

TechCon 2021

Virtual

64th Annual Technical Conference Proceedings Virtual Event: May 3 – 7, 2021
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Vacuum Thin Film Deposition for Automotive Applications

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There is a long history of vacuum thin film deposition in the manufacture of automotive components such as mirrors, reflectors, glazings, or displays. During the past 5 years, a paradigm shift and technology advances in the automotive industry based on electrification, ADAS, and driver information format have triggered new developments of PVD coatings for the automotive value chain, some of which have been developed up to market maturity. The talk will highlight some of these recent developments including coatings for fuel cells, batteries, and car displays, and explain the related technologies, layer stacks, and equipment.

AGENDA

1. VON ARDENNE - Introduction

2. Coatings for Automotive Applications

3. Coatings for Fuel Cells

4. Coatings for Automotive Batteries

5. Coatings for Automotive Displays

MANFRED VON ARDENNE



MANFRED VON ARDENNE

1907 – 1997

Scientist, Inventor & Entrepreneur

Key Inventions

1930 First transmission of fully electronic television

1937 Scanning electron microscope

His inventions laid the foundation for our work today in the fields of vacuum, plasma and electron beam technology.

VON ARDENNE TODAY INDUSTRIAL VACUUM COATING EQUIPMENT SUPPLIER



Small (Lab Tool)



Medium-sized (Pilot Tool)



Large (Mass Production)

RELIABILITY | FINANCIAL KPIS 2020 (PRELIMINARY RESULTS)

VON ARDENNE

General Management



Pia von Ardenne-Lichtenberg (CEO)



Klaus Löffler (CSO)



Order Intake
~ € 190 m



Revenue
~ € 221 m



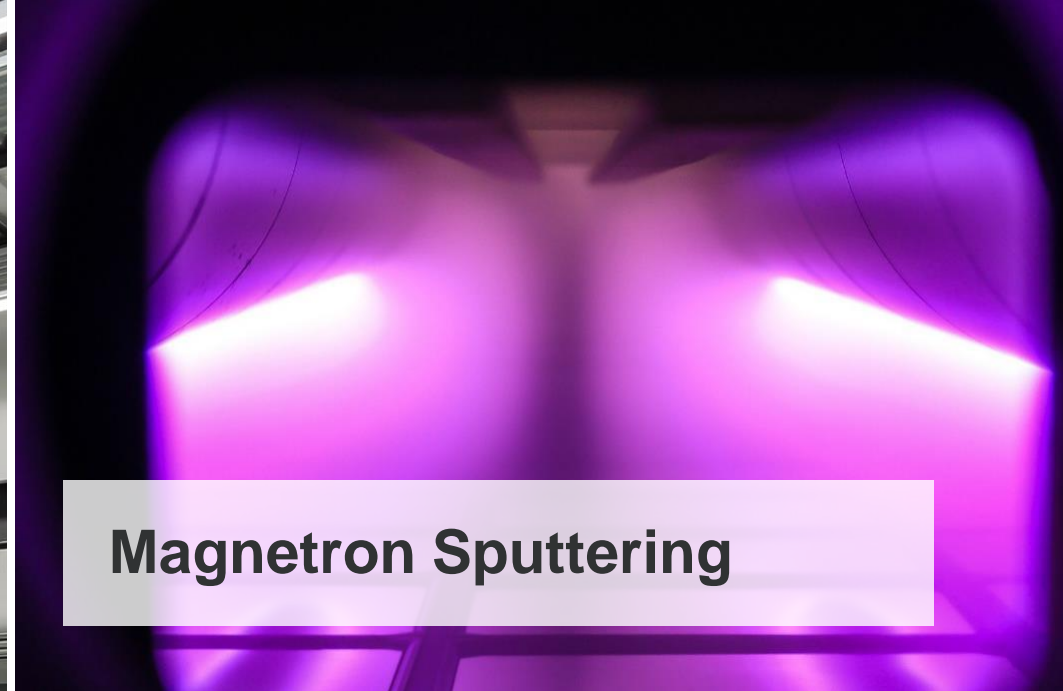
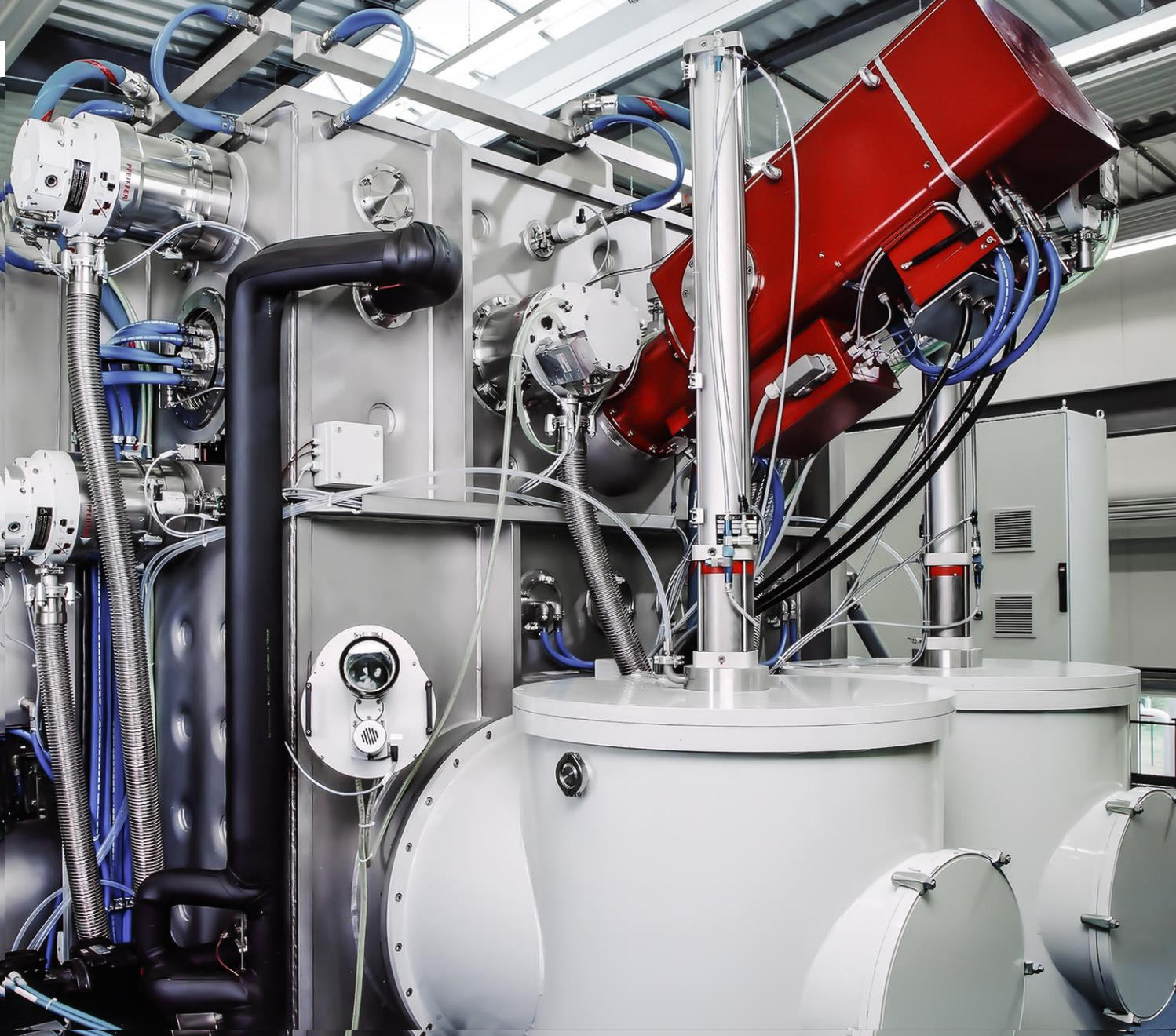
Operating Performance
~ € 219 m

Family-owned company
based in Dresden

> 500 coating systems
installed in 50 countries

~ 1000
employees

> 650 patents
worldwide



Magnetron Sputtering



Electron Beam Technology

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AUTOMOTIVE MEGATRENDS

**E-Mobility
and H2**

**Climate
Neutrality**

**Comfort &
Saving Energy**

**Safety &
Autonomous
Driving**

EXTERIOUR CAR GLAZING

Application

Coatings for Passenger Climate Comfort

Comfort driving by improved thermal management

Technologies

- ▶ Infrared-Reflex
- ▶ Low Emissivity
- ▶ Metallic or Semiconductor Coatings

Benefits

- ▶ Reduced heat load and cooling demand
- ▶ Reduced fuel consumption/battery demand
- ▶ UV-Protection
- ▶ De-icing & Anti-fog

Mass Production Equipment
developed in Dresden

AUTONOMOUS DRIVING SYSTEMS

Application

Coatings for Autonomous Driving Systems

High durability for Sensors and Cameras

Benefits

- ▶ High Precision Optics
- ▶ High Durability
- ▶ Miniaturization

Technologies

- ▶ Coatings for LIDAR, Coatings for MEMS
- ▶ Anti-Reflection, Anti-Scratch, Easy-to-Clean

Advanced Radar Sensor ARS 540
(Source: Continental)

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E-MOBILITY

Application

Fuel Cells

Low weight, higher cost efficiency by metallic Bipolar Plates

Benefits

- ▶ Substitution of noble base material (e.g., Ti)
- ▶ Substitution of noble coating (e.g., Au)
- ▶ CoO reduction – productivity increase

Technologies

- ▶ Vacuum coating and surface treatment equipment for key H² technologies (PEM/SOFC, Electrolysis)
- ▶ Coating of Stainless Steel with non-noble material

Technology developed in Dresden

Bipolar Plate Coating

with functional Metal/Carbon layer for improved electrical contact and corrosion resistance

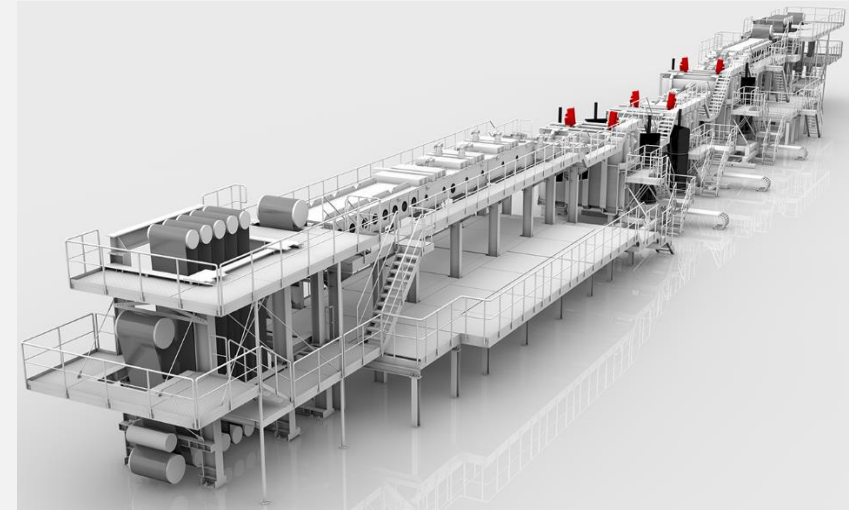
COATER PLATFORMS FOR FUEL CELL BIPOLAR PLATES

Post coating – coating of complete bipolar plates after cutting & stamping



- Carrier based In-line system with entry and exit load lock systems,
- EB-PVD process runs uninterrupted for campaign length of ~1 week
- Productivity of several 100k m² per year

Pre coating – coating of metal strip before cutting & stamping of bipolar plates

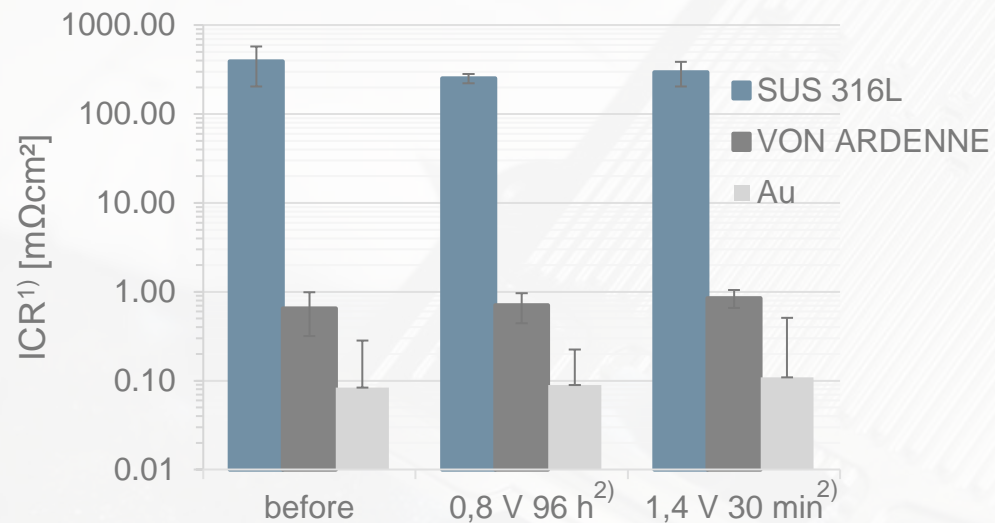


- Air-to-air strip coating with multi-stage continuous roller-type vacuum lock systems
- Productivity up to several Mio m² per year
- lowest cost of ownership

FUEL CELL BIPOLAR PLATE COATINGS - TEST RESULTS

Electrochemical corrosion test

VON ARDENNE coatings maintain constant interface contact resistance (ICR) after long exposure to fuel cell relevant electrochemical potential levels - similar to a gold coating.



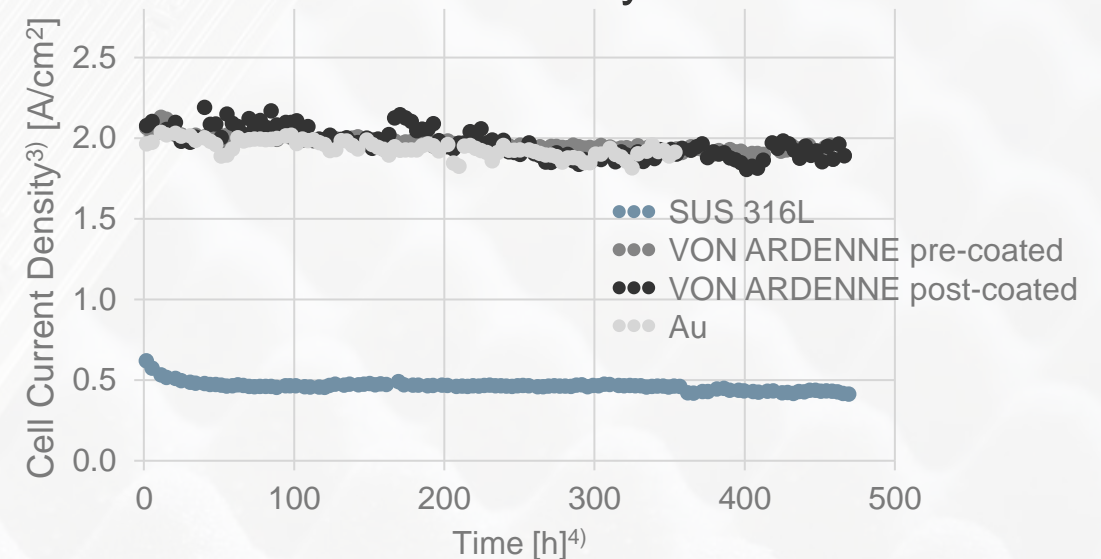
1) 150 N/cm², using gas diffusion layer

2) Potentiostatic test, RE: RHE, 1 mM H₂SO₄ (pH=3) with 0,1 mg/l HF, 80°C

Live performance in fuel cell –

Accelerated stress test

VON ARDENNE coatings (pre- and post-coating) maintain constant performance over simulated automotive life cycle.



3) ZBT's AST-3 at 0,6 V cell voltage, single cell assembly

4) Test duration corresponds with several thousand hours of operation

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E-MOBILITY

Application

Li-Ion Batteries

Higher Performance by Surface Engineering

Benefits

- ▶ Increased Energy & Power
- ▶ Improved Safety
- ▶ Sustainable Manufacturing
- ▶ Higher Productivity

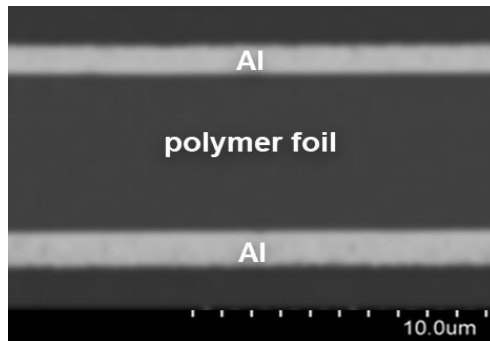
Technologies

- ▶ Metal at Polymer Current Collectors
- ▶ Functional Metal Foil Current Collectors
- ▶ Active Material & Particle Coating
- ▶ Roll-to-Roll Secondary Electrode Drying

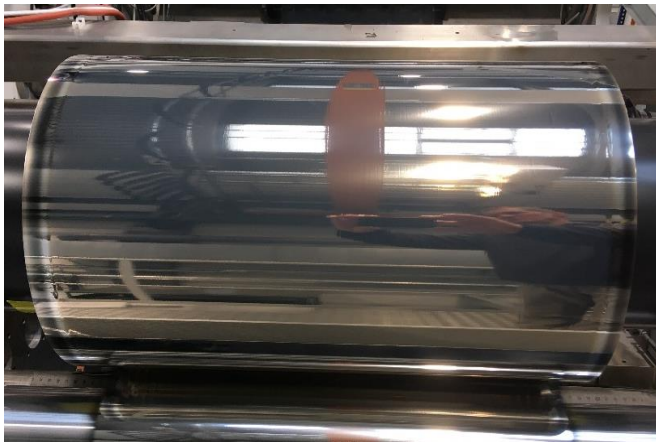
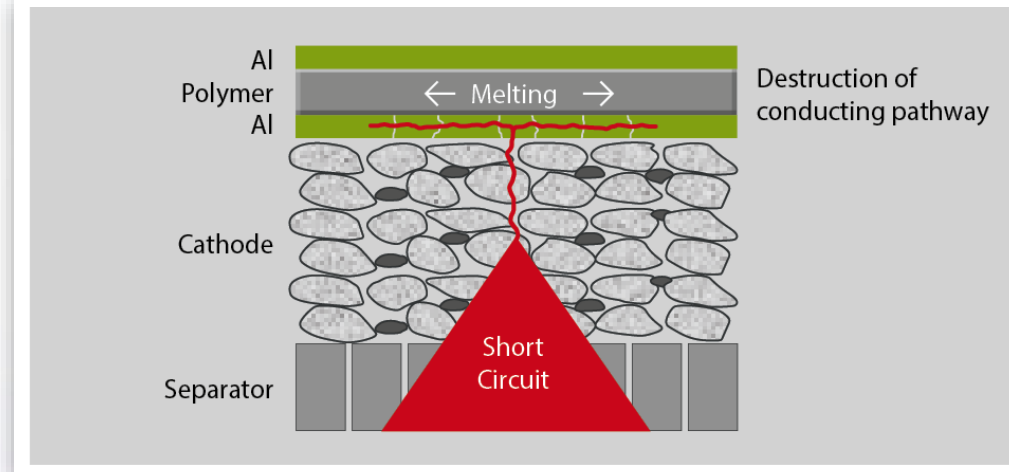
Production system, developed in Dresden
Cu on Polymer

APPLICATION EX.: METALLIZED POLYMER FILM CURRENT COLLECTORS

> 800 nm



+ Improved Safety



+ Reduced Thickness

+ Slightly increased energy density (Wh/l)

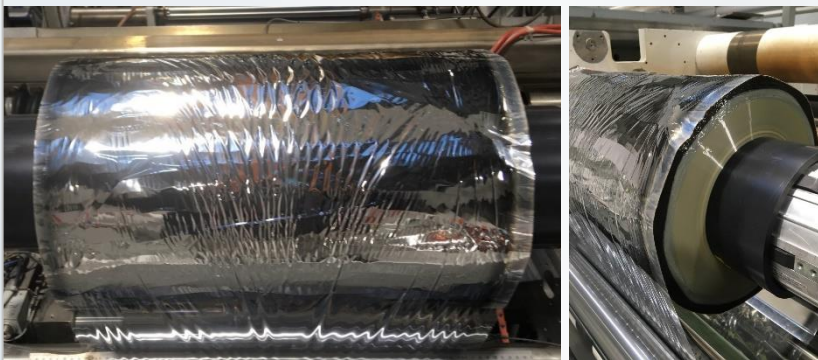
+ Substrate Width

+ Increased productivity (GWh) per coating line

METALLIZED POLYMER FILM CURRENT COLLECTORS: ACHIEVED TASKS – HANDLING AND COATING OF POLYMER FOILS

Starting point of process development:

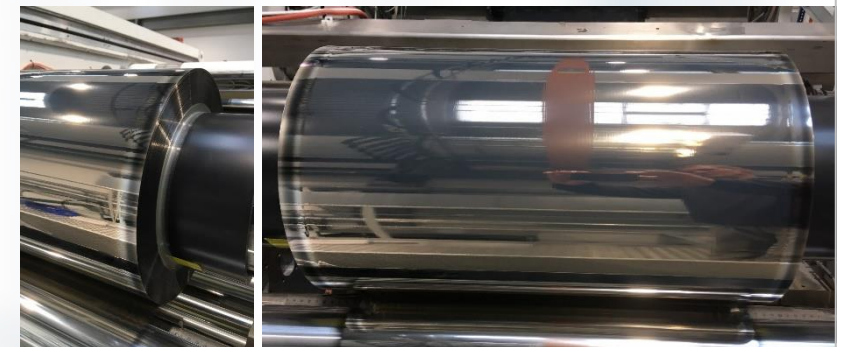
- Heavy wrinkling due to heat transfer during EB-based coating and challenges in handling thin polymer films



- Usage of VA's unique cooling drum technology
- Optimization of process parameters
- Adjustment of winding system

Current status:

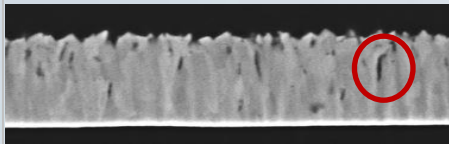
- Wrinkle-free and homogeneous R2R-processing of very thin polymer films possible



METALLIZED POLYMER FILM CURRENT COLLECTORS: ACHIEVED TASKS – IMPROVED CONDUCTIVITY

Starting Point of Process Development:

- High resistivity of the material due to resulting morphology of the Al-layer and impurities



Voids affecting conductivity

Al thickness	1120 nm
Sheet resistance	62 mΩ□
Resulting resistivity	7*10 ⁻⁸ Ω*m

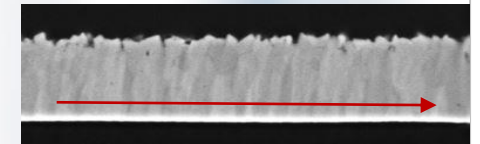
- Optimization of process parameters

- Adjustment of pretreatment

Current Status:

- Reduced sheet resistance and simultaneously decreased layer thickness achieved by an increased density of the coating layer

No voids, no impurities



Al thickness	625...1200 nm
Sheet resistance	80 ... 35 mΩ□
Resulting resistivity	4...5 *10 ⁻⁸ Ω*m

FOBA COATER FAMILY - SIZES

Coating systems based on electron beam evaporation developed for high productivity, efficiency and scalability

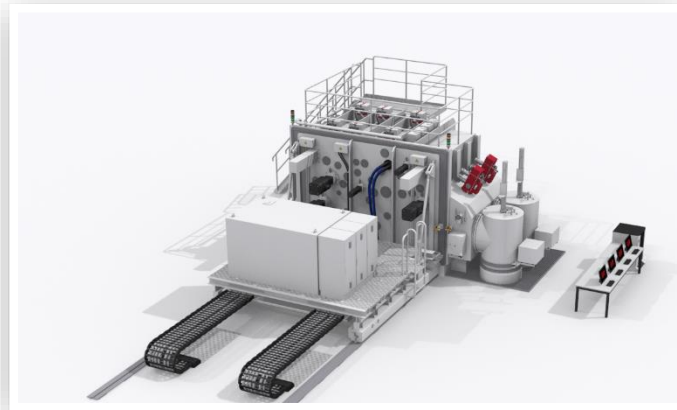
FOBA 600

- ▶ R&D and pilot-scale production
- ▶ 650 mm substrate width
- ▶ Low initial invest
- ▶ 1x electron beam gun



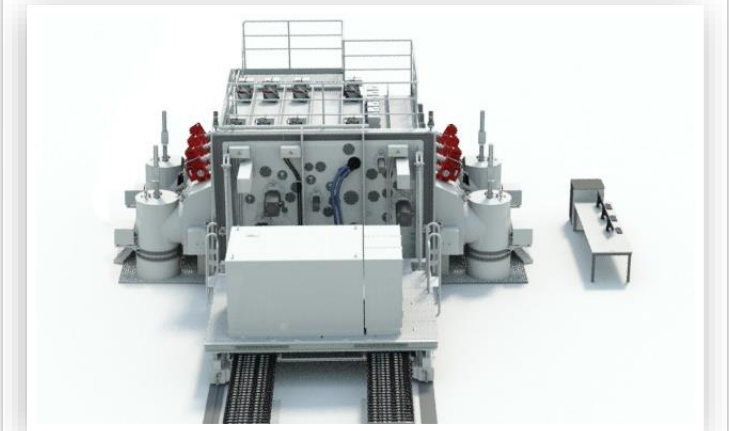
FOBA 1600

- ▶ Mid-scale production
- ▶ 1650 mm substrate width
- ▶ 2x electron beam gun



FOBA 2400

- ▶ Mass production scale
- ▶ 2450 mm substrate width
- ▶ 6x electron beam gun



100 % scalable production of metallized polymer foils

METALLIZED POLYMER FILM CURRENT COLLECTORS: – CURRENT STATUS

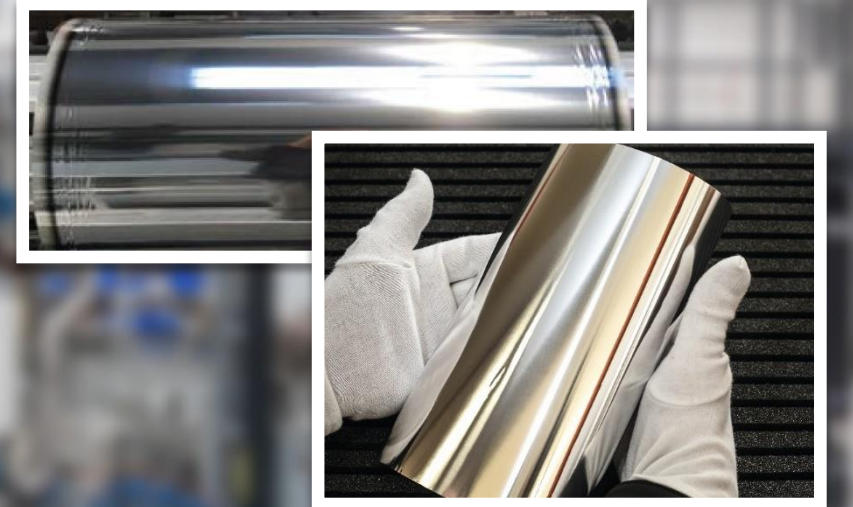
Copper on polymer current collector

Stage: industrialization



Aluminum on polymer current collector

Stage: R&D / sampling ongoing
industrialization started



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AUTOMOTIVE MID CONSOLE DISPLAYS - COATINGS TO TUNE PROPERTIES

▶ **Optical and appearance**

▶ **Durability**

▶ **Haptics and ease of cleaning**

▶ **Other functionalities**



Source: Cotec

HIGHLY PRODUCTIVE VERTICAL COATER GC120V FOR COATING OF DISPLAY COVER GLASS



Capacity up to 1 Mio. m²/yr

Highlights

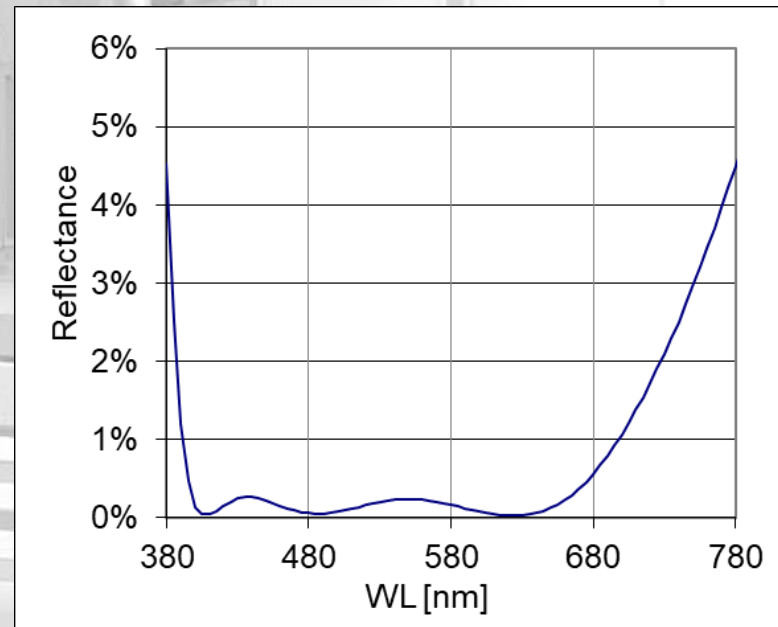
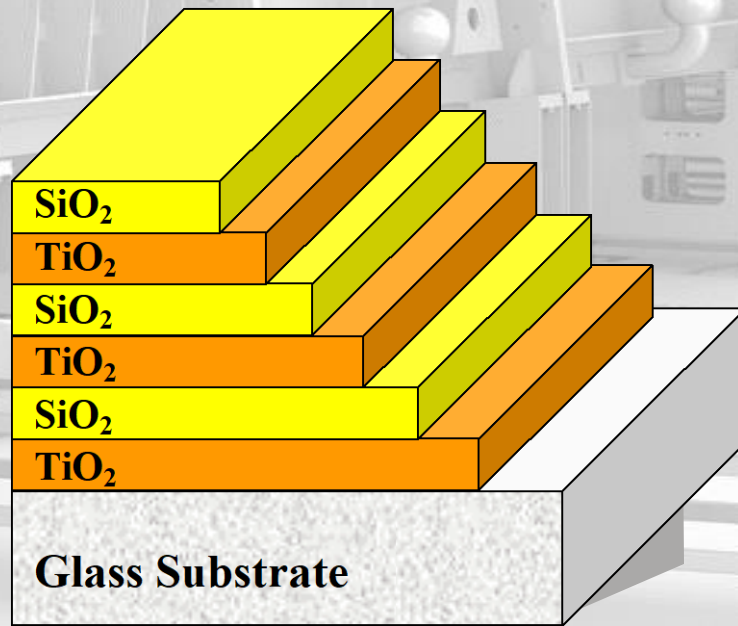
- Modular process zone design for flexible usage
- Pre-treatment by plasma glow discharge
- Thickness uniformity of +/- 1% of average
- Several vertical orientations available (-7° ... +7°)
- Process uptime > 85%*

DISPLAY COVER GLASS - SPUTTERED ANTI-REFLECTIVE COATING

Typical performance

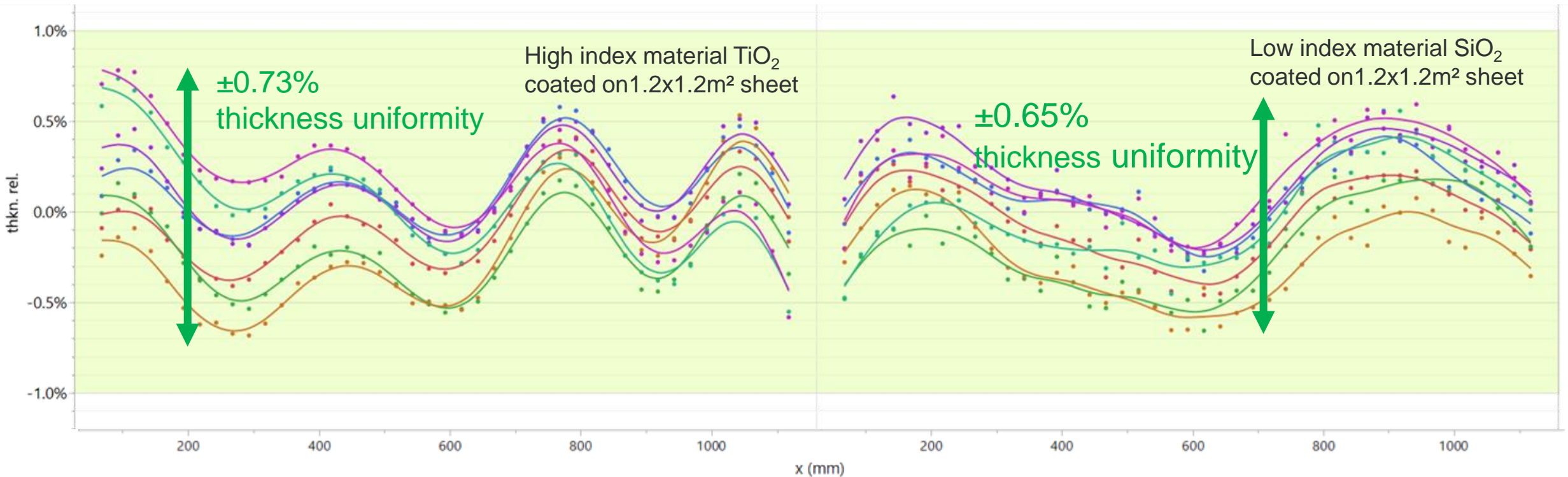
- Reflection (stack) $R_{vis} < 0.25\%$ (Y in CIE XYZ system), first surface photometry
- Optical transmission D65, $10^\circ \approx 95\% ^*$
- Reflectance color deviation, $\Delta E < 2.5$ (where $\Delta E = \text{square root} (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})$)
- Single layer thickness uniformity $\pm 1\%$ of avg.

Example stack



a*	-0.6
b*	-0.16
Rvis [%]	0.16
Sigma a* @ 1% thickn.var	0.7
Sigma b* @ 1% thickn.var	1.1
Sigma Y* / 1% @ 1% thickn.var	0.03

THICKNESS UNIFORMITY ON 1.2 X 1.2 m² SUBSTRATE



- Thickness uniformity below $\pm 1\%$ is crucial for reflectance color stability
- Tuned by
 - Reactive gas control by VAprocos™ reactive sputter process control system
 - Online tuning of magnetron magnet systems (remotely adjustable magnet bar)
 - Optimized carrier and chamber design

AUTOMATIC CLOSED LOOP LAYERSTACK CONTROL – VA INDIGO™ PROCESS MASTER™

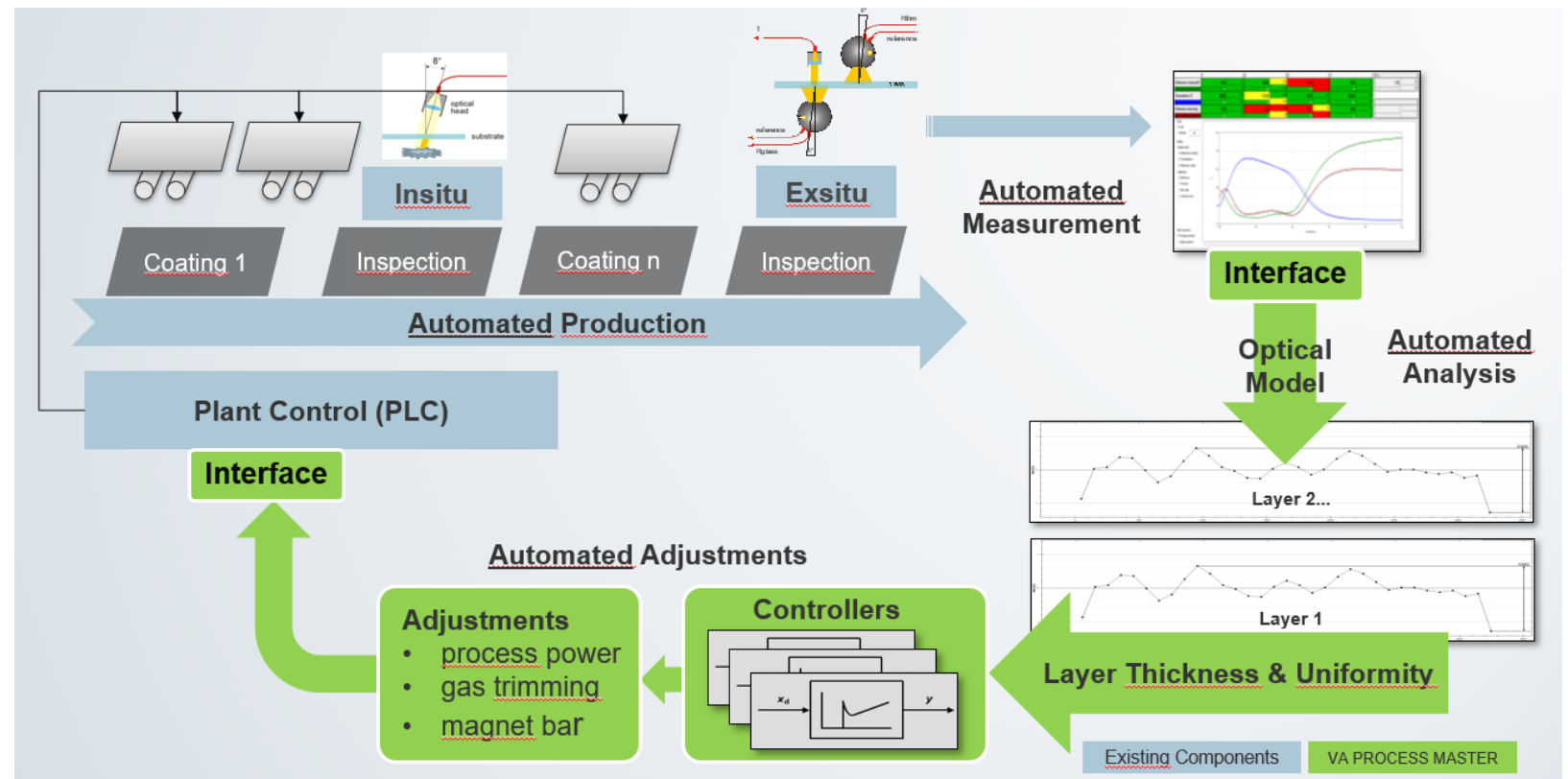
– Closed loop control of layer thickness & uniformity involving

- In-situ and ex-situ optical measurements
- Calculation of layer thickness of AR stack data from optical spectra
- Feedback loop control of
- Magnetron power AND
- Magnetron trimming (gas, magnet bar)

– Benefits:

- Faster production ramp up
- Drift compensation – optical data are continuously kept in optimum w/o operator interference
- More challenging stacks and smaller color boxes can be run

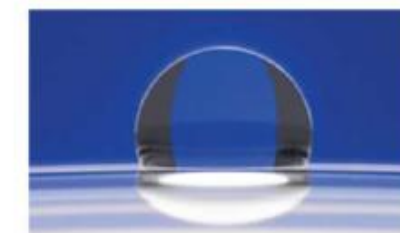
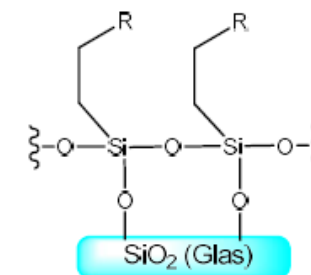
→ Increased Yield and Productivity



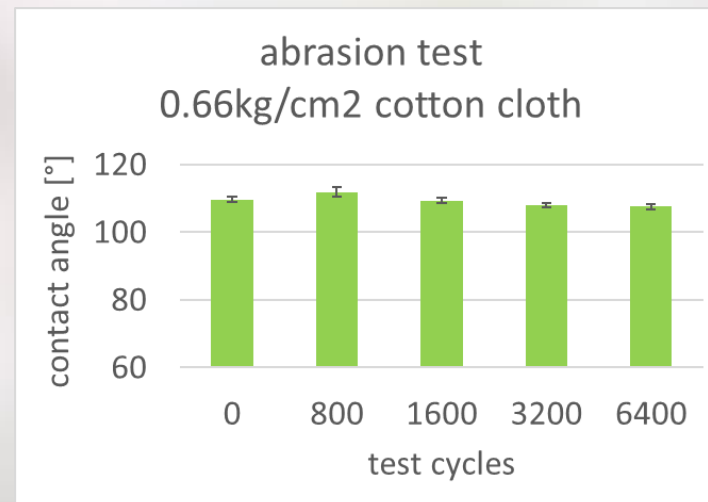
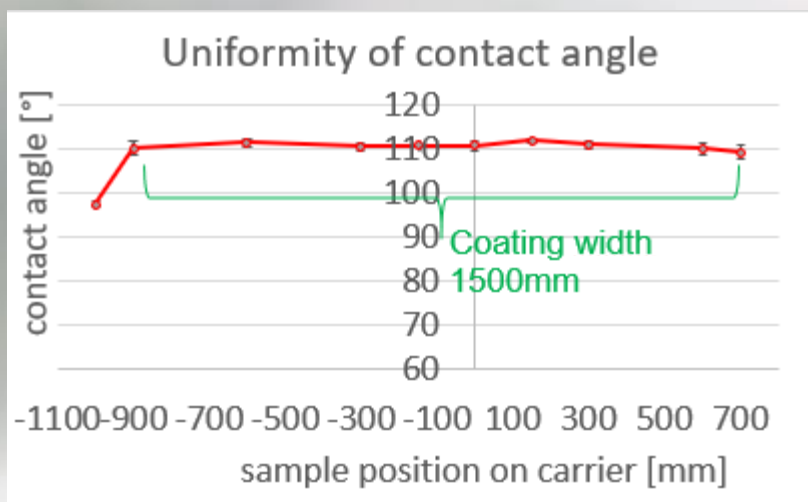
DISPLAY COVER GLASS: EASY-TO-CLEAN TOP COATING

Surface functionalization with Easy to Clean (E2C) Layer for combination with AR sputter coating

- Oleophobic and hydrophobic functionalization & improvement of tribology and haptics
- Evaporation of E2C monomers by linear source for 1500mm coating width
- Excellent uniformity, performance and durability



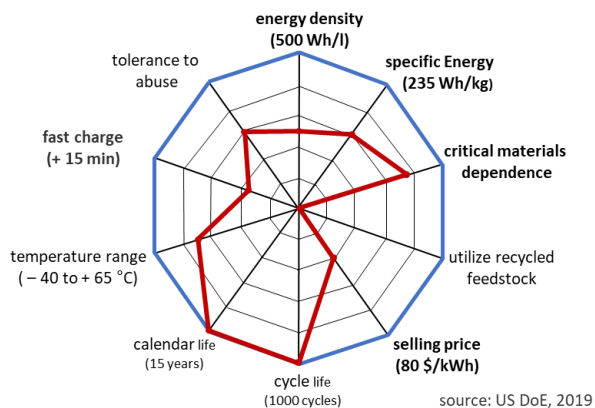
E2C material DURALON provided by COTEC



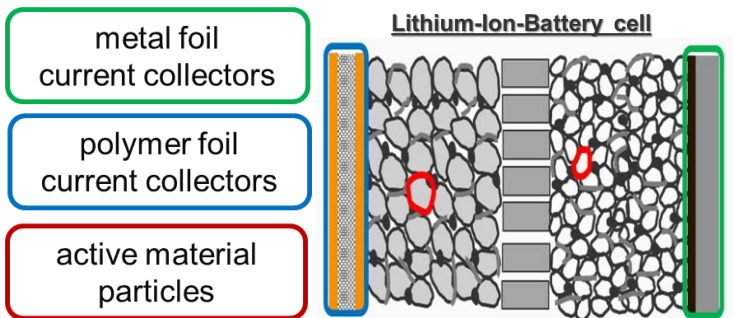
VON ARDENNE
E2C Linear evaporation source
(1500 mm)

CONCLUSION

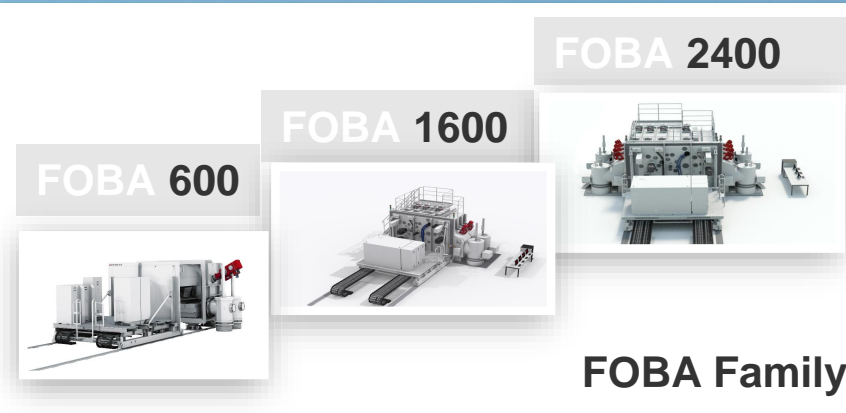
New Demands



New Technologies



New Equipment



VON ARDENNE

Contact



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Thanks for your attention.

vonardenne.biz

**THANKS TO CO-WORKERS,
PARTNERS,
PUBLIC CO-FUNDING**

In collaboration with



In collaboration with



Europäische Union

Europa fördert Sachsen.

EFRE

Europäischer Fonds für
regionale Entwicklung



This work was partially funded by
the Saxon State Ministry for Economy, Labour and Traffic
and the European Fund for Regional Development
(EFRE-Technology Funds 2014-2020)