

ROLL-TO-ROLL VACUUM WEB COATING SYSTEMS

FOSA MX | FOSA CX | FOSA MX 300/600
FOSA LABX 330 GLASS | FOBA

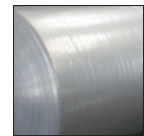
VACUUM WEB COATING APPLICATIONS

VON ARDENNE provides tailored web coating solutions for today's most ambitious thin-film applications on polymer films, flexible glass and metal strip. These solutions comprise coating equipment, key technology components and application technology.

Our customers benefit from our extensive process know-how and our experience, which we have gained for more than 15 years in roll-to-roll coating, 40 years in magnetron sputtering and 55 years in electron beam

technology. Moreover, we support our customers in qualifying their products and processes step by step. For that, we offer unique facilities, such as our in-house sample coating equipment and technology support for various substrate types and sizes.

Together with our customers, we develop their ideas, from the first laboratory tests to the manufacturing of the most competitive large-scale production equipment.



BARRIER LAYERS ON POLYMER FILMS

VON ARDENNE provides high barrier multilayer technology and equipment to create moisture and oxygen barriers on polymer films. They are scalable, reliable on large surfaces and keep costs below the benchmark.



THIN FUNCTIONAL LAYERS FOR LI-ION BATTERIES

We provide solutions for the roll-to-roll deposition of functional layers for battery applications on thin polymer or metal substrates. These coatings help reduce costs and increase the performance of Li-ion batteries.



FLEXIBLE DISPLAYS/ FLEXIBLE ELECTRONICS

Anti-reflective & protection coatings on polymer films

VON ARDENNE is the leading supplier of web coating equipment for anti-reflective and antistatic coatings on polymer films, such as PET and TAC.

Metal mesh for new polymer film based touch sensor applications

We provide application technology for metal mesh based touch sensors with a layer stack of metal and metal/oxide layers. This solution enables the perfect combination of adhesion, conductivity and color on both sides of the polymer film.

ITO coatings on polymer films and flexible glass

VON ARDENNE provides the technology and the equipment for wet and dry index matching ITO coatings. Beyond that, it is a strategic goal for us to develop equipment and processes for the roll-to-roll coating of flexible glass, starting with ITO for OLED applications.

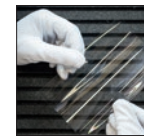


ADVANCED WINDOW FILM

Low-emissivity (Low-E) and solar control optical filters on polymer films (PET, PTFE)

VON ARDENNE is the worldwide leading equipment supplier for architectural coating solutions on glass and web.

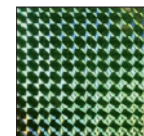
We provide expertise and intellectual property in single, double and triple Low-E layer stacks on those materials. The specific requirements for window film coatings are taken into account in "ready to use" configurations of our FOSA production equipment.



R2R COATING OF FLEXIBLE GLASS WITH FUNCTIONAL LAYERS

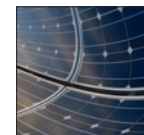
Flexible glass is a material of the future with a unique combination of properties. It is available in rolls and is ideally suited for applications such as flexible electronics, photovoltaics and displays.

VON ARDENNE has developed a roll-to-roll vacuum coating system optimized for the processing of flexible glass: the FOSA LabX 330 Glass. It is available for demonstrations, sampling and joint product developments in Dresden to help flexible glass move from the laboratory to the mass market.



ANTI-COUNTERFEITING TECHNOLOGY

Holographic coatings on microstructured polymer films



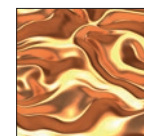
FLEXIBLE PHOTOVOLTAICS

Metallization, optical filter coatings and barrier coatings for flexible PV substrates



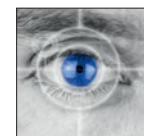
ADVANCED PACKAGING

Coatings for next-generation packaging applications based on electron beam evaporation



DECORATIVE COATINGS

Scratch resistant, color and adhesion optimized coatings on polymer substrates for decorative applications



CUSTOMIZED VACUUM WEB COATING SOLUTIONS

It is our aim to help our customers evolve and focus on their product ideas.

Therefore, we offer solutions to customize existing equipment concepts or to design specifically customized equipment for our customers.

Furthermore, the customer is able to incorporate specific coating technology, for example their own coating components. Finally, we support our customer in scaling up their products from R&D scale to mass production for worldwide roll-out.

OUR STRENGTHS IN WEB COATING

With more than 26 web coating systems for large-scale industrial production in the field and 55 years of process experience, VON ARDENNE has secured an enormous intellectual property portfolio in application technology.

This knowledge capital ranges from complete layer stacks for the window film business to specific process know-how in the variety of all thin-film materials, and is the basis for customer-driven optimizations.

IN-HOUSE TECHNOLOGY & APPLICATION CENTER

Product & process verification and optimization; sample coatings of customer applications



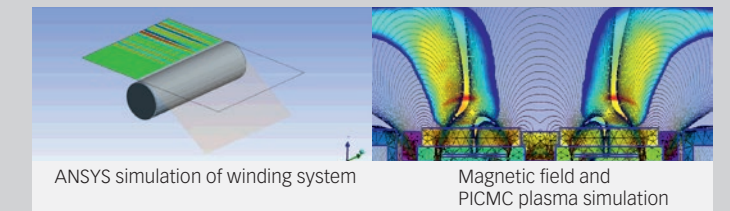
CLOSE PARTNERSHIP

with Fraunhofer FEP, European Society of Thin Films and AIMCAL



EXPERTISE AND SIMULATION SUPPORT

for qualified concept development and evaluation



WORLDWIDE ROLLOUTS

of mid-size and large-scale equipment



PRODUCTION SUPPORT

at customer's site after SOP for efficient ramp-up



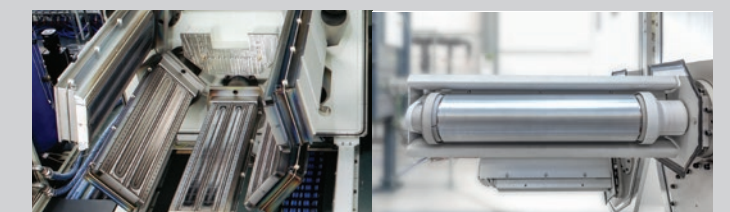
TAILORED SERVICE & SUPPORT

around the world, up to 24/7



UPGRADE OF EXISTING EQUIPMENT

with new components and application technologies



PRODUCT RANGE

VON ARDENNE provides five machine platforms as a basis for customization according to the required solution defined by the process, the annual throughput, the facility surroundings and the budget.

Each FOSA uses our process and technology components, such as rotatable magnetrons and our proven winding system, which is suited for the forward and backward coating of sensitive thin substrates.

The **FOSA MX** and **FOSA CX** are ideal tools for mass production, e.g. of displays and window films. The **FOSA MX 300/600** is designed for small-scale production and process and product qualification – at a small scale, but with our original key components.

The **FOBA** uses our proven electron beam evaporation technology to deposit functional layers at high rates on polymer film or thin metal strip, e.g. for holographic applications.

In addition to our standard products, we offer **customized web coating systems** according to the requirements of our customers.

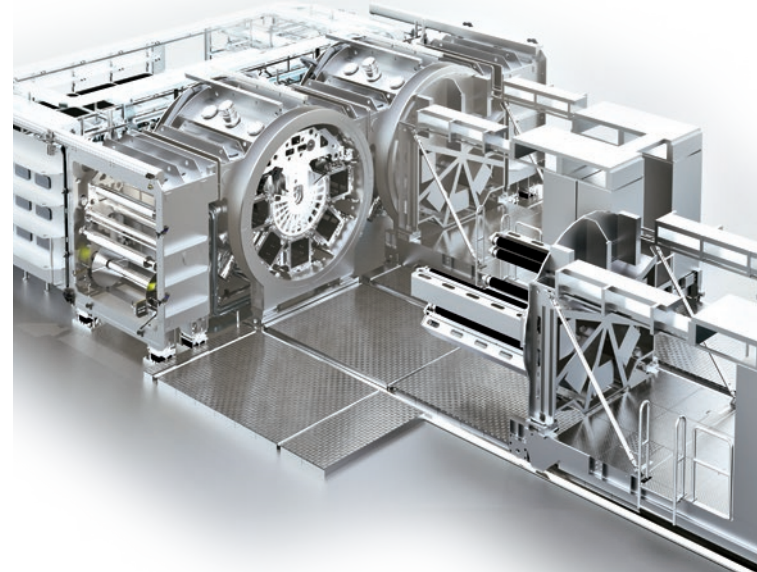
FOSA MX

The FOSA MX is a web coating system with a modular design. It is ideal for high-volume production and can be configured with up to three coating drums.

Furthermore, it offers an advanced maintenance concept. The FOSA MX is engineered for minimized downtime for complex layer stacks, such as AR and window films.

KEY FEATURES

- ✓ Single, dual or triple drum configuration
- ✓ Load locks with gate valves for short campaign times
- ✓ Individually pumped compartments
- ✓ Superior maintenance concept



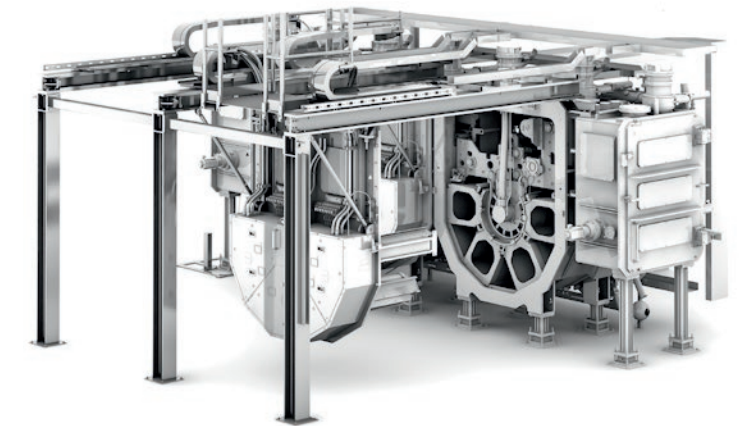
FOSA MX 300/600

The FOSA MX300/600 is a web coating system based on a modular, expandable and highly customizable platform for a wide range of substrates and applications. It is especially designed for all process and product qualification steps from the laboratory to production.

The system uses the same key components as our web coating systems for industrial production, however at a smaller scale. Thus, our customers can test their applications under laboratory conditions and save time when they scale their products up to mass production.

KEY FEATURES

- ✓ Flexible arrangement of different process sections and sources
- ✓ Modular process chambers
- ✓ Winding chambers with load locks
- ✓ Configurable for interleaf and thin substrate winding



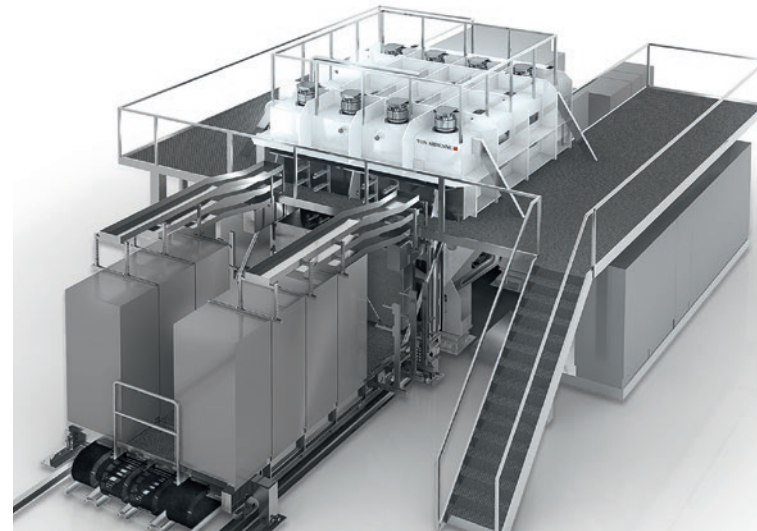
FOSA CX

The FOSA CX is a compact production tool for the roll-to-roll deposition of thin functional layers on polymer films. It is ideal for high-volume production and is optimized for single drum applications.

Furthermore, it benefits from a freely configurable compartment structure and can be maintained easily from two sides. The FOSA CX is engineered for long production campaigns with minimal operator intervention.

KEY FEATURES

- ✓ Single drum, single chamber
- ✓ Reverse mode
- ✓ Powerful vacuum pump set

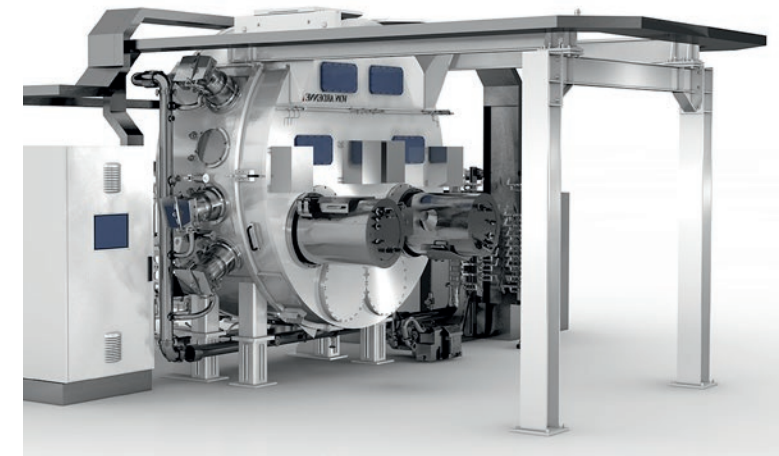


FOSA LabX 330 GLASS

VON ARDENNE has developed the FOSA LabX 330 Glass, a roll-to-roll vacuum coating system optimized for the processing of flexible glass. The system was put into operation in 2016 and is available for demonstrations, sampling and joint product developments. Please contact us if you are interested in taking this opportunity.

KEY FEATURES

- ✓ Ultra-thin glass, 100 µm thin, flexible and lightweight, perfect for electronic applications
- ✓ Configured for hot ITO deposition
- ✓ Based on practical expertise in roll-to-roll (R2R) handling and coating of flexible glass rolls provided by the main suppliers

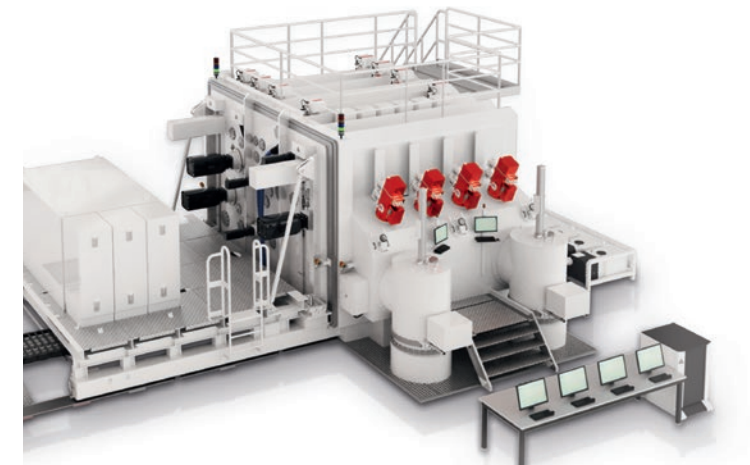


FOBA

The FOBA is a coating system for the roll-to-roll coating of flexible materials. It uses our proven electron beam evaporation technology to deposit functional layers at high rates on polymer film or thin metal foil, for instance for holographic applications, battery applications and next-generation packaging.

KEY FEATURES

- ✓ E-beam evaporation web coater for polymer films and thin metal strip
- ✓ Uses VON ARDENNE E-beam evaporation technology and all types of pre-treatment and sputter sources
- ✓ High-speed coating up to 1000 m/min



CUSTOMIZED WEB COATING SYSTEM

- ✓ Customized equipment according to the product and business case requirements of the customer
- ✓ Verified and tested at in-house technology and application center
- ✓ Especially designed winding system (e.g. no front touch, double-sided coating, exotic substrates)
- ✓ Various process components (planar or rotatable magnetrons, thermal evaporation, electron beam systems, PECVD, etc..)
- ✓ Full support by VON ARDENNE: from verification & initial engineering to pilot tool, 1st production tool, world wide roll out and world wide service

VON ARDENNE KEY COMPONENTS

FOR VACUUM WEB COATING

We develop and provide the key process components for VON ARDENNE coating systems. They have been tested in our in-house technology and application center and have proven in the field. The requirements for web coating components are determined by demanding substrate properties, high-speed throughput, complex technology processes, costs, quality standards and limited space.

VON ARDENNE is equipped with the expertise, the in-house facilities and the qualified staff to define the ideal configuration of these components.

OUR KEY COMPETENCIES FOR WEB COATING COMPONENTS

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| <p>1 WEB HANDLING</p> <ul style="list-style-type: none"> — Fully reversible winding system for forward and backward coating — Winding without touching the front side — Free span coating, e.g. winding and coating of flexible glass | <p>4 PRE-TREATMENT OF THE SUBSTRATE</p> <ul style="list-style-type: none"> — Glow discharge device — IR heater — Ion source |
| <p>2 POST-TREATMENT</p> <ul style="list-style-type: none"> — Flash lamp annealing — Web marker | <p>5 DEPOSITION COMPONENTS</p> <ul style="list-style-type: none"> — Magnetrons, optimized for web coating (e.g. DAS) — Electron beam guns for web coating — Process control systems — New deposition sources (e.g.. ICP source) |
| <p>3 INLINE MEASUREMENT SYSTEM</p> <ul style="list-style-type: none"> — Transmittance, reflectance in VIS and NIR — Eddy current resistance measurement — Quality inspection system (e.g. wrinkle control, particle scanner) — Data retrieval and analysis system | <p>6 MACHINE OPERATION INTERFACE</p> <ul style="list-style-type: none"> — Fully integrated system — Data storage and analysis tools — Connection to manufacturing execution and quality inspection system |

MAGNETRON TECHNOLOGY

Thanks to many years of experience gained from designing and installing advanced sputtering equipment, we can offer a complete portfolio of components for specific tasks:

- | | | |
|---|---------------------------------------|--|
| <p>+ SPUTTERING MODES</p> <p>DC, DC-pulsed, DC with DAS, AC-MF, bipolar processes</p> <p>MAGNETRON TYPES</p> <p>Single, dual or triple planar or rotatable</p> <p>MAGNET BARS & MAGNET SYSTEMS</p> <p>Planar (150 gauss to 800 gauss), rotatable (500 gauss to 1000 gauss)</p> <p>GAS INLET SYSTEM</p> <p>Binary system, fast reaction time, fully system integrated gas delivery solution, enables reactive gas sputtering application using the VON ARDENNE process control system (VAprocos2).</p> | <p>UPGRADES ARE SUPPORTED!</p> | <p>+ ROTATABLE MAGNETRON TECHNOLOGY - GET THE BEST COST OF OWNERSHIP!</p> <p>We have incorporated our rotatable magnetrons into the FOSA platform. They have a proven target substrate distance for optimized energy impact and deliver a superior coating uniformity.</p> <p>CUSTOMER BENEFITS compared to planar magnetrons:</p> <ul style="list-style-type: none"> — Coating uniformity of $\pm 1.5\%$ over a width of up to 3 m — Higher deposition rates — Target utilization of up to 85 % — Reduced maintenance times — Lowest cost of ownership per coated m² of film |
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E-BEAM TECHNOLOGY

With more than 60 years of experience and over 400 electron beam systems installed worldwide, VON ARDENNE provides the most advanced and powerful electron beam systems.

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| <p>+ IN WEB COATING, ELECTRON BEAM TECHNOLOGY ENABLES:</p> <ul style="list-style-type: none"> — Heat treatment — Much higher deposition rates (metals, alloys and compounds) compared to sputtering — Superior layer properties, e.g. improved adhesion, color and uniformity | <p>+ PATENTED VARIO CATHODE</p> <p>The high acceleration voltage ensures the stable vapor penetration of the electron beam. This leads to a superior and stable evaporation process, especially with multiple skip beam processes used for substrates with a width of more than one meter.</p> | <p>+ ELECTRON BEAM DEFLECTION SYSTEMS</p> <p>Limiting the energy impact and substrate stress is the key for high-throughput web coating. VON ARDENNE provides advanced magnetic deflection systems for the inbound AND outbound electron beam. This helps to eliminate up to 94 percent of the electrons before they reach the substrate.</p> |
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HIGH-POWER ELECTRON BEAM GUNS

VON ARDENNE develops and manufactures electron beam systems which are used for melting, refining, evaporation or heat treatment. The first electron beam gun was developed in 1959 at the Manfred von Ardenne Research Institute.

Our current **EH150V**, **EH300V** and **EH800V** electron beam guns are the most powerful in the world. We work on the continuous improvement of our key components at our development center for electron beam technologies. This is where we produce and test our high-quality electron beam guns.

VA PROCOS 2 PROCESS CONTROL SYSTEM

Since 1980, VON ARDENNE has been in a leading position in reactive sputtering processes. Furthermore, we have provided and optimized our process control system VAprocos for many years. Today, **VAprocos2** controls the reactive magnetron sputtering of compound layers (such as ITO, TiO₂, TiN, Al₂O₃, AlN, SnO₂, SiO₂, Si₃N₄, ZnO, ZrO or Ta₂O₅) by reliably fixing the working points in the crucial transition region. VAprocos also controls one or more reactive gas inlets (e.g. oxynitrides).

- | CONTROL SCHEMES | KEY FEATURES |
|---|---|
| <p>+ PEM (intensity) control</p> <ul style="list-style-type: none"> — Impedance control — Lambda probe control — Balance/IMBAL — Cascaded controller — Others | <ul style="list-style-type: none"> — Scalable system for monitoring and process control — Process adapted and ready to use configuration — Specialized processing for ARC event detection and handling — Designed for operation in an industrial environment (IP54/EMC) — Sensors and actors from previous VAprocos application are "plug-and-play" compatible |

DAS DUAL ANODE SPUTTERING TECHNOLOGY

The heat load is a major limiting factor in mass production due to thermal sensitivity of polymer substrates. The energy impact, and thus the substrate temperature, is strongly determined by the plasma mode (AC or DC).

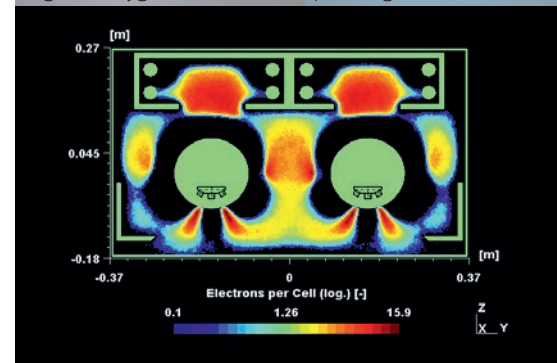
Plasma quenching and re-ignition by each AC voltage alternation causes heat and decreases the deposition rate compared to the DC mode. Unfortunately, in reactive sputtering the DC mode leads to a coated anode: the disappearing anode problem. It makes the process unstable and not reliable for mass production.

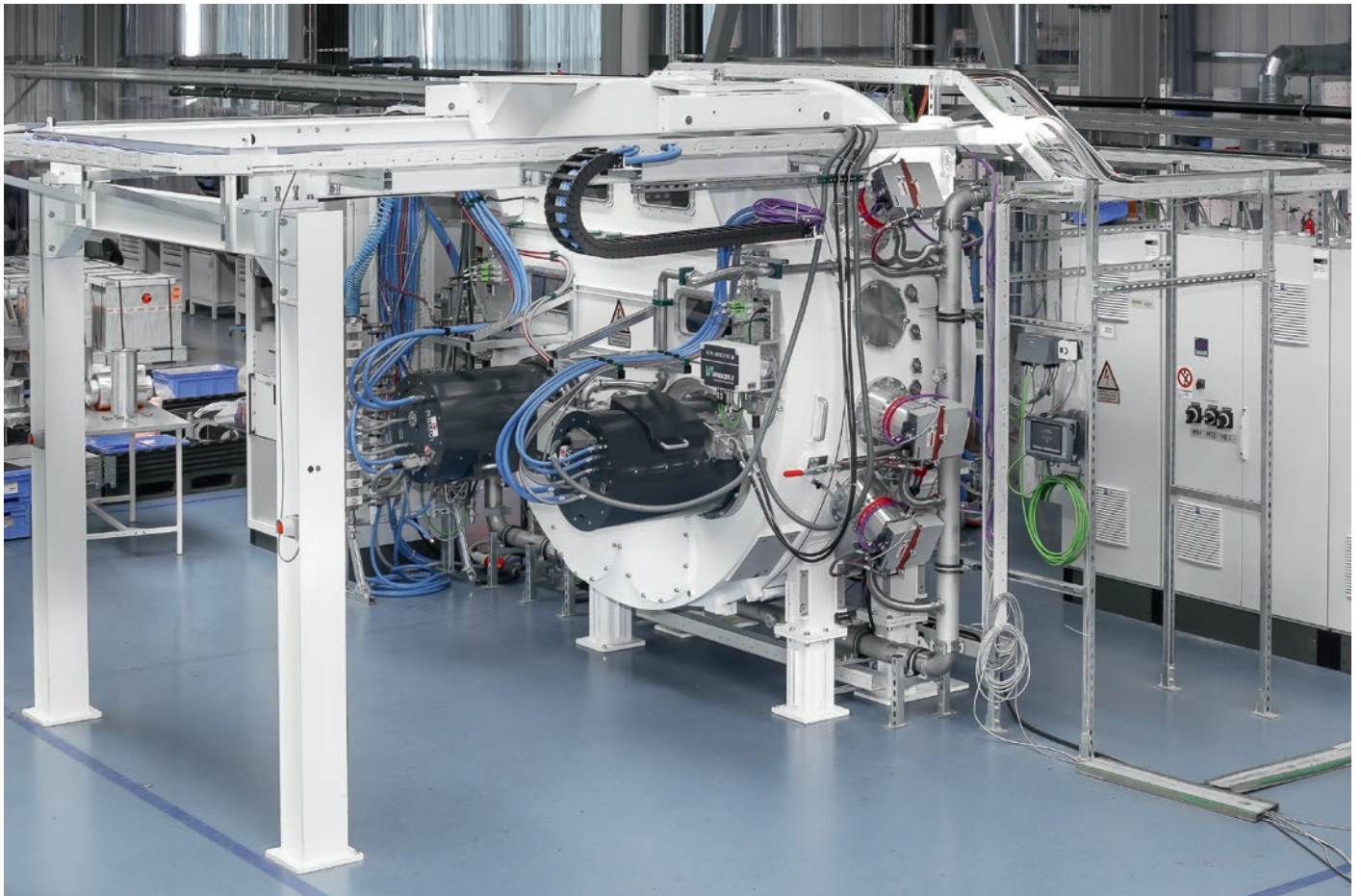
The solution for limiting the heat stress is Dual Anode Sputtering (DAS), a technology provided and patented by VON ARDENNE. It opens new perspectives for high throughput web coating applications.

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| <p>+ BENEFITS OF DAS:</p> <ul style="list-style-type: none"> — Up to 50 % less DC energy impact AND stable AC reactive process — Less heat impact on sensitive polymer substrates — Reactive sputtering without disappearing anode problem — 100 % duty cycle of DC sputtering used (compared to DC bipolar) — Available for planar and rotatable magnetrons used in the FOSA MX, CX and LabX |
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Reactive mode argon + oxygen Metallic mode pure argon





FOSA LabX 330 Glass installed in Dresden



PRODUCT
TOPICS



PRODUCT
INDEX



COMPONENTS



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WHO WE ARE & WHAT WE DO

VON ARDENNE develops and manufactures industrial equipment for vacuum coatings on materials such as glass, wafers, metal strip and polymer films. These coatings give the surfaces new functional properties and can be between one nanometer and a few micrometers thin, depending on the application.

Our customers use these materials to make high-quality products such as architectural glass, displays for smartphones and touchscreens, solar modules and heat protection window film for automotive glass.

We supply our customers with technologically sophisticated vacuum coating systems, extensive expertise and global service. The key components are developed and manufactured by VON ARDENNE itself.

Systems and components made by VON ARDENNE make a valuable contribution to protecting the environment. They are vital for manufacturing products which help to use less energy or to generate energy from renewable resources.



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