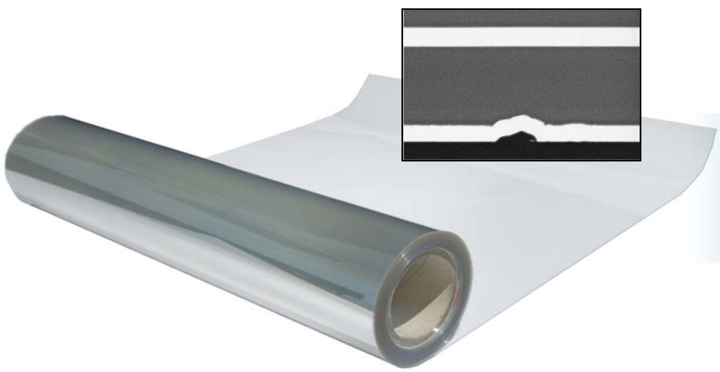
Vacuum Thin Film Coating on Plastic Surfaces
Materials, Technologies, Applications

EuroNanoForum 2019, 13th June 2019, Bucharest, Romania



John Fahlteich

Cindy Steiner

Michiel Top

Matthias Fahland

My Institute Fraunhofer FEP – Facts and Figures

- Employees: 174
- Total budget: 26.8 M€
- Industry returns: 11.5 M€
- Public funding: 7.82 M€
- Investments: 1.6 M€

(March 2019)

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Management System
ISO 9001:2015
ISO 50001:2011
www.tuv.com
ID 9105050079

Our commitment: quality and energy efficiency

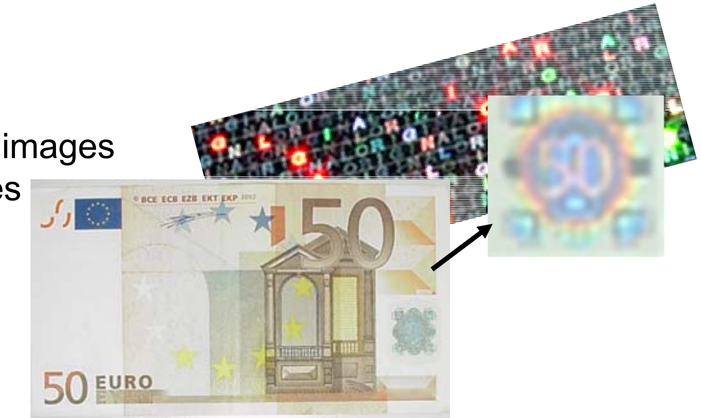
Director

- Prof. Dr. Volker Kirchhoff

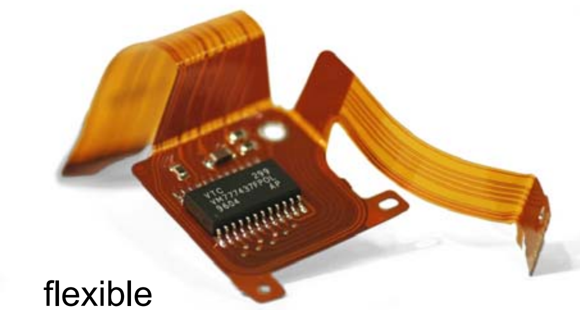
Vacuum coated thin film nanomaterials in our daily life

optical filters (*e.g.* solar control films) for car windows

holographic images on banknotes



architectural glass
source: wikipedia



flexible circuit boards

food packaging

cell phone displays
source: apple.com

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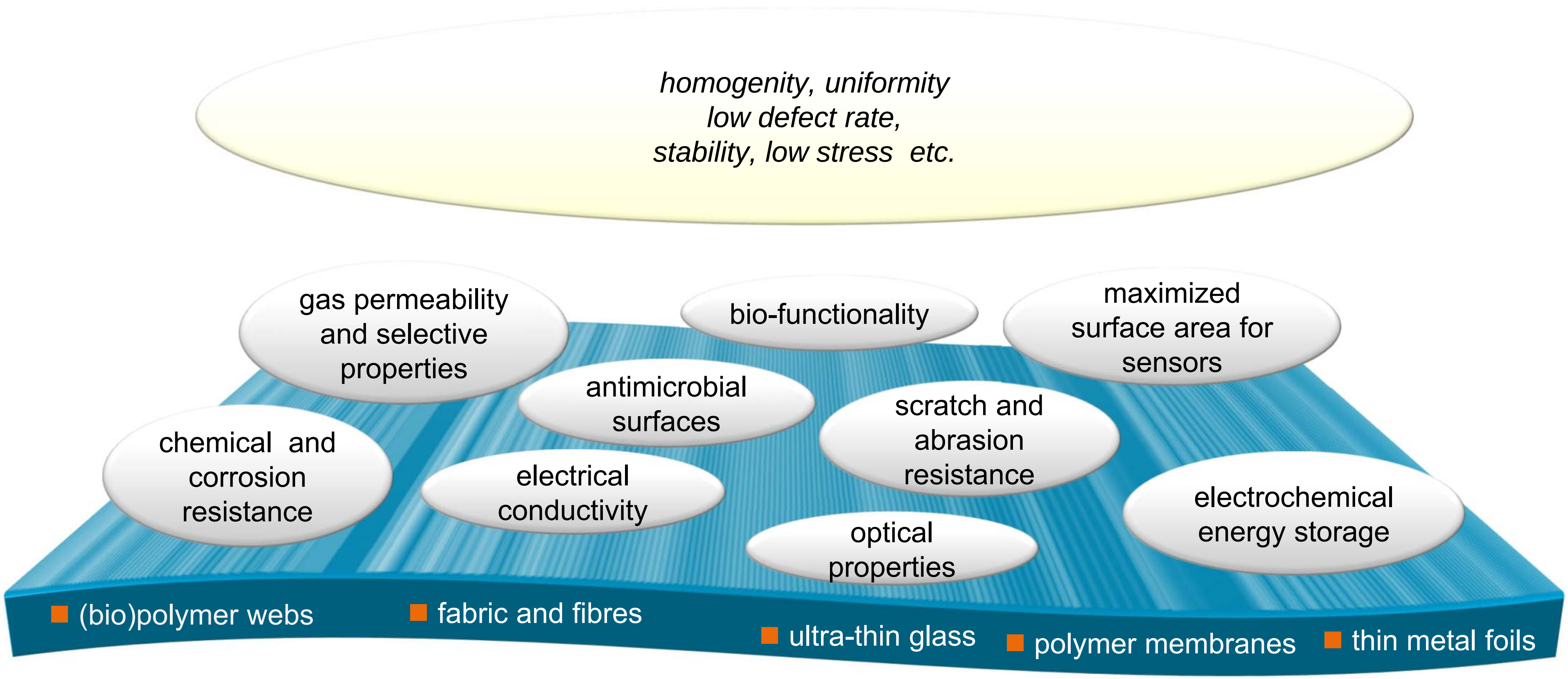
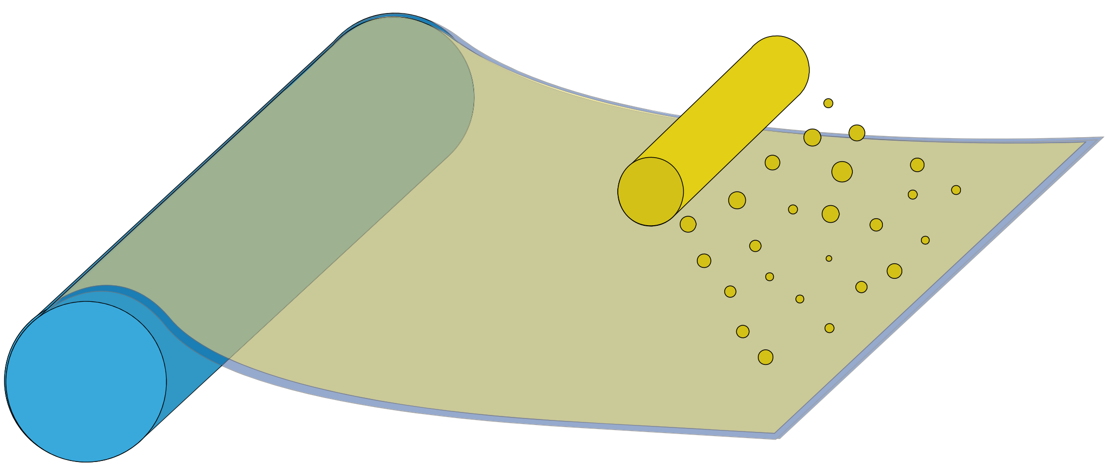
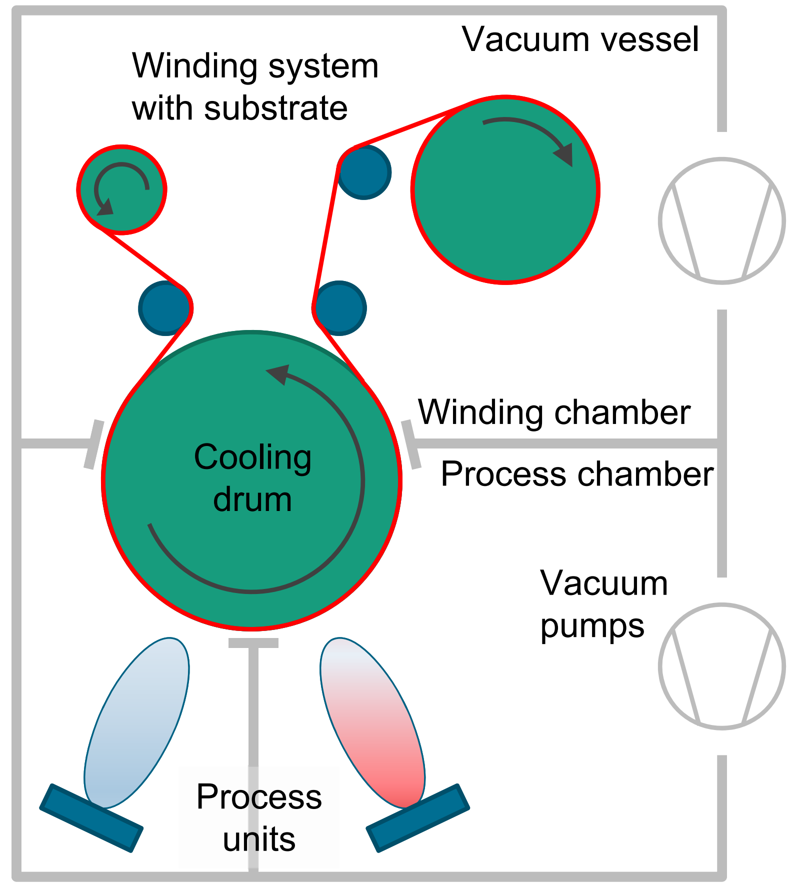
What surface properties are we interested in?



Vacuum Roll-to-Roll Coating and Surface Modification

- semi-continuous process
  - coating width up to 4.5 m
  - substrate lengths up to 100 km
  - process speed up to 20 m/s





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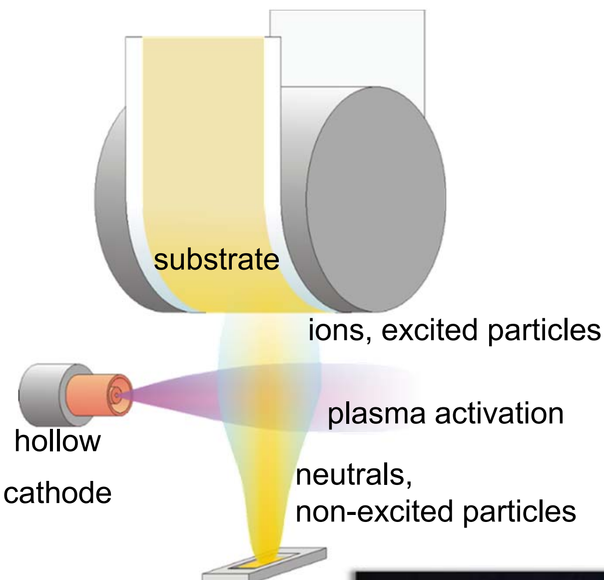
Industry suited plasma processes for thin film nanomaterial deposition

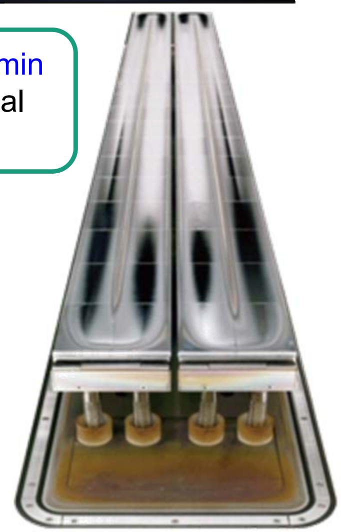
High-rate evaporation



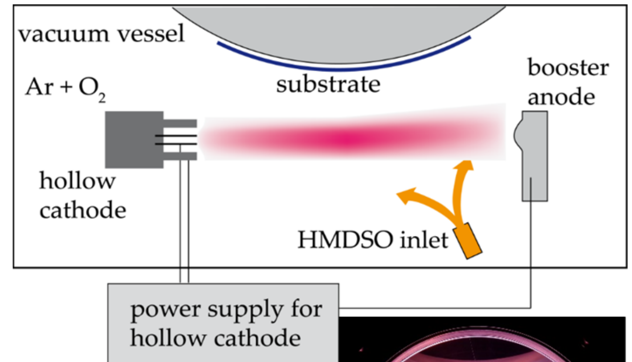
highest productivity,
low cost
≈ 6000 nm·m/min

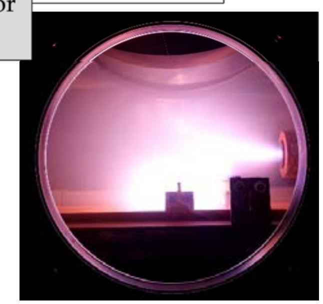
Magnetron Sputtering

≈ 100 nm·m/min
wide material selection



High-rate PECVD





≈ 100 … 1000 nm·m/min
in-situ layer composition adjustment
from SiO_2 to $[Si(CH3)_2\text{-}O]_n$“ with **HMDSO**

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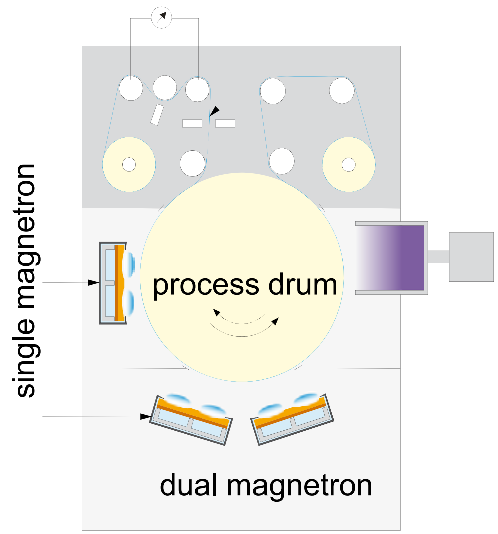
Lab-2-Fab Facilities for Vacuum Roll-to-Roll Coating

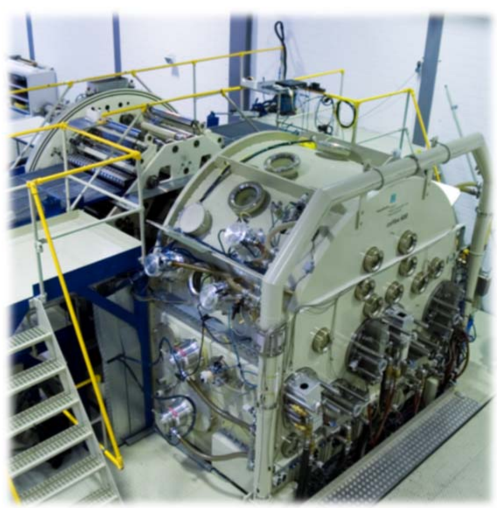
lab-scale equipment (TRL 3 – 5)

pilot-scale equipment (TRL 5 – 7)

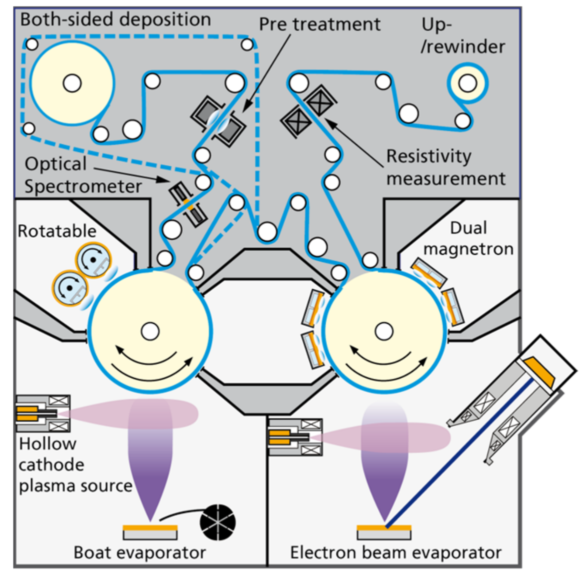
LB9



labFlex® 200

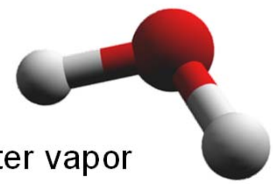


coFlex® 600



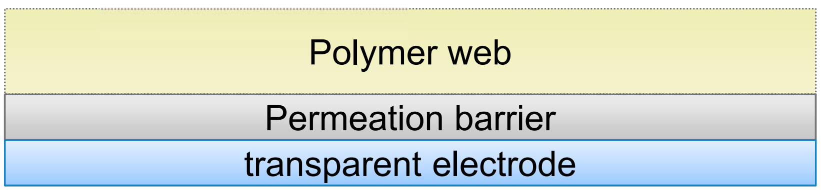
novoFlex® 600

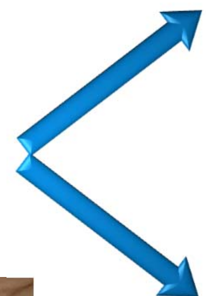
Application Example #1: Gas Permeation Barriers

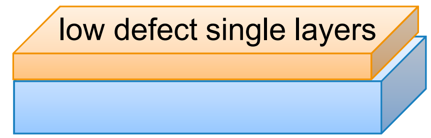


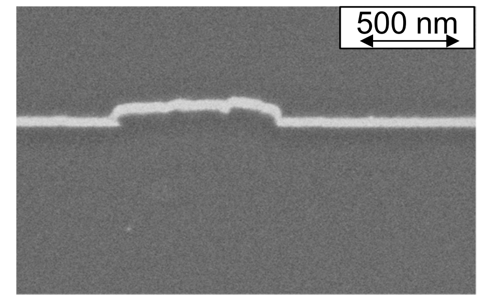
water vapor

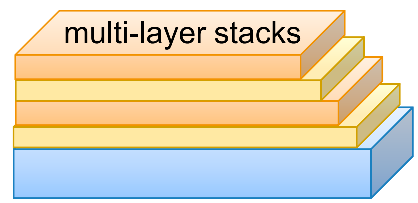
oxygen

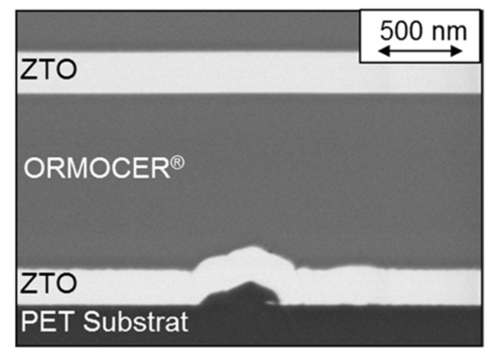










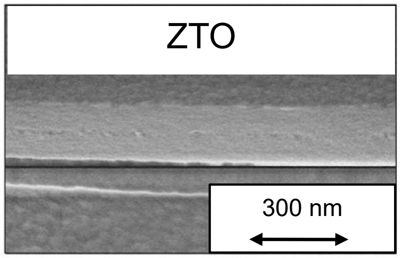


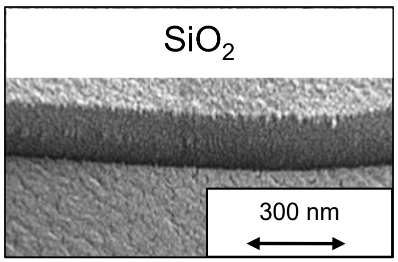
flexible
solar cell

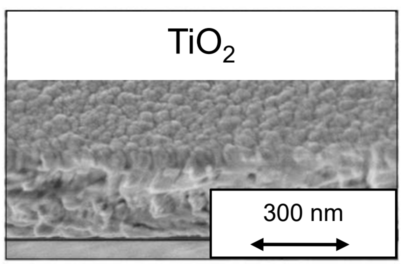
sensitive food
and drink

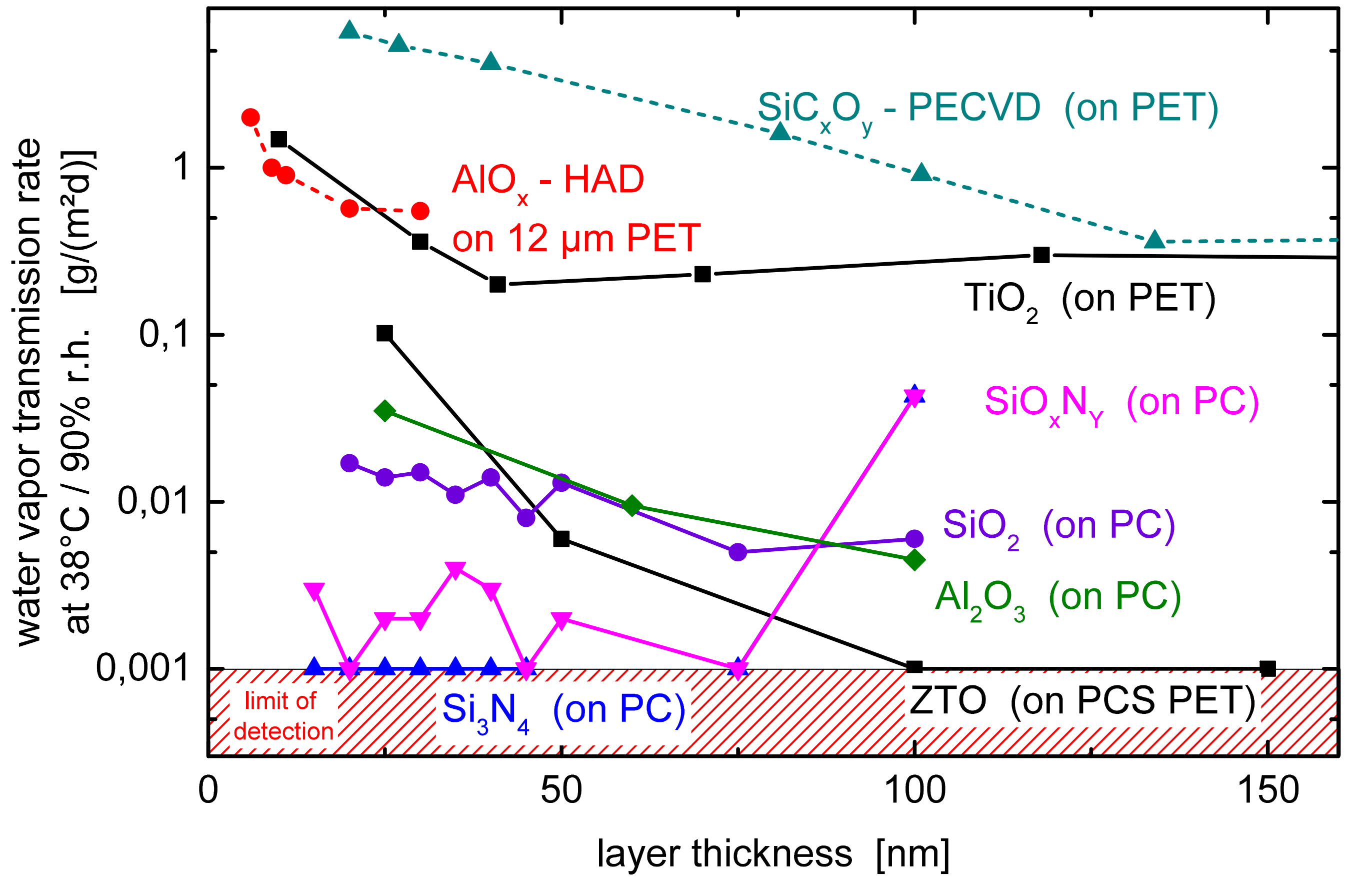
flexible
display

Gas Barrier Performance by Materials and Thickness

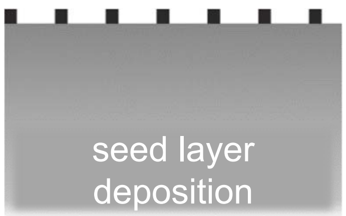




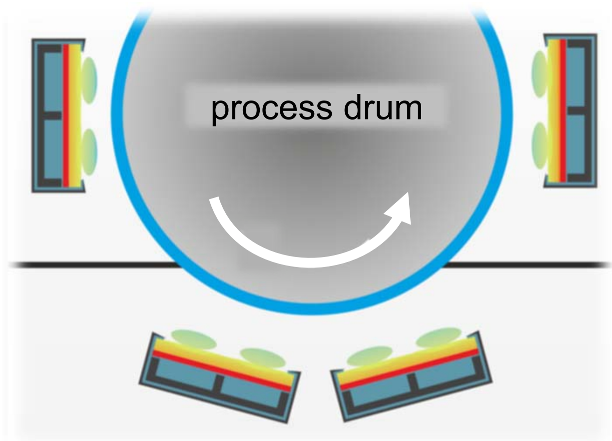


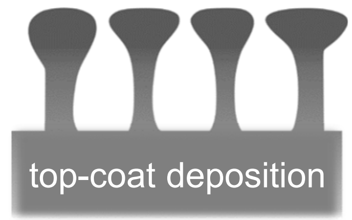


Application Example #3:
Reactive plasma surface nano-structuring

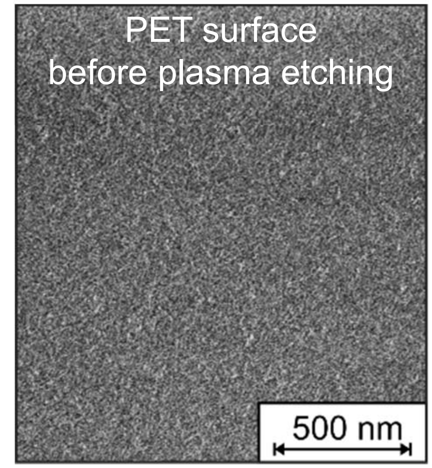


thin SiO_2
(< 10 nm)

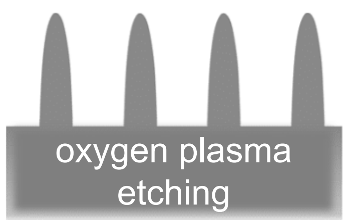


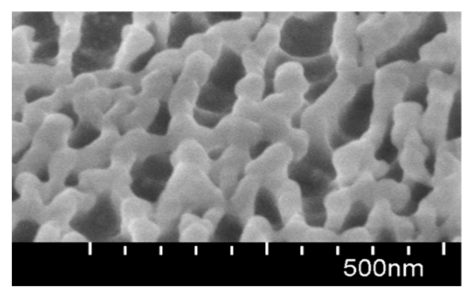


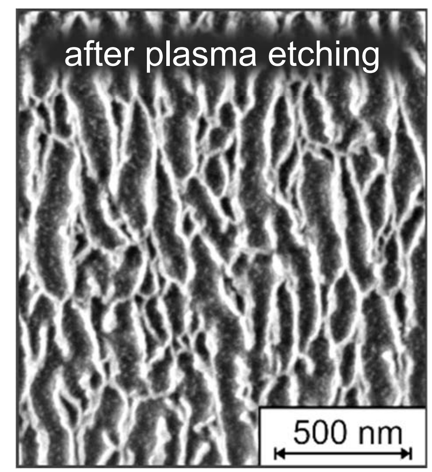
thin SiO_2 layer
(< 10 nm)



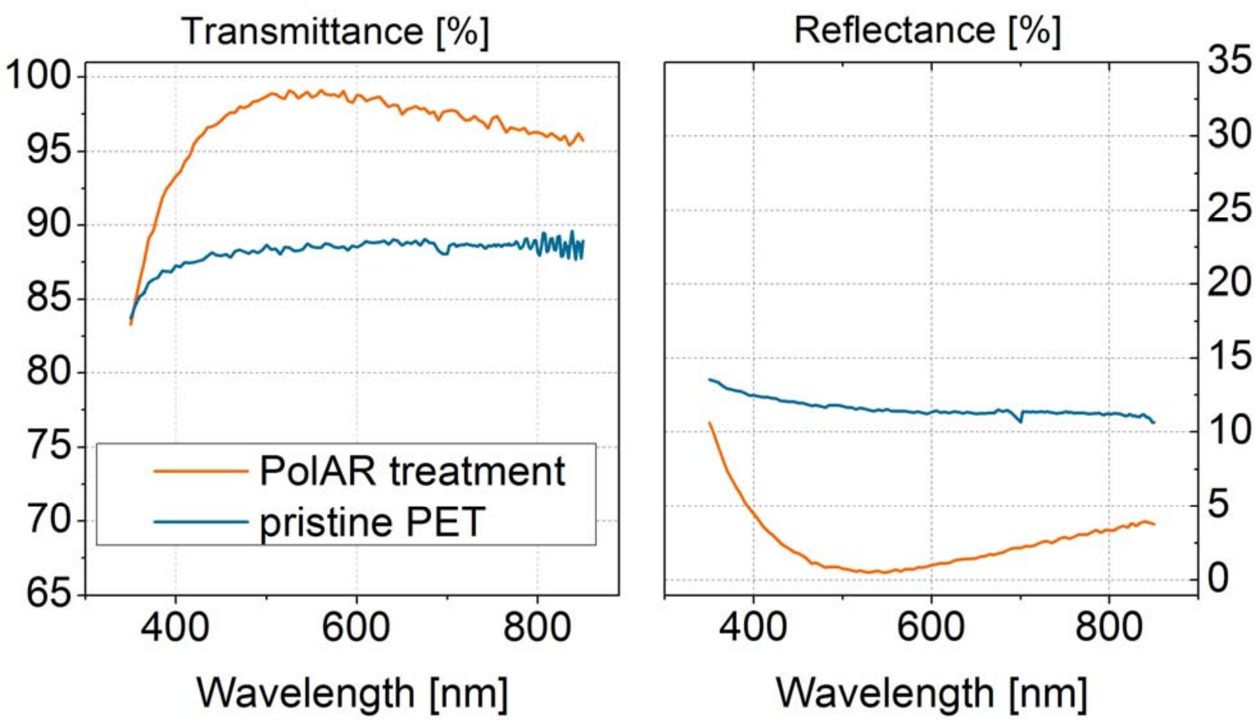
- reactive oxygen plasma treatment
- single run roll-to-roll process
- 0.5 … 2 m/min run speed

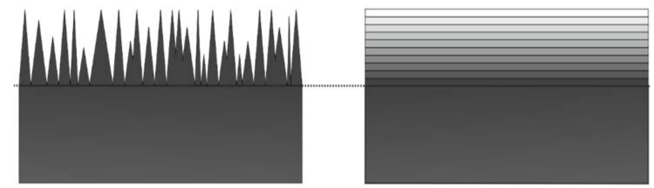






Properties of nanostructured surfaces (Optical Anti-Reflection)



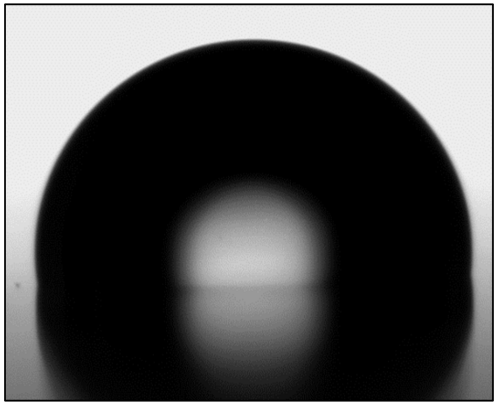


broadband anti-reflective effect through “simulated” refractive index gradient

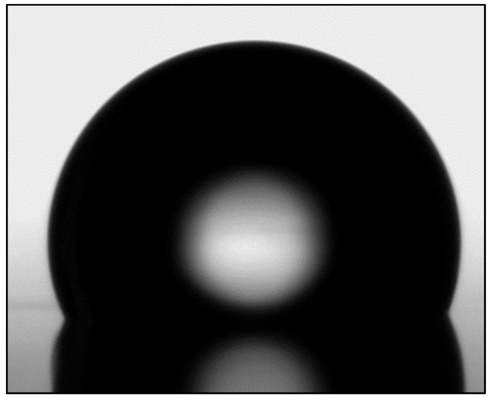
maximum in transmittance:

- untreated PET 89 %
- single side treatment 93.7 %
- double side treatment 98.5 %

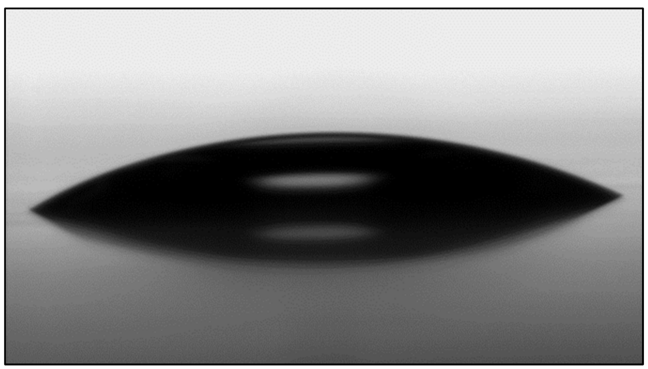
Surface Energy | Wetting Behavior of Water



ETFE film surface ➔ 95°

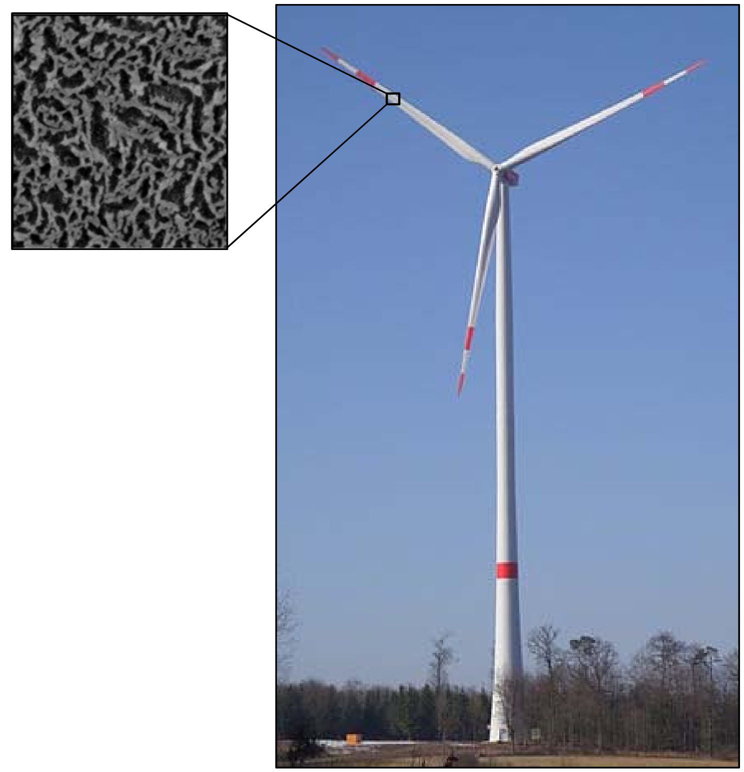


nanostructured ETFE surface
with 10 nm TiO_2 top coat ➔ 110°



nanostructured ETFE surface
10 nm SiO_2 top coat ➔ 30°

wings with anti-ice
edge-protection polymers



Application Example #3: Flexible Organic Light Emitting Diodes

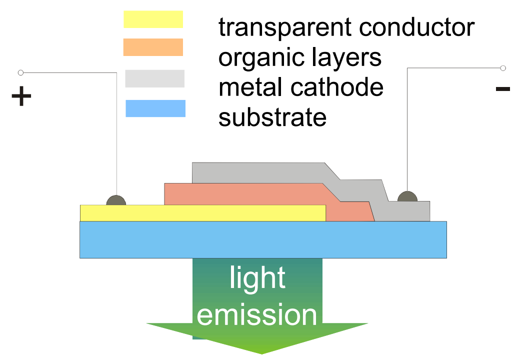
R2R surface inspection

R2R vacuum coater

R2R printing and lamination unit (N_2)

Substrate Inspection → Structuring → Substrate inspection → Vacuum coating → Encapsulation → OLED characterisation

- **300 mm** web width
- additive surface structuring (flexo-printing) and substractive laser surface structuing
- thermal evaporation of organic semiconductors
- OLED layer thickness ≤ 200 nm



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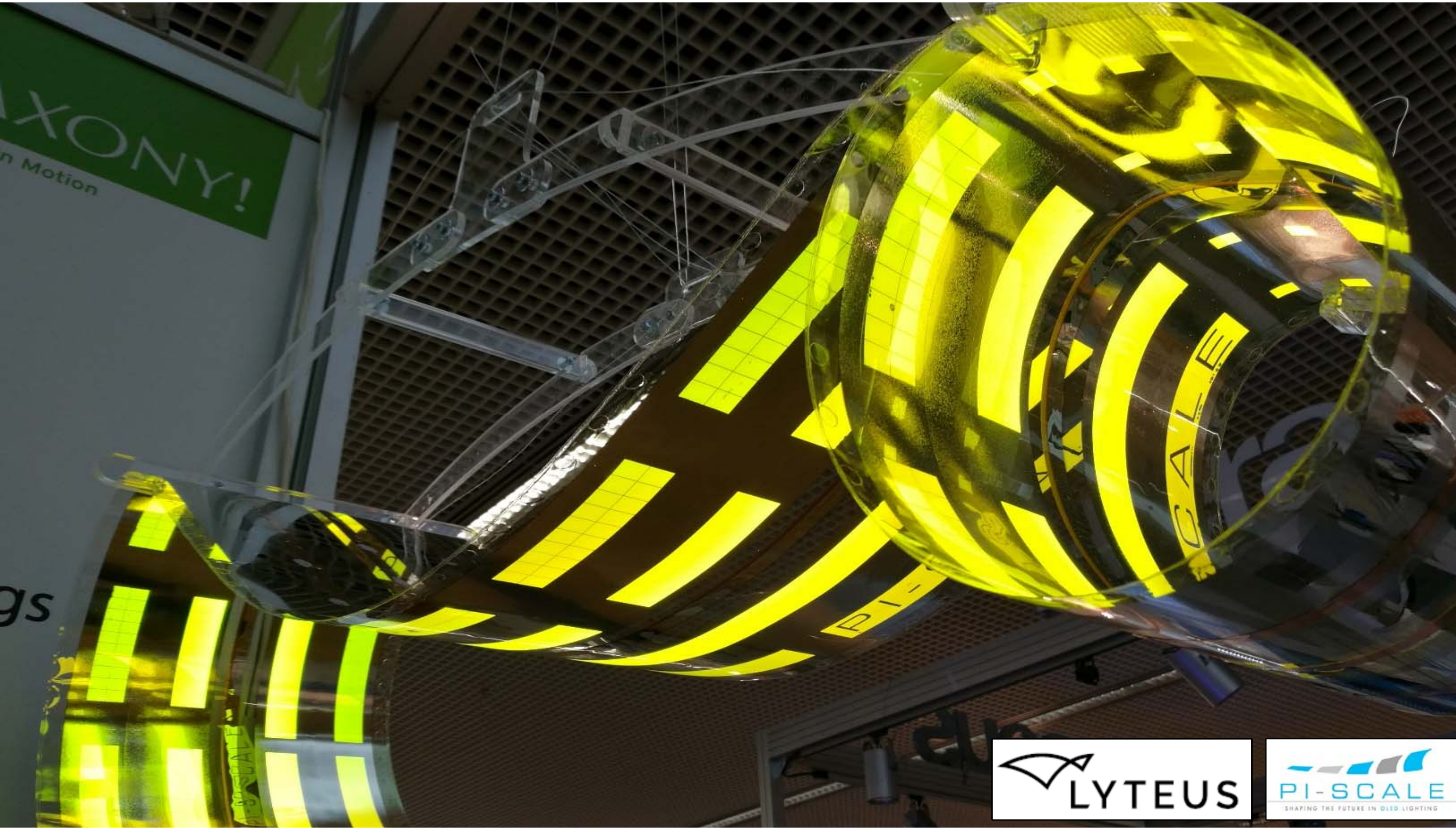
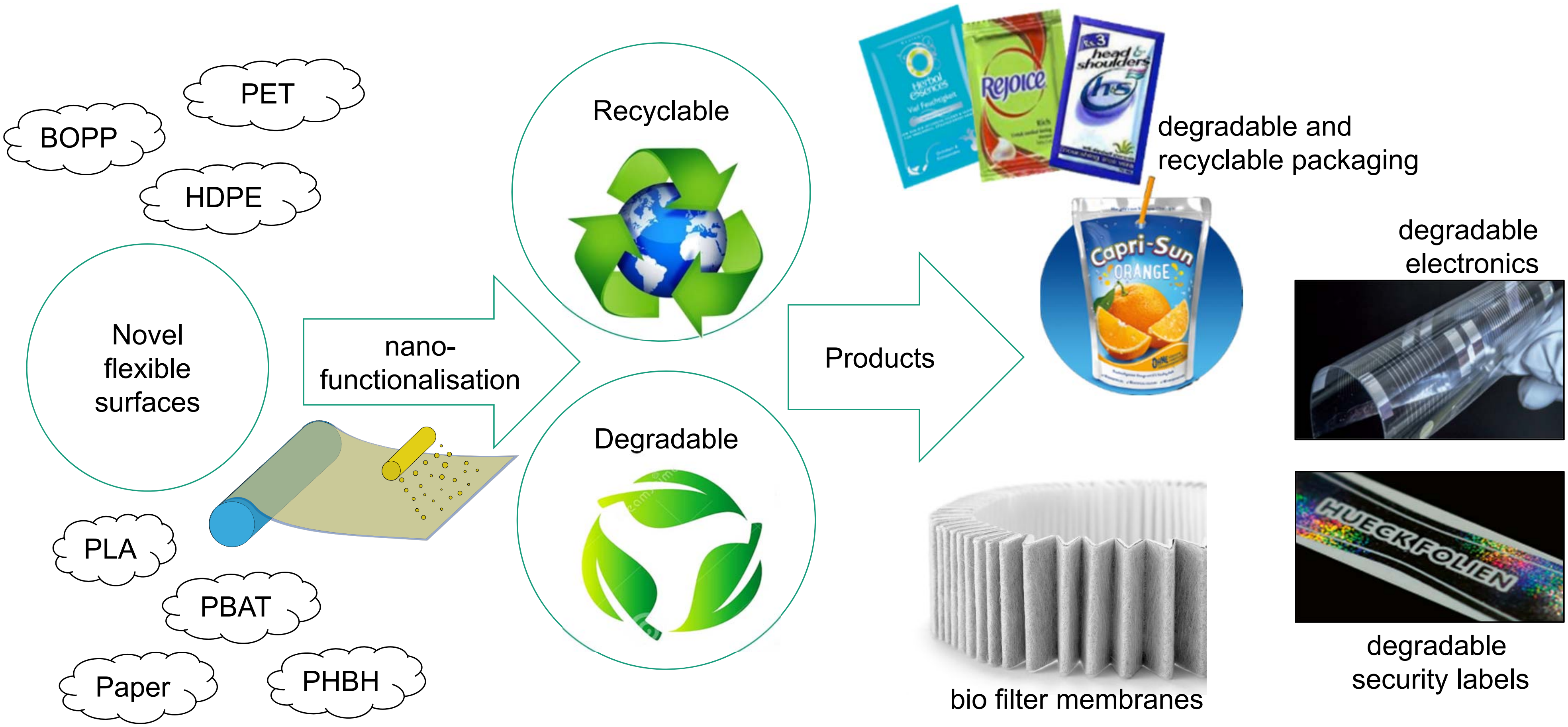

LYTEUS
PI-SCALE
SHAPING THE FUTURE IN OLED LIGHTING

Latest Research Topics: Thin-Film Nano-materials in Circular Economy of Plastics



images provided by: I3Membrane, P&G, Capri-Sun, Hueck Folien

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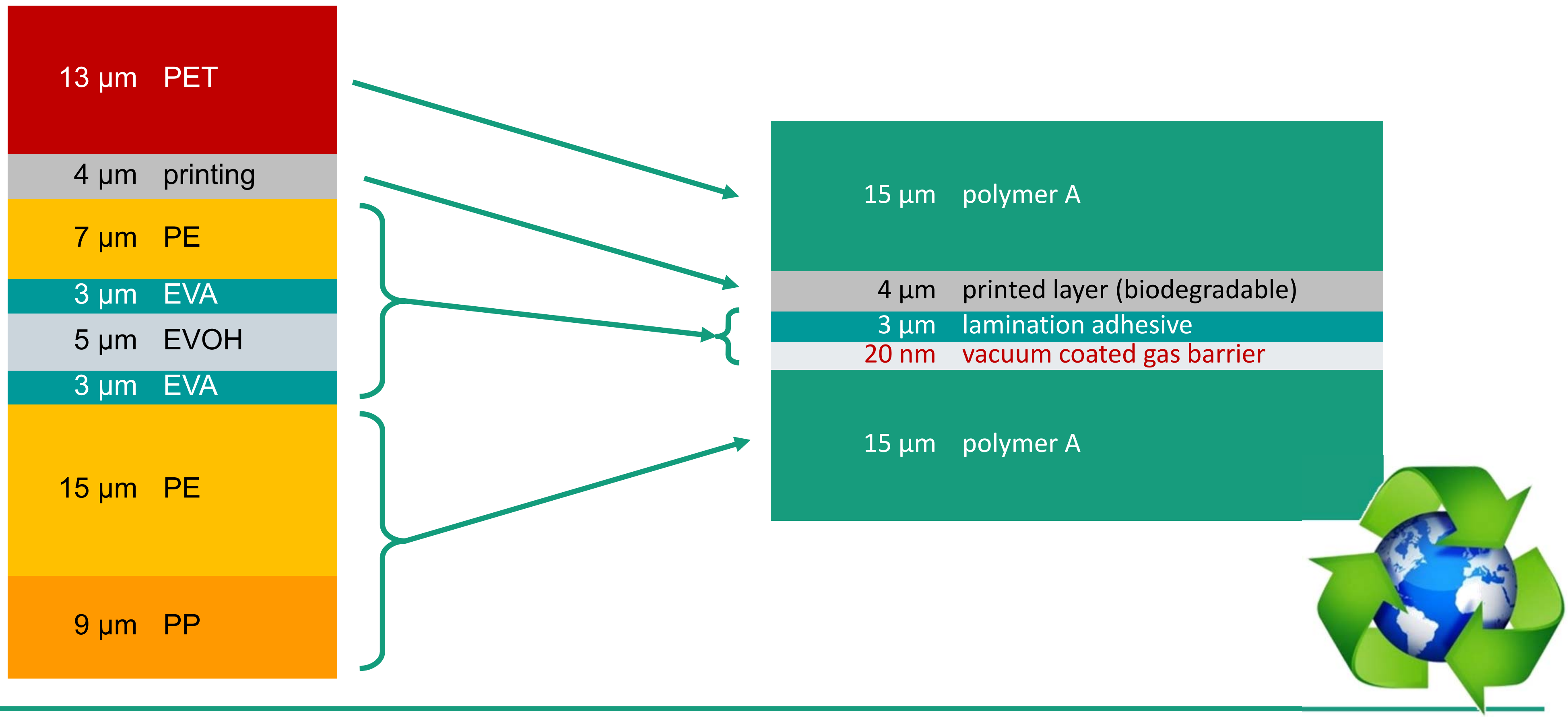
An Example: Towards Sustainable Packaging



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Thank You for Your Interest!

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Presented projects have received funding from the European Union with the 7th Framework and Horizon 2020 research and innovation programmes
EU Horizon 2020 – „PI-SCALE“ GA no. 688093
EU FP7 SMARTONICS: GA no. 310229
EU Horizon 2020 – „Smart2Go“: GA no: 825143

Fraunhofer FEP – core comptencies

ELECTRON BEAM TECHNOLOGIES

PLASMA-ACTIVATED LARGE AREA AND PRECISION COATING

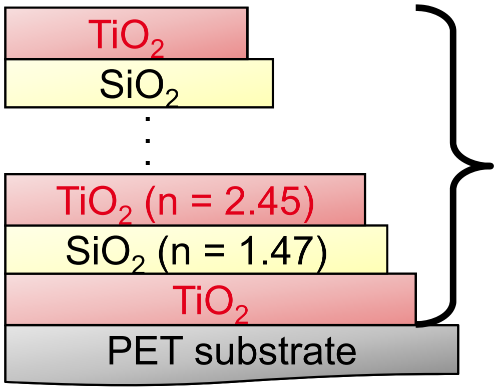
ORGANIC ELECTRONICS

ROLL-TO-ROLL TECHNOLOGY

TECHNOLOGICAL
KEY COMPONENTS

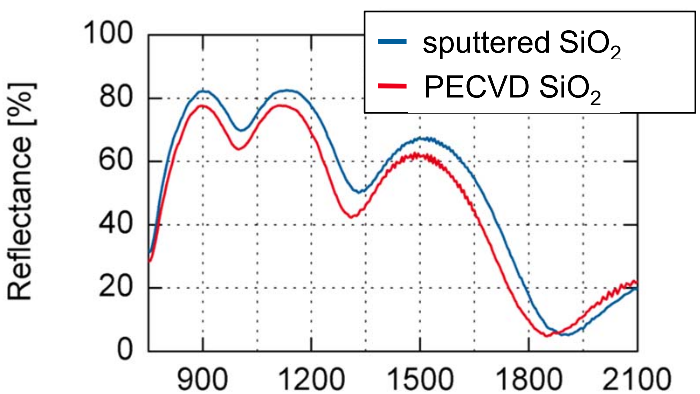
IC DESIGN

Application Example #2: Adjust optical properties with thin film nano-laminates



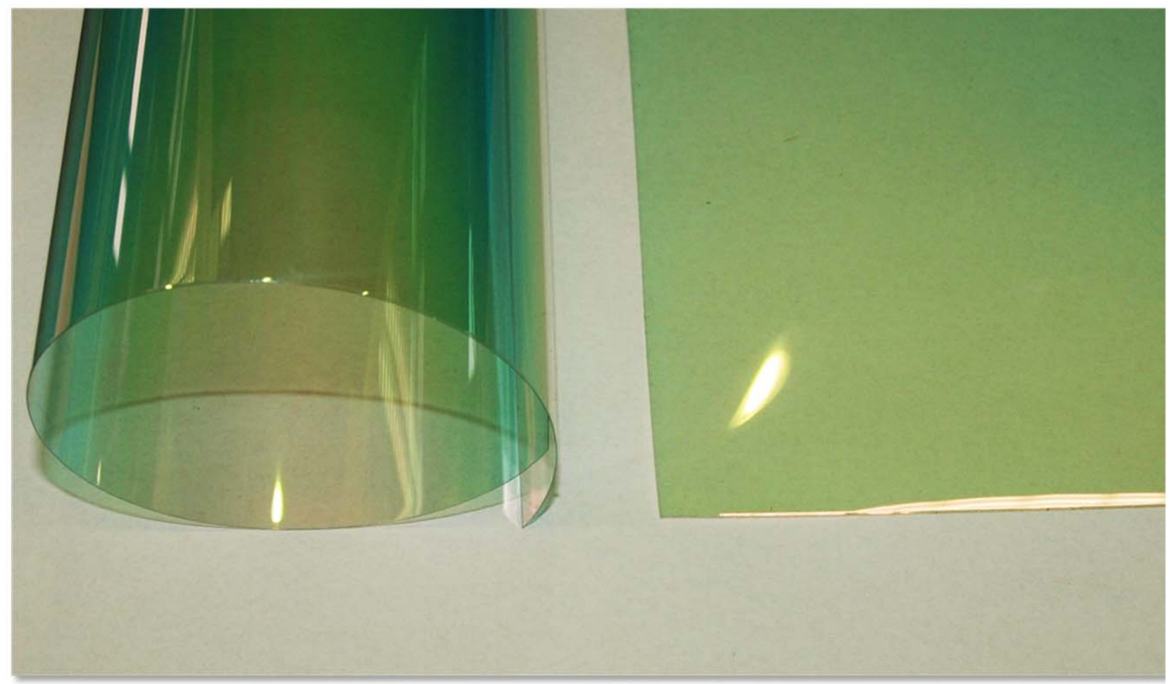
9 layers

30 … 100 nm each

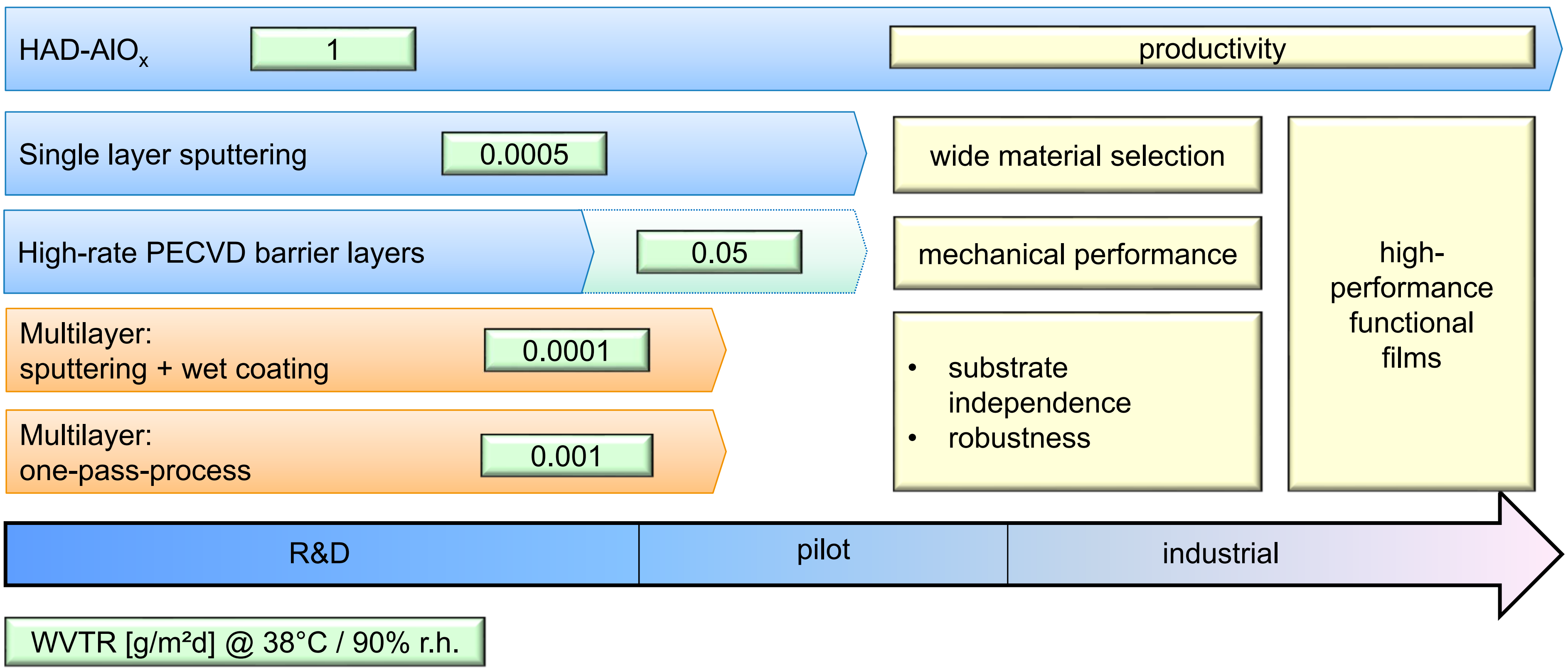


SiO_2 sputtered

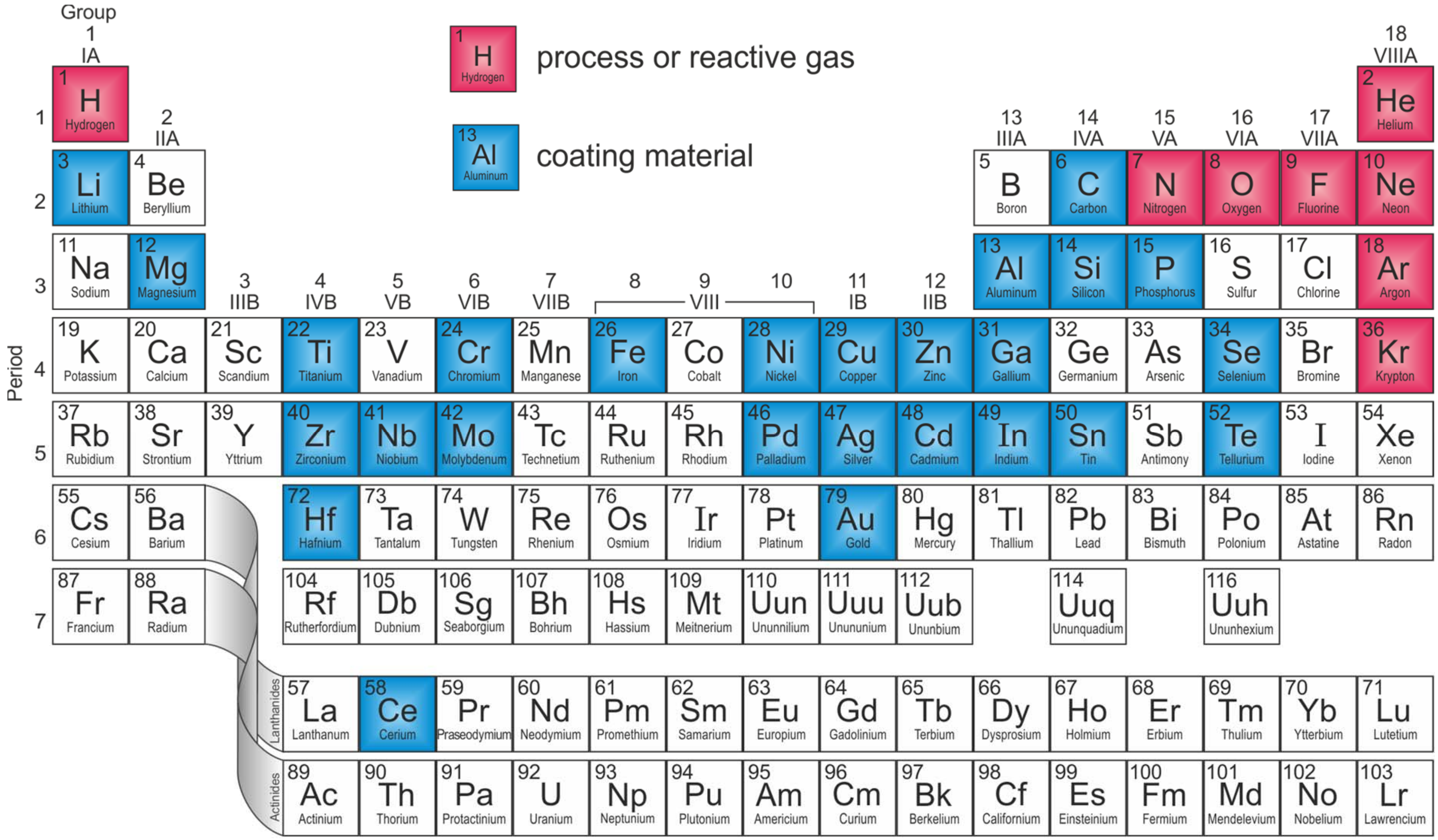
SiO_2 made with PECVD



Gas Permability



Materials



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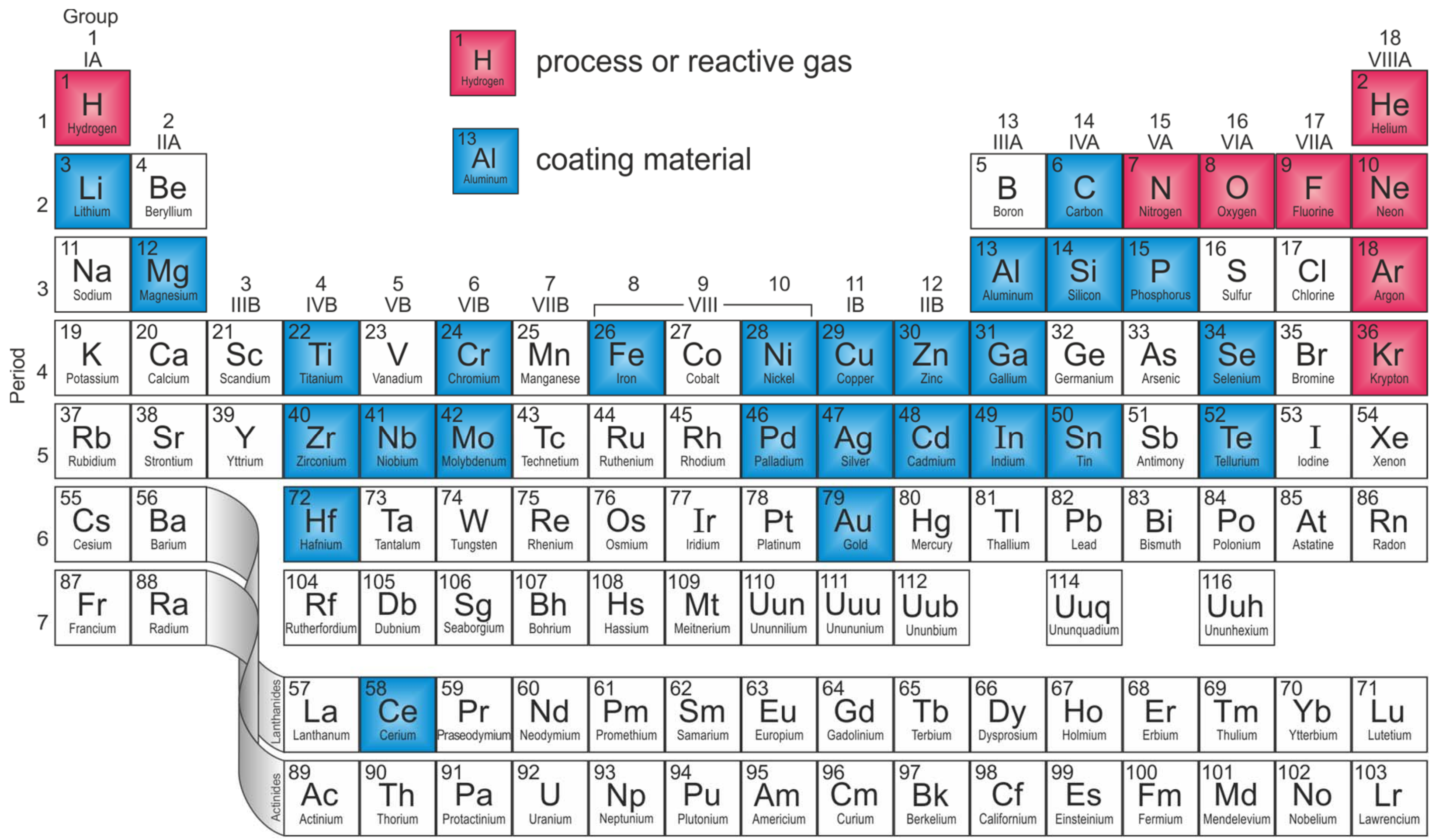
Materials



Group
1 IA
2 IIA
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8
9 VIII
10
11 IB
12 IIB
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
18 VIIIA
Period
1 H Hydrogen
process or reactive gas
13 Al Aluminum
coating material
1 H Hydrogen
2 He Helium
3 Li Lithium
4 Be Beryllium
5 B Boron
6 C Carbon
7 N Nitrogen
8 O Oxygen
9 F Fluorine
10 Ne Neon
11 Na Sodium
12 Mg Magnesium
13 Al Aluminum
14 Si Silicon
15 P Phosphorus
16 S Sulfur
17 Cl Chlorine
18 Ar Argon
19 K Potassium
20 Ca Calcium
21 Sc Scandium
22 Ti Titanium
23 V Vanadium
24 Cr Chromium
25 Mn Manganese
26 Fe Iron
27 Co Cobalt
28 Ni Nickel
29 Cu Copper
30 Zn Zinc
31 Ga Gallium
32 Ge Germanium
33 As Arsenic
34 Se Selenium
35 Br Bromine
36 Kr Krypton
37 Rb Rubidium
38 Sr Strontium
39 Y Yttrium
40 Zr Zirconium
41 Nb Niobium
42 Mo Molybdenum
43 Tc Technetium
44 Ru Ruthenium
45 Rh Rhodium
46 Pd Palladium
47 Ag Silver
48 Cd Cadmium
49 In Indium
50 Sn Tin
51 Sb Antimony
52 Te Tellurium
53 I Iodine
54 Xe Xenon
55 Cs Cesium
56 Ba Barium
72 Hf Hafnium
73 Ta Tantalum
74 W Tungsten
75 Re Rhenium
76 Os Osmium
77 Ir Iridium
78 Pt Platinum
79 Au Gold
80 Hg Mercury
81 Tl Thallium
82 Pb Lead
83 Bi Bismuth
84 Po Polonium
85 At Astatine
86 Rn Radon
87 Fr Francium
88 Ra Radium
104 Rf Rutherfordium
105 Db Dubnium
106 Sg Seaborgium
107 Bh Bohrium
108 Hs Hassium
109 Mt Meitnerium
110 Uun Ununnilium
111 Uuu Unununium
112 Uub Ununbium
114 Uuq Ununquadium
116 Uuh Ununhexium
Lanthanides
57 La Lanthanum
58 Ce Cerium
59 Pr Praseodymium
60 Nd Neodymium
61 Pm Promethium
62 Sm Samarium
63 Eu Europium
64 Gd Gadolinium
65 Tb Terbium
66 Dy Dysprosium
67 Ho Holmium
68 Er Erbium
69 Tm Thulium
70 Yb Ytterbium
71 Lu Lutetium
Actinides
89 Ac Actinium
90 Th Thorium
91 Pa Protactinium
92 U Uranium
93 Np Neptunium
94 Pu Plutonium
95 Am Americium
96 Cm Curium
97 Bk Berkelium
98 Cf Californium
99 Es Einsteinium
100 Fm Fermium
101 Md Mendelevium
102 No Nobelium
103 Lr Lawrencium