10 Ways to Improve Corona & Atmospheric Plasma Treatment Results

The Opportunities

Presented by

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Presentation Agenda

- Overview of Surface Treatment Systems
- Corona-Generated Adhesion
- Plasma-Generated Adhesion
- Corona Surface Treatment Effects
- Plasma Surface Treatment Effects
- 10 Ways to Improve Surface Treatment Results
- Maintenance Recommendations
- Additional Resources
Overview of Surface Treatment Systems
Principle of Corona Treatment

- Polymer surfaces are continuously treated at a wide range of web speeds

Key Takeaway: Positively-charged ions, electrons, metastable N2 and O2 bombard surfaces to provide etching, oxidizing, and polarizing effects.
## Types of Corona Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| **Bare Roll**           | - No roll covering to fail  
- Ceramic electrodes  
- Treats conductive / non-conductive materials  
- All converting applications | - Roll oxidation requires cleaning  
- Requires large volumes of makeup air, as air is needed to cool the electrodes |
| **Covered Roll**        | - Wide range of roll coverings, metal electrode  
- Designed to treat non-conductive materials  
- Easy to adjust treat width, and lane treating with segmented electrodes | - Organic roll coverings can have short life  
- Cannot treat conductive materials |
| **Dual Dielectric**     | - Ceramic roll covering, ceramic electrode  
- Treats conductive / non-conductive materials  
- Higher treat levels  
- Even distribution of discharge  
- Increased roll surface capacitance.  
- Nearly eliminates wrinkling, pinholes, backside treat | - None |

**Key Takeaway**

System designs are driven by material and application requirements.
Corona Treater
Surface Effects
Corona Discharge

- Surface degradation by chain scission.
- Increases surface oxidation, roughness.
- Higher ratios of O to OH in corona conducive to oxidized material production.
- Excessive chain scission creates layer of short-chained oxidized material (LMWOM boundary layer).
- Boundary layer is water-soluble; extent of layer determines level of promoted adhesion.
- Can distort interpretation of wettability measures (i.e., dyne, contact angle)

Key Takeaway: Ionizing air will deliver hydrophilic OH groups to films and promote adhesion IF there is no overtreatment.
Corona-Generated Adhesion
Corona-Generated Adhesion

- Increased surface roughness (mechanical adhesion)

- **Formation of polar** functional groups and reactive species.

- Major polar species include:
  - Hydroxyl
  - Peroxy
  - Carbonyl
  - Ester
  - Carboxylic Acid
  - Carbonate

- Shift in morphology from fibrillar crystalline structure to globular (O2 content).

**Key Takeaway**
Corona treatment introduces polar groups into polymer surfaces, improving surface energy, wettability and the potential for adhesion.
Corona-Generated Adhesion

- Excited O2 molecules become unstable and decompose into radicals, ions and photons.
- Discharge creates initiating H, O, OH and N radicals, which in turn create ketone, aldehyde, ether, and carboxyl groups.
- Surface etching and roughness created by micro-arcs.

**Key Takeaway**

Free radicals formed will react with oxygen to create crosslinking and new functional groups, like carbonyl groups.
Atmospheric Plasma Treatment Surface Effects
What does a Plasma Treater do to a Surface

Polymer Film

Glow Discharge Plasma Source
(Discharge composed of molecules, atoms, ions)

Exhaust Stream
Volatilized, vaporized contaminants, water vapor, CO, CO2, unreacted process gases

Clean surface w/ dangling bonds

Exhaust Stream
Volatilized, vaporized contaminants, water vapor, CO, CO2, unreacted process gases

Key Takeaway
Plasma discharges are more homogenous and have a higher electron density, relative to corona discharges.
Internally-cooled atmospheric plasma electrode

Customized discharge density

Single electrode design capable of speeds > 3700 fpm (>1100 mpm)
Plasma-Generated Adhesion
A wide range of polar functional groups can be delivered with plasma treatment. Chemical uptake is faster than other treatments.
Plasma-Generated Adhesion

Depending on the material to be treated and the nature of the plasma gas, several mechanisms contribute to adhesion:

- **Surface Activation:** Plasma activation has a large mechanical effect, continuously removing single atoms from surfaces.

- **Density of Functional Groups:** Adhesion strength can be linearly aligned to functional group density.

- **Free Radical Effect:** Remaining radical sites highly reactive and promote adhesion of inks, coating and adhesives.

- **Increased Polarity:** Reactive gases added to the plasma activation process can deliver new surface functionalities which reverse polarity of materials, such as polypropylene.

- **High Wettability:** After plasma activation, aqueous solutions with high surface tension spread on the activated surface, showing very small contact angles.

- **Reductive Chemistry:** On foils, surface oxide layers form within minutes. Plasma activation with hydrogen-containing plasma gas reduces superficial oxide layers to improve foil surfaces for bonding.
10 Ways to Improve Surface Treatment Results
#1- Understand how to Measure Surface Tension Accurately and Consistently

<table>
<thead>
<tr>
<th>Polymer Type</th>
<th>mN/m (Dymes/cm)</th>
<th>Contact Angle</th>
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</thead>
<tbody>
<tr>
<td>Polydimethylsiloxane (PDMS)</td>
<td>20.1</td>
<td>107.2</td>
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<tr>
<td>Polyethylene (PE)</td>
<td>31.6</td>
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<tr>
<td>Polyethylene oxide (PEO, PEG, polyethylene glycol)</td>
<td>43</td>
<td>63</td>
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<tr>
<td>Polyethylene terephthalate (PET)</td>
<td>39</td>
<td>72.5</td>
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<tr>
<td>Polyisobutylene (PIB, butyl rubber)</td>
<td>27</td>
<td>112.1</td>
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<tr>
<td>Polymethyl methacrylate (PMMA, acrylic, plexiglas)</td>
<td>37.5</td>
<td>70.9</td>
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<td>Polyoxymethylene (POM, polyacetal, polymethylene oxide)</td>
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<td>Polyphenylene sulfide (PPS)</td>
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<td>Polypropylene (PP)</td>
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<td>Polyvinylidene chloride (PVDC, Saran)</td>
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<tr>
<td>Polyvinylidene fluoride (PVDF)</td>
<td>31.6</td>
<td>89</td>
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</table>

**Key Takeaway**

Surface tension levels can vary within material types.
#2- Understand the “Wettability Gap”

The “Wettability Gap”

**Key Takeaway**
Wettability Gap – Difference in surface energy between the base material and that of the ink, coating or adhesive. Target: + 10 dynes/cm
#3 – Apply the Proper Power Density

Low molecular weight oxidized polymeric material following over-treatment of BOPP film

Key Takeaway

High applied power does not necessarily improve adhesion.
#4 – Commit to Periodic Ground Roll Cleaning Commensurate with its Contamination

Backside Treatment / Strike-Through

Key Takeaway

Keep ground rolls clean; Move toward dual dielectric systems.
#5 – Design Treater to Provide the Maximize Wrap Angle at Optimal Web Tension

The greater the wrap angle, the less propensity for backside treatment

Key Takeaway: The greater the wrap angle, the less propensity for backside treatment
#6 – Know How to Manage Additive Migration (Oleamide, Erucamide, Stearamide)

Key Takeaway

Long chain, unsaturated amides bloom from polymers. Formulation optimization is key.
#7 – Evaluate switching to a Higher Capacitance Ground Roll Covering with your Treater Manufacturer

Higher capacitance roll coverings provide better energy distribution and higher treatment levels.

**Capacitance of the ground roll:**
- Proportional to the surface area of the electrode
- Proportional to the dielectric constant of the roll cover
- Inversely proportional to the thickness of the dielectric roll covering

**Key Takeaway**

*Higher capacitance roll coverings provide better energy distribution and higher treatment levels.*
#8 – Avoid Exposing Treated Materials to Heat prior to Conversion

Key Takeaway

Corona treatment will degrade under high heat and humidity conditions; Plasma treatments are more stable due to discharge density, chemical bonding.

Source: Dow Chemical Company
#9 – Introduce Atmospheric Plasma Technology at Film Extrusion and/or Conversion

Introduce atmospheric plasma to introduce functional groups which can increase surface tension and extend treatment longevity.

Key Takeaway

- Introduce oxygen to increase film surface oxidation
- Cross-linking reaction (electron bombardment 100x of corona)
- Increase in film surface polar groups
- Higher surface tension
- Reduces watt density, and possible film surface breakdown

Atmospheric plasma can introduce functional groups which can increase surface tension and extend treatment longevity.
#10 – When Web Wrinkling Occurs During Lane Treating, Install Static Charge Equalizing Nip Rollers Within the Station

Key Takeaway

When various "lanes" of film are being treated, difference in static charge between these areas results.
## Maintenance Recommendations

<table>
<thead>
<tr>
<th>Clean &amp; Adjustment Schedule</th>
<th>Daily</th>
<th>Weekly</th>
<th>2 Weeks</th>
<th>Monthly</th>
<th>3 Month</th>
<th>Yearly</th>
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</table>
Maintenance Recommendations

Electrode Maintenance

- Ceramic Electrode can be cleaned with Isopropyl alcohol & cloth, or with 3M Scotch-Brite pad if needed.
- SS segmented, fin, or shoe electrodes can be cleaned with Isopropyl alcohol & 3M Scotch-Brite pad. If electrodes are pitted, contact supplier.

Roll Maintenance

- Bare Aluminum Rolls can be cleaned with a 3M Scotch-Brite pad or a fine steel wool
- Roll coverings can be cleaned with a 3M Scotch-Brite pad and soapy water
- With proper cleaning and maintenance, organic roll coverings generally last from 3 to 6 months
- With proper cleaning and maintenance, inorganic roll coverings (ceramic, glass) generally last 20+ years
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