

LATEST DEVELOPMENTS IN ACRYLIC UV-HOTMELTS

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Acrylic UV-hotmelts are solvent- and water-free adhesive raw materials for the production of pressure sensitive tapes, labels and films.

In the light of current market trends for PSAs (increasing cost and regulatory pressure), they offer a valuable alternative to solvent-borne acrylics. However, despite their economic and ecological advantages, acrylic UV-hotmelts have to meet the technical performance, which is provided by solvent-borne acrylics.

Main focus of this presentation is on their application as specialty tapes, however general mechanistic explanations how to escape the adhesion/cohesion conflict are given, as well.

1. Introduction to acrylic UV-hotmelts

Acrylate-based polymers have long been used to manufacture pressure-sensitive adhesives (PSAs). Typical applications are adhesive tapes, labels and graphic films (1).

One particular class of acrylic polymers for PSAs are UV-crosslinkable hotmelts (see Fig. 1). They combine the advantages of classical hotmelts – being solvent-free thus environmentally friendly and economical due to the omission of a drying step – with the advantages of acrylic chemistry – high transparency and outstanding resistance to adverse conditions. Possible downsides are the need for a UV source for curing and the somewhat limited performance when compared to best-in-class solvent-borne acrylics.



Figure 1. Sample of an acrylic UV-hotmelt in molten stage

A typical UV-acrylic hotmelt is a highly viscous, nearly solid material at room temperature. It is heated up to temperatures of approximately 250°F to be coated onto carriers. Afterwards, the UV-acrylic film is crosslinked by specific UV-C irradiation to yield the desired adhesive properties (see Fig. 2) (2).

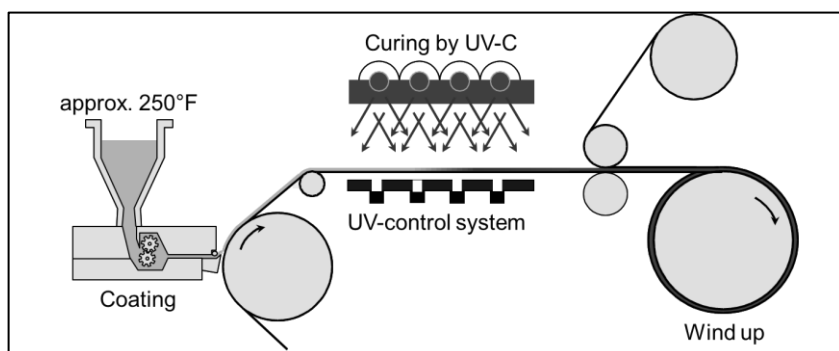


Figure 2. Coating of an acrylic UV-hotmelt

Chemically, the polymer chains of these UV-acrylics are formed from the same acrylate monomers as those used for the well-known solvent-borne acrylic PSAs. Since they need to be coated as a melt, their average molecular weight is limited to around 200,000 g/mol (weight average, as measured by SEC against styrene standards). Additionally, UV-acrylics contain photo-reactive groups that are chemically bonded to the polymer backbone. By exposure to UV-C light, the photo-reactive group crosslinks the polymer by grafting onto a neighbouring polymer chain. The crosslinking reaction is extremely fast, can be accurately controlled and stops as soon as the UV-C irradiation is discontinued (see Fig. 3).

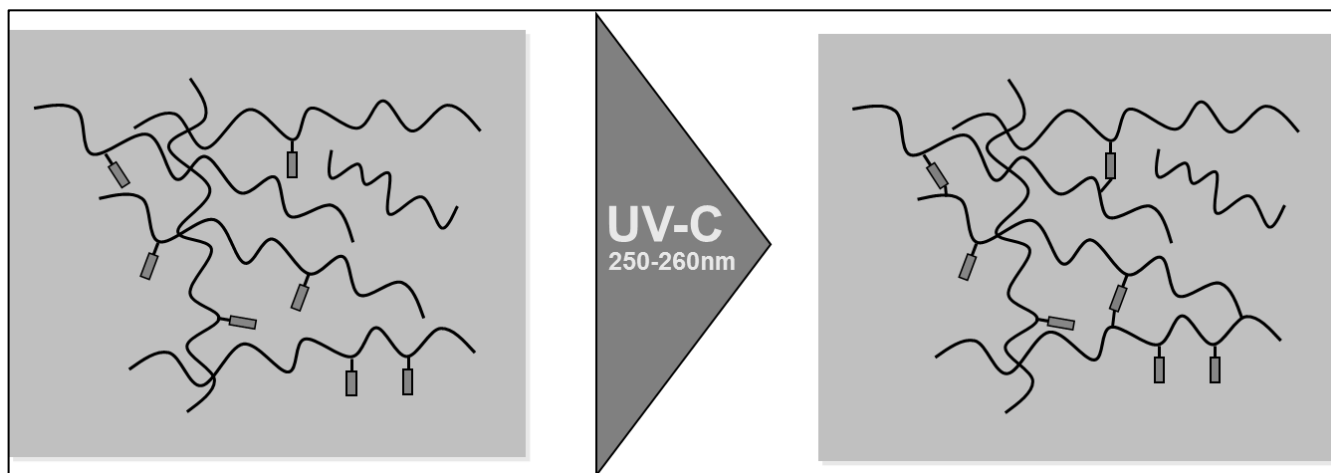


Figure 3. How do acrylic UV-hotmelts work

The degree of cross-linking in UV-acrylics is influenced by the amount of UV-C radiation. Hence, the ratio from adhesion to cohesion can be finetuned within certain limits by the UV-C radiation energy. The higher the UV-C dose, adhesive layers, made from UV-acrylics, become more cohesive and less tacky.

While acrylic dispersions, acrylic or polyisoprene solvent-borne systems and styrene-diene based hotmelts are known for their use as pressure-sensitive adhesives for many decades, acrylic UV-hotmelts are the latest system which nonetheless are a well-established market player nowadays. So, which property combination has allowed them their successful market entry?

It is their optical transparency what makes them the system of choice when it comes to clear-to-clear labelling, it is the combination of being crosslinked and of acrylic nature which makes them resistant to adverse conditions such as chemicals, oils, water, moisture, heat or combinations thereof and allows for their use in specialty tapes and durable labels, and, finally, they exhibit best-in-class low values of volatile compounds and migratables which predestines them for the use in medical tapes, food labelling and automotive tapes (see Fig. 4) (3).

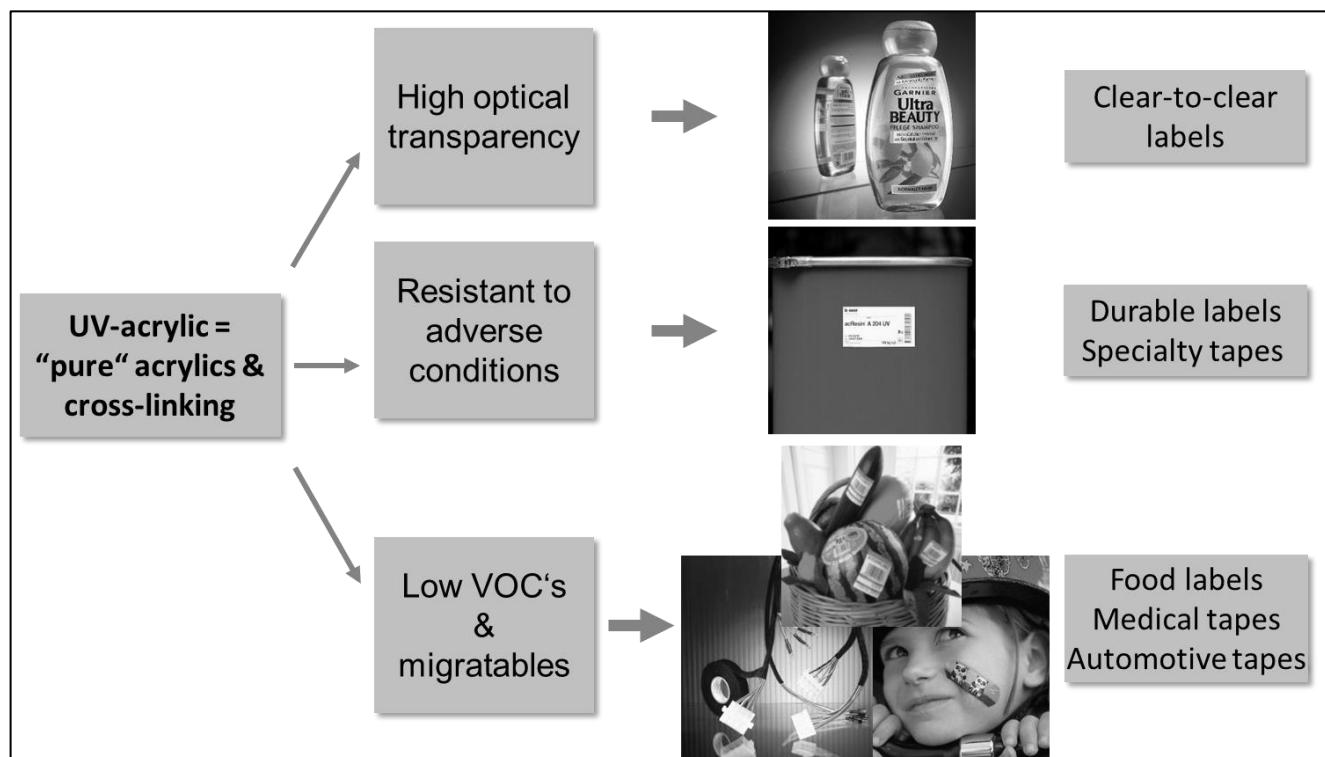


Figure 4. Benefits and uses of acrylic UV-hotmelts

2. Acrylic UV-hotmelts for automotive applications

Tapes are used in a huge variety of applications within the automotive industry. This paragraph will concentrate on their use in the automotive interior such as the mounting or assembly of ventilation shafts, instrument panels, mirrors and interior trim in doors, dashboards and headliners (see Fig. 5).

Nowadays, this field of application is dominated by acrylic dispersions. These perform well, so, why bother about the introduction of a new class of PSAs?



Figure 5. PSA tapes in automotive interior

The answer lies in the ongoing efforts of the OEM's to further reduce the emissions in the interior of a car. This does not stop at the tapes which are used today. What is being discussed are the so-called VOC and FOG emissions whose threshold values are subsequently lowered by car manufacturers. In a nutshell, VOC resembles what you smell in a car and FOG is what you see as fogging on a windshield over time. Both values are determined via GC from the specimen in question, either in a direct manner via analyzing the head space or indirectly via absorption methods (see Fig.6).

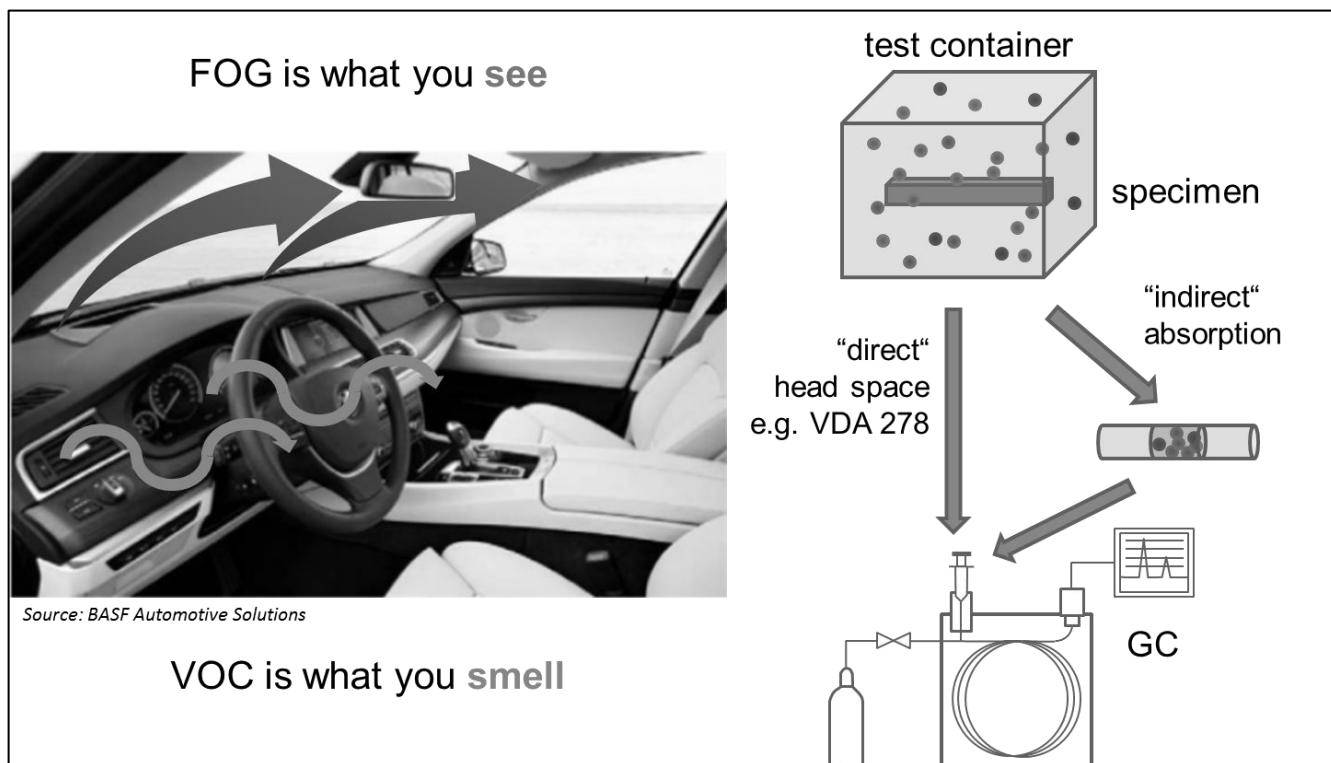


Figure 6. What is VOC and FOG

To complicate things further, each car manufacturer has its own method (or even methods) to determine VOC and FOG. Nevertheless, there is a test norm of the German car manufacturer's association (VDA), which is followed by many OEM's. The next table gives an idea about the corresponding test conditions:

Table 1. Test conditions of VDA 278

VDA 278	VOC	FOG
Test item	Determined case by case	Determined case by case
Test method	Thermodesorption	Thermodesorption
Test item age	8h prior to packaging	8h prior to packaging
Conditioning in standard climate	7 days	7 days
Test item size	30 g	30 g
Volume of test item storage vessel	10 – 20 mL	10- 20 mL
Dwelling temperature	90°C (195°F)	120°C (250°F)
Dwelling time	30 min	60 min
Results	µg C/g	µg C/g
Analysis method	GC	GC
Detector type	MS	MS

The distinction between VOC and FOG does not lie within the basic test method but within the volatility of the compounds concerned. At first, the test specimen is heated to 90°C (195°F) and the resulting emissions are determined via head space GC/MS as VOC. Thereupon, it is heated further to 120°C (250°F) for 60 mins and the substances found in the head space are then determined as FOG.

It is important to emphasize that for VDA 278, the kind of specimen is not preassigned. It can be either a complete component like a ventilation shaft or it can be only the tape by itself. In the first case the PSA film on the tape has a minor influence on the emissions (since the VOC and FOG values are always determined relative to the net weight of the specimen under observation) or a major influence in the latter case.

The choice of specimen is defined by the article you intend to qualify within this norm. Again, the decision about the kind of specimen under examination can vary from OEM to OEM. Most OEM's determine the specimen case by case, however, some have issued norms which define the specimen, e.g. being the component or the tape itself.

For our own investigations, we've chosen VDA 278 since we have our own means to conduct these tests within our premises. To investigate a kind of worst-case-scenario, we coated the PSA on aluminium foil to assure that no volatiles are emitted by the carrier. Later-on, the aluminium foil was weighed back, so our values for VOC and FOG are determined relative to the net weight of the free adhesive film and nothing else whatsoever. This gives an idea of the amount of VOC and FOG to expect from the neat adhesive film but does not resemble the current modus operandi of the OEM's, which is less harsh.

As stated earlier, most PSAs used for tapes in the automotive interior are derived from acrylic dispersions. However, it is not the neat dispersion itself but rather a formulated recipe of the latter which is usually applied. Most commonly, these formulations include wetting agents and defoamers if not tackifiers, such as rosin esters.

Consequently, in our comparative study we've chosen two commercial market samples of dispersions which are intended for the use in automotive interiors. Both samples have undergone a steam stripping process by their producers, to predestine them for interior uses. These neat dispersions were compared against corresponding coater ready formulations (either a commercially available one based on the 1st market sample or formulations, made in our laboratory, based on our own product, the 2nd commercial sample). The 1st own formulation included a standard set of wetting agent and defoamer, the second formulation was optimized by using as few auxiliaries as possible and using grades with little volatiles. We did not include any tackified formulation in our study, since the addition of rosin esters led to a multiplication of the corresponding VOC and FOG values. To see, how the best available acrylic dispersions compare against acrylic UV-hotmelts, we've included a commercial grade acrylic UV-hotmelt, as well (see Fig. 7 and 8).

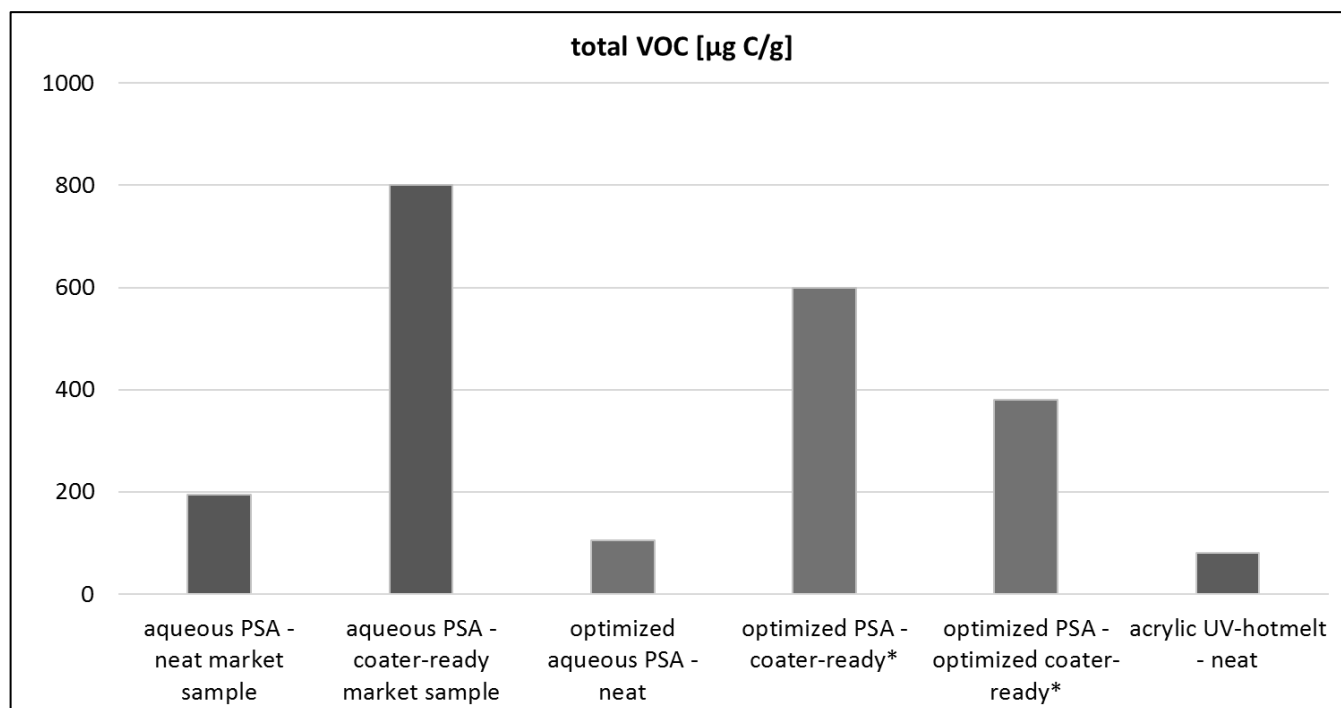


Figure 7. VOC results for free PSA films

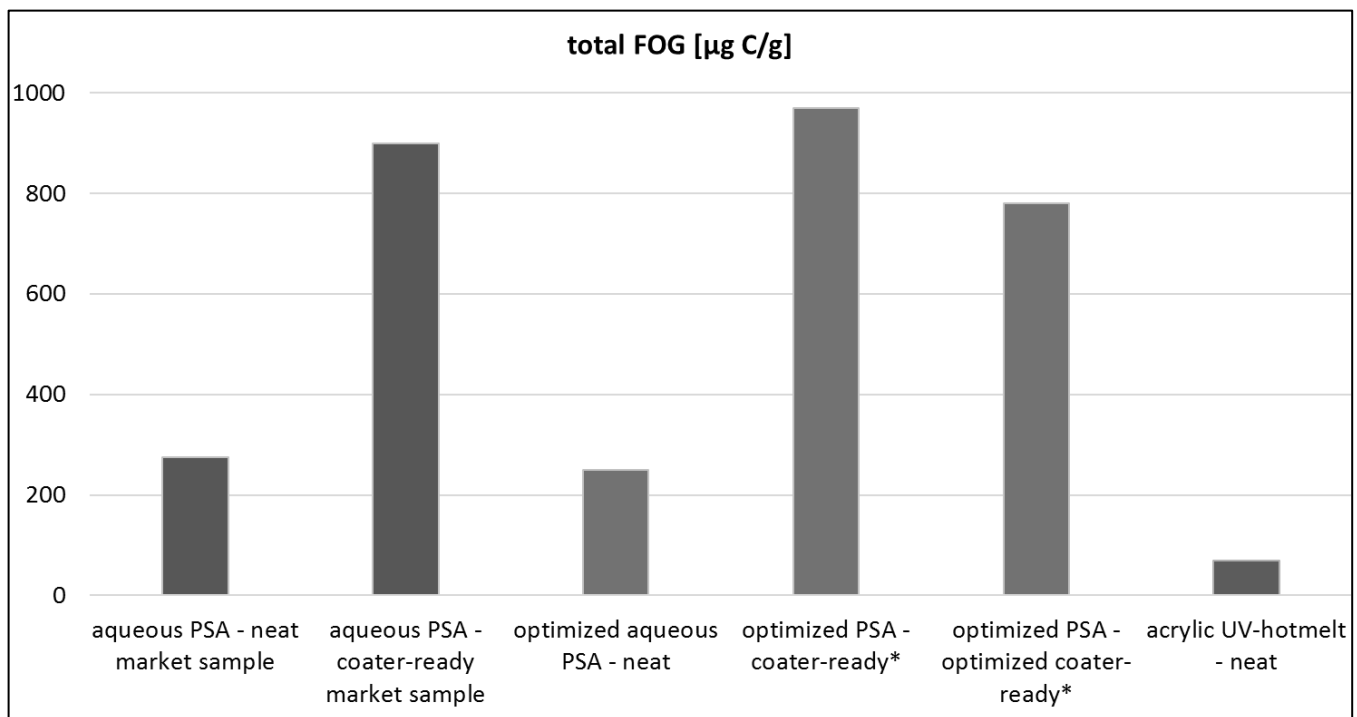


Figure 8. FOG results for free PSA films

The observed trends are the same for VOC values as well as for FOG values: formulation of dispersions with auxiliaries such as defoamers or wetting agents multiplies the respective values by a factor of around four. Optimization of the formulation can reduce VOC and FOG to a certain extent but still outnumbers the neat dispersions.

The acrylic UV-hotmelt outperforms all systems, even the films which are derived from steam-stripped neat dispersions.

This is due to the complete lack of surfactants or other ingredients which shall ensure the colloidal stabilization of the latter. It is not the surfactant itself, which induces VOC or FOG but volatile by-products that come as impurities with the surfactants.

So, our basic assumption holds true: Acrylic UV-hotmelts, being a truly pure acrylic system, offer superior performance when it comes to low volatiles!

These findings induce the question if tapes, derived from aqueous acrylics, face an issue for automotive interior applications. The answer is, as always: it depends...

First of all, our VOC and FOG values refer to the free adhesive film as net weight. No OEM demands this: At worst, they refer to the tape as specimen. If one assumes a tape with a backing and an adhesive layer of equivalent weight and the backing not contributing to VOC and FOG, all values in our findings are already reduced by half. If you consider a whole component with a tape being only a minor part of the net weight, the corresponding values for VOC and FOG would likely dwindle.

Nevertheless, OEM's like e.g. Daimler have set goals for VOC and FOG according to VDA 278 to be below 100 ppm for VOC and below 250 ppm for FOG. If you consider the tape as specimen, these thresholds become challenging to reach for a coater-ready formulation. With an appropriate acrylic UV-hotmelt you would not face any issues whatsoever.

For the time being, current offerings for tapes for automotive interior applications are doing well. However, if the trend towards lower emissions continues, acrylic UV-hotmelts can become the adhesive of choice.

3. Development tools for acrylic UV-hotmelts

The final product properties of an acrylic UV-hotmelt are not defined alone by its composition. Not to be mistaken, this is an important parameter since the monomer choice influences the softness of the adhesives and adds chemical functionalities which interact with surfaces to induce adhesion. However, in a polymer, its structure, defined by the molecular weight, its distribution, crosslinking or branching, plays as important a role. All these structural varieties have an influence on the viscoelastic properties of the adhesive film which contribute strongly to the final product properties such as tack, peel and shear (see Fig. 9).

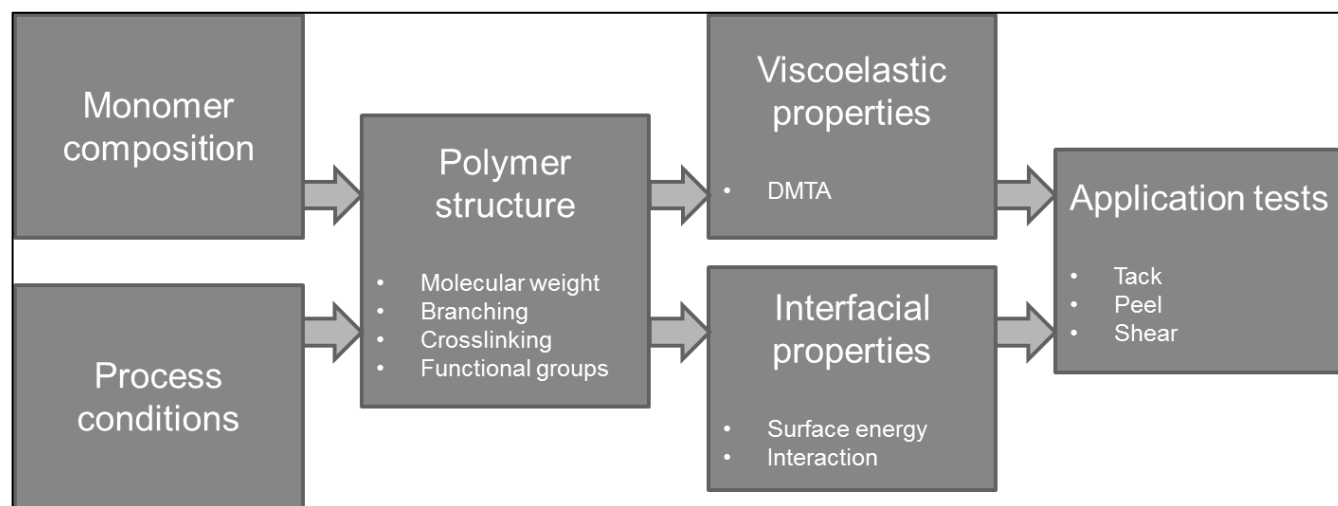


Figure 9. Development stages of a PSA

A pressure sensitive adhesive should be able to flow easily onto uneven surfaces (so-called wet out) to induce tack and, at the same time, should build up significant peel force when peeled-off (resist deformation) and, after all, should resist shear as well. Translated into the language of rheology, it means that good wet out requires easy deformation of the adhesive, e.g. a low modulus, high peel requires resistance of the polymer chains to deformation, e.g. a high modulus and high cohesion requires resistance to shear forces, e.g. a high modulus, too.

This sounds like squaring the circle, but is it really so? Fortunately, it is not: these processes take place on different time scales: shear happens on a time scale where the time till break (failure) is significantly longer than the relaxation time of the polymer chains. Wet-out is a question of seconds, sometimes minutes, whereas for peel, the deformation of a film into fibrils which finally detach or break is at the fastest pace, usually fractions of a second (see Fig. 10) (4).

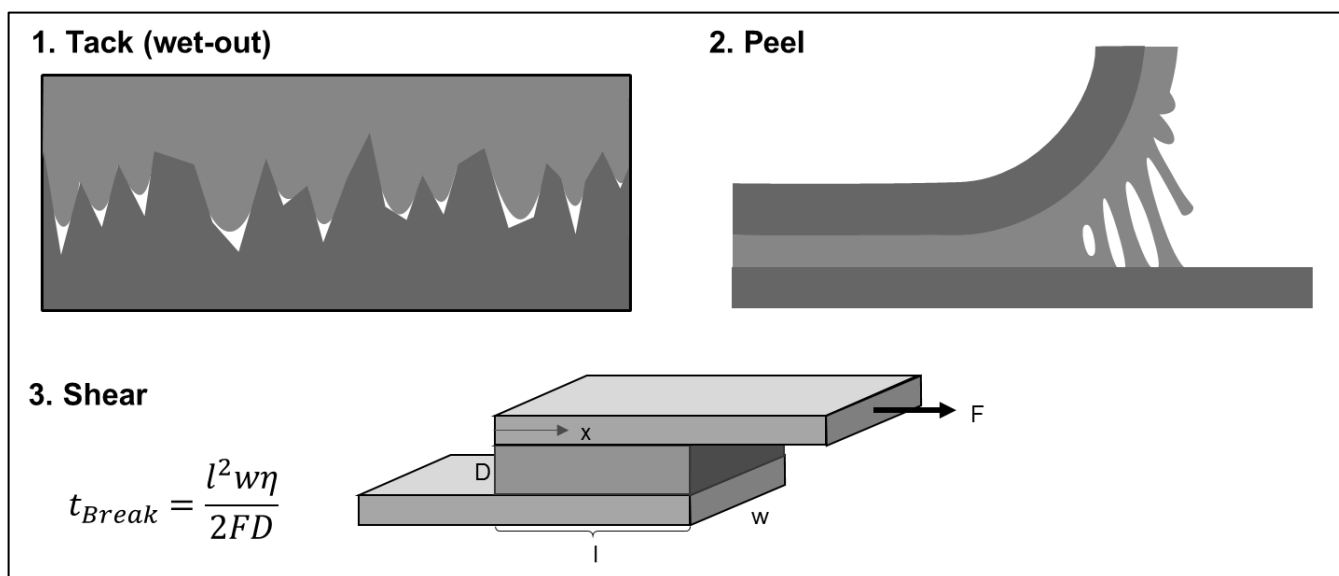


Figure 10. Physics of peel, loop tack, and shear

Hence, a pressure sensitive adhesive can be characterized by determining its viscoelastic properties (i.e. its modulus) at different time scales. This is what a dynamic mechanical analysis (DMA) typically does. It gets even more valuable as a tool if you add a heating device (DMTA). If you're determining the shear modulus G in relation to the oscillating frequency at different temperatures you'll recognize that low temperatures equal high frequencies (i.e. fast processes) and high temperatures equal low frequencies (i.e. slow processes).

This correlation is expressed mathematically by the Williams-Landel-Ferry equation that allows you to convert frequencies into temperatures or vice versa (5). The following figure illustrates the shear modulus G^* over temperature for a typical pressure sensitive acrylic adhesive (see Fig. 11). This graph is an illustration and not an actual measurement.

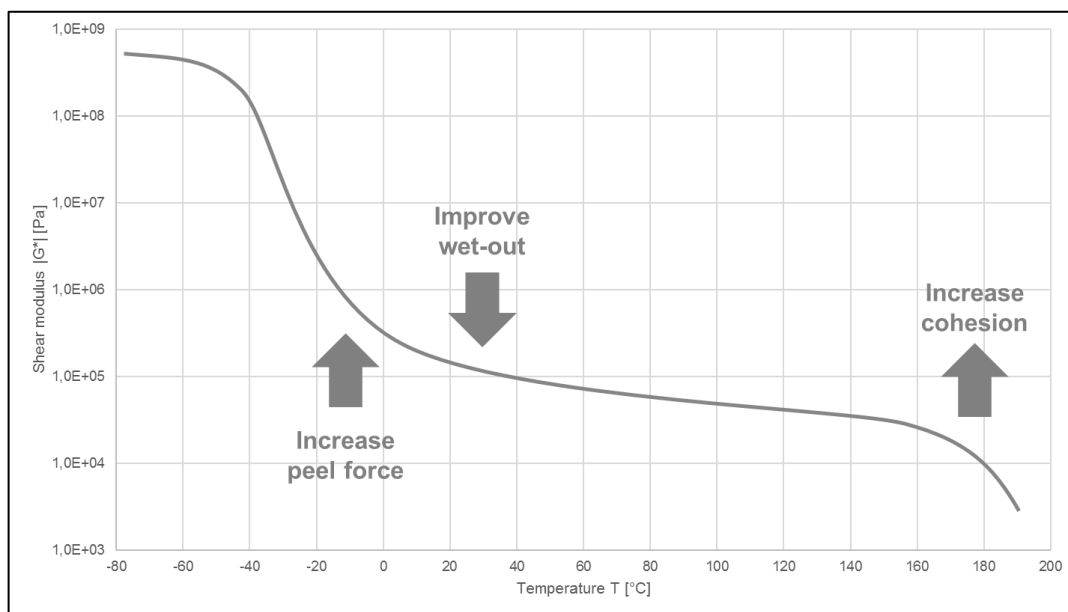


Figure 11. DMTA of a PSA – what do we want?

Please keep in mind that fast processes, i.e. high frequencies, resemble low temperatures in this graph and slow processes, i.e. low frequencies, resemble high temperatures. Therefore, the peel characteristic of a PSA is resembled best by the shear modulus in the temperature range below 0°C (32°F), the flow (wet-out) characteristics by the plateau for the shear modulus starting at around 20°C (70°F) and the cohesion (as well as the heat resistance) by the drop in modulus at elevated temperatures (here: above 140°C/285°F).

So, what do we want for an ideal PSA? We'd like to shift the first drop in shear to higher temperatures, keep the plateau as low as possible and extend it to as high temperatures as possible (see arrows in Fig. 11).

The first drop in shear modulus in this graph results from the conversion of a frozen state to a viscoelastic film. This is the so-called glass transition. By adding monomers which increase the glass transition temperature of the polymer, this step shifts to higher temperatures, thereby increasing peel. However, adding high Tg monomers usually results in a denser entanglement. As a rule of thumb, the higher the Tg, a monomer induces in a polymer, the lower the average molecular weight between two entanglements (the so-called entanglement molecular weight: M_e) (6). Unfortunately, the plateau height of the shear modulus correlates in a reciprocal ratio to M_e : the smaller M_e , the higher the plateau. In effect, if you increase the Tg of your polymer by choice of monomers, you'll decrease the M_e and, thereby, reduce its tack (i.e. wet out). Consequently, you have to carefully counterbalance your choice of monomers to fine-tune the adhesive properties (see Fig. 12).

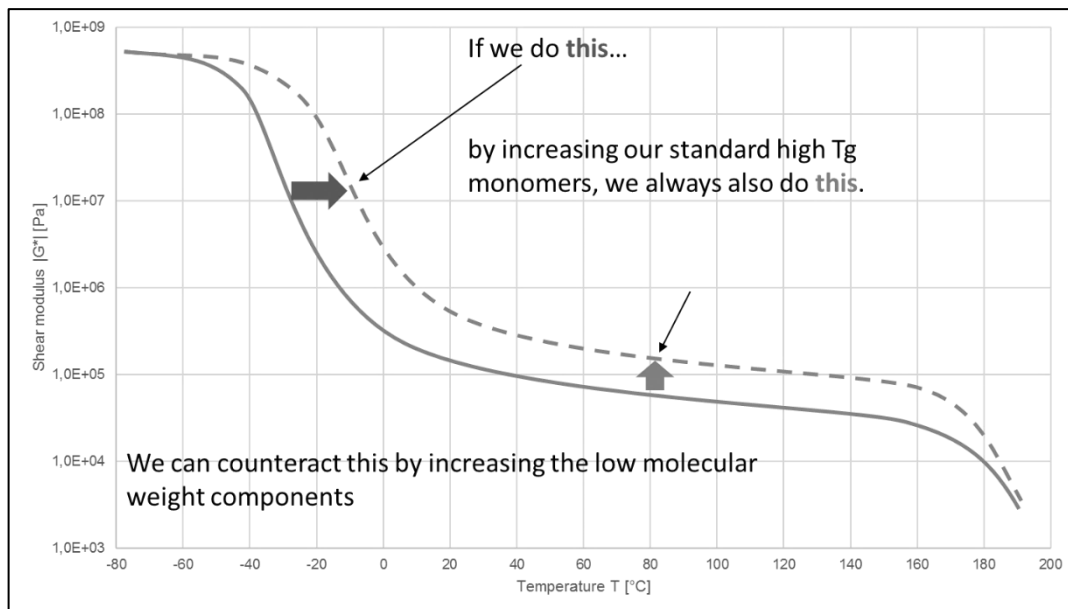


Figure 12. Influence of monomers on viscoelastic properties

The second drop in shear modulus in the graph of Fig. 11 results from the conversion of the viscoelastic film to a viscous melt. From this point on, your film will not exhibit any cohesion. Important polymer parameters to control the onset point of this second step are the molecular weight of the polymer (e.g. given by e.g. its weight average M_w), the width of the molecular weight distribution, and the branching or crosslinking density (see Fig. 13).

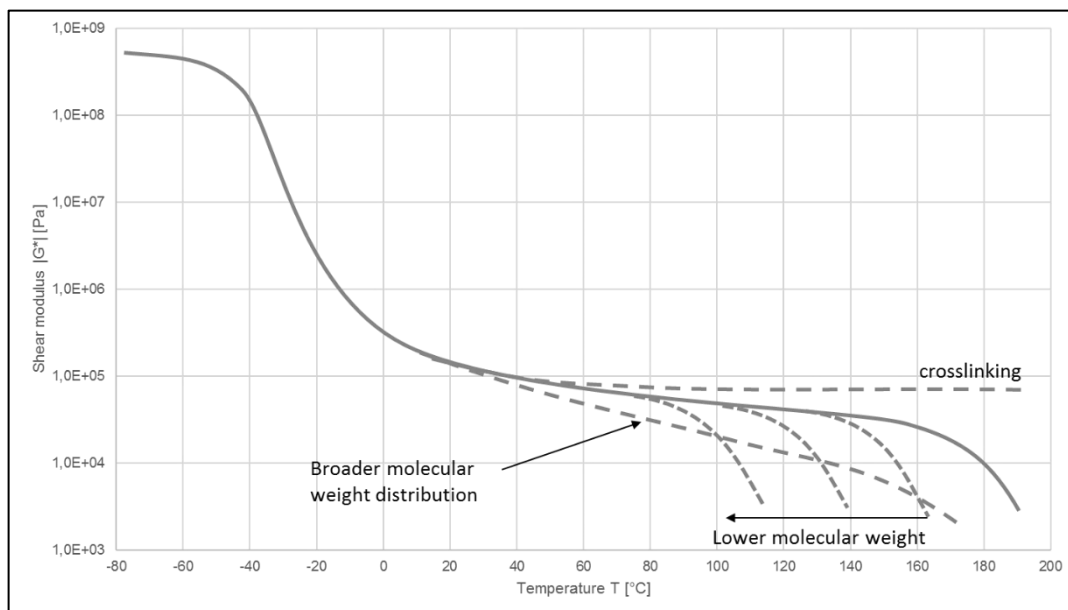


Figure 13. Influence of polymer structure on viscoelastic properties

If you lower the molecular weight of your polymer, the shear force will drop earlier (i.e. at lower temperatures). A similar effect takes place with the addition of low molecular weight components like oligomers. In effect, the route to high cohesion seems simple, then: just increase the molecular weight. Yet, there is another parameter to be kept in mind: the workability of your PSA. May it be a solution or a melt, in order to coat it on any given carrier, you have to keep its viscosity in mind. Consequently, there is an upper limit to the molecular weight of your PSA given by the highest viscosity your coating equipment can tolerate.

Crosslinking is another well-proven strategy to increase the shear modulus (i.e. cohesion) (7), especially when the crosslinking takes place after the coating itself either through a drying or a curing process. The latter is the essential working principle of the acrylic UV-hotmelts: while processing you have a workable melt and after UV-curing, it is a crosslinked polymer with the desired degree of cohesion. Crosslinking is neat, but if your crosslinking becomes too dense it will start interfering with the mobility of the polymer chains. Once the average molecular weight between two crosslinks comes in the vicinity of the entanglement molecular weight, the plateau modulus will increase and tack is lost. Accordingly, though crosslinking is a very valuable tool to optimize cohesion and heat resistance of a PSA, it needs to be counterbalanced against tack and peel of the final product.

4. Latest developments for high performance tapes

Despite the many different types of specialty tapes, the developer of pressure-sensitive adhesives regularly confronts the same essential problem of achieving a balance between the adhesive power (adhesion) and load-bearing capacity (cohesion) of the bond (see above). A pressure-sensitive adhesive can attract considerable interest if it provides both high adhesion and high bond strength. Further desirable technical properties that should not be overlooked are the stability of the bond at elevated or high temperatures and the resistance to weathering.

While other applications for pressure-sensitive adhesives, such as adhesive labels, are dominated by dispersions and hotmelts because of their economic and ecological advantages, what is striking about specialty tapes is the large market share represented by solvent-based systems. Indeed, the most challenging technical requirements in terms of adhesion/cohesion balance and stability to heat and weathering are still matched by solvent-based systems. And since it is these applications that are of particular economic interest, it is attractive to develop products for them. Acrylic UV-hotmelts already play a vital role in the area of specialty tapes. So, this technology offers an excellent starting ground for the development of high performance products (see Fig.14).



Figure 14. Examples of specialty tapes

The next paragraph concentrates on acrylic-based raw materials, either solvent-borne acrylics or acrylic UV-hotmelts.

Both raw materials have more in common than just the same raw material base: they are equally obtained by solution polymerization. Thereafter, their pathway divides: Whereas solution polymers are distributed to the coating facility in their diluted form and are dried after coating, UV-acrylics are stripped off the solvent as part of their manufacturing process before being shipped elsewhere. So, it is the raw material producer who takes care of the solvent. The UV-acrylic is supplied as a 100% pure system, which implies advantages in handling and ecological profile (as discussed earlier). It is coated out of the melt and forms homogeneous polymer films, just like solvent-borne systems. However, it is the solvent-borne system which excels in cohesion and heat resistance whereas some adhesive strength and tackiness are typically somewhat lower compared to the UV-curable acrylics. These differences derive from different molecular weights as well as different crosslinking strategies.

Let's focus on the molecular weight, first. In the previous paragraph, different kinds of molecular weight were already introduced: weight average molecular weight, M_w ; entanglement molecular weight, M_e and crosslinking molecular weight, M_c (see Fig. 15).

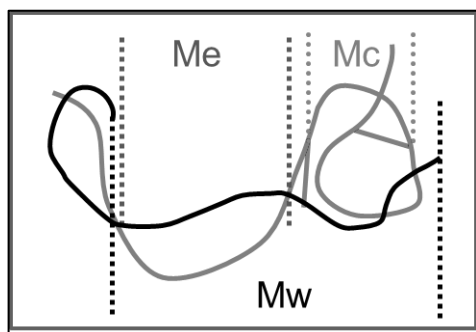


Figure 15. Different kinds of molecular weight

Even a highly cohesive tape must show sufficient tack and peel as a basic requirement. As a rule of thumb, its entanglement molecular weight should be somewhere in the range of 20,000 g/mol (e.g. Me of pure poly(butyl acrylate) (6)). Its weight average should be at least tenfold, better more to maintain high levels of entanglement for good cohesion and heat resistance. In other words, for a high performance PSA, the Mw should be higher than 200,000 g/mol, better 500,000 or even 1,000,000 g/mol.

Here's where the limits of an acrylic UV-hotmelt are: to ensure good flowability in the molten state, the weight average usually equals to around 200,000 g/mol, 250,000 g/mol at best. High performance solvent-borne acrylics can exhibit higher weight averages in the range of 500,000 to 1,000,000 g/mol. Of course, this comes at the expense of reduced solid contents of the latter, but it is doable.

Apart from the molecular weight, the polymer structure, e.g. branching or crosslinking, needs to be discussed as well. Again, there are subtle differences between solvent-borne acrylics and acrylic UV-hotmelts, though crosslinking is decisive for the properties of both:

Solvent-borne acrylics can be modified further by addition of metal chelates. When dried, the chelating agent evaporates together with the solvent, leaving the metal cation behind which subsequently forms an ionic bond with acidic groups (see Fig. 16). The latter are present in form of co-polymerized (meth)acrylic acid. This ionic interaction forms a reversible bond whereby the adhesive forces remain relatively unaffected.

Together with a sufficient molecular weight, as mentioned above, these effects are responsible for the high cohesive strength and temperature resistance of tape articles made thereof.

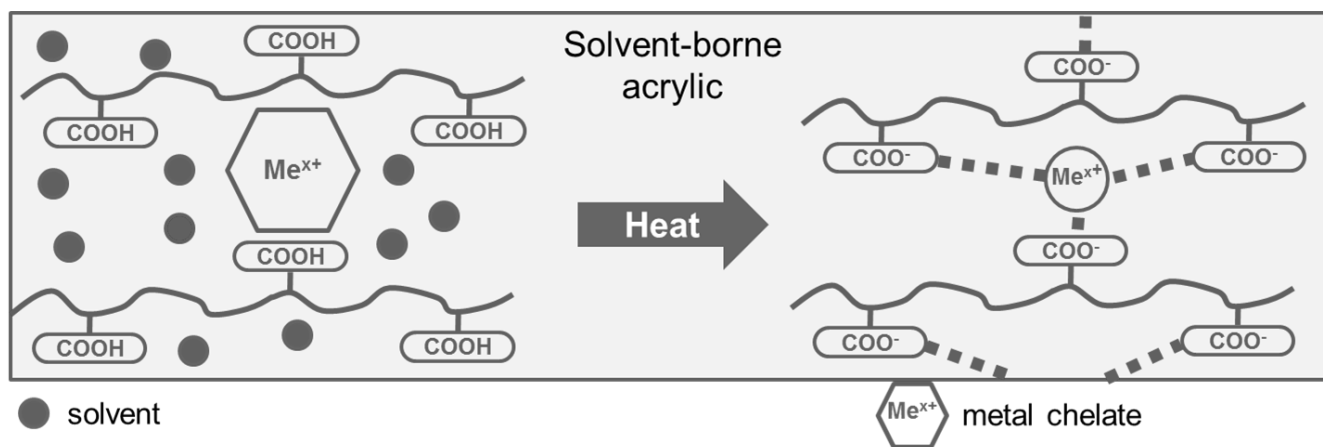


Figure 16. Active principle of a solvent-borne acrylic

A temperature-triggered cross-linking mechanism is not viable for a hotmelt since the highest processing temperatures are applied during the coating step and not afterwards. The incorporation of metal chelates, for example, would inevitably clog the coating device by gel-formation.

Nevertheless, for an acrylic UV-hotmelt, it is the curing mechanism which is decisive to yield a high performance product. Both properties, cohesion, as well as heat resistance, can in principle be enhanced by increased UV-induced crosslinking (see Fig. 17). However, this leads to the formation of permanent chemical bonds, which can reduce the adhesive strength when the polymer network becomes too dense.

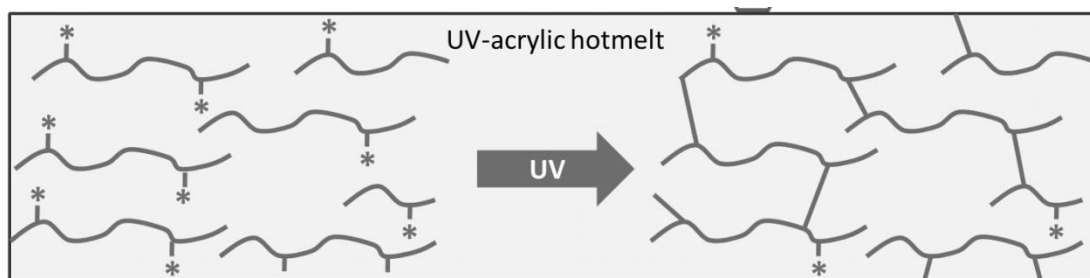


Figure 17. Active principle of an acrylic UV-hotmelt

The concept of distributing an acrylic UV-hotmelt that accomplishes its final properties by permanent chemical bonds formed through UV irradiation is widely accepted within the industry. This is confirmed by the economic success of this product class.

However, due to the limitations as discussed above, they do not reach the highest performance levels of some solvent-borne systems yet (see Table 3; test conditions: see appendices).

Property	Standard acrylic UV-hotmelt	High performance solvent borne
Cohesion on steel	2 hours	> 10 hours
Holding power	25 N	> 80 N
Cohesion @ 160°F	0.5 hours	> 10 hours
SAFT (heat resistance)	250°F	> 360°F
Adhesion to steel	25-30 N/inch	15-20 N/inch

Table 3. Application properties of high performance solvent-borne vs. standard acrylic UV-hotmelt

Since the workability as a melt limits the overall molecular weight (M_w) it is the crosslinking mechanism which can be reworked. The concept of reproducing the beneficial properties of solution polymers by acrylic UV-hotmelts is thus based on incorporating reversible bonds between the polymer chains in combination with the well-established UV-curing mechanism (see Fig. 18).

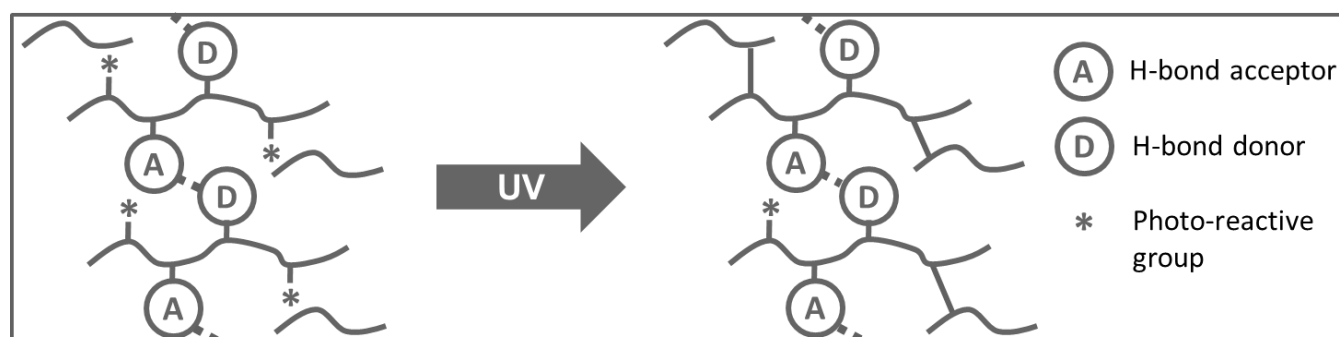


Figure 18. Schematic concept for a high performance UV-acrylic hotmelt

In order to incorporate a reversible bond into the model, either hydrogen bonding or dipole interactions can be applied. Other strong interactive forces such as salt formation or π - π interactions were not considered. The former would dramatically increase the viscosity and cause gel-formation, the latter is pre-dominantly developed by aromatic compounds which constrain the UV-cross-linking reaction.

To yield a strong complex between the polymer chains, hydrogen bonding is preferred over dipole interaction, since the former exhibits stronger interactive forces. The degree of complex formation by reversible bonds is thus controlled by either the degree of hydrogen bonding or the strength of the hydrogen bond.

Once the ‘ideal’ combination of permanent and reversible bonds was identified, the concept had to be transferred into the real world. Among other things, reproducible product properties, safe handling for customers, reliable production processes and secure raw material supply had to be ensured.

Finally, we were successful in identifying a recipe that complies with these demands. It has been transferred to production scale and is commercially available. Within this work, it is called ‘New acrylic UV-hotmelt’. A commercial grade sample was assessed using the same test protocols as described above (see Table 4).

Property	New acrylic UV-hotmelt	High performance solvent borne
Cohesion on steel	> 10 hours	> 10 hours
Holding power	80 N	> 80 N
Cohesion @ 160°F	1-2 hours	> 10 hours
SAFT (heat resistance)	300°F	> 360°F
Adhesion to steel	15-20 N/inch	15-20 N/inch

Table 4. Application properties of high performance solvent-borne vs. new acrylic UV-hotmelt

Though the new acrylic UV-hotmelt still does not reach its highest performing competitors yet, it is a great leap forward.

In a matrix with adhesive power (adhesion) on one axis and internal strength (cohesion) on the other, commercially available UV-acrylics were previously found in a zone of rather high adhesive forces and sufficient cohesive strengths. The same zone is occupied by acrylic dispersions as well as some solvent-borne acrylics. The latter, however, extend to a zone of high cohesive strengths. The new acrylic UV-hotmelt now falls well into this zone that was previously occupied by solvent-borne acrylics alone (see Figure 19).

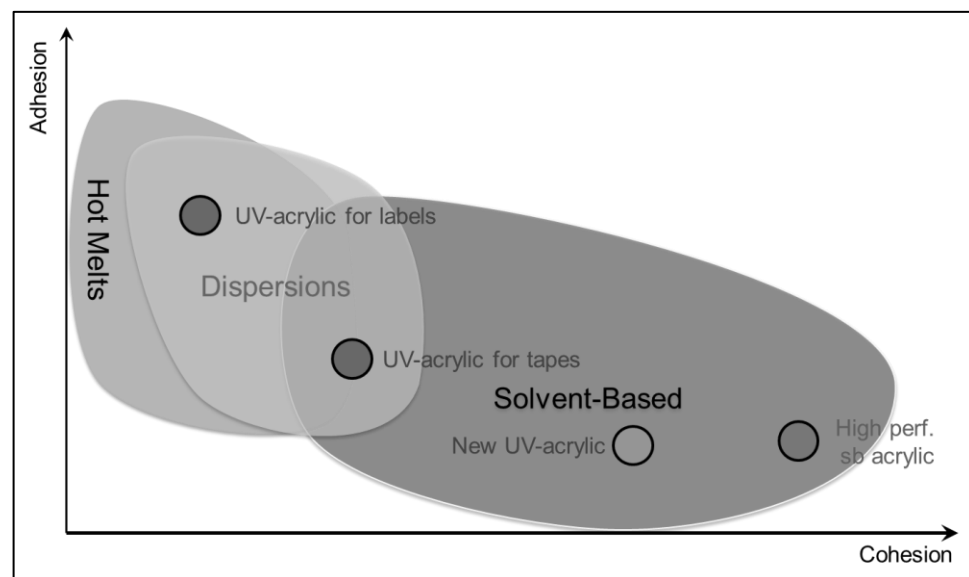


Figure 19. Adhesive properties of commercially available UV-acrylic hotmelts

5. Conclusion

There is an ongoing market trend to reduce the toxicological impact of our products on our daily lives. Customers and end-users alike demand ‘cleaner’ products whatsoever. In the automotive industry, this leads to car manufacturers subsequently lowering threshold values for interior emissions. Not surprisingly, a product class such as acrylic UV-hotmelts, which are rather ‘pure’ excels in meeting these demands. Of course, it is a challenge for any producer to securely deliver such a product at highest levels of quality. However, with quite a history in producing acrylic UV-hotmelts, proper products are available.

Nevertheless, changing market conditions aren’t enough to secure the future of acrylic UV-hotmelts. Constant efforts to enhance the properties of this product class guarantee its further success in the market. As shown in this work, there is still room for improvements. By carefully controlling the combination of temporary and permanent crosslinking points on the one hand, and ensuring reproducible properties and safe handling of the product on the other, a UV-acrylic hotmelt was developed that stretches far out in the range of high performance systems for adhesive tapes.

6. Appendices

Unless stated otherwise, all tests were performed under normalized climate conditions, e.g. a temperature of 73°F (r.t.) and a relative humidity of 50%.

Melt Viscosity:

The measurement is carried out in a Paar/Physica viscosimeter under oscillating conditions using a plate/plate geometry at 260°F in frequency sweep mode. The resulting values are extrapolated to zero shear.

VOC/FOG:

The whole procedure is carried out in accordance to VDA 278. The adhesive films are coated and dried with a thickness of 1.8 mil between two silicone release papers. 30 mg of the free adhesive film are cut out and coated onto a tared stripe of aluminum film. The test specimen is heated in a storage vessel to 90°C (195°F) for 30 mins (i.e. VOC) and the emitted substances are trapped at -150°C and injected for a GC/MS analysis. Subsequently, the storage vessel is heated to 120°C (250°F) for 60 mins (i.e. FOG) and the emitted substances are trapped and measured as described above. Results are reported in µg carbon per g specimen (µgC/g).

Preparation of test specimen:

- i) Tape, coated with acrylic UV-hotmelt: the adhesive melt is direct coated on polyester film with a thickness of 2.4 mil and cured with an UV-C dose of 40 mJ/cm². It is conditioned for 24 hrs at norm climate before performing the application tests.
- ii) Tape, coated with solvent-borne acrylic: the adhesive is transfer coated on polyester film and conditioned for 24 hrs at norm climate before performing the application tests.

Adhesion on steel:

The test is conducted with a bond width of 1” and a peel-off speed of 1.2”/min (300mm/min) after 24h bonding to stainless steel. The measured values are reported in N/inch.

Cohesion on steel:

The test is conducted with an adhesive surface of 0.5”x 0.5” and a weight of 1kg after 10 min (acrylic UV-hotmelt) or 24 hrs (solvent-borne acrylic) bonding to stainless steel. The static cohesion is determined, i.e. the time in hours until bond failure.

Cohesion on steel at 70°C:

The test is conducted at 160°F instead of room temperature with an adhesive surface of 0.5" x 0.5" and a weight of 0.5kg after 10 min (acrylic UV-hotmelt) or 24 hrs (solvent-borne acrylic) bonding to stainless steel. The static cohesion is determined, i.e. the time in hours until bond failure.

SAFT (°F):

The test is conducted with an adhesive surface of 1" x 1" and a weight of 1kg after 24 hrs bonding to stainless steel. Unlike the cohesion measurement, the sample is heated at a rate of 0.28°F/min (0.5°C/min), beginning at 73°F. The temperature at which the bond fails is determined in °F.

Holding power:

The test is conducted with an adhesive surface of 1" x 1" on stainless steel and a starting weight of 2kg. Every 4 hours, the weight is subsequently increased in steps of 0.5 kg till a total weight of 4kg is reached. From there on, the weight is increased in 2 kg steps every 4 hours till infinity. The highest load the adhesive holds for four hours determines the holding power in N by the following equation: *holding power [N] = highest load [kg] * 10.*

7. Literature citations

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