The Science of Adhesion

Two Types of Bonding

Chemical

&

Mechanical
Polypropylene Woven: Basic Lamination – “Mechanical” Adhesion
What is a Bag Without printing?

- Surface Printing does not interfere with extrudate adhesion
- Benefits of reverse printing:
  - Gloss
  - Clarity
  - Scuff Resistance
  - Moisture Resistance
Reverse Printed Lamination

INK

PP Woven

PP Extrudate

OPP Film
What happens next?

Ink does not stick to OPP film OR extrudate:
Failure will be at weakest interface
Ink Needs “Chemical” Adhesion

- Corona not only provides wet-out of ink – but chemical “anchors” for ink.
Corona Treatment

**Watt-Density** = **Power** / *(area × time)*

US Units: **W/(ft²/minute)**

[KW setting × 1000] / [Line Speed (ft/min) × width (ft)]

**Example:**

Treater output = 3.0kW; line speed = 450 fpm; Treater width = 5 ft

The watt-density is:  
\[(3.0 \times 1000)/(450 \times 5) = 1.7 \text{ W/(ft}^2/\text{min)}\]

**Important:** You must determine optimum watt-density for each film and for each set of running conditions.

**Some starting suggestions:**

- BOPP films: 3.0 – 4.0 WD
- OPET films: 1.5 – 2.0 WD
- BON films: 0.5 – 1.5 WD

(metric units are factor of 10 higher)
What Happens next?

Ink now sticks great to OPP:
Makes ink/extrudate interface appear even weaker
Two part Solution:

Part 1: Primers
What is a Primer?

- Surface modifier
  - ✓ increases energy
  - ✓ cleans, removes contaminants
  - ✓ adds reactive sites
- Facilitates “wet-out” of secondary coating
- Provides adhesion between substrate and coating/extrudate
- Enhances chemical resistance
Mica Water-Based Primers for Film When Using Polyolefin Extrudate

- Cross-linked (!) Polyethylene Imine (PEI)
- Mica A-131-X – 5% solids, standard of the industry, pH 10.5, easy to use and clean-up, components are FDA CFR 175.105
- Mica H-760-A – 12% solids, less shipping, more attention to dilution, easy clean-up and components are FDA CFR 175.105
How do you apply a Primer?

- Smooth Roll Applicator
- Gravure or Anilox Applicators
- Mayer Rod (Wire Wound) Applicator
How do you apply a Primer?

**Smooth Roll Applicator**

- Hard rubber impression roll
  - 90 durometer
  - Does not have to be undercut
- Low compression
  - Approximately ¼ inch (6 mm)
- Vary application weight by:
  - Applicator roll speed
  - Primer dilution recipe
How do you apply a Primer?

Smooth Roll (3) Applicator (Indirect)

- Web
- Backup Roll
- Flooded Nip
- Transfer Roll
- Flooded Nip
- Pick-up Roll
- Primer Reservoir
How do you apply a Primer?

**Smooth Roll Applicator (Direct)**

- Web
- Flooded Nip
- Rubber Impression Roll
- Smooth Rubber Pickup Roll
- Primer Reservoir
How do you apply a Primer?

Direct Gravure Applicator

Web → Backup Roll
Gravure Roll
Chambered doctor blade

Primer reservoir
How do you apply a Primer?

**Gravure Applicator – Specifications**

To deliver target wet/dry weight;
Specify a cell volume - not a line count.

Example: **PEI type primer for film substrate**

- Dilute primer 1:1
- Apply 0.02 dry lbs/ream

**Many possible configurations:**
- Direct forward gravure, 180 pyramid, 3.2 bcm
- Direct forward gravure, 360 pyramid, 3.7 bcm
How do you apply a Primer?

**Gravure Applicator – Materials**

- **Ceramic**
  - Long service life
  - Prone to clogging
  - Add 15 – 20% cell volume to compensate

- **Chrome**
  - Easier to clean
  - Shorter service life
How do you apply a Primer?

**Mayer Rod Applicator**

- Wire Wound Coating Rod

- Space between wire windings determine amount delivered (0.003" - 0.060" in 0.001" increments).
How do you apply a Primer?

*Steps to follow:*

1) **Treat**
   - Corona, Flame
2) **Apply**
   - Smooth roll, Gravure, Flexo
3) **Dry**
   - Hot, circulating air; infrared
   - Flame (paper only)
How do you apply a Primer?

2. **Ensure Proper Coatweight**

   Recommended Range is: 0.02 – 0.03 dry lbs/ream

- % Solids by refractometer or gravimetric oven test.
- Monitor coatweight by consumption of primer.
- Use Mica “Color-Chip” Stain Test
- Primer coating uniformity;
  - a) Water soluble optical brightener with a UV lamp.
  - b) Eosin stain testing and “Color-Chip”/Colorimeter.
How do you apply a Primer?

3. **Ensure Complete Drying**
   
a) Drying MICA A-131-X is relatively easy.

b) Oven airflow is equally important as the exit web temperature.

c) Recommended Exit Web Temperature: 140°F – 180°F
Primers and reactive sites

- Primer adds reactive sites to the ink?
  - green = primer

- But what about the extrudate?
Part 2

The Resins
Polyethylene

- Oxidized in extrusion process
- Reactive sites form chemical bonds with primers
- Does not stick to polypropylene woven (will stick the HDPE though)
- Does not have strength, heat and grease resistance of polypropylene
Polypropylene

- “Inert” chemical nature – does not oxidize during extrusion
- No reactive sites for chemical reaction (inks OR primers)
- Does “mix” with PP poly-woven (mechanical)
- Tough, strong, excellent moisture and grease resistance
Maleic Anhydride Adhesive Resins

- Known to give adhesion as tie-layer (costly and requires co-extrusion)
- Mica has discovered that “MAH” concentrates can be blended in polypropylene
- Mica water-based primers have perfect chemistry for reaction with MAH – serves as the reactive site for the extrudate
Maleic Anhydride Concentrate Considerations

- Backbone (concentrate base resin) needs to be compatible with resin to be extruded
- Needs 1-2% maleic anhydride (or equivalent) in order to be diluted to 0.2% total anhydride content in final blend
- Blending 10 – 20% of material must not interfere with extrusion properties (melt strength, neck-in etc.)
Materials

- Resin 1: DuPont Bynel 50E803
- Resin 2: Chemtura Polybond 3000
- Resin 3: Arkema Orevac CA 100

- Concentrates were blended into polypropylene so that the final MAH concentration was 0.20%
Finished Structure

= primer = MAH resin

Chemical reactions at every interface = destructive bonding
Steps to Making Poly-woven Lamination

1. OPP with 54 or higher dyne level
2. Print
3. Prime with 0.02 dpr cross-linked PEI
4. Dry thoroughly
5. Extrude with PP + 15-20% MAH concentrate
6. Laminate PP woven
Some Additional Considerations

- PP base resin (extrusion grade!)
  - Homo-polymer
  - Co-polymer
  - Added polyloefin for run-ability
  - Final mix should be at least 70% PP
- Slip additives in OPP film
- Cohesive strength of the ink
  - Ink chemistry
  - Coverage
  - Drying
  - In-line/out of line priming
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<th>Primer</th>
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<th>Bonding</th>
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<td>PP only</td>
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<tr>
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<td>PP + resin three</td>
<td>60% ink removal</td>
</tr>
</tbody>
</table>
Discussion of Results

- Strength of structure will be strength of the weakest interface
- In this case – ink cohesion was weakest
- Primer can be used under the inks when this is the issue (still needs corona treatment)

OPP/”T”/primer/ink/primer/PP+MAH/woven
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THANK YOU!