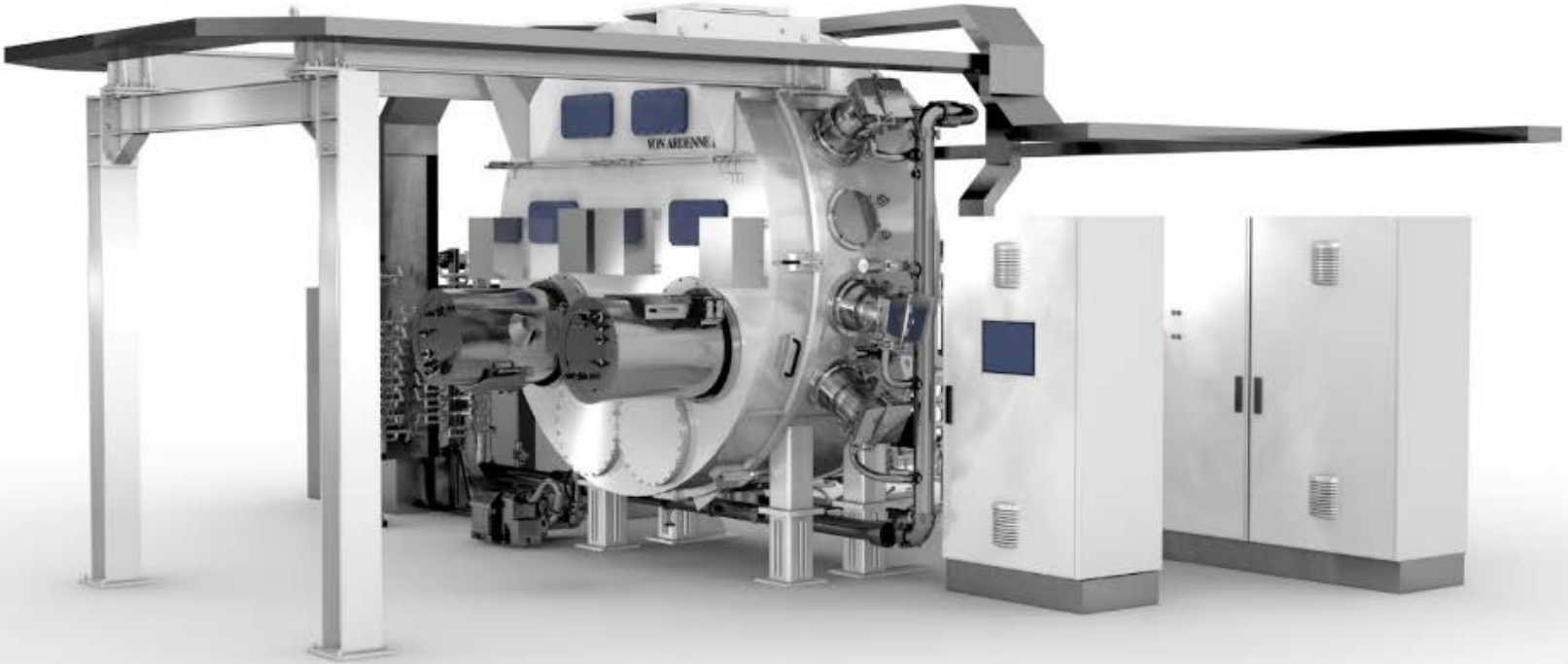
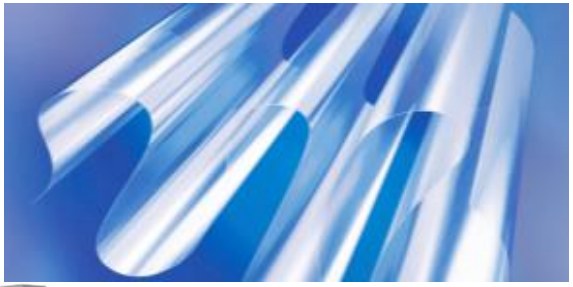
Roll-to-Roll PVD Coating System for Flexible Glass for Applications in the Field of Flexible Electronics and Others

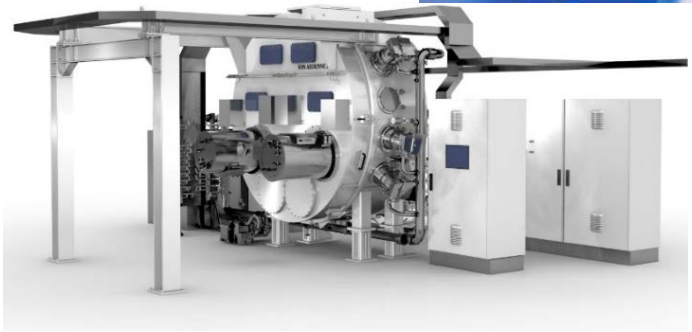
Dr. Andreas Nilsson, Tina Dietsch, Carsten Deus

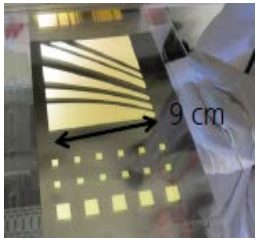


CONTENT

- Flexible Glass – some background
- FOSA LabX 330 Glass – a system for R2R vacuum coating of flexible glass
- Application examples
  - ITO for OLED
  - ITO for touch
  - AR
  - (CSP) mirrors
- Summary / conclusions

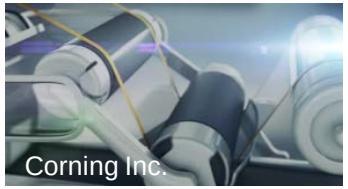






FLEXIBLE GLASS – A NEW MATERIAL WITH EXCELLENT PROPERTIES

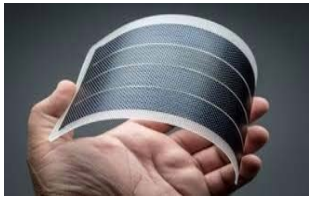
Commercially available	Thickness between 25 µm to 100 µm Available in rolls of up to 1.2 m width and in sheets
Benefits	**Compared to standard glass** • Low weight (thinner, lighter products) compared to rigid glass • Flexibility (R2R, flexible products, 2½ D shaped products) **Compared to plastic film** • High optical quality (extremely low absorption & scattering) • Dimensional stability • Very smooth surface, low roughness • Excellent temperature & chemical stability • Inert (no outgassing of softeners, extremely low water load) • Excellent water vapor / oxygen barrier
Challenges	• Handling different compared to polymer film or metal foil • Availability of proven R2R manufacturing equipment and experience throughout processing chain

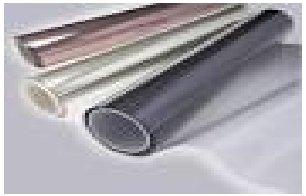


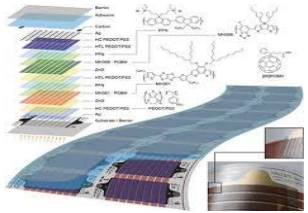
FLEXIBLE COATINGS & DEVICES

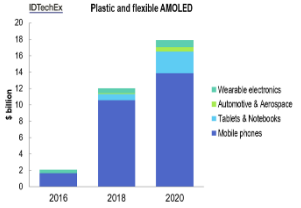
APPLICATIONS / MARKETS / MEGA TRENDS?

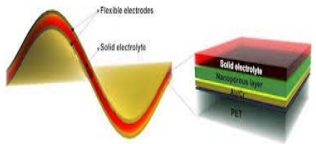
Flexible Solar | **Window Film** active & passive | **Flexible Electronics** | **Flexible Battery** | **Flexible Display &Touch**











GERMAN PUBLIC FUNDED PROJECT KONFEKT – GLASS ON ROLL IN ORGANIC ELECTRONICS

CONSORTIUM AND FRAMEWORK

KONFEKT is a **collaborative project** with support from the German ministry of Education and Research, time frame: **2014-2017**

Federal Ministry of Education and Research

Partners

- **SCHOTT AG:** rolled glass manufacturing and processing
- **TESA SE:** glass-plastic lamination, barrier adhesives, processing
- **VON ARDENNE:** vacuum coating equipment and demonstration coater for rolled glass
- **Fraunhofer FEP:** vacuum coating expertise for rolled glass

SCHOTT glass made of ideas

tesa

VON ARDENNE

Fraunhofer FEP

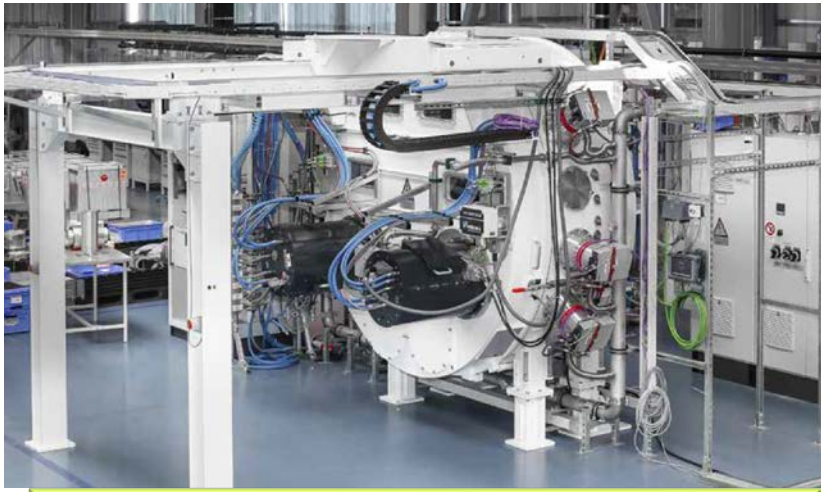
Aim

Supplying **flexible glass and laminates in rolled form** including **vacuum coatings** and **processing know-how** to industries like **flexible electronics / displays / OLED / building / solar**

VON ARDENNE FLEXIBLE GLASS PILOT COATER FOSA LabX

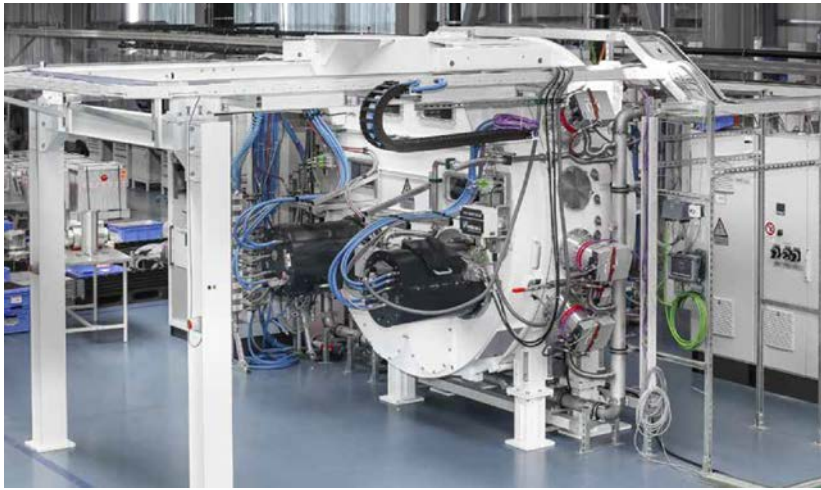
Specifications:

- R2R sputter coater: 2x magnetrons + pre-treatment
- No front-side contact, minimized particle load
- interleaf winding capability
- Substrate speed: up to 10 m/min
- Substrate width: 200 mm to 330 mm
- Substrate thickness: 50 µm to 100 (200) µm
- Coating temperature: up to 350 °C
- Substrate tension: 0.5 N/mm^2 to 2 N/mm^2
- Inline optical and sheet resistivity measurement



Designed and optimized for handling flexible glass

First 12 months of operation:



A) Commissioning & initial testing

- Winding
  - Tests with rolls of various flexible glass fabricates
  - Up to 10 m/min
  - E.g. > 5 coils wound over 10 times back and forth
- Heating: static and dynamic, up to 350 °C
- Sputtering: metallic and reactive processes

B) Routine R&D use (collaboration with Fraunhofer FEP)

- Operation and handling procedures developed and optimized for flexible glass
- Over 40 glass rolls have been processed (various fabricates, length, thickness)
- Work on various sputtered layer stacks (hot/cold deposition, multi-pass coating)

SPUTTERED LAYER STACKS ON FLEXIBLE GLASS

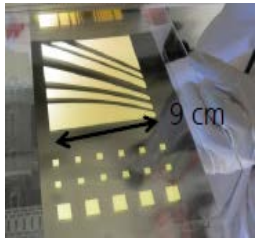
APPLICATION EXAMPLES ROLL-TO-ROLL: ITO FOR FLEXIBLE OLED LIGHTING

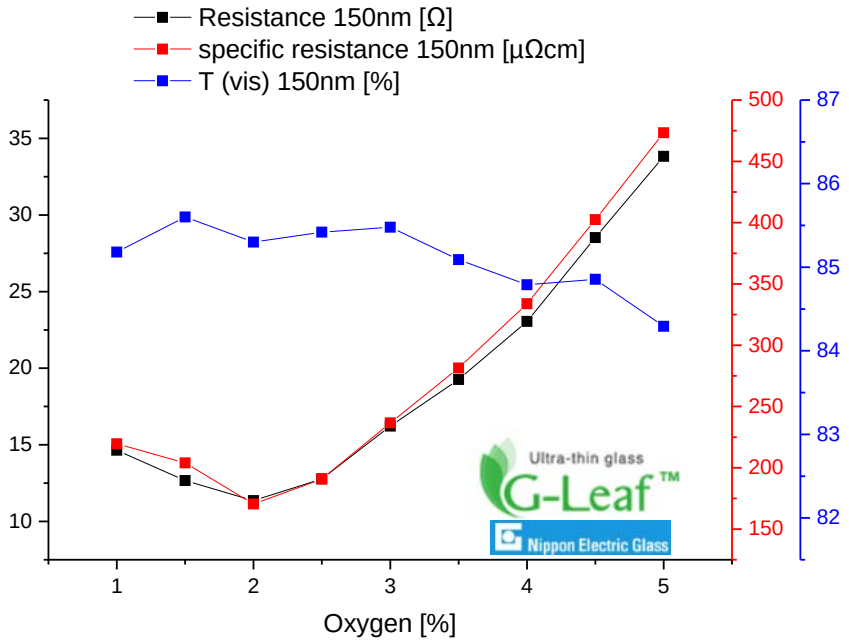
Flexible Glass USPs:

- Perfect barrier, flexible
- Smoothness
- Heated ITO deposition possible

Experimental

- NEG G-Leaf substrate (100 µm)
- ITO layer thickness 150 nm
- >300 °C / 4.6 kW/m / Ar (O_2)





Results

➔ < 12 Ohmsq (170 µOhmcm)

➔ > 85 % transmission

➔ Adequate for >100 cm² OLED lighting devices

In collaboration with Fraunhofer FEP

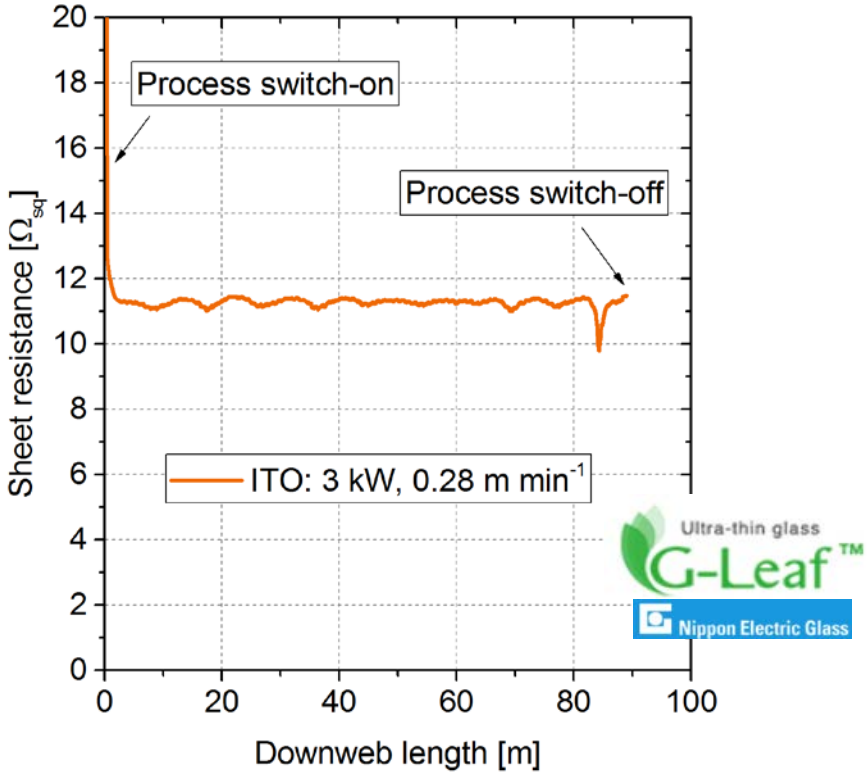
VON ARDENNE

ITO for flexible OLED lighting

- NEG G-Leaf substrate (50 µm)
- ITO layer thickness 150 nm
- >300 °C / 4.6 kW/m / Ar (2 % O_2)

Process stability

Coating on a 100 m long roll,
down web layer property stability

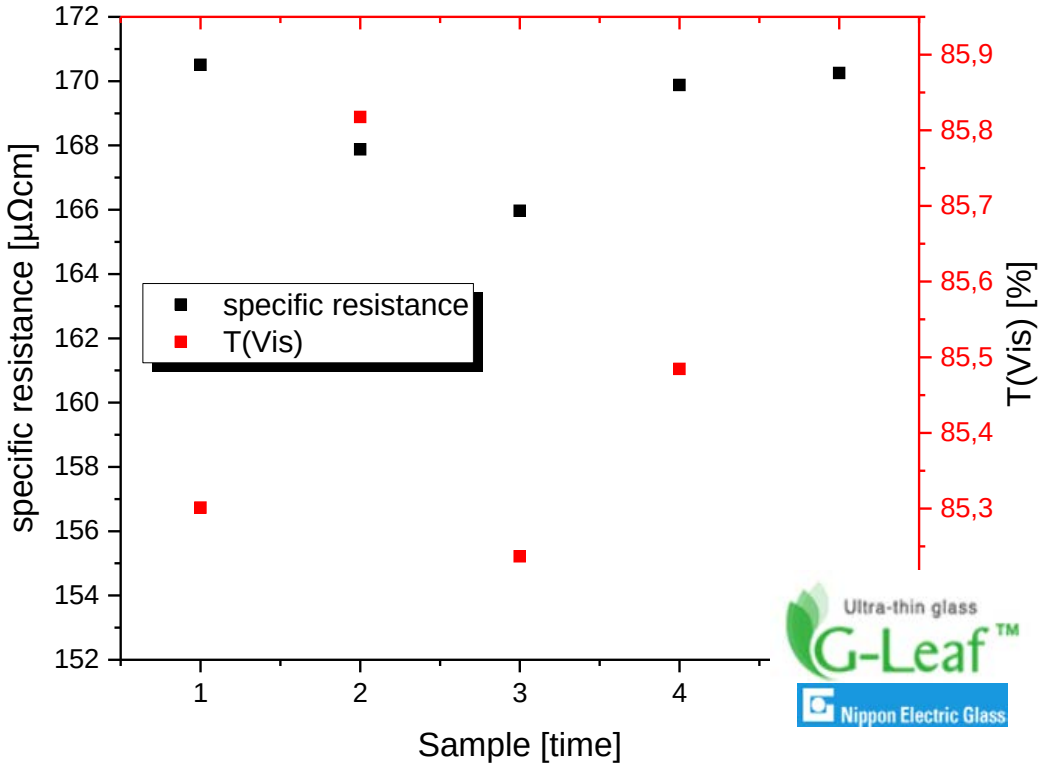


ITO for flexible OLED lighting

- NEG G-Leaf substrates
- ITO layer thickness 150 nm
- >300 °C / 4.6 kW/m / Ar (2 % O_2)

Reproducibility of the system?

➔ 5 samples from different rolls over a period of 1 month



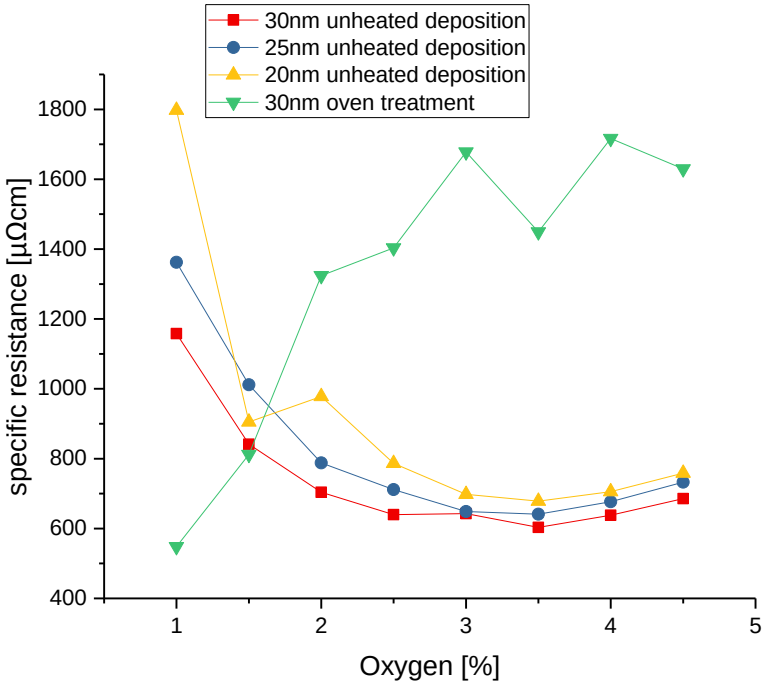
CORNING

ITO for touch - USPs of flexible glass

- Bendable
- Can be used as hard outer surface
- Hot ITO deposition (low Rsq) enables large scale touch devices

Experimental

- Corning® Willow® Glass substrates
- ITO layer thickness 20 nm to 30 nm
- 4.6 kW/m / Ar (O_2), cold deposition
- Furnace tempering at 350 °C / 15 min



Anti reflective coating – USPs of flexible glass

- Flexible, can be laminated on curved surfaces
- Thin, lightweight, high optical clarity
- Suitable as 1st surface

Experimental

- SCHOTT ultra-thin glass (100 µm)
- Nb_2O_5 – ceramic process
- SiO_2 – reactive process
- Deposition in 3 runs, one side only

Pass#	Material	Layer #	d
			nm
1	Nb2O5	1	11.6
	SiO2	2	31.7
2	Nb2O5	3	71.8
3	Nb2O5	4	35.2
	SiO2	5	84.3

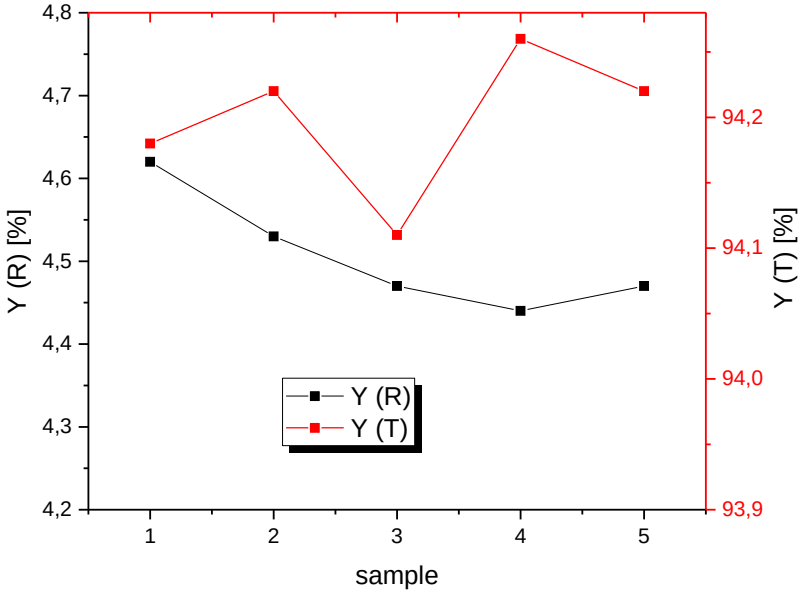
➔ **Drift over time and/or by direction change with multi-run processes?**

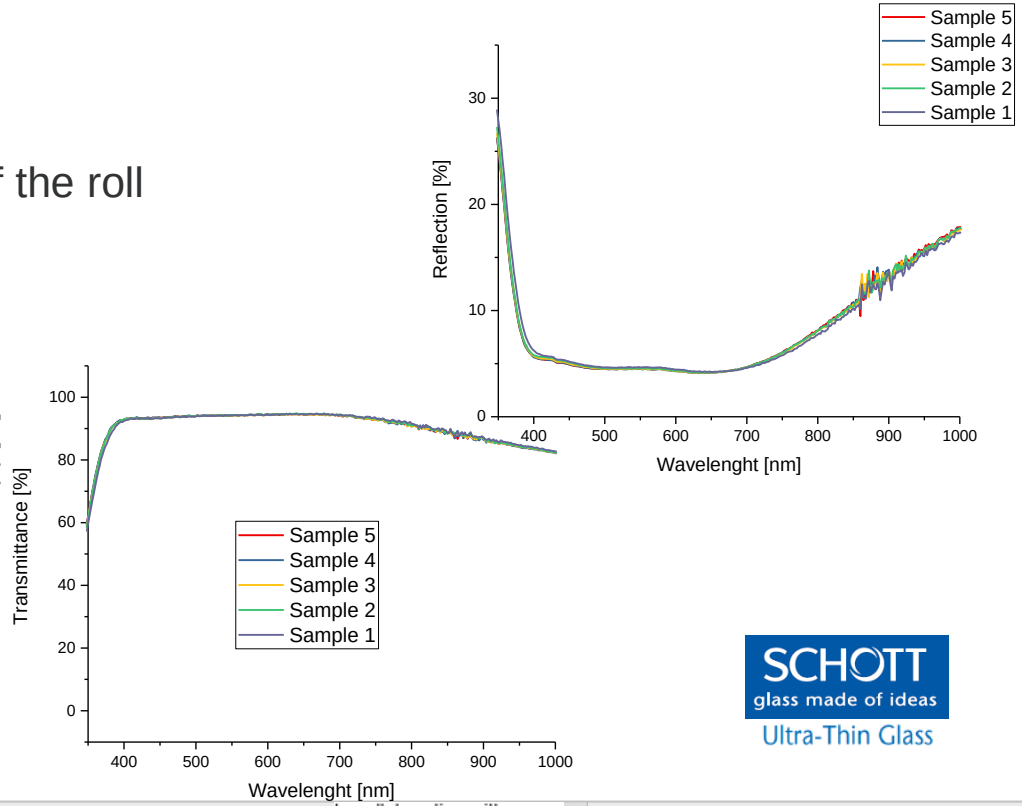
➔ **Results at 5 points over the length of the roll**

Anti-reflective coating - results

– SCHOTT ultra-thin glass (100 µm)

➔ Results at 5 points over the length of the roll





SCHOTT glass made of ideas

Ultra-Thin Glass

SPUTTERED LAYER STACKS ON FLEXIBLE GLASS

APPLICATION EXAMPLE (SHEET COATING)

Highly reflective mirror coating

for concentrated solar power applications

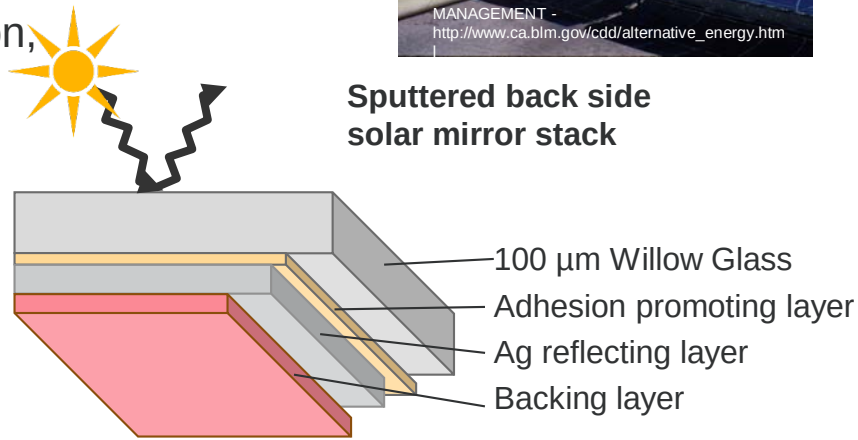
USPs of flexible glass

- Can be laminated onto cheap parabolic carrier structure – no precision glass bending needed
- High optical clarity – perfect specular reflection, minimized absorption losses

Experimental

- Corning® Willow® Glass (100 µm)
- 3-layer back side mirror stack
- Silver layer as main reflecting layer
- Processed with sheet sputter tool

Sputtered back side solar mirror stack



CORNING

Highly reflective mirror coating for concentrated solar power applications - results

Reflector type	Total solar reflectance	Corrosion stability
Wet coated Ag backside mirror on 4mm solar glass (State of the Art)	93.8%	✓
Sputtered back side mirror on 4mm solar glass	94.9%	✓
Wet coated Ag backside mirror on 100µm Willow glass	95.7%	✓
Sputtered back side mirror on 100µm Willow glass	96.9%	✓
Front side mirror on 4mm sodalime glass	97.9%	✗

Best performing CSP mirror

- **+2% performance gain** by using 100 µm ultrathin glass instead of 4 mm solar glass
- **+1% performance gain** by using sputtered back side mirror stack instead of standard wet coated mirror stack

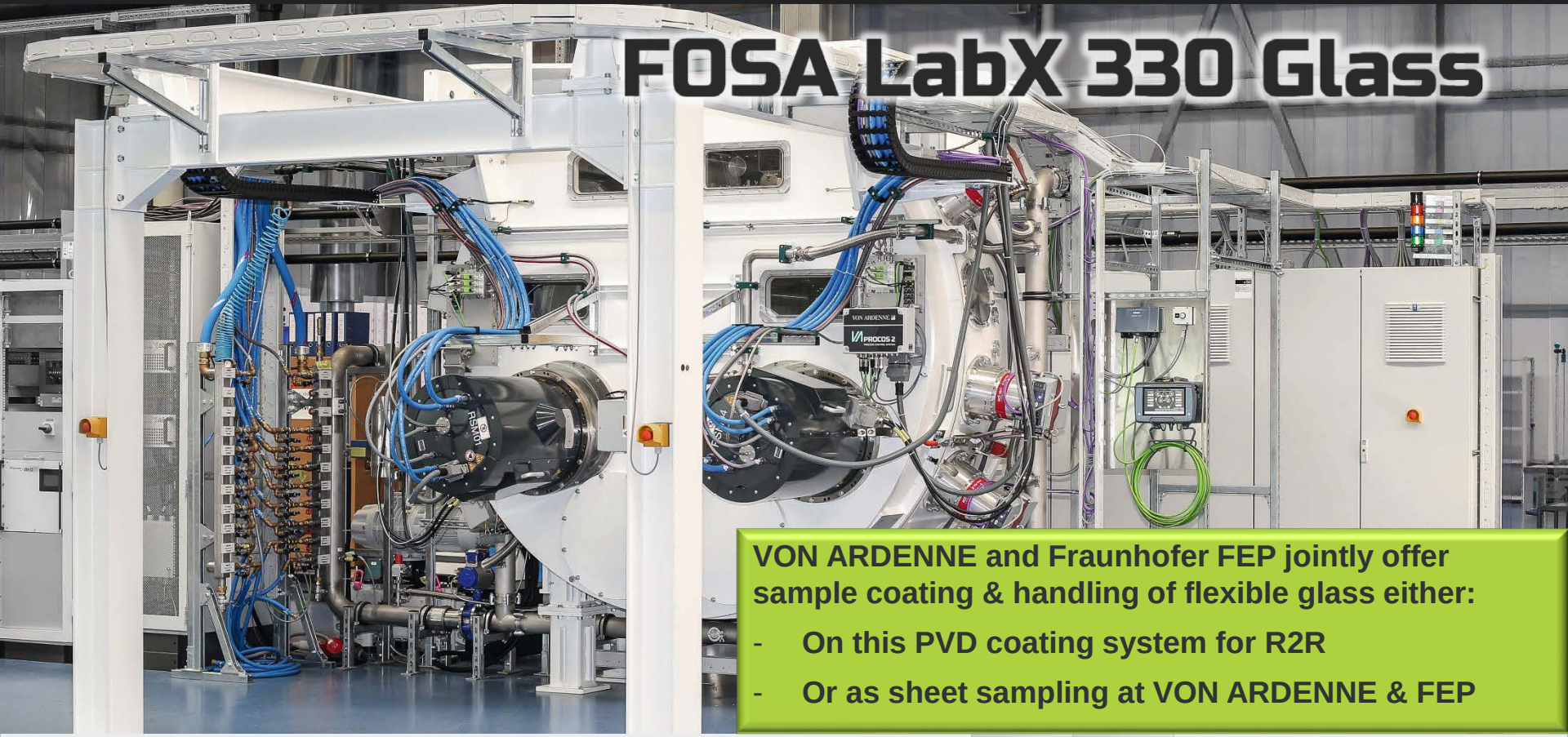
- Front side mirrors (so far) not sufficiently corrosion resistant

SUMMARY / CONCLUSIONS

- Flexible glass is an **outstanding material**, available in roll form from three internationally leading specialty glass manufacturers
- Processing in roll form can generate **substantial cost advantages**
- This **requires adapted R2R equipment** → realized with the **FOSA 330 LabX Glass**
- VON ARDENNE & partners have **successfully implemented R2R processing** of flexible glass in a vacuum coater at temperatures of up to 350 °C
- The coater has been running in **routine** development use for more than 4 months
- Sputtered layer stacks (ITO for OLED, AR, mirrors, ITO for touch) have been demonstrated, **with qualities superior to state-of-the-art coatings on classical flexible substrates**

→ **It has been demonstrated that R2R processing of flexible glass is a feasible technology opening new perspectives for processing advanced flexible devices**

COLLABORATION OFFER

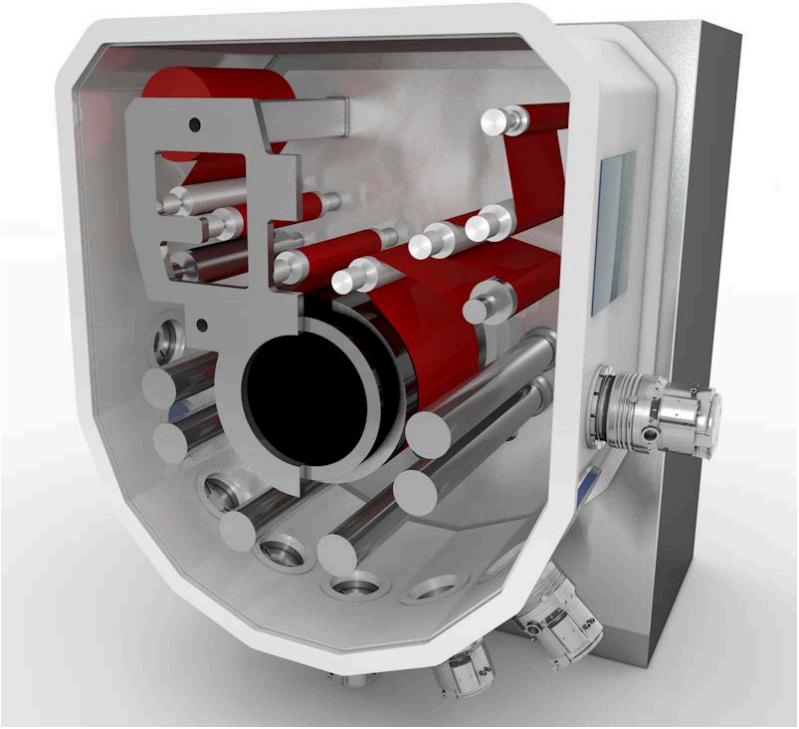


VON ARDENNE and Fraunhofer FEP jointly offer sample coating & handling of flexible glass either:

- **On this PVD coating system for R2R**
- **Or as sheet sampling at VON ARDENNE & FEP**

FOSA LabX – FLEXIBLE FOR THE FUTURE

- The new basis for R&D and small scale production
- Easy, fast & reliable transfer from pilot to mass production
- 2 standard versions:
  - 300 mm & 600 mm web width
- Unique flexible winding system
- Unique flexible process section arrangement
- Uses proven VON ARDENNE process components and technology
- Future proof due to upgrade possibilities in winding system and process sources



THANK YOU.

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- Colleagues and co-workers

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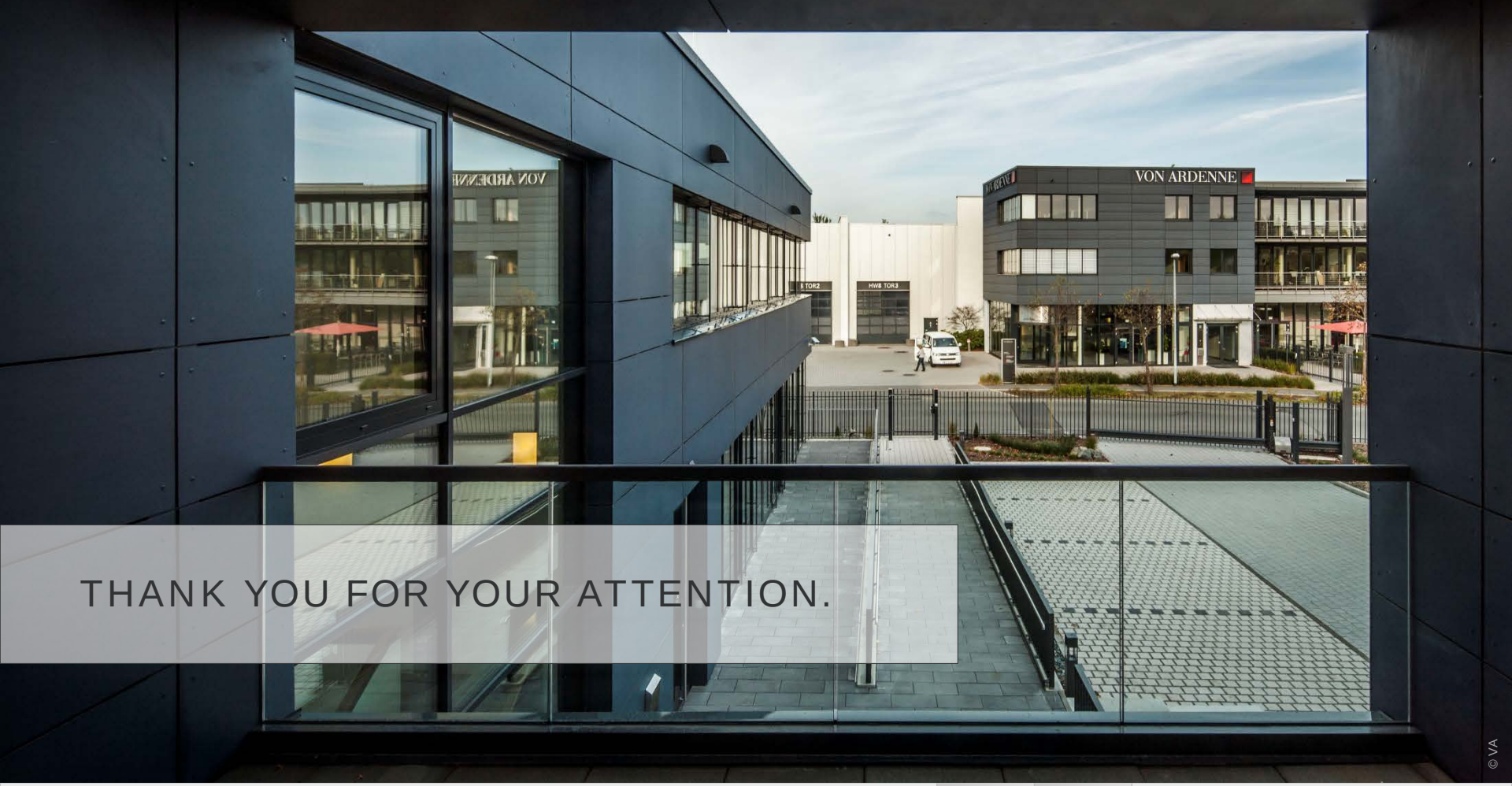
VON ARDENNE GmbH
Am Hahnweg 8, 01324 Dresden, Germany



THANK YOU FOR YOUR ATTENTION.