Production Proven Vacuum Web Coating System with High Process Flexibility for Robust and Environmentally-Friendly Transparent Barriers

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Web Coating Group

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Outline

- Transparent Barrier Market
  - Environmental Sustainability
  - Vacuum Based Processes for Clear Barrier
  - Reactive Al - Evaporation
  - Benefits of the New System
  - Process Performance
  - First Products based on New Processes
  - Summary & Conclusions
Transparent Barrier Market Overview

<table>
<thead>
<tr>
<th>Material</th>
<th>2005</th>
<th>2006</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVdC</td>
<td>224.2</td>
<td>229.5</td>
<td>255.5</td>
</tr>
<tr>
<td>EVOH</td>
<td>215.0</td>
<td>231.9</td>
<td>335.7</td>
</tr>
<tr>
<td>PEN</td>
<td>10.5</td>
<td>11.1</td>
<td>14.6</td>
</tr>
<tr>
<td>PPCs</td>
<td>11.3</td>
<td>12.0</td>
<td>16.0</td>
</tr>
<tr>
<td>SBCs</td>
<td>24.4</td>
<td>25.5</td>
<td>31.6</td>
</tr>
<tr>
<td>Other Polymers</td>
<td>5.5</td>
<td>6.1</td>
<td>10.0</td>
</tr>
<tr>
<td>Metal Oxide Coatings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AlOx</td>
<td>12.0</td>
<td>13.0</td>
<td>17.0</td>
</tr>
<tr>
<td>SiOx</td>
<td>15.0</td>
<td>17.0</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Flexible Packaging, 5,400,000 t/a [PCI, AMI 2007]

Metallizing [PP], 500,000 t/a [Brückner 2007]

Transparent Barrier, 1,030,000 t/a [Pira, 2006]

Metallizing [PP], 500,000 t/a [Brückner 2007]

Vacuum-deposited layers cover only a small fraction of the very large clear barrier market.
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## Comparison
### Vacuum Coated vs. Polymer Barriers

<table>
<thead>
<tr>
<th>Category</th>
<th>Polymer Transparent Barrier</th>
<th>Vacuum Coated Transparent Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer thickness</td>
<td>1-20µm</td>
<td>0.01-0.02µm</td>
</tr>
<tr>
<td>Environmental Concerns</td>
<td>PVdC in Discussion: banned by several major retailers</td>
<td>Much less waste material, no critical chemicals used in production</td>
</tr>
<tr>
<td>Recycling</td>
<td>More difficult with additional thick polymer layer</td>
<td>Better recyclability with oxide barrier of nanometer thickness</td>
</tr>
<tr>
<td>Biodegradable</td>
<td>No</td>
<td>Yes with biodegradable base films</td>
</tr>
</tbody>
</table>

Vacuum coating provides orders of magnitude thinner layers, leading to better sustainability.
Environment and Chlorine-Containing Plastic

Uncontrolled burning of chlorine-containing plastics like PVdC can generate dioxin.

Formation of toxic chemicals including dioxin-related compounds by combustion from a small home waste incinerator

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Available online 22 June 2005

presence or non-chlorine-containing plastic in combustion samples did not increase overall dioxin or dioxin-precursor emissions. In contrast, chlorine-containing plastic resulted in a several-fold increase in total polychlorinated dioxins
Aluminum Oxide

- AlOx is a natural, non-poisonous material
- No decomposition in incinerator, no poisonous composition products

Natural Al2O3: Corundum
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Vacuum-Based Clear Barrier Processes

Niche Application

High Speed Process

High Quality Process

High Speed High Quality Process

PECVD

Evaporation

Sputtering

Plasma Assisted Evaporation

EB-Heating

Boat Type

Smartweb™

Topmet Clear™
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Reactive AlOx Evaporation

Evaporation of Al + Oxygen Inlet = AlOx on Substrate
Reactive AlOx- Evaporation

Evaporation of Al in oxygen -
increase in optical transparency
decrease in barrier performance

1) Method for coating a flexible sheet with a transparent metal oxide layer, in which a metal is vaporized in a recipient and brought into contact with oxygen in the vapor phase and in which the metal oxide layer forming is scanned by means of optical sensors during coating and the process is controlled accordingly, characterized in that a slightly sub-stoichiometric quantity of oxygen, which does not lead to adequate transparency of the metal oxide layer thickness applied and control the rate of vaporization, the optical sensors are arranged in an area in which the layer has sufficient absorption for optical measurement owing to a proportion of unoxidised metal, and that, after determination of the layer thickness by means of the optical sensors, secondary oxidation of the layer is undertaken.

EP 0695815B1, February 23rd, 1995

Due to the narrow process window optical inline coating control is essential.
Plasma-Assisted AlOx Evaporation

New advanced process developed by and upscaled with the Fraunhofer FEP in Dresden
Process Window for Reactive Evaporation with Plasma Assistance

With plasma increased process window

- Optical Transparency
- OTR
- WVTR

oxygen flow, process pressure

Source: Fraunhofer FEP
Effect of Plasma Activated Evaporation: $\text{Al}_2\text{O}_3$ on PET

Plasma assistance creates denser and more uniform coating structure

Source: Fraunhofer FEP
Mechanical Barrier Stability of Plasma Assisted AlO$_x$ Process

- Improved Mechanical Stability due to Plasma Assisted Process
- Better Downstream Robustness

Source: Fraunhofer
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New Vacuum Web Coater Family
- TOPMET CLEAR™

TOPMET CLEAR – Based on proven TOPMET Standard Machine Type
Process Options for TOPMET CLEAR™

- Metallizing with base system
- All other Processes optional
- Also available for Field Retrofit

- Standard AI Metallizing
- High Barrier AlO$_x$ on PET (No plasma)
- High barrier AlO$_x$ on PET, OPP, PLA, CPP (HAD-plasma assisted process)

- Freshure® single coat, directly on polymer substrate
  or Freshure® topcoat on Al / AlO$_x$

Source: DSM
HAD plasma sources in TOPMET CLEAR™

AlOx Process Proven for Web Speed up to 8m/s and Coating Length 50,000m
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## Comparison of AlO$_x$ Barrier Properties

<table>
<thead>
<tr>
<th>Polymer Film Type</th>
<th>OTR [cm$^3$/m$^2$xdxbar] (23°C, 0 % r. h.)</th>
<th>WVTR [g/m$^2$xd] (38°C, 90 % r. h.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncoated Film</td>
<td>AIOx No Plasma</td>
</tr>
<tr>
<td>PET 12µm</td>
<td>110</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>BOPP 17µm</td>
<td>2000</td>
<td>300 to 1500</td>
</tr>
<tr>
<td>PLA 20µm</td>
<td>800</td>
<td>...</td>
</tr>
<tr>
<td>CPP 20µm</td>
<td>2500</td>
<td>...</td>
</tr>
</tbody>
</table>
## Comparison of AIO$_x$ Barrier Properties

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<tr>
<th>Polymer Film Type</th>
<th>OTR [cm$^3$/m$^2$xday] (23°C, 0 % r. h.)</th>
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</tr>
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<tr>
<td></td>
<td>Uncoated Film</td>
<td>AlO$_x$ No Plasma</td>
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<tr>
<td>CPP 20µm</td>
<td>2500</td>
<td>…</td>
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Without plasma: acceptable barrier on PET
With HAD-plasma: good barrier on all tested substrates
Properties of the Freshure® Coating

- Transparent crystalline Freshure® barrier coating
- Surface tension >50 dyne/cm for 6 – 12 month
- Printability: direct without primer
- Microwavable, biodegradable, FDA approved for indirect food contact
- Retortable as laminate: PET coated with AlOx/Freshure® with OPA/CPP

Source: DSM
## Gas Barrier Properties of Freshure® Coating

<table>
<thead>
<tr>
<th>Substrate</th>
<th>OTR [cc/m2/day, 23°C/0% RH]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOPP (20µm)</td>
<td>1600</td>
</tr>
<tr>
<td>BOPP/ Freshure® Single Coat</td>
<td>&lt;20</td>
</tr>
<tr>
<td>PET (12µm)</td>
<td>110</td>
</tr>
<tr>
<td>PET/ Freshure® Single Coat</td>
<td>&lt;2</td>
</tr>
<tr>
<td>PLA (20µm)</td>
<td>800</td>
</tr>
<tr>
<td>PLA /Freshure® Single Coat</td>
<td>&lt;40</td>
</tr>
<tr>
<td>OPA (15 µm)</td>
<td>40</td>
</tr>
<tr>
<td>OPA / Freshure® Single Coat</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Freshure® TOP COAT on AlOx: improvement of OTR up to a factor of 3 and mechanical protection resulting in better WVTR

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Products From the First Production Machine

- A First Product with new Transparent Packaging was commercialized in 2009. In the meantime different regional and national manufacturers in USA, as well as national manufacturers in Mexico and Columbia are using the new processes in laminated structures for applications like:
  - Breakfast cereal
  - Fried Snacks
  - Baked Snacks
  - Pork Rinds
  - Popcorn
  - Tortilla Snacks

- Coated Monolayer Film is used for
  - Soft Cookies
  - Hard Cookies

Source: Biofilm
Product Examples

Source: Biofilm
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Summary & Conclusions

New Vacuum Web Coater Family provides:

- Different Processes AlOx based on Thermal Boat Evaporation
  - Without Plasma for transparent Barrier on PET
  - With HAD-Plasma for robust transparent Barrier on PET, OPP, CPP, PLA

- Stable Processes based on Proven Technology

- Environmental-Friendly Coatings

- High Process Flexibility for Metallizing
  - different transparent AlOx-Processes (depending on required Coating Properties) and
  - Freshure® Top or Single Coating
Opportunities and Values for the Users

- New Alternative for High Performance Clear Barriers
- Enables Vacuum Coating Companies to Expand Their Markets
- Based on Proven Metallization Tools
The authors wish to thank

**Gabriel Durana, Biofilm**  
for providing information about product applications.

**Steffen Straach and Dr. Nicolas Schiller, Fraunhofer Institute FEP in Dresden**  
for providing of new, not already published test results of AlOx coatings.

**Dr. Shahab Jahromi, DSM**  
providing of new, not already published test results of Freshure® coatings.
Turning innovations into industries.