Primer Coatings on Paperboard for Extrusion Coating and Heat Sealing Applications

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What is a Primer?

Simply stated:
“A primer is a coating put on the surface of a material to ensure better adhesion”.

It promotes adhesion between substrates; such as Extrusion resins, Inks, Hot Melts and other types of coatings.

Products essentially are “Adhesion Promoters”.
Classes of Bonding

**Chemical** bonding relies on atomic attractions

![](image1.png)

Electron from hydrogen
Electron from carbon

**Mechanical** bonding relies on physically-interlocked molecules

![](image2.png)
Classes of Bonding

**Mechanical** bonding relies on physical anchors

The molecules with this type of bonding are similar to a chain link fence. The links are not directly connected to each other, but the molecules cannot be separated without breaking the loop/molecule.
Three Types of Chemical Bonding

- Ionic or Covalent Bond
- Hydrogen Bonding
- Van der Waals forces

Strongest Chemical Bond

Weakest Chemical Bond
Types of Chemical Bonding

Covalent Bond - Molecules share pair of electrons
Types of Chemical Bonding

Covalent or Ionic Bonding (Strongest Chemical Bond)

Oxidation or Ozone (Direct or Free Radical)

The addition of oxygen to a molecule and/or the removal of hydrogen from a molecule

\[(\text{CH}_2-\text{CH}_2)_n\]  

Polyethylene

\[\text{O}_2 \text{ or } \Delta \]

Oxidized Polyethylene
Types of Chemical Bonding

Hydrogen Bonding
(Second Strongest Chemical Bond)

Guanine

Cytosine
Types of Chemical Bonding

Van der Waals Forces:
(Weakest Chemical Bond)

Similar to a magnet
Polymers used as a Chemical Primer

Polyethylenimine (PEI)

Reactive groups are Primary and Secondary amines

Tertiary amines are the least reactive amines due to steric hinderance (blocked).
Polymers used as a Chemical Primer

Polyethylenimine (PEI)

Morphology is a Branched, Spherical, cationic polyelectrolyte

There is no Hydrogen Bonding (no oxygen) between the amine groups

This is the reason there is no cohesive strength for the coating

Can only apply a mono layer of the polymer
Polyethylene Adhesion

Oxidized Polyethylene Melt + Crosslinked PEI Primer

Bonded Product

Amide Linkage
Proper Steps for Priming

- **Pre-treat Substrate**
  (Proper Surface Energy for specific substrate)**
- **Ensure Proper Coat-weight**
  (PEI based primer: 0.025–0.03 dry lb/rm)
- **Ensure Complete Drying**
  (Exit Web Temperature between: 140–180°F)

** Paper/Paperboard only requires burn-off of the fibers “sticking up” on surface
Proper Steps for Priming

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  (Proper Surface Energy for specific substrate)

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** Paper/Paperboard moisture content will affect final coat weight.
Coating Methods

Meyer (wire wound) Rod
Coating Methods

Smooth Roll or Gravure Applicator (Direct)
Coating Methods

Direct Gravure Applicator with Enclosed Doctor Blade Chamber
Coating Methods

Reverse (Indirect) Smooth Roll Applicator
Gravure Cylinder – Cell Geometry
Specify Cell Volume or Wet Weight, not Line Count

**Chrome Roll**
- Easy to Clean
- Short Service Life
- Easily damaged

**Ceramic Roll**
(SEM micrograph)
- Long Service Life
- Can Clogg porous fiber surface
- Add 15-20% cell volume vs chrome

Centennial Celebration
Proper Steps for Priming

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** Paper/Paperboard backside flame treatment is typically enough to dry the primer.**
Extrusion Conditions

Optimizing Air Gap

Papers and Films:
Offset should be ~1 cm toward substrate.
Extrusion Conditions

Optimizing Air Gap

Offset

Substrate >>>

Air gap

Nip

Chill Roll

TIAG (msec) = [air gap (in) x 5000]/fpm

Recommended air gap time
80 – 120 msec
Extrusion Conditions

Optimizing Air Gap

Equations found in the Industry to calculate the TIAG:

Du Pont - TAPPI Technical Presentation (V. Antonov & A. Souter)
“Foil Adhesion with Copolymers: Time In The Air Gap”

DuPont – TAPPI Technical Presentation (B. Morris)
“Effect of Time, Temperature and Draw Down on Interlayer Peel Strength During Co-extrusion Coatings, Film Casting and Film Blowing”

Dow Chemical Company - Microsoft Excel Spreadsheet
“Time in the Air Gap Calculator” (Developed by M. Heard)
Extrusion Conditions

Air Gap Equations (Antonov and Souter) for Min/Max Line Speeds (10 inch Air Gap)

\[
\text{Time in the Air Gap (msec)} = \frac{[\text{Distance (in)}] [5000]}{[\text{Line Speed (mpm)}]}
\]

\[
\text{Line Speed (fpm)} = \frac{[\text{Distance (in)}] [5000]}{[\text{Time in the Air Gap (msec)}]}
\]

\[
\text{Min TIAQ Line Speed (fpm)} = \frac{[10 \text{ (in)}] [5000]}{[80 \text{ (msec)}]} = 625 \text{ fpm}
\]

\[
\text{Max TIAQ Line Speed (fpm)} = \frac{[10 \text{ (in)}] [5000]}{[120 \text{ (msec)}]} = 420 \text{ fpm}
\]
“Optimizing time in the air gap in extrusion coating for improved adhesion”

Paper given by Kelly Frey, Chevron Phillips 2012 TAPPI PLACE Conference

This presentation looked at the oxidation equations and looked for a correlation to bond performance.

Good adhesion was achieved even after exceeding the traditional working limit for the air gap equation.
Extrusion Conditions

Air Gap Distance vs. Line Speed

Variables used in the experiments:

✓ TIAG varied by line speed or air gap distance

✓ Continued experiment at various melt temp targets; 560°F, 580°F, 590°F, 600°F, 610°F, 620°F, 630°F

✓ 600°F showed little difference with parameter changes

✓ Line-speed constant (700 fpm) and changed air gap distance
  Minimum 6” to Maximum 14”

✓ Only adjusted line speed if air gap limited
  Increase line speed (decrease TIAG)
  Decrease line speed (increase TIAG)
Extrusion Conditions

TIAG to Achieve Full Fiber Tear

Melt Temperature (°F) vs. TIAG (ms)

- Blue line: 40 # Nat Kraft - LD
- Green line: 40 # Nat Kraft - Primed LD
- Red line: 70 ga OPP Primed - LD
- Blue line: 70 ga OPP - Primed HD
- Red line: 70 ga OPP - Primed LL

Not able to achieve bond below 580 °F

K. Frey 2012 PLACE
Coatings on Paperboard for Heat Sealing Applications

New Technology

Packaging Source Reduction Through Novel Sealant/Adhesive Emulsion Technology

Water-based Emulsions composed of:

a. Flexible Packaging Sealants
b. Lidding Adhesive Sealant Compounds
c. Hot Melt Adhesives
Typical Property of Wet Emulsion

- High Solids: 30 - 40%
- Viscosity: 200 - 500 cps.
- Particle Size: 0.1 to 1.0 micron
- No VOC’s
Particle Size Distribution – early formulation (range now 0.1 to 1.0 μm)

<table>
<thead>
<tr>
<th>Diameter on %</th>
<th>Frequency (%)</th>
<th>Diameter (μm)</th>
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</thead>
<tbody>
<tr>
<td>(1) 5.000 (%)</td>
<td>0.2676(μm)</td>
<td>(7) 70.00 (%)</td>
</tr>
<tr>
<td>(2) 10.00 (%)</td>
<td>0.3231(μm)</td>
<td>0.8713(μm)</td>
</tr>
<tr>
<td>(3) 20.00 (%)</td>
<td>0.4273(μm)</td>
<td>(8) 80.00 (%)</td>
</tr>
<tr>
<td>(4) 30.00 (%)</td>
<td>0.5332(μm)</td>
<td>0.9835(μm)</td>
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<tr>
<td>(5) 40.00 (%)</td>
<td>0.6240(μm)</td>
<td>(9) 90.00 (%)</td>
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<tr>
<td>(6) 60.00 (%)</td>
<td>0.7862(μm)</td>
<td>1.1627(μm)</td>
</tr>
<tr>
<td>Median</td>
<td>0.7056(μm)</td>
<td>(10) 95.00 (%)</td>
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<tr>
<td>Mean</td>
<td>0.7361(μm)</td>
<td>1.3486(μm)</td>
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<tr>
<td>S.D.</td>
<td>0.3431(μm)</td>
<td>CV</td>
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<tr>
<td>CV</td>
<td>46.6139</td>
<td></td>
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</table>
The Coating Process

As Applied

Particles fuse during drying of the web from oven temperature and capillary pressure

~ 30% Solids

Continuous Film
Benefits

✓ Uses only Gravure or Anilox Coater to apply the sealant layer.

✓ Water-based product, with no VOC’s.

✓ Source Reduction available
  a. Lower coat weights than extrusion.
  b. Pattern applied to only seal areas.
Source/Cost Reduction

Coating Weight Reduction

Typical Extrusion – 12 to 25 g/m².
Typical Sealant Emulsion – 2 to 5 g/m².
Potential for 80% reduction in sealant material

Pattern Application

Extrusion or Lamination – N/A
Sealant Emulsion – Possible
Potential for 80% reduction in material
Properties of Dry Sealant Resin

- Physical and Adhesive properties similar to extruded resin.
- May require primer.
- FDA direct food compliant (21 CFR 175.300)
- Lower coat weights give lower seal strength.
- Adheres to wide variety of substrates
  a) Paper, Al Foil, Films (OPET, BOPP, PLA, OPA)
  b) Containers made of: APET, PE, PP, HIPS, PVC
Fiber Tear versus Heat Seal Temperature and Dwell Time
HME Coating (5 gsm) on APET; Heat Sealed to Paper (40psi)

- Heat Seal Temperature 115°C
  - 83% Fiber Tear
    - Dwell Time: 6 sec
  - 55% Fiber Tear
    - Dwell Time: 3 sec

- Heat Seal Temperature 125°C
  - 89% Fiber Tear
    - Dwell Time: 6 sec
  - 10% Fiber Tear
    - Dwell Time: 3 sec

- Heat Seal Temperature 135°C
  - 80% Fiber Tear
    - Dwell Time: 3 sec
  - 13% Fiber Tear
    - Dwell Time: 6 sec

Dwell Time (sec)
Heat Seal Curve of Paper/Poly/Foil/Sealant Emulsion
4 dry lbs./ream

Film Tear

Bond Strength (g/25mm)
Heat Seal Temperature (deg. C)

HME-118
HME-130

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Summary of Benefits

Potential Applications:

1) Pouches for dry foods
2) Lidding stock (cups, trays) – dry foods only
3) Liner-less labels
4) Grease resistance (paper)

Material savings with lower coat weights and pattern application in only heat seal areas.

Emulsions applied on conventional coating equipment.

100% water based – NO VOC's.