HOW CAN UV CURABLE ADHESIVES CONTRIBUTE TO SUCCESS IN THE TAPE INDUSTRY?

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1. Summary

UV curable pressure-sensitive hotmelt adhesives have been successfully used for label, tape and self-adhesive insulation materials for several years. Although there is only a limited range of crosslinkable raw materials available, formulation of these materials has opened a wide range of new adhesives. Adhesive formulation is needed to tailor a product to specific application or customer requirements. Besides conventional formulation with non-reactive tackyfier resins, Collano discovered additional routes.

Compounding with UV reactive additives results in chanced viscosity and adhesion properties. In the presence of a UV curable base resin, these additives do not necessarily require a further photoinitiator system and establish a covalent bond to the base polymer. The chemical bond between additive and base polymer, results in very low out-gassing or fogging values. Furthermore the additives reduce the melt viscosity significantly and make the products suitable for direct coating of temperature sensitive materials like polyethylene. This formulation technique adds another dimension to satisfy the market needs with UV curable pressure sensitive adhesives and therefore further develop an environmentally safe adhesive technology.[1]

2. UV curable hotmelt technologies

Nowadays, mainly two polymer systems are the base for UV curable pressure-sensitive hotmelt adhesives:

- Acrylic polymers with a co-polymerized photoreactive group
- Styrene-block-copolymers with free vinyl groups

The today available acrylic systems already contain a photoreactive group polymerized into the acrylic backbone. Systems based on styrene-block-copolymers require an additional photoinitiator system.

From the adhesive formulators, the converters and the end users' point of view there is a multitude of differences which are summarized in the following table.

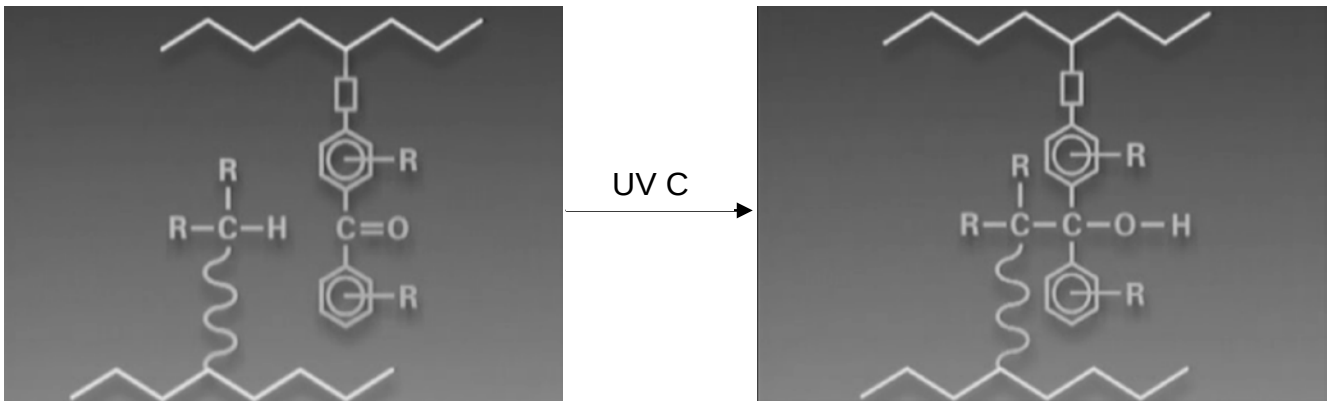
Table 1: Comparison of different polymer systems for UV curable HMPSA's

Polymer base	Acrylic	Styrene-block-copolymer
Adhesion to polar surfaces	Very good	Moderate
Adhesion to non-polar surfaces	Moderate	Very good
Cohesive properties	Very good	Exceptional
Chemical resistance	Very good	Poor
UV light resistance	Very good	Poor
Odor (photoinitiator)	Exceptional	Poor
Transparency	Exceptional	Moderate
Formulation window	Moderate	Very good
Reactivity of formulated systems	Very good	Exceptional

The summary shows that none of the technologies delivers superior performance in every aspect. UV curable adhesives based on the acrylic polymer have a higher significance in the market place than their styrene-block-copolymer counterparts. The following work will concentrate on the formulation of acrylic UV curable materials.[1]

Crosslinking reaction starts under the influence of UVC radiation at a wavelength between 250 and 260 nm. Standard mercury bulbs for curing UV printing inks can be used.
The principle of the reaction mechanism can be seen in Chart 1.

Chart 1: Crosslinking reaction of UV curable acrylic adhesives (schematic)[2]



3. Comparison of UV curable acrylic hotmelts against other pressure-sensitive adhesive technologies

UV curable acrylic hotmelts show various advantages compared with other pressure-sensitive adhesive technologies. These 100% solid systems do not need energy consumptive drying technologies compared to waterborne or solvent-based adhesives. This reduces the necessary space and the monetary investment in coating lines. Furthermore, no expensive solvent recovery is needed. And when considering the transport cost of adhesives from the manufacturer to the coating plant, it is just half of the costs compared to solvent or waterborne adhesives – because no water or solvent which has to be evaporated is transported. So this technology shows an additional environmental aspect.

It is shown in Table 2 that UV curable adhesives have the potential to substitute waterborne and solvent-based adhesives due to their good performance in particular cases.

Table 2: Adhesive comparison

	Water-based acrylics	**Solvent-based acrylics**	**Rubber-based hotmelt**	**UV-curable acrylics**
Shear resistance	■■	■■■	■	■■■
Temperature	■■	■■■	■	■■■
Water resistance	—	■■■	■■■	■■■
UV resistance	■■	■■■	—	■■■
Plasticizer resistance	■■	■■	—	■■
Adhesion at low temperatures	■■	■■	■■■	■
Adhesion on non-polar surfaces	■■	■■	■■■	■■
Die-cutting properties	■■■	■■■	■■	■■■

■■■ very good
■■ good
■ fair
— poor

4. Formulation of UV curable acrylic hotmelt adhesives

The idea of UV curable acrylics was to make adhesive formulation (*i.e.*, blending with resins and other additives) obsolete. The desired adhesion characteristics were to be controlled mainly with the applied UV dose. From the adhesives formulators view this approach is only feasible in limited cases. Only the suitable formulation of acrylic base polymers can cope with demanding application requirements like:

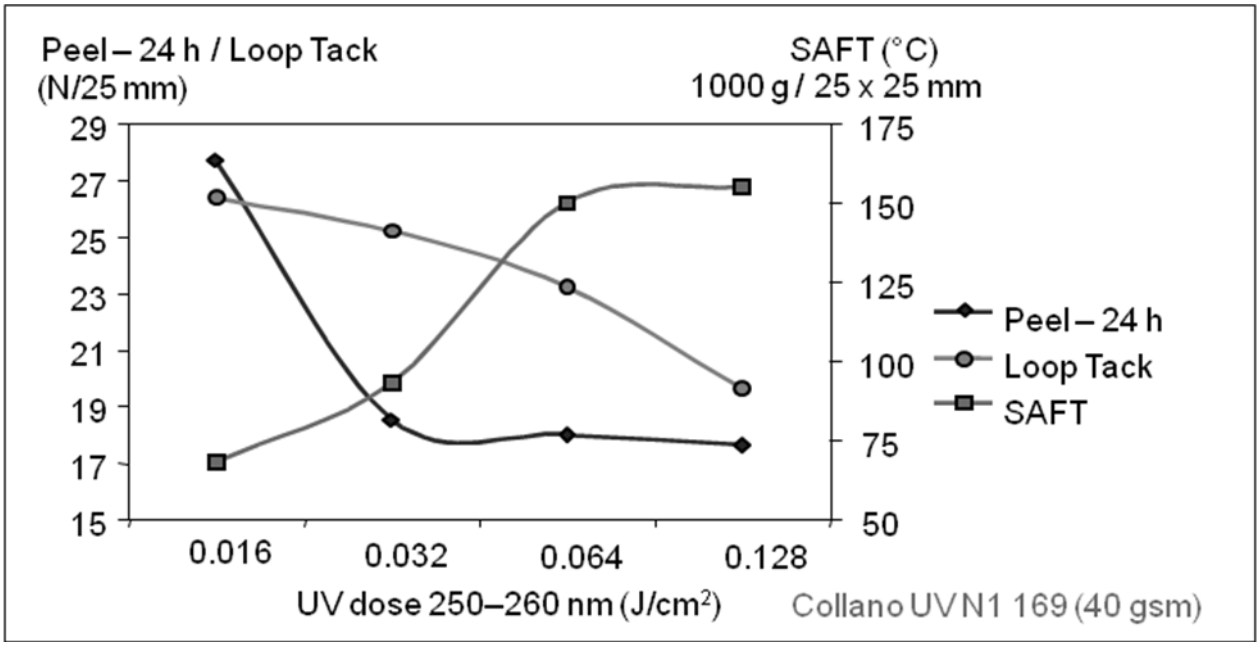
- Specific adhesion profiles on difficult surfaces (e.g. human skin)
- Complete removability from various substrates
- Plasticizer resistance
- Water vapor transmission
- Water storage capability
- Optical detectability (e.g. addition of optical brightener)

There are already various formulations existing for different applications. By choosing the right compounding with the same base polymer easy peelable as well as high-performance-products can be created.

Table 3: PSTC values of different UV curable adhesive compositions
Adhesive based on the same acrylic polymer
Coating weight: 25 gsm
Curing energy: 40 mJ/cm^2

		Unformulated Acrylate	Formulation 1	Formulation 2
Peel on stainless steel (PSTC 101)[3] 20 min	N/inch	8	6	16
Peel on stainless steel (PSTC 101) 24 h	N/inch	9	8	21
Loop Tack on glass (FTM 9)[4]	N/inch	9	7	18
Rolling ball (PSTC 6)	cm	11	8	> 26
Shear 70 °C (1000 g /25 x 25 mm/PSTC 107)	min	4300	30	500
SAFT (0.5 °C/min / 1000 g / 25 x 25 mm)	°C	115	92	> 140

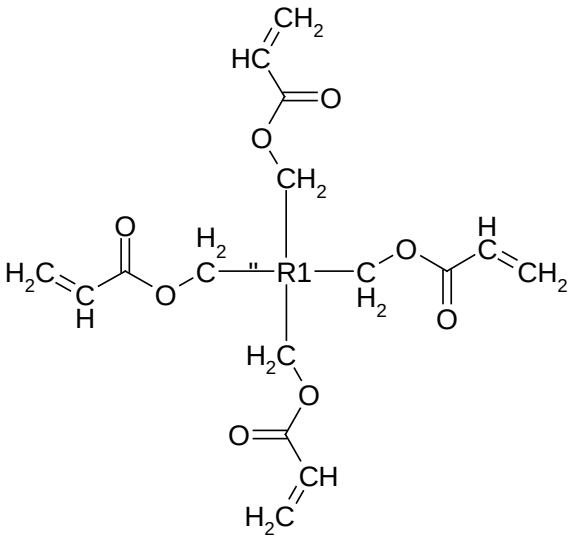
But not only the formulation is the relevant factor for the adhesive properties. The curing level plays an important role as well. Properties of the adhesives can be finetuned by choosing various UVC dosages. Softer adhesive with higher peel force and reduced cohesive properties can be achieved as well as high cohesive products with lower peel.



5. Alternative approach to formulate UV curable hot melt adhesives

Besides the classical acrylates and resins which can be used for composition of UV curable adhesives, we have been searching for other raw materials suitable for blending with UV curable acrylics. This led us to a group of urethane, epoxy and polyester modified acrylics. These substances have a molecular weight of 100 to 1000 g/mol, are low viscosity liquids at ambient temperature, show low 255nm UV absorption and have compared to acrylic monomers a low odor.

A typical product is a commercially available tetrafunctional urethaneacrylate with a molecular weight of 1000 g/mol.[1]



R1= Urethane oligomer
Structure: tetrafunctional urethaneacrylate

Mixtures with UV curable acrylic polymers from BASF resulted in a clear, free flowing mass with interesting adhesion/cohesion properties.

Table 4: Comparison of adhesion and cohesion
Coating weight: 60 gsm
Curing dose: 40 mJ/cm^2 UV-C (250-260 nm)

		Unformulated Acrylate	Formulated Adhesive
Peel on stainless steel (PSTC 101) 20 min	N/inch	16.2	23
Peel on stainless steel (PSTC 101) 24 h	N/inch	18.2	28
Loop Tack on glass (FTM 9)	N/inch	25.0	26
Rolling ball (PSTC 6)	cm	3	5
Shear 70 °C (1000 g / 25 x 25 mm / PSTC 107)	min	240	> 4300 min
SAFT (0.5 °C/min / 1000 g / 25 x 25 mm)	°C	100	> 150

In this case an additional photoinitiator was added for better crosslinking of the molecules.
As a result the shear resistance properties of the formulated adhesive rise significantly.

This formulation technique (patent pending) allows the preparation of low viscosity UV curable acrylic hotmelt adhesives with:

- 20–30 °C lower coating temperatures
- excellent fogging values

and adds another possibility to develop adhesives with specialty properties.

6. Applications

Depending on the requirements for the application, various adhesives with different peel and shear values can be formulated; with coating weights up to 125 gsm.

Table 5: PSTC values of different UV curable adhesive compositions
Coating weight: 100 gsm
Curing energy: 80 mJ/cm^2 UVC
Applications: Tapes for various indoor and outdoor uses

		Adhesive A	Adhesive B	Adhesive C
SAFT, 0.5 kg	°C	56	106	121
Shear 60 °C, 0.5 kg	min	19	388	3000
Shear (FTM 8)	min	201	1706	4000
Peel on stainless steel (PSTC 101)	N/inch	24	37	6
Peel on PE (PSTC 101)	N/inch	29	8	5

Loop Tack on glass (FTM 9)	N/inch	25	31	12
Loop Tack on PE (FTM 9)	N/inch	25	16	10

Coating weight: 83 gsm on textile Tape
Curing energy: 70 mJ/cm^2 UVC
Application: Cable Harness

		Adhesive D	Adhesive E
Peel on stainless steel (PSTC 101)	N/inch	33.7 KB	39.5 KB
Peel on textile Tape (PSTC 101)	N/inch	19.6 KB	24.4 KB
Loop Tack on glass (FTM 9)	N/inch	29.5 AB	29.8 AB

7. Outlook

UV curable acrylic adhesives can be used for a variety of label and tape applications. Removable as well as high performance adhesives can be formulated. The use of reactive additives in UV curable acrylic hotmelt adhesives allows the reduction in processing viscosity without the need for a further photoinitiator system. Furthermore an interesting set of adhesive properties has been found:

- Lower coating temperatures
- Lower coating / processing viscosities
- Excellent fogging behavior
- High adhesion together with high cohesion

However there is still a limit to a coatweight of 125 gsm with this adhesive and formulation technology. New ways have to be found to raise that limit. This is our challenge for new developments.

[1]Collano Paper New Formulation Techniques for Acrylic UV curable Pressure Sensitive Hotmelt Adhesives
[2]BASF
[3]Test Methods for Pressure-Sensitive Tapes, 13th Edition, August 2001, Pressure-Sensitive Tape Council, Glenview, Ill.
[4]FINAT Technical Handbook – Test Methods – 8th Edition, The Hague, February 2009