Applied Research for Vacuum Web Coating: What is Coming Next?

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AIMCAL R2R Conference

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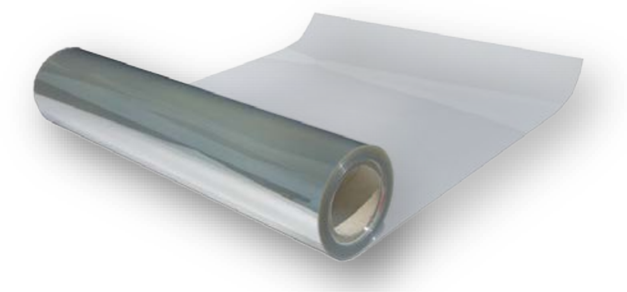
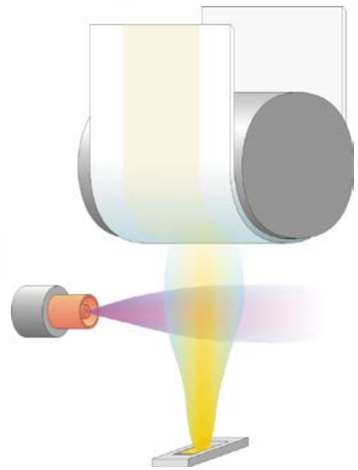
Fraunhofer FEP

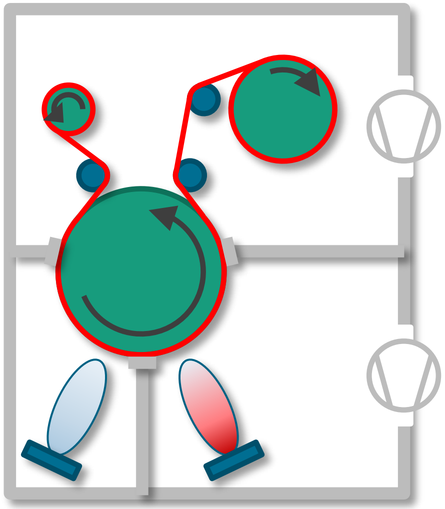
presenter's perspective

R&D services for the industry and flexible products

Service along the R&D chain for flexible products



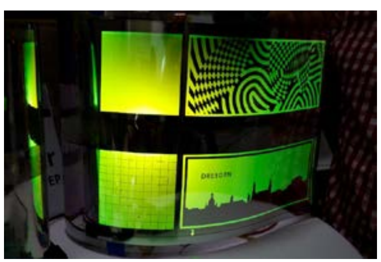


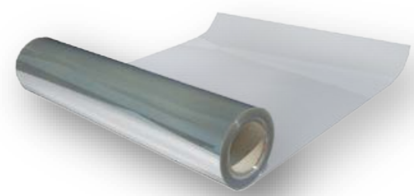


testing
substrate materials

coating technologies

key components





application

technology
transfer

pilot production

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Hot R&D topics

- ultra-thin flexible glass
- high-rate PECVD
- advanced packaging films
- encapsulation of flexible electronics
- flexible materials for batteries
- functional films for buildings and outdoor use

Ultra-thin flexible glass

product, application	ultra-thin flexible glass for displays, wearables, sensors, batteries
state of the art	increasing availability of flexible glass
R&D need	surface functions
approach, solution	roll-to-roll and sheet-to-sheet vacuum coating technologies
latest R&D results at FEP	• installation of a vacuum pilot roll coater (ARDENNE GmbH) • roll-to-roll coating technology development: magnetron sputtering (e.g. ITO) • Flash lamp annealing (FLA)

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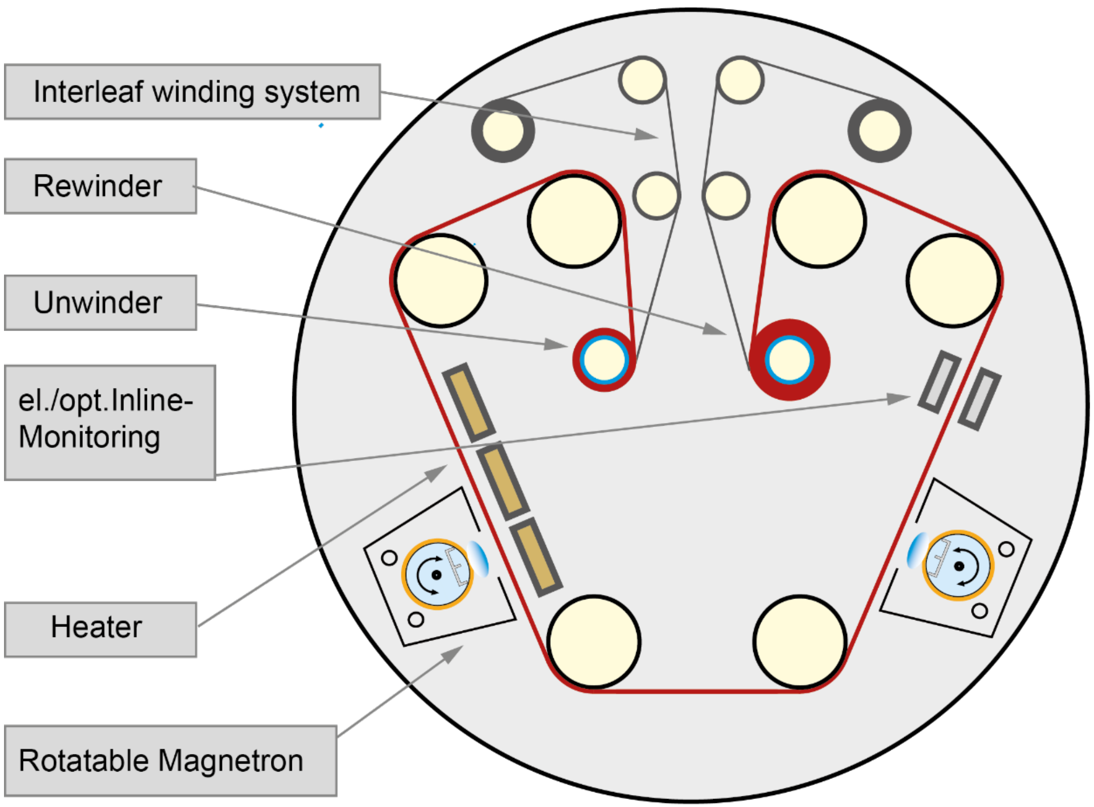
Pilot roll-to-roll coater FOSA labX 330 glass

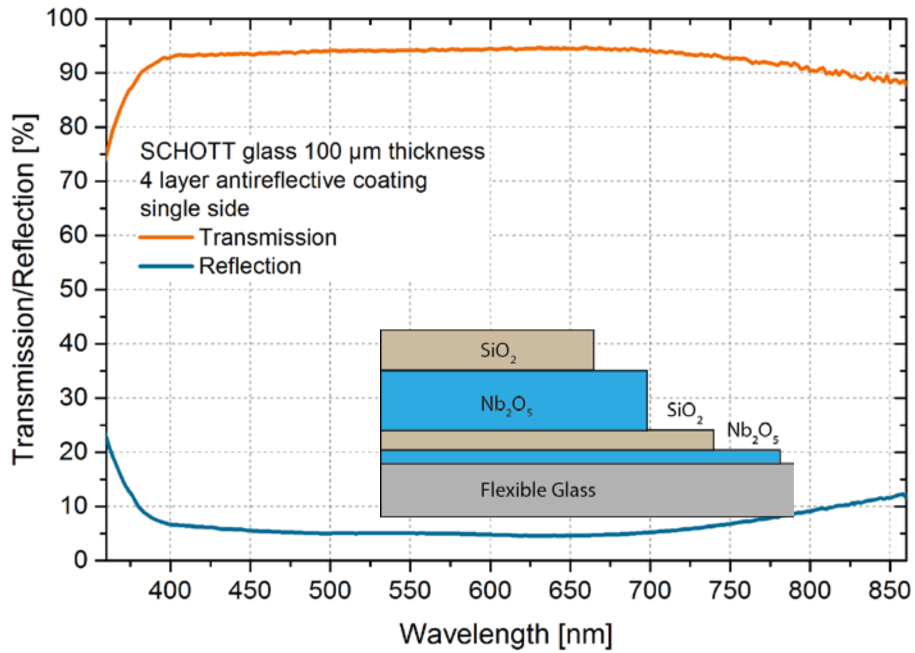
- Flexible glass, polymer film, metal foil
- up to 330 mm deposition width
- Substrate temperature up to 350 °C
- up to 4 coating zones
- Dual Anode Sputtering
- Front-side touchless



Ultra-thin flexible glass

Project KONFEKT: R2R Coating on Flexible Glass

Objective	■ Development of adapted coating equipment ■ Application development ■ Establishing cooperation with glass makers and lamination facilities
Technology	■ Sputtering & heating ■ Sputtering and lamination processes



project funded by BMBF, contract Nr. 13N13818

Bundesministerium für Bildung und Forschung

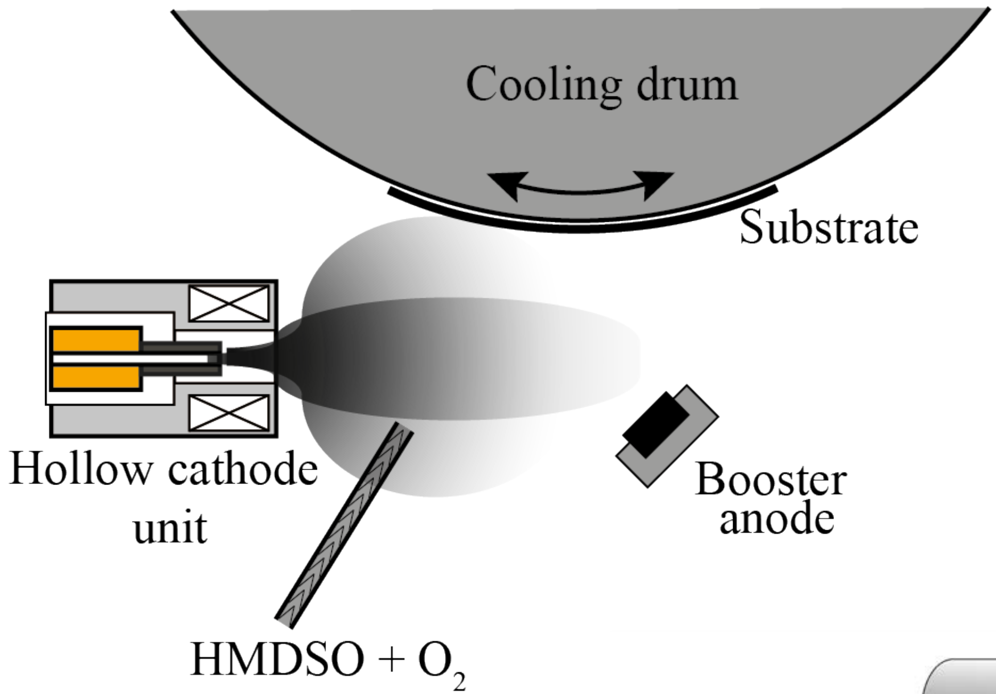
VON ARDENNE

Fraunhofer FEP

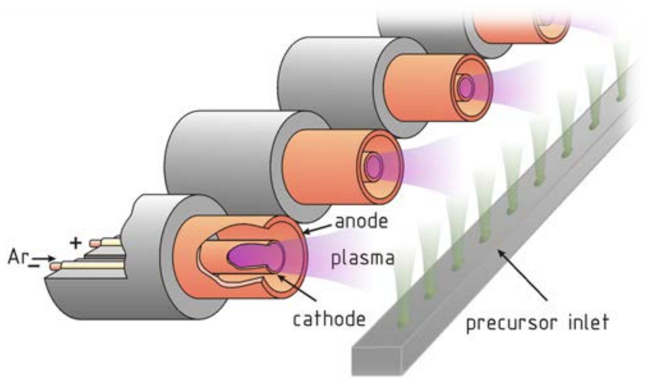
High rate PECVD process

product, application	protective or adhesion promoting layers for various applications
R&D need	• increase of productivity • technology tayloring for specific applications
approach, solution	arcPECVD: high-rate PECVD process
latest R&D results at FEP	• protective layer on barrier film • adhesion promoting layer • anti-fingerprint • color coatings

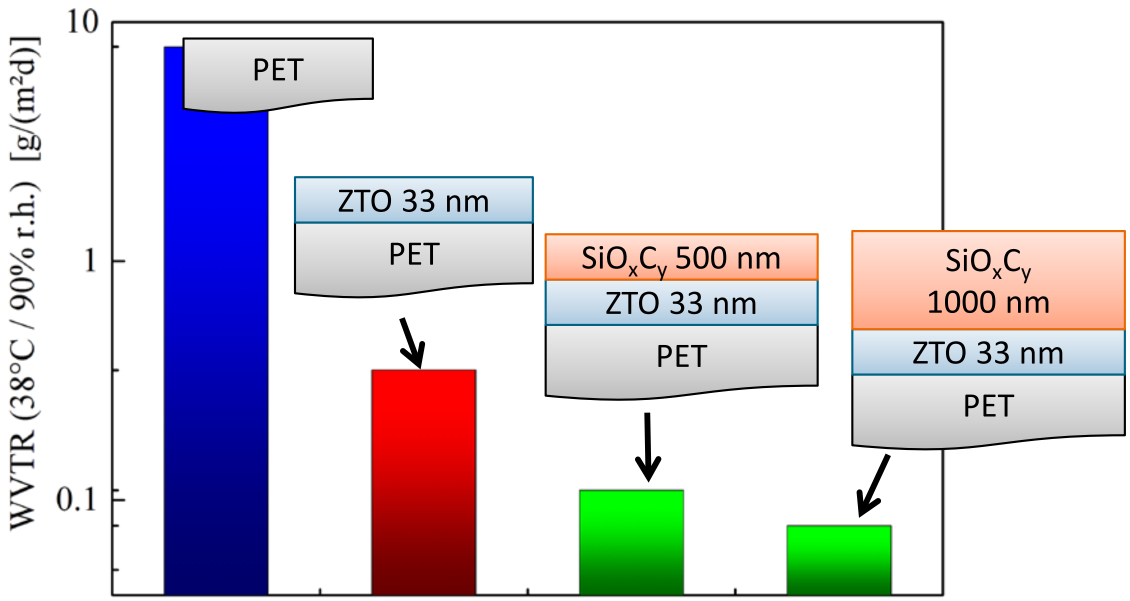
High rate PECVD: arcPECVD



- Low pressure PECVD (0.1 – 5 Pa)
- Very high coating rates (> 2000 nm m/min)
- Plasma sources for web widths > 2.85 m



Protective coating on a barrier layer by arcPECVD



- Roll-to-roll in-line deposition of both barrier layer and protective layer: in-line combination of sputtering and arcPECVD
- protective layer provides significant protection of barrier layer

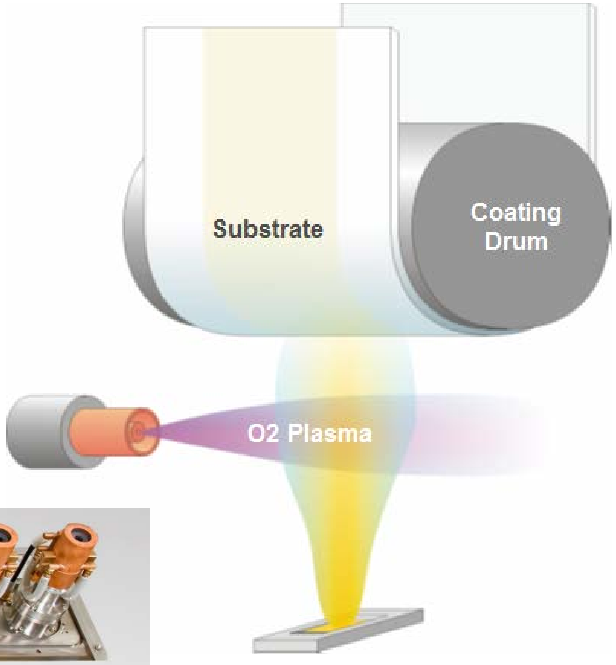
Advanced packaging films

product, application	Transparent barrier films for packaging
state of the art	• increasing need for transparent barrier films • AlOx technology available
R&D need	• advanced product quality (barrier, convertability) • wide range of polymer films (including biopolymers) • retortable packaging
approach, solution	HAD-AlOx technology: Plasma-supported reactive evaporation of Al from boats
latest results at FEP	• several industrial installations together with Applied Materials WEB Coating GmbH • advanced barrier performance on a wide reange of polymer films

HAD-AlOx technology
(HAD: Hollow cathode Activated Deposition)

Plasma assisted AlO_x evaporation

- High density oxygen plasma expands into evaporated Al plume
- Molecular oxygen strongly dissociated & incorporated at growth surface
- High degree of control of **energetic** particle flux to growth surface significantly expanding process window



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Barrier performance: comparison with conventional AlOx technology

Substrate	Uncoated WVTR	Standard AlO_x WVTR	Plasma Assisted AlO_x WVTR	Uncoated OTR	Standard AlO_x OTR	Plasma Assisted AlO_x OTR
PET (12 µm)	40-50	≤ 0.7	**≤ 0.35**	100-140	≤ 1.6	**≤ 0.8**
BOPP (17 µm)	4-7	≤ 7	**≤ 0.30**	2000-2500	≤ 50	**≤ 35**

WVTR: Water Vapor transmission rate, measured in g(m^2 d) at 38°C, 90 % r. h.
OTR: Oxygen transmission rate, measured in cm^3/(m^2 bar day) at 23°C, 0 % r. h.

barrier values may vary depending on substrate and process conditions

- Optical transmission ≥ 98%
  (measured inline during coating process)
- web speed 8 m/s

Source: Neil Morrison,
Applied Materials WEB Coating GmbH
Presentation at AMI Coral Springs, Florida, USA, 2017

APPLIED MATERIALS
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Barrier performance for “non-conventional” substrates

Polymer film type thickness		OTR [$cm^3/m^2 \times d \times bar$] (23°C, 0 % r. h.)	WVTR [$g/m^2 \times d$] (38°C, 90 % r. h.)
PLA	20 µm	25	25
CPP	20 µm	50	0.5
PE	20 µm	40	0.9

barrier values may vary depending on substrate and process conditions

- Optical transmission ≥ 98%
- web speed 8 m/s

High barrier films for encapsulation of flexible electronics

product, application	transparent high barrier films for encapsulation of flexible electronics
state of the art	• increasing number of flexible electronic products (like flexible organic solar cells) • increasing need for encapsulation
R&D need	• barrier, optical performance, low defects rate • reduction of cost • production equipment
approach, solution	• systematic investigation of sputtering process • development of substrate smoothing layer based on electron beam curable coatings
latest R&D results at FEP	• reduction of defect rate in sputtering processes • optimized winding procedure • optimization of layer composition

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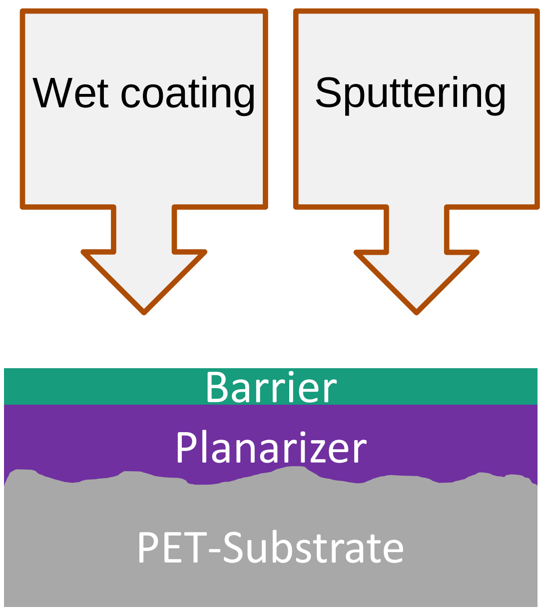
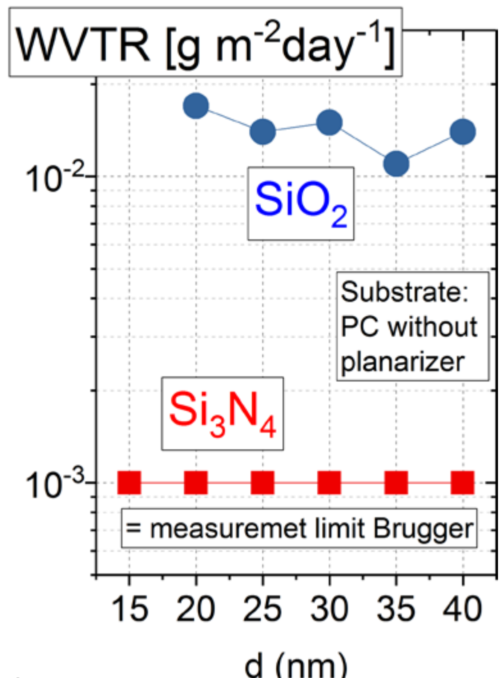
Project OPTIPERM: Encapsulation films for flexible electronics

Objective	■ Simplified barrier layer stack ■ Robust technology concept
Technology	■ Wet coating and electron beam curing ■ Sputtering





Project partners

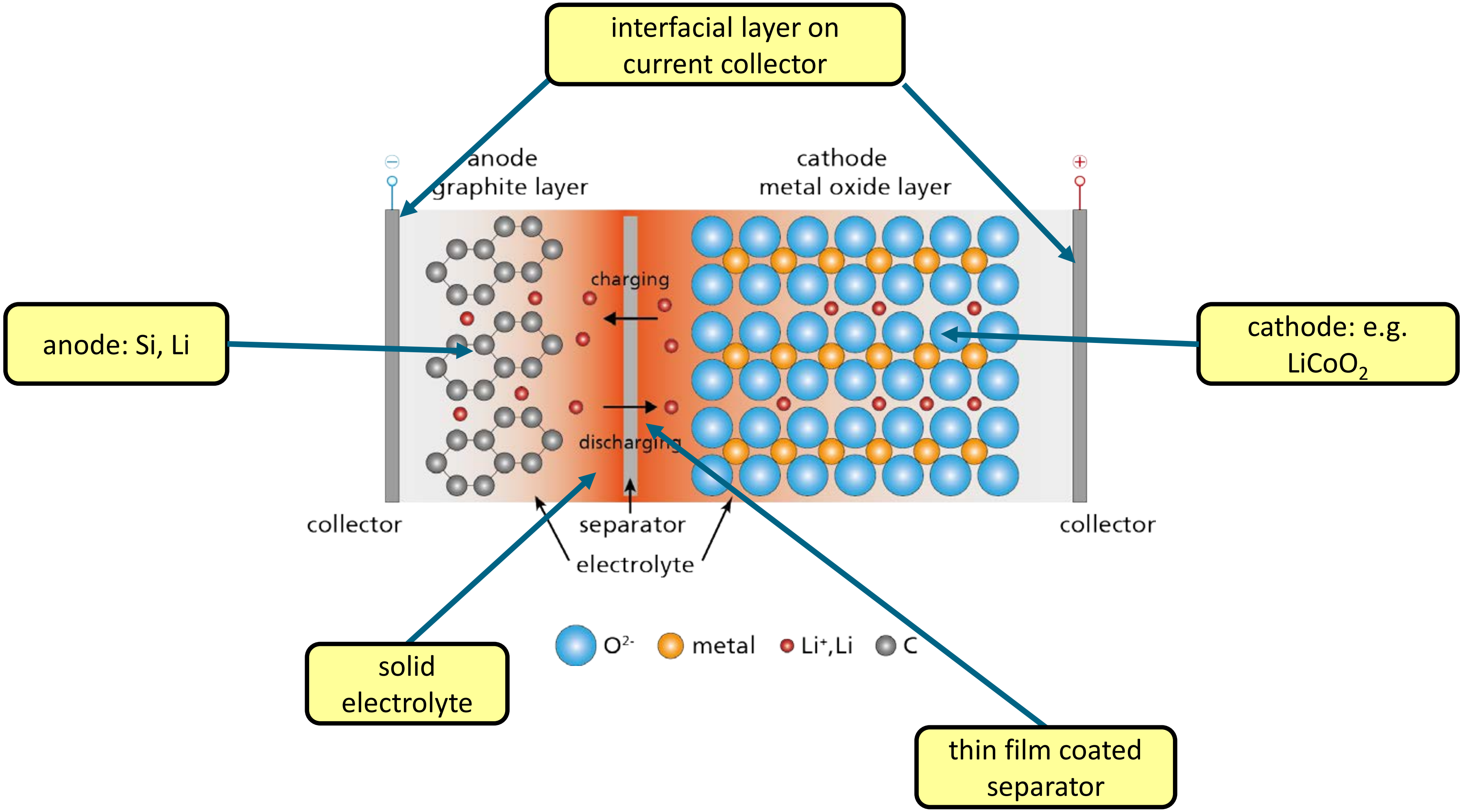
- VON ARDENNE
- 3D Micromac
- GfE Fremat
- IOT
- Vision optics

Funding contract Nr. 100236574/3160

Flexible materials for batteries

product, application	future batteries with improved energy density
R&D need	cost effecient technologies for thin functionla layers
approach, solution	vacuum roll-to-roll technologies
latest R&D results at FEP	• Si anode layers on copper foils for Lithium-Sulfur batteries • protective layers on current collectors for Lithium Metal Polymer batteries • plasma supported coating technologies for solid state electrolytes

Vacuum deposited thin films: potentials and R&D needs



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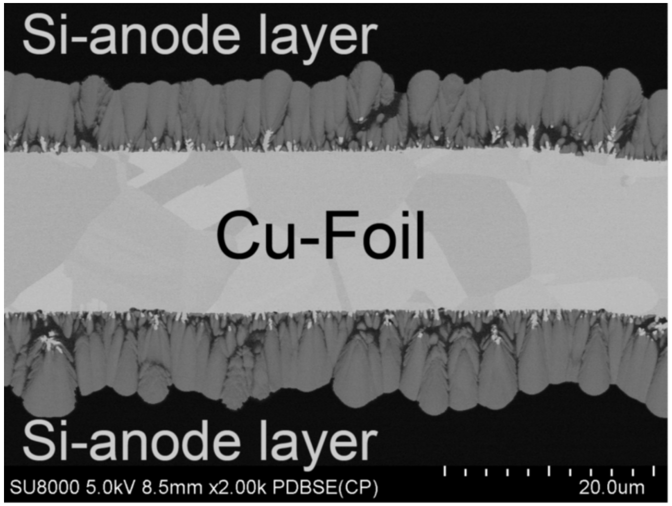
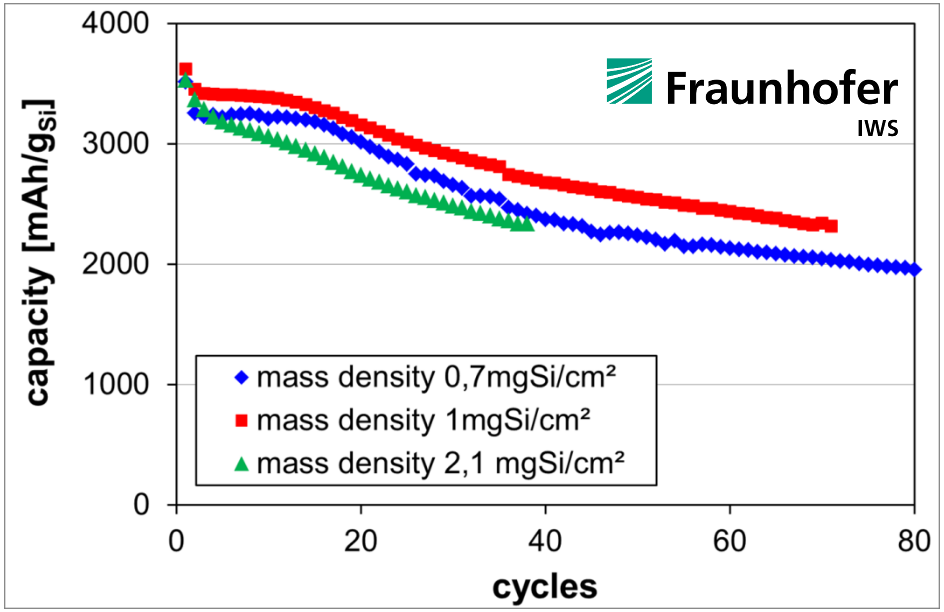
Silicon anodes for Li-S-Batteries

Copper foil with silicon anode layers –
SEM picture of an ion beam prepared cross-section



Capacity vs. charge cycles after additional structuring of Si anode layers and testing in test cells



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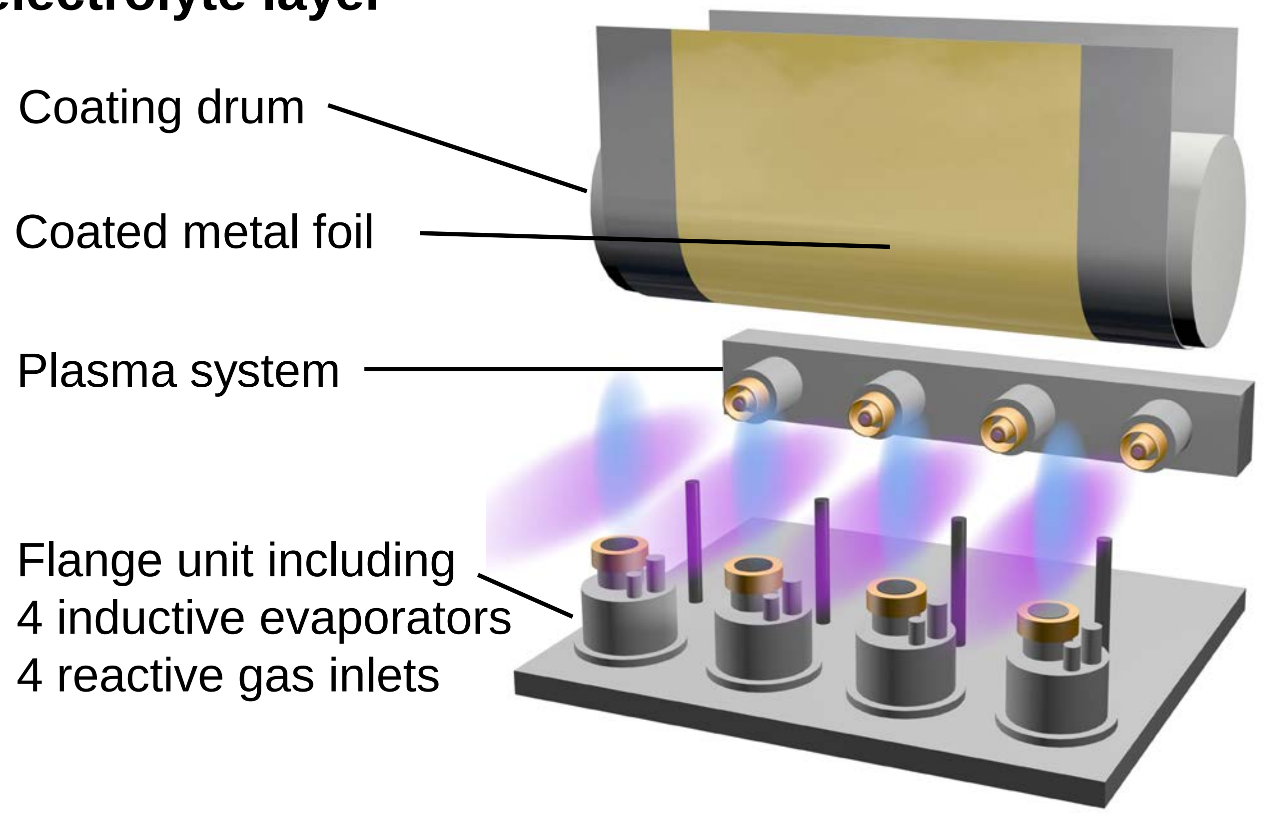
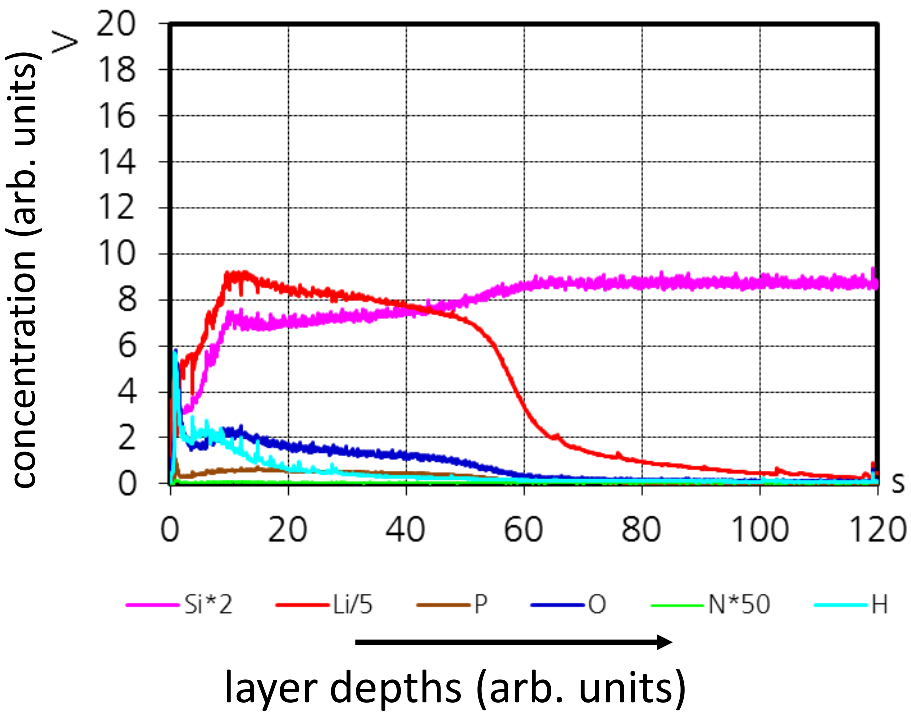
Roll-to-roll process for high-rate deposition of solid electrolyte layers on metal foils

Schematic layout of an arrangement for depositing a LiPON solid electrolyte layer

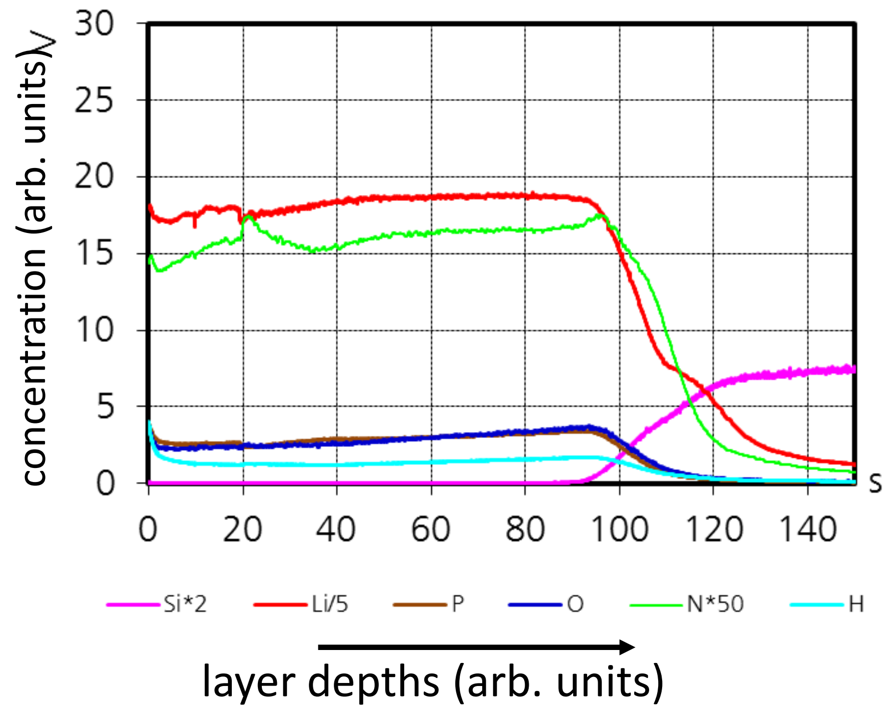


High-rate deposition of solid electrolyte:Influence of the plasma activation

Without plasma activation
No nitrogen integration



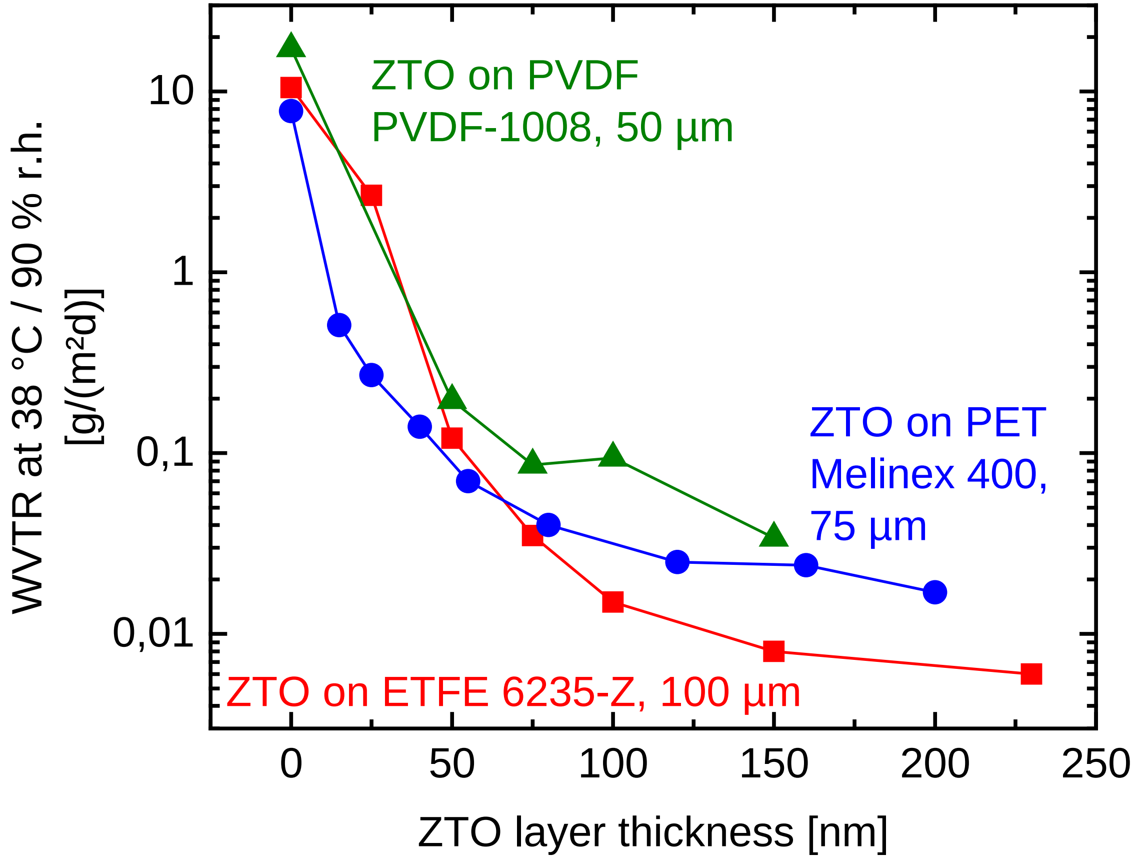
With plasma activation
high nitrogen integration



Functional films for architecture and outdoor use

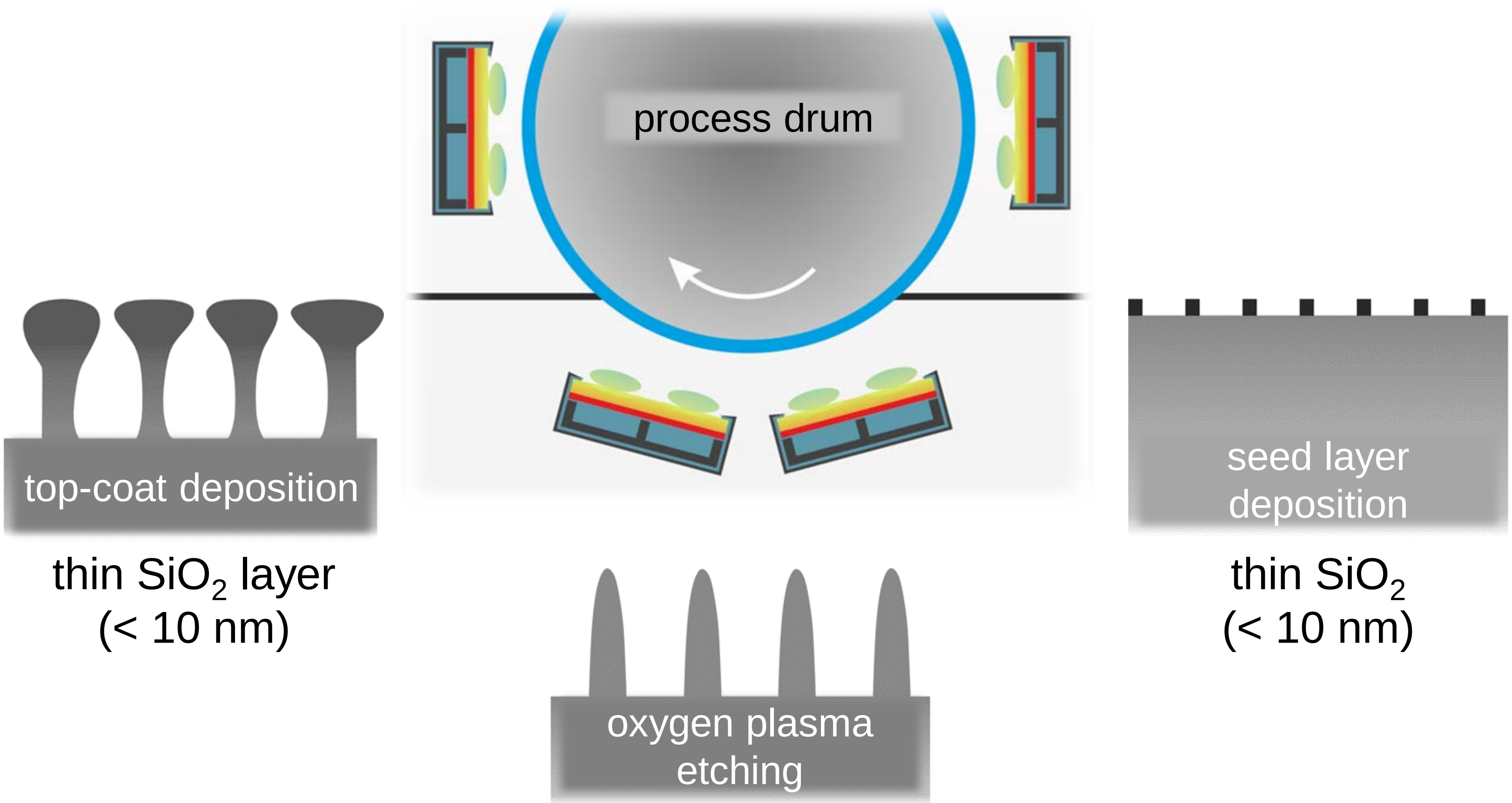
product, application	functional films for outdoor use like • flexible solar cells • integration in membrane roofs and façades
R&D need	vacuum PVD and PECVD on outdoor-stable substrates
approach, solution	optimization of vacuum coating processes to special properties of fluoropolymer substrates
latest R&D results at FEP	• sputtered permeation barriers on ETFE with same performance as on PET • outdoor-stable anti-reflective surface treatment

Permeation Barrier Performance on Fluoropolymers



reactive dual magnetron sputtering zinc-tin-oxide (ZTO)

Reactive Plasma Etching of ETFE surfaces to promote adhesion thin layers



thin SiO_2 layer (< 10 nm)

thin SiO_2 (< 10 nm)

Summary

R&D for vacuum web coating

- ultra-thin flexible glass
- advanced packaging films
- encapsulation of flexible electronics
- flexible materials for batteries
- functional films for buildings and outdoor use
- high-rate PECVD

I thank you for your attention