UV Curable Solution Acrylic PSA with Optical Clarity

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Presentation Outline

- Introduction
  - Applications of optically clear PSA
  - Adhesion and optical clarity requirements
- Design of Optically Clear PSA
  - Adhesive composition and adhesion properties
  - Optical properties
- Optically Clear PSA Products
  - Window and safety film PSA
  - PSA for electronic displays
- Summary
Applications of Optically Clear PSA

Graphics, Films and Labels

- Window and safety film
- Overlaminating
- Clear labels (clear on clear)
- Window advertising (clear vinyl)

Electronics Displays

- TFT-LCD
- Touch screen
- e-Book
Adhesion and Optical Clarity

General Requirements

- High cohesion and peel strength for bonding transparent substrates
- High heat and humidity resistance
- Light transmission >99% when corrected for reflection losses
- Refractive index match for bonding substrate (Glass, PC, PET, etc)
- Long term durability without yellowing, delaminating or degrading
- Coating quality to reduce the bubbles, dirt, and various optical distortions
- Application specific performance requirements
Factors that Influence Optical Properties of Adhesives

• Chemical structure of polymers
  • Transmission
  • Refractive Index
  • Resistance to discoloration
    • Chemical
    • Moisture
    • Heat
    • UV radiation

• Morphology of polymers
  • Phase separation
  • Crystallinity

• Coating quality
  • Surface roughness
  • Dirt
  • Bubbles
  • Optical defects, etc.
Acrylic PSA Polymers

Various Acrylic Monomers and Functionalities for Adhesion and Optical Property Control

![Chemical structure]

R = H, acrylate
R = CH₃, methacrylate
R’ = H, acrylic acid
R’ = C₁ – Cₙ

Acrylic PSAs are typically composed of:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Monomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 - 90 %</td>
<td>Soft monomers</td>
</tr>
<tr>
<td>10 - 30 %</td>
<td>Hard monomers</td>
</tr>
<tr>
<td>3 - 6 %</td>
<td>Functional monomers</td>
</tr>
</tbody>
</table>
Acrylic PSA Property Control

Soft Monomer  Hard Monomer  Functional Group

\[
\begin{align*}
\text{Soft Monomer} & : & \begin{array}{c}
CH_2 \quad CH \\
\text{O} \quad \text{O} \\
\text{O} \quad \text{CH}_2 \\
\text{H}_3 \text{C} \quad \text{CH} \\
\text{H}_2 \quad \text{CH}_2 \\
\text{H}_2 \text{C} \\
\text{H}_3 \text{C}
\end{array} & \quad n_1 \\
\text{Hard Monomer} & : & \begin{array}{c}
CH_2 \quad CH \\
\text{O} \quad \text{O} \\
\text{O} \quad \text{CH}_3 \\
\text{H}_3 \text{C} \quad \text{CH} \\
\text{H}_2 \quad \text{CH}_2 \\
\text{H}_2 \text{C} \\
\text{H}_3 \text{C}
\end{array} & \quad n_2 \\
\text{Functional Group} & : & \begin{array}{c}
CH_2 \quad CH \\
\text{O} \quad \text{O} \\
\text{O} \quad \text{H} \\
\text{H}_3 \text{C} \quad \text{CH}_3 \\
\text{H}_2 \quad \text{CH}_2 \\
\text{H}_2 \text{C} \\
\text{H}_3 \text{C}
\end{array} & \quad n_3
\end{align*}
\]

PSA Property Design via Monomer Selection
Control of Acrylic PSA Adhesion
A Variety of Methods, e.g., Crosslinking

One-part
- Metals – Al, Ti, Zn
- Self-crosslinking monomers
- Polymeric epoxies
- Blocked isocyanates
- Carbodiimides

Two-part
- Isocyanates
- Aziridines

Radiation Curing
- UV
- EB

from Advances in Pressure Sensitive Adhesive Technology, Don Satas, p. 3, © 1989, Satas & Associates, RI.
PSA for Window and Safety Films
Optically Clear PSA for Window and Safety Film Applications

Window & Safety films: Polyester film, Dyed, Metallized

- Reduce radiant heat loss
- Control light transmission
- Provide shatter resistance
- Ensure privacy

Key requirements for the window film PSA

- Optically clear and long term optical stability
- Strong adhesion on glass substrates
- High temperature / humidity performance
Window Film Construction

SR Coating → Clear
Polyester Film
Laminating Adhesive → Metallized Surface
Polyester Film
PSA
Release Liner
Clear or Dyed/UV Inhibitors
GLASS
Historical Window Film PSA Product Features

- Several products for window/safety film in the market

- Performance Features
  - Optically clear and colorless
  - Long term optical stability
  - Strong adhesion on glass substrates
  - Strong cohesion and shear strength
  - High temperature / humidity performance
  - Excellent coatability
  - Repositionability
Continuous Product Development

Further Product Improvement

- Optical clarity of formulation and coatings
- Shear adhesion performance

<table>
<thead>
<tr>
<th>Polymer composition</th>
<th>Improve PSA properties, solubility &amp; optical clarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent selection</td>
<td>Match solubility parameters</td>
</tr>
<tr>
<td>Crosslinking upgrade</td>
<td>Higher crosslinking density Different mechanisms</td>
</tr>
</tbody>
</table>

Solubility Parameter of Solvent Mixture

\[ \delta = \sum_{i=1}^{n} \delta_i v_i \]

where \( \delta_i \) is solubility parameter and \( v_i \) the volume fraction of individual solvent
## New Development of Window Film PSA

<table>
<thead>
<tr>
<th>Properties/Adhesion</th>
<th>Commercial Products</th>
<th>Newly Developed Products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product A</td>
<td>Product B</td>
</tr>
<tr>
<td>Total Solid (%)</td>
<td>40.5</td>
<td>35</td>
</tr>
<tr>
<td>Viscosity (mPa·sec)</td>
<td>1000</td>
<td>2700</td>
</tr>
<tr>
<td>Peel, 24hr (N/25mm)</td>
<td>20.8</td>
<td>17.8</td>
</tr>
<tr>
<td>Shear, hr (1&quot; x 0.5&quot; x 2kg)</td>
<td>8</td>
<td>0.4</td>
</tr>
<tr>
<td>Solution Clarity</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Coating Clarity</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

- Extension of the proven product line
- Similar polymer composition and formulation approach
- **Further improvement of optical properties**
- **Substantially improved shear strength**
PSA for Electronic Displays
Optically Clear UV Curable PSA for TFT-LCD Construction

Critical to the overall display performance

- Protective film Adhesive
- Protective layer (TAC)
- Polarizer (PVA)
- Protective layer (TAC)
- Construction Adhesive
- Release film
Key Requirements for Construction Adhesives

- Removability and Repositionability
- Optical Clarity
  - Transmission rate >98%
  - Refractive index approaching 1.5
- No Defects upon Aging
  - 60°C / 90% RH resistance
  - 80°C / 95°C temperature resistance
  - Thermal shock cycling (-40 to 85°C)
- Good Mura Value
  - Very low shrinkage
  - High cohesion
Leverage of Existing Technical Capabilities

Solution Acrytics
- Composition
- Architecture
- Proprietary monomers

UV Platform
- Proprietary photoinitiator
- Polymer design
- Immediate cure

Optically Clear UV Curable Solution Acrylic PSA for Electronic Displays

Window Film
- Optical clarity
- Durability
- Glass adhesion
# UV Curable vs. Current Technology

<table>
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<tr>
<th></th>
<th>UV Curable Technology</th>
<th>Current Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Design</strong></td>
<td>UV Solution acrylic</td>
<td>Solution acrylic</td>
</tr>
<tr>
<td><strong>Optical Clarity</strong></td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td><strong>Product Form</strong></td>
<td>1 Part system</td>
<td>2 Part system</td>
</tr>
<tr>
<td><strong>Curing Mechanism</strong></td>
<td>UV Radiation</td>
<td>Chemical XL</td>
</tr>
<tr>
<td><strong>Curing Rate</strong></td>
<td>Fast (Instant)</td>
<td>Slow (Up to 7 days)</td>
</tr>
<tr>
<td><strong>Solid Level</strong></td>
<td>Medium - High (40 - 60%)</td>
<td>Low (20%)</td>
</tr>
</tbody>
</table>
UV Crosslinking Mechanism
UV Curable Acrylic Polymer Building Blocks

- PSA backbone
  Provides PSA Properties & optical clarity

- Interaction with substrate
  Improves adhesion

- Coupling agent
  Interaction with glass
  Humidity resistance

- Photoinitiator: Xlinking
  Improves cohesion

Functional Monomers

- [Structure of Functional Monomers]

- [Structures of Functional Monomers]
Comparison between UV and Current Technology

Peel values on different substrates

Aging Resistance at 80°C & 85% RH
Summary

• Henkel window film adhesive portfolio has thirty years of proven history.

• Further improvement has been made to the product line with better optical properties and shear performance.

• UV curable solution acrylic PSA technology is being developed for display industry by leveraging the window film PSA capability and patented UV technology.

• Free radical UV curable solution PSAs offer several benefits to chemical crosslinked adhesives: instant cure, one-part system, and efficient coating at higher solids.
Acknowledgements:
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Thank you for your attention!