acResin® UV – COMBINING HOTMELT COATING TECHNOLOGY WITH ACRYLIC HIGH PERFORMANCE CHEMISTRY

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1. Conventional UV-Curable Adhesives for Pressure Sensitive Adhesives

The introduction of UV-curable products into many coating and printing processes to replace thermally cured solvent-based systems has become increasingly successful in recent years. The basic advantages of the UV-technology over solvent-based systems have raised also the interest of the pressure sensitive adhesive industry. These advantages of UV-curable polymers include their superior ecological qualities and their economic attractiveness due to low capital investment for processing equipment and high productivity as a result of high production speeds. However, in the pressure sensitive adhesive industry, the big commercial breakthrough of UV-curable polymers has not yet occurred. A possible explanation is that the basic approach, which has been favored so far for UV-curable PSAs, has been derived from those systems being successfully commercialized for varnishes and inks, and this approach seems not to be the ideal concept for all the needs of the PSA industry. This conventional concept can be described as a UV-polymerization of monomer-containing mixtures on the carrier. Typical formulations of this kind consist of the following components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligomer</td>
<td>20-35</td>
<td>Urethane acrylate, Polyester acrylate (MW 5000-20000)</td>
</tr>
<tr>
<td>Chain extender</td>
<td>25-50</td>
<td>Tridecyl acrylate, ethoxylated nonyl phenol acrylate</td>
</tr>
<tr>
<td>Tackifier resin</td>
<td>10-30</td>
<td>C5-C9 hydrocarbon resin</td>
</tr>
<tr>
<td>Adhesion Promotor</td>
<td>0-10</td>
<td>Carboxylated alkyl methacrylate</td>
</tr>
<tr>
<td>Photoinitiator</td>
<td>2-10</td>
<td>2-Hydroxy-2-methyl-1-phenylpropan-1-one</td>
</tr>
</tbody>
</table>

Table1: Conventional UV-curable adhesives for PSA

Although this technology offers substantial benefits, like a wide formulation range for tailor made adhesives, the limitations of these adhesives have restricted their commercial success in the PSA industry so far:

- Odor and toxicity risks due to low molecular weight residues in the adhesive
- Good balance of adhesion and cohesion difficult to achieve
- Exclusion of oxygen for an optimum polymerization process necessary
- High cost of the raw materials

Considering the benefits of the UV-technology in general, but taking also the limitations of the conventional UV-curable adhesives into account, BASF has developed a new class of UV-curable adhesives for PSA applications, which is marketed under the trade name acResin UV.
2. UV-Acrylic Hotmelts – acResin UV

The acResin UV grades are a new solvent- and water-free acrylic raw material for the production of pressure sensitive tapes and labels. They are processed as hotmelts. This means that acResin UV, which is a very high viscosity, nearly solid material at room temperature, has to be heated to a temperature of about 250°F to become fluid enough for the coating process on paper or plastic carriers. After being coated on the carrier, the acResin film is crosslinked by UV-irradiation to produce the adhesive properties as required.

Figure 1: Processing acResin UV

acResin UV can be processed with standard coating equipment for SIS/SBS-hotmelts (common slot-die or roll systems) that may already be available in a production site for self adhesive articles. The remaining required investment is the modification of the machine with UV-lamps. Standard mercury medium pressure vapor lamps can be used as the light source. This type of UV-lamp possesses the right wave length bands in their emission spectrum as needed for an efficient UV-crosslinking of acResin UV.

Figure 2: Chemical principle of acResin UV
Chemically acResin UV consists of acrylic polymer backbone molecules that are modified with polymerized photoreactive groups. This means that in contrast to the conventional UV-crosslinkable adhesives the photoinitiator in acResin UV is not mixed as a low molecular weight component into the material, but fixed to the polymer by chemical bonds. By exposing the coated film to UV-light, the photoreactive groups in acResin UV crosslink the acrylic polymer backbone molecules by a chemical grafting reaction.

3. UV-Crosslinking of acResin UV

With UV-acrylic hotmelts, the ratio of adhesion to cohesion can be varied within certain limits by controlling the amount of radiant energy applied to the adhesive film after it has been coated. Films formed by UV-acrylic hotmelts gradually become more cohesive as more radiant energy is applied, while their adhesion and tack decrease.

![Diagram](image)

**Figure 3: UV-dose and adhesive properties**

This phenomenon is the result of the crosslinking that takes place when the film is exposed to UV radiation. The quantity of radiant energy to which the adhesive film is exposed is expressed by the UV-dose \([\text{mJ/cm}^2]\). The higher the UV-dose in the UV-C wavelength band between 220 and 280 nm, the more polymer chains undergo the crosslinking reaction as shown in Fig. 3. The UV-dose can be controlled by adjusting the power of the lamps and/or the speed at which the substrate is passed under the lamps in the production plant.

A good example of how the adhesive properties of a self-adhesive tape can be tailored via the UV dose is the use of acResin A 258 UV in mounting tape applications. Depending on the relative importance of the balance between adhesion v. cohesion/heat resistance for a particular tape product, for example, an optimum UV-dose can be adjusted.

As seen in Fig. 4 a maximum of adhesion is achieved if the adhesive is crosslinked with a UV-C dose of 25 mJ/cm\(^2\) (dose measured with the UV Power Puck\textsuperscript{®} in the UV-C wavelength band). This UV-dose is
achieved at production speeds of about 750 ft/min, if 6 lamps with an output power of 200 W/cm each are used. If the heat resistance is the focus of the application, the optimum UV-C dose would be 35 mJ/cm², which corresponds to approx. 500 ft/min.

<table>
<thead>
<tr>
<th>Peel Strength after 24 h on steel</th>
<th>Shear Adhesion Failure Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>load 2 lbs. heating rate 0.5°F/min</td>
<td></td>
</tr>
<tr>
<td>°F A = adhesion failure C = cohesion failure</td>
<td>°F A = adhesion failure C = cohesion failure</td>
</tr>
<tr>
<td>15 25 35 50 70 UV C-Dose [mJ/cm²] 15 25 35 50 70 UV C-Dose [mJ/cm²]</td>
<td></td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 A/C C A/C A</td>
<td></td>
</tr>
<tr>
<td>0 50 100 150 200 250 300 A/C C A/C A A</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Typical adhesive properties of acResin A 258 UV (3 mil on polyester)

A precondition to use this tool of tailoring the adhesive properties by the UV dose is that the coating machine is equipped with a suitable UV dose or intensity control device. The major suppliers of UV equipment offer such systems to guarantee an efficient dose control for constant adhesive properties in the production process, and there are companies who are using these tools very successfully to produce a whole range of different articles with tailor made adhesive properties from one acResin raw material. This is not only true for acResin A 258 UV, but also for the other acResin grades that have been commercialized so far: acResin A 203 UV is recommended for formulations with tackifier resins and coating weights < 60 g / m² and acResin DS 3532 for removable and deep-freeze label and tape applications⁴).

However, some companies would prefer to use acResin with a higher tolerance of UV-dose to reach a constant level of adhesive performance. For those customers we are going to develop a modification of acResin A 258 UV.

4. Modified acResin A 258 UV – High UV-Dose Tolerance for Optimum Performance

As seen in Fig. 5 with this new development, a constant level of peel strength is produced for a wide range of the applied UV-C dose. This represents a wide cure window, which means there is a minimal risk for under- or overcrosslinking the coated acResin if the UV-dose deviates to a larger extent from the set point.

Thus two different acResin concepts will be offered to produce self adhesive tapes: if the UV-dose can be controlled efficiently, acResin 258 UV would be the right choice to produce tapes with a very high
adhesive performance at high production speeds. By adjusting the UV dose a whole range of different tapes with tailor made adhesive properties can be produced. With the modified acResin A 258 UV, which is under development at the moment, the adhesive performance will depend little on a definite UV-dose with which to treat the coated film. Hence a constant high level of adhesive performance will be achieved in a wider UV range. However, with the modified acResin A 258 UV the possibility of tailoring the adhesive properties by the UV-dose will be limited, and the line speeds will be slightly lower than for the standard acResin A 258 UV.

Figure 5: Typical adhesive properties of acResin A 258 UV and of a new development (3 mil on polyester)

5. Benefits of acResin UV
acResin UV combines the economic attractiveness of the hotmelt coating technology with the high performance characteristics of the acrylic chemistry.
5.1. Aging Resistance
Like all acrylic polymers, UV-acrylic hotmelts have the advantage that they are extremely resistant to aging. They do not become brittle or yellow like conventional SIS/SBS hotmelts or rubber solutions when they are exposed to oxygen or natural UV radiation. In this respect, the performance of UV-acrylic hotmelts is on the same level as that of adhesives based on acrylic dispersions or solutions.

The high resistance of UV-acrylic hotmelts to aging in combination with the high clarity of the adhesive films themselves make them predestined for use on tapes and labels that are exposed to sunlight and a great deal of value is placed on optical appearance. Self-adhesive films in the graphic arts industry represent another interesting field of application.

5.2. Heat Resistance
Because UV-acrylic hotmelts are capable of crosslinking, they can be used to produce pressure-sensitive adhesives with excellent resistance to deformation at high temperatures. This is reflected in the high shear strength of adhesive tapes at elevated storage temperatures and high SAFT temperatures. It must be emphasized that the high heat resistance of UV-acrylic hotmelts does not impair their adhesion to a great extent, as can be seen from Fig. 4 and 5.

The high heat resistance of adhesive tapes coated with UV-acrylic hotmelts makes them an interesting alternative for many mounting tape applications. The high heat resistance of UV-acrylic hotmelts is also useful for overcoming the problems that are often caused by edge ooze when tapes or labels are cut or punched in high speed converting processes.

5.3. Water Resistance
One disadvantage of adhesives based on aqueous dispersions is their moderate resistance to water and moisture. The reason for this disadvantage is that aqueous dispersions contain hydrophilic auxiliaries like emulsifiers or protective colloids, which are capable to absorb water. An undesired whitening of the adhesive film or a loss of adhesive strength may be the consequence.

Contrary to this, adhesive films formed by UV-acrylic hotmelts do not absorb significant quantities of water when being exposed to moisture or stored under water. This benefit of UV-acrylic hotmelts is advantageous, e.g. for the production of tapes for outdoor applications or for medical plasters being in contact with moist skin.

5.4. Ecological and Toxicological Safety
The UV-acrylics fulfill the highest standards of safety in terms of ecology and toxicology. They are free of solvents and they contain a minimum of substances that are capable of migration. The most important advantages of UV-acrylics are summarized below.

• Only very small traces of organic solvents are emitted.
• They are compact, and need no energy expenditure on transporting organic solvents or water.
• Less energy is consumed compared to adhesives formulated with polymer solutions or dispersions, because no drying is necessary.
• They contain a minimum of substances that are capable of migration. Therefore, a critical cell toxicity and skin irritation is not evidenced for acResin UV.

This ecological and toxicological profile makes acResin UV interesting for many medical applications.
An other field of application, in which acResin offers unique properties, are fogging-free tapes. Here acResin makes it possible to produce aging resistant self-adhesive tapes with a minimum of out-gassing of volatiles, which may be noticed as undesired odors. This aspect is becoming more and more important, e.g. for the automotive industry.

5.5. High Productivity

As UV-acrylic hotmelts can be processed with standard hotmelt technology comparable to SIS/SBS-hotmelts, they can be coated at much higher line speeds than those common for aqueous dispersions and solvent-borne adhesives, especially if the coating weights are high. No water or organic solvents have to be evaporated, no explosion limits for solvents in the drying system have to be obeyed and no investments for solvent incineration or recovery facilities have to be made.

UV-acrylic hotmelts are processed at 210-280°F. This temperature range is significantly lower than that for standard SIS/SBS-hotmelts and enables direct coating of thermally sensitive substrates like PVC and polyolefins.

6. Conclusion

acResin UV, the UV-acrylic hotmelts of BASF, are a new solvent- and water-free raw material for the production of pressure sensitive tapes and labels. They consist of acrylic copolymers including a chemically bonded photoinitiator. By exposing the coated acResin film to definite UV doses in the UV-C wave length band (230 – 280 mm) polymer networks with tailor made adhesive properties can be produced. acResin UV combines the advantages of the hotmelt coating technology with the high performance characteristics of the acrylic chemistry, including an excellent aging resistance, heat resistance and optical transparency. Fogging-free, crystal clear and water-resistant tapes are typical applications for acResin UV.

References