Coating Plasma Innovation

Atmospheric Plasma treatment, effect on the plasma chemistry on adhesion

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Plasma

4th state of matter: ionized gas
Cold atmospheric plasma

Cold:
\[ T_{gas} < 100 \, ^\circ C \]
\[ T_{ions, neutral} < 100 \, ^\circ C \]
\[ T_{electrons} \approx 10,000 \, ^\circ C \]

Hot:
\[ T_{gas} \approx T_{ions, neutral} \approx T_{electrons} \]
\[ 10^4 < T < 10^8 \, ^\circ C \]

Atmospheric:
Plasma gas is at atmospheric pressure
Open reactor, high density of particles

Energetic electrons ➔ chemistry
Corona

- Used for activation or cleaning
- Flat substrate
- Most of the time need to be used inline with other process
- Gas used: none (ambient air)
Plasma DBD

- Used for activation or cleaning and deposition
- Flat substrate
- Used online or offline
- Gas used: $\text{N}_2$, (Ar, He)
Plasma vs Corona

Surface energy measurements on BOPP film

Controlled chemistry ➔ Stable treatment
Plasma vs Corona

Microscopy (AFM) image of BOPP film
1 µm x 1 µm images (Tapping)

Untreated

Plasma DBD

Corona

$E_s \leq 30 \text{ mN/m}$

$E_s = 60 \text{ mN/m}$

$E_s = 38 \text{ mN/m}$

Identical discharge power

Controlled chemistry, homogenous discharge $\Rightarrow$ no surface damage
Process

Plasma gas + dopant

Dopant:
ppm of reactive gases mixed with plasma gas (only safe gas *green top bottles*)
APPLICATIONS
Applications: Cleaning

Removal of surface contamination without substrate degradation
Applications: Grafting

Gas: $\text{N}_2 +$ dopants

Surface functionalization
Applications: Grafting

Grafting of nitrogen containing groups

Tunable surface functionalization
Specific molecules (precursor) are added to the plasma gas. Those molecules are activated by the plasma and react with the sample surface to form a thin film.

Coating nature dependend on precursor AND plasma chemistry.
ADHESION IMPROVEMENT
ECTFE – Surface energy increase

Very limited ageing after 3 weeks
ECTFE – Adhesion increase

ECTFE laminate (Araldite 2028)

Surface energy is not the main factor improving adhesion
Chemistry, not SE, is the main factor improving adhesion
Adhesion not always directly related to surface energy
Chemistry, not SE, is the main factor improving adhesion
Adhesion increase

<table>
<thead>
<tr>
<th>Material</th>
<th>Untreated vs Corona</th>
<th>Untreated vs Plasma</th>
<th>Corona vs Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic PET</td>
<td>15%</td>
<td>Up to 85%</td>
<td>35%</td>
</tr>
<tr>
<td>Thermoset PET</td>
<td>200%</td>
<td>Up to 2300%</td>
<td>800%</td>
</tr>
<tr>
<td>Araldite 2028 ECTFE</td>
<td>1000%</td>
<td>Up to 4870%</td>
<td>350%</td>
</tr>
</tbody>
</table>

Results depend on adhesive and plasma chemistries
Conclusion

• Plasma treatment enables stable modification of surface energy

• Plasma allows to tailor the surface modifications to specific adhesive and substrate combination

• Level of adhesion can be controlled over a large range

• Plasma treatment can be applied to almost any materials (PEEK, Fluorinated polymers, PI, metals, paper...)