TRANSPARENT SINGLE LAYER METAL OXIDE ***COATINGS*** ON ***FLEXIBLE POLYMER FILMS*** FOR ***HIGH PERMEATION BARRIER*** APPLICATIONS

Patrick Schlenz[1], Valentijn J.J. Von Morgen[2], Leopold Moimeaux[3]

[1]*Fraunhofer FEP, Germany*

[2]*DuPont Teijin Films UK Ltd, UK*

[3]*ASCA SAS, France*

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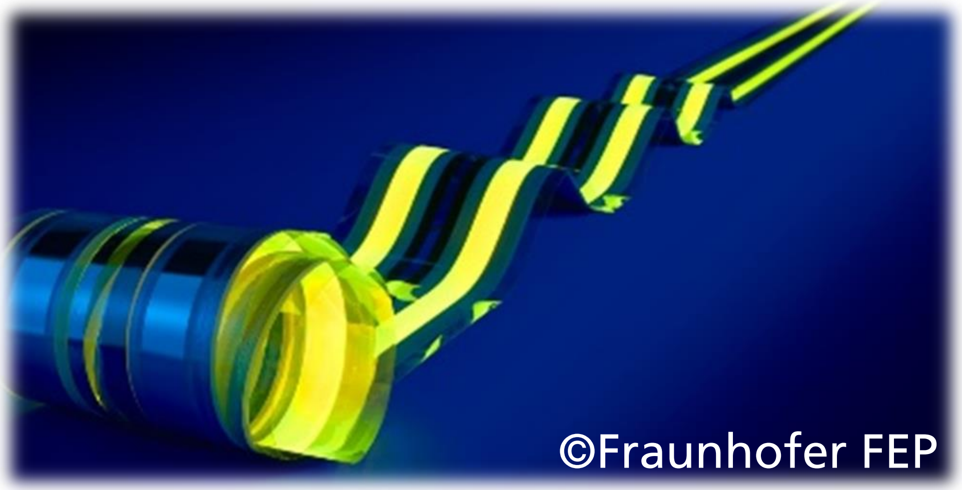
Motivation

→ Large area opto electronic devices

Why functional polymer films?

- reduce module weight
  from > 20 kg/m² to < 1 kg/m²
- Energy saving manufacturing
- Simplified installation
- Allowing more freedom in design



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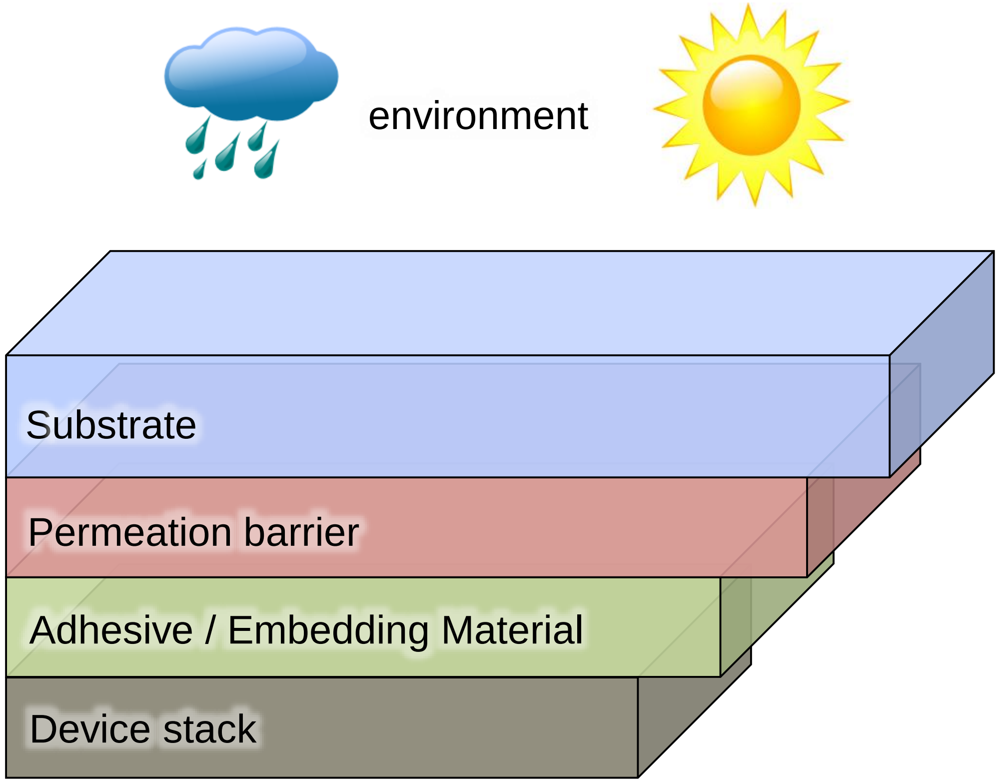
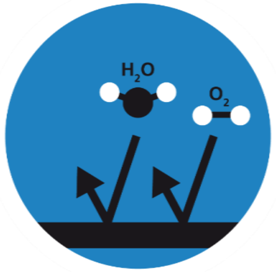
Challenge: What are the requirements?

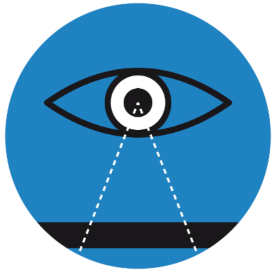




humidity and oxygen resistance

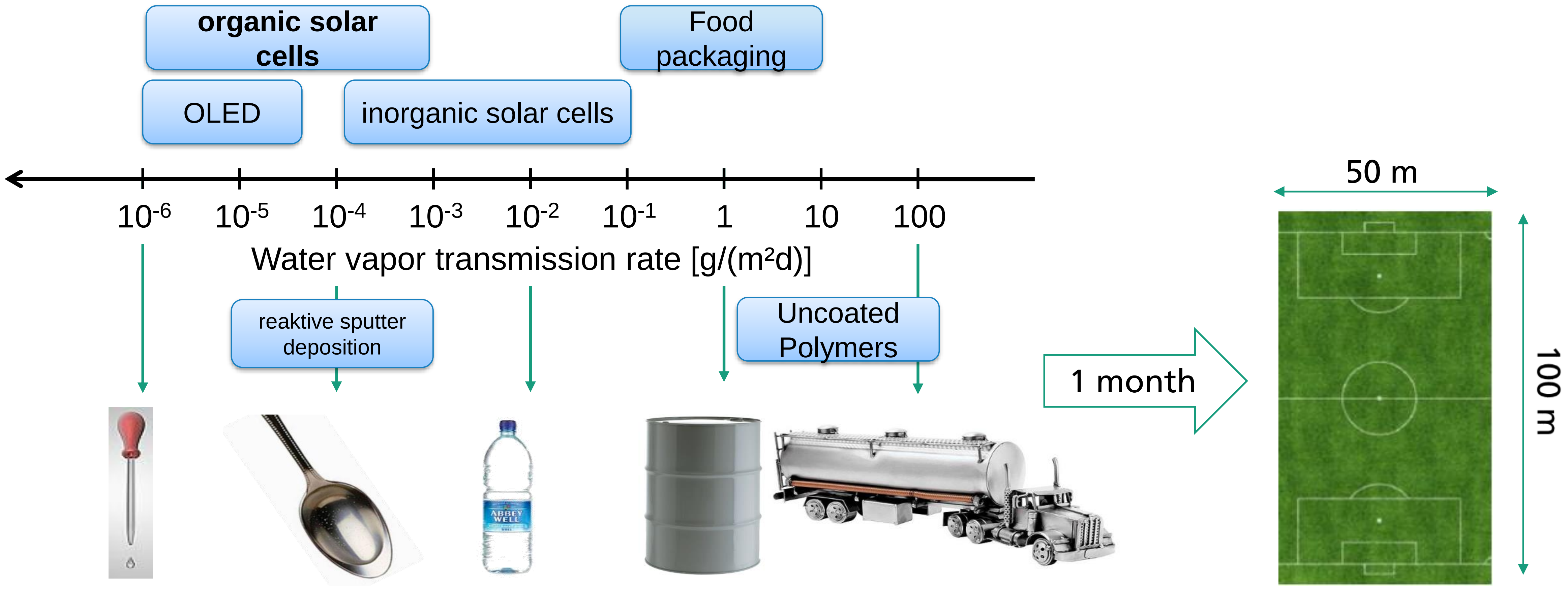
stability against mechanical impacts

blocking UV-radiation



optical properties: transparency and color

Permeation rates – applications vs. requirements



Water vapor transmission rate (WVTR)
Quantity of water vapour (m_{H2O}) that permeates the sample material per unit of time (t) and area (A)

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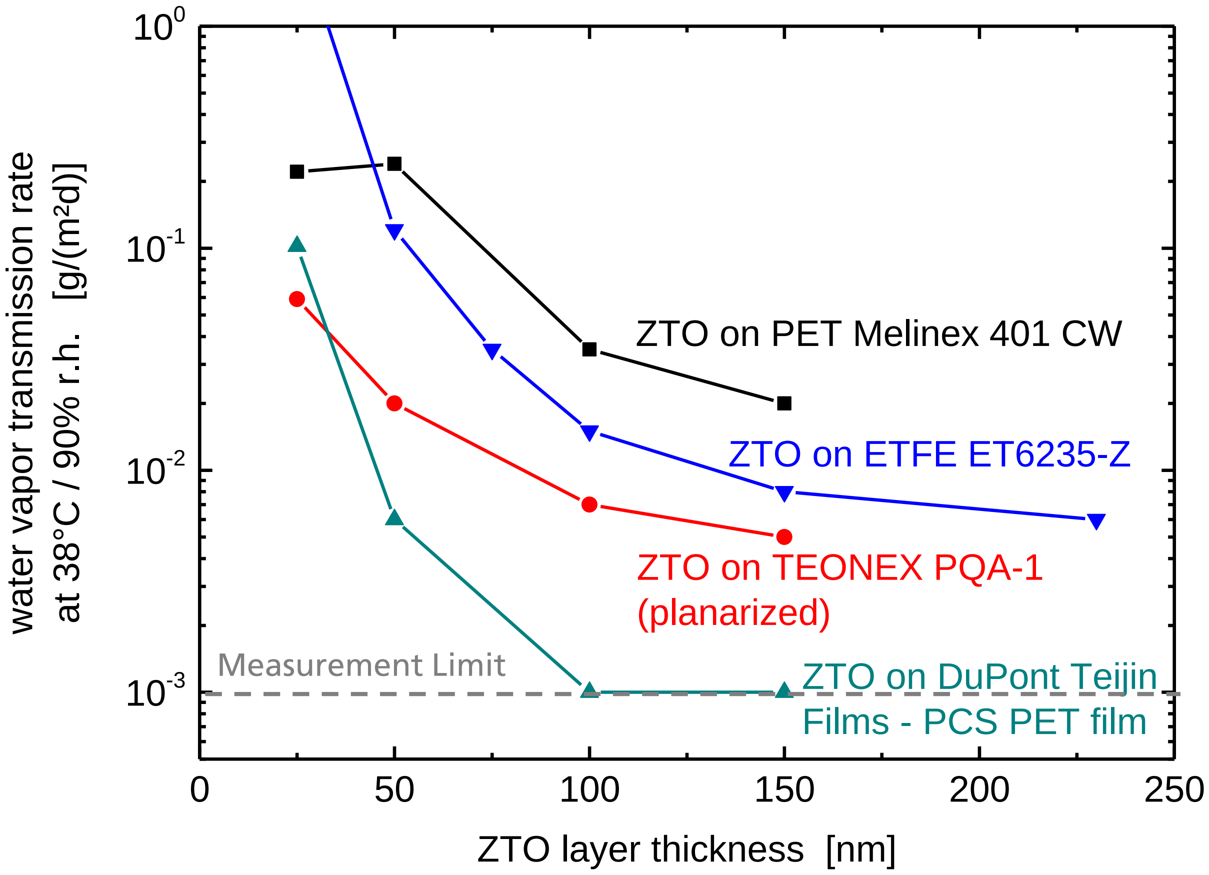
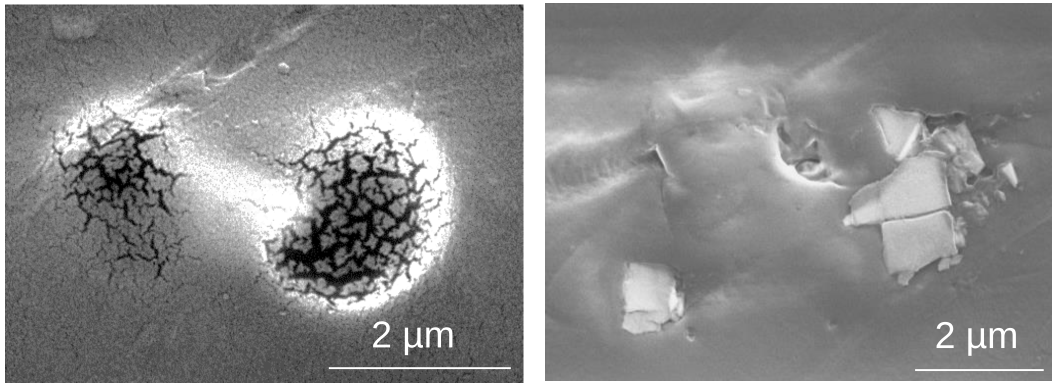
Important choice: the substrate material





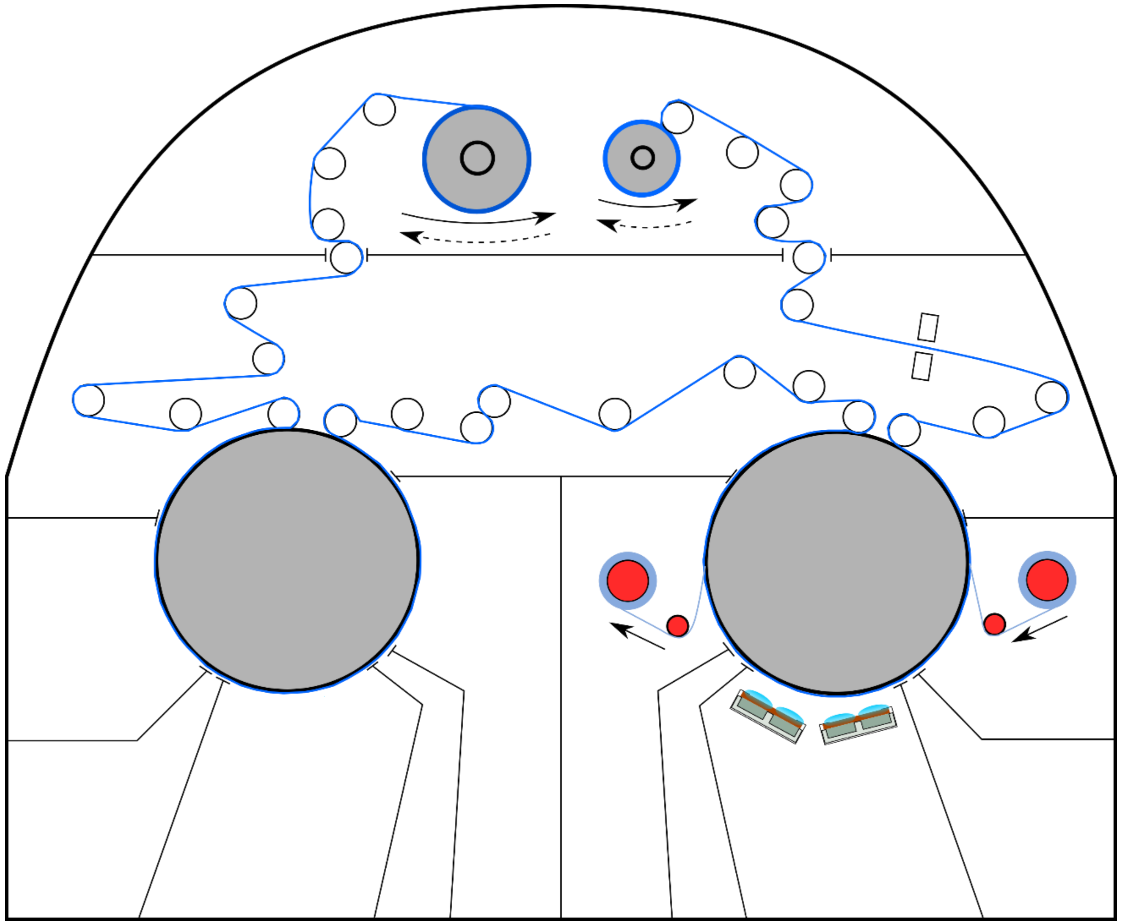
Typical substrate defects

- ZTO – Zinc Tin Oxide (state of the art material)
- Melinex® PCS – peelable clean surface
- 100 µm PET Melinex + 25 µm protective liner film

offen/public

DuPont Teijin Films™ Fraunhofer FEP

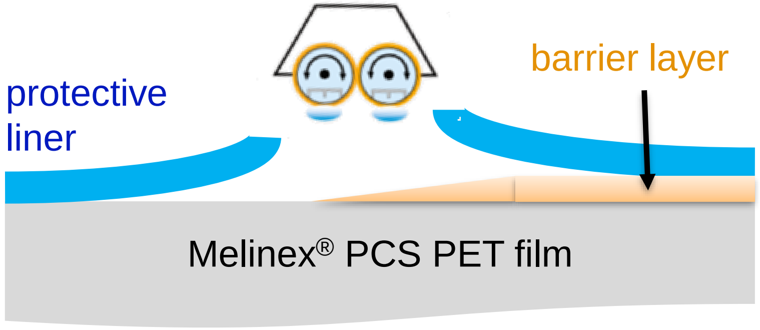
Special feature: Protective films



Pilot web coater *coFlex*® *600*

Aim:

- protect film surface until coating
- instantly add another protective liner film (PL) after coating
- liner adheres well to the coating and gives a robust barrier solution
- liner can be considered as an encapsulant



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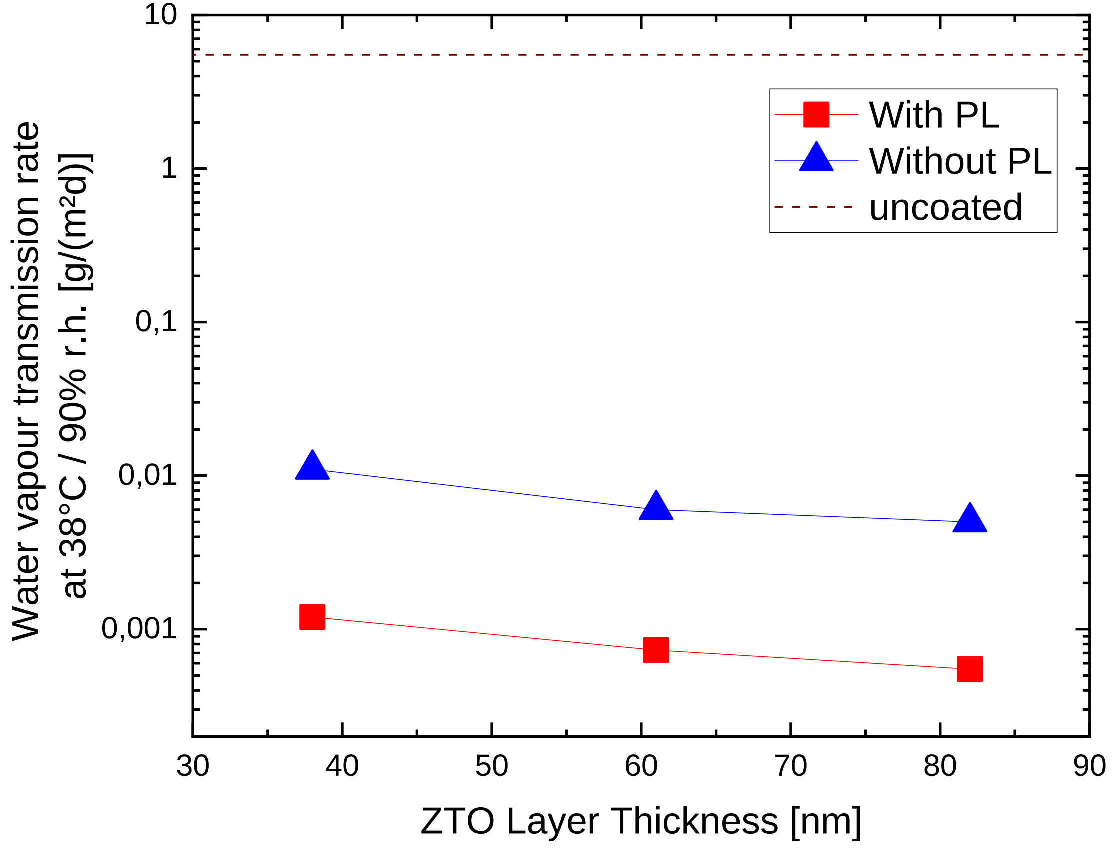
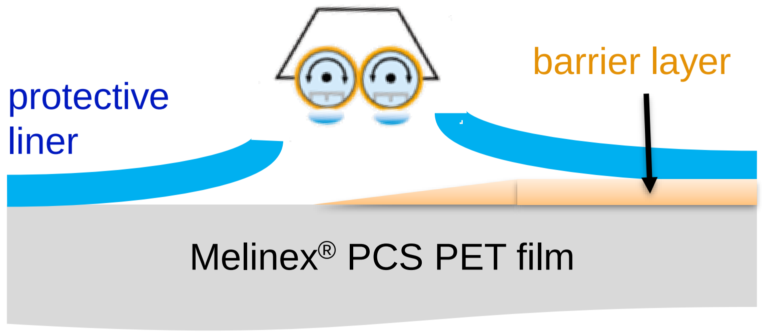
Special feature: Protective films



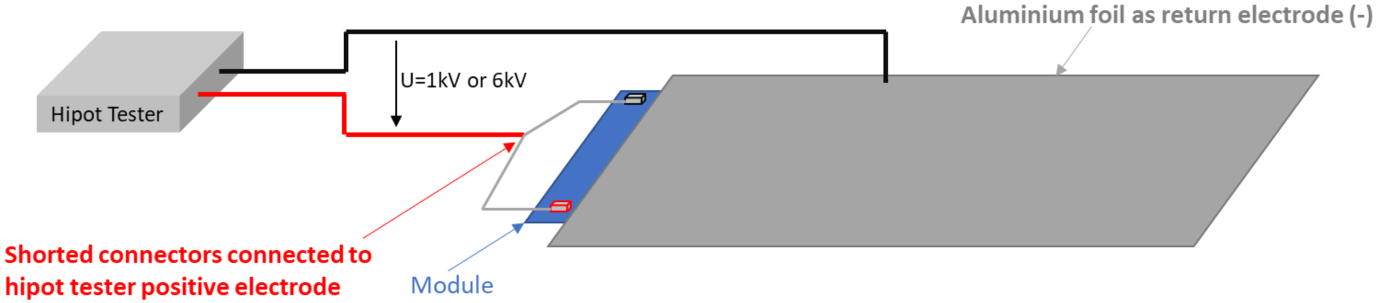
- PL protects the deposited layer from roller contact
- Otherwise the layer would be damaged
- Results in an increase in WVTR
- Enables single layer solution - Reduces production costs



[1] M. Ehrhardt, Optimierung von Zink-Zinn-Oxid Barriereschichten für organische Photovoltaik durch Variation des Beschichtungsprozesses, diploma thesis, 2022

ZTO: Not quite perfect barrier material

- IEC 61730: Safety qualification for photovoltaic modules
- OPV Module has to be submitted to 6 kV for 60 s with no sign of insulation breakdown during the test



- OPV Modules with Melinex® PCS + ZTO do not pass the test:
  Arc failures, sparkling due to a too high leakage current

Oxide layer	Surface tracking
ZTO	Fail @ 6kV
AlO_x	PASS @ 6kV
$SiAlO_xN_y$	PASS @ 6kV

- ZTO has a low residual conductivity

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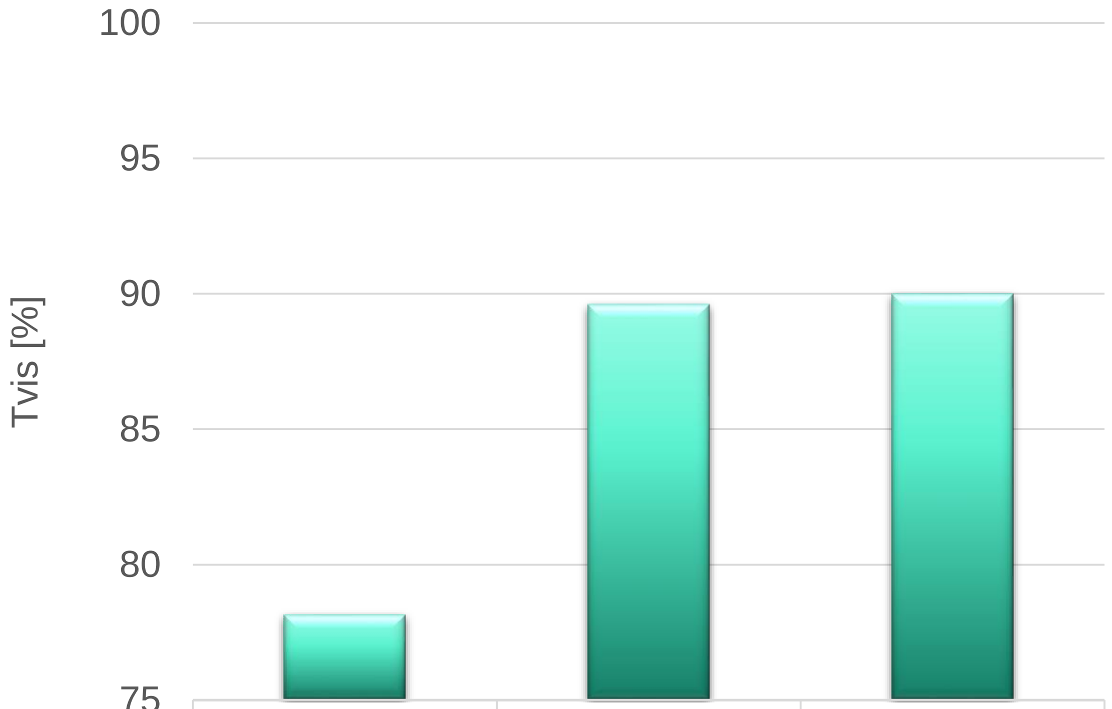
ZTO: Not quite perfect barrier material

- Lower transmittance leads to lower solar cell outputs
- Depending on layer thickness* and reactive gas composition



	ZTO	AlSi50 OxNy	PCS
Tvis [%]	78.15	89.60	90.00

$$T_{vis} = \frac{\int_{\lambda=380\,nm}^{780\,nm} T(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\int_{\lambda=380\,nm}^{780\,nm} V(\lambda) \cdot \Delta\lambda}$$

*Comparison of layers with WVTR in the same order of magnitude

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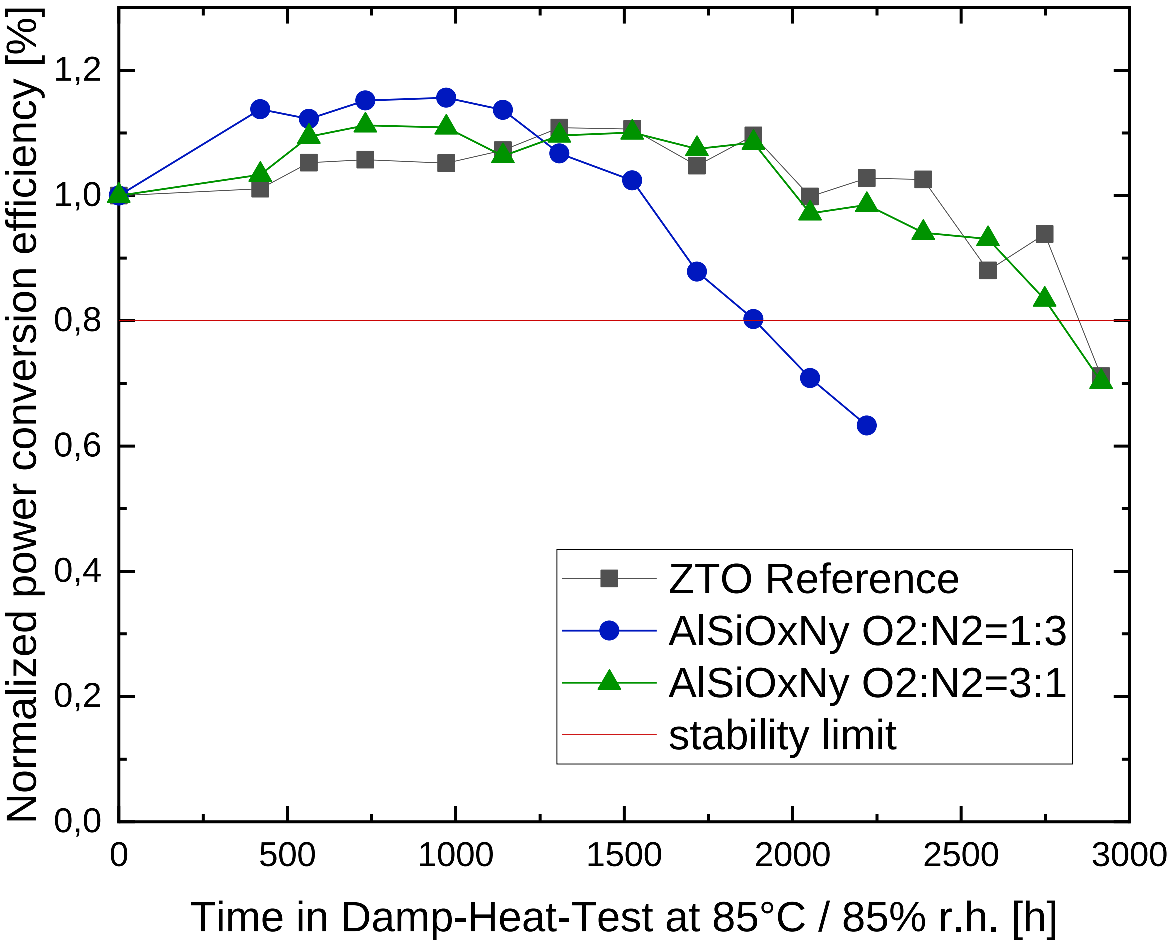
New barrier material $AlSiO_xN_y$: It works, but why?

- Target: $AlSi_{50}$
- Gas Composition O_2:N_2 = 3:1
- WVTR = $8.0 \cdot 10^{-4}$ g/(m²·d)
- T_{vis} = 89.6 %
- Life time in Damp Heat Test (85°C / 85% r.h.) = 2800h



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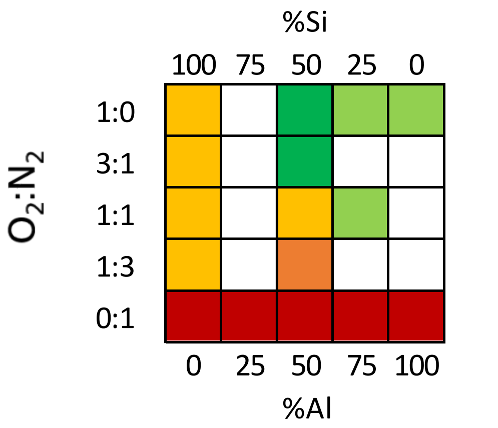
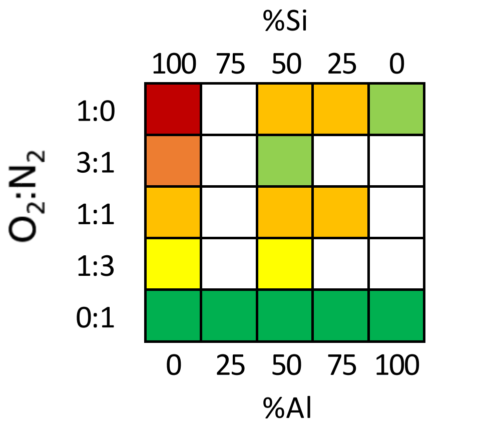
Oxide barriers – qualitative overview

optical properties*



WVTR*



- ZTO barrier layer deposition (reference)
- Deposition of different $SiAlO_xN_y$ modifications
  - Why a 4 component material system?
  - Other properties are important for application
    - Ductility and crack resistance improve with Al content
    - Process stability
    - 4 component system is necessary
    - First Step: Understand 3 component system

*Only qualitative statements possible. Many trials on different substrates.

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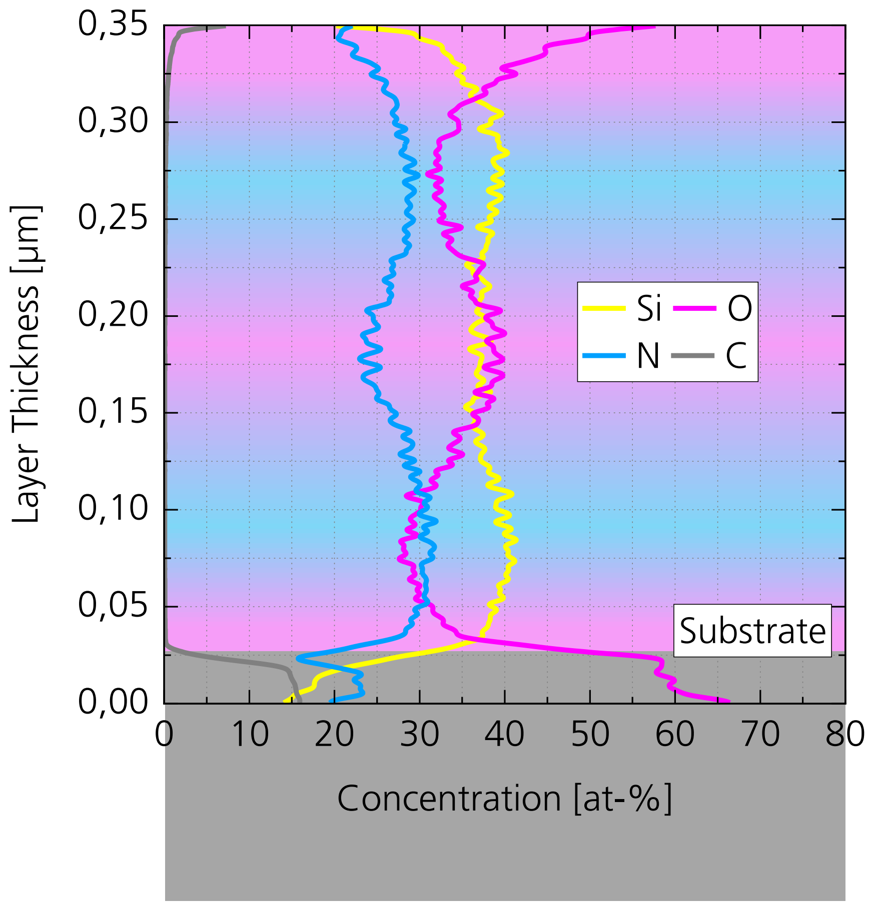
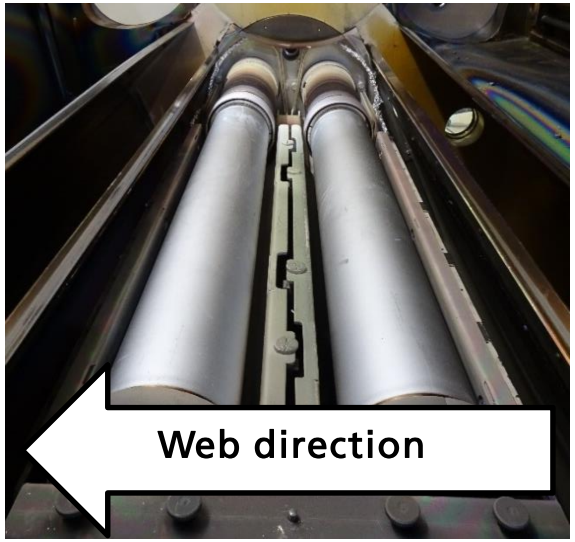
It is a single layer, but...

- SiO_xN_y: used gas compostion O_2:N_2 = 1:1
- Optical simulation as 5 layer system



- max. in nitrogen content
- areas with high plasma density and close proximity to the target during coating
- max. in oxygen content
- when the degree of coverage increases at the selected operating point



[2] A. Himmler et al: Roll-to-roll deposition of silicon oxynitride layers on polymer films using a rotatable dual magnetron system: Surface and Coatings Technology 336, 2018, 123-127

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Process scaling: Engineering vs. Science

- Technically feasible - requirements are achieved

- Engineering question: Deposition time of $AlSiO_xN_y$ is higher than of ZTO → Process time optimization
- Next Step: work with 2 Double Magnetron systems simultaneously

- Scientific questions:
  → Deeper investigations of the coatings
  → Creates an interface between the “layers”?
  → What influence does this have on the WVTR and optical properties?

- Engineering question: More process optimization

THANK YOU FOR LISTENING

Dipl.-Ing. Patrick Schlenz
Fraunhofer FEP
Winterbergstraße 28,
01277 Dresden, Germany
Tel: +49 351 2586 115,
patrick.schlenz@fep.fraunhofer.de
www.fep.fraunhofer.de

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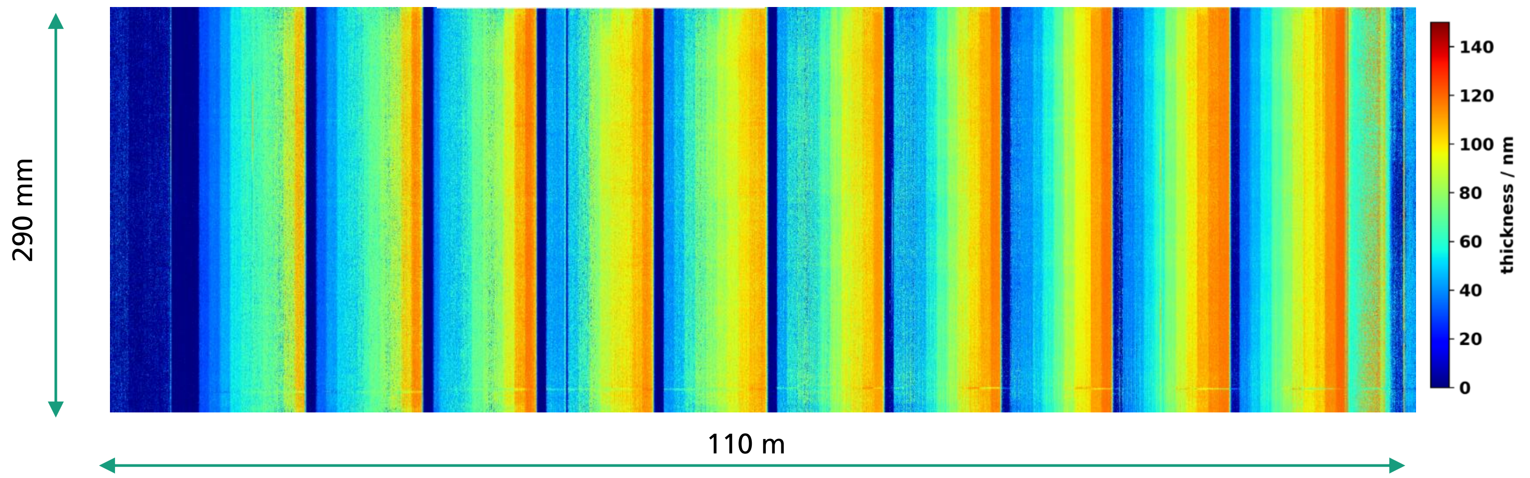
Next Event: DPG Spring Meeting,
Thursday, 30 March, 10:00, Session DS 13.21

LARGE AREA FUNCTIONAL THIN FILM PROPERTIES MAPPING USING IN-LINE HYPERSPECTRAL IMAGING DURING ROLL-TO-ROLL MAGNETRON SPUTTER DEPOSITION

P. Schlenz[1], F. Gruber[2], J. Hernandez[3], C. Sternemann[4] and S. Cornelius[1]



[1]Fraunhofer FEP, Germany
[2]Fraunhofer IWS, Germany
[3]Norsk Elektro Optikk AS, Norway
[4]Delta Technische Universität Dortmund, Germany

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