

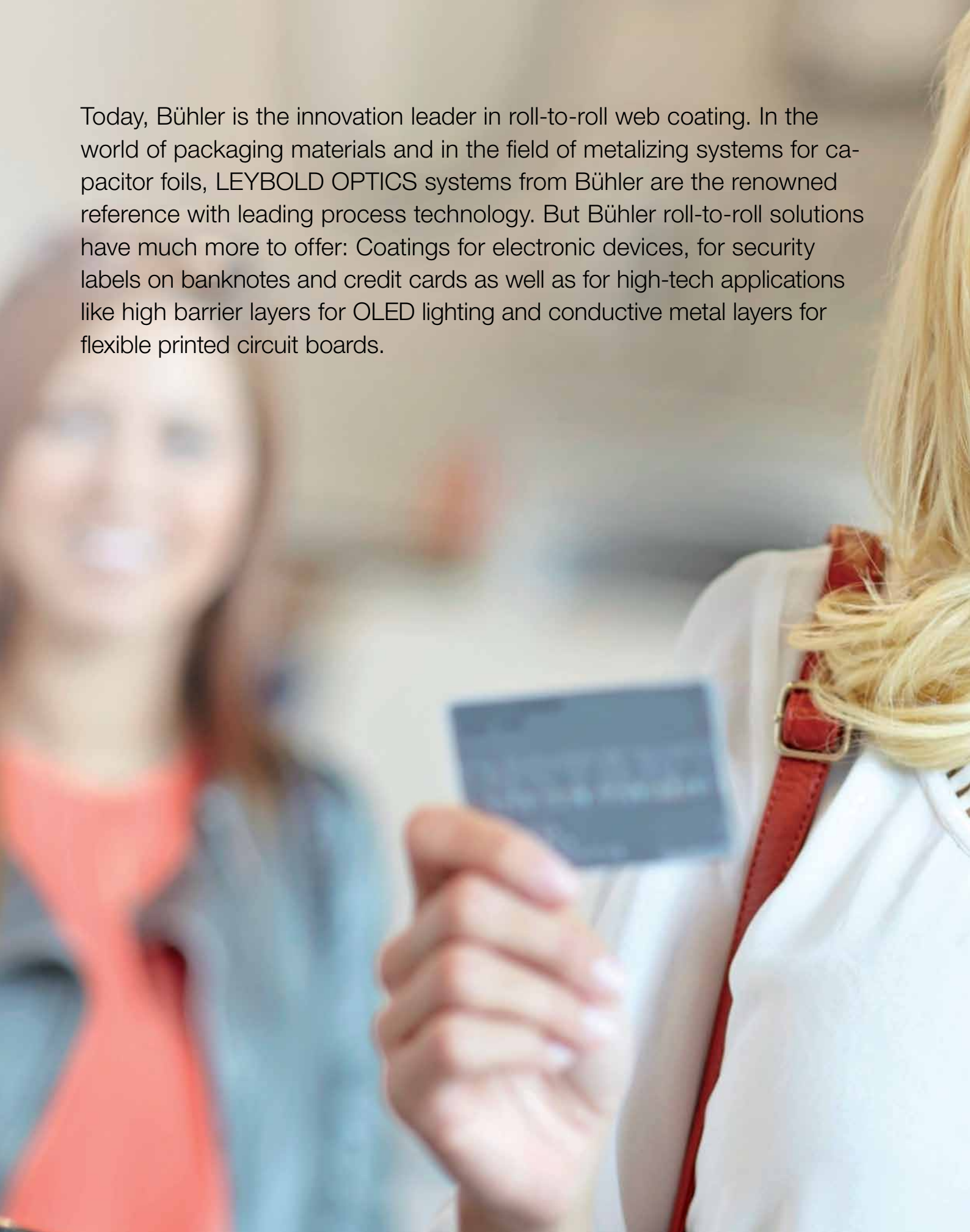
# Solutions for web coating.

Roll-to-roll metalizing and high-vacuum sputter coating.

- Food packaging
- Holographic security labels
- AC/DC film capacitors
- Flexible electronics



Today, Bühler is the innovation leader in roll-to-roll web coating. In the world of packaging materials and in the field of metalizing systems for capacitor foils, LEYBOLD OPTICS systems from Bühler are the renowned reference with leading process technology. But Bühler roll-to-roll solutions have much more to offer: Coatings for electronic devices, for security labels on banknotes and credit cards as well as for high-tech applications like high barrier layers for OLED lighting and conductive metal layers for flexible printed circuit boards.





#### **Bühler Leybold Optics – activities at a glance:**

- 2003** Development of pattern printing system.
- 2004** Development of SuperBias, consisting of electron-beam gun and single-side plasma pretreatment.
- 2004** Development of FMMS Free Margin Measuring System.
- 2006** Development of UNIVAP aluminum evaporator.
- 2007** Development of SuperBias with double-side plasma post-treatment.
- 2008** Development of free margin oil evaporator based on flash evaporation.
- 2009** Development of DISS Dual In-Situ Sensor.
- 2010** Redesign of pattern printing system.
- 2010** Launch of new plant FLEX-M (today LEYBOLD OPTICS SEC) for holographic and security materials.
- 2011** Redesign of META-M (today LEYBOLD OPTICS PAK).
- 2013** Launch of new product META-M (today LEYBOLD OPTICS PAK +), a high-rate metalizer for packaging.
- 2014** Launch of new product META-LUX (today LEYBOLD OPTICS PAK T), metalizer for transparent barriers.



# Bühler technology for web coating.

## We make market-leading solutions even better.



As an important step toward expanding the Advanced Materials division within Bühler with a strategic focus on environmentally friendly and energy-saving technology, Leybold Optics was acquired in May 2012. With this acquisition, Leybold Optics became part of a family-owned conglomerate of specialists and technology partners for plant, equipment and services for manufacturing advanced materials and for processing basic foods.

Not only does Bühler now hold the leading market position in the field of aluminum die casting, transforming grain into flour and feeds, and making pasta and chocolate, but also in vacuum thin-film coating.

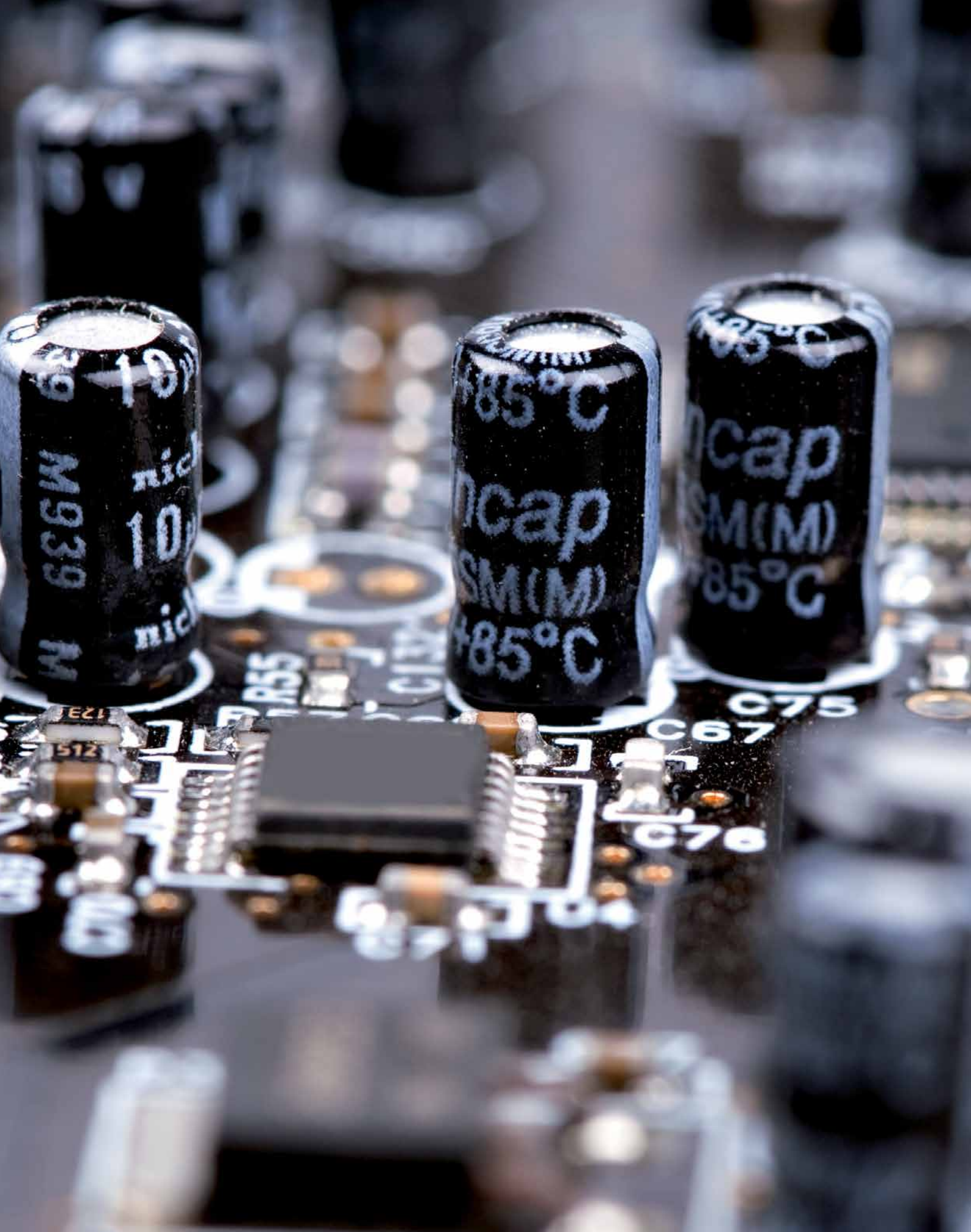
Within Bühler, we are stronger than ever and in an even better position to drive our most modern coating solution, process expertise and 1<sup>st</sup> class service and thus keep our leading role in optical thin-film vacuum deposition equipment. Over the next few years, we want to focus on our existing expertise in emerging markets with our most eco-friendly coating solution and an outstanding cost-performance ratio. Additionally, we will invest in high-class technology for developed markets to provide new applications.

We are centering our efforts on ensuring our customers' success by improving our core component technologies with a strong focus on cost of ownership. Our advances, for example in architectural layer stack design, aim not only for performance and reliability but also for cost efficiency.

Every year we spend a significant amount on basic research and applied development to further improve our technology with regard to quality and precision, sustainability, serviceability and the ecological footprint of our design and systems.

Sincerely yours

**Antonio Requena**  
Managing director  
Bühler Alzenau GmbH  
Leybold Optics



# Bühler technology for roll-to-roll metalizing. Efficient solutions for challenging applications.



## **LEYBOLD OPTICS CAP**

The LEYBOLD OPTICS CAP series is optimized for the metalization of films used in roller-type capacitors, with standard coating widths of 650 or 900 mm. The modular concept with multiple options and proprietary components make the LEYBOLD OPTICS CAP series the system of choice, both for mass-throughput standard products as well as for highly sophisticated applications such as ultra-thin film and segmented patterns.

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## **LEYBOLD OPTICS SEC**

The LEYBOLD OPTICS SEC is the innovative Bühler Leybold Optics solution for the production of holographic materials for security and brand protection purposes. Two separated evaporators enable combinations of different materials and guarantee maximum flexibility and minimum setup time.

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## **LEYBOLD OPTICS PAK / PAK +**

The LEYBOLD OPTICS PAK / PAK + are the roll-to-roll metalizing solutions for aluminum barrier packaging applications. Highest productivity in an industry with low margins, combined with excellent product properties, is the answer to tomorrow's challenges.

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Protection for fresh foodstuff: Plasma reactive deposition of aluminum oxide onto flexible materials such as BOPP and PET



#### **LEYBOLD OPTICS PAK T / PAK T+**

The LEYBOLD OPTICS PAK T / PAK T+ are dedicated vacuum coating machines for the plasma reactive deposition of aluminum oxide onto flexible materials such as BOPP and PET. Barrier performance and long-term stability of packaging materials refined with aluminum oxide layers have been enhanced with a plasma-reactive process to achieve better permeation values.

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#### **LEYBOLD OPTICS FLC**

The LEYBOLD OPTICS FLC is the perfect high-vacuum sputter roll-to-roll coating solution for a wide range of future-trend products. Flexibility by almost unlimited possibilities regarding the system configuration enables the machine to be outstandingly productive in a manufacturing environment as well as being versatile when used as a R&D machine.

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Further information on key-features of Leybold Optics vacuum coaters see page 18

# LEYBOLD OPTICS CAP vacuum coater.

## System for high-volume film capacitor solutions.

Due to increasing use of electronic devices in everyday products and the industry, many new applications for film capacitors have been developed which have to meet the highest standards in function, precision and life time, directly linked with the requirement for miniaturization. Reducing weight and space can be achieved through the use of ultra-thinnest films. The processing of these high-tech materials in conjunction with sophisticated precision in terms of layer profile deposition and segmentation requires production equipment with a high degree of innovation, automation and reproducibility.



### Reference machine in the capacitor film metalizing market

The LEYBOLD OPTICS CAP roll-to-roll vacuum metalizing system is the future-orientated solution for these demanding applications and meets the requirements of an unlimited range of metalized films for capacitors. From standard to high-end applications, from thick to thin films, from plain to segmented designs, from thick to thin

layers, from pure layers to layer stacks, every conceivable combination can be realized in one system.

### The flexibility of the system is the key to success

Sophisticated individual components, integrable into the modular machine concept, make the difference and allow optimized cost of ownership due to the high productivity of the LEYBOLD OPTICS CAP.

#### Customer benefits:

- 100 % in-situ quality control with ISS technology
- High product consistency and layer adhesion thanks to powerful plasma pre-treatment

- Unrivaled layer uniformity thanks to innovative evaporator design and arrangement
- High-precision and reproducible product quality due to sophisticated masking technology





Dual In-Situ Sensor technology

ISS technology for quality control, SuperBias technology for marginal, special products, pattern printing system based on flexography for high-precision segmentation, free margin oil evaporator based on flash evaporation for uniform margin generation, and the multi-source evaporation station to name only few. All are combined with a robust design for high volume-production of a wide range of products.

Products manufactured with the LEYBOLD OPTICS CAP are used for e-mobility, smart grid, renewable energy, buildings and many other fields.

### Applications

- Aluminum coatings
- Aluminum/zinc coatings
- Aluminum/zinc heavy-edge coatings
- Silver/zinc coatings
- Plain/ramp/slope layer profiles
- Layer ratio: active area/heavy edge up to 1:20

All coatings and profiles can be combined with segmented structures by using the pattern printing system.

### Available machine sizes

LEYBOLD OPTICS CAP 650 / 900 \*

### Key figures of the system

- Type of substrates – PET, (B)OPP – smooth and hazy grade, other substrates on request
- Ultra-thin substrates, e.g. (B)OPP < 2.0 µm
- Max. substrate width up to 920 mm
- Max. substrate diameter up to 620 mm
- Max. winding speed 20 m/s
- Height-adjustable Al evaporator

### Options (examples)

- Plasma pre-treatment
- Pattern printing system
- SuperBias technology
- Wire feed unit for thinnest layer applications
- ISS, FMMS technology

For further information to technical features of this machine see page 18, 19, 20, 21, 22

\* Max. coating width in mm

# LEYBOLD OPTICS SEC vacuum coater.

## System for high-volume holographic solutions.

Every day millions of people show their passports while traveling, security cards at work, or pay using cash or with their credit cards. Modern security systems ensure that these cards and documents are tamper-proof. Manufacturing security labels for these kinds of applications is a quite complex and sophisticated process. In total, it requires several individual processing steps. In the case of the layer deposition, special solutions are required, which guarantee high precision, quality and reproducibility. The LEYBOLD OPTICS SEC provides the appropriate platform and technology for these products. It successfully combines corresponding productivity with the required flexibility.



### First choice for PET and (B)OPP coating processes

The LEYBOLD OPTICS SEC is a roll-to-roll vacuum metalizing system for the high-volume production of applications in the areas of protection, security and optical effects. PET and (B)OPP are among the typical substrates used in these processes.

Two separate evaporators for different materials maximize flexibility while minimizing setup time. The layer deposition is based on thermal evaporation. Aluminum, copper and zinc-sulfide are the most commonly used coating materials.

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#### Customer benefits:

- 100 % in-situ quality control due to ISS technology
  - Optimized total cost of ownership due to high productivity and high uptime
  - High product consistency and layer adhesion thanks to powerful plasma pre-treatment
  - Unrivalled layer uniformity thanks to innovative evaporator design and arrangement
-



Evaporator station with zinc sulphide and aluminium evaporator

### **The multi-purpose utilization of the system is the key to success**

Suitable for various applications ranging from classic full-area aluminum layers to applications with demanding interference layers, including applications where – with the additional use of the pattern printing system – a wide range of products can be realized.

LEYBOLD OPTICS SEC products are used for governmental and fiduciary documents, bank notes, vehicle protection, product and brand protection and many other fields.

### **Applications**

- Aluminum coatings
- Copper coatings
- zinc-sulfide coatings

### **Available machine sizes**

LEYBOLD OPTICS SEC 650 \*

### **Key figures of the system**

- Type of substrates – PET, (B)OPP, other substrates on request
- Max. substrate width up to 670 mm
- Max. substrate diameter up to 620 mm
- Max. winding speed 12 m/s

### **Options (examples)**

- Plasma pre-treatment
- Pattern printing system
- ISS technology

For further information to technical features of this machine see page 19, 20, 21, 22

\* Max. coating width in mm



# LEYBOLD OPTICS PAK vacuum coater.

## System for high-quality barrier packaging solutions.

Shelf life and the protection of sensitive packed goods are increasingly important in modern packaging applications. A high diffusion barrier to protect the packed goods from various external influences, especially oxygen and water vapor, is a crucial topic in food packaging and other industries. The demand for thin-film packaging, in combination with the importance of barrier properties, was already predicted in the context of earlier market trend studies and has been confirmed during the past years. With high probability, this trend will also lead to a corresponding growth potential, especially due to the emergence of a middle class in populous states.



### Roll-to-roll coating system for high-quality barrier packaging

For aluminum coated packaging materials robust and service-friendly production equipment is required, with the focus on maximum uptime and excellent product properties. Bühler's LEYBOLD OPTICS PAK provides a perfect balance between investment, productivity and product quality for this application.

The LEYBOLD OPTICS PAK roll-to-roll metalizing system is the workhorse in the Bühler Leybold Optics portfolio for the packaging industry, enhancing optical, protective and barrier properties by deposition of conventional aluminum coatings to a wide range of flexible substrate materials. The LEYBOLD OPTICS PAK series covers coating widths from 1,300 to 2,500 mm and all common plastic film and paper substrates.

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#### Customer benefits:

- High uptime due to a robust and service-friendly machine concept
  - High product consistency and improved barrier performance thanks to powerful plasma pre-treatment
  - Unrivalled product quality in terms of layer homogeneity due to an optimized arrangement of Al evaporator sources
  - Operator-friendly equipment due to simplified operation and optimized accessibility
-



Plasma pre-treatment

A special feature of the system is the patented Al-evaporator. In addition to the measurable layer uniformity the technology is also visually convincing.

The machine's design allows for easy and intuitive operation, even for newcomers to vacuum coating systems.

There are three main application areas for flexible coated substrates of the type produced by the LEYBOLD OPTICS PAK series. These vary according to layer thickness: very thin coatings, such as those used for

inter-layers between architectural glass panels, medium-thicknesses, as used in food packaging, for example, and thick coatings, typically used in the packaging of highly photosensitive electronics.

#### Applications

- Aluminum coatings
- Copper coatings

#### Available machine sizes

LEYBOLD OPTICS PAK 1300 / 1700 / 2100 / 2500 \*

#### Key figures of the system

- Type of substrates – PET, (B)OPP, CPP, HDPE, LDPE, PA, other substrates on request
- Max. substrate width up to 2,520 mm
- Max. substrate diameter up to 1,150 mm
- Max. winding speed 17 m/s
- Layer uniformity Al  $\pm 5$  %

#### Options (examples)

- Plasma pre-treatment
- Air-injection
- Advanced Al evaporator

For further information to technical features of this machine see page 19, 22

\* Max. coating width in mm

# LEYBOLD OPTICS PAK + vacuum coater.

## System for high-volume barrier packaging solutions.

The challenges in the margin-sensitive packaging material industry are clear – highest productivity with shortest downtimes, lowest cost per coated area through high process speed and minimal scrap, but also no compromises on final product quality and performance. The increase in productivity is composed of several factors, and the process speed offers the most effective lever. In addition to technical challenges in the design of robust high-speed production equipment, crucial product/layer quality requirements, in particular barrier properties, as well as adhesion, uniformity and a full surface homogeneous structure and the successful thermal management of the substrate during metalizing need to be considered. Bühler's LEYBOLD OPTICS PAK + represents the perfect solution for highly productive production equipment combined with excellent product properties.



### Roll-to-roll coating system for margin-sensitive products

The LEYBOLD OPTICS PAK + series applies aluminum coatings to flexible substrates for various solutions at unrivaled speeds for maximum output. Using the LEYBOLD

OPTICS PAK + vacuum coater process speed increases of > 25 % over conventional systems can be achieved.

In addition to overcoming the technical challenges in the design of a robust, high-speed production machine,

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#### Customer benefits:

- Optimized total cost of ownership due to high productivity
- High product consistency and improved barrier performance thanks to powerful plasma pre-treatment

- Innovative design and concept of the winding system enables the winding path to be flexibly adapted to the individual requirements of substrates and applications
  - High uptime thanks to robust machine design
-





High-rate Al evaporator

operator-friendly process stations have been developed, along with successful thermal management of the substrates during the metalizing process. The machine's design allows for easy and intuitive operation, even for newcomers to vacuum coating systems.

There are three main application areas for flexible coated substrates of the type produced by the LEYBOLD OPTICS PAK + series. These vary according to layer thickness: very thin coatings, such as those used for

inter-layers between architectural glass panels, medium-thicknesses, as used in food packaging, for example, and thick coatings, typically used in the packaging of highly photosensitive electronics.

#### Applications

- Aluminum coatings
- Copper coatings

#### Available machine sizes

LEYBOLD OPTICS PAK 2500 + / 2900 + / 3300 + / 3700 + \*

#### Key figures of the system

- Type of substrates – PET, (B)OPP, CPP, HDPE, LDPE, PA, other substrates on request
- Max. substrate width up to 3,720 mm
- Max. substrate diameter up to 1,500 mm
- Max. winding speed 20 m/s
- Layer uniformity Al  $\pm 5$  %

#### Options (examples)

- Plasma pre-treatment
- Plasma post-treatment
- Air-injection

For further information to technical features of this machine see page 19, 21, 22

\* Max. coating width in mm

# LEYBOLD OPTICS PAK T / T+ vacuum coater. System for high-volume transparent barrier packaging.

Consumer markets for food have been expanding in recent years, particularly in emerging economies. That growth has been accompanied by increasing demand for transparent packaging, as many consumers want to see the products inside the wrapping and thus favor clear barrier films as packaging for fresh and dry edible goods. Transparent barrier packaging has until now been too costly to be used in all but high-end goods. Bühler's new vacuum coating machine LEYBOLD OPTICS PAK T / T+ provides a novel approach for the high-volume manufacturing of transparent barrier packaging considering an optimum total cost of ownership through an innovative machine design and process concept.



## Roll-to-roll coating system for transparent barrier packaging

The LEYBOLD OPTICS PAK T / T+ is a new vacuum coater employing plasma reactive deposition to apply aluminum oxide layers onto flexible plastic substrates such as PET and (B)OPP.

There are several technologies on the market to apply transparent barriers to flexible plastic substrates – some characterized by good product performance at the expense of high investment in combination with technical complexity of the systems, while others offer low investment and a simple technology but deliver limited product performance.

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### Customer benefits:

- Optimum total cost of ownership thanks to optimum balance between investment, complexity of technology and product performance
  - Improved barrier performance and long-term stability thanks to powerful plasma reactive deposition
  - Unrivalled layer uniformity thanks to an innovative evaporator arrangement and gas distribution
  - High flexibility thanks to an innovative design and concept for different kind of coatings
- High uptime through robust machine design
-



Al-feeder drive system for low rates

The design and concept of the plasma reactive process as realized in the LEYBOLD OPTICS PAK T / T+ represents an optimum balance between investment, complexity of technology and product performance.

The plasma reactive process provides a significant improvement over conventional reactive deposition and also enhances barrier performance and long-term stability of packaging materials in combination with lowest permeation values.

In addition to the measurable layer uniformity across the substrate width, the innovative evaporator arrangement

and gas distribution delivers striking results in the visible range, important for special optical applications.

Especially when it comes to flexibility the LEYBOLD OPTICS PAK T / T+ sets the benchmark, and even though the system is primarily intended for aluminum oxide coatings, only small modifications are necessary to do pure aluminum or copper coatings.

#### Applications

- Aluminum oxide coatings
- Aluminum coatings
- Copper coatings

#### Available machine sizes

LEYBOLD OPTICS PAK 1700 T / 2100 T / 2500 T \*  
LEYBOLD OPTICS PAK 3700 T+ \*

#### Key figures of the system

- Type of substrates – PET, (B)OPP, other substrates on request
- Max. substrate width up to 3,720 mm
- Max. substrate diameter up to 1,500 mm

- Max. winding speed 20 m/s
- Layer uniformity: AlOx  $\pm 10\%$ , Al  $\pm 5\%$

#### Options (examples)

- Plasma pre-treatment, Plasma post-treatment
- Wire feed unit for thinnest layer applications
- Air-injection

For further information to technical features of this machine see page 19, 21, 22, 23

\* Max. coating width in mm



# Technical features of Bühler vacuum coaters. Leybold Optics first-class technology.

## Dual In-Situ Sensor technology



The DISS technology is a measuring system for in-situ quality control. With its various advantages and features, this innovative and powerful technology represents a unique selling proposition in the manufacture of film capacitors or holographic applications.

### Challenges

The challenges are to increase productivity and product quality as well as reducing scrap with a 100 % quality control and efficient data evaluation.

### Solution

The DISS technology is a combination of two sensors and an additional HMI with controller. The housing and internal sensors cover the entire width of the substrates. The first sensor is a non-contact, real-time layer-profile measuring system based on optical density. The second is a line sensor used for simultaneous measurement of the widths of free margins. With a sampling rate of 1.0 mm at a process speed of 19 m/s, a complete layer profile, in a dynamic range from 0 to 3 O.D., and the width of all free margins are measured and indicated on the HMI. As well as other special features, such as data logging for downstream evaluation of process data or accurate indication of the center between two free margins for aligning the heavy edge to the margins, the sensor signal can be used for closed-loop control.

### Advantages

- Increased productivity due to higher efficiency, special features and reduced scrap
- Consistent, high product quality due to 100 % in-situ control
- Ease of operation due to closed loop control

**Available for:**  
**LEYBOLD OPTICS CAP**

## SuperBias technology



To avoid thermal damage, the SuperBias technology supports the thermal management of sensitive, thin polymer substrates for film capacitors while processing.

### Challenges

One of the biggest challenges in metallizing flexible polymer substrates is to prevent thermal overloading of the substrates, especially when processing sensitive, thinnest and hazy-grade substrates.

### Solution

Bühler Alzenau developed what is known as SuperBias – a revolutionary technology consisting of an electron-beam gun and two plasma sources – for its LEYBOLD OPTICS CAP systems.

As soon as the substrate is applied to the process drum, the electron-beam gun applies static charge to the substrate in order to achieve maximum adhesion to the cooled surface of the drum. This adhesion ensures an optimum heat-transfer coefficient for the dissipation of the thermal load. Electron-beam-induced bias allows a charge of the substrates compared to conventional bias due to the immobile, static charge. The pressure of the substrate to the cooled surface and, accordingly, the heat-transfer coefficient can be increased by one order of magnitude during the time before the substrates are exposed to the heat load, that is, before the metallizing takes place. The significantly more efficient pre-cooling also results in a considerably lower peak temperature of the substrates during the process. As a result, comparable processes using SuperBias technology are faster than processes using conventional bias.

### Advantages

- Increased productivity thanks to efficient substrate cooling
- High diversity in terms of different substrates and processes

**Available for:**  
**LEYBOLD OPTICS CAP**

### Free margin oil evaporator



The component is used to generate unmetallized margins in machine direction. Standard widths of margins are in a range of 0.4 up to 10 mm. With its various advantages, this innovative technology represents a unique selling proposition in the manufacture of film capacitors.

#### Challenges

The challenges are precision, quality and high diversity in terms of the number and dimensions of margins.

#### Solution

The entire component consists of the evaporator – body and gas generator, micro pump, oil reservoir and the nozzle. The nozzles are tailored to the individual products. The body and gas generator are heated and the temperatures are kept constant in a closed loop during the processes. The gas generator is supplied with oil through a pipe connected to the micro pump and oil reservoir, both of which are located outside the vacuum chamber. The oil reservoir can be re-filled without interrupting the coating process.

As soon as oil runs onto the hot surface of the gas generator, it is evaporated and evenly distributed in the body. The supplied quantity of oil is controlled by the speed of the micro pump, depending on the total area of free margins, the winding speed and the layer thickness, and is automatically controlled in a closed loop. The evaporator is installed on a motion unit. The motion unit is equipped with three stepper motors for flexible positioning.

#### Advantages

- Increased productivity due to minimized setup time and scrap
- Cost savings thanks to 100 % oil utilization and prevention of used oil disposal
- Consistent product quality due to an increased degree of automation

**Available for:**  
**LEYBOLD OPTICS CAP**

### AI-feeder – drive system for low rates



The feeding system is used to continuously supply aluminum wire at a certain speed to the sources of the aluminum evaporator.

#### Challenges

For general layer uniformity in machine direction, slow and continuous feeding of aluminum wire at an appropriately high resolution must be guaranteed.

#### Solution

The feeding system consists of a certain quantity of stepper motors including drives and holders for the aluminum spools. The number of feeders depends on the size of the system. Besides the continuous slow feeding at high resolution, it is important to eliminate the typical jerk characteristic of stepper motors.

The new, innovative drive system meets all the requirements for thinnest layer applications. Furthermore, in combination with any available sensor technology, for example ISS / DISS / LMS, it provides an excellent platform to realize a fully automatic cross control of aluminum layers, even for sophisticated capacitor applications.

#### Advantages

- Increased performance due to extended range of speed and 97 % higher resolution
- High product quality due to improved layer uniformity
- Consistent product quality due to operation with an increased degree of automation
- Ease of operation due to closed-loop layer cross control
- Technology is backward compatible and can be retrofitted in existing systems

**Available for:**  
**all LEYBOLD OPTICS systems**

# Technical features of Bühler vacuum coaters. Leybold Optics first-class technology.

## Advanced Al-evaporator



The evaporator is used for depositing aluminum layers in a range of 1  $\Omega/\square$  up to 100  $\Omega/\square$ . As well as pure aluminum applications, the evaporation source can also be used simultaneously with other sources for applications with layer stacks.

### Challenges

The challenges of a conventional aluminum evaporator with individual sources are layer uniformity and layer quality.

### Solution

The evaporator consists of a certain quantity of evaporation sources, evaporation box including shutter and flap and individual power supplies. The number of sources depends on the size of the system.

The arrangement of the sources is staggered and twisted in order to minimize the interaction between individual aluminum clouds and to optimize the layer uniformity in transverse direction. Furthermore, the evaporation sources are height adjustable. The advantage of flexible height adjustment is again an improved uniformity using a bigger distance between sources and substrate.

The flap in the evaporation box allows a direct view from the operating side through a stroboscope to the sources, allowing observation and adjustment during processing.

### Advantages

- Increased productivity due to minimized setup time
- High product quality due to the innovative arrangement and flexible setup of individual sources
- User friendly due to optimized accessibility

**Available for:**  
**LEYBOLD OPTICS CAP**

## ZnS evaporator



The evaporator is used for depositing interference ZnS layers in a range of 10 nm up to 120 nm. Besides pure ZnS applications, the evaporation source can also be used simultaneously with other sources for applications with layer stacks.

### Challenges

The challenges of an evaporator with individual sources are layer uniformity and layer quality.

### Solution

The evaporator consists of a certain quantity of directly heated metal crucibles, an evaporation box and individual power supplies. The number of sources depends on the size of the system.

The arrangement of the sources and individual control combined with the low mass of the crucibles is the basis for the outstanding performance in terms of layer uniformity. Due to an innovative crucible cover design, the layer quality can be improved with a focus on avoiding splashes. Both the productivity of the system and the efficiency of the evaporator were significantly increased by the huge capacity of the crucibles and their optimum arrangement. A 50 nm layer at 3.0 m/s process speed on a 12,000 m substrate length in one turn serves as a reference for the process capability and productivity of this system.

### Advantages

- Increased productivity due to huge crucible capacity and optimum arrangement
- High product quality due to innovative arrangement of the sources and crucible design
- Versatility due to simultaneous use of the evaporator with other sources
- User friendly due to optimized accessibility

**Available for:**  
**LEYBOLD OPTICS SEC**



## Pattern printing system



This component is used to produce unmetallized structures for segmented film capacitors, for holographic and for packaging applications.

### Challenges

Precision, quality, and high diversity in terms of the designs of the structures, linked to winding quality, in particular for applications using the thinnest substrates for film capacitors.

### Solution

The system is installed in a drawer and consists of an oil evaporator, anilox and flexo roll including sleeve. The structure of the sleeves is tailored to the individual products. The sleeves can be manufactured with dimensions of structures down to 1/100 mm.

The most important thing for a precise and reproducible high printing quality is consistent transfer and the optimum quantity of oil according to product and process requirements, such as design of the structure, winding speed and layer thickness. A basic prerequisite for consistent oil transfer is constant and uniform contact pressure between the individual rolls. This constant contact pressure is achieved by means of four highly accurate positioning servo motors. Two servo motors are connected to the anilox roll for the approach to the flexo roll, the other two are connected to the flexo roll for the approach to the process drum. Also essential for precise printing quality is optimum synchronization between the process drum and flexo roll and, last but not least, the design and quality of the anilox and flexo roll.

### Advantages

- Increased productivity thanks to minimized setup time and scrap
- High product quality with a high-end printing system
- User friendly due to optimized accessibility

**Available for:**  
**LEYBOLD OPTICS CAP, LEYBOLD OPTICS SEC,**  
**LEYBOLD OPTICS PAK**

## High rate Al-evaporator for maximum output



The LEYBOLD OPTICS PAK + and PAK T+ series apply conventional aluminum coatings onto flexible plastic substrates at unrivalled speeds for maximum output. In order to maximize productivity, a high-rate aluminum evaporator was implemented.

### Challenges

In addition to overcoming the technical challenges that arise when designing a robust, high-speed production machine, easy-to-handle process stations have been developed, along with successful thermal management of the substrates during the metallizing process. This still takes into account crucial product and layer-quality requirements, in particular barrier properties, as well as adhesion, uniformity and a full-surface homogeneous structure.

### Solution

The evaporator consists of a certain quantity of evaporation sources, evaporation box including flap and individual power supplies. The number of sources depends on the size of the system, whereby the density of sources is accordingly higher when compared to standard-rate technology.

The arrangement of the sources is staggered in order to minimize the interaction between individual aluminum clouds and to optimize the layer uniformity in transverse direction.

Compared to conventional systems the process speed of the LEYBOLD OPTICS PAK + and PAK T+ series was increased by > 25 %.

### Advantages

- High productivity due to high rate evaporation
- User friendly due to optimized accessibility

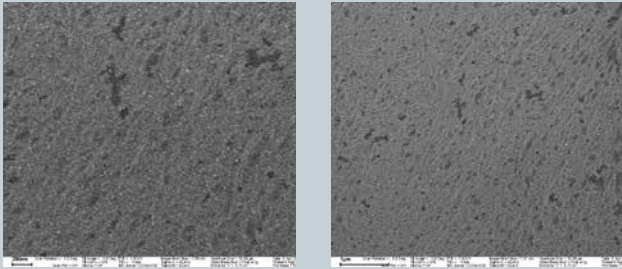
**Available for:**  
**LEYBOLD OPTICS PAK + / PAK T+**

# Plasma treatment in Bühler vacuum coaters.

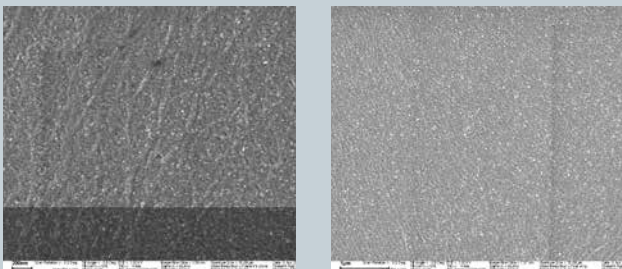
## Technology that brings you a step ahead.

### Plasma pre-treatment – excellent barrier characteristic and layer adhesion

#### Al on polymer film without plasma pre-treatment



#### Al on polymer film with plasma pre-treatment



The plasma pre-treatment is a process unit designed for all Bühler web-coating machines and is required for enhancing different materials on flexible polymer substrates.

#### Challenges

The desire to move from rigid to light-weight, flexible packaging continues to increase for economic and processing reasons. At Bühler, our focus is on improving the metallization process step, which would improve the quality of flexible packaging films.

The challenge of tailoring a thin, flexible polymer is to understand its surface structure in order to subsequently improve layer adhesion and barrier properties.

Both of these properties are highly important for the packaging industry and specifically for food packaging, in which an optimum barrier of a packaging material should completely protect the contents against gases, moisture, odors and micro-organisms.

A shortlist of the consumer demands can be made, including properties such as transparent, microwavable, hygienic and temperature resistant. These properties can be fulfilled using other materials and by

optimizing the processes with this unit. The base film would not satisfy most of the demands, but the effect of enhancing the adhesion property of the polymeric base film can be achieved by means of surface modification using a glow discharge plasma.

The desire to trigger the adhesion of the flexible film and the subsequent metal/metal oxide using the plasma pre-treatment unit would subsequently reduce the permeability, which is the prerequisite for an extended shelf life of the packed product.

#### Solution

The plasma pre-treatment unit consists of a gas-injection module built within a single-side cathode, electrically connected to a unique characteristic power supply. For all the machines, the plasma pre-treatment is installed immediately after the unwinder, before the layer deposition is carried out.

Regardless of the web-process speed, the main effects of the reactive plasma created using the plasma pre-treatment unit include substrate cleaning, ablation, crosslinking and surface modification. Optimizing the process conditions would result in a tailored surface, and thus in improved layer adhesion and reduced permeability.

Using the Bühler design for pre-treating films results in a quantum leap with respect to the performance of the properties achieved for the simple base films available on the market.

#### Advantages

- High product quality due to efficient surface modification
- Versatility due to the use of different gases or even gas mixtures
- User friendly due to optimized accessibility

#### Performance

Pure aluminum – Coating thickness 2,2 O.D

PET 12 µm	
OTR – Oxygen Transmission Rate [cm <sup>3</sup> /m <sup>2</sup> * day]	≤ 1
WVTR – Water Vapor Transmission Rate [g/m <sup>2</sup> * day]	≤ 0.5
(B)OPP 20 µm	
OTR – Oxygen Transmission Rate [cm <sup>3</sup> /m <sup>2</sup> * day]	≤ 35
WVTR – Water Vapor Transmission Rate [g/m <sup>2</sup> * day]	≤ 1.0

Barrier data depending on substrate type; test conditions  
OTR 23 °C / 50 %r. h., WVTR 38 °C / 90 %r. h.

**Available for:**  
**all LEYBOLD OPTICS systems**



Plasma energy – highly efficient power for various applications

## Plasma source in evaporation zone – high-quality transparent barriers

The LEYBOLD OPTICS PAK T and PAK T+ series are new vacuum coaters assisted with plasma-reactive technology to fabricate thin, transparent aluminum-oxide layers on flexible polymer substrates, such as PET and (B)OPP.

The plasma-reactive deposition of aluminum-oxide is achieved by means of an integrated plasma cathode with a customized gas-supply design in the conventional aluminum-evaporation zone.

### Challenges

The challenges linked to the plasma-reactive deposition of transparent layers are the required barrier properties, with long-term stability, layer adhesion, layer quality, layer uniformity and transparency being of major importance. Furthermore, both the concept and design must be optimally balanced with respect to investment and complexity of technology.

### Solution

The components of Bühler Alzenau's technology consist of a double-sided cathode with the respective power and gas supplies at different positions. The cathode is positioned above the aluminum evaporator, directly below the process drum. The required amount of gas for each process is controlled and injected at different positions within the evaporation zone, which also improves the uniformity of the deposited aluminum oxide.

A simultaneous step, the evaporation of aluminum and the injection of a defined amount of gas, is the initial step for the oxidation of aluminum to yield aluminum oxide; well known as conventional reactive oxidation. A more advanced step, Bühler Alzenau's approach, is to subject the mixture of aluminum vapor and the desired amount of gas to high-energetic plasma conditions, thus yielding an ionized gas state.

In this approach, a planar magnetron plasma source equipped with a different process gas is operated to achieve the ionization step. During this plasma step, the chemical interaction of aluminum atoms and the process-gas ions is enhanced. The plasma state fosters the densifica-

tion process of aluminum and oxygen to yield aluminum-oxide films, AlOx. These transparent AlOx films are tailored using this technology to yield high-barrier and optically transparent films specifically for the packaging industry.

Consistent and reliable results have been achieved using this technology, proving that the plasma-reactive process provides significant improvement of the desired properties compared to the conventional reactive-oxidation process for a wide range of flexible polymer films.

The barrier performance is enhanced and a distinct long-term stability of packaging materials, in combination with lowest permeation values achieved, all without the yellowing effect often seen on samples from competitors.

### Advantages

- High product quality due to efficient plasma reactive deposition
- Long-term stability and high peel strength over 180 days
- Optimum total cost of ownership due to innovative concept and design
- User friendly due to optimized accessibility

### Performance

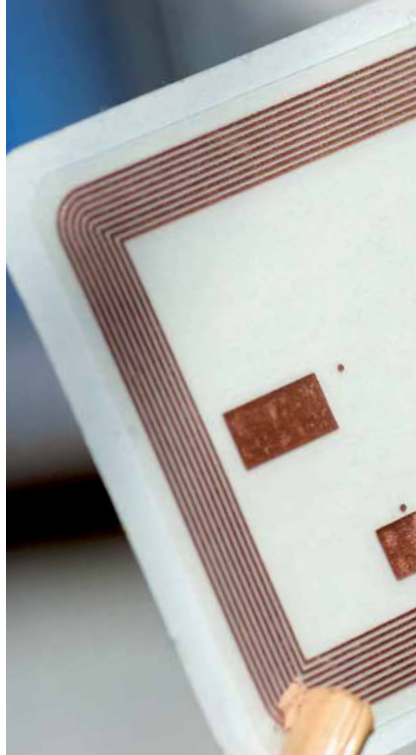
Aluminum oxide – Physical layer thickness approximately 10 to 15 nm

PET 12 µm	
OTR – Oxygen Transmission Rate [cm <sup>3</sup> /m <sup>2</sup> * day]	≤ 0.5
WVTR – Water Vapor Transmission Rate [g/m <sup>2</sup> * day]	≤ 0.5
(B)OPP 20 µm	
OTR – Oxygen Transmission Rate [cm <sup>3</sup> /m <sup>2</sup> * day]	≤ 30
WVTR – Water Vapor Transmission Rate [g/m <sup>2</sup> * day]	≤ 3.5

Barrier data depending on substrate type; results using inline plasma pre-treatment; test conditions OTR 23 °C / 50 % r. h., WVTR 38 °C / 90 % r. h.

**Available for:**  
**LEYBOLD OPTICS PAK T / T+**





## Roll-to-roll high-vacuum sputter coating. Flexible solutions for sophisticated products.

### **Transparent conductive layers: Touch panels, flexible PV, OLED lighting**

Touch panels of smart phones and tablet PCs are only one example for roll-to-roll high vacuum sputter deposition. Vacuum-coated transparent conductive oxide (TCO) layers on plastic films have been and are the prerequisite for cost-effective manufacturing of high-quality touch panel displays. TCO layers, for instance ITO or AZO, are furthermore used as front contact layers in many other applications, such as flexible photovoltaics or OLED lighting.

### **Conductive metal layers: Flexible printed circuit boards (FPCB), Radio Frequency Identification (RFID), Metal mesh touch panels**

Flexible printed circuit boards are applied wherever small, lightweight and flexible electrical circuits are needed as in mobile devices or laptop PCs. Furthermore, applications such as Radio Frequency Identification (RFID) or metal meshes for touch panel displays also require cost-effective copper layers with outstanding electrical properties for creating the integrated electrical circuits.

### **Low emissivity and electrochromic layers: Architectural and automotive glazing**

A huge part of the primary energy produced worldwide is used for heating or cooling of buildings. A high proportion of this energy is lost by heat transfer through the glazing of the buildings. Foils with low thermal emissivity (low-e) or smart glass coatings can minimize the energy losses drastically when integrated into the glazing. In addition to the energy savings aspect, the roll-to-roll deposition process makes the production very cost effective, while the equipment compared to a typical glass coating system is also very small in size.



Cost efficiency, excellent layer quality, and outstanding process versatility are the key features of Bühler Leybold Optics sputter coating technology.

#### **Sensor layers: Medical, bio and physical sensors**

Medical sensors, e.g. blood glucose sensors, are a multi-billion dollar market. There are already different technologies available for the economical roll-to-roll manufacturing of piezo-resistive, piezo-electric, capacitive, temperature or photoelectric sensors, for instance. Depending on the respective sensor type almost the whole sensor or at least several integrated layers, such as front or back contacts, are applied using high vacuum sputter roll-to-roll coating technology. When the sensors are unavoidably a disposable item, such as for blood glucose sensors, this technology gives a clear cost and productivity advantage.

#### **High barrier layers for technical applications: OLED lighting and displays**

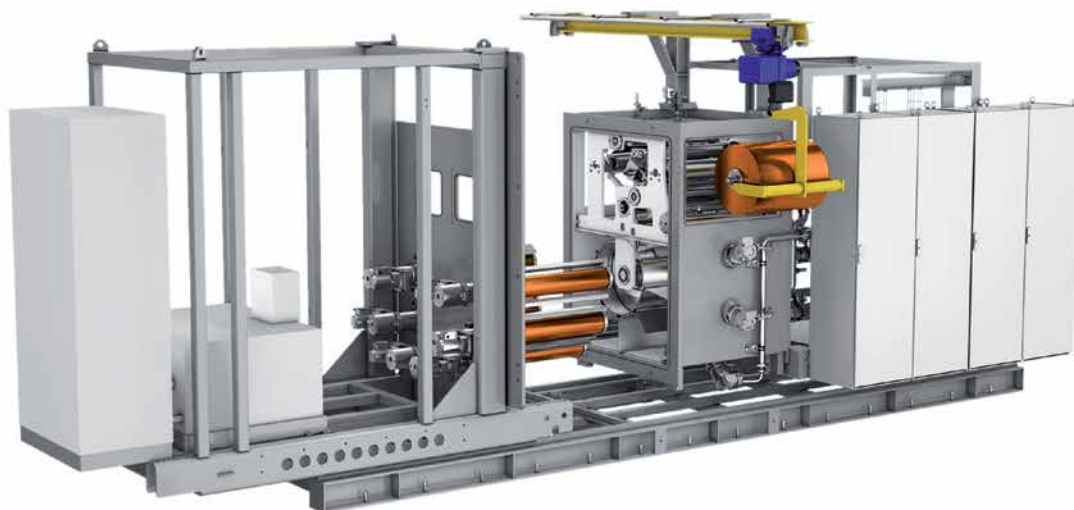
Many technical applications, for example OLED lighting or displays, have strict requirements with regards to the maximum oxygen and water vapor transmission rate of their encapsulation. High barrier values are needed to prevent the single layers from being damaged and to maximize the overall lifetime of the complete device. Multilayer high barrier films on flexible substrate, for instance based on  $\text{SiO}_2$  or  $\text{Al}_2\text{O}_3$ , are state-of-the-art technology realized by high vacuum sputter roll-to-roll deposition.

#### **Energy storage layers: Solid-state lithium battery (SSLB)**

The need for high-capacity batteries for handheld and mobile devices has increased. Today, high-vacuum sputtering is the key technology for creating the required fine layer structures for reaching the highest possible energy storage capacity per battery weight. Hence all crucial layers in solid-state lithium batteries (SSLB), which is today's leading battery technology, are created with the help of roll-to-roll vacuum sputtering technology.

# LEYBOLD OPTICS FLC vacuum coater.

## High-vacuum sputter roll-to-roll coating system.



**New technologies and markets for flexible electronics have grown rapidly. Today, we can find a wide range of applications and a huge variety of final products: flexible and wearable electronics, sensors, RFID tags, smart glass, intelligent packaging and many others. Applications with high-quality and low-resistivity copper or with TCO-layers and structures, for instance Bühler's roll-to-roll vacuum deposition solution, offer a very competitive and cost effective thin-film coating technology.**

### **Flexible vacuum sputter roll-to-roll coating**

Bühler's new high vacuum sputter roll-to-roll coating system LEYBOLD OPTICS FLC successfully bridges the gap between productivity and versatility while meeting the requirements of today's and future markets.

The LEYBOLD OPTICS FLC is the perfect choice for production and R&D purposes. The almost unlimited possibilities in the arrangement of the up to six rotatable magnetrons and the machine's capability to apply a huge variety of in-situ measurement sensors enables the machine to be outstandingly productive in a manufacturing environment, while being very versatile and flexible when used as an R&D machine.

This also makes the machine the first choice for applications such as ITO films, flexible printed circuit boards (FPCB), low-e or smart glass. The rotatable magnetrons, the maximum coating width of 650 mm and a possible substrate roll diameter of 500 mm are the basis for high productivity.

Furthermore, the optional gas separation between neighboring process sections allows a huge variety of conceivable layer stacks of metals and dielectrics to be deposited in one pass.

In addition to the ability to run reactive sputter processes alongside non-reactive sputter processes, the LEYBOLD OPTICS FLC can be equipped with various in-situ sensors for continuous and accurate monitoring of the desired physical layer properties, such as layer resistivity, reflectance or transmittance.

### **Applications**

- ITO films
- Flexible printed circuit boards (FPCB)
- Medical sensors
- Solid-state lithium battery (SSLB)
- EC smart glass
- Low-E/solar control films
- And much more





Bühler's roll-to-roll vacuum deposition solutions enable the development and production of sophisticated thin-film applications

#### Customer benefits:

##### ■ Outstanding productivity, high system versatility and flexibility:

- Up to six rotatable magnetrons with DC, DC unipolar pulsed, DC bipolar pulsed or MF power supplies
- Gas separation between process sections
- Metal and reactive sputtering

##### ■ Consistently brilliant end product quality thanks to intelligent machine concept:

- Lowest particle generation (sputter up orientation of magnetrons)
- Ease of maintenance and cleanability

- Scratch and wrinkle-free winding (closed-loop tension control)
- Plasma pre-treatment (optional)
- Temperature-controlled coating drum (-15 to +80°C)
- Turbomolecular pumps and cold traps for high-vacuum pumping
- In-situ layer measurement systems

##### ■ Easy maintenance and high machine uptimes thanks to smart and robust design.

##### ■ Minimum facility floor space thanks to compact design.

#### Key figures of the system

- Typical substrate types are PET, PEN, PI, Al, SST, Copper, Flexible Glass
- Substrate roll diameter up to 500 mm
- Coating width up to 650 mm
- Typical deposition materials:
  - Metals: Ag, Al, Cu, Cr, NiCr, Ti
  - Dielectrics: AZO, ITO, SiO<sub>2</sub>, SiN, SnO<sub>2</sub>, Nb<sub>2</sub>O<sub>5</sub>, TiO<sub>2</sub>
- Winding speed: 0.1–25.0 m/min
- Winding tension: 25–600 N
- Space requirements: Approx. 70 m<sup>2</sup>

#### Options

- Plasma pre-treatment
- IR-heater for substrate degassing
- In-situ layer measurement systems:
  - Resistivity
  - Reflectance
  - Transmittance
- And much more

#### Available machine sizes

LEYBOLD OPTICS FLC 400 / 650 / 1600 / 2000 \*

\* Max. coating width in mm

# LEYBOLD OPTICS FLC vacuum coater.

## Applications and processes.

### One machine – various applications

The following table shows how easily layer stacks for different applications can be realized with the LEYBOLD OPTICS FLC by simply changing the target materials and process gases, without the necessity for considerable modification of the high vacuum coating system itself.

Application	Process section 1	Process section 2	Process section 3	Process section 4	Process section 5	Process section 6
Flexible printed circuit boards (FPCB)	NiCr		Cu	Cu		Cu
Low-E films	Sn		Ag	NiCr		Sn
Invisible ITO films	Si	Si	Nb <sub>2</sub> O <sub>5</sub>	Si	Si	ITO
Power supply type	DC bipolar pulsed		DC	DC bipolar pulsed		DC
Gas separation	1		2	3		4

Used process gases: ■ Ar ■ Ar, O<sub>2</sub> ■ Ar, less O<sub>2</sub>

### Application information – low-E car glazing

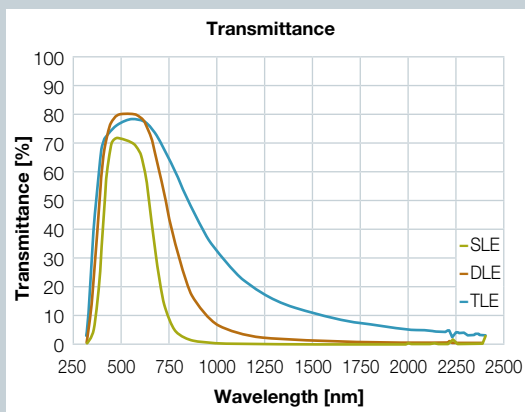
Car glazing with integrated low-E foil helps to reduce cars' fuel consumption by minimizing the energy which is used for air conditioning (about 20–30 % less AC energy).

Less fuel consumption also means less weight which needs to be transported for covering the same distance. By saving energy and weight low-E foil can help to minimize the CO<sub>2</sub> emissions of vehicles and protect our environment.

### BÜHLER low-E layer stacks – perfectly fulfilling the industry's requirements

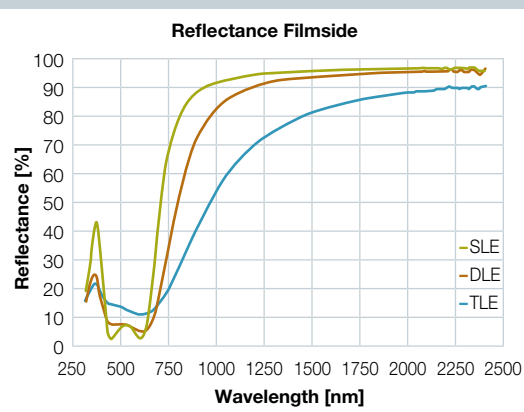
- Highly visible transmittance
- Low sheet resistance and emissivity
- Reflectance color neutral or bluish
- Small changes when heat treated
- Excellent chemical and mechanical durability
- Nitrogen-free sputter processes

### Performance examples



#### Transmittance T<sub>v</sub>

Single Low Emissivity (SLE) ≥ 81 %  
 Double Low Emissivity (DLE) ≥ 79 %  
 Triple Low Emissivity (TLE) ≥ 68 %



#### Reflectance color values (L\*, a\*, b\*)

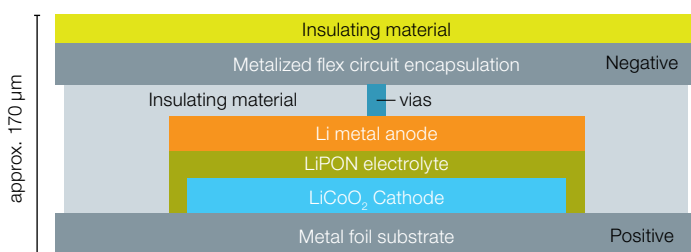
SLE: -2 ≤ a\* ≤ 0    -6 ≤ b\* ≤ -2  
 DLE: -4 ≤ a\* ≤ -1    -9 ≤ b\* ≤ -5  
 TLE: -1 ≤ a\* ≤ 2    -5 ≤ b\* ≤ -1



### Application information – thin-film lithium battery

The availability of today's lithium battery technology was crucial for the development of many of today's new products, trends and applications. Without the ability to store sufficient energy in a small volume with little weight, devices like smart phones or wearable devices would be unthinkable. Furthermore, future and fast-growing markets, like hybrid or electric vehicles, will generate a strong need for even lighter and smaller high-energy-density thin-film batteries. This trend in the requirements for thin-film batteries makes vacuum deposition one of the major battery manufacturing technologies of today and in the future.

The schematic (below) shows the cross section with the main functional layers of a conventional flexible thin film solid state lithium battery. Intermediate layers, which can of course drastically improve and influence the device's performance, are not illustrated. For instance like gold (Au) which can be used for minimizing the power losses between cathode ( $\text{LiCoO}_2$ ) and current collector (metal foil substrate, e.g. Cu).



In the table on the right the thin-film materials typically used and the corresponding vacuum deposition technologies are listed. It can be seen that almost all of the

Thin film layer material	Typically used vacuum deposition technology
Co	DC sputtering
Ni	DC sputtering
Au	DC sputtering
$\text{LiCoO}_2$	DC pulsed or RF sputtering
LIPON	DC pulsed or RF sputtering
Li	Thermal evaporation
$\text{Li}_3\text{PO}_4$	DC pulsed or RF sputtering
AlON	DC pulsed or RF sputtering

layers used in flexible batteries can be realized by high vacuum sputtering technology. Furthermore, especially when it is about the optimum layer and final device performance, vacuum deposition and therefore the LEYBOLD OPTICS FLC is the right technology to choose.

### Advantages of vacuum deposited thin-film layers for flexible batteries

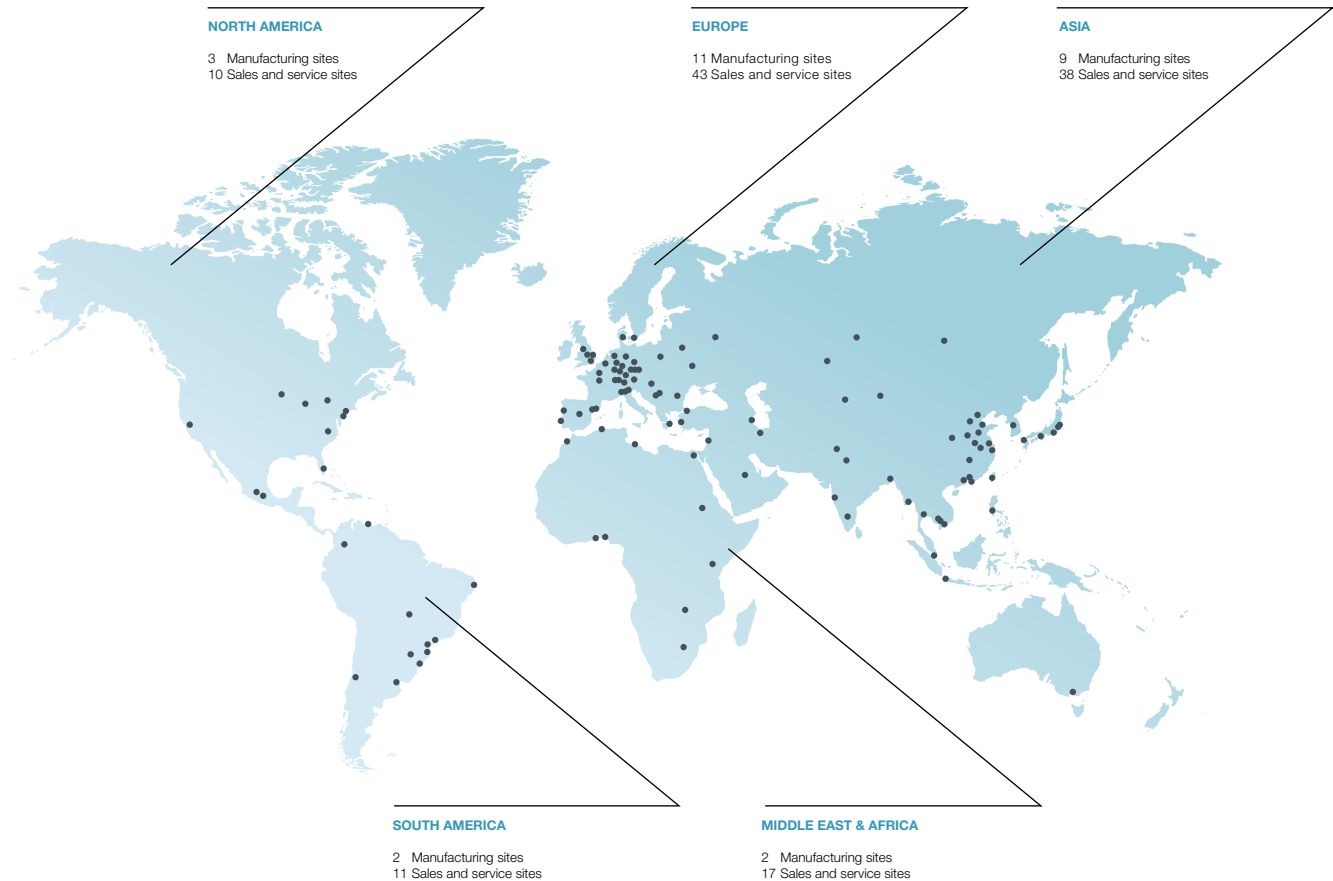
- High-energy storage capacity due to perfect layer structure
- Low overall device weight because of thin-film technology
- Long battery cycle life and stability thanks to very few layer defects
- Increased safety thanks to solid-state electrolyte
- Low manufacturing cost based on highly productive roll-to-roll manufacturing



# Customer support and services.

## Always on hand to sustain your business.

### Global presence of Bühler



Bühler Leybold Optics' relationship with its customers does not end once the machines start production — it is a continuation and an extension of a close partnership. Wherever Bühler Leybold Optics machines are, one of the worldwide centers of competence is close to your site. The company therefore ensures that you receive the right support so that your machines deliver perfect product quality and benefit from high uptime.

Bühler's worldwide customer service as well as the fast delivery of replacement and wear-and-tear parts are just two important aspects of customer support. Preventive maintenance and inspection together with machine re-conditioning and upgrading round off the after-sales services. Contact information for Bühler's worldwide

services can be found on the company's homepage: [www.buhlergroup.com](http://www.buhlergroup.com).

Bühler Leybold Optics' service commitment to customers guarantees fast identification of parts, components or consumables, tracked and logged to ensure readiness for shipment within one day so that fast delivery to any country in the world is possible.

Bühler is a specialist and technology partner for ophthalmic optics coating solutions. With its expertise and over 150 years of experience, Bühler continuously rolls out unique and innovative solutions for its customers, helping them achieve success in the marketplace. The Bühler Group operates in more than 140 countries and has a global payroll of over 10,000.



## HELPDESK

- Always available during German, US and Asian business hours: contact the Helpdesk of your local service or at headquarters. The phone numbers are:  
EUROPE: +49 6023 500 777 (or +41 71 955 1900)  
USA: +1 919 657 7100  
CHINA: +86 (10) 67803366-537
- Problems are analyzed promptly via remote diagnosis

## FITNESS CHECK

### Preventive maintenance and inspection

- Full check of all machine functions
- Comprehensive, customer-specific maintenance service for continued optimal productivity and cost savings when repairs are needed
- Monitoring of the maintenance cycle allows timely appointment scheduling

## FLEXCARE / TOTALCARE

### Customer service and consultation

- Flexible and adapted to your needs, these service contracts consist of an annual contingency allowance of hours, selectable in different packages – BRONZE, SILVER and GOLD
- Qualified service engineers worldwide
- Quick response times through local resources and close cooperation with suppliers

## REPLACEMENT PARTS AND ACCESSORIES

- Worldwide replacement-part-management network, shipment of main parts in one day
- Guaranteed original parts for safe production and highest uptime
- Proven quality for accessories for best qualitative products
- The parts are manufactured by Bühler Leybold Optics or by first-class material specialists like UMICORE with highest availability

## RENOVATION OF MACHINES AND ASSEMBLIES

- Software optimization
- PLC and HMI exchange
- Full exchange of electric cabinet and PLC and HMI exchange
- Improved cycle times
- For Leybold Optics products and other machines

## OVERHAUL AND UPGRADES

- Upgrade to new components
- Machine extensions
- Improved performance and longer equipment life
- Used machines with «buy back option» for all Leybold Optics products and other machines

## RELOCATION OF MACHINES

- Relocation of one machine or a full production site to another site

## TRAINING

Thoroughly trained and motivated personnel will raise the quality standard that you achieve in utilizing Bühler equipment and will ensure your long-term success. Would you like to increase your employees' level of training to the latest standards in maintenance and operations? To achieve this, Bühler offers you various training courses in a specialized Training Center. In a group of five persons and more, training can be tailored to specific requirements.

- Safety and regulations
- Basics of vacuum technology
- Basics of coating tools
- Basic theoretical training in equipment and technology
- Practical training in preventive maintenance
- Practical training in machine operation
- In-depth training on EB-Gun, Ion source, optical or physical measurement units and process analysis, leak detection, etc.

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