The future of capacitor web films:
versatile source capabilities for high-end applications.

Technology & Performance

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AIMCAL EUROPE
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In the region for the region. Bühler Leybold Optics shows global presence. Global market leader with strong local roots since 1860.

- Headquarters in Uzwil, Switzerland.
- 10,000 employees, including 500 trainees.
- Turnover 2,332 bn CHF in 2014
- 20 manufacturing sites and 24 service stations around the world.
- 70 sales & service companies.
- 100 % family owned.
- Innovation leadership in food and grain technology, die casting, optical sorting, pelleting.
LEYBOLD OPTICS is one of the world's leading providers of vacuum coating technology.

**LEYBOLD OPTICS Product Portfolio**

**Optics**
- Precision Optics
- Ophthalmics
- 3D Coatings

**Large Area Coating**
- Glass (Arch & Auto)
- Display
- Photovoltaics
- **Web (roll 2 roll)**
- Special Systems

**Customer Support**
- Parts & consumables
- Components
- Service
- Upgrades

High Performance Optical Coatings
Organization chart:

Divisions & Business Units.

GRAIN & FOOD PROCESSING
Grain Milling & Grain Logistics
Pasta & Extruded Products
Chocolate, Cocoa & Coffee
Nutrition Solutions
Feed & Biomass
Sortex & Rice

SALES & SERVICES

MANUFACTURING & LOGISTICS

ADVANCED MATERIALS
Die Casting
Grinding & Dispersion
LEYBOLD OPTICS
Leybold Optics a part of Bühler since 2012. 
164 years of experience in vacuum technology.

- Production site and headquarters in Alzenau (Germany).
- Other production sites in Beijing (China), and Cary (USA).
- 3000 systems total installed base.
- Innovation leadership in key areas such as sputtering, PECVD and plasma assisted evaporation.
# Packaging activities

<table>
<thead>
<tr>
<th>2001</th>
<th>2016</th>
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<tbody>
<tr>
<td>SEC for security applications</td>
<td>PAK 2100 T</td>
</tr>
<tr>
<td>PAK Update paper-metalizing machine</td>
<td>PAK 3700 T+</td>
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## Machine types (sizes), Performance, Productivity

### SEC
- Holographic & security application

### PAK T+, PAK +
- High rate deposition,
- transparent films,
- Plasma Assisted
- Deposition of Al / AlO_x
- Defect-free metallization

### FLC 650
- High-vacuum sputter roll-to-roll coating machine for flexible electronics applications like solid-state lithium batteries, biosensors, smart glass and many others.

## Activities at a glance

- SEC
- PAK T+, PAK +
- FLC 650
### Leybold Optics value proposition

<table>
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<th>Product</th>
<th>Application</th>
<th>Differentiation</th>
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<tr>
<td><strong>PAK +</strong>&lt;br&gt;High-rate Aluminum coating by Thermal Evaporation</td>
<td><strong>PAK T and T+</strong>&lt;br&gt;Aluminum Oxide (Transparent Barrier) coating by Plasma Assisted Thermal Evaporation</td>
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**Application**

- **PAK +**
  - Aluminum coating for water –and oxygen- barrier improvement
- **PAK T and T+**
  - Aluminum-Oxide coating - water & oxygen- barrier improvement, visibility

**Differentiation**

- **Highest productivity:**
  - Process speed of 15 m/sec @ 2.2 O.D. (Optical Density)
- **Highest performance:**
  - WVTR & OTR $< 1$ PET
  - WVTR $< 3.5$ BOPP
  - Transparency : 92%
1. System is designed for one-sided deposition of thin films onto flexible substrate materials like PET by means of magnetron sputtering.

2. The system consists of a vacuum chamber with the winding system and the sputter sources, a high vacuum pumping system and the system control.
3. The system is equipped with up to six magnetrons, that are mounted onto a movable chamber flange and arranged around a temperature-controlled coating drum.

4. This flange can be moved away from the chamber for easy target exchange, service and maintenance.
FLC 650: Solutions for large area coatings.

Configuration:
1. reactive AR-coating of TiO$_2$ and SiO$_2$ on PET
2. Film winding system >70 µm PET
3. 4 rotatable magnetrons including corresponding gas supply and one set of shield.
4. Bipolar pulsed power supply: 2 x 30kW DC: (→ 2 magnetrons are connected as “MF-couple”)

Additional features:
- Lambda sensor for O$_2$ partial pressure control for reactive sputter processes
- In-situ transmittance and reflectance measurement
- Plasma pre-treatment
- Gas separation between process sections
- Voltage and frequency adaption kits
- additional set of shieldings
**Agenda: The future of capacitor web films:**

1. **Versatile capacitor web coater**
   multiple sources Ag, Zn, Al, process diversification

2. **Process & Product optimization, process control with Dual In Situ Sensor**
   Thin substrate metallization, web handling & management of thin substrates (e.g. 2.7µm BOPP).

3. **Al heavy edge: Deposition and film analysis (Optimization of process control)**
   Al amount, length of deposition, flexibility of machines, Application for DC Link capacitors.

4. **Enhanced coating uniformity, (MD, TD distribution, Al-feed speed)**
   Optimized boat configurations for high productivity, Advanced process control

**GOAL**
Improve the performance of final product
Versatile capacitor web coater

„The implemented technologies for the reduction of substrate & metal defects, increasing process and machine efficiency,

The trend: targets the production of high quality metallized films with main focus on cost effectiveness and process reliability, this is what is required now and continuous improvement for the future“
Versatile capacitor web coater

winding section

coating section

Schematic of web coater
Versatile capacitor web coater

Thermal evaporation of metal layers

The general concept of the system combined with the comprehensive selection of options, allows the production of an unlimited range of metalized electrodes

- zinc with silver pre-nucleation,
- zinc/aluminium composites and
- aluminium bilayers films for standard- to high-end capacitors.

Machine concept is based on a modular design with

- standard &
- high-end configuration (standard configuration incl. options), both available at 650 mm & 900 mm coating widths.
Versatile capacitor web coater

Metal evaporation at 3 station sources: Zinc, Silver, Aluminium

These vacuum metallizers are capable of or adapted for turning easily from one process to another of the various metals available for the production of capacitor films.
## Agenda

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**Product and Process Optimization**

[A] Plasma pre-treatment

**Benefit:** improved adhesion of subsequent thin metal layer & removal of defects

**Pre-treatment:** bombardment of film surface with plasma particles

**Surface activation:** cleavage of the chemical bonds (cleaning, radical formation, bond formation).

[B] Super Bias

**Benefit:** Higher productivity, improved product quality

**Electron Beam Bias [Super Bias]:** subjecting charges on film to improve contact to coating drum. → better substrate cooling.

[C] Post-treatment

**Benefits:** discharge, removal of implanted electrons, degeneration of static charges surface cleaning and permanent back film surface modification

**Double side cathode** on film and metal side (Quadrupole) → charge discharge
Product and Process Optimization

Free Margin Evaporator (FME)

Cylindrical Evaporator Tube (conventional method)

- Large, excess amount of oil heated.
- Degradation of oil during processing.
- Temperature regulation dependent upon oil level.
- Laborious refill & unable to refill during process.
- Contamination of chamber and waste of oil.
- Limitations of free margin width.

Free Margin Evaporator (Leybold Optics Innovation)

- Fast start, & stop of masking
- Optimum amount of masking oil required
- Minimum oil consumption
- No excess oil heated in machine (No waste oil)
- Free margin edge steepness
- No contamination of chamber & rollers at start/stop
- Easy refill of oil during process

Oil cost saving / year: 45%
Product and Process Optimization

Dual In Situ Sensor (Real time process control)

- Reduce scrap and tolerances (homogeneity and metal thickness)
- Real time quality control and subsequent process action.
- Size resolution for detection

Benefits:

1) Scrap reduction by real time control
2) Free margins are measured simultaneously
3) Real time control of layer uniformity across and along the web
4) ‘100%’ quality control of film quality
5) No moving parts, simple adjustment.

Optical density [OD]: \(0.3 - 3\)
Wavelength [nm]: \(640\)
Probe frequency [kHz]: \(20\)
Geometrical resolution in MD @ 20 m/s [mm]: \(3\)
Product and Process Optimization

Dual In Situ Sensor (Real time process control)

→ Visualization: Screen display of Densitometer and Free Margin CIS

1. Improved process cross control → homogeneity
2. Hardware; industrial PC
3. Process capabilities: registration at 20 kHz
4. Real time analysis
5. Ease of fault diagnostics with PC
6. Retrofit to all web coating systems
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Aluminium Heavy Edge:

General information

Properties – higher current carrying capability as well as lower dissipation, self-healing at high frequencies.

Applications: DC Link capacitors, railway, solar plants, wind power units & automobile industry

1. Replace Al/Zn capacitors with Al only (single metal evaporation)
2. Easier to process only Al metallization
3. Reduction of metal weight on polymer film
4. Product quality; contamination or “tin-canned” rolls
Aluminium Heavy Edge

Fabrication of Al –HE in a web coating machine

Drawback:

→ *Al-growth on “shield aperture” impairs metallized length and width*  
  *(unsymmetrical widths of HE region).*

- Max. length available in the market: *ca. 10 km*.
- Buhler technology → *over 30 km* achieved with symmetrical width of HE
- Proven technique to prevent “blocking” of shield profile
- High automation control of diverse parameters → reliability and productivity
Aluminium Heavy Edge

Optimization of process control: setting of Al-feed and process control using DISS at a fixed heavy edge position, MD & TD control.

Evaluation:

Profile as requested

Results obtained
Aluminium Heavy Edge

Evaluation of process stability: 95%

Flexibility to switch from Al/Zn to Al heavy edge hardware: 120 sec.
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**GOAL**

Improve the performance of final product.
Enhanced coating uniformity

Improving the uniformity of deposited Al and optimizing edge trimming for excellent final product performance

a) Positioning of boat height (distance to coating drum)

b) Configuration of boats (arrangements)
Enhanced coating uniformity

a) Positioning of boat height (advanced height adjustment)

Coating drum
distance to boat
180 mm or 210 mm
Enhanced coating uniformity

a) Configuration of boats

- Standard evaporator
- Advanced 1 (option, high-end configuration)
- Advanced 2 (option, high-end configuration)
Enhanced coating uniformity

→ Improved uniformity & reduced edge trimming has been achieved for the CAP machines.
→ 97% speed resolution, elimination of wire pulse characteristic

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<th>Advanced 2</th>
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<td>180 mm</td>
<td>6.7 %</td>
<td>5.7 %</td>
<td>3.8 %</td>
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<td>Boat height</td>
<td></td>
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<tr>
<td>210 mm</td>
<td>5.6 %</td>
<td>4.8 %</td>
<td>2.5 %</td>
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Results based on 2.0 OD, Aluminium, 10m/s web speed
Data registered at MD /TD for 3 mm resolution – 40 km web
### Summary – technology & performance of capacitor machines

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