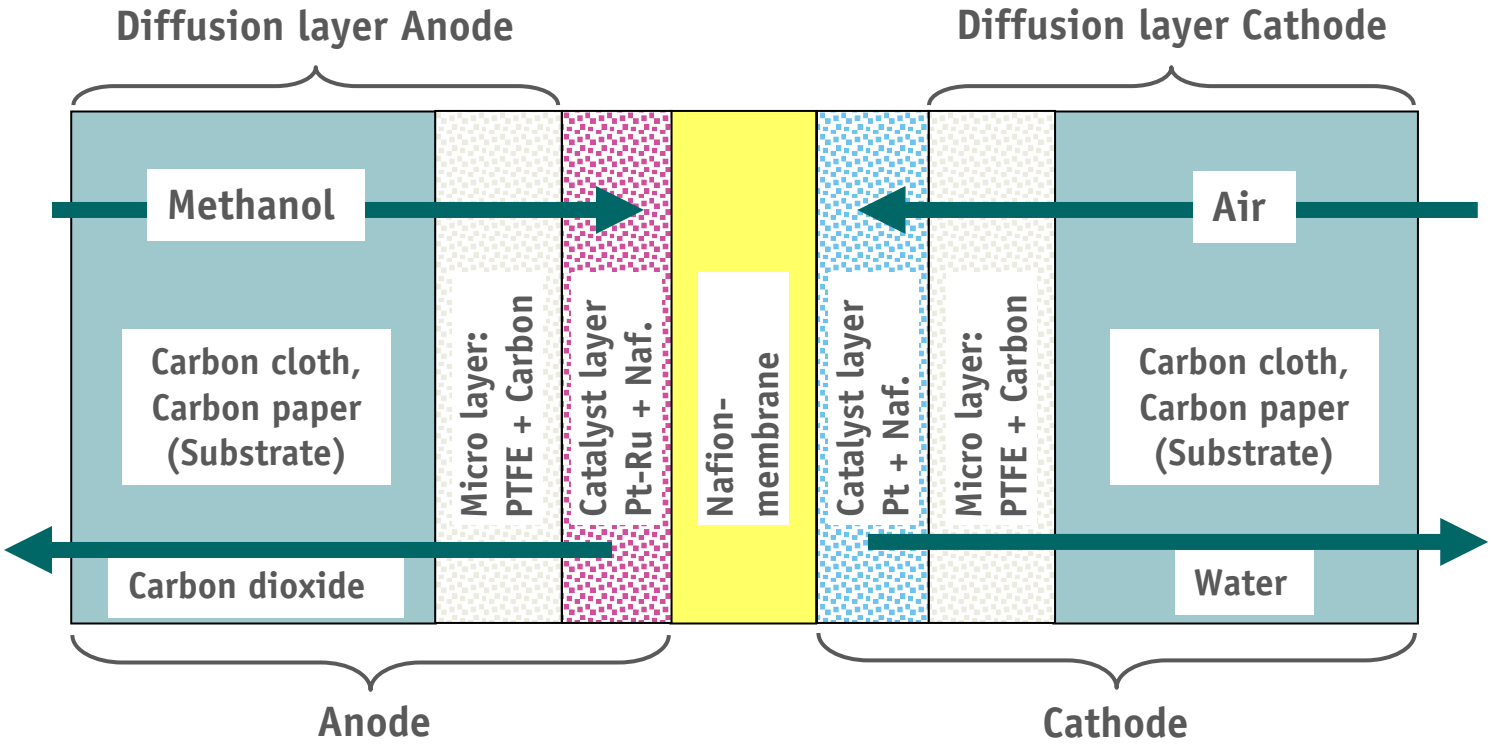
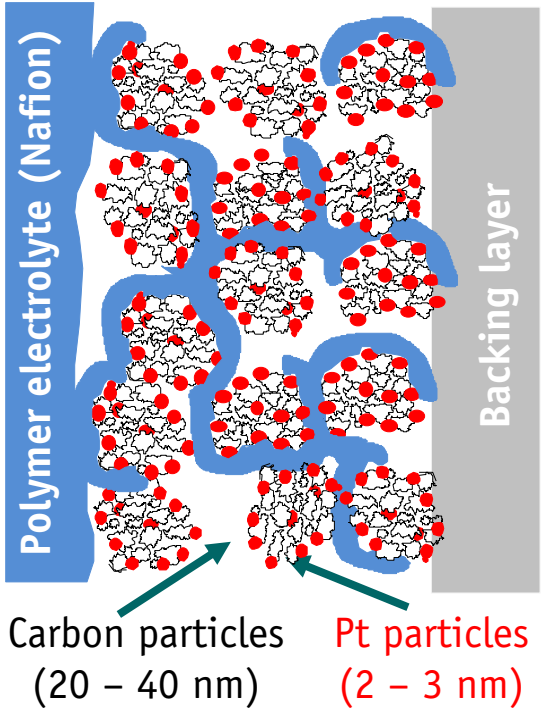
MEA-components



Structure of an MEA



catalyst,
ionomer colloid,
solvent mixture,
additives mixing

Catalyst ink

Coating on GDL or membrane
(Spraying, screen printing,
ink jet, knife …)

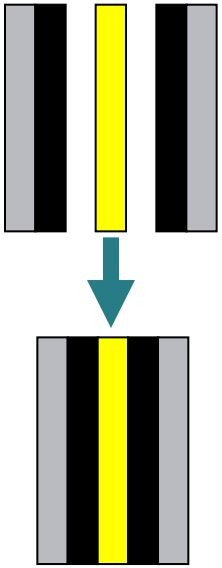
Hot pressing

MEA

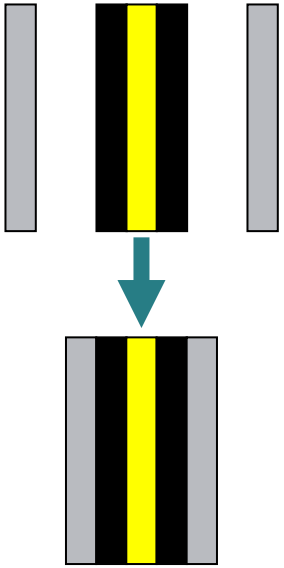
Quelle: Institute of Energy Research – Fuel Cells (IEF-3),
Juelich Research Center part of Helmholtz-Community

Manufacturing methods

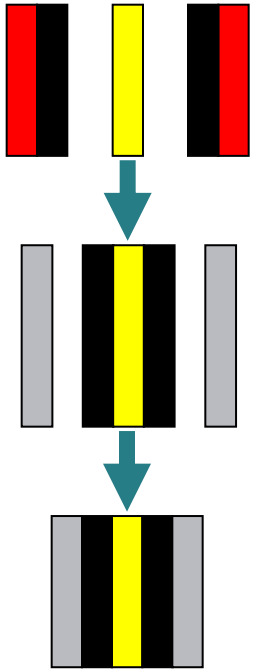
GDE method



CCM direct



CCM indirect



MEA: **M**embrane-**E**lectrode-**A**ssembly
GDL: **G**as **D**iffusion **L**ayer
GDE: **G**as **D**iffusion **E**lectrode
PEM: **P**olymer **E**lectrolyte **M**embrane
CCM: **C**atalyst **C**oated **M**embrane

Status MEA 1999 – 2010

CCM method

- ✓ Application of catalyst layer to membrane by direct coating or decal, transfer by hot pressing
- ✓ Laminating GDL to CCM

- ✓ Membrane dimension instability
- ✓ Reinforced membranes needed
- ✓ Less flexibility to GDE/MEA configuration or dimension change
- ✓ Difficult to scale up for mass production
- ✓ expensive laboratory instrument investment and expensive to scale up

GDE method

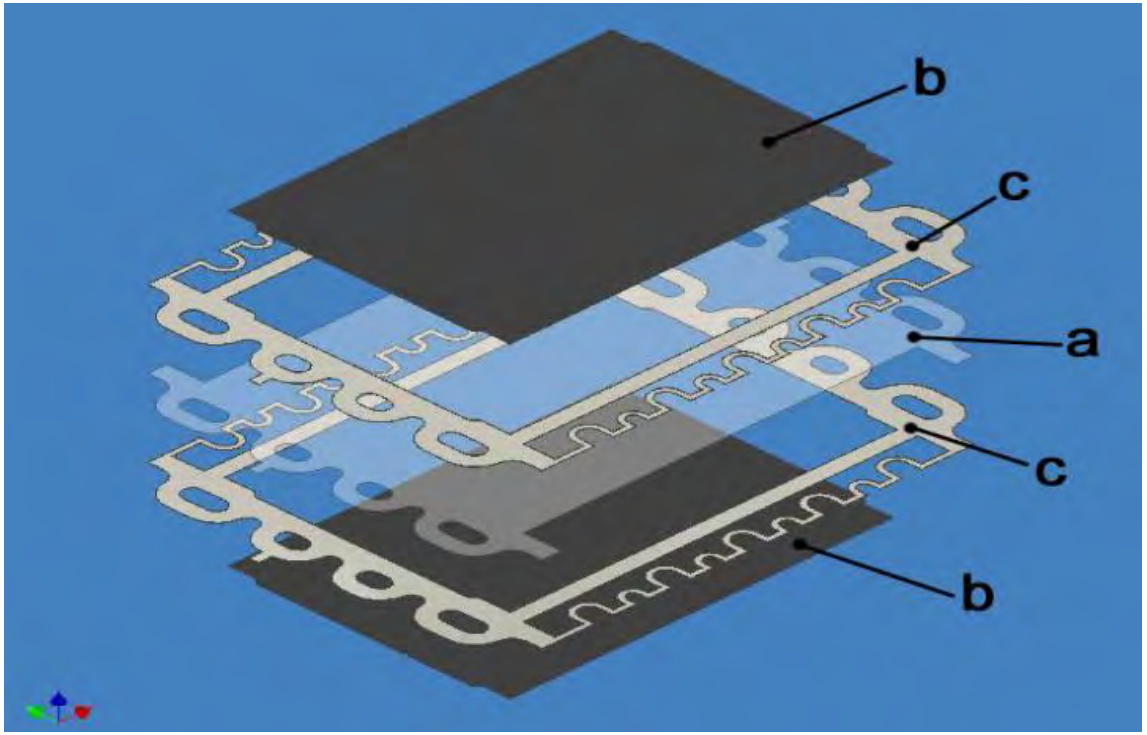
- ✓ Application of catalyst layer to gas diffusion layer (GDL)
- ✓ Laminating GDE to membrane

- ✓ Easy to transfer from laboratory scale to mass production scale
- ✓ Flexibility in MEA flexibility in MEA configuration & dimension change

- ✓ Difficulty in catalyst layer thickness (low catalyst loading)

Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Manufacturing methods



Parts of an MEA

a) Membrane
b) Gasdifusion layer
c) Subgasket /Gasket

Equipment in 1999 – Deskcoater

Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Conclusion in 1999

Common points for fuel cell development are:

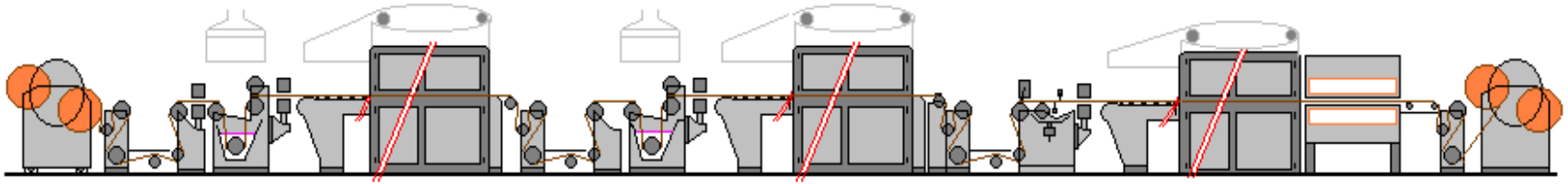
- ✓ Thinner coatings with defined edges for the CCM are needed – thin film coating methods, intermittend coatings etc.
- ✓ Laminating of GDL/GDE with CCM/Membran – Research on parameters in the continous laminating process has to be focused
- ✓ New developments of reinforced membranes are needed to get higher production speed

Where are the mass markets for fuel cell application?

The vision in 1999

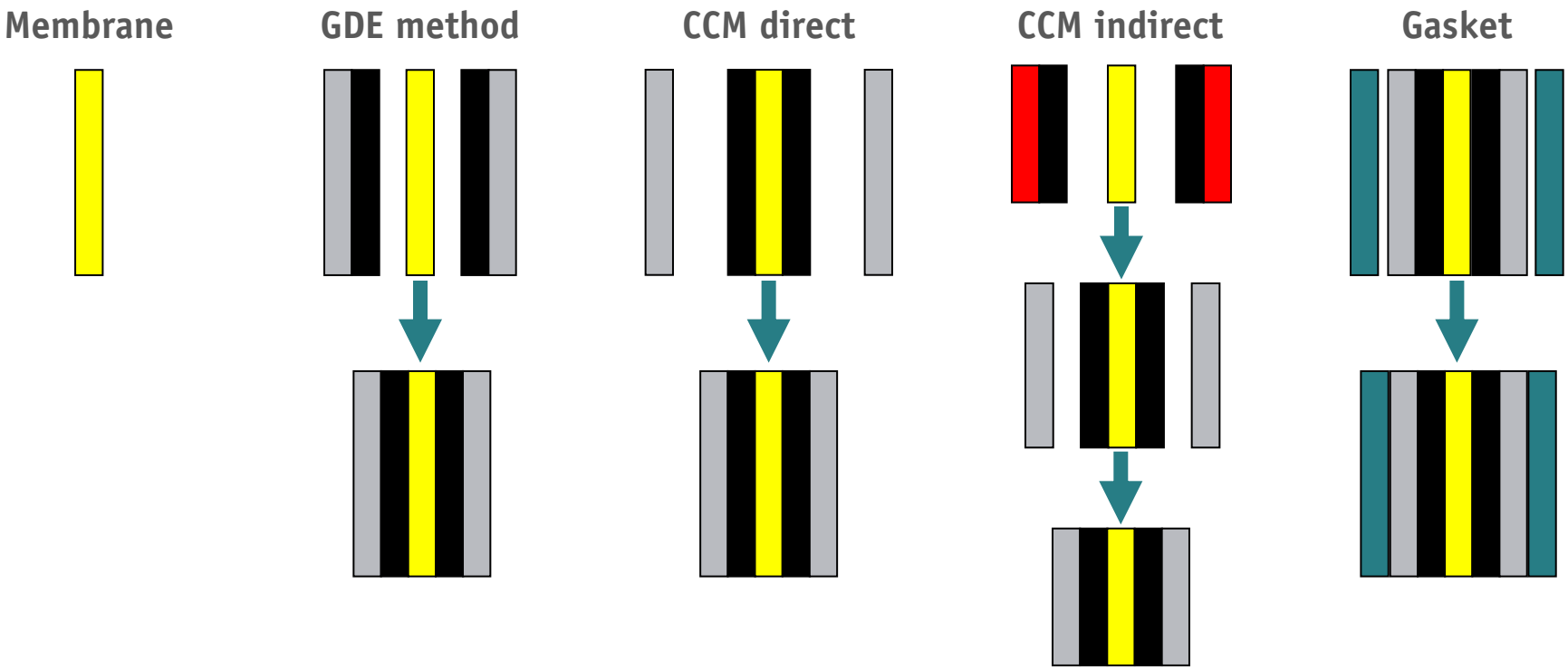
Turning winder, autom. edge controlled
pulling roller station with tension controll
thickness gauge unit
impregnation bath with squising roller and thickness gauge unit
clamp clip tenter with exhaust hood
COATEMA Jet- Dreyer with air duct system to be combined with incenerator plant
pulling roller station with tension controll
pulling roller
impregnation bath with squising roller and with thickness gauge unit
clamp clip tenter with exhaust hood
COATEMA Jet- Dreyer with air duct system and to be connected with incenerator plant
pulling device with tension regulating device and pedestal
both sites coating and applicating equipment with thickness gauge unit
Klemm-Spannrahmen mit Absaughaube
COATEMA Jet dreyer with air duct system and to be connected with an incenerator plant
IR operated sintering station
edge guiging device with tension controll
winding station

Impregnation- & Coating Plant: GDE



Realization in 2008

Coatema‘s today products



Coatema's today products

GDE method

CCM direct

CCM indirect

Membrane manufacturing

Coatema‘s today products

CCM method	Coating area / working width (ww)
✓ EC fuel cell	✓ (A4/A3)
✓ Smartcoater fuel cell	✓ ww 300 mm
✓ Linecoater fuel cell	✓ ww 500 mm / 1,000 mm
✓ Double side coating CCM unit	✓ Available in different ww
✓ Mixer for catalyst layer available	
✓ Quality control system	

Coatema‘s today products

Indirect CCM method	Coating area / working width (ww)
✓ EC fuel cell	✓ (A4/A3)
✓ Test Solution combi	✓ ww 100 mm
✓ Basecoater combi	✓ ww 300 mm / 500 mm
✓ Smartcoater combi	✓ ww 300 mm
✓ Linecoater combi	✓ ww 500 mm / 1,000 mm
✓ Production combi	✓ ww 1.500 mm and on request
✓ Hot pressing station	✓ Available in different ww

Coatema‘s today products

Membrane production	Coating area / working width (ww)
✓ Basecoater combi	✓ ww 300 mm / 500 mm
✓ Smartcoater combi	✓ ww 300 mm
✓ Linecoater combi	✓ ww 500 mm / 1,000 mm
✓ Production combi	✓ ww 1.500 mm and on request

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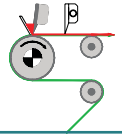
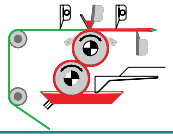
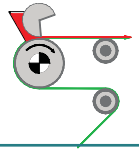
Coating systems



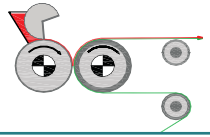
Knife system



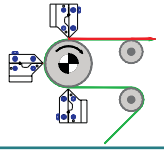
Double side system



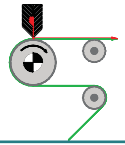
Commabar system



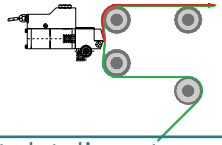
Reverse commabar system



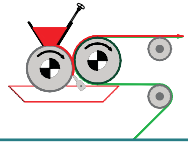
Slot die system



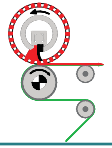
Curtain coating system



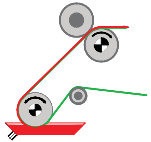
Hotmelt slot die system



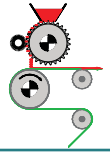
Case knife system



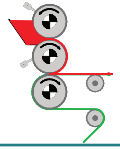
Rotary screen system



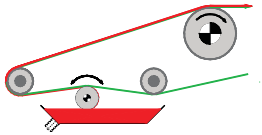
Dipping system (Foulard)



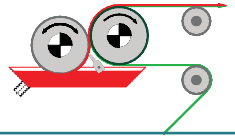
Powder scattering system



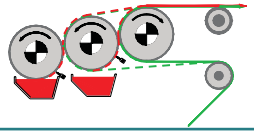
Reverse roll system



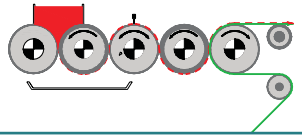
Micro roller system



2 Roller system

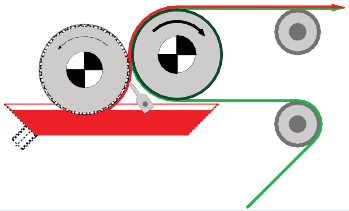


3 Roller combi system

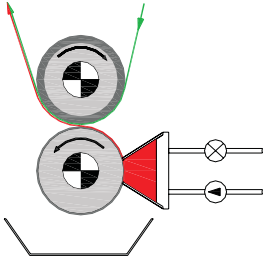


5 Roller system

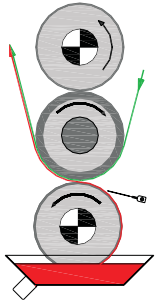
Printing systems



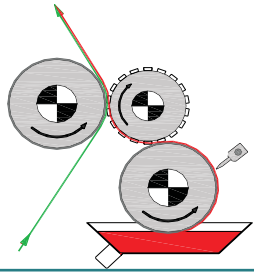
Engraved roller system



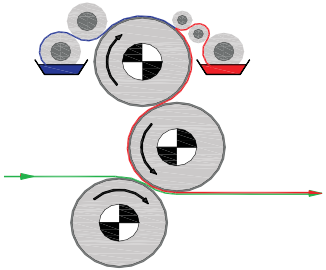
Gravure roller system



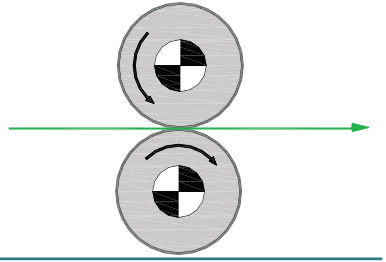
Gravure indirect system



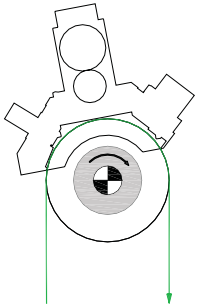
Flexography system



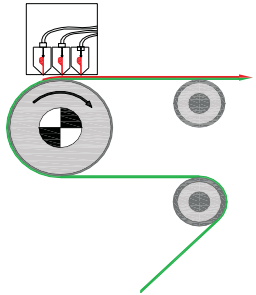
Offset lithography system



Hot embossing system



Nanoimprint system



Inkjet system

Processes – definition of coating systems

Category of coating methods	Examples of coating methods belonging to the category	Characteristics
Self-metered	✓ Dip roll ✓ Nip forward roll ✓ Reverse roll	✓ Wet thickness is determined by the conditions of the coating meniscus
Doctored	✓ Mayer rod ✓ Blade / knife ✓ Air knife ✓ Dip & scrape	✓ Post applicator device determines the wet thickness
Pre-metered	✓ Slot die ✓ Slide curtain ✓ Spray	✓ All the ink fed into an applicator is transferred to the web

Technologies & processes – process parameters

Process parameters are:

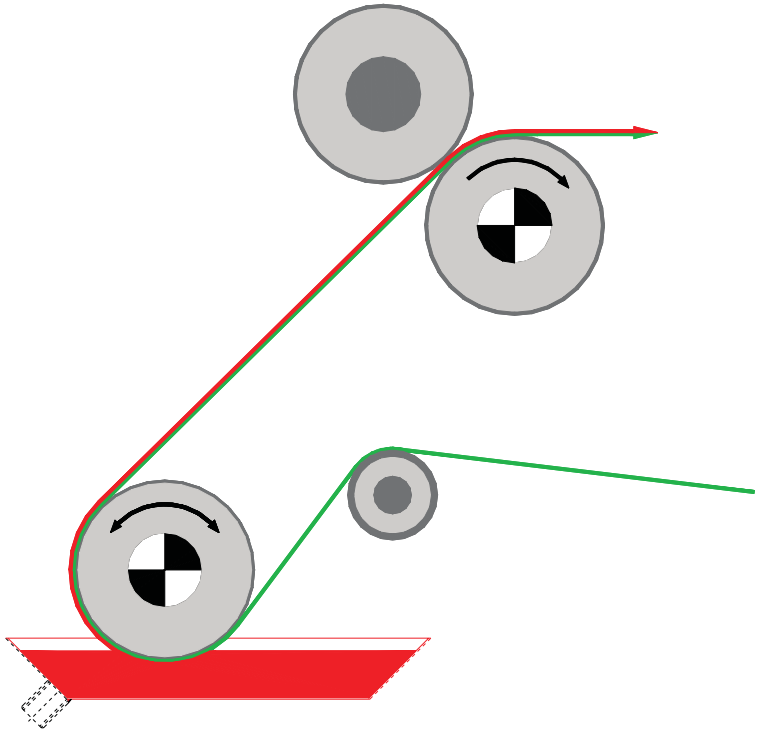
- ✓ Operation speed
- ✓ Rheology of coating and printing inks
- ✓ Substrate condition
- ✓ Tension control MD / CD
- ✓ Edge control
- ✓ Resolution and registration accuracy of printing / laminating systems
- ✓ Precision of coating operations
- ✓ Curing / drying / crosslinking

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			

Dipping system



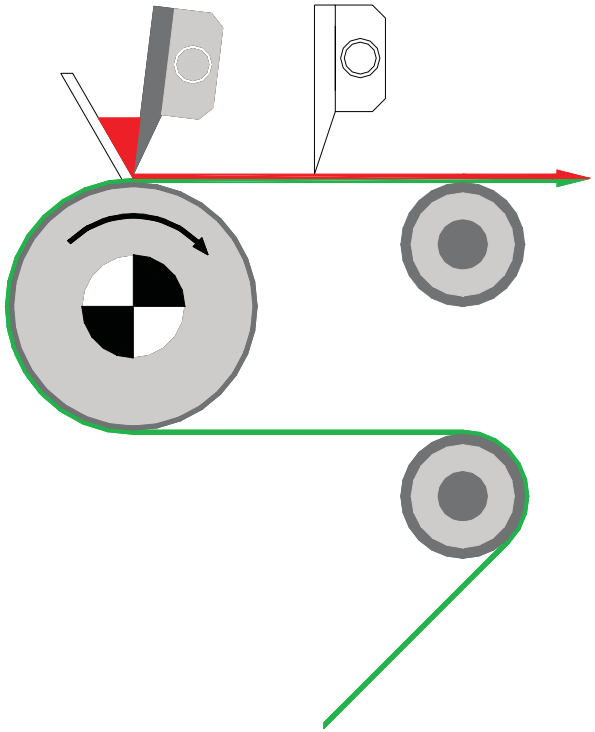
Variation of the coating weight

✓ Depending on the textile

Range of viscosity

✓ 1 – 10 000 mPas

Knife coating



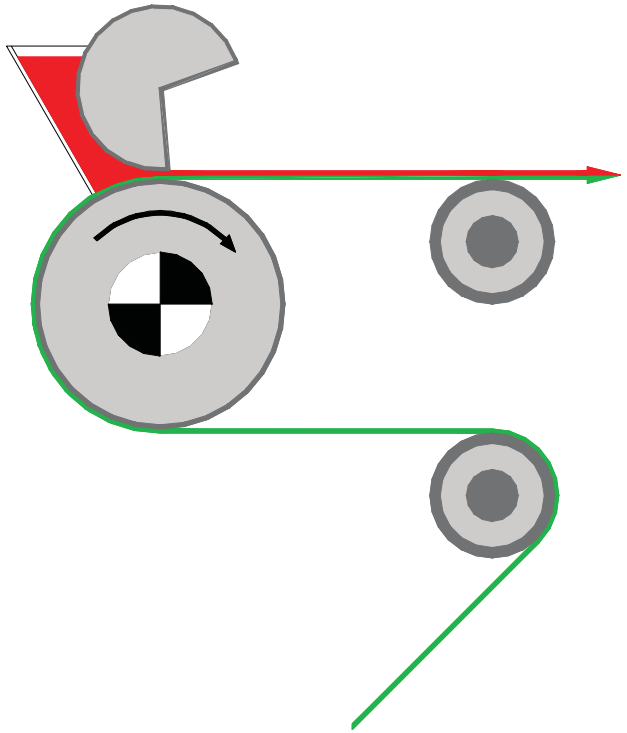
Variation of the coating weight

- ✓ Roller knife
  10 – 1.250 g/m²
- ✓ Air knife 5 – 6 to 60 g/m²

Range of viscosity

- ✓ Paste (1000)
  100 – 50 000 mPas
- ✓ Foam
  10 000 – 25 000 mPas
- ✓ Air knife
  5 – 10 000 mPas

Commabar coating



Variation of the coating weight

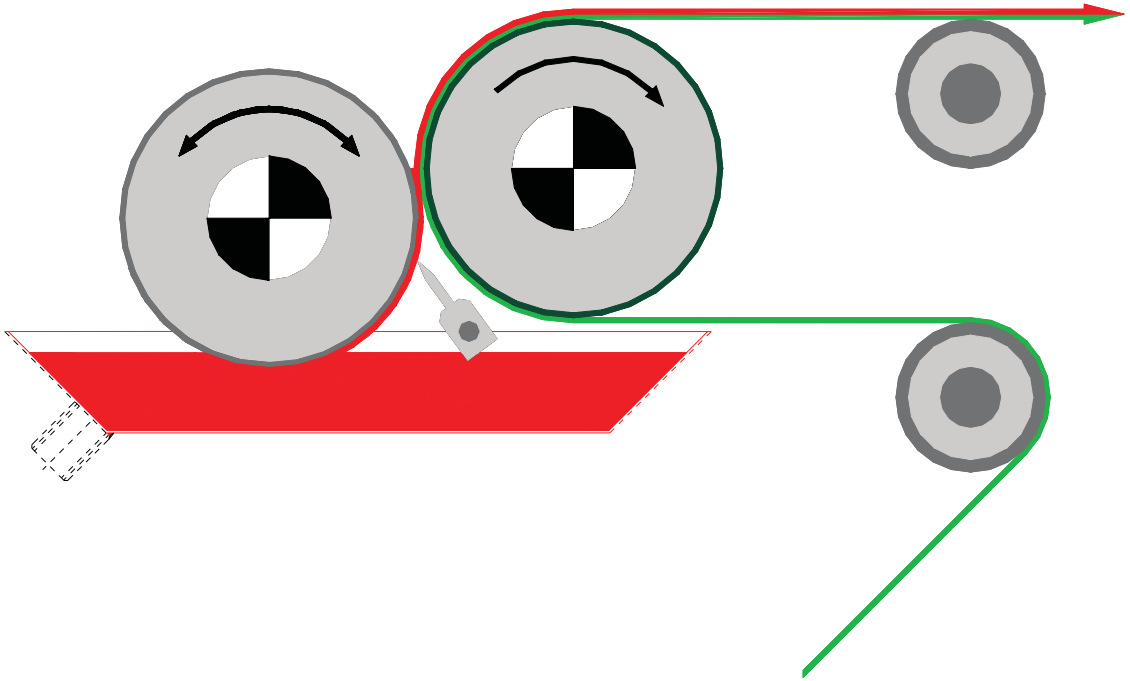
✓ Air knife
5 – 6 to 1.250 g/m²

Range of viscosity

✓ Paste
5 – 6 to 60 g/m²

✓ Foam
10 000 – 25 000 mPas

Gravur coating



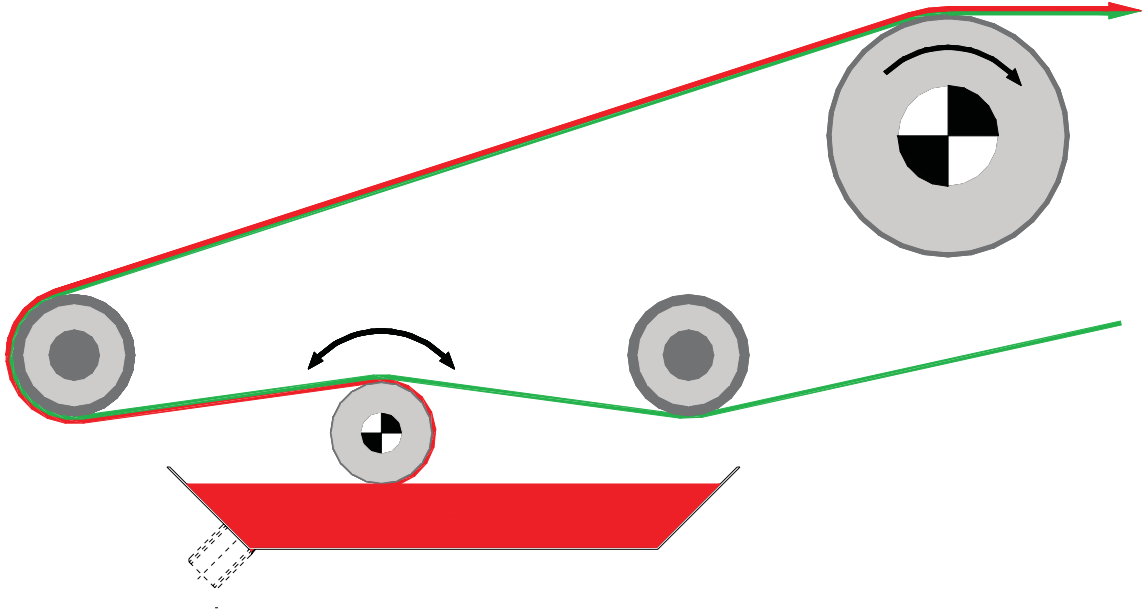
Variation of the coating weight

✓ 2 – 200 g/m²

Range of viscosity

✓ 1 – 15 000 mPas

Micro roller coating



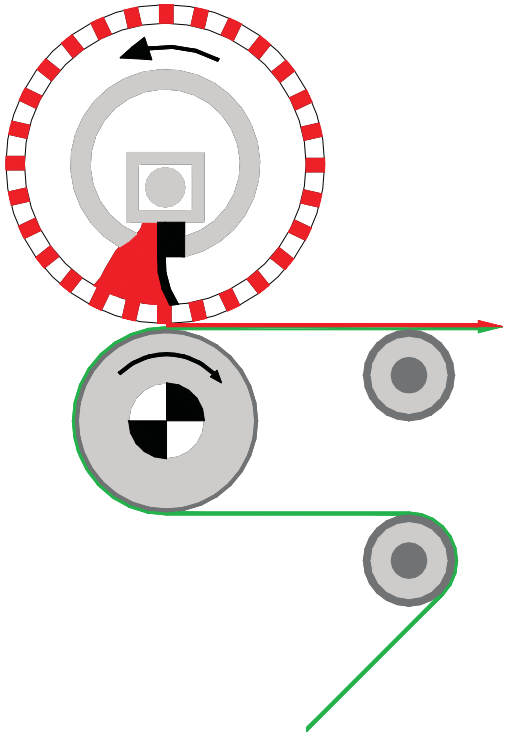
Variation of the coating weight

2 to 100 g/m²

Range of viscosity

1 – 15 000 mPas

Rotary screen coating



Variation of the coating weight

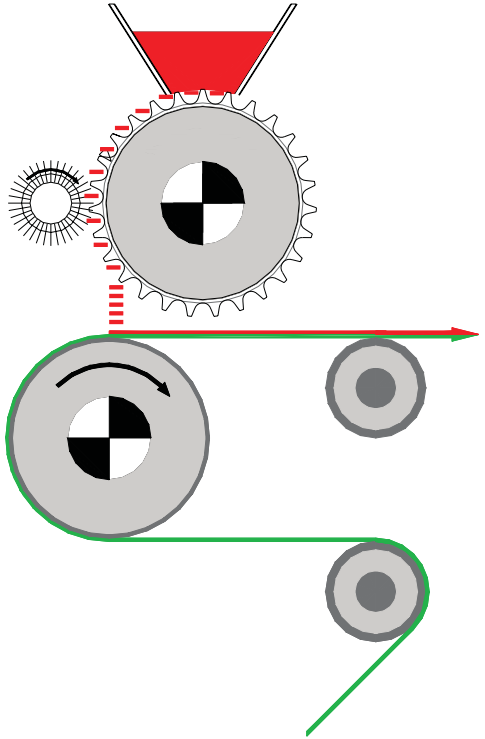
✓ 10 – 300 g/m²

Range of viscosity

✓ Paste
10 000 – 80 000 mPas

✓ Paste
10 000 – 25 000 mPas

Powder scattering coating



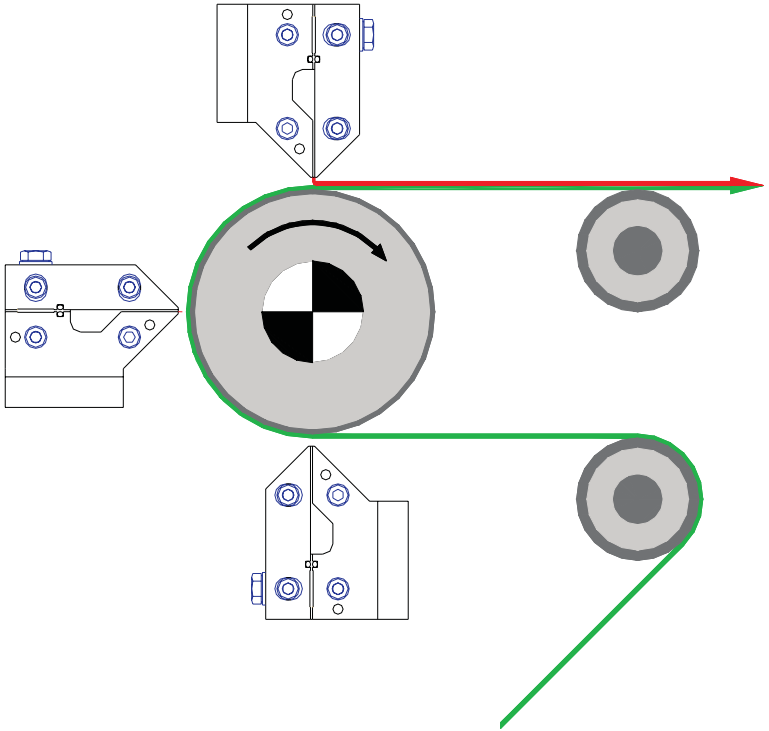
Variation of the coating weight

✓ 10 – 300 g/m²

Range of viscosity (mPas)

✓ Application of powdery materials

Slot die coating



Variation of the coating weight

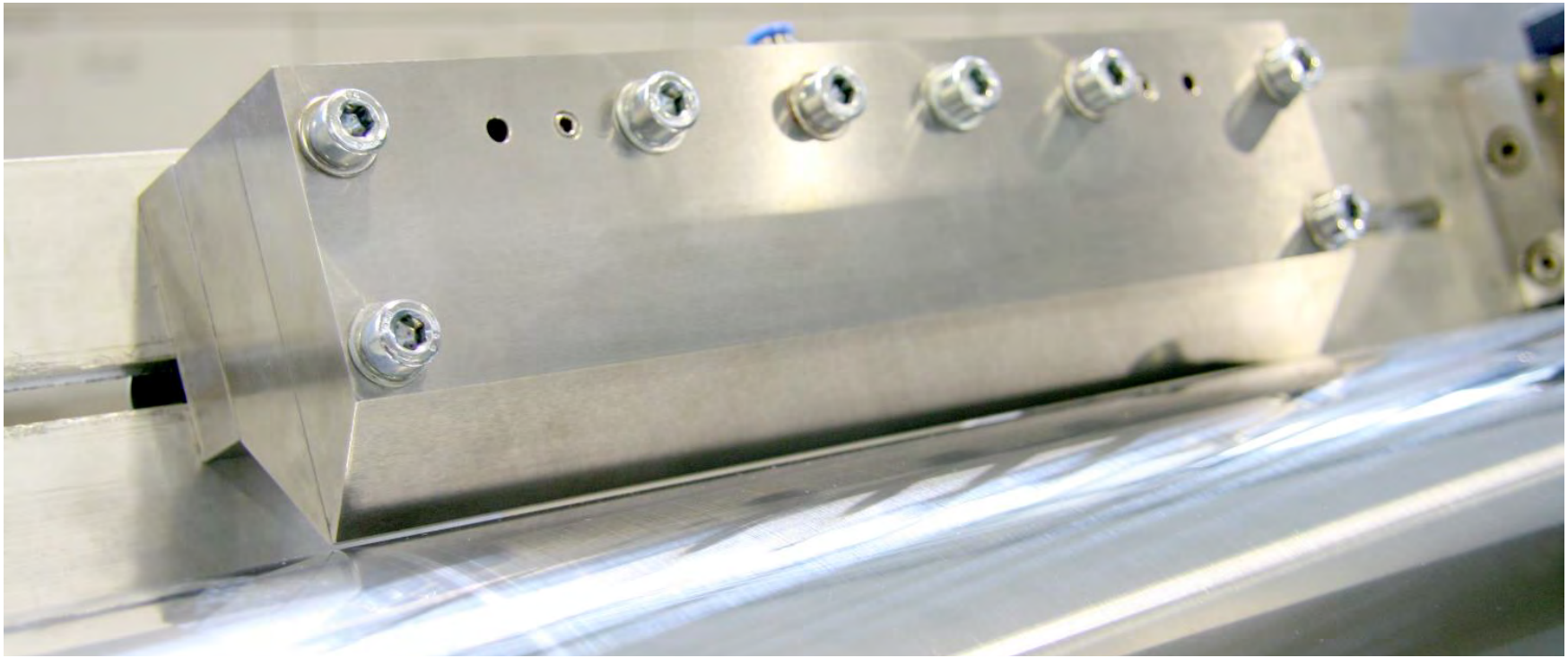
✓ 1 – 200 g/m²

Range of viscosity

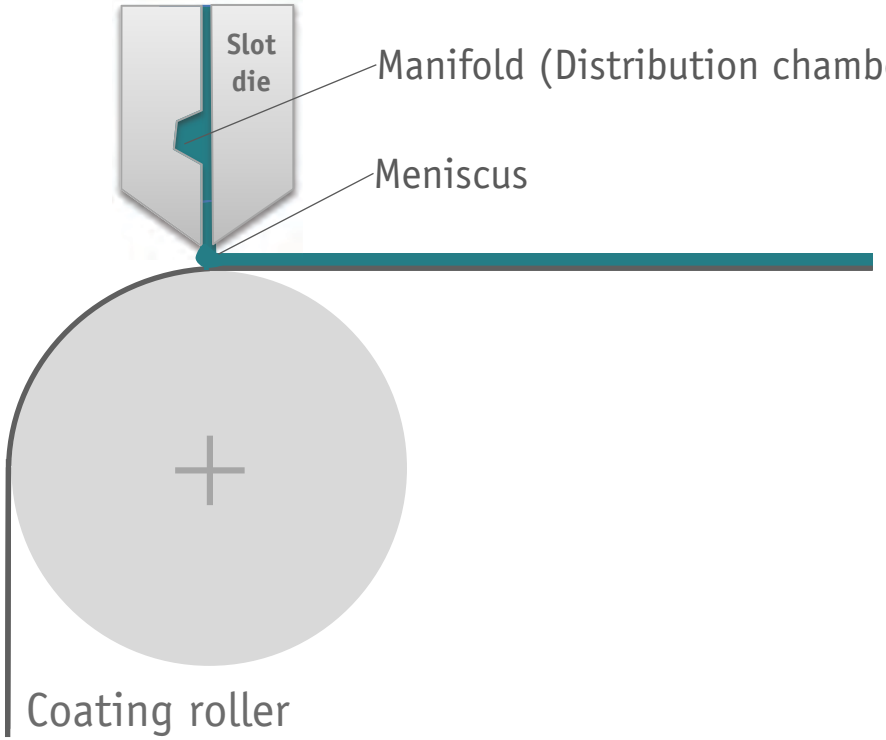
✓ 1 – 30 000 mPas

New design principle

Slot die system



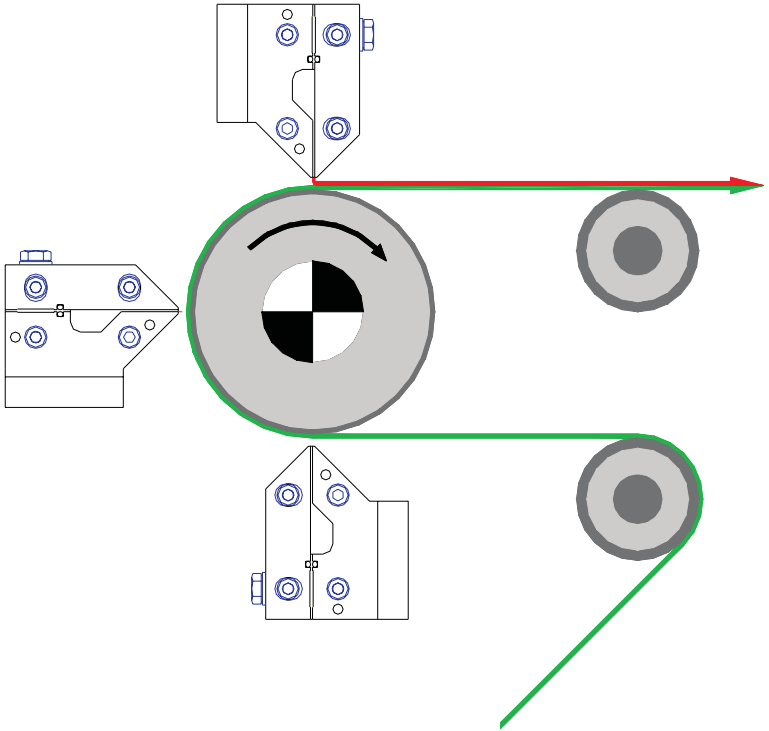
Technologies & processes – slot die coating



Operating a slot die

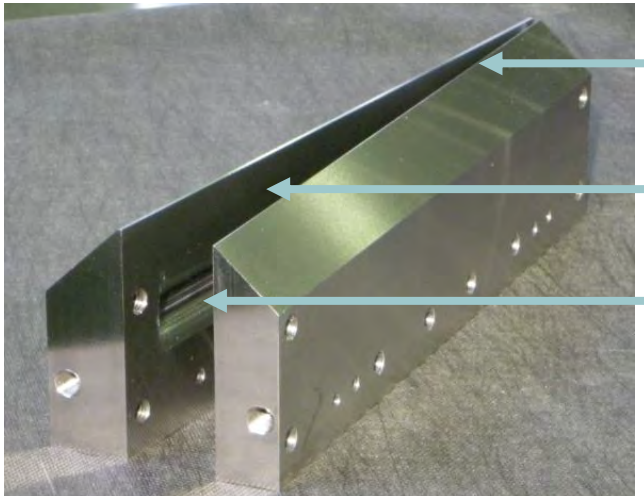
- ✓ Meniscus is formed between die lips and substrate
- ✓ Adhesive stabilization of meniscus by die lips
- ✓ Very low minimum flow rate possible
- ✓ For a stable process the range of rheological parameters is limited

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

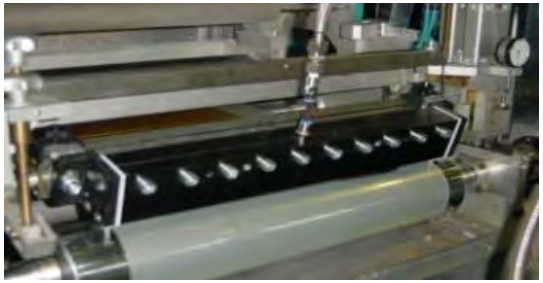
Basics of slot die coating – Coatema standard layout



Basics of slot die coating – slot die examples

100 mm, 11 o‘clock

300 mm, 9 o‘clock



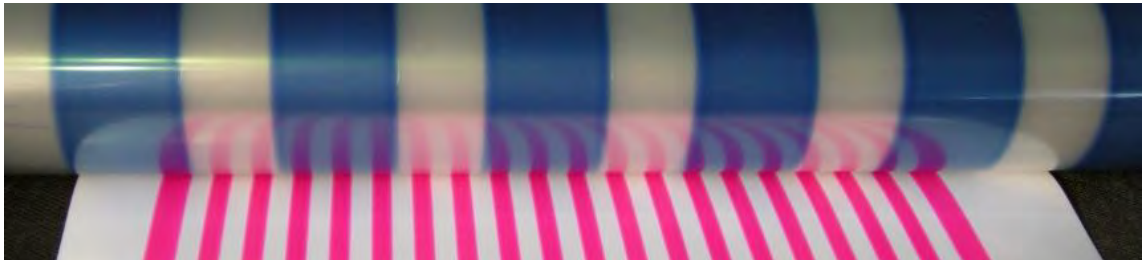
500 mm, slightly tilted

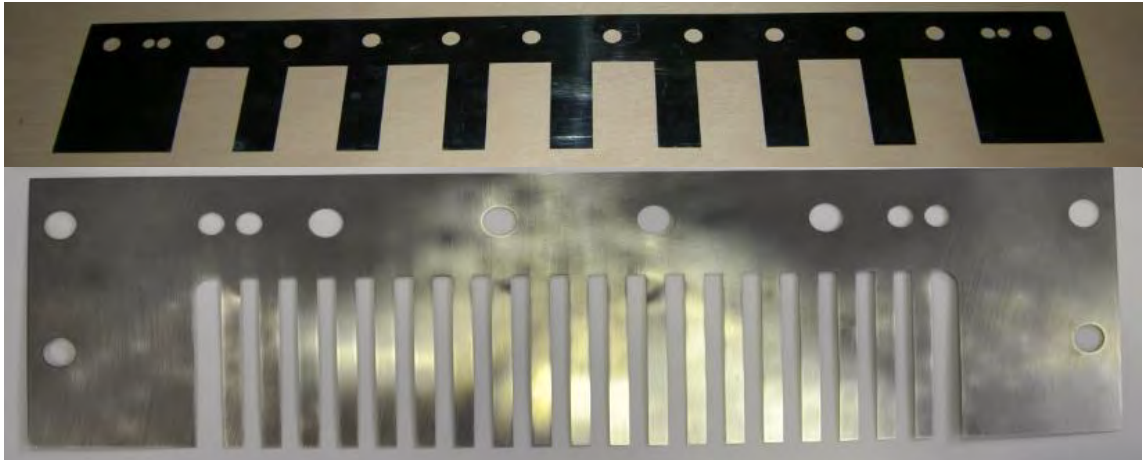
300 mm, double sided

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

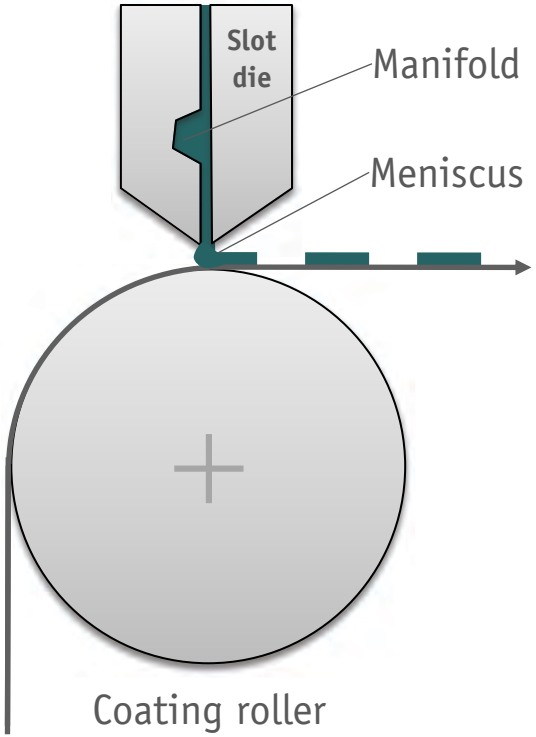




Downweb stripes of different width …

… 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.

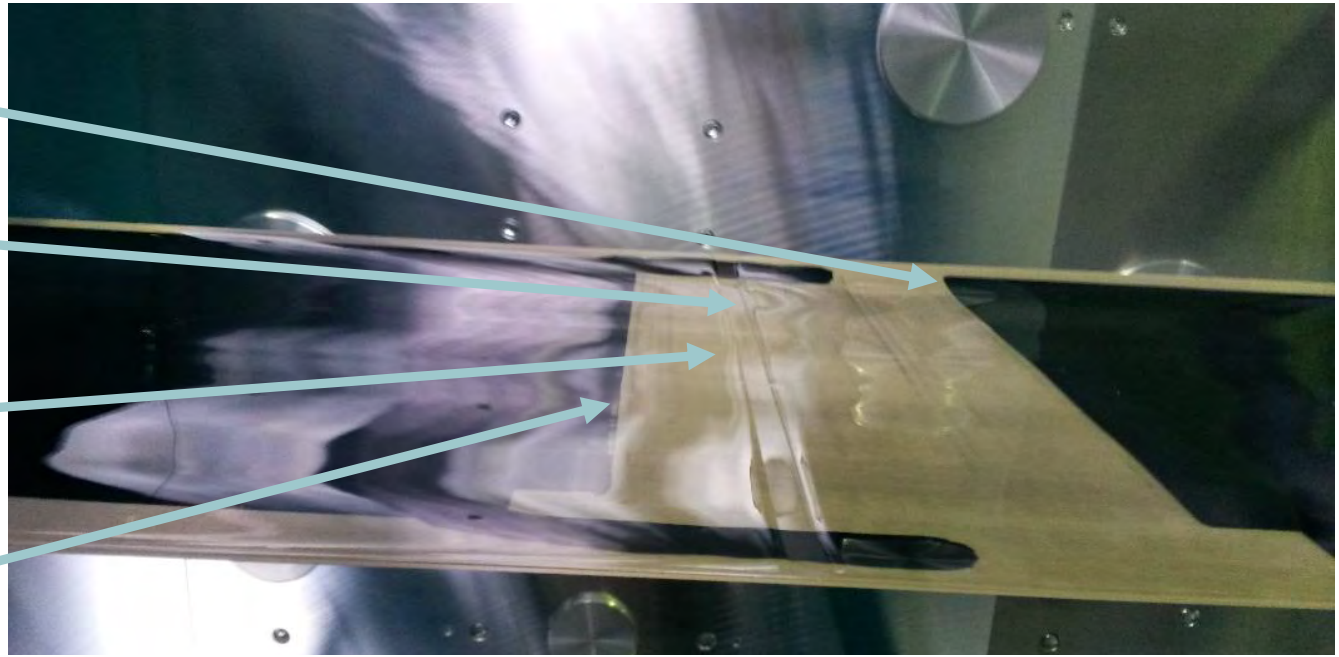
Structured coating – well defined edges at high viscosity

Leading edge battery paste

Leading edge silicone

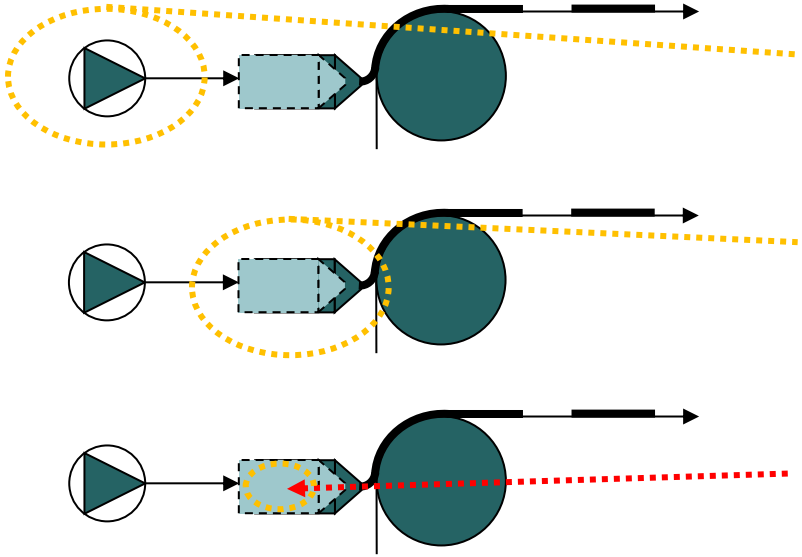
Trailing edge silicone

Trailing edge battery paste



Two different stripe patterns, one on top of the other

Standard techniques for intermittent coating



Pump:
stop – reverse – restart

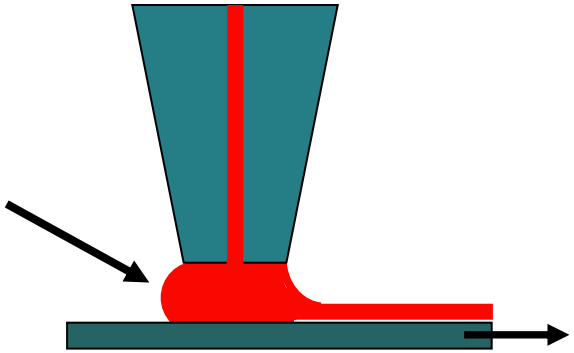
Slot die body:
move back – move forth to minimum gap – move back to working gap (wedge procedure)

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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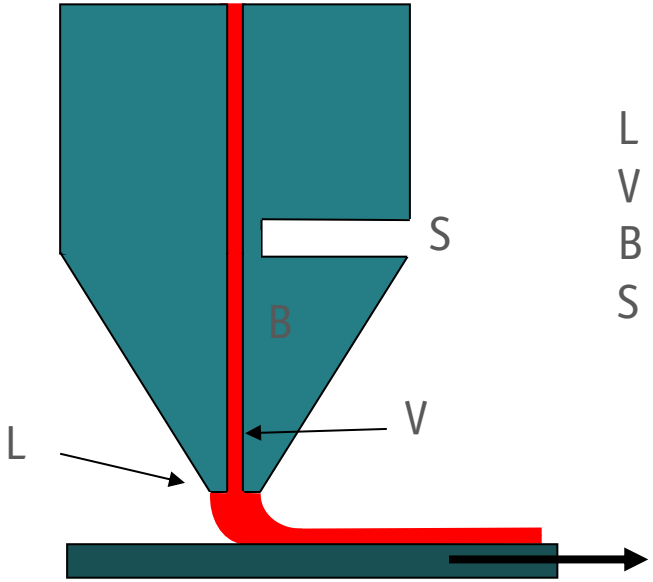
Structured coating – the switching slot die lip

Slot die with movable lips:
coating mode



L lip
V slot volume
B bendable lip
S bending slot

coating works as usual

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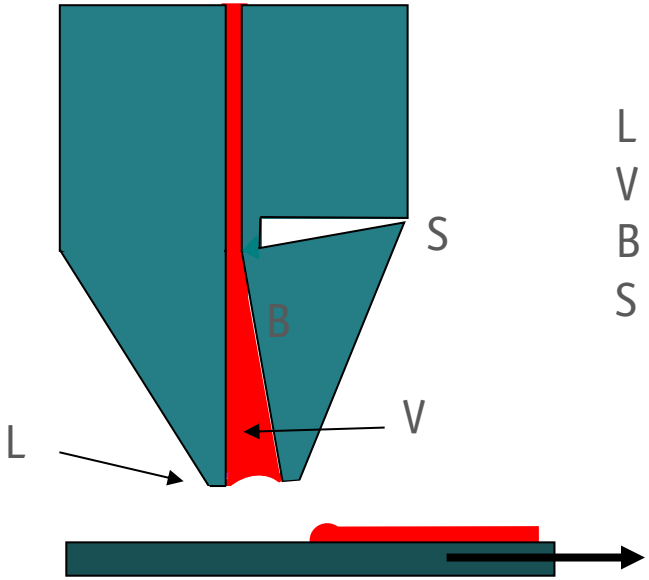
Structured coating – the switching slot die lip

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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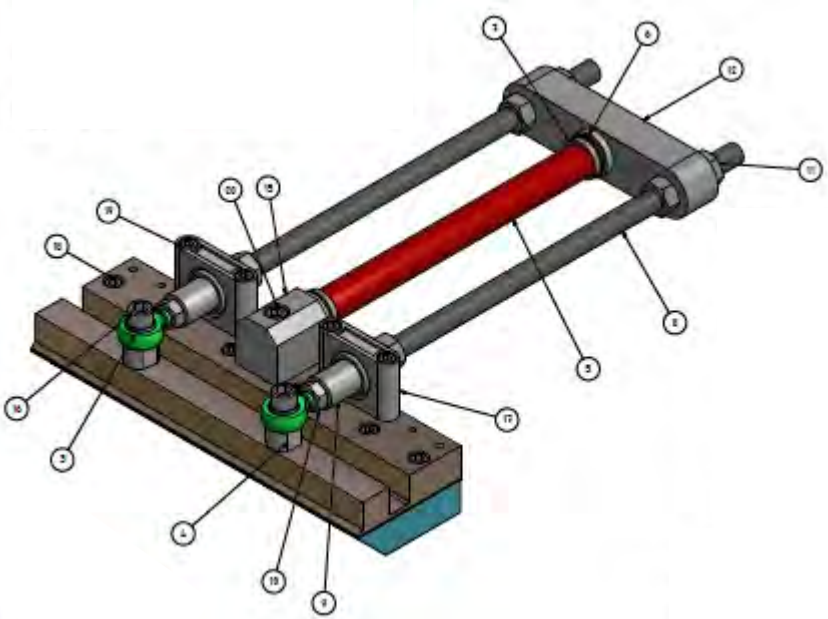
Structured coating – technical realisation with Piezo-Drive



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

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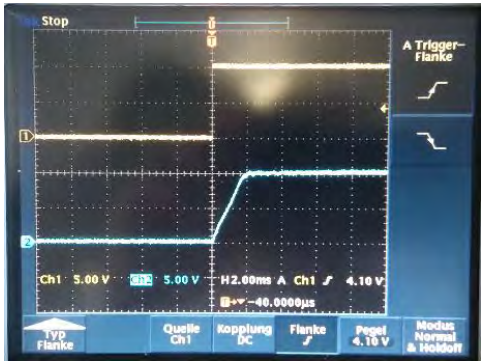
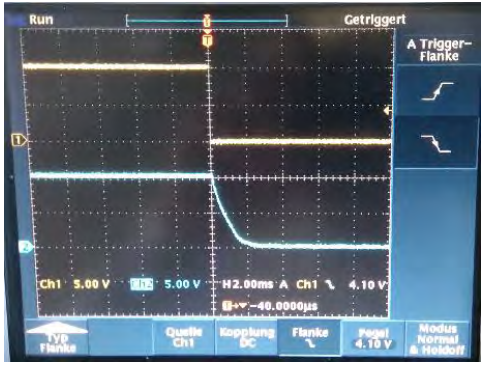
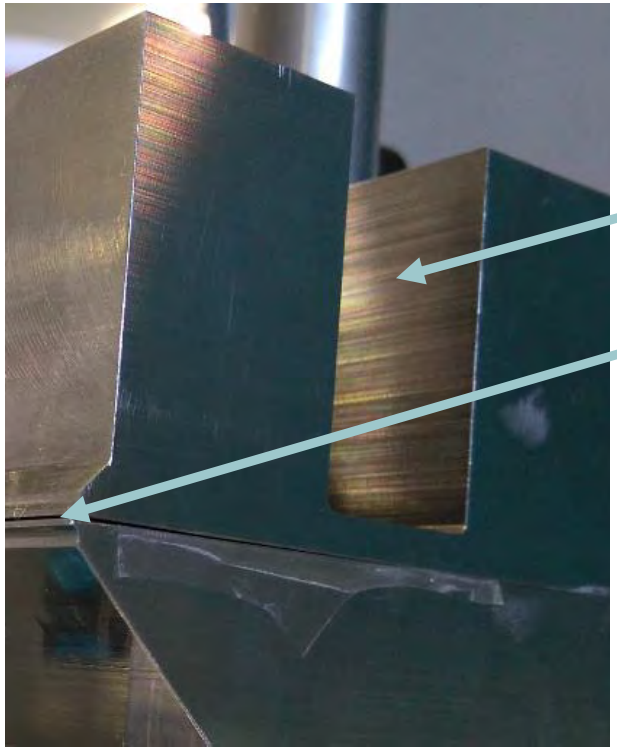
Control Voltage

Piezo Response





Structured coating – technical realisation with bendable lips

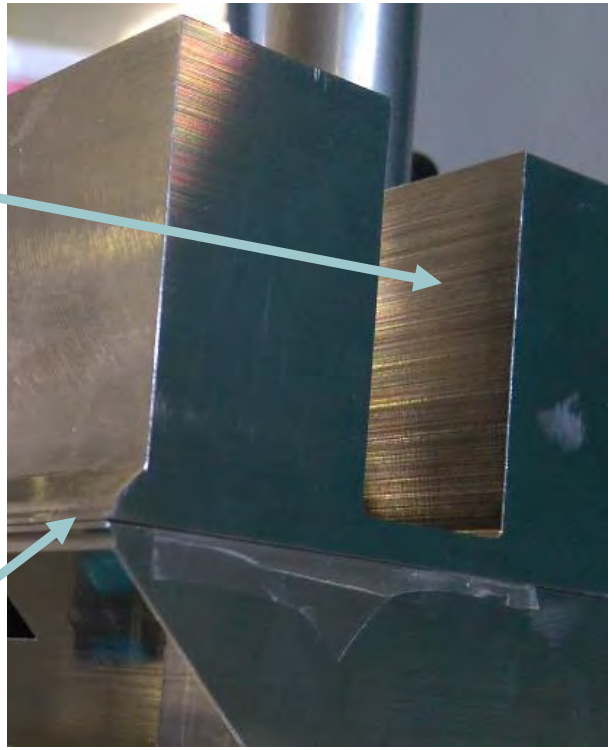


Bending slot

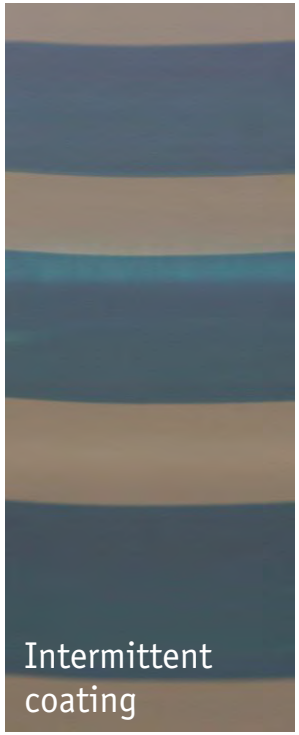
Lips open

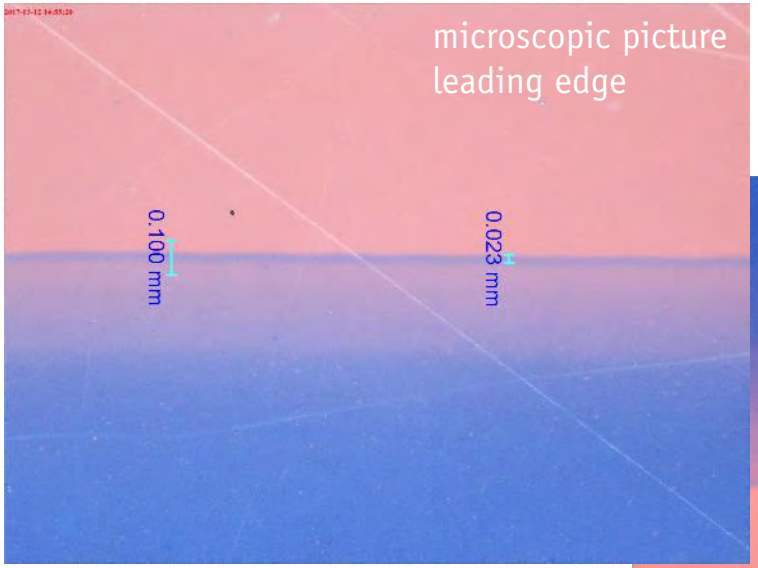
Difference is 300 µm only

Lips closed

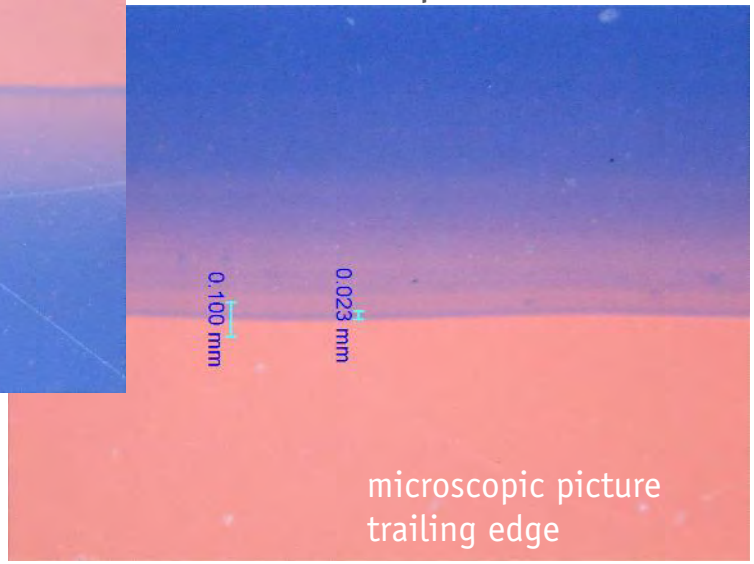


Structured coating – switching slot die: first results

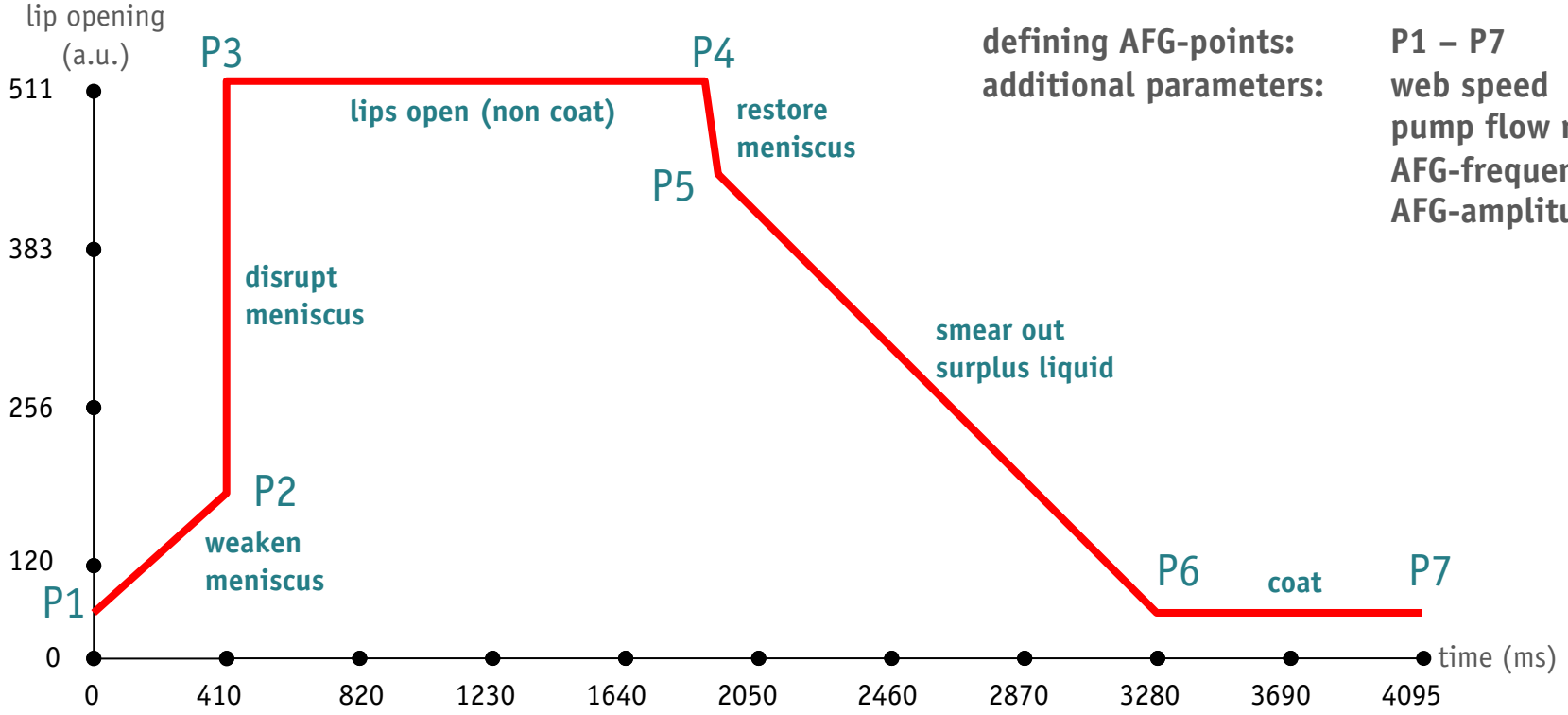




Straight edges well
defined
within 20 µm



Structured coating – course of lip motion



defining AFG-points: P1 – P7

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

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

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Summary

Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
Drying & curing	GDE & CCM approach	Todays equipment	Production line for MEAs	Summary

Drying & curing

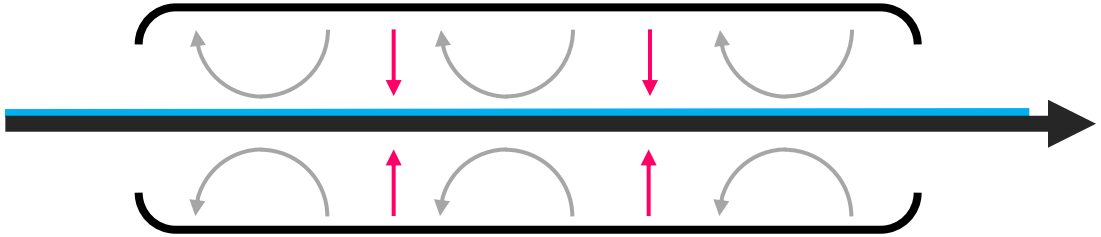
Coating parameters

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			

Drying technologies – drying with hot air technology

Drying Topics – general tasks of drying



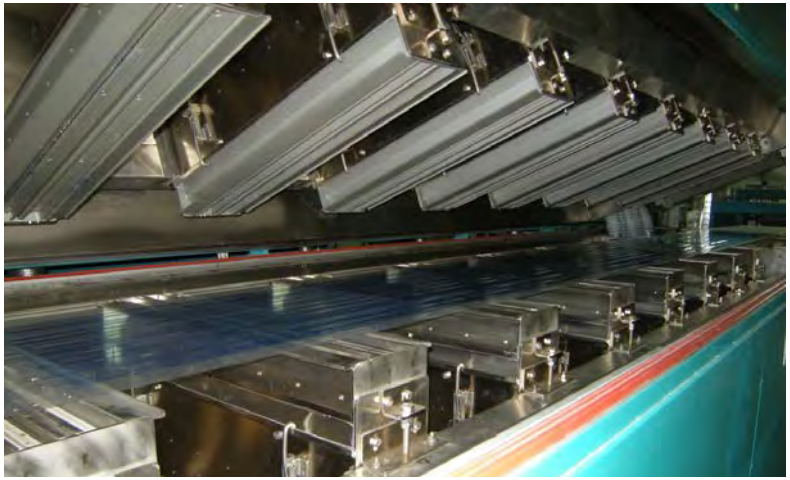
Substrate
Coating
Heat transfer
Vapor removal

1.) Transfer the drying energy into solids and solvent to achieve the drying temperature
solvent heat capacity → Dryer technology
solid heat capacity

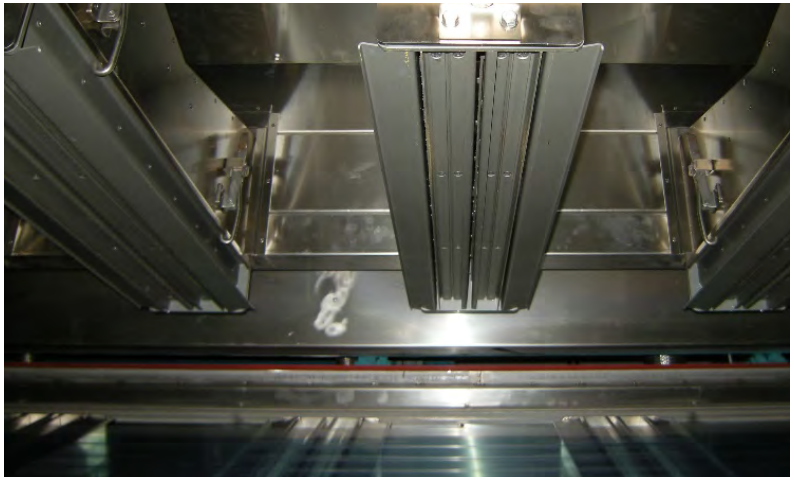
2.) Evaporate the solvent
solvent evaporation energy → Solvent evaporation speed

3.) Remove the solvent vapor → Dryer technology

Drying Topics – drying systems: hot air technology



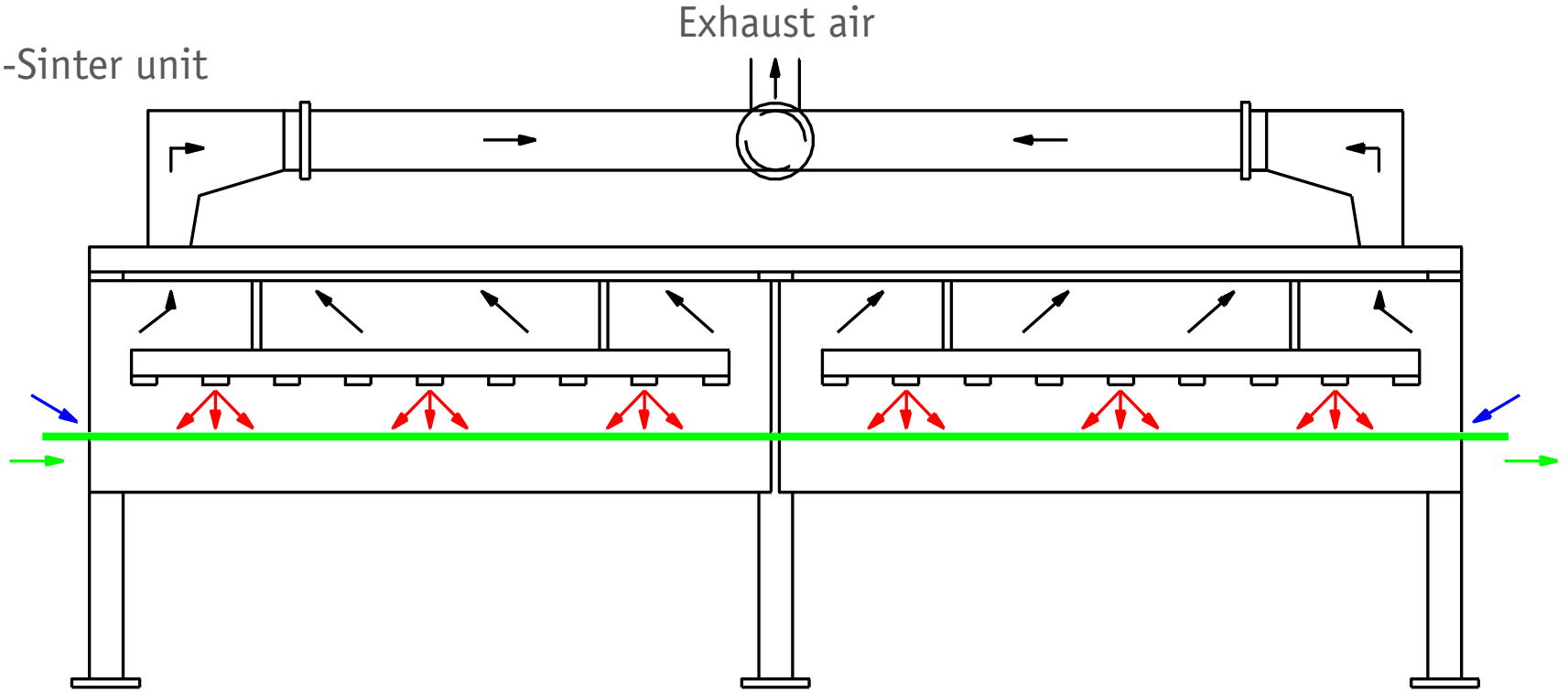
Floatation dryer



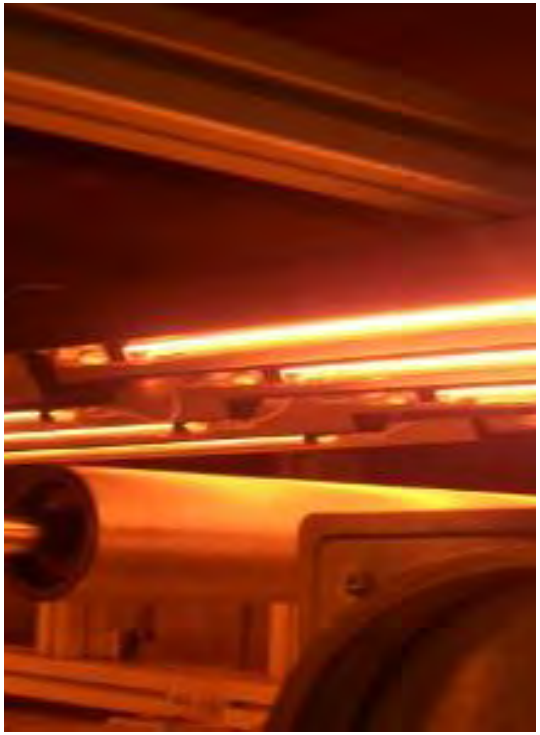
Single nozzle

Drying topics – drying technologies

IR-Sinter unit



Drying topics – drying technologies



Drying topics – infrared dryers – combined hot air / IR dryer

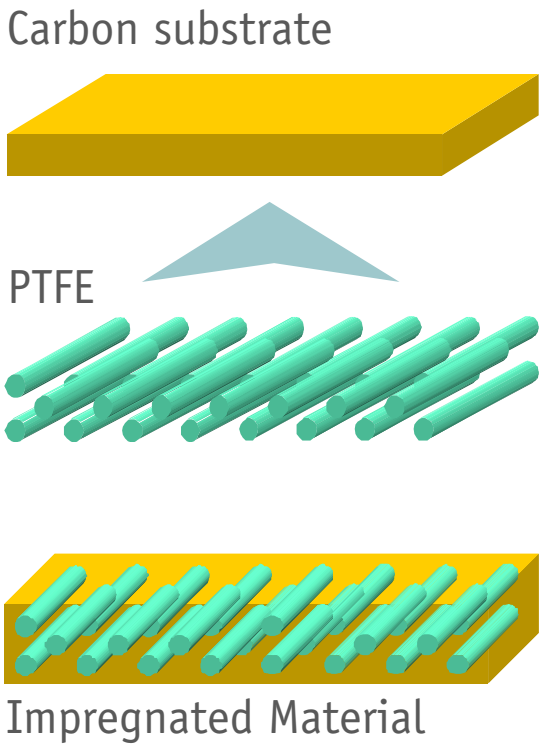
Summary

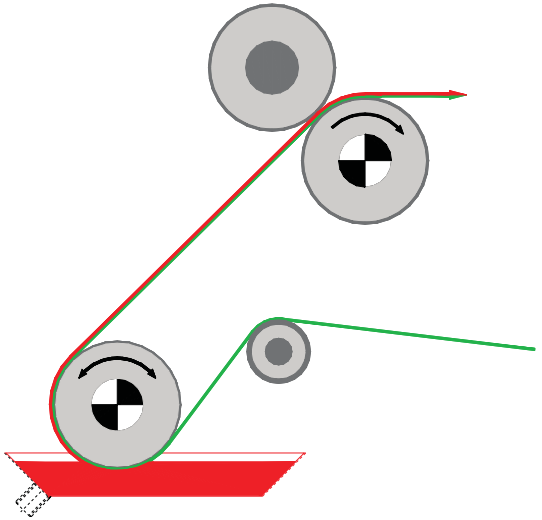
Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
Drying & curing	GDE & CCM approach	Todays equipment	Production line for MEAs	Summary

Production steps for MEAs

1st production step: Hydrophobization

✓ Impregnation of carbon substrate by dipping into a PTFE solution





Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

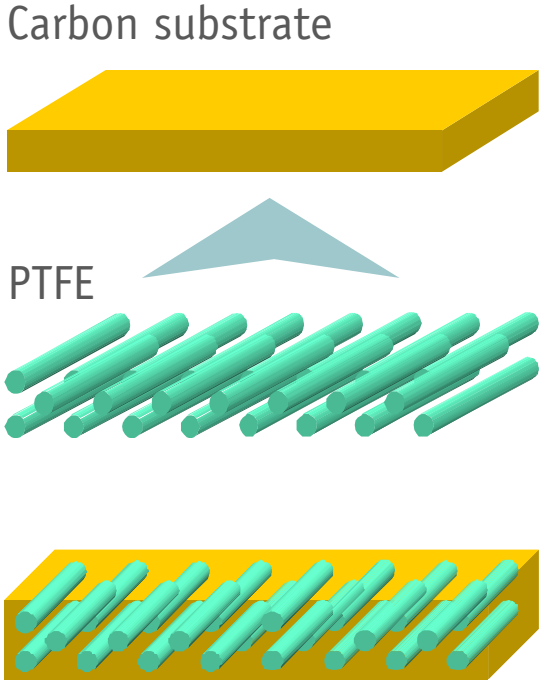
Production steps for MEAs

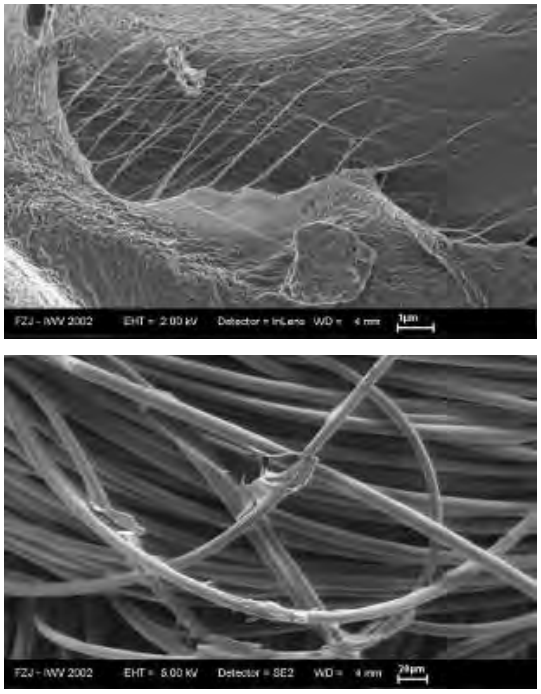
1st production step: Hydrophobization

PTFE content adjustable by PTFE Concentration of the solution

1st sub-step:
impregnation + drying

2nd sub-step:
sintering



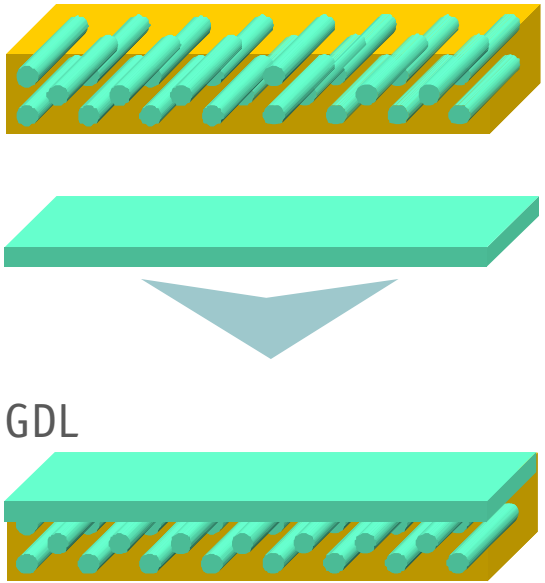


Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Production steps for MEAs

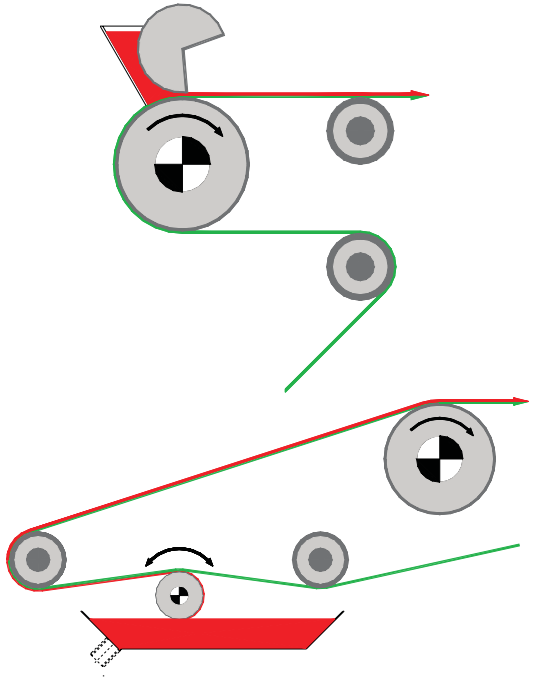
2nd production step:
Micro layer

Impregnated material



GDL

Carbon base coating



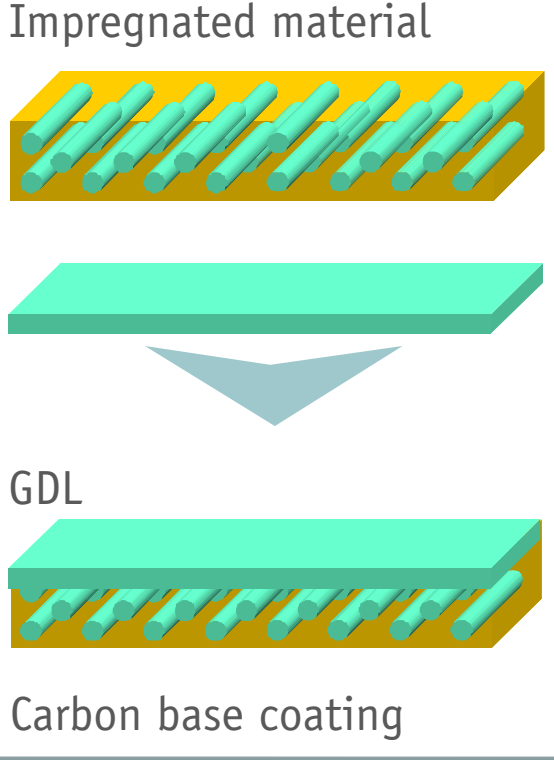
Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

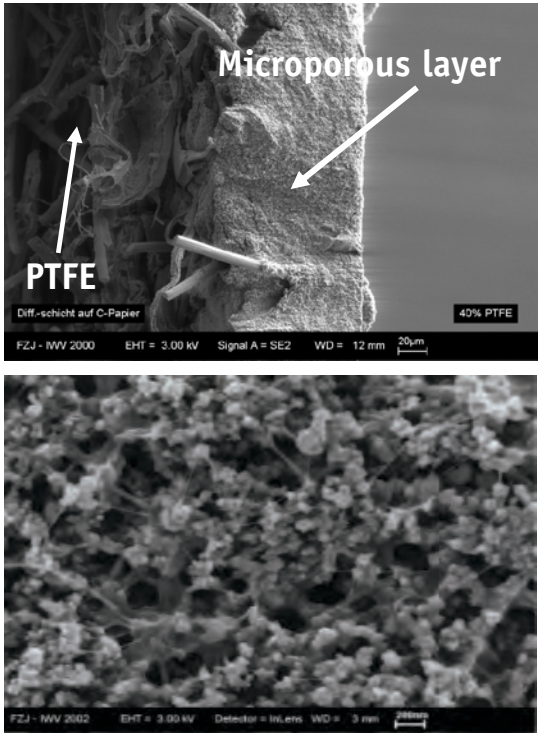
Production steps for MEAs

2nd production step:
Micro layer

1st sub-step:
coating + drying

2nd sub-step:
sintering

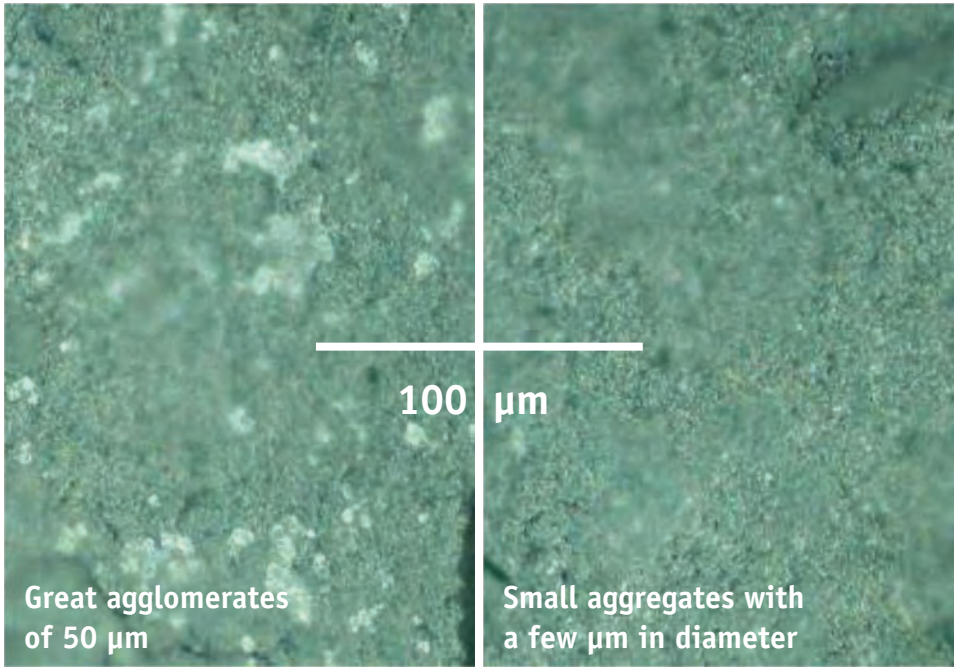


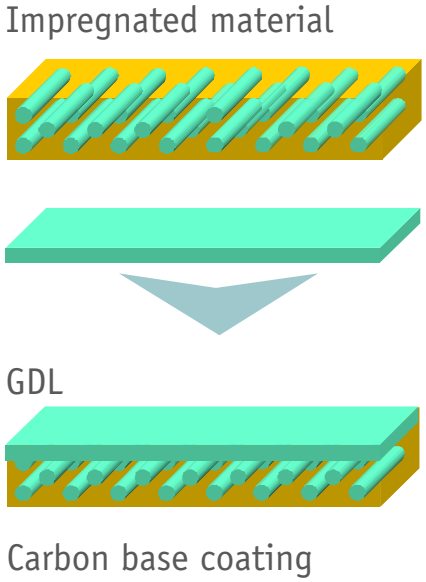


Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Production steps for MEAs

Dispersed in dissolver – adjustment of speed and dispersing time

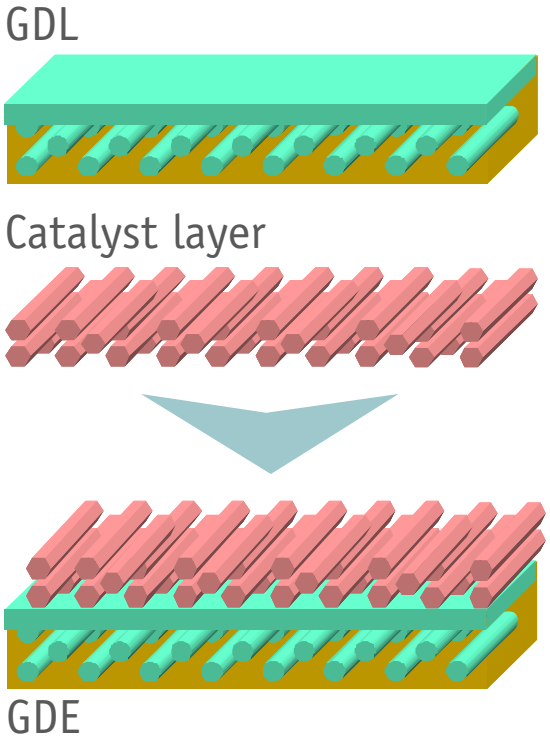


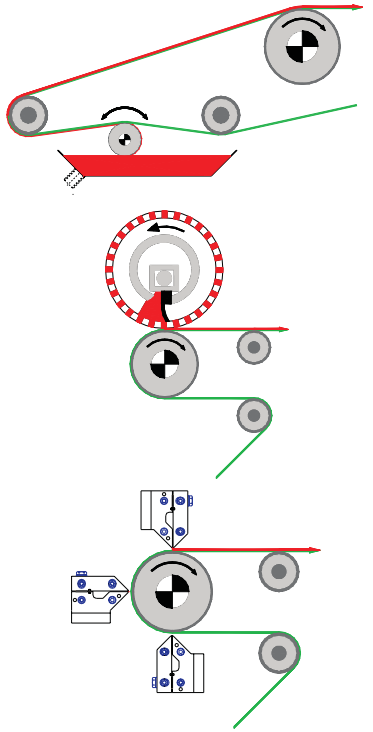


Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Production steps for MEAs

3rd production step:
Catalyst layer





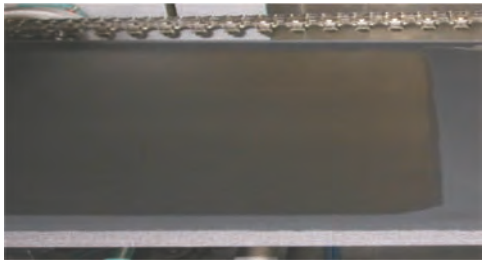
Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

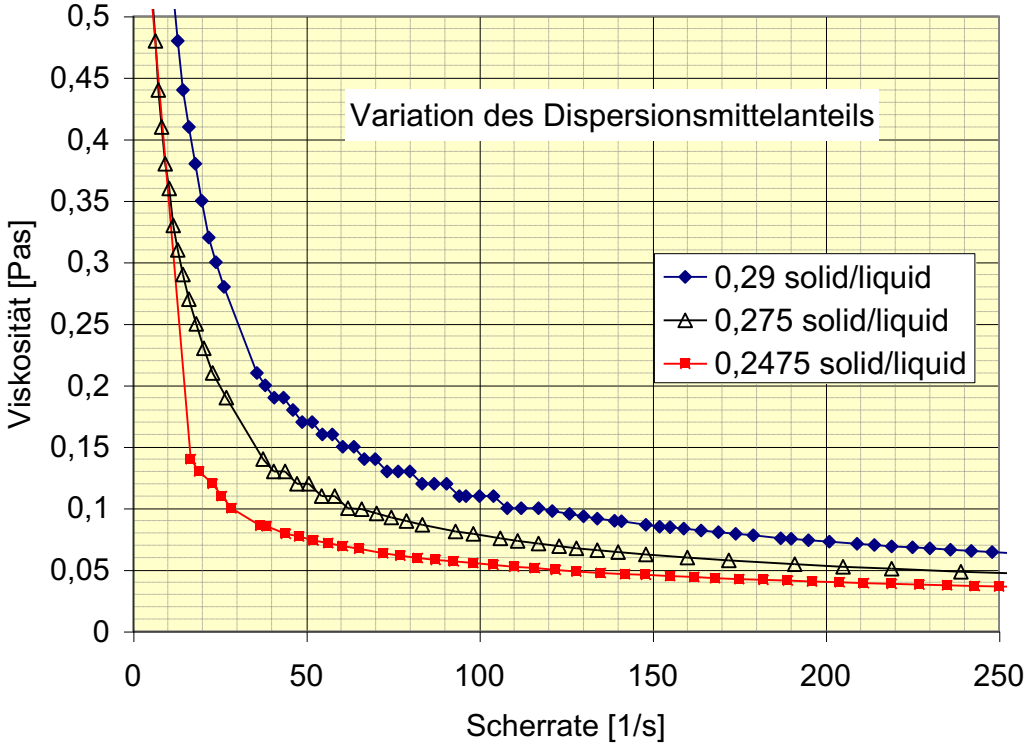
Production steps for MEAs

3rd production step:
Catalyst layer

The structure of catalyst layer depends on:

- ✓ Catalyst paste
- ✓ Coating technique/ coating speed
- ✓ Drying conditions





Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Production steps for GDE

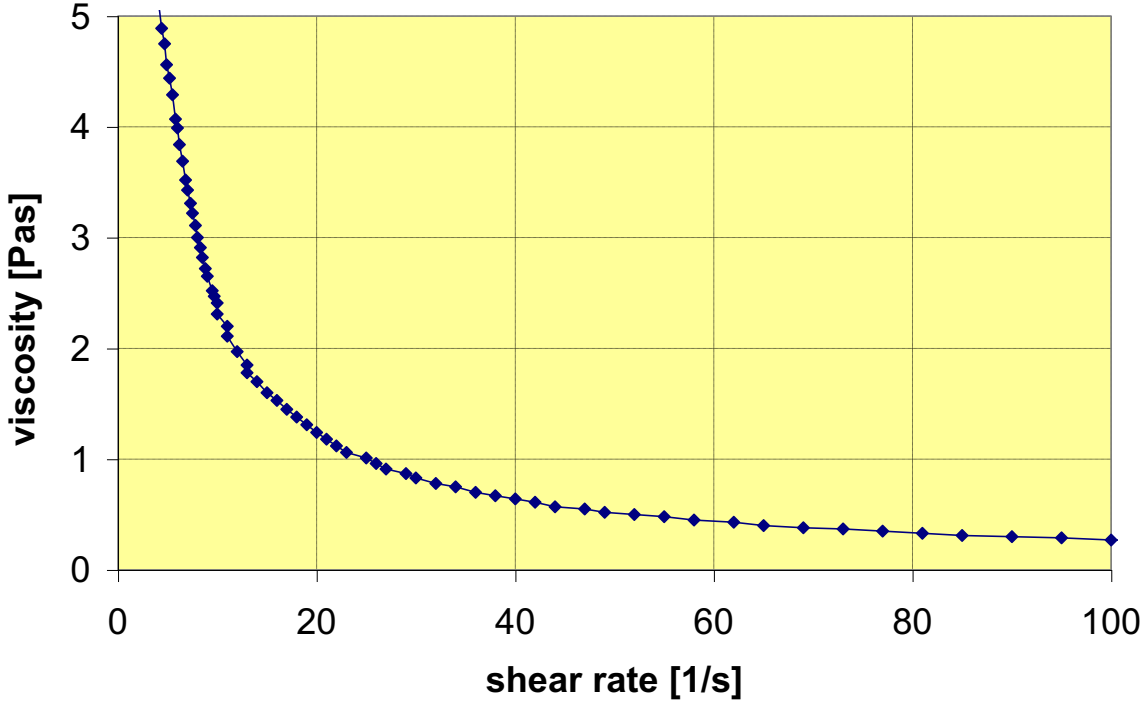
3rd production step:
Catalyst layer

The structure of catalyst layer depends on:

- ✓ Catalyst paste
- ✓ Coating technique/ coating speed
- ✓ Drying conditions

The viscosity of catalyst depends on:

- ✓ Catalyst
- ✓ Dispersing agent
- ✓ Dispersing method

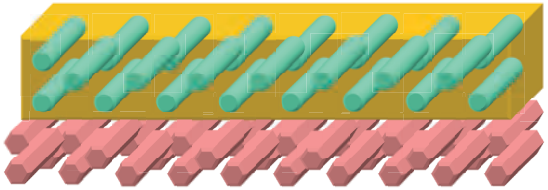


Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

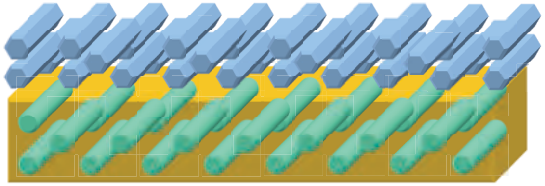
Production steps for GDE

4th production step:
Laminating / sealing

GDE Cathode

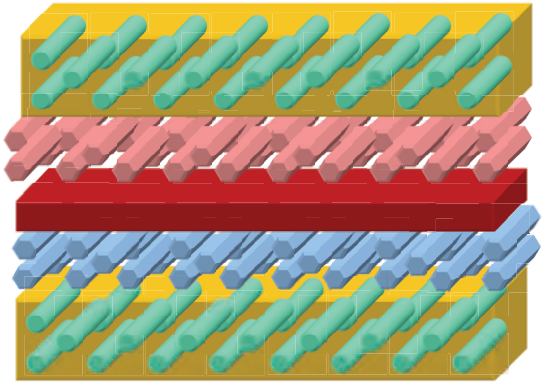


GDE Anode



PEM =
Nafion or other membrans

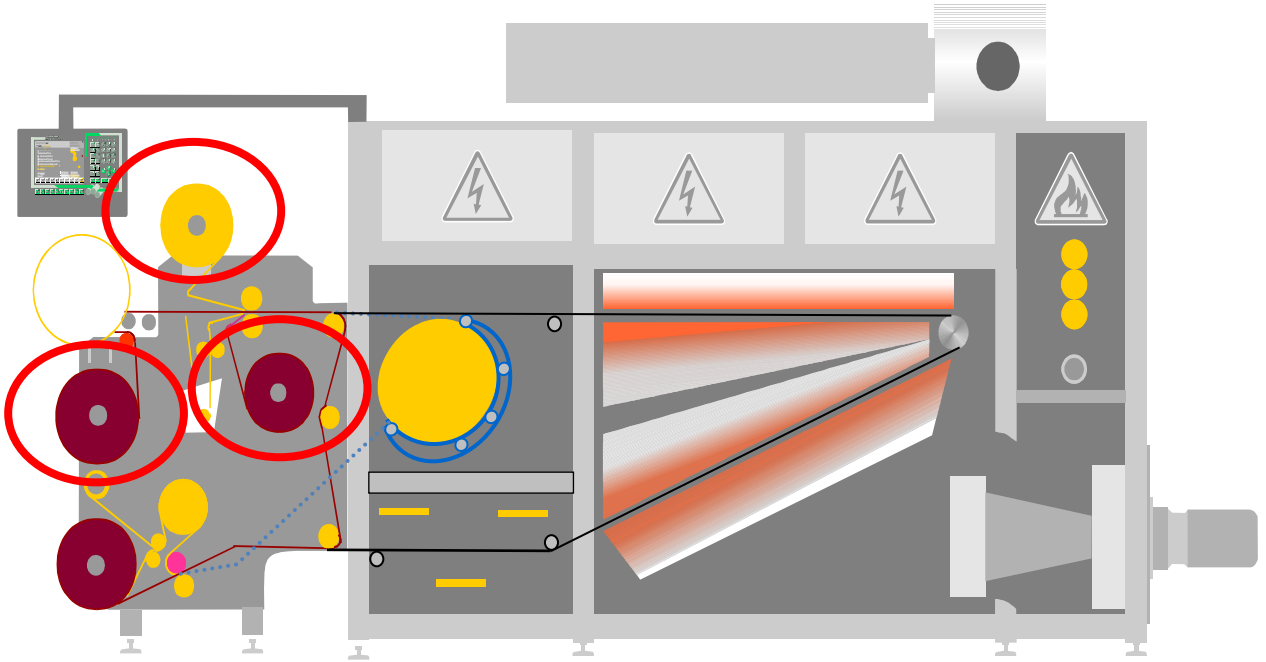
MEA & GDE



Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Production steps for GDE

4th production step: Laminating / hot pressing



Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Deskcoater

500 W DMFC-Stack

Quelle: Institute of Energy Research – Fuel Cells (IEF-3), Juelich Research Center part of Helmholtz-Community

Summary

Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
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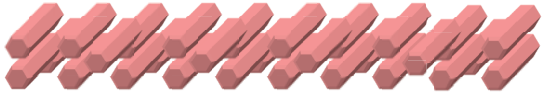
Production steps

1st production step:
coating / drying / cooling

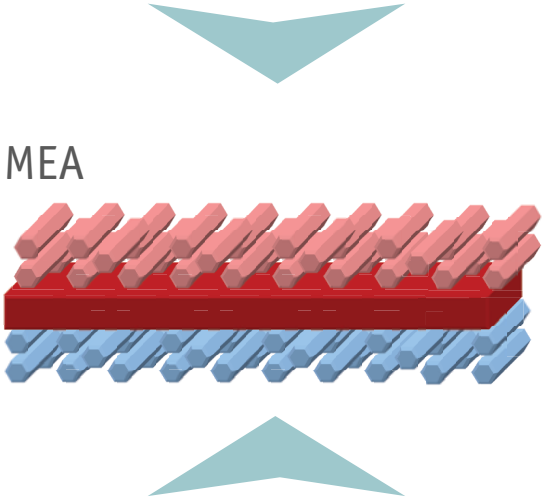
PEM



Cathode base coating

Anode base coating

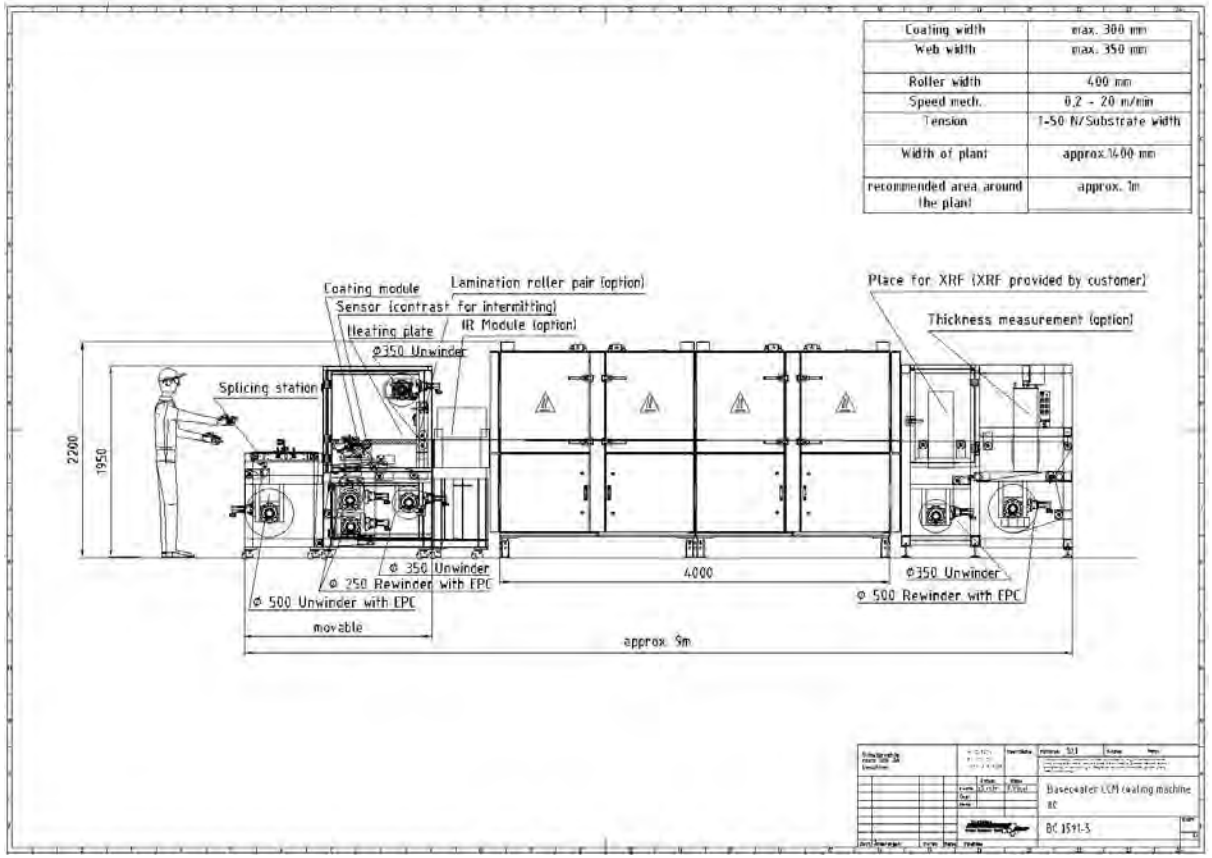
MEA



Production steps

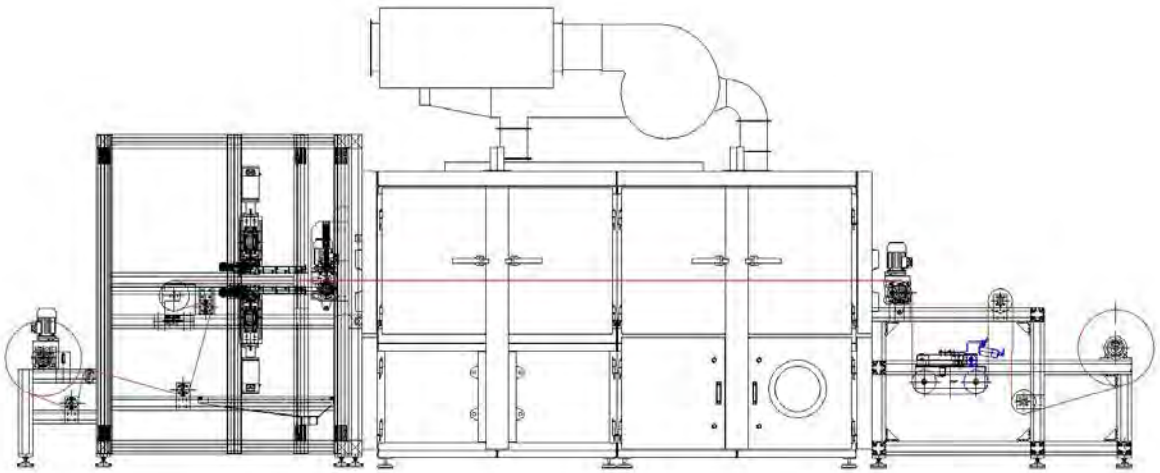
Single side step:
coating / drying / cooling

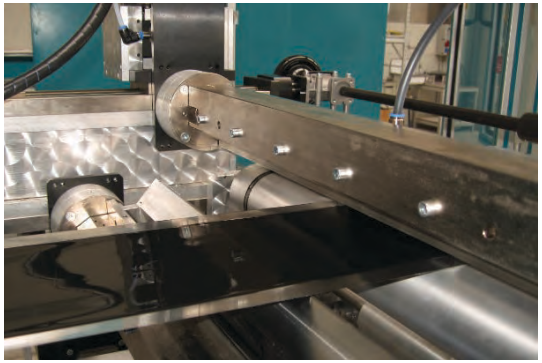
Overview on layouts

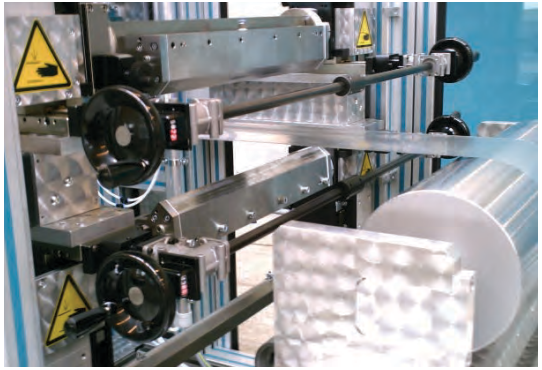


Production steps

Double side step:
coating / drying / cooling







Summary

Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
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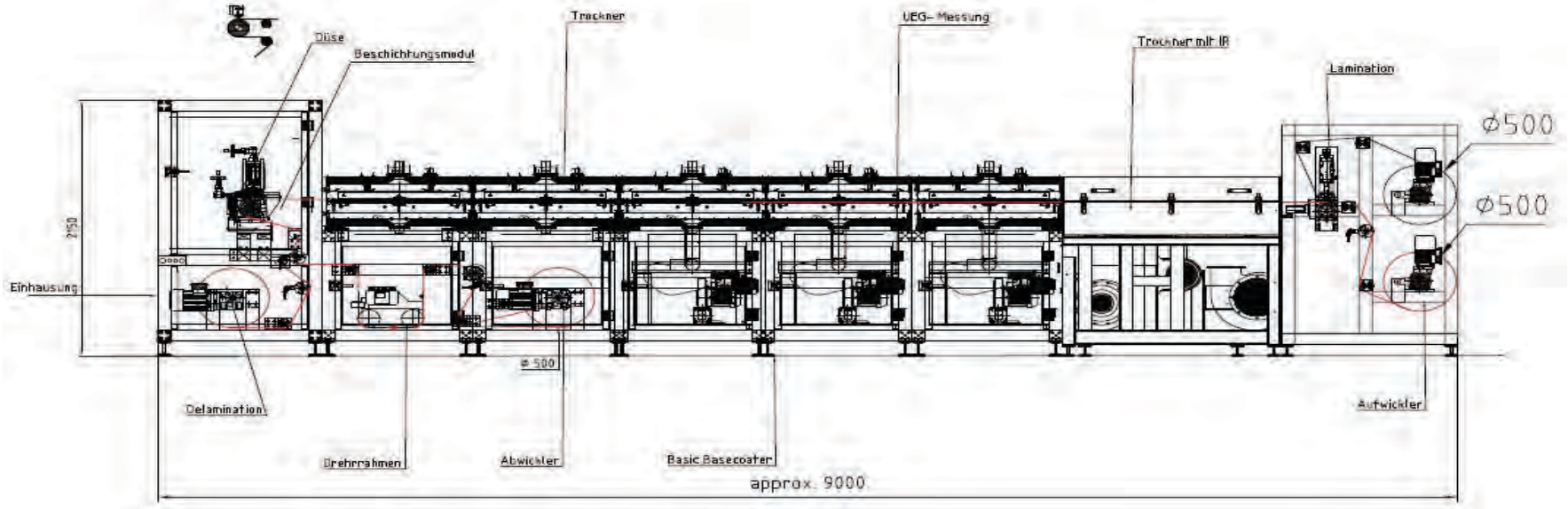
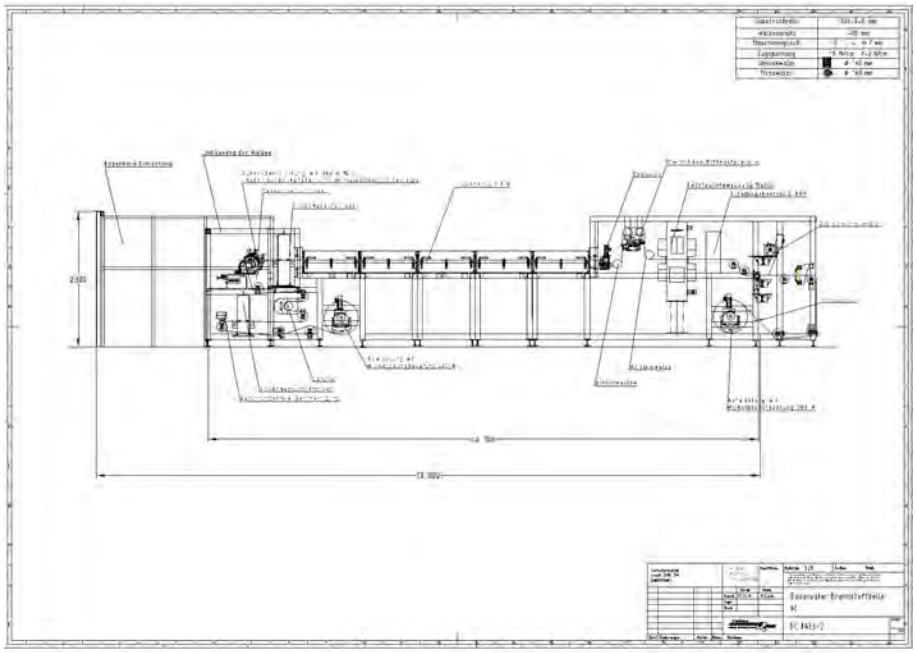
The Basecoater



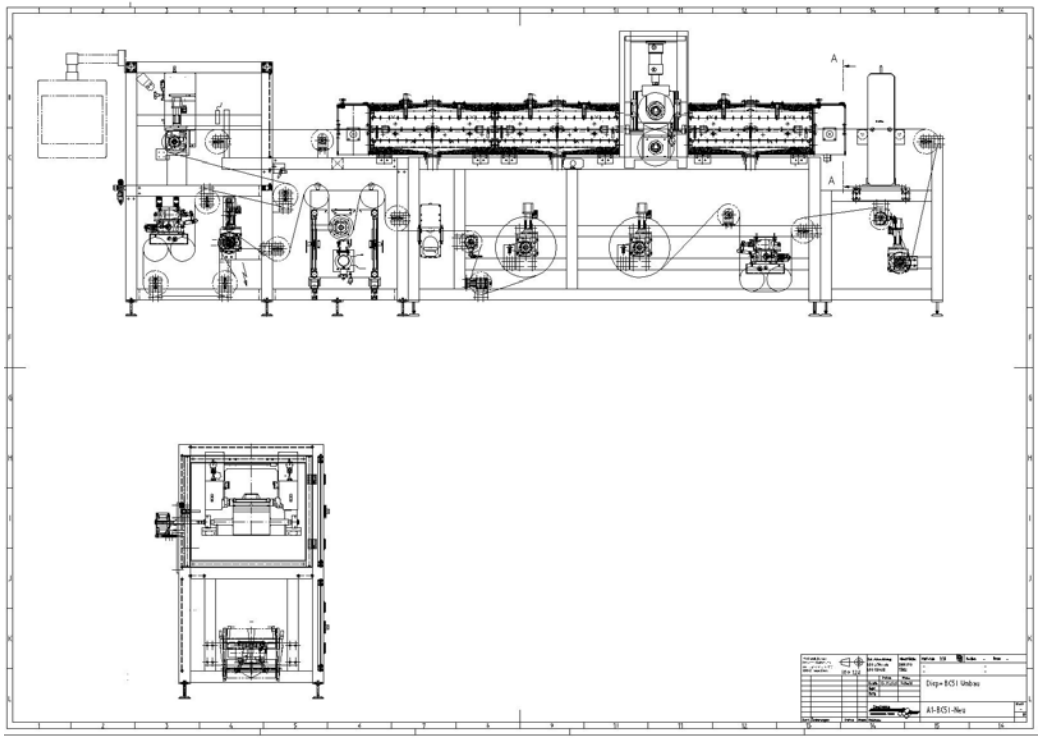
The Basecoater

The Basecoater

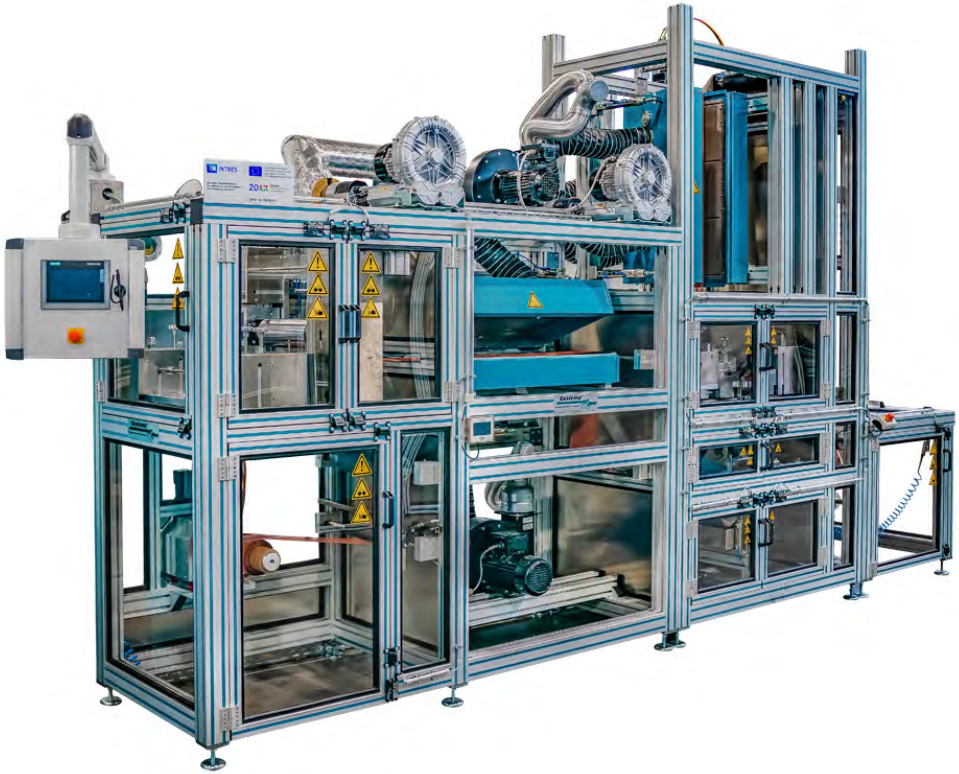
Overview on layouts



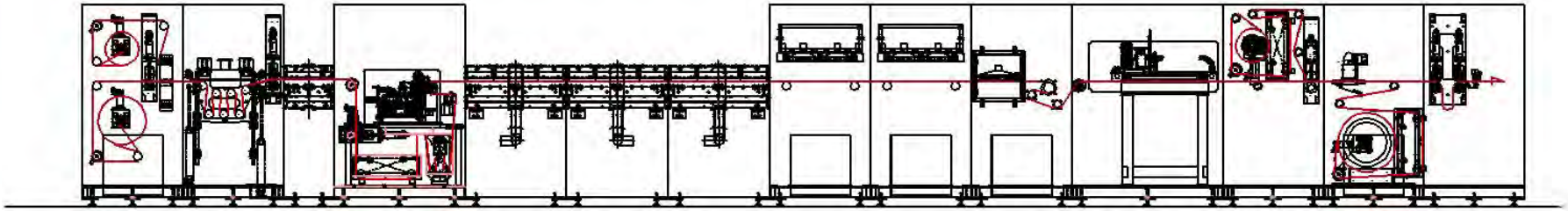
Overview on layouts



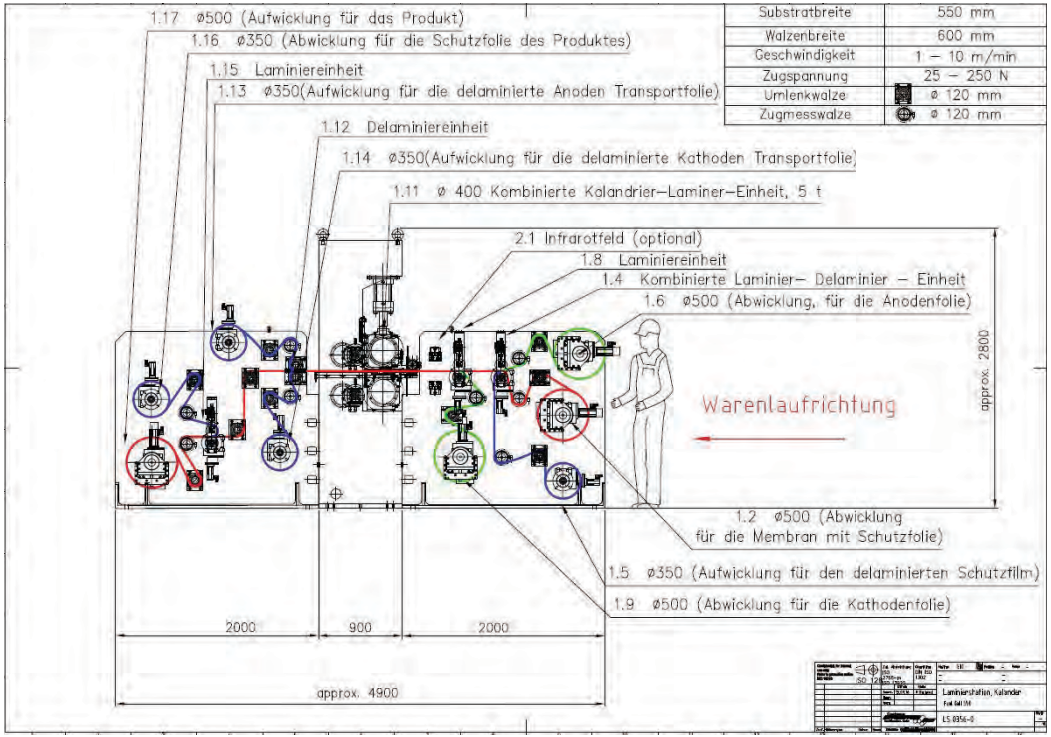
The Basecoater



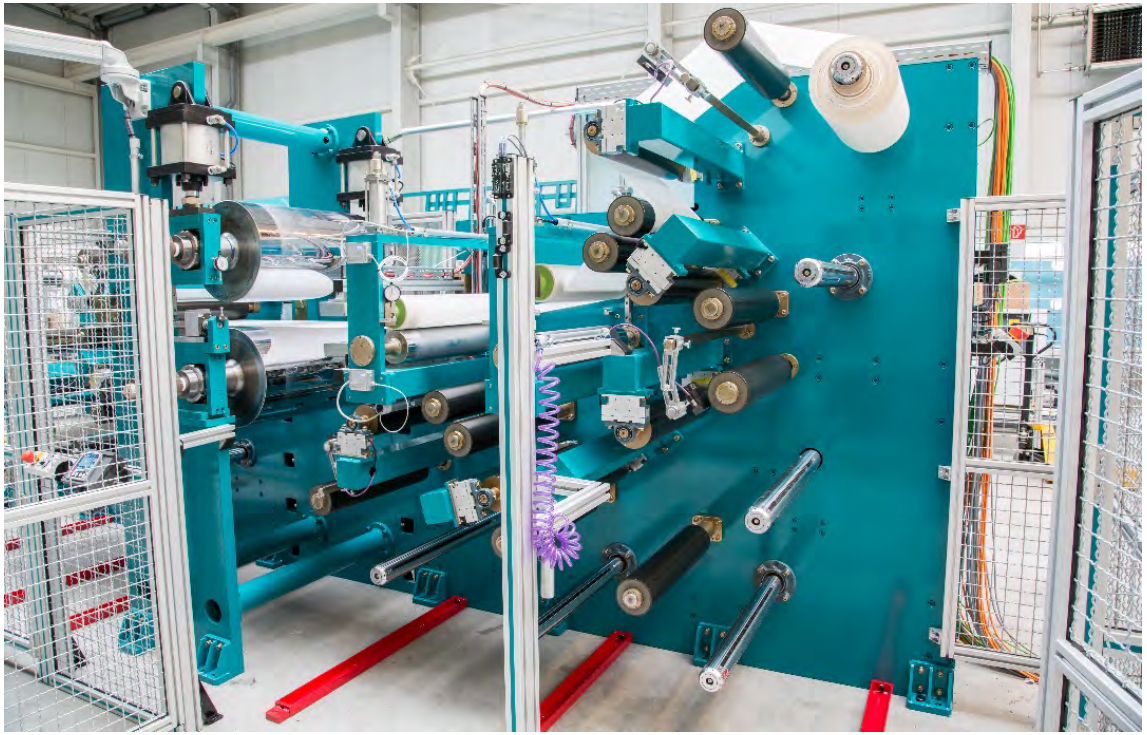
The Basecoater 3rd Generation

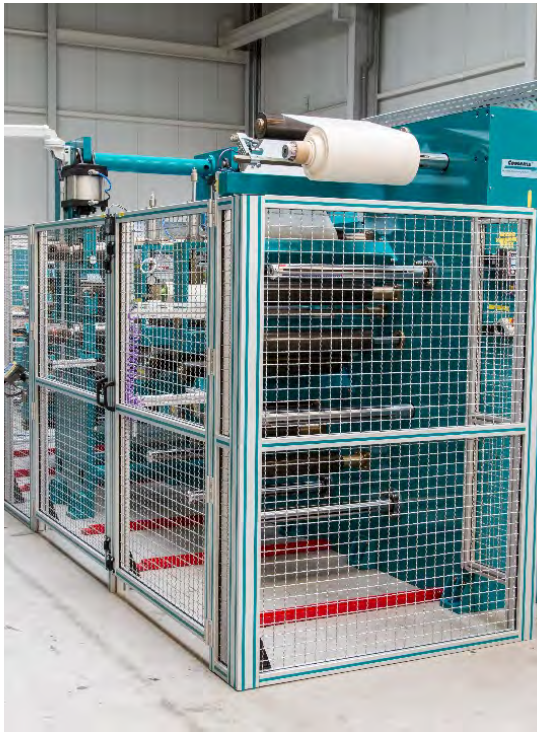


The Basecoater 3rd Generation

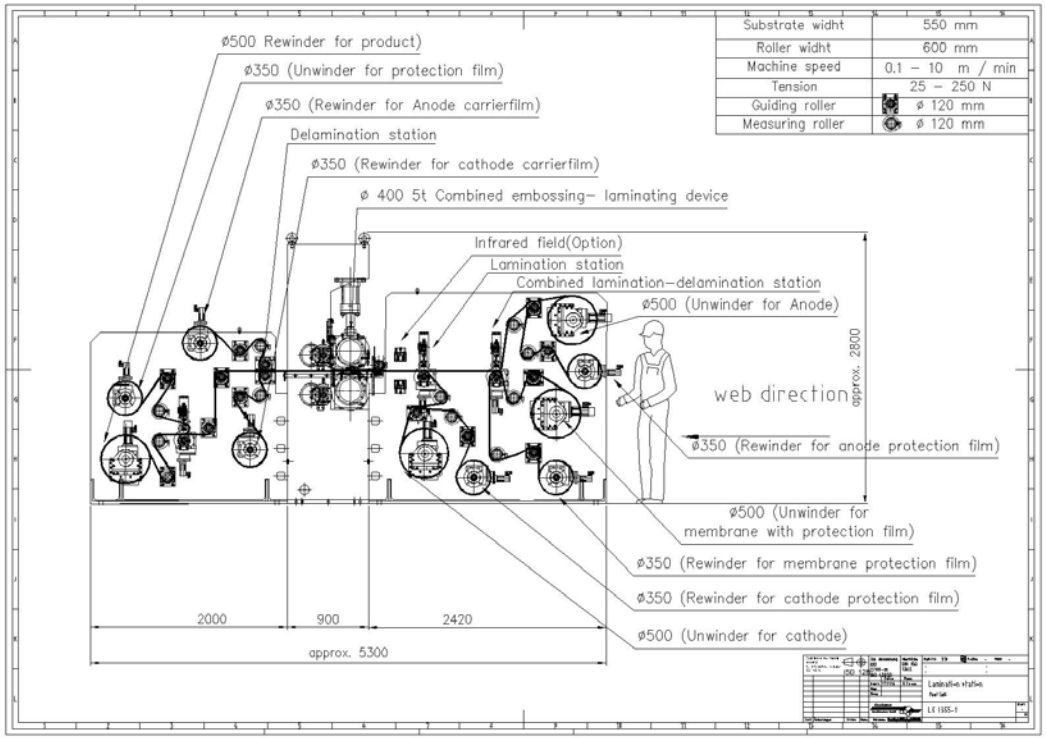


Hot pressing

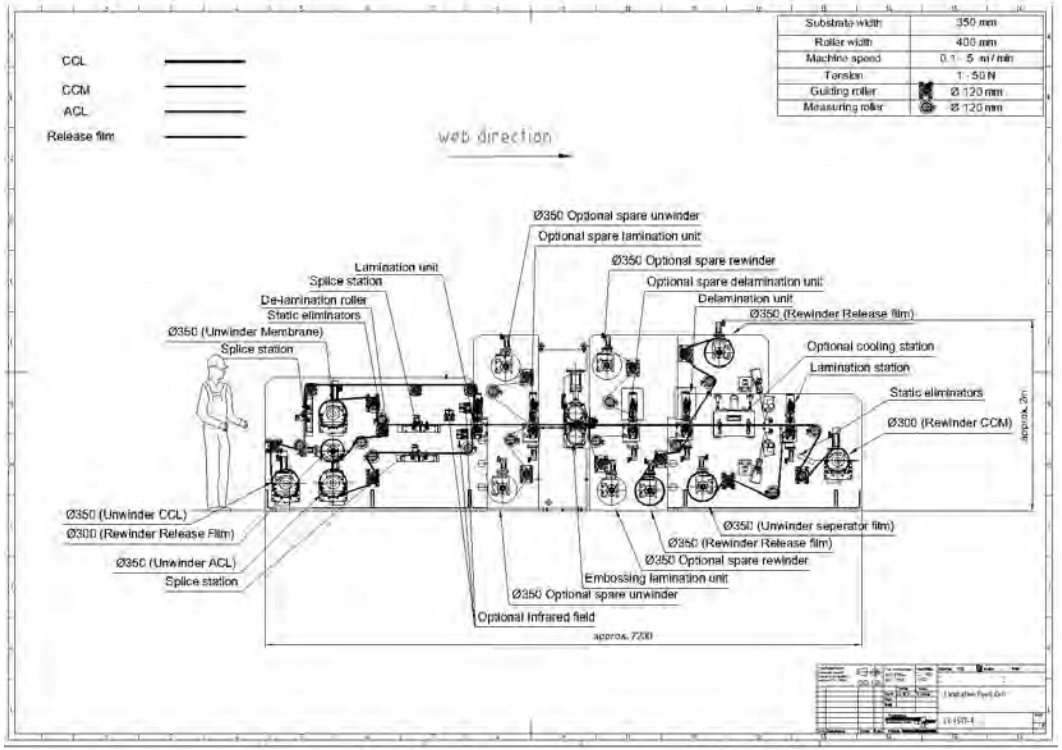




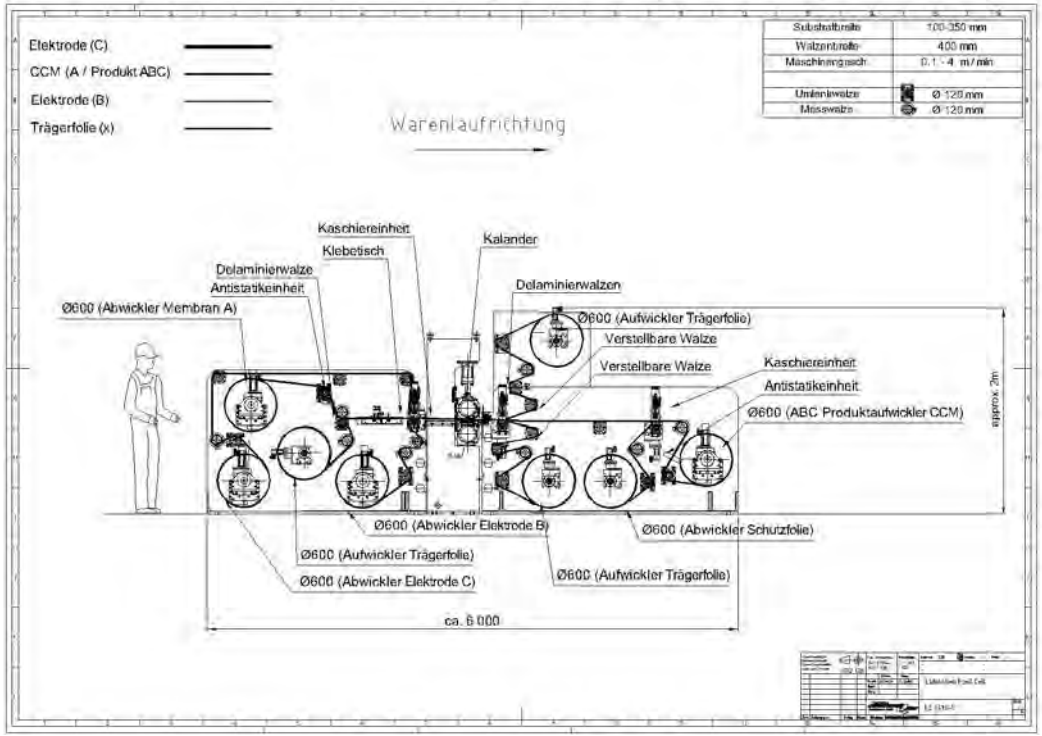
Hot pressing



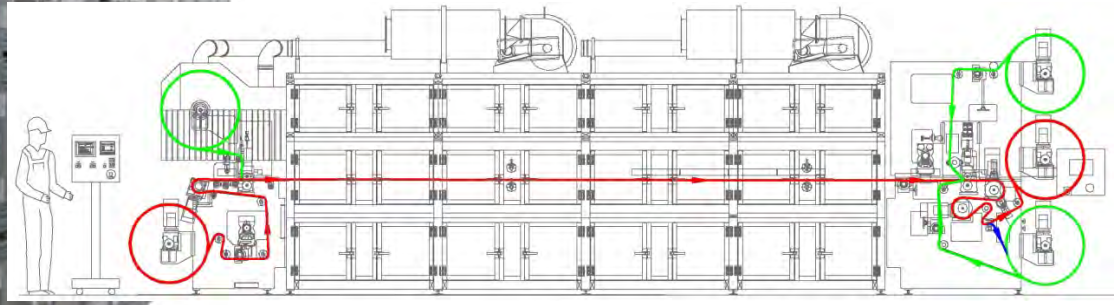
Hot pressing



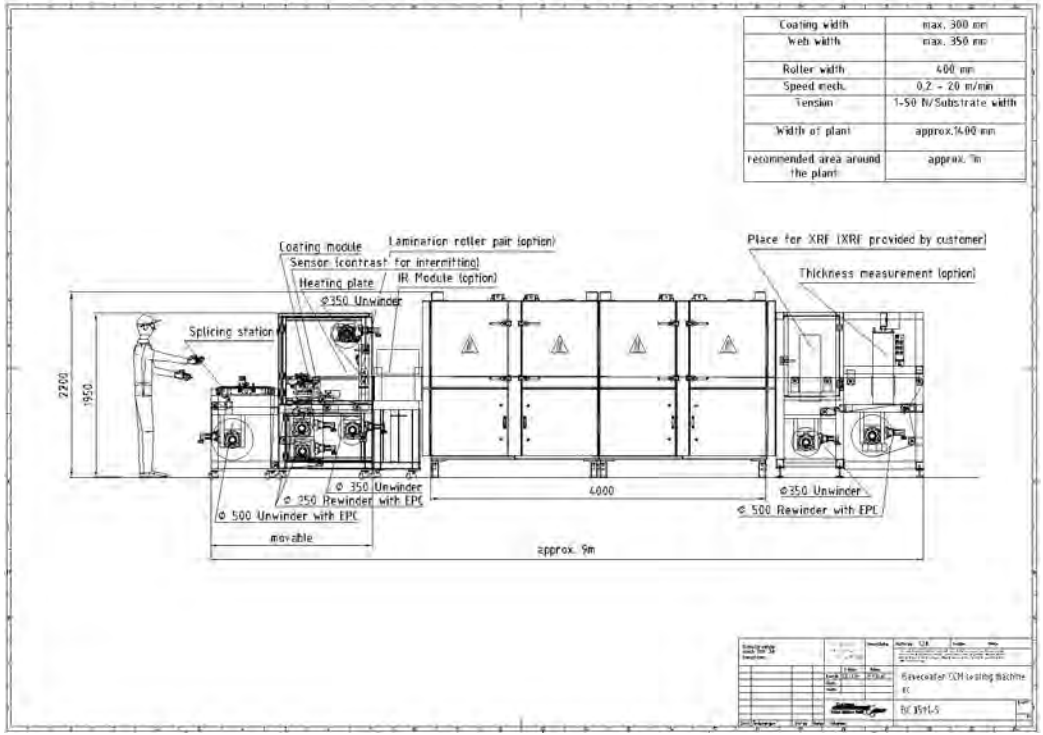
Hot pressing



The Linecoater

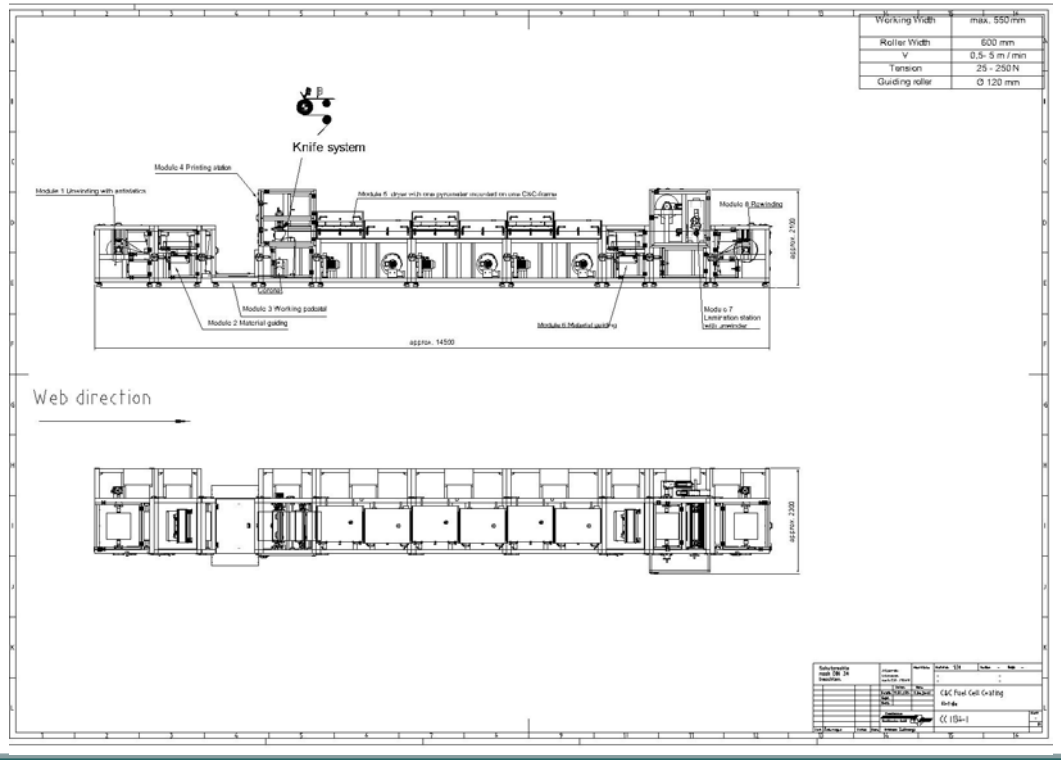


The Linecoater

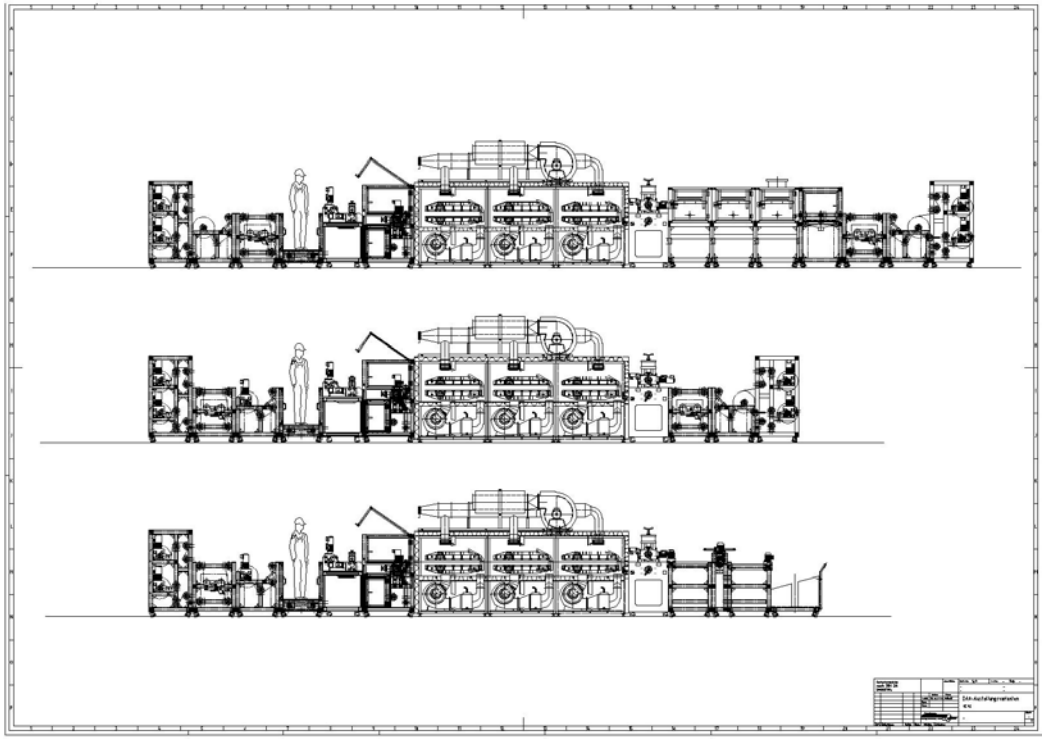


The Click&Coat™

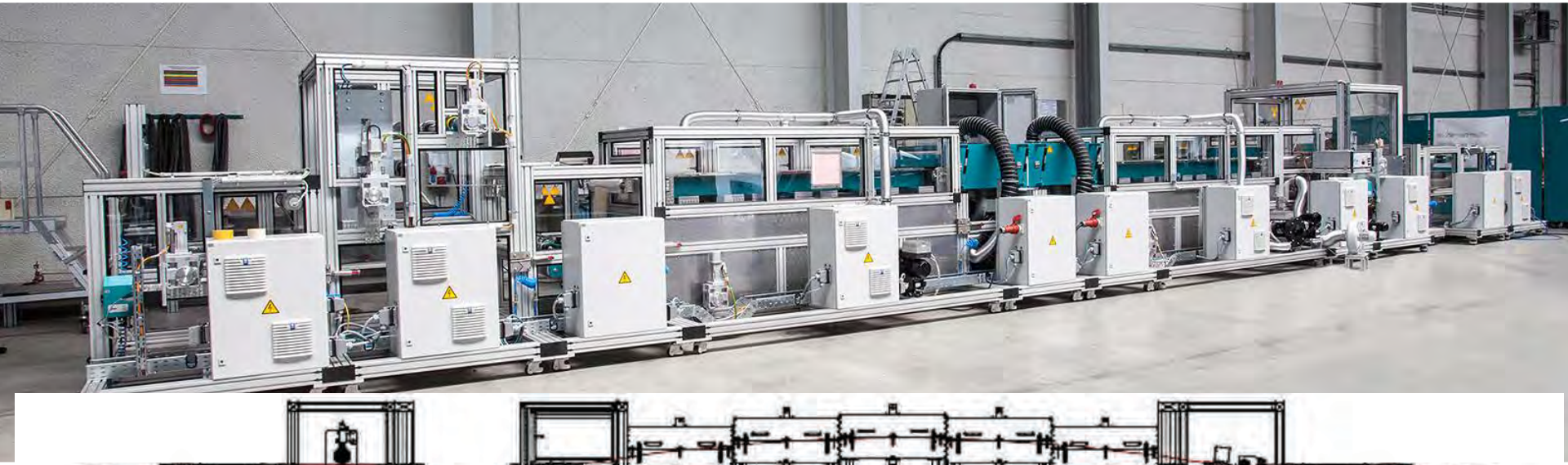
The Click&Coat™ – overview drawing

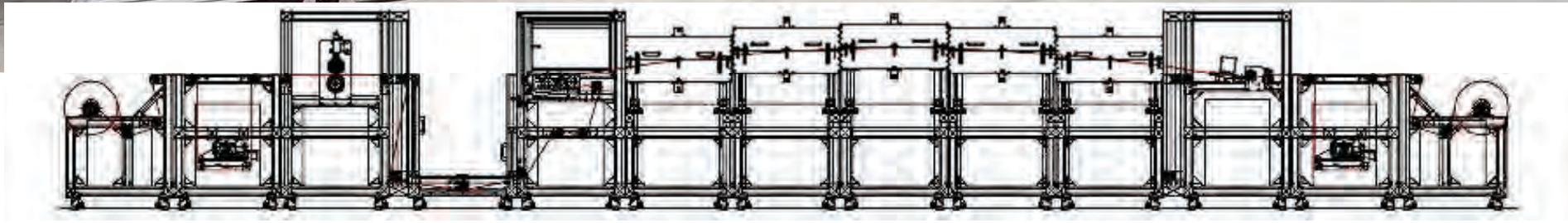


The Click&Coat™ – overview drawing

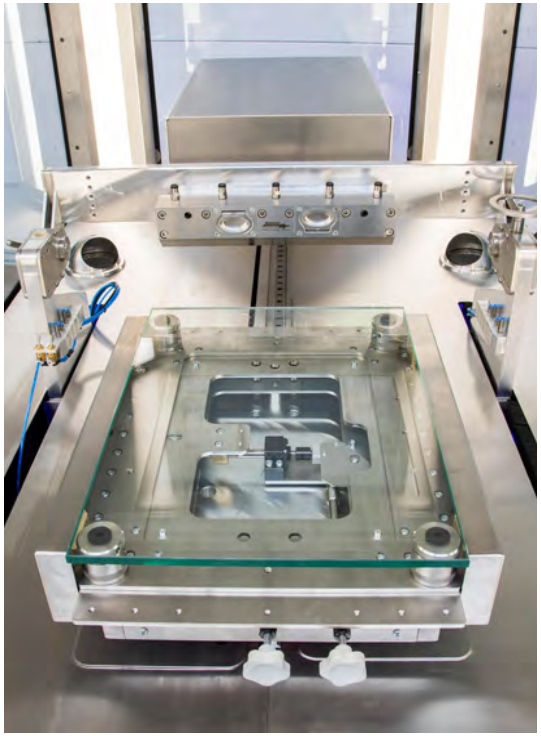


The Click&Coat™





The Click&Coat™



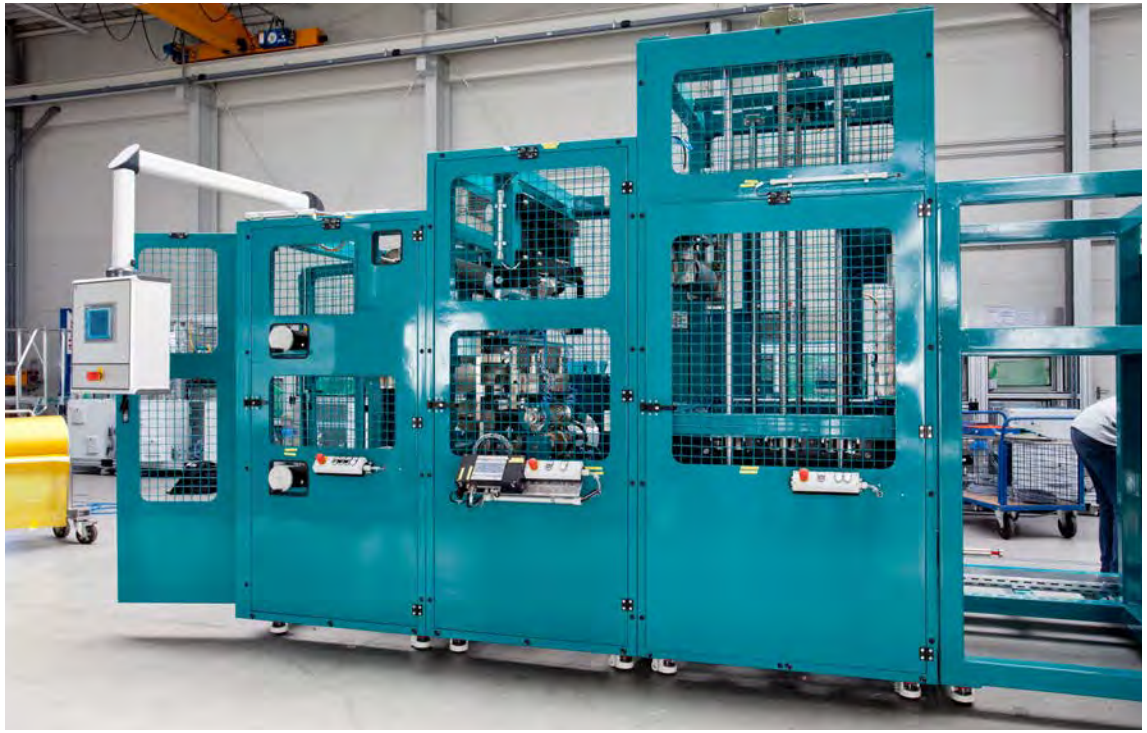
Facts

- ✓ Working pedestral
- ✓ Edge control
- ✓ Corona unit
- ✓ Coating module
- ✓ Lamination
- ✓ Vacuum conveyor
- ✓ Dryer (with fan air supply heater)

The Click&Coat™ Steel layout

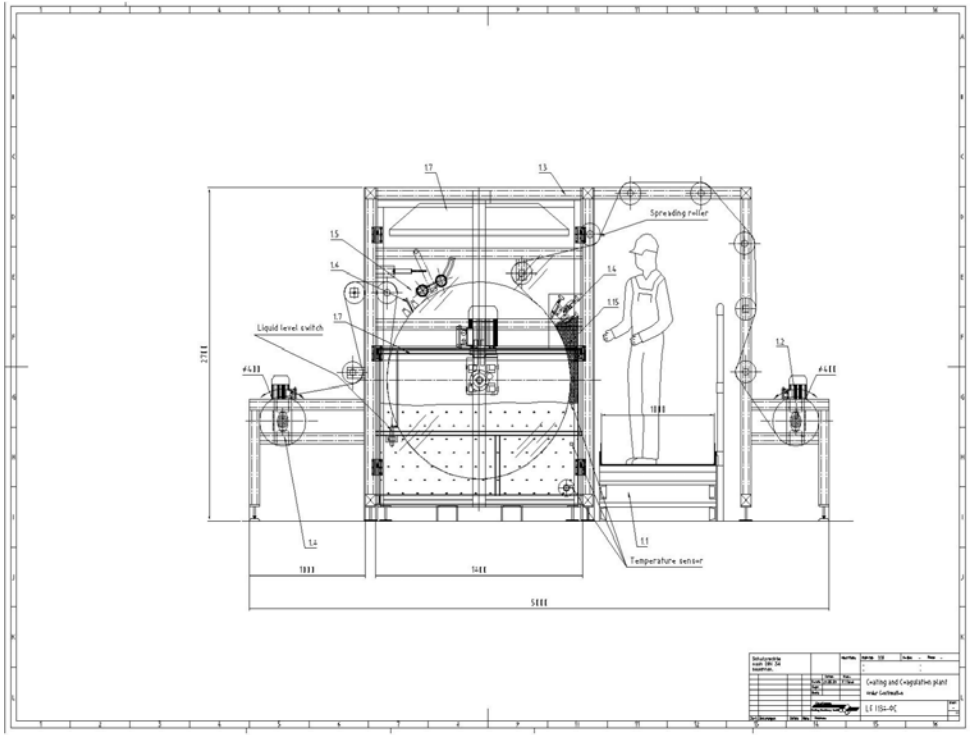
The Click&Coat™ Steel layout

The Click&Coat™ Steel layout



Membrane casting

Membrane casting



Summary

Introduction	Our markets & Equipment	R&D Projects	Overview on the basics	Coating systems
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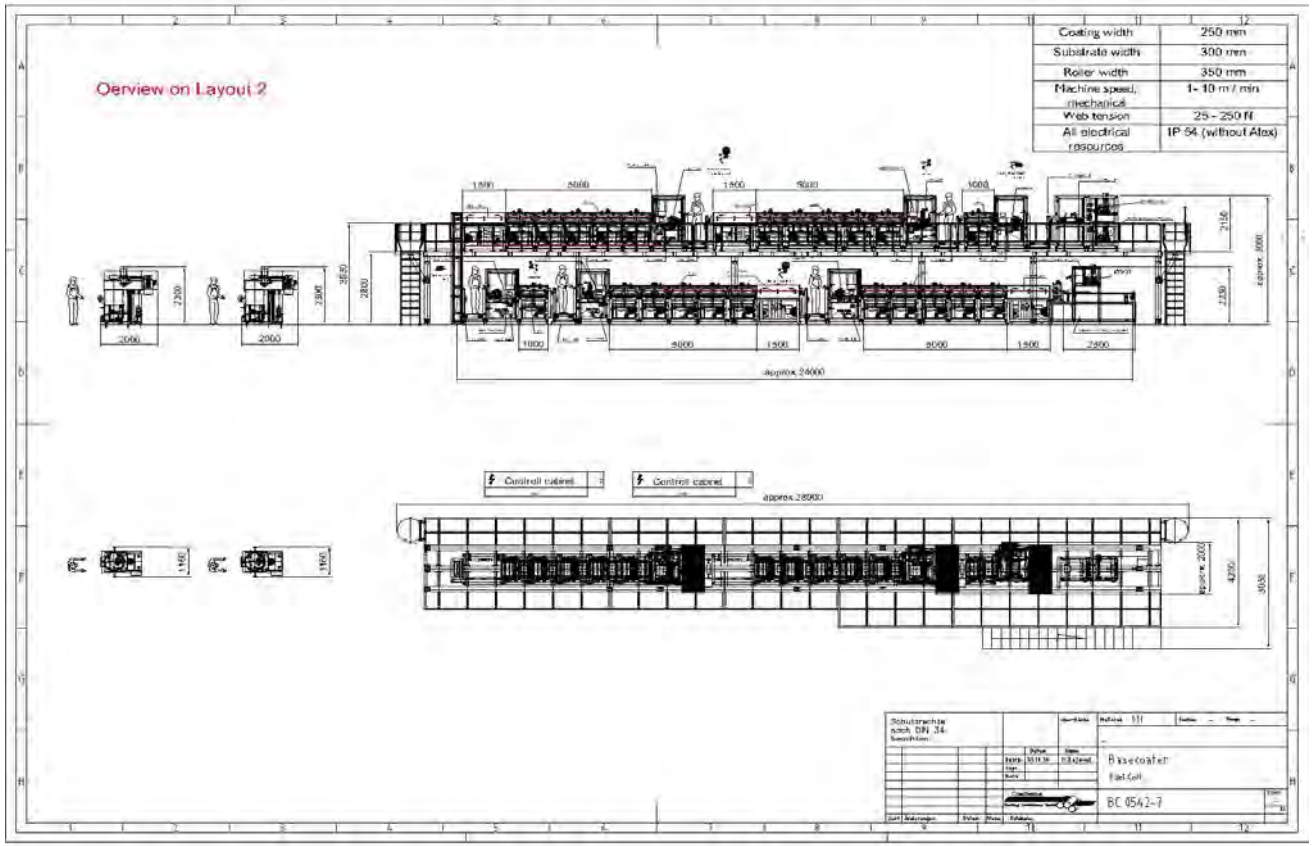
Production line for fuel cells – 1000 mm working width

Production line for MEAs



Summary

Introduction	Our markets & equipment	R&D projects	Overview on the basics	Coating systems
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The pathway to production

The benefits:

- ✓ Single side coating of catalyst layer
- ✓ Single side coating of gasket
- ✓ Coating of second side catalyst
- ✓ Coating of second side gasket
- ✓ Die cutting of the MEA and stapling
- ✓ Included are mixers, regisration control and splicing table

- ✓ Missing – atomated assembly of CCM with GDL and hotpressing in a discontinous step

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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