Web Coating and Handling Conference

The Premier Event for Web Processing, Handling, and Finishing

2016 Europe

Dresden, Germany

Industrial Roll to Roll fabrication of PV and LOW-E thin films

S. Kreher

Agenda

- Layer stacks and process demands
- Process/ drum concepts - Temperature Control
- Gas separation - Setups and corresponding gas separation factors
- Results

Layerstacks and process demands

Temperature and gas separation

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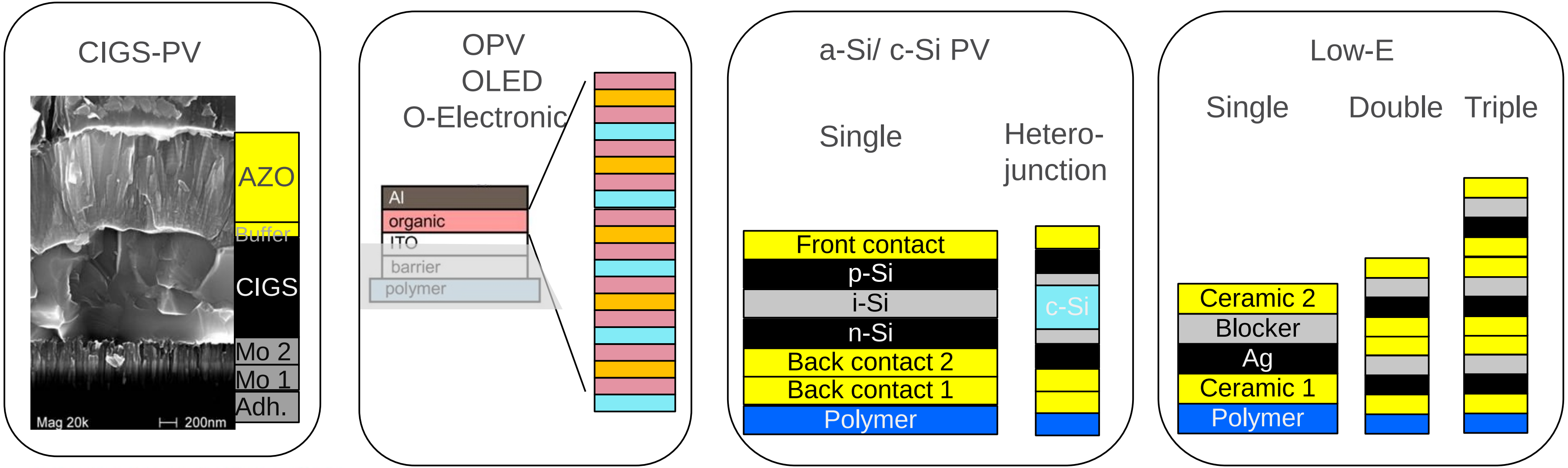
Layer stacks

- Apllications and layer stacks



Layer stacks

- Substrates, process temperatures and gas separation factor [GSF]

CIGS-PV

Substr.: PI, metal

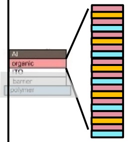
AZO / Buffer: ~200° C, GSF 1:5

CIGS: ~400° C

Mo 2 / Mo 1 / Adh.: ~250° C, GSF 1:5

O-PV

Substrate: PET

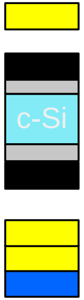


max. 80° C

GSF ...1:10…1:1000

a-Si-c-Si PV

Substrate: PI, metal

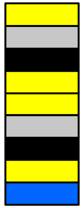


~200° C

~200° C
PECVD
GSF: 1:10 000

Low-E

Substrate: PET



-15…40° C
GSF: 1:100

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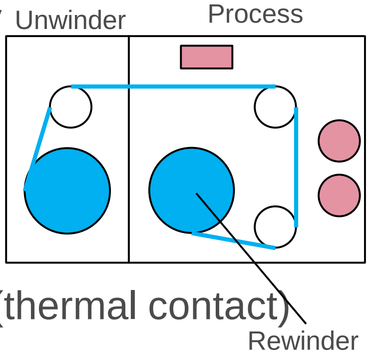
Process/ drum concepts

Temperature control

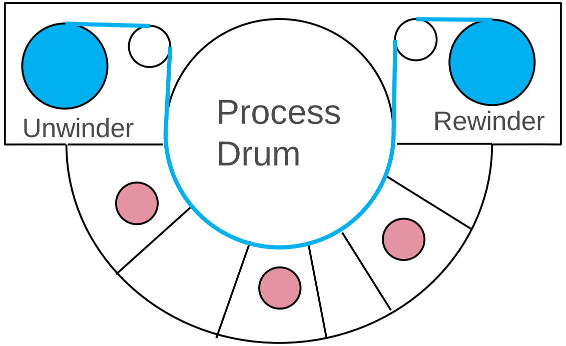
Process/ drum concepts

- Drum setups
- Free span
  no temperature control of web,
  defined by radiation properties
  surface, surrounding geometry
  hot, robust processes,
  PI-Web, metal substrate
- Process Drum
  (temperature controlled)
  efficient for plastic foils
  limited usability for metal foils (thermal contact)

Free Span, e.g.
FHR.Roll.300.PECVD
FHR.Roll.1000



Process Drum
Cool: -15…80° C PET foil
Warm: up to 300° C PI-foil
Hot: up to 600° C



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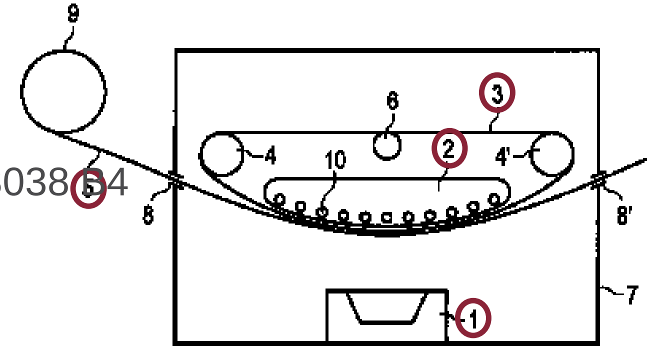
Process/ drum concepts

- Avoiding front contact of web and the need of large number or long deposition/ process zones for temperature controlled web would need large drum diameter e.g. >8m

- Solution:

- Metal belt drive
  Patent DE 102009058038 B4

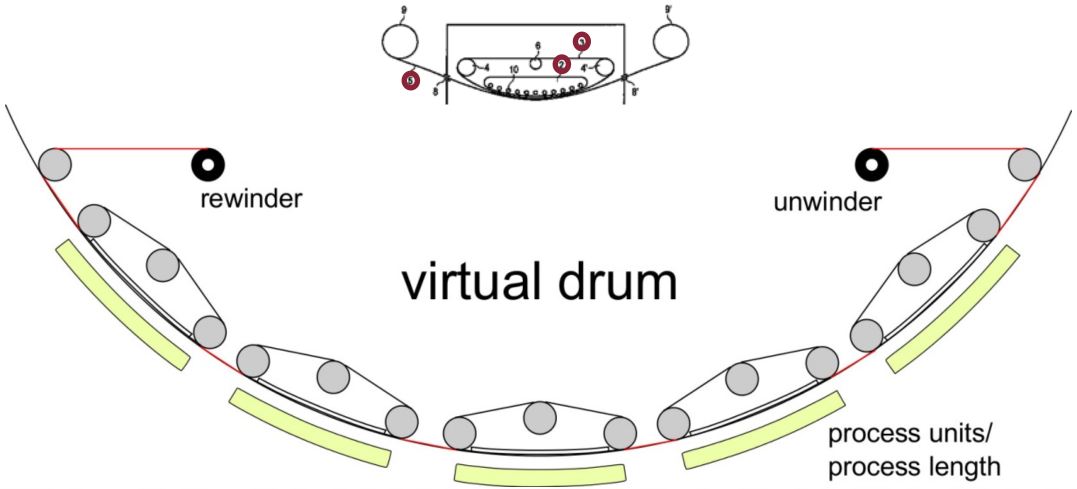
- Virtual drum



(1) **Evaporator**
(2) **Temperature controlled unit**
(3) **Metal belt (driven synchronously)**
(4) Drums
(5) **R2R Substrate**
(6) Band tension drum
(7) Vacuum chamber
(8) Valve/slit
(9) Unwinder/rewinder
(10) Tubings for temperature fluid

Process/ drum concepts

- Drum setups
- Metal belt drive
  patent DE 102009058038 B4
- Virtual drum
- No front contact
- Theoretic diameter >10 m



Gas Separation

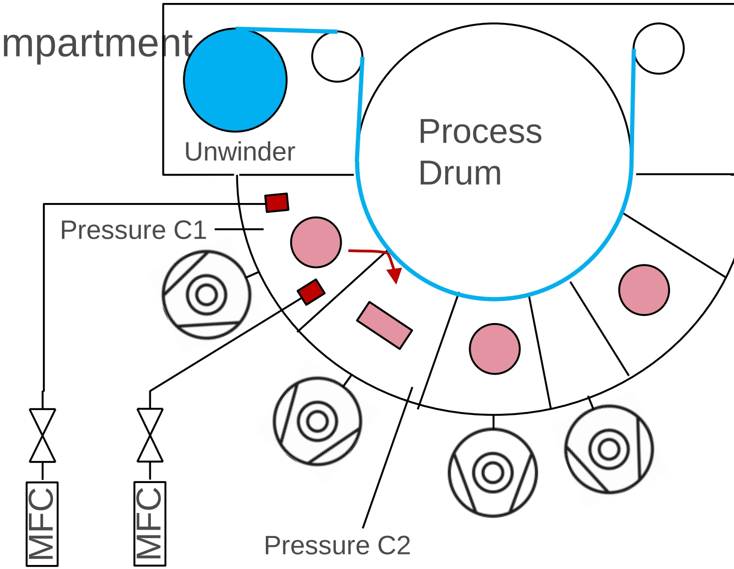
Setups and corresponding gas separation factors

Gas Separation

- Intention: No gas contamination from adjacent process compartment

$$GSF = \frac{(\Delta)p_{SC1}}{(\Delta)p_{SC2}(-p_{baseSC2})}$$

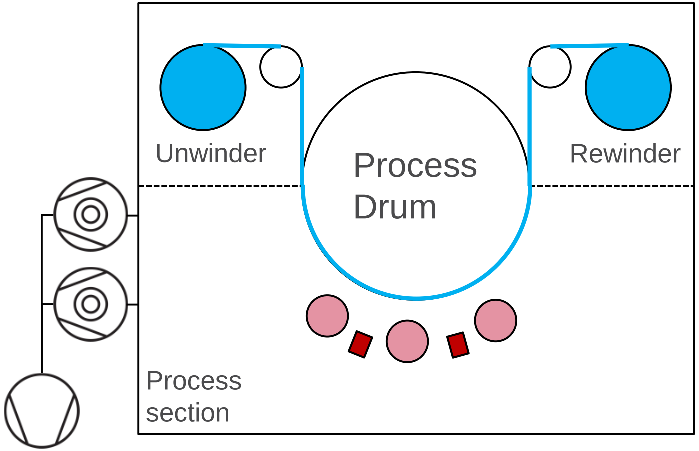
- Measurement
  gas inlet in SC1
  measure pressure (rise) in SC2



$(\Delta)p_{SC1}$ …Pressure of compartment with active gas inlet
$(\Delta)p_{SC1}$ …Pressure of adjacent compartment with no gas inlet
$p_{baseSC2}$ …Base pressure of adjacent compartment with no gas inlet

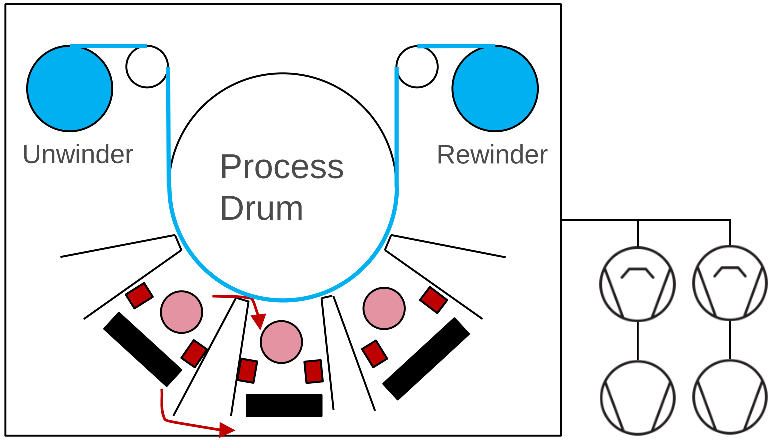
Gas Separation

- Gas separation factor[GSF]



Sputter process on drum without gasseparation

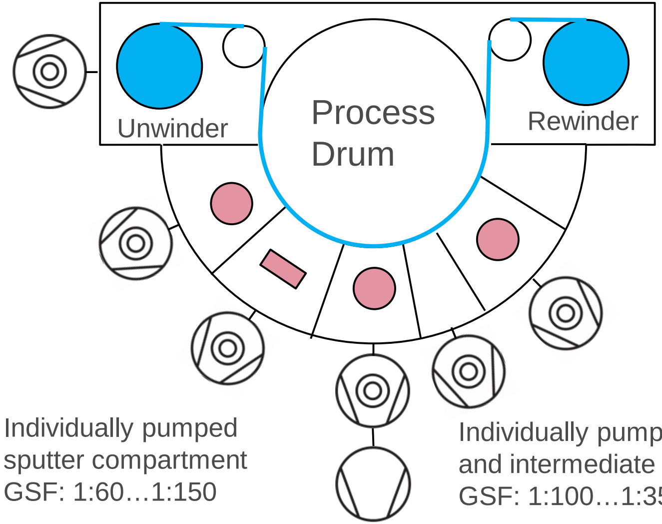
Sputter
Cathodes



Sputter process on drum with back ground pumping
Gas separation factor 1:20 ~1:70

Gas Separation

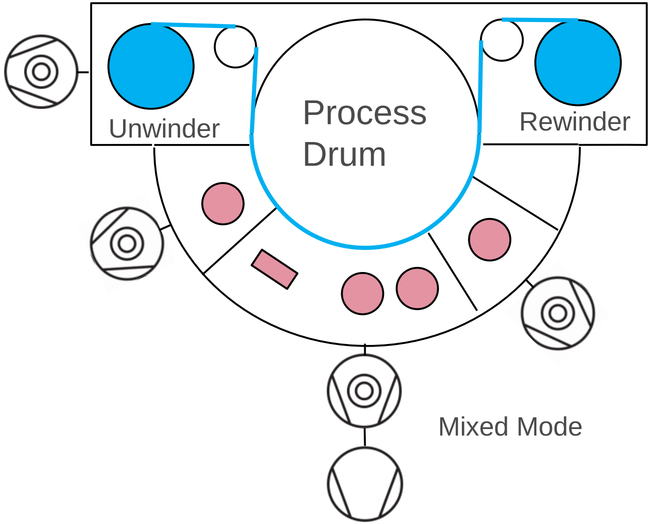
- Substrates, process temperatures and gas separation factor[GSF]



Process
sections

Individually pumped
sputter compartment
GSF: 1:60…1:150

Individually pumped compartments
and intermediate pumping
GSF: 1:100…1:350



Mixed Mode

Gas Separation

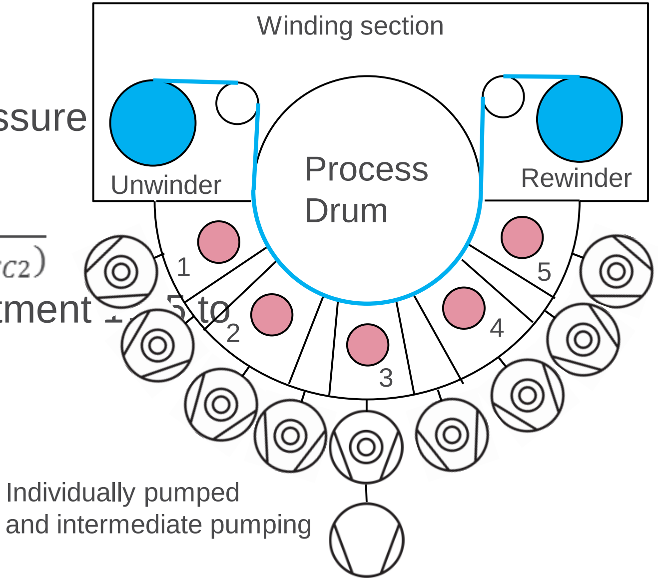
- Gas separation factor [GSF]

- Thin metallic layers e.g. Ag react with oxygen partial pressure => high Gas Separation Factor is needed

$$GSF = \frac{(\Delta)p_{SC1}}{(\Delta)p_{SC2}(-p_{baseSC2})}$$

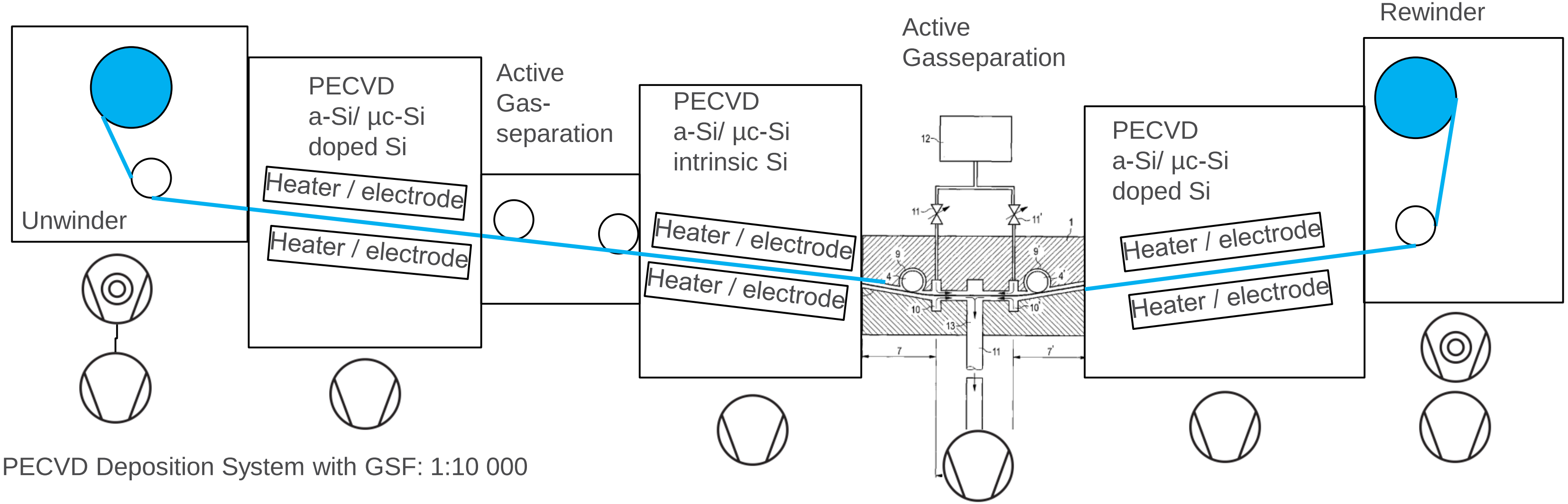
- Results:Measured Gas Separation Factors from compartment 1 ... 5 to compartment 3 (critical / sensitiv material e.g. Silver)

Gas separation factor	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
Compartment 3 Ag	1575	399	-	250	1500



Gas Separation

- Ultra high gas separation between intrinsic Silicon and doped Silicon neccessary



PECVD Deposition System with GSF: 1:10 000

Patented EP000002312014B1

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Gas Separation

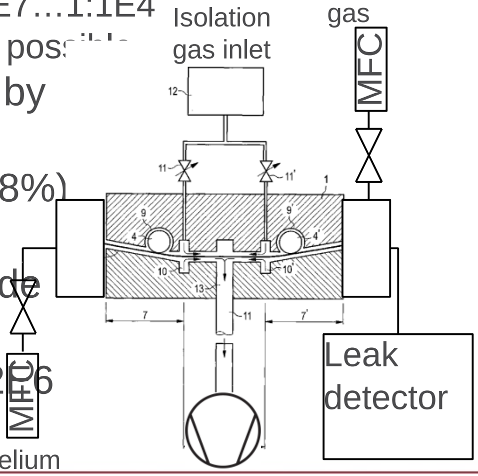
- GSF in PECVD-System:
  - Process pressure ~ 1 mbar / torr / 100 Pa range
  - High GSF needed between doping and intrinsic chambers

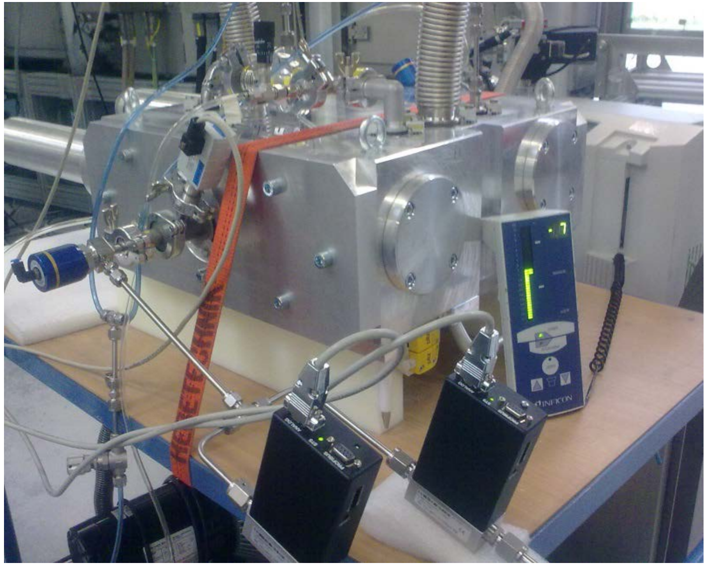
  => Doping of Si in the order 1:1E7…1:1E4
  - no pressure rise measurement pos
- Gas separation to be measured by He-“Leakage rate“ method: 100sccm N2+ 14sccm He inlet (8%) (simulating molecule behavior) and leak detector on opposite side

1E-7mbar*l/s=6,6E-6sccm

14sccm:6,6E-6sccm => GSF = 1:2E6

=> 1:2 000 000





Patented EP000002312014B1

Results

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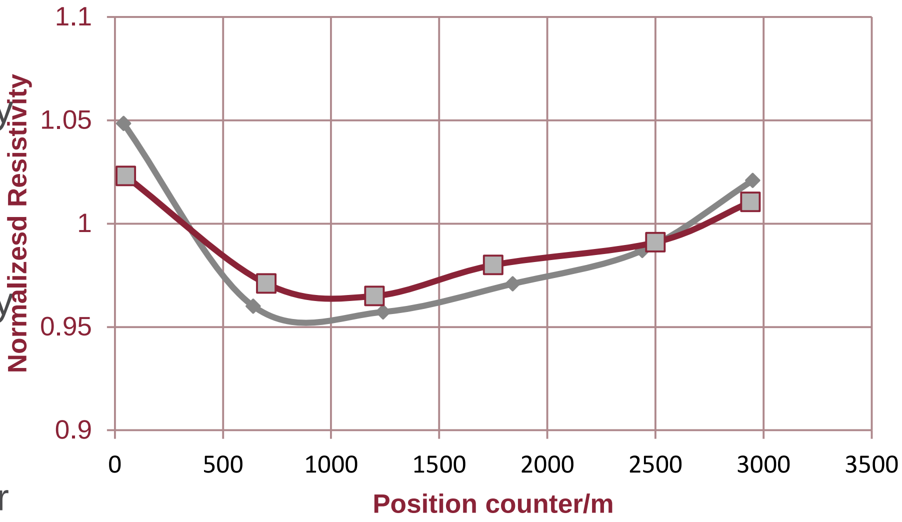
Results - Production stability

- TCO e.g. for PV Application, Touch panel
- TCO down web resistivity +-5% nonuniformity
  Constant process Parameters
  Gray curve [1]
- TCO down web resistivity +-3% nonuniformity
  with runtime dependent parameter change
  Red curve



Measured inline (eddy current) and off line (4 point probe)

[1] S. Kreher, Dr. S.M. Van Eek, ITO processes for display and touch panel applications - SVC TechCon Proceedings (2016)

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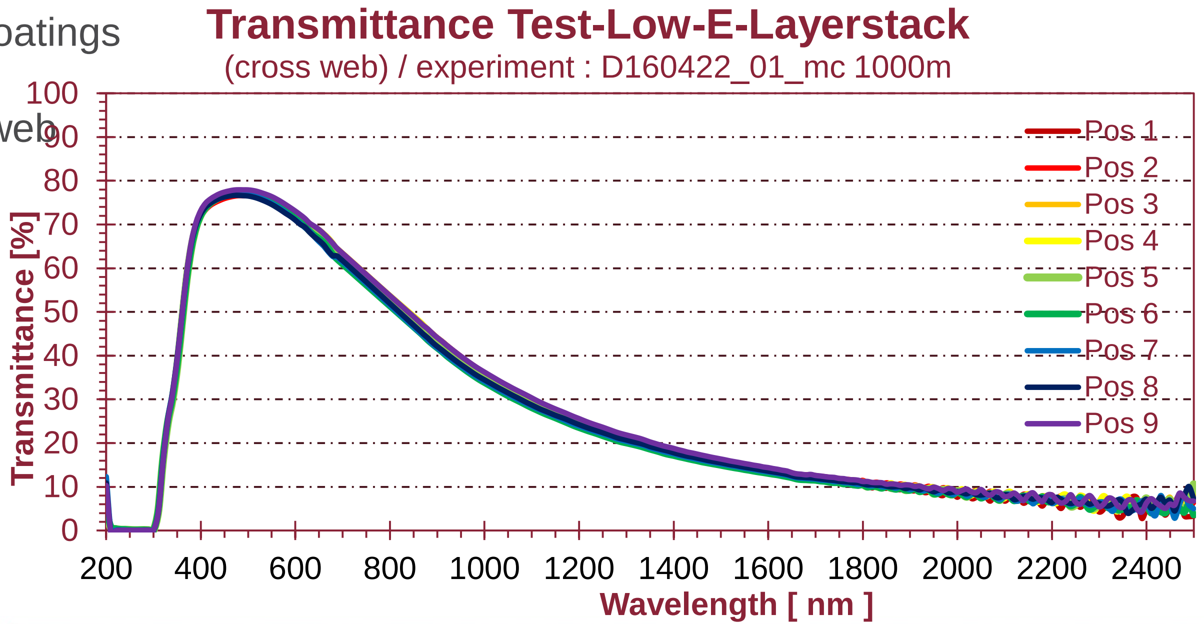
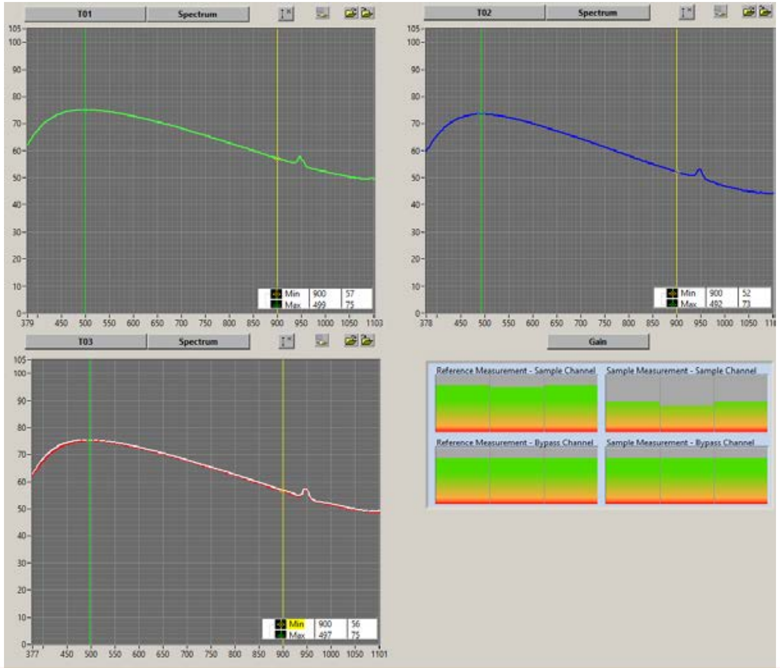
Results - Production stability

- Results Low Emmisivity coatings
- Opt. transmittance cross web
- 9 measurement positions
- 1600mm width
- Single Ag Low-E



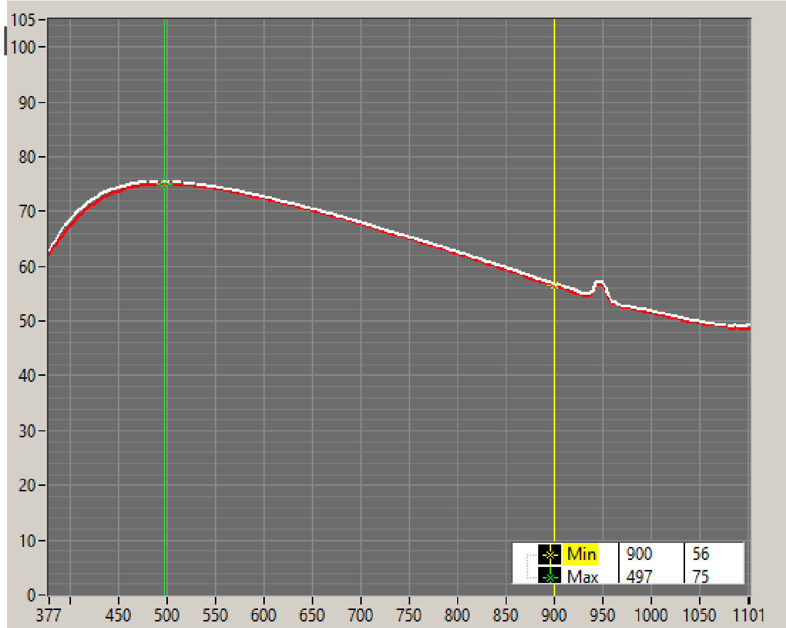
Results – Production stability

- Single Low-E test layer stack
- Transmittance 3 positions cross web
- Recorded after 4000m coating (green, blue red)
- White curve recorded at 150m



Results - Production stability

- Single Low-E test layer stack
- Transmittance
- 150m -> white curve
- 4000m -> red curve



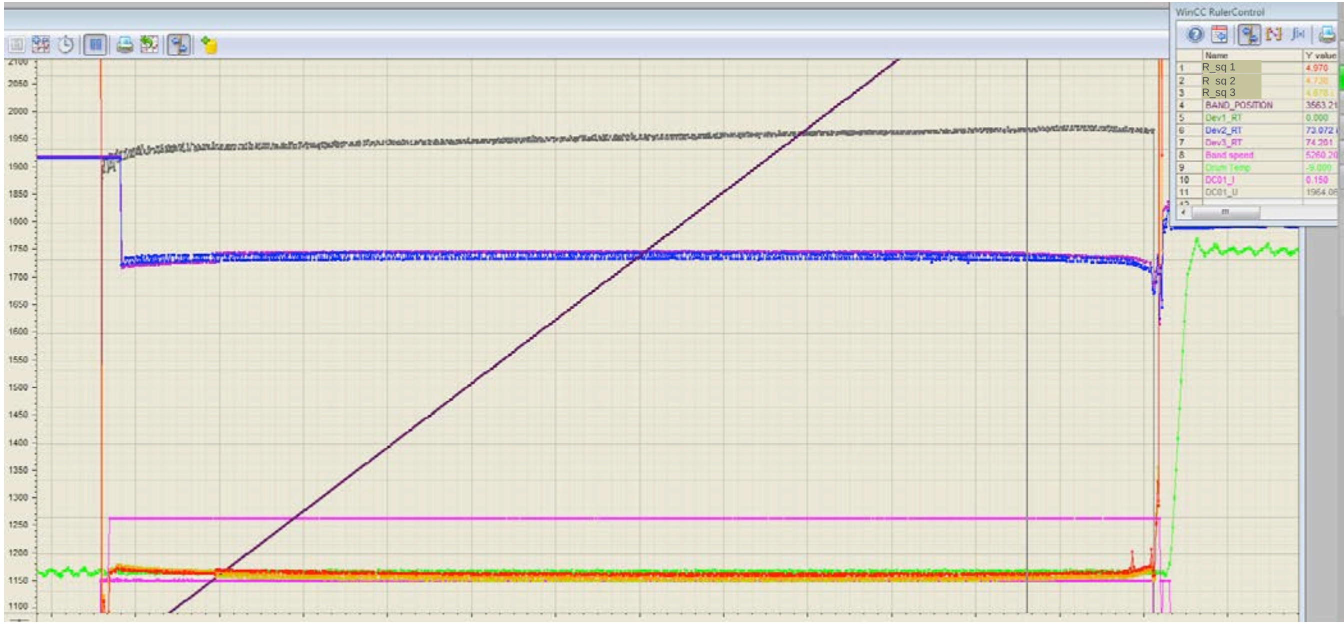
Results – Production stability

- Results LOW-E

- production stability
- Red, orange, yellow
  = Square resistance

- Blue, purple
  = Transmittance
  narrow spectral range
  approx 550nm.

- Diagram shows 4200m of production



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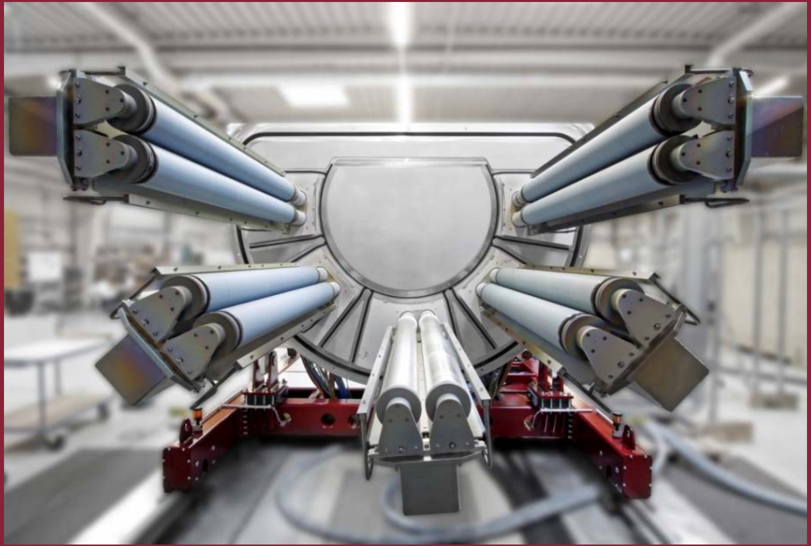

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