VACUUM COATERS PRODUCTION AND ENERGY EFFICIENCY: NEW DESIGN AND INDUSTRY EXPERIENCE

by

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Vacuum Coating leading performance factor

Energy and Material savings strategy

Quality and Barrier Properties of metallized film

A case study: BOPP Metallizing at highest industry standard

Conclusions
High Performance Vacuum Coating: The project Motivation (1)

✓ A Global Market for metallized Films.

✓ A Moderately but ever growing demand.

(Source AWA, 2015)
In recent years, Film Producers invested, the most, in new Metallized Film Lines.
High Performance Vacuum Coating: *Production Efficiency* (1)

**KEY PRODUCTION EFFICIENCY FACTORS:**

- **ACTUAL METALLIZATION SPEED**
- **UPTIME vs. DOWTIME**
- **PRODUCTION MIX vs. CAPACITY**
- **WASTES**
The effects of changing factors on the production change «sensitivity analysis».

Basic results:

- An (obvious) high sensitivity to web width balanced by a detrimental effect of low capacity utilization.

- Web speed and run length are significantly important but downtime reduction looks crucial as well.
The effects of changing factors on the cost change «sensitivity analysis».

Basic results:

- Increasing the machine size has limited effect on unit costs reduction (logistic complexity).
  - Again, it is very crucial the high capacity utilization factor.

- The relatively low waste impact is true for film producer (film scrap reprocessing). Wasting «high» cost purchased film material is potentially more critical for film converters.
Current state-of-the-art

• 1000 m/min @ 2 OD +/- 5% (Pet/BOPP)

KEY POINTS:

✓ Evaporation system

✓ Winding mechanism & tension control

✓ Film cooling efficiency
SOLUTIONS FOR HIGH PRODUCTION SPEED

- High capacity aluminium evaporation system

- Narrow-spaced evaporators for intense vapour density.

- Staggered lay-out for deposition uniformity.

- Stable Aluminium feed and supported-electrically isolated wire path to guarantee vibration and spitting-free evaporation.

- Balanced power distribution to avoid electromagnetic interference from the high current flow (> 1000 A each).

- Integral system cooling to withstand high intensity heat and long metallization run.

- **1000 m/min @ 2 OD +/- 5%

- **Al > 9 gr/min/boat ~ 0.1 gr/m²**
SOLUTIONS FOR HIGH PRODUCTION SPEED

- Film winding mechanism and Tension control

- Web Path designed for steady film support and guide.
- Low inertia and High modulus rollers materials for firm web path control at high rotation speed (e.g. carbon fibers).
- Smooth roller surface finishing (e.g. ceramic coated) for winding-induced defects minimization.
- Latest generation winding control with multiple differential tension zone.
- Features to handle different properties materials such as:
  - Pre-set winder oscillation for thermally sensitive films.
  - Varied bow and variable configuration spreading to set for stretchable or rigid materials.
SOLUTIONS FOR HIGH PRODUCTION SPEED

- Film cooling Efficiency
  - High cooling capacity chilled rollers (-20°C).
  - Controlled gas injection for efficient heat exchange from film and chilled rollers.
  - 1000 m/min @ 2 OD +/- 5%
  - Nearly isothermal metallization (deltaT ~ 0 – 3 °C)

To avoid Heat generated defects

✓ High cooling capacity chilled rollers (-20°C).

✓ Controlled gas injection for efficient heat exchange from film and chilled rollers.
Production Efficiency Factors: *Minimizing Downtime*

- EFFICIENT & CONSISTENT VACUUM TIME
- CONVENIENT & SAFE CLEANING OPERATION
- ROLL HANDLING, FILM THREADING etc.
SOLUTIONS FOR MINIMUM DOWNTIME

EFFICIENT & CONSISTENT VACUUM TIME

- Current benchmark: evacuation time in 10 min at «industrial standard» conditions

- High Capacity pumping Group.
- «Vacuum zoning» with limited volume deposition area and Diffusion pumps close to process and protected from debris.
- Variable speed motors for soft starting and power saving.
- Last generation Cryogenic system – higher condensation capacity.
Examples of Solution

✓ Evaporation system is the most critical part: accessibility to clean and maintenance is key to production consistency and efficiency.

✓ Shields collect large amount of debris especially during long run and need regular cleaning.
Production Efficiency Factors: Waste material reduction

- Industry target: <3% film waste (extrusion - metallization - slitting)

- FULL PRODUCTION MONITOR AND AUTOMATIC CONTROL.
  - HMI: Supervisor
  - Live cam for chamber inside
  - Aluminium thickness OD
  - Defect monitor

- Towards «zero off-spec» material during metallization start and stop (through «transient automatic control»).
Production Efficiency Factors: *Plasma Treatment for high film metallization*

- **Industry target:** Actual plasma power >5 Kw/m

- Some film materials demonstrated to be positively affected by higher energy dose (400 – 500 Joule/m²).

- Upgraded treater and Power supply design can deliver higher energy with high response arc detection and control.
Electrical Energy: a major metallization cost item..................

Approximately one half of all consumables cost.

One third of all metallization costs.
Multiple heating and cooling periodical sequences.

An high temperature process which requires a quick, and, somehow redundant cooling system.

High Performance Vacuum Coating: Energy Efficiency (2)
ENERGY SAVING KIT: 10-15% energy saving.
ROI: < 1 year.
NORDMECCANICA METALLIZERS PERFORMANCE

Energy Saving Configuration’s Key Factors

- Diffusion pumps heating control –
- Holding pump
- Cryogenic system equipped with saving energy module
- Chilling unit tunable capacity
A case Study: High Barrier BOPP

Basic Facts about Bopp:

✓ Bio-Oriented PolyPropylene is the most used polymer film for Flexible packaging approx 60% of all plastic films (source AWA 2012).

✓ Bio-Oriented PolyPropylene has a very high moisture barrier and a medium level oxygen barrier.

✓ Bio-Oriented PolyPropylene is produced in multiple composition and functionality. Barrier properties for plain and metallized film reflect the base film variability.

✓ Increasing Metallized BOPP barrier properties (especially O2TR) represents a general industry trends.
A case Study: High Barrier BOPP

BARRIER PROPERTIES (examples from major manufacturers)

Source: Published data from web site and brochures.
High Performance Vacuum Coating: *Quality and film Barrier Effects (3)*

A case Study: High Barrier Metallized BOPP

Factors for Barrier improvement:

- **✓ Base Polymer Film**
- **✓ Aluminium collecting film special skin**
- **✓ Plasma (in vacuum) pre-treatment**
- **✓ Machine design and Process Parameters**
High Performance Vacuum Coating: Quality and film Barrier Effects (4)

Note: Film 1/2/3 represent standard film material of a single manufacturer (co-extruded/3-layers Bopp).
High Performance Vacuum Coating: Quality and film Barrier Effects (5)

Note: Film 1/2/3 represent standard film material of a single manufacturer (co-extruded/3-layers Bopp).
The Factors influence

From a Factorial Analysys: 3 Factors – 2 Levels:

O2TR depends on:  
PLASMA 25%  
FILM TYPE 46%  
ADHESION SKIN: 28%

WVTR depends on:  
PLASMA 90%  
FILM TYPE 7%  
ADHESION SKIN: 3%

<table>
<thead>
<tr>
<th>Factors</th>
<th>LEVEL 1</th>
<th>LEVEL 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLASMA</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>FILM TYPE</td>
<td>Type 2</td>
<td>Type 3</td>
</tr>
<tr>
<td>SKIN Adhesion</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
FILM CHARACTERISTIC AND PLASMA

- This project confirms the common wisdom that the film characteristics determine the barrier properties … but it shows a general positive effect of plasma treatment on O2TR & WVTR.
- The plasma contribution to barrier changes depending on film type.
- An adhesion promoting layer in film blend has a visible effect on improving barriers, too.
- Film 3 (representing a popular Bopp product) showed a dramatic effect of plasma treatment on moisture barrier.
## A case Study: High Barrier Metallized BOPP

### Machine design and Process Parameters

Three –generation metallizers: a results-based comparison.

<table>
<thead>
<tr>
<th>Key item</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1998</td>
<td>2004</td>
<td>2015</td>
</tr>
<tr>
<td>Max speed</td>
<td>900 mpm</td>
<td>1000 mpm</td>
<td>1100 mpm</td>
</tr>
<tr>
<td>Evap. syst</td>
<td>Design 1</td>
<td>Design 2</td>
<td>Design 3</td>
</tr>
<tr>
<td>Winding/Tension control</td>
<td>Design 1</td>
<td>Design 1</td>
<td>Design 2</td>
</tr>
<tr>
<td>Film cooling</td>
<td>Main drum</td>
<td>Main drum+p.chiller</td>
<td>Main drum+post ch.</td>
</tr>
<tr>
<td>Plasma</td>
<td>no</td>
<td>First gen.</td>
<td>Latest gen.</td>
</tr>
</tbody>
</table>
High Performance Vacuum Coating: *Quality and film Barrier Effects* (9)

**A case Study: High Barrier Metallized BOPP**

<table>
<thead>
<tr>
<th>Key item</th>
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<tr>
<td>Year</td>
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<td>2015</td>
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</table>
The qualitative table of «Merit» gives general indications about the barrier determining factor. (Statistical factor analysis still in progress).

### Preliminary Factor Analysis for two popular bopp films

<table>
<thead>
<tr>
<th>Key Item</th>
<th>A</th>
<th>B+Pl</th>
<th>C</th>
<th>C+Pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Film Temp increase</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Metal surface integrity</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Metal uniformity</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

- Plasma: B<5 Kw/m, C>5 Kw/m
- Film Temp increase: A: 5-7 °C, B: 4 – 5 °C, C: 0 – 3 °C

**Graph**: The graph shows the relationship between the factors and the barrier effect, with Key Item L and P indicating different conditions or stages.
High Performance Vacuum Coating: Quality and film Barrier Effects (11)

A case Study: High Barrier Metallized BOPP

Equipment design and process conditions: a preliminary/qualitative Factor Analysis.

✓ The Progress of Machine Design and Components leads, in overall, to higher product quality
✓ Plasma treatment represents a key tool for achieving high barrier: the study on Bopp shows:
  ▪ Diversified but noticeable effect (on OTR or WVTR depending on material).
  ▪ The latest generation plasma (higher power density, uniform spatial power distribution and faster arc protection) shows consistent advantages over first generation one.

✓ The Barrier improvement is possibly determined by the other factors (tentative weighed effects):

<table>
<thead>
<tr>
<th>O2TR</th>
<th>WVTR</th>
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<tbody>
<tr>
<td>*</td>
<td>***</td>
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</tbody>
</table>

▪ Film Cooling
▪ Surface integrity due to better film tension control and roller construction
▪ More uniform and, possibly, denser coating
CONCLUSIONS

-The presentation discussed three key aspects of a state-of-the-art high efficiency metallizers:

- High Productivity
- Energy Saving
- Product quality, in particular high barrier Film

Data collected from months of metallized film production line have been analysed to identify the barrier improvement factors, including shop level comparison among different generation machines (full data factor analysis still in progress)

ACKNOWLEDGEMENT

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