

Microoptics Summit, Amsterdam 3rd December 2024

Precision Roll-to-Roll Coating for Consumer Products

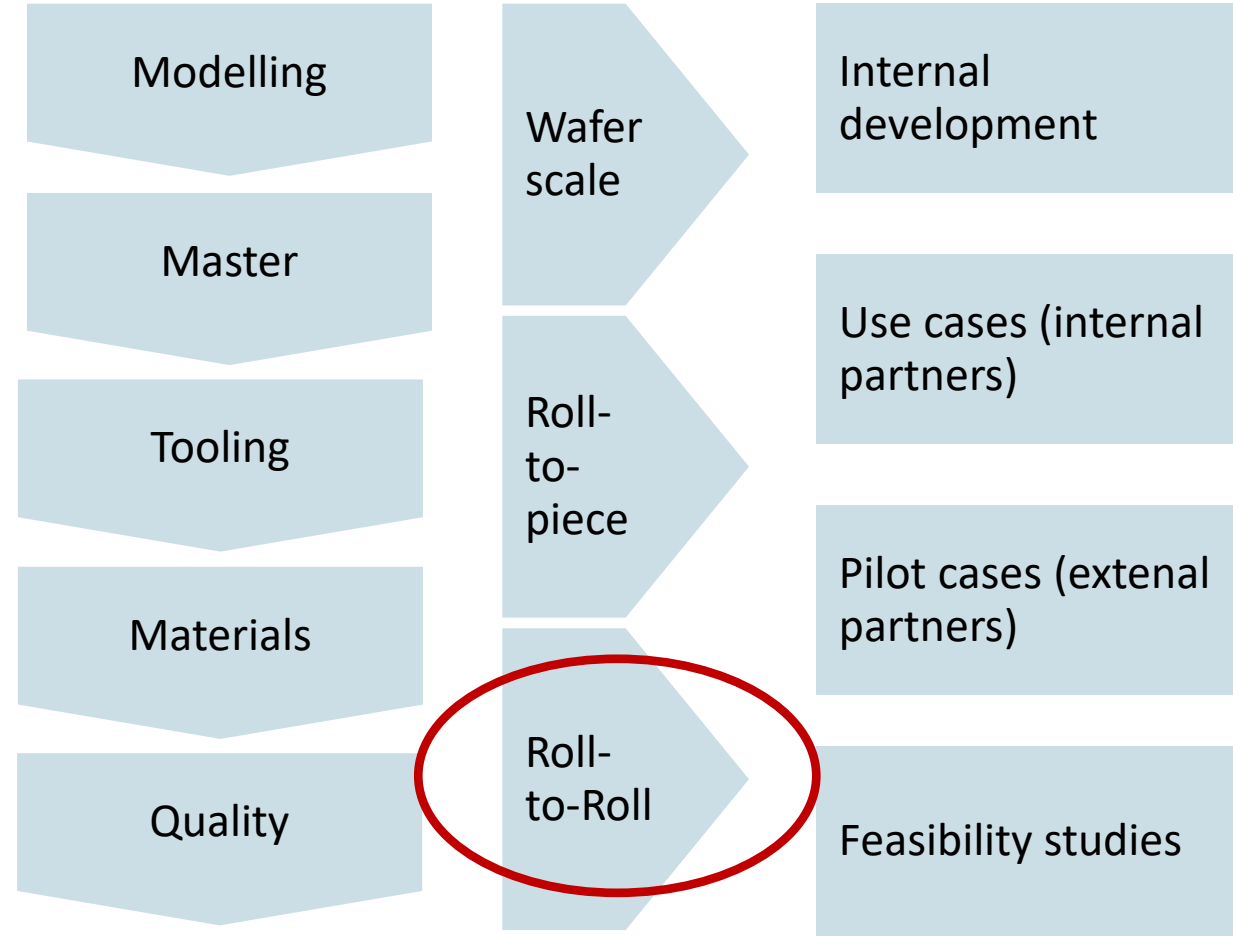
M. Fahland, Fraunhofer FEP, Phabulous consortium members



About PHABULOUS

Structure of the Project

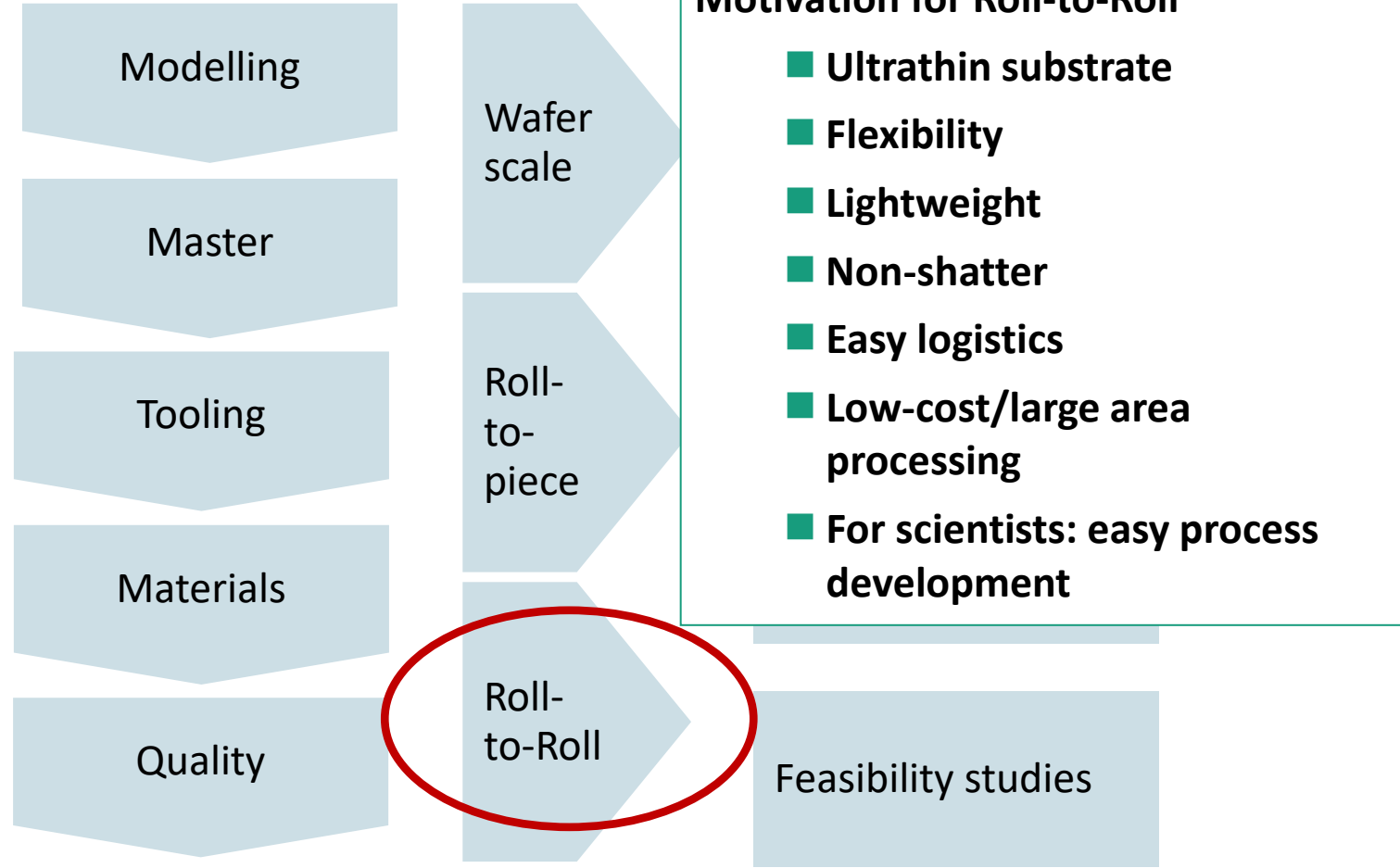
- Open Design Platform
- Tools, algorithms, design kits
- Laser micromachining
- Grey scale lithography
- Step & Repeat
- Mold, Shim
- Adaptation /modification
- Materials, coatings
- Inline measurement
- Offline measurement



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PHABULOUS Pillar

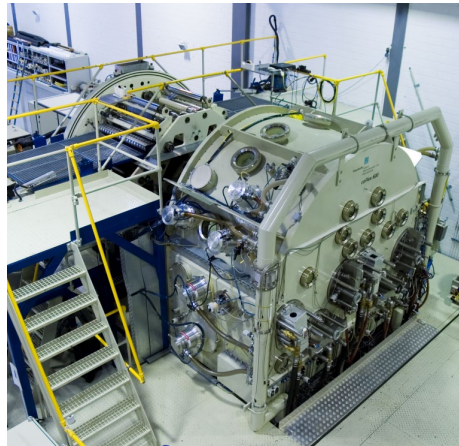
Roll-to-Roll service

■ Partners

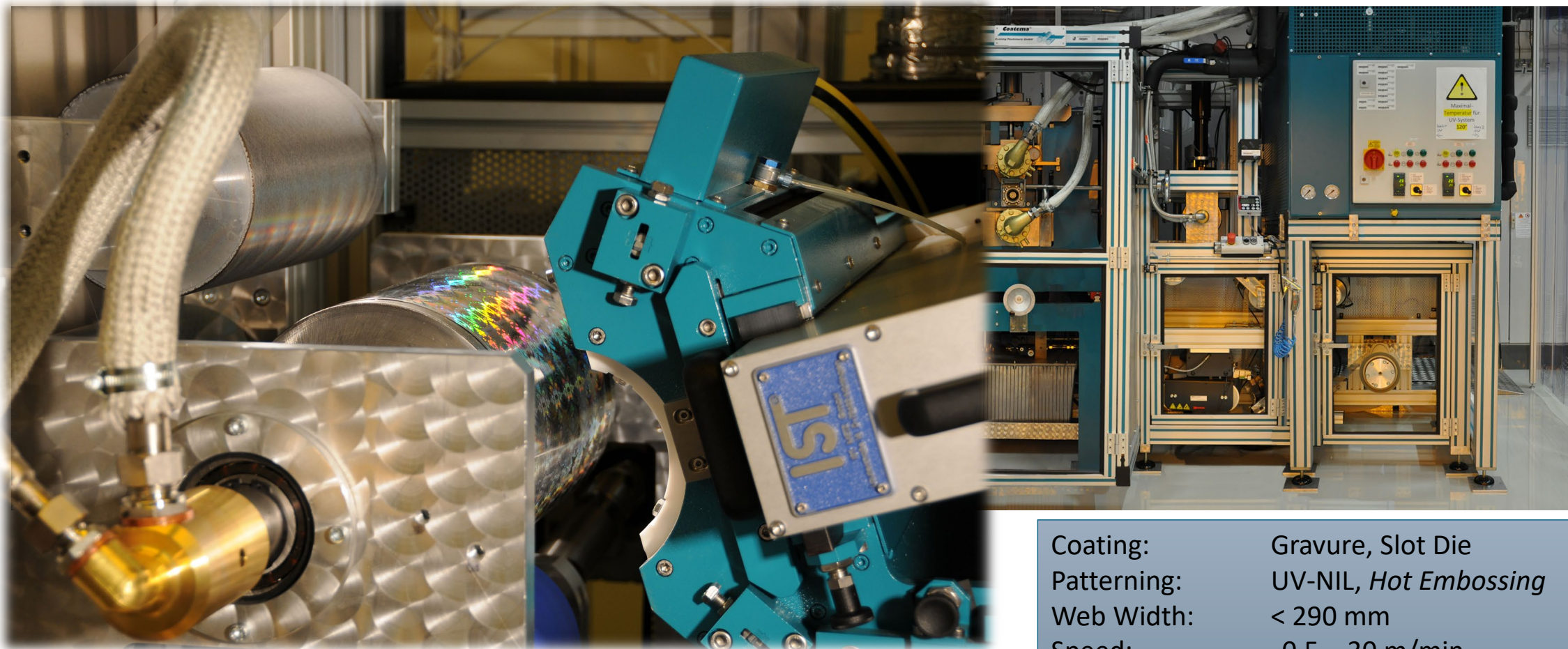
- Fraunhofer FEP
- Joanneum Research
- Nanocomp

■ Technologies

- Nano-Imprint Lithography
- Grafting
- Coating
- Plasmaetching
- Inspection and measurement



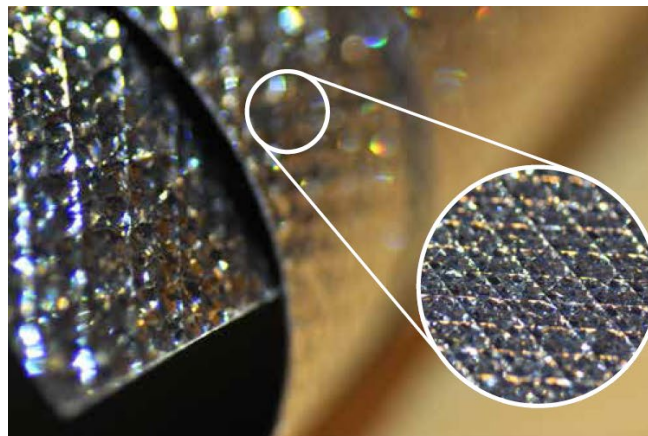
R2R-Nanoimprint Line



Coating:	Gravure, Slot Die
Patterning:	UV-NIL, <i>Hot Embossing</i>
Web Width:	< 290 mm
Speed:	0.5 – 30 m/min
In-line camera, wet thickness control	

Applications – Optics & Bionics

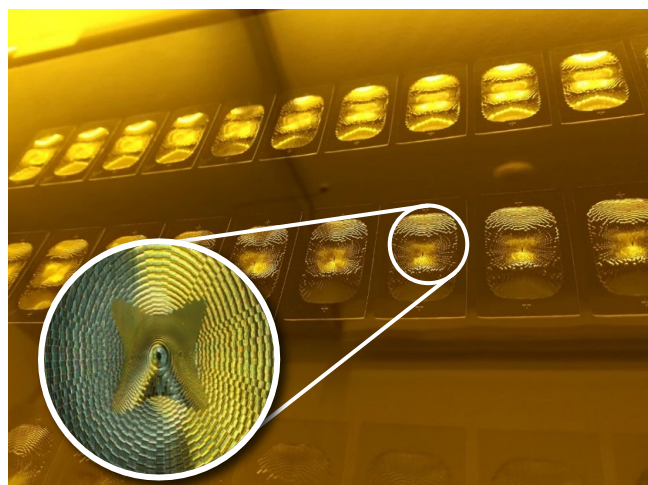
Decorative foils with artificial crystal facets



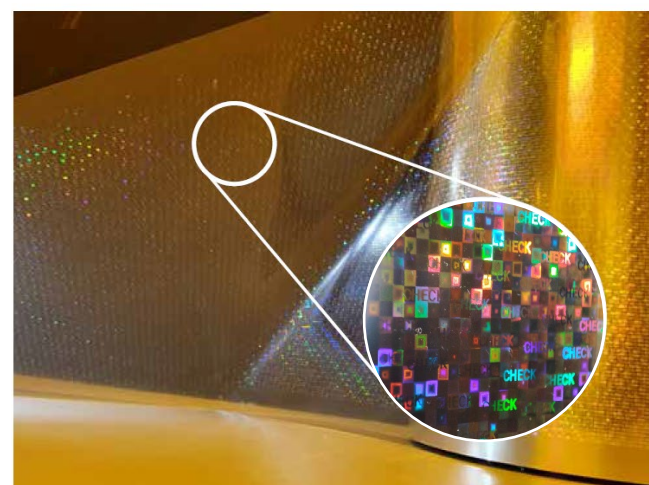
Riblet foils for drag-reducing bionic surface finishing in transport



Optical foils with freeform microoptical elements



Labels and packaging foils with diffractive holograms



Use Case 2: Decorative Films

Application:

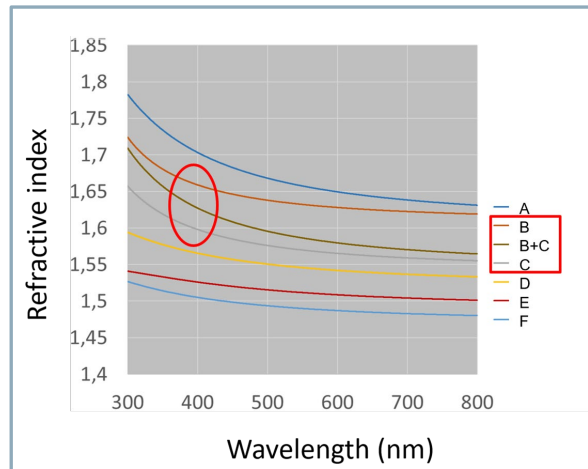
Freeform micro-facets to realize a sparkling effect for luxury goods

Upscaling target: Seamless Step & Repeat Upscaling for Roll-to-Roll production

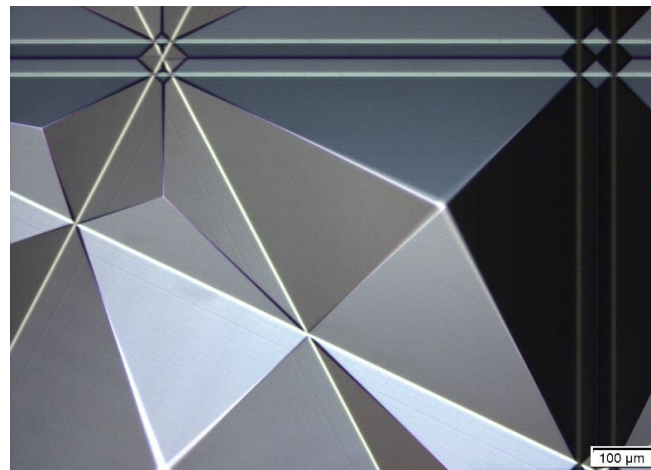
Seamless stitching of distributed facets with extremely high edge accuracy, low shrinking and low Abbe number



Resin with high dispersion



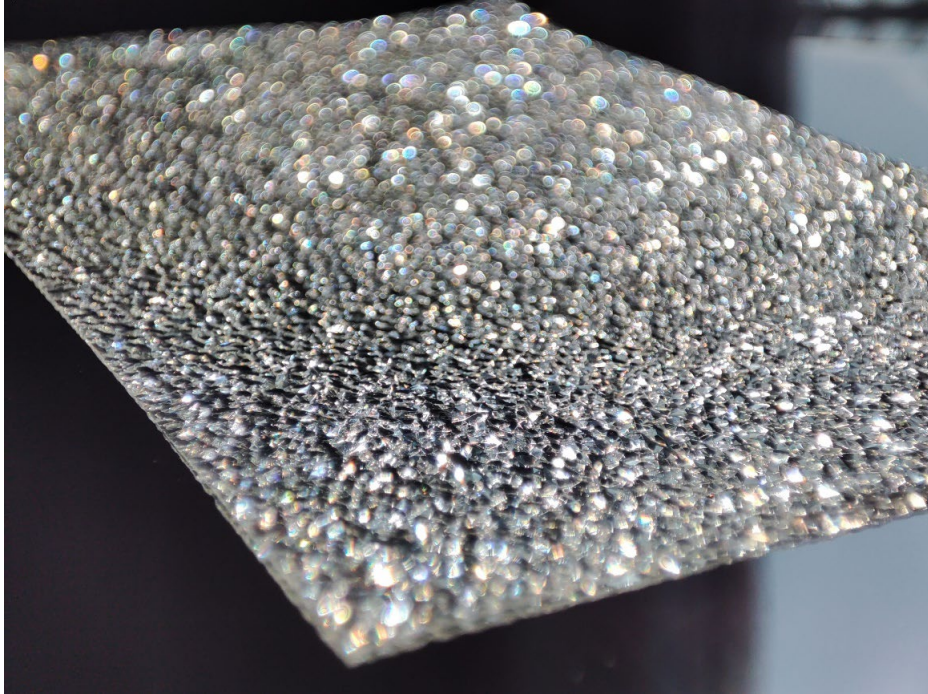
„Crystals“ with facet designs



Double side imprinted „crystals“



Roll-to-roll (R2R) replication: finished products



R2R UV imprint into **high dispersion resin**
+ R2R backside metallized

View: reflection



R2R UV imprint into **high dispersion resin**

View: transmission

About Fraunhofer FEP

The Institute in Figures

Employees	196
Total budget	30.7 M€
Industry returns	11.6 M€
Public funding	6.2 M€
Investments	2.1 M€

(April 2024 | Figures from 2023)

Director



Prof. Dr. Elizabeth von Hauff



Location / Buildings of the Fraunhofer FEP

Core Expertise of Fraunhofer FEP

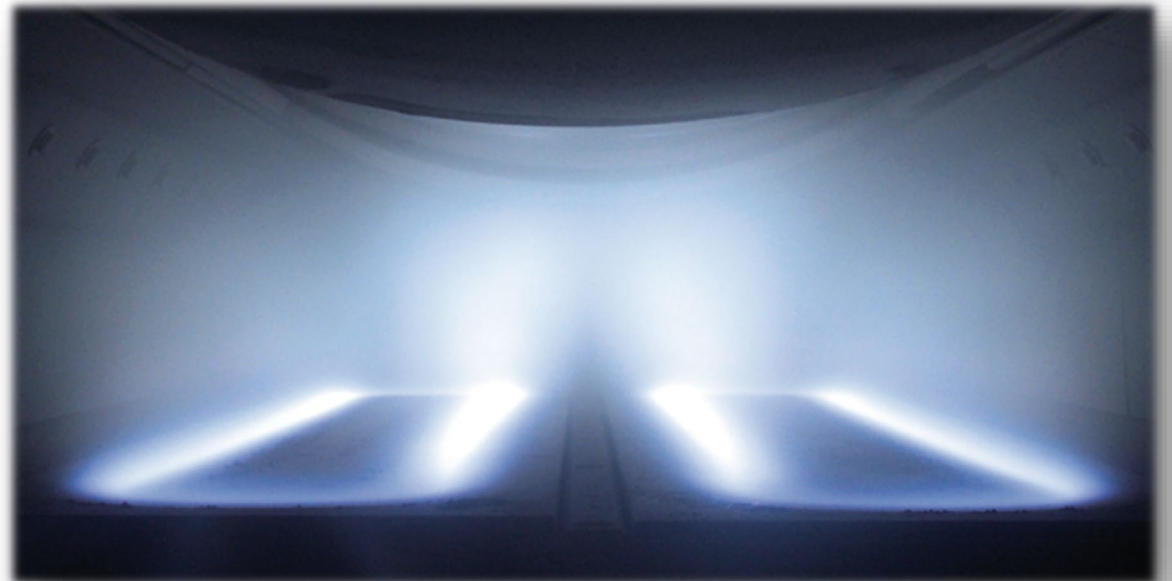
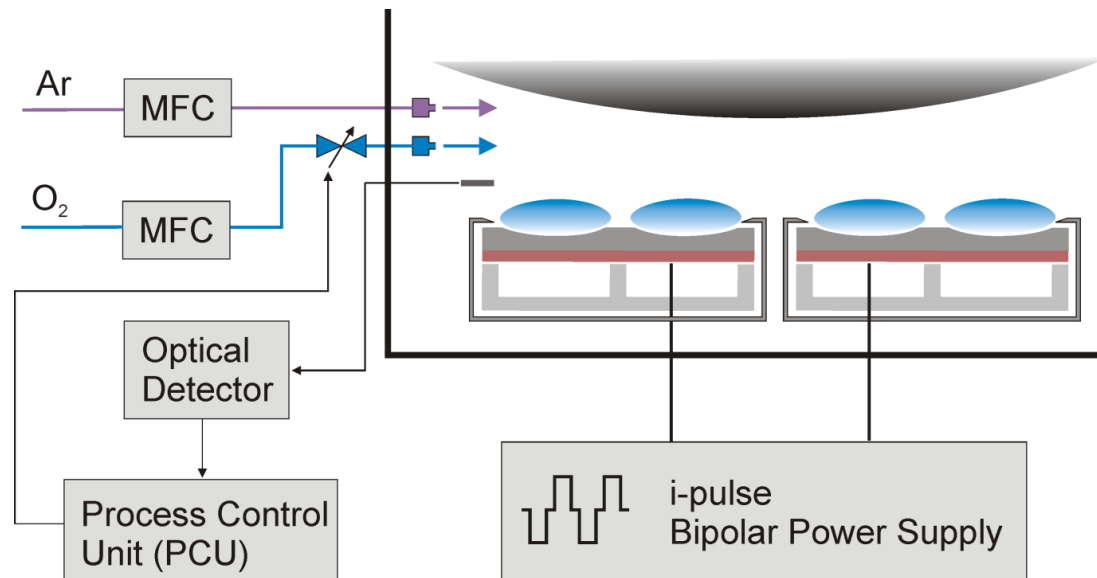


PHABULOUS Technology

Reactive sputter deposition

Objectives

- Both from planar and rotatable magnetrons
- TiO_2 , SiO_2 , Nb_2O_5 , Al_2O_3 , TiN , Si_3N_4 , SnO_2 , ZnSnO_x , WO_3 , VO_2 , AlN



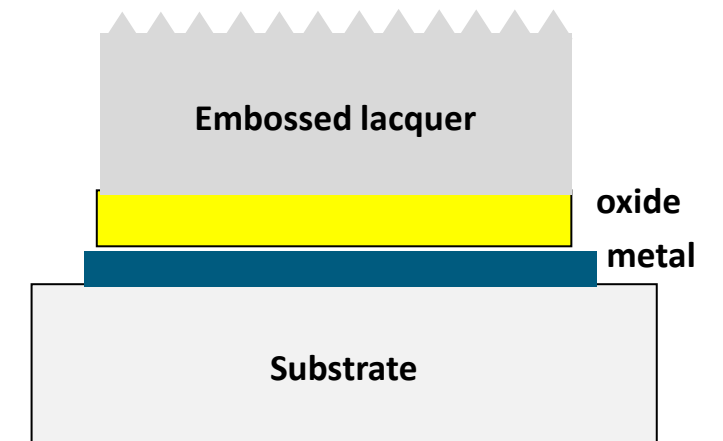
PHABULOUS Technology

Reactive sputter deposition

The periodic table shows the following chemical formulas highlighted in green boxes:

- Group 1 (IA):** H (Hydrogen)
- Group 2 (IIA):** Be (Beryllium)
- Group 3 (IIIB):** Na (Sodium)
- Group 4 (IVB):** Ti (Titanium)
- Group 5 (VB):** V (Vanadium)
- Group 6 (VIB):** Cr (Chromium)
- Group 7 (VIIB):** Mn (Manganese)
- Group 8 (VIII):** Fe (Iron), Co (Cobalt), Ni (Nickel)
- Group 9 (IX):** Cu (Copper)
- Group 10 (X):** Zn (Zinc)
- Group 11 (IB):** Ag (Silver)
- Group 12 (IIB):** Cd (Cadmium)
- Group 13 (IIIA):** Al (Aluminum)
- Group 14 (IVA):** Si (Silicon)
- Group 15 (VA):** P (Phosphorus)
- Group 16 (VIA):** S (Sulfur)
- Group 17 (VIIA):** Cl (Chlorine)
- Group 18 (VIIIA):** He (Helium), Ne (Neon), Ar (Argon), Kr (Krypton), Xe (Xenon), Rn (Radon)
- Group 19 (IIA):** K (Potassium)
- Group 20 (IIA):** Ca (Calcium)
- Group 21 (IIIB):** Sc (Scandium)
- Group 22 (IVB):** Ti (Titanium)
- Group 23 (VB):** V (Vanadium)
- Group 24 (VIB):** Cr (Chromium)
- Group 25 (VIIB):** Mn (Manganese)
- Group 26 (VIII):** Fe (Iron)
- Group 27 (VIII):** Co (Cobalt)
- Group 28 (VIII):** Ni (Nickel)
- Group 29 (IX):** Cu (Copper)
- Group 30 (X):** Zn (Zinc)
- Group 31 (IIIA):** Ga (Gallium)
- Group 32 (IVA):** Ge (Germanium)
- Group 33 (VA):** As (Arsenic)
- Group 34 (VIA):** Se (Selenium)
- Group 35 (VIIA):** Br (Bromine)
- Group 36 (VIIIA):** Kr (Krypton)
- Group 37 (IIA):** Rb (Rubidium)
- Group 38 (IIA):** Sr (Strontium)
- Group 39 (IIIB):** Y (Yttrium)
- Group 40 (IVB):** Zr (Zirconium)
- Group 41 (VB):** Nb (Niobium)
- Group 42 (VIB):** Mo (Molybdenum)
- Group 43 (VIIB):** Tc (Technetium)
- Group 44 (VIII):** Ru (Ruthenium)
- Group 45 (VIII):** Rh (Rhodium)
- Group 46 (VIII):** Pd (Palladium)
- Group 47 (IX):** Ag (Silver)
- Group 48 (X):** Cd (Cadmium)
- Group 49 (IIIA):** In (Indium)
- Group 50 (IVA):** Sn (Tin)
- Group 51 (VA):** Sb (Antimony)
- Group 52 (VIA):** Te (Tellurium)
- Group 53 (VIIA):** I (Iodine)
- Group 54 (VIIIA):** Xe (Xenon)
- Group 55 (IIA):** Cs (Cesium)
- Group 56 (IIA):** Ba (Barium)
- Group 57 (IIIB):** La (Lanthanum)
- Group 58 (IVB):** Ce (Cerium)
- Group 59 (VB):** Pr (Praseodymium)
- Group 60 (VIB):** Nd (Neodymium)
- Group 61 (VIIB):** Pm (Promethium)
- Group 62 (VIII):** Sm (Samarium)
- Group 63 (VIII):** Eu (Europium)
- Group 64 (VIII):** Gd (Gadolinium)
- Group 65 (IX):** Tb (Terbium)
- Group 66 (X):** Dy (Dysprosium)
- Group 67 (IIIA):** Ho (Holmium)
- Group 68 (IVA):** Er (Erbium)
- Group 69 (VA):** Tm (Thulium)
- Group 70 (VIA):** Yb (Ytterbium)
- Group 71 (VIIA):** Lu (Lutetium)
- Group 72 (IIA):** Fr (Francium)
- Group 73 (IIA):** Ra (Radium)
- Group 74 (IIIB):** Ac (Actinium)
- Group 75 (IVB):** Th (Thorium)
- Group 76 (VB):** Pa (Protactinium)
- Group 77 (VIB):** U (Uranium)
- Group 78 (VIIB):** Np (Neptunium)
- Group 79 (VIII):** Pu (Plutonium)
- Group 80 (VIII):** Am (Americium)
- Group 81 (IX):** Cm (Curium)
- Group 82 (X):** Bk (Berkelium)
- Group 83 (IIIA):** Cf (Californium)
- Group 84 (IVA):** Es (Einsteinium)
- Group 85 (VA):** Fm (Fermium)
- Group 86 (VIA):** Md (Mendelevium)
- Group 87 (VIIA):** No (Nobelium)
- Group 88 (VIIIA):** Lr (Lawrencium)

- Physical colours
- Sensitive to oblique angle
- Microoptic create uniform colour appearance



PHABULOUS Technology

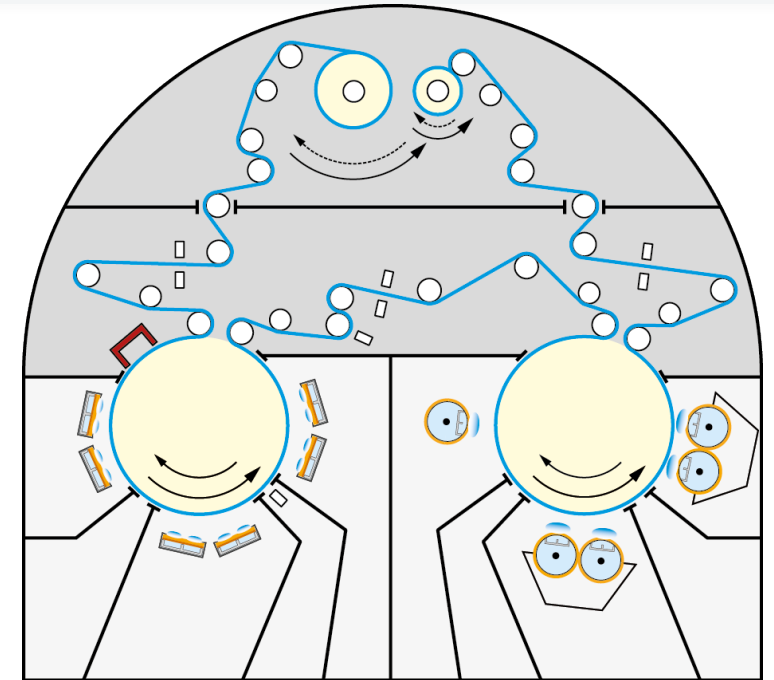
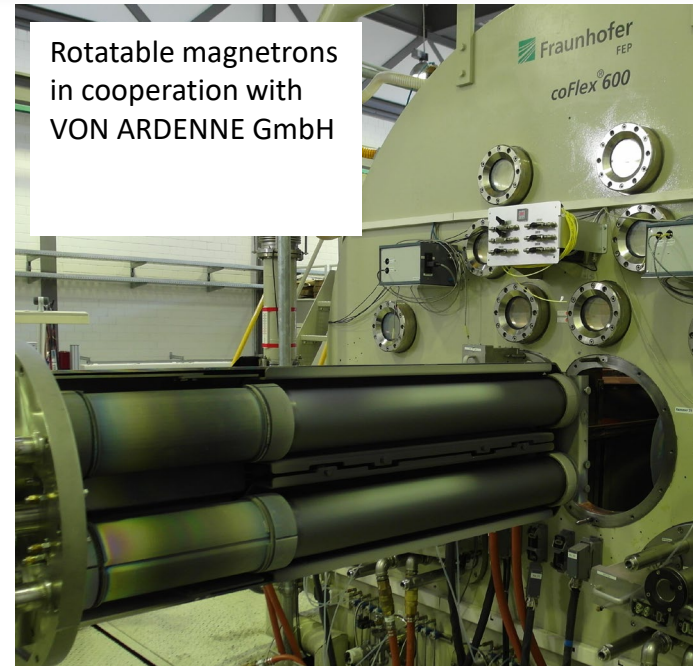
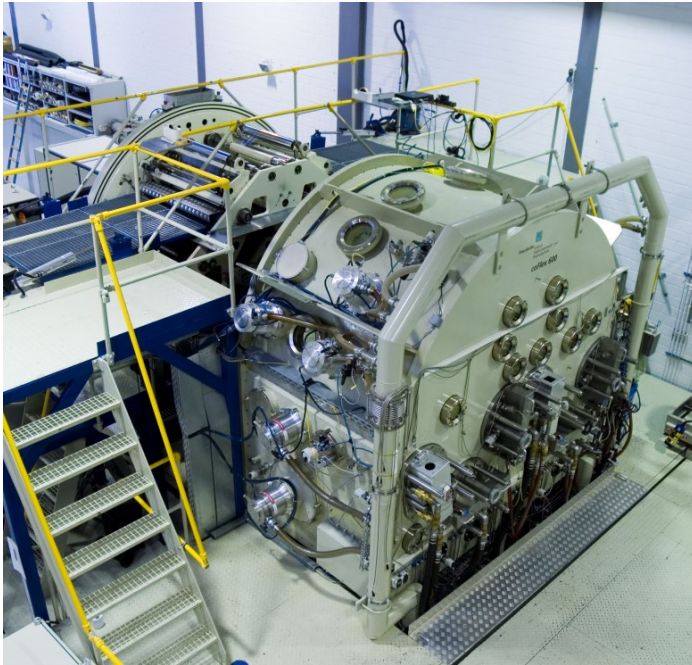
Reactive sputter deposition

Objectives

- Sputtering & PECVD on flexible materials
- Large area upscaling of roll-to-roll processes, pilot deposition

Features

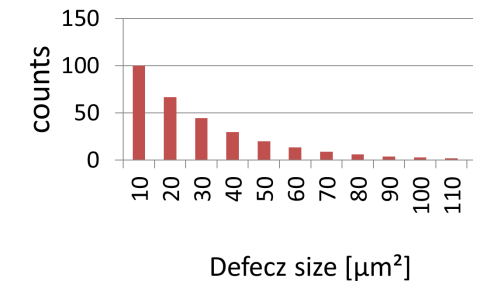
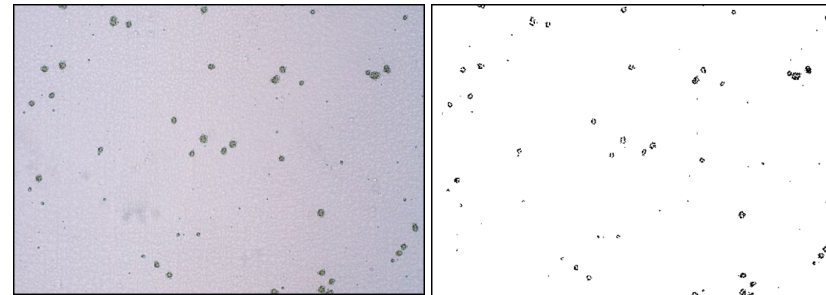
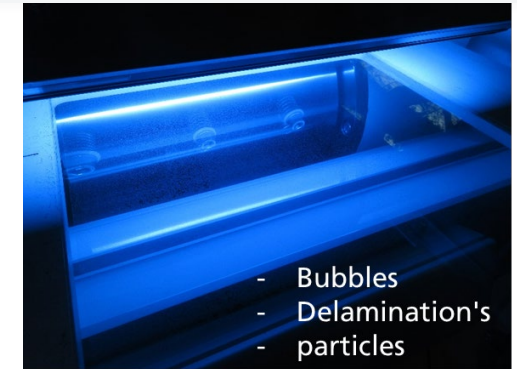
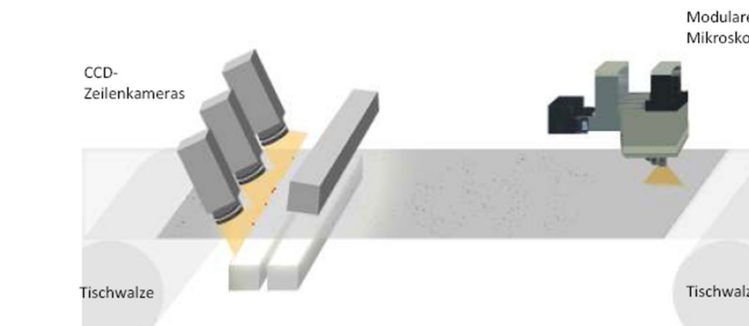
- 600 mm deposition width, adaptive deposition zone setup
- Pulsed sputtering, arcPECVD, optical and electric inline monitoring



Inline monitoring : WILMA

Roll-to-Roll Inspection system

Objectives	■ Defect mapping, classification ($1\mu\text{m}$ size) with modular, moveable optical microscope ■ CCD line scan cameras and light bank (white or blue), resolution $40\mu\text{m}$ defect size
Features	■ 300 mm band width inspection of 10 to 100m length ■ 100% mapping or field of view depending of used microscope objective (x2,5...x20)

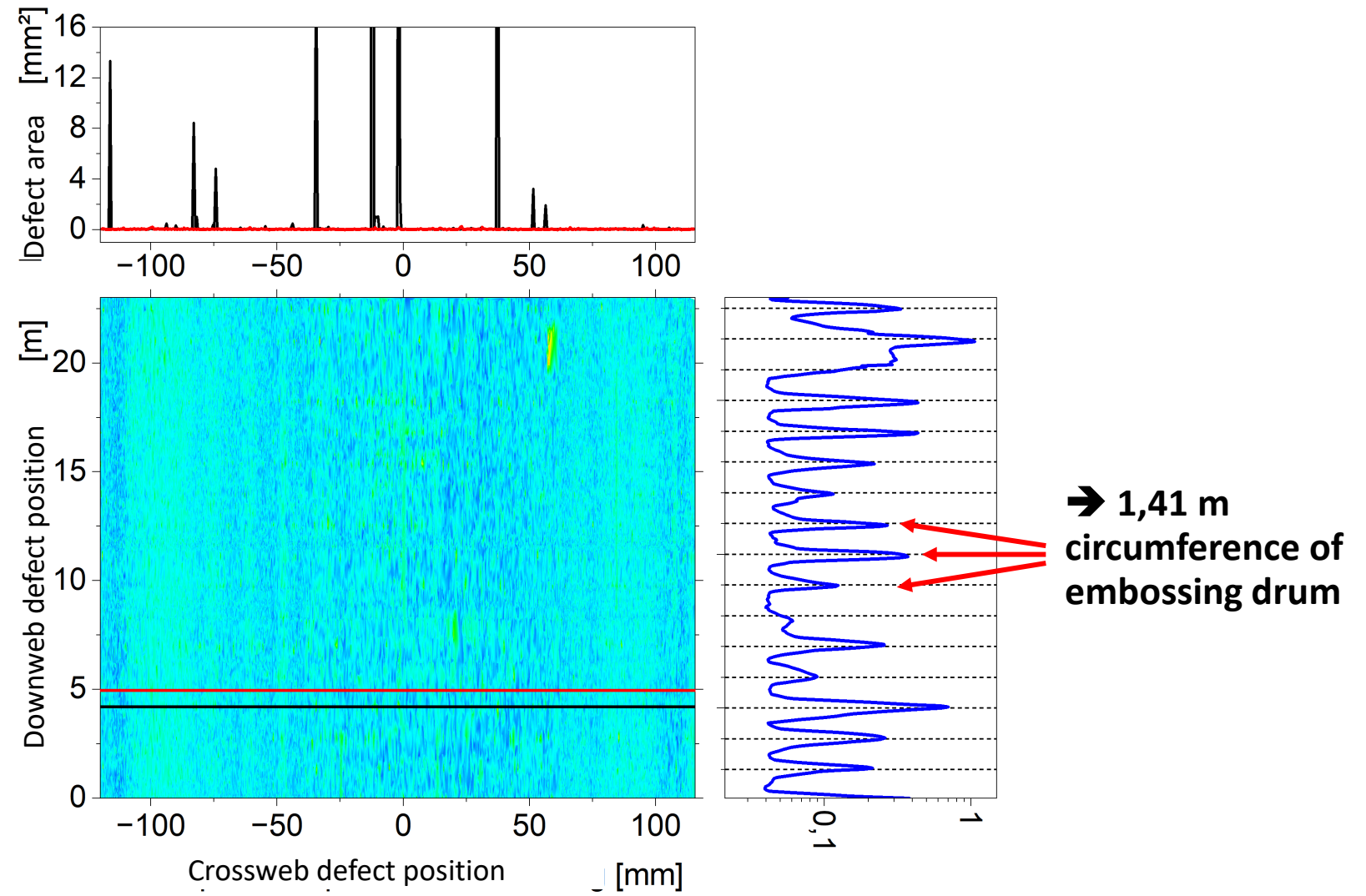


Inline monitoring

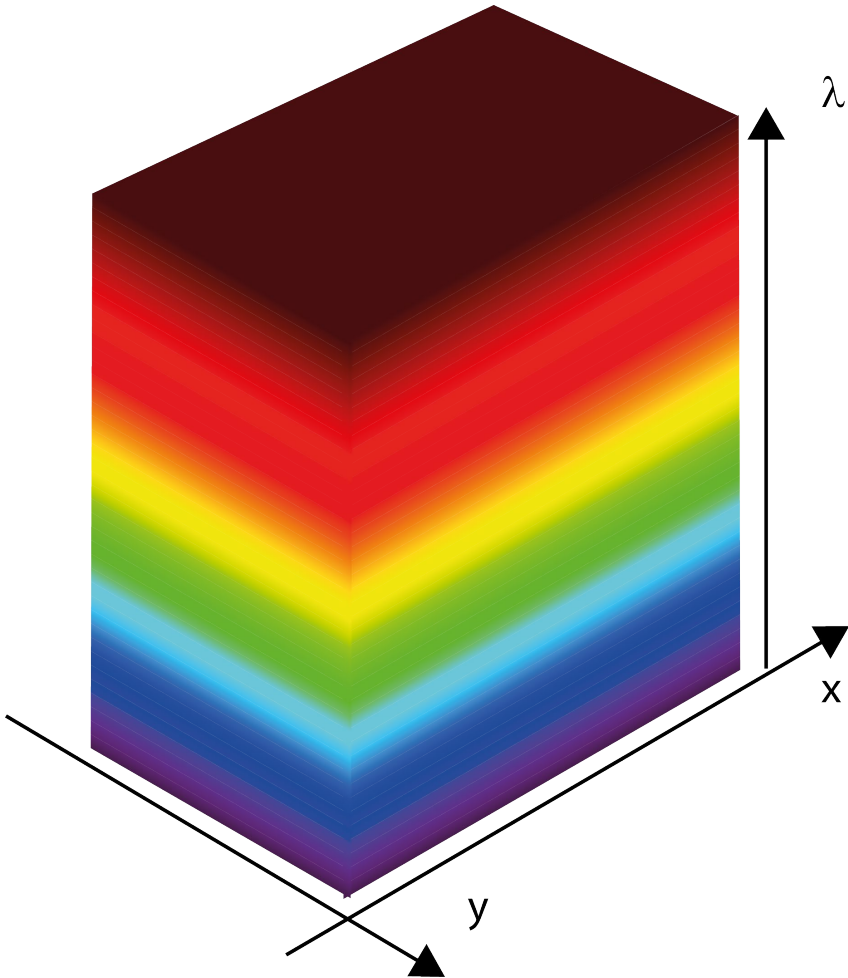
Camera-based inspection system

100 %-inspection of a patterned surface

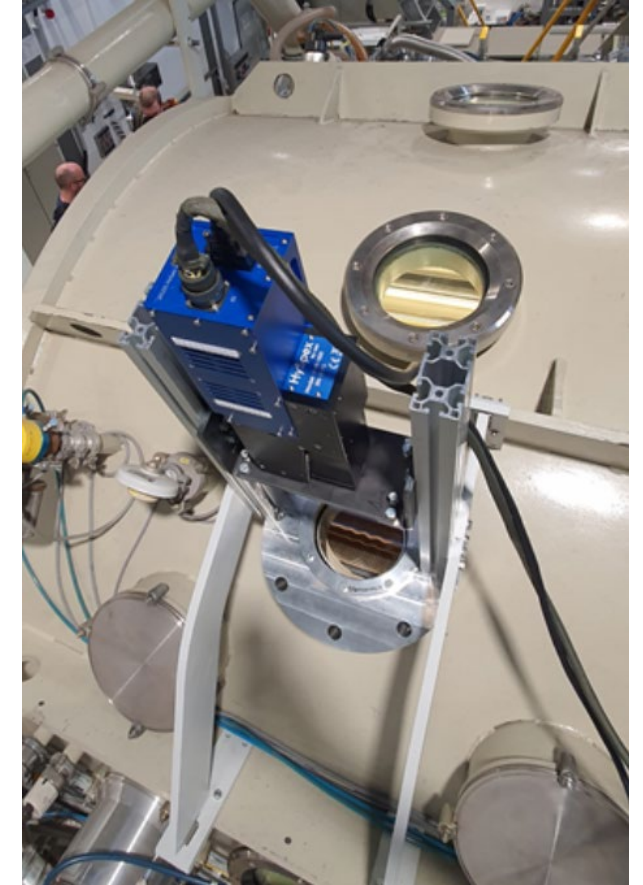
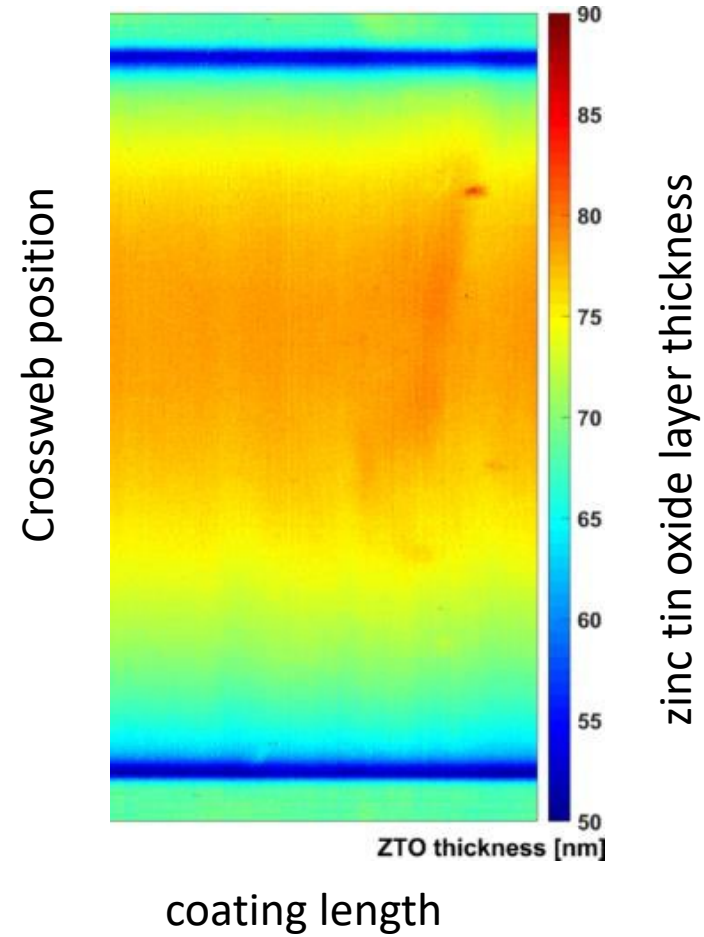
- The defect picture of a roll is shown
- Small points represent the regular pattern
- The irregularity in the embossing tool is clearly seen



In-line Monitoring Hyper-spectral Imaging



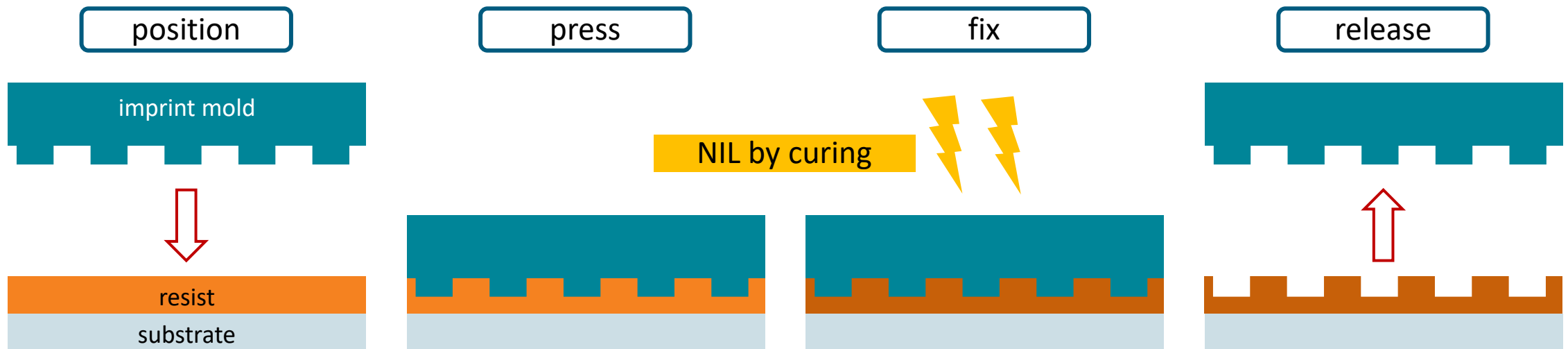
Imaging of
relevant properties



PHABULOUS Technology

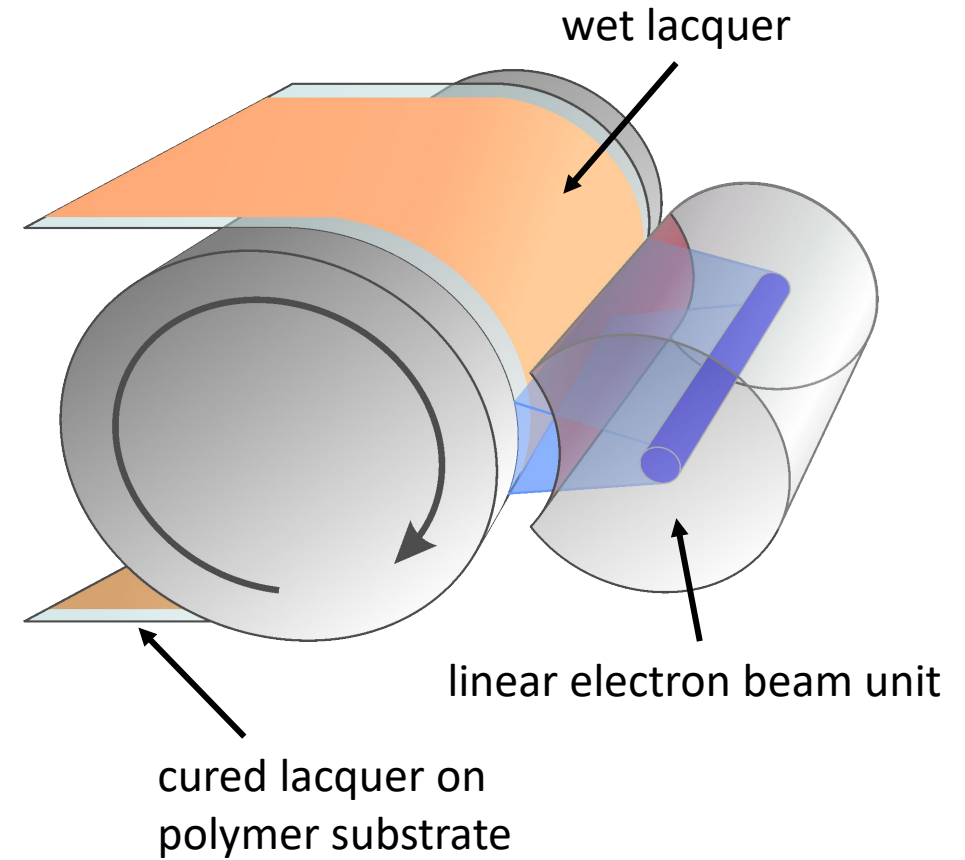
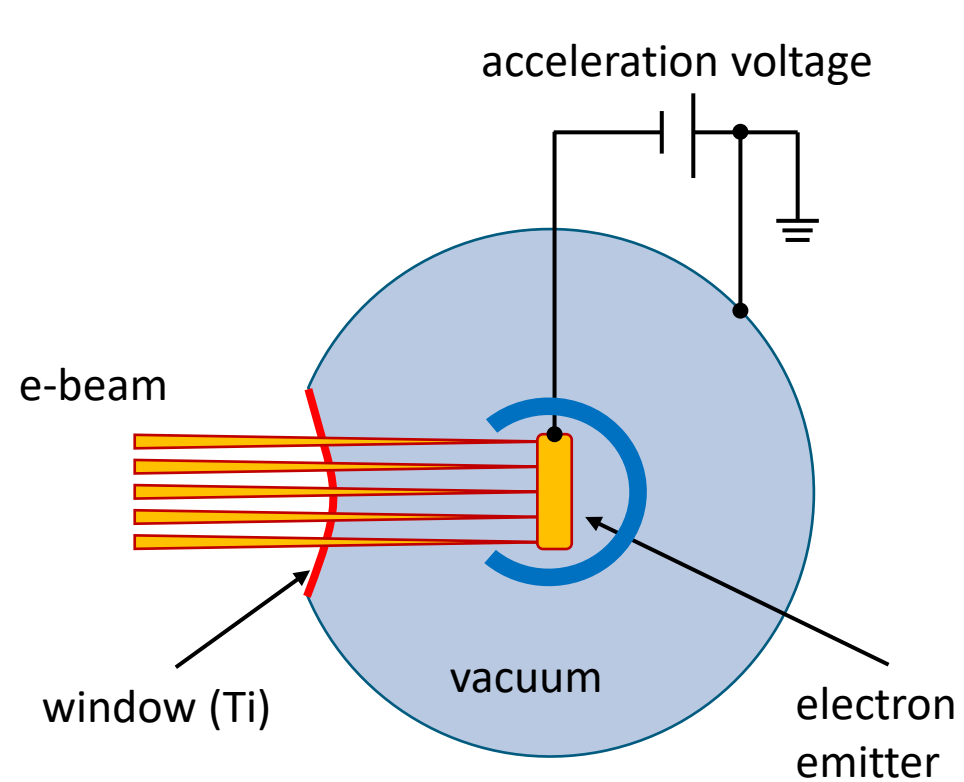
Nano-Imprint Lithography

- coating step required
- resist must be curable – substrate becomes independent from being imprintable
- curing within milliseconds – no cooling time necessary
- substrate or imprint mold must be „curing“ transparent
- imprinting force much lower due to lower viscosity of resist



PHABULOUS Technology

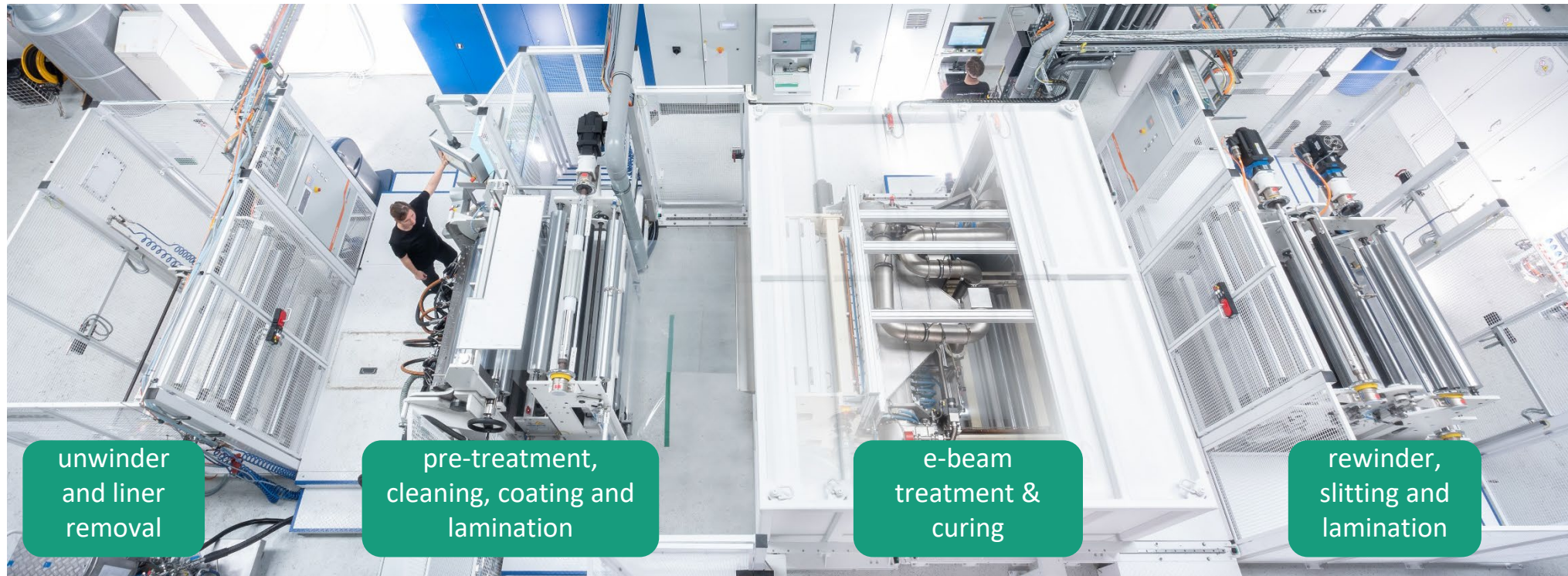
Electron Beam Curing



AtmoFlex 1250

Slot die coating & electron beam curing

- up to 1250 mm web width
- web speed up to 150 m/min
- wet/dry lamination
- slot die coating @ 1200 mm coating width
- electron beam treatment & curing
- typical substrates: polymer films, paper, metal foils



Roll-to-Roll Application

Hierarchical structures

Objectives

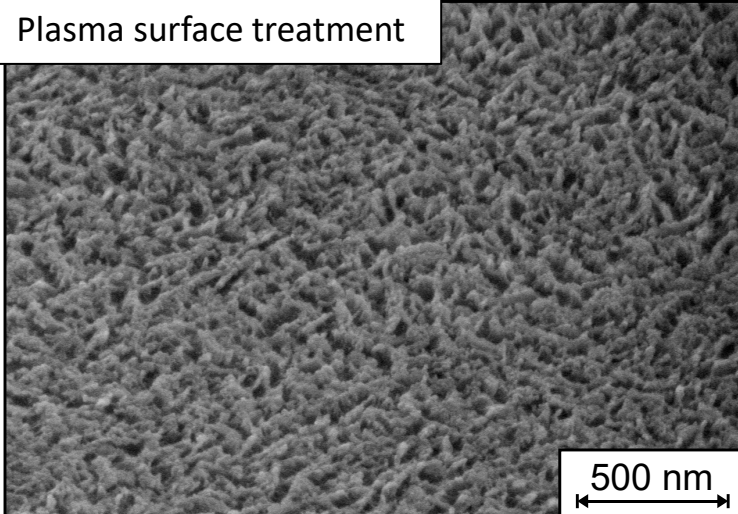
- Influence on surface morphology on different length scales
- Adjustment hydrophobic/hydrophilic surface properties,
- Broadband antireflection/antiglare properties

Technology

- Plasma based surface modification, thin film deposition, electron beam curing

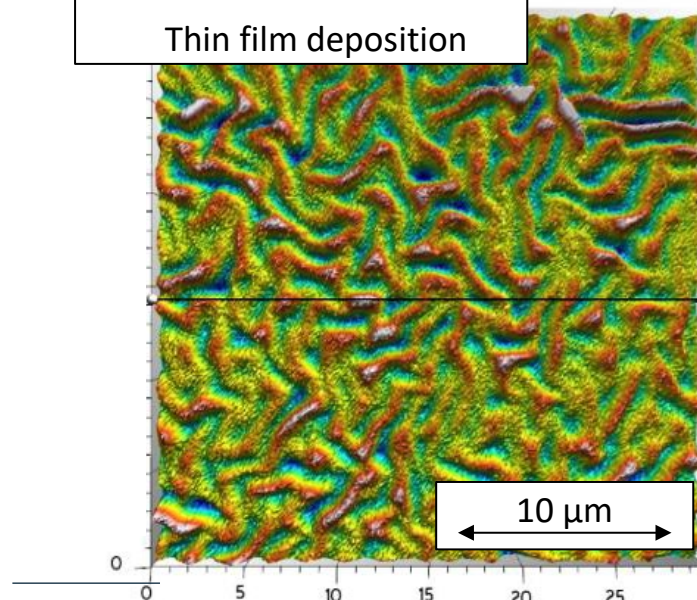
Method:

Plasma surface treatment



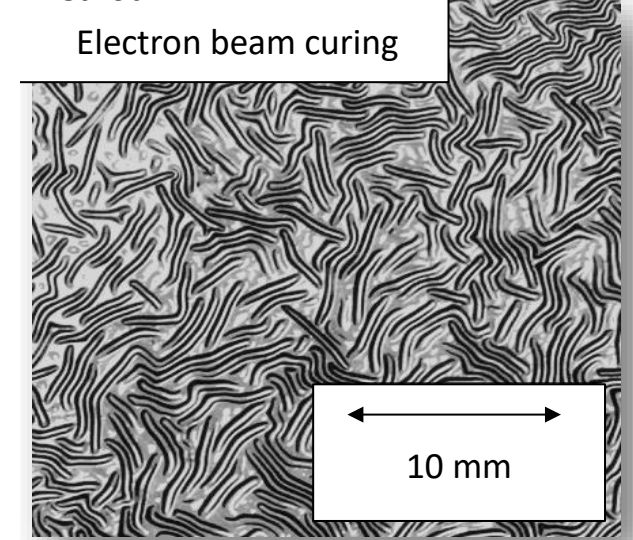
Method:

Thin film deposition



Method:

Electron beam curing



PHABULOUS Application example

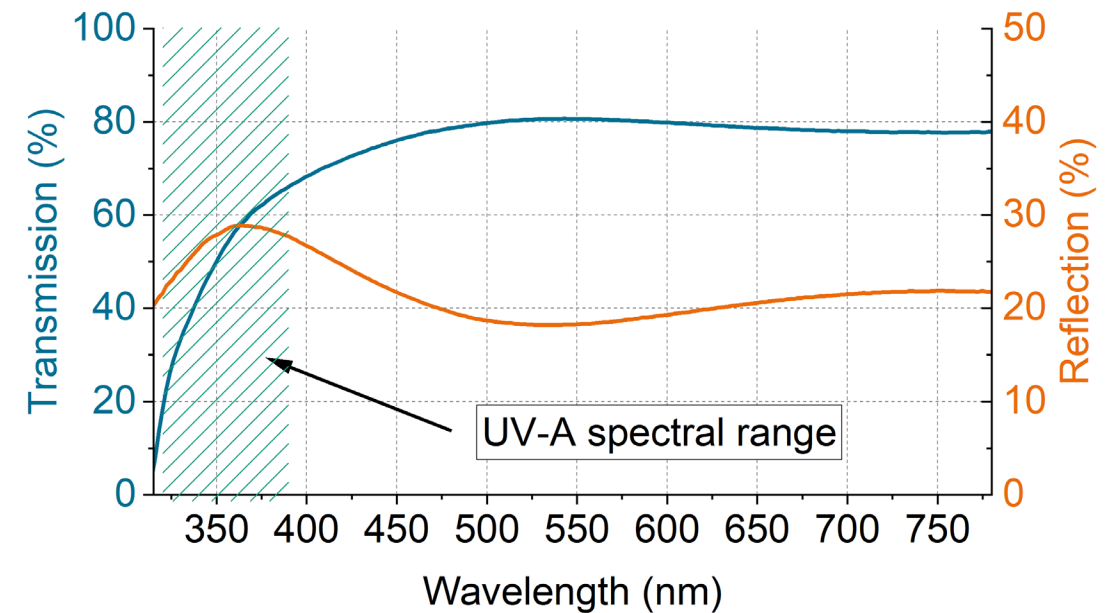
Bird Protection film

Objectives

- Protection of glass panes from bird collision
- Minimum disturbing in appearance

Technology

- FEP: Roll-to-roll plasma etching and deposition
- Most of the contrast in UV-A spectral range



PHABULOUS Application example

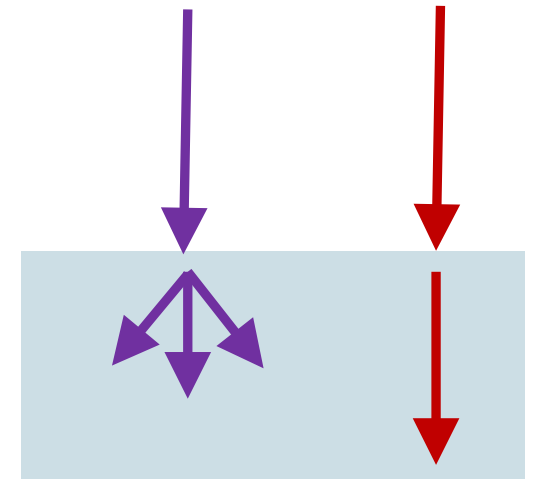
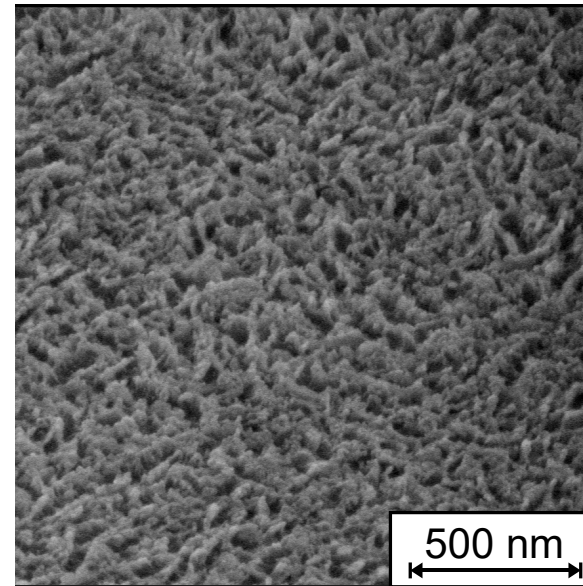
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Application Example

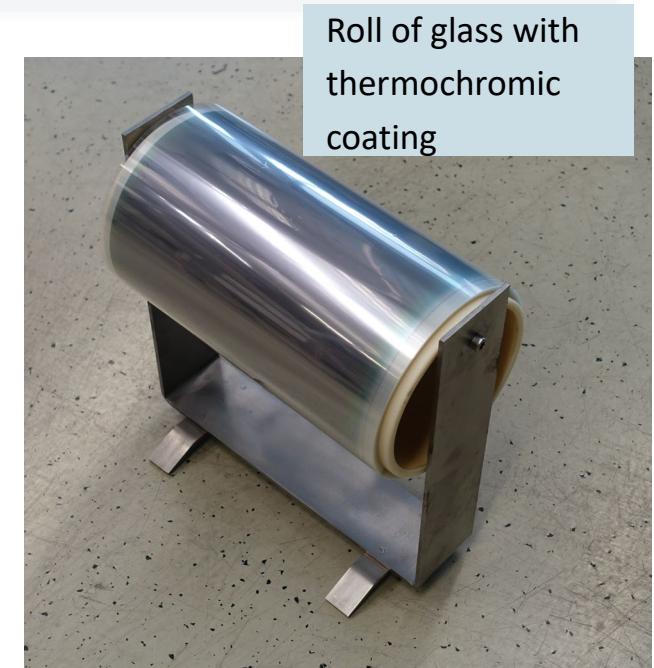
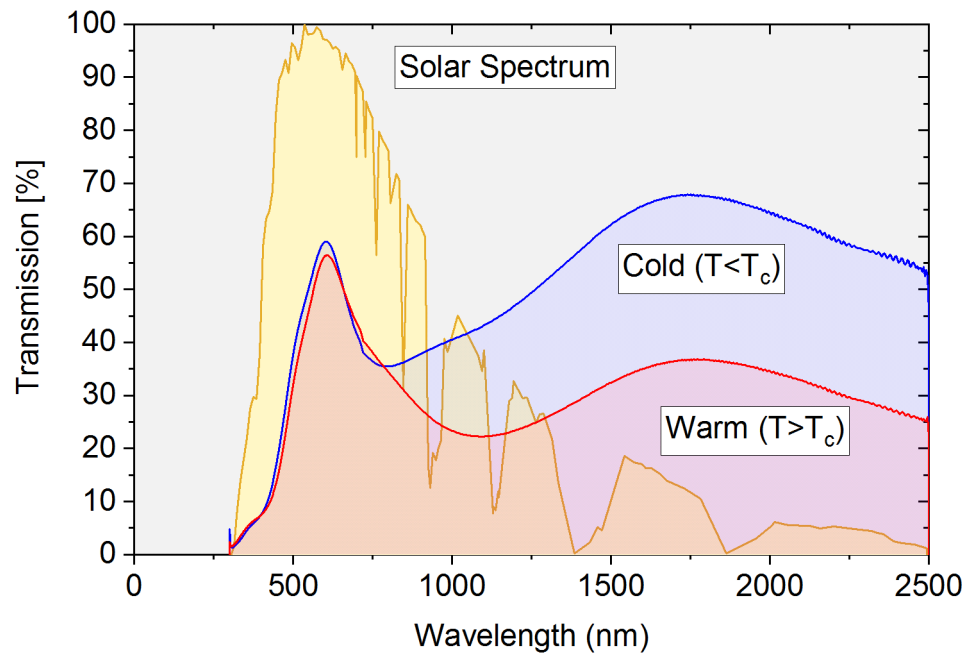
Thermochromic coating on Flexible Glass

Objectives

- Smart window technology for retrofitting existing buildings
- FEP: R2R sputtering of **Thermochromic coatings** on ultrathin flexible glass

Technology

- Reactive HIPIMS at elevated substrate temperatures
- Precise inline property monitoring



Application Example

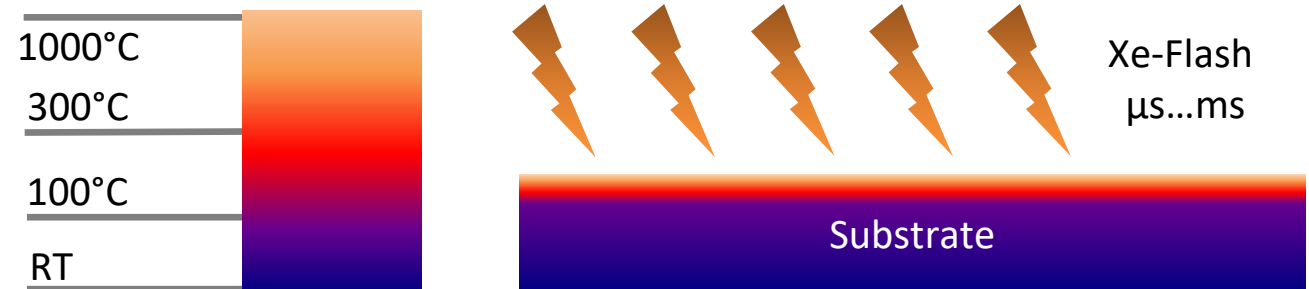
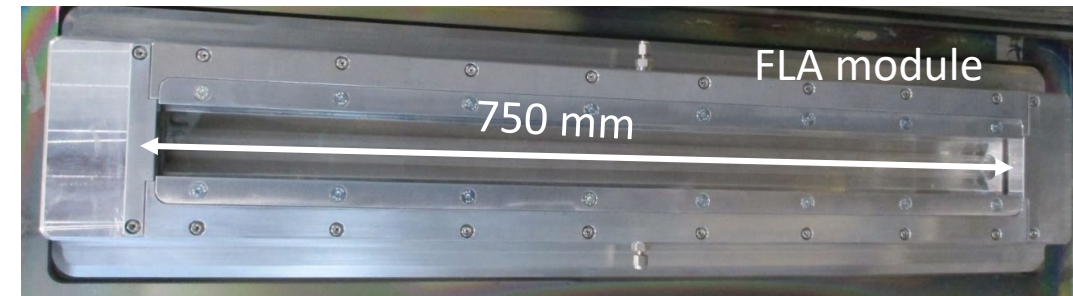
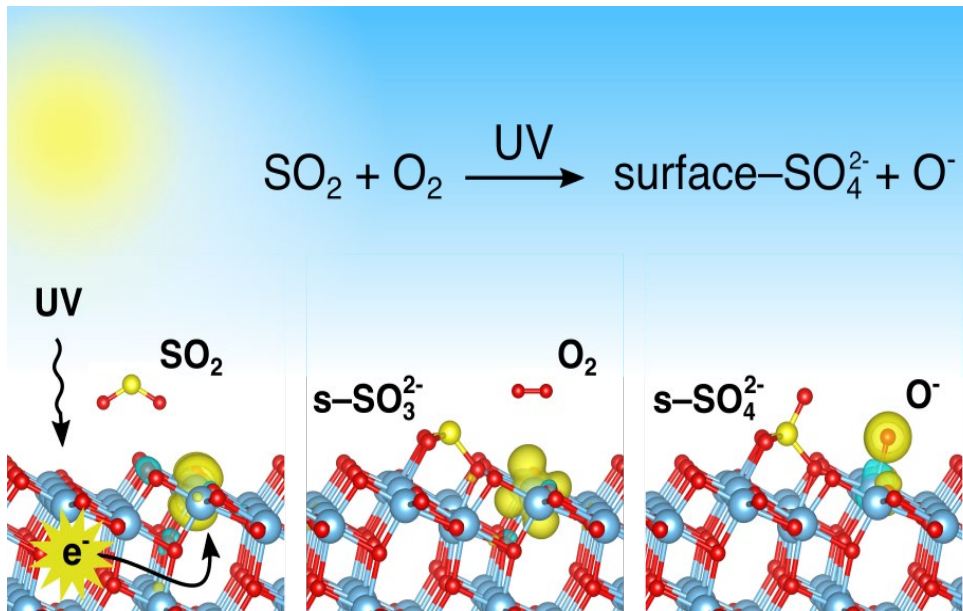
Antipathogenic coating for touchscreens

Objectives

- Creation of anti-pathogen surface on polymer film
- Prevention of healthcare-associated infections

Technology

- High-energy sputtering of oxides on polymer films
- Photo-fixation of sulfur radicals by flash lamp annealing



Contact

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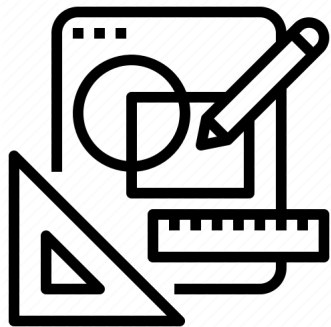
Thank you
for your attention

About PHABULOUS

Micro-Optics: Support of Metrology and Design

ACCELERATE TRANSITION FROM DESIGN TO PILOT PRODUCTION

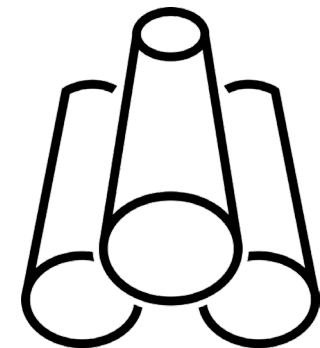
HELP DESIGNS COMPLY WITH
MANUFACTURING
CONSTRAINTS



COMPLETE
CHARACTERIZATION
PORTFOLIO

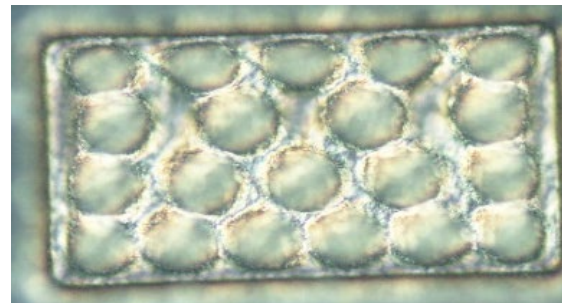
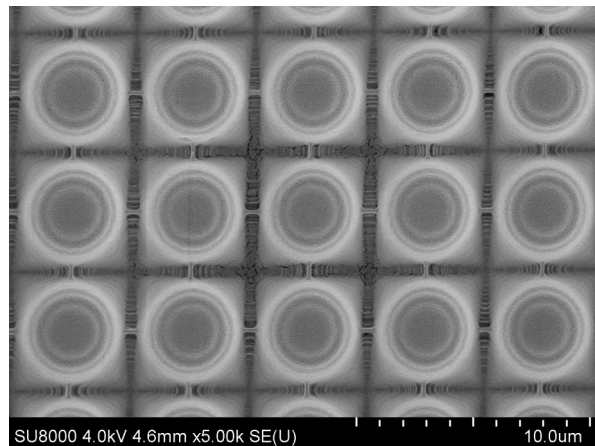
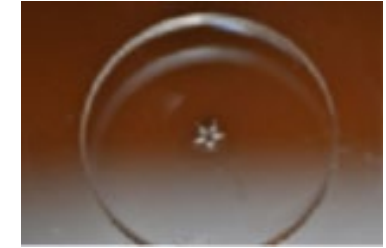
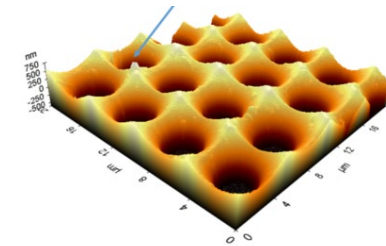
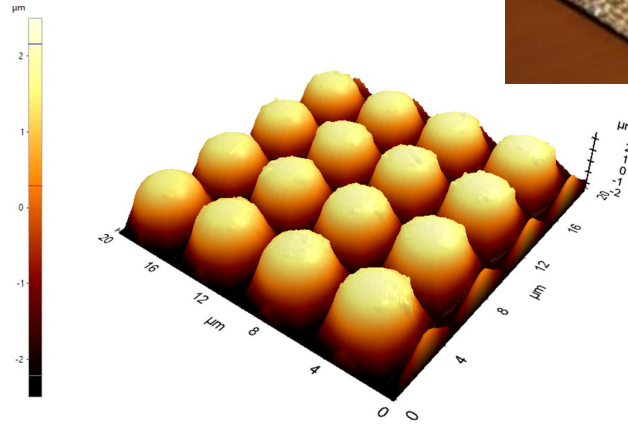
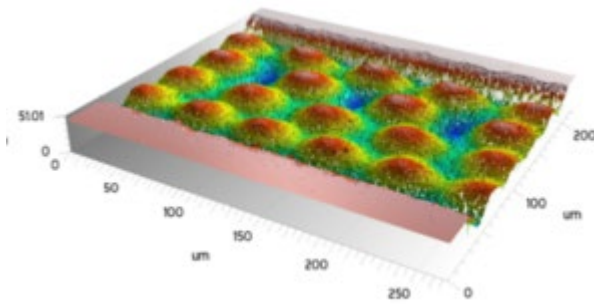


OPTIMUM MATERIAL
FORMULATIONS



About PHABULOUS

Metrology Expertise



- Different surface metrology techniques
- Know how of the partners integrated
- Verified in Round-Robin Tests
- **Complemented by Inline Metrology**

About PHABULOUS

Phabulous Design Approach

