Vacuum Plasma Deposition of Water and Oil Repellent Nano-coatings

Nick Rimmer
VP – Filtration and Business Development, P2i
Contents

• Introduction

• Liquid Repellent Coating Technologies

• Pulsed Plasma Deposition Process

• Results and Impact on Product Performance

• Discussion
Liquid Repellency

Low surface energy coatings reduce the interaction between liquids and surfaces

Liquids tend to bead-up and roll-off
Applications of Liquid Repellent Materials

Advanced air filtration

Performance textiles
Standard Technologies

- Standard approaches to creating liquid repellency:
  1. Use a material that is naturally liquid repellent
  2. Spray coat
  3. Screen or spread coat
  4. Dip-coat
Limitations of Standard Approaches

- Limited number of materials have any natural repellency
- Poor adhesion to substrates
- Blocks pore structure in breathable media
- High chemical usage
- Requirement for additional heat treatment or curing step
Bulk vs Surface Properties

Some properties are defined by the bulk, others by the surface...

- Weight
- Strength
- Compressibility
- Thermal expansion
- Melting point
- Colour
- Roughness
- Corrosion performance
- Liquid repellency
- Flame retardancy

Nano-coating gives us the opportunity to change the surface with the thinnest possible coating without changing the bulk properties.
Plasma Coatings

Plasma is the 4th state of matter:

Plasma processes can be used to create thin, high quality coatings on the surface of virtually any object
What is P2i’s technology?

- Liquid repellent nano-coating that bonds to a surface
- Originally developed for use by the UK military
- Coating thickness is 1/1,000th the width of a human hair
- Makes an object hydrophobic (water repellent) & oleophobic (oil repellent) without changing how it looks or feels
- Can be applied to any 2D or 3D object – fully manufactured products or raw materials
Introduction to P2i

- P2i was spun-out from the UK Ministry of Defence in January 2004
- We operate across multiple market sectors
- We provide liquid repellent technologies for high-volume manufacturing
- Patented technology to achieve the highest possible levels of repellency
Typical Products Treated
What is the coating?

PTFE

‘Benchmark’ low surface energy coating

(surface free energy 18 mN/m)

P2i Technology

High levels of liquid repellency to low surface tension liquids

(surface free energy 7 mN/m)
Plasma Polymerization

Surface activation

Pulsed RF Plasma + Monomer

Growth of coating

Surface attachment

Finished coating
Continuous vs. Pulsed Wave Plasmas

- Conventional plasmas fragment the monomer

- The pulsed plasma retains the monomer structure leading to the highest levels of liquid repellency
Functionality Retention

FTIR Spectroscopy

(c) Deposition with continuous plasma

(b) Deposition with pulsed plasma

(a) Monomer
Process Machines

- Roll-to-roll, sheet, or finished product processing
Roll-to-roll Processing Machine

- Full servo-motor control for excellent web tension and speed control
- Easy access for load/unload
Schematic Hardware Configuration

Unwind / rewind rolls

Vacuum Pump

RF Plasma Electrodes

Monomer vapour and gas inlet
Measuring Water and Oil Repellency

### 3M water repellency scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>% Water</th>
<th>% IPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>W10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>W9</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>W8</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>W7</td>
<td>30</td>
<td>70</td>
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<tr>
<td>W6</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>W5</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>W4</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>W3</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>W2</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>W1</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>W0</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

### AATCC118-2002 oil repellency scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>Alkane</th>
<th>Formula</th>
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</thead>
<tbody>
<tr>
<td>O10</td>
<td>Pentane</td>
<td>C₅H₁₂</td>
</tr>
<tr>
<td>O9</td>
<td>Hexane</td>
<td>C₆H₁₄</td>
</tr>
<tr>
<td>O8</td>
<td>Heptane</td>
<td>C₇H₁₆</td>
</tr>
<tr>
<td>O7</td>
<td>Octane</td>
<td>C₈H₁₈</td>
</tr>
<tr>
<td>O6</td>
<td>Decane</td>
<td>C₁₀H₂₂</td>
</tr>
<tr>
<td>O5</td>
<td>Dodecane</td>
<td>C₁₂H₂₆</td>
</tr>
<tr>
<td>O4</td>
<td>Tetradecane</td>
<td>C₁₄H₂₈</td>
</tr>
<tr>
<td>O3</td>
<td>Hexadecane</td>
<td>C₁₆H₃₄</td>
</tr>
<tr>
<td>O2</td>
<td>65% Kaydol: 35% Hexadecane</td>
<td></td>
</tr>
<tr>
<td>O1</td>
<td>Kaydol</td>
<td></td>
</tr>
</tbody>
</table>
Water Repellency

- Water repellency of P2i treated membranes

![Bar Graph showing water repellency rating of different materials with and without nano-coating.]

- Nylon
- PES
- PP
- PTFE

Water Repellency Rating

- Untreated
- Nano-coating

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Oil Repellency

- Oil repellency on filtration media

![Bar chart showing oil repellency rating for different materials with and without nano-coating.](image)

- Nylon
- PES
- PP
- PTFE

**Oil repellency rating**

- Untreated
- Nano-coating
Measuring Water Repellency

- Contact angle measurement

<table>
<thead>
<tr>
<th>Material</th>
<th>Average contact angle (°)</th>
<th>Average contact angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untreated</td>
<td>P2i Treated</td>
</tr>
<tr>
<td>PEEK film</td>
<td>82</td>
<td>122</td>
</tr>
<tr>
<td>Spunbond PP</td>
<td>125</td>
<td>142</td>
</tr>
<tr>
<td>PVDF film</td>
<td>120</td>
<td>139</td>
</tr>
</tbody>
</table>
Effect on Pore Structure

The coating is too thin to block the pore structure in breathable materials:

- Untreated PP (0.2 micron), 15000x
- P2i Treated PP (0.2 micron), 15000x
- Untreated PTFE (0.2 micron), 15000x
- P2i Treated PTFE (0.2 micron), 15000x
Standard Membrane Treatment Technology

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P2i Plasma Treatment Technology

Global Leadership in Invisible Functionality
## Breathability / Airflow

<table>
<thead>
<tr>
<th>Material</th>
<th>Airflow BEFORE Treatment cm(^3) cm(^{-2}) s(^{-1})</th>
<th>Airflow AFTER Treatment cm(^3) cm(^{-2}) s(^{-1})</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester spunbond</td>
<td>9.30</td>
<td>9.60</td>
<td>+ 3.0 %</td>
</tr>
<tr>
<td>Cellulose/nanofibre filter media</td>
<td>12.10</td>
<td>12.08</td>
<td>- 0.5 %</td>
</tr>
<tr>
<td>Polyether Sulfone filter media</td>
<td>2.58</td>
<td>2.50</td>
<td>- 3.1 %</td>
</tr>
<tr>
<td>Microporous polyurethane</td>
<td>0.042</td>
<td>0.039</td>
<td>- 7.8 %</td>
</tr>
<tr>
<td>PTFE spun nanofibre</td>
<td>2.86</td>
<td>2.77</td>
<td>- 3.0 %</td>
</tr>
<tr>
<td>ePTFE membrane</td>
<td>0.151</td>
<td>0.118</td>
<td>- 22 %</td>
</tr>
</tbody>
</table>

*Measurements performed at 125 MPa pressure using TexTest FX3300.*
Benefits for Web Based Materials

Plasma enhancement of web based materials:

- Tailoring of surface properties to meet product requirements
- Minimal effect on airflow for porous media
- Non-leaching
- Resistance to steam sterilization and irradiation
Concluding Remarks

• Surface modification provides a method to improve product performance

• Plasma processing can modify the surface without affecting bulk properties

• The P2i pulsed plasma process can be used to generate the highest levels of water and oil repellency

• The process is applied at the industrial scale on roll-to-roll processing equipment
Thank-you for listening!