

Solvent-Free Radiation-Curable Polyacrylate Pressure-Sensitive Adhesive Systems

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ABSTRACT: This article shows radiation-curable solvent-free pressure-sensitive adhesive polyacrylates, their synthesis, chemical modifications, important properties and use after crosslinking with UV-lamps and UV-lasers for the production of self-adhesives tapes. © 2002 Wiley Periodicals, Inc. *J Appl Polym Sci* 87: 182–191, 2003

Key words: pressure-sensitive adhesives (PSA); hotmelts; acrylic; UV-crosslinking; UV-lamps; UV-laser; PSA-tapes; tack; adhesion; cohesion

INTRODUCTION

Polyacrylates have been well established among solvent-free pressure-sensitive adhesives (PSA) for long time because of their excellent properties and their aging stability. As an additional variation to the classical hot-melts, research and development in the PSA industry increasingly involves radiation-curable, hot-melt pressure-sensitive adhesives (HMPSA).

In addition to commercial technology to cure solvent-free systems with an electron beam radiator, there is an ultraviolet (UV) curing technique that in part is already being used. Either a photoinitiator that polymerizes is incorporated into the main chain of the polymer or a side chain of the polymer is modified by a photoinitiator that is able to add itself. The UV-initiated curing may be conducted by broad spectrum radiation from a UV lamp or by a monochromatic light of a UV laser. The new generation of UV-radiation-curable polyacrylate PSAs does not contain free double bonds and is characterized by excellent thermostability.

Regarding the manufacture of solvent-free systems, a significant amount of time and manpower has been invested in the solvent-based polymerization and more recently on the removal of evaporating components (solvent and unreacted monomers) parallel to the typical bulk polymerization in the polymerization vessel, extruder, or directly on the carrier. With such a process, the selection of the monomers as well as the

molecular weight and the viscosity of the polymerized PSA that is formulated in solvent plays an important role. The recovered solvent can easily be used again as a polymerization medium.

PRESSURE-SENSITIVE ADHESIVES

A special type of macromolecular material

The difference between PSAs and other adhesives, such as contact adhesives, is in the permanent surface stickiness of the PSAs before or after the application.

The glass transition temperature (T_g) is the main issue for adhesion properties of various polymers. It is specific for homopolymers, but also reveals important information about suitability of the copolymers as a PSA that is synthesized from various components. For the permanent adherent pressure sensitive adhesives T_g ranges from -70 to -20°C . Not every polymer is by nature suitable for the production of PSAs. The best known examples of polymers that can be considered here as potential raw materials are synthetic and natural rubbers, ethylene-vinyl acetate (EVA)-copolymers, polyamides, polyesters, polyvinylethers, polyurethanes, polysiloxanes, and polyacrylates.

The most important requirements for a PSA, such as high tackiness (adhesion by touch), high cohesion (inner stability), high stickiness (adhesion), UV absorption, solvent ability, and temperature stability, are fulfilled by polyacrylates in an outstanding way.

For manufacture of polyacrylate PSAs, primarily tackifying common acrylic acid esters are preferred with C_4 – C_{12} carbon atoms in the alkyl moiety together with other comonomers. The most important monomers of this class are compiled in Table I.

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TABLE I
Important Monomers

Group	Monomer (Homopolymer)	T_g (°C)
Tackifying alkylacrylates ^a	2-Ethylhexylacrylate	-70
	Isooctylacrylate	-70
	Isononylacrylate	-58
	<i>n</i> -Butylacrylate	-54
Functional groups containing acrylate derivatives ^b	2-Hydroxypropylacrylate	-7
	β -Acryloyloxypropenic	-10
	Acrylic	106
Hardening monomers ^c	Methylacrylate	-6
	<i>N</i> -vinyl pyrrolidone	54

^a Decrease the T_g of the polymer and provide a certain adhesion.

^b Improve the specific adhesion to the various substrates, positively influence the molecular weight and form active crosslinking centres for the later crosslinking reaction). The selection of suitable starting acrylates is fairly limited for the manufacture of solvent-free systems due to the tendency of gelling.

^c Provide a higher cohesion; in this case, both monomers increase the plasticizer resistance of the polyacrylate pressure sensitive adhesives.

SOLVENT-FREE PRESSURE SENSITIVE ADHESIVES

The need to replace solvent-containing systems, which still have maintained a large market share in various areas, results in a further push of innovations in the development of hot-melt PSAs. For the next 5 years, there are predictions of 20% growth rate for the hot-melt sector.¹ Compared with the classical solvent-containing or aqueous systems, the hot-melt coating technology provides the following advantages:

- reduction of environmental impacts to a minimum
- saving of energy costs² (the energy/m² for conventional coating plus drying channel with solvent acrylate is 100% and with dispersion is 90% compared with that for HMPSA coating plus UV crosslinking, which is 33%)
- savings in costs for space (low investment costs: no drying channel)
- high production speed at PSA coatings ≤ 60 g/m²
- production of thick PSA coatings (>140 g/m²) in a one-process step
- production of emission-free PSA products (no fogging effect)

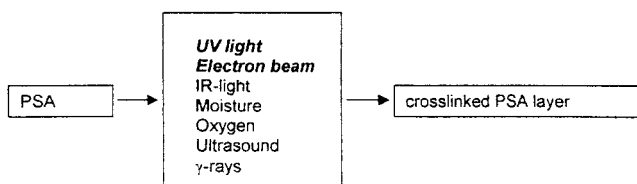


Figure 1 Types of crosslinking.

The disadvantages are primarily as follows:

- only medium or lower molecular weights (MW $\leq 300,000$ Dalton) possible
- limited thermostress
- tendency to gel at coatings at $> 150^\circ\text{C}$
- limited modification options

Heat-shear-stable PSAs can not be made by use of conventional crosslinkers or by thermoreactive crosslinking resins from solvent-free systems.³ To increase the cohesion of HMPSA, the PSA mass is added, thereby creating a crosslinking- initiating impulse directly after the coating (see Figure 1). The application of UV radiation (UV crosslinking) or electron beam curing (EBC) is an effective method to achieve solvent-free PSA layers with high cohesion levels. In this way, irreversible intermolecular chemical bonds occur due to the radiation by forming a three-dimensional network.

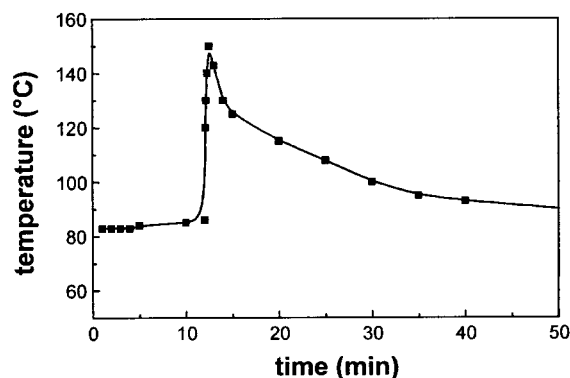


Figure 2 Curve of an uncontrolled substance polymerization.

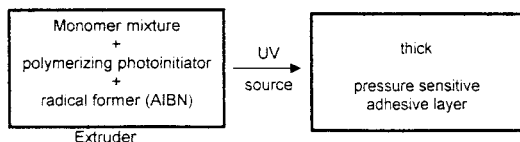


Figure 3 Variation to manufacture thick pressure-sensitive adhesives.

MANUFACTURE OF SOLVENT-FREE PRESSURE SENSITIVE ADHESIVES

Based on polyacrilates

In the case of substance polymerization, monomers are polymerized without diluents. Despite several polymerization techniques, the dissipation of the emitted polymerization heat from a technical point of view is extremely difficult. An uncontrolled heat build-up can occur due to a gel effect. The local overheating (Figure 2) during polymerization leads to extreme cases to degradation or eventually to discoloration of the polymers.

Bulk polymerization in extruder

First developments in the use of the extruder as a chemical reactor for polymerization date back ~50 years. The goal was the manufacture of solvent-free, crosslinkable PSAs based on polyacrylates that were characterized by a yield of >99%, a molecular mass of >200,000 Dalton, and a quality free from gel particles. Despite many efforts, no one succeeded in making a usable PSA by substance polymerization that would meet the desired adhesive characteristics.

An interesting variation to manufacture thick PSA layers (300–1200 g/m²) is a process by which the extruded pressure-sensitive adhesive bulk reaches its final cohesion under UV light (see Figure 3).⁴

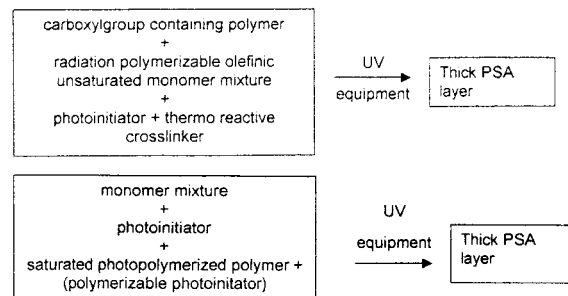


Figure 4 Examples of processes for the manufacture of “thick” pressure-sensitive adhesive layers.

Polymerization on a carrier (UV polymerization/UV crosslinking)

The highly sophisticated technology that was developed and commercially used at 3M in the early 1980s, revealed completely new manufacturing options, however, primarily in the area of the finished PSAs articles. In this area, applications for 130 patents were made, and the source does not seem to end.

There are two principles of different processes run simultaneously that cannot be separated. These processes are UV initiated polymerization and UV initiated crosslinking. The strength and weakness of these processes are shown in Table II. The combination UV polymerization/UV crosslinking plays a special role in the manufacture of “thick” PSA layers, where conventional production processes (e.g., multilayer structure of the PSA tapes) are uneconomical.

Among new processes, there are two systems that appear to be interesting. The UV source additionally functions as a heat source, which increases the activity of the photo initiator (Figure 4).^{5,6}

Concept

A hot-melt PSA, for example, can be made as follows under consideration of the mentioned facts. Starting

TABLE II
Strengths and Weaknesses of Processes

UV Polymerization		UV Crosslinking	
Advantages	Disadvantages	Advantages	Disadvantages
<ul style="list-style-type: none"> • Pressure-sensitive adhesive layers with high viscoelastic properties and good tear force values • “Thick” pressure-sensitive adhesive coatings are possible 	<ul style="list-style-type: none"> • Technologically difficult to control • during UV radiation, addition of various additives limited or not possible due to transfer reactions • Some monomers are left (concentration?) • Inhibition by oxygen 	<ul style="list-style-type: none"> • Modification without problem by resin addition • Process technically relatively simple • Low emission pressure-sensitive adhesive tapes with residual monomer/solvent concentration $\leq 0.3\%$ • No inert gas necessary 	<ul style="list-style-type: none"> • Molecular weight in medium range (upto 3000,000 Dalton) • time intensive process

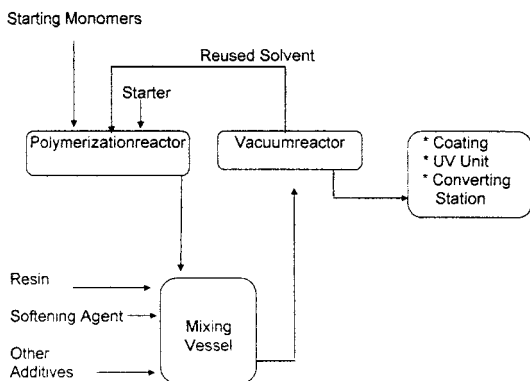


Figure 5 Manufacturing concept for production of adhesives articles based on solvent-free UV crosslinked polyacrylates.

monomers, which are mixed with thermoreactive starter, are specifically synthesized to a PSA bulk with a viscosity of 2–3 Pa·s in such a way that the evaporation of solvents and final monomers can still be accomplished and the resulting, solvent-free polymer can still be modified (can be melted). The polyacrylate hot melt is transferred to a release film at 130–150°C and is converted to self PSA products after UV radiation (Figure 5).

UV crosslinkable solvent-free polyacrylate adhesives belong to the group of one-component products. The photoinitiator is well incorporated into the polymer. Such systems have high reactivity towards UV radiation and have lower amounts of volatile components. Migrating photolysis products are not generated. The PSAs do not have after-crosslinking, are aging resistant, temperature resistant, and dermatologically friendly.

CONTROLLED SOLVENT POLYMERIZATION

The manufacture of PSAs based on polyacrylates is done by polymerization of starting monomers in organic solvents such as ethylacetate, *n*-hexane, or acetone in the presence of radical formers (initiators) at

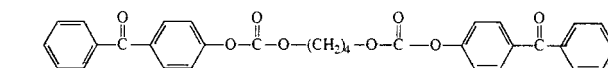
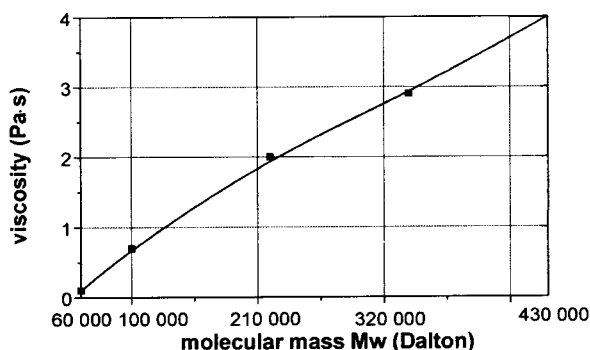


Figure 7 Multifunctional benzophenones.

elevated temperature. The molecular weight of a polyacrylate PSA is of eminent importance for its mechanical and physical properties.

Highly efficient polyacrylate PSAs have molecular weights in the range 200,000–1,500,000 Dalton. UV-curable HMPSA has a molar mass in the range 100,000–300,000 Dalton.

An increase of molecular weight above 300,000 Dalton effects negatively the process viscosity when volatile components are evaporated. In fact, it makes the hot melt unsuitable for coating process (Figure 6).

An interesting possibility of increase in cohesion is achieved with such PSAs systems by radiation with UV light (300–400 nm) from UV lamps or UV lasers. Because of the huge technical efforts, the complicated development of the formulation and insufficient efficiency the EBC method was not further pursued.

PHOTOREACTIVE ADJUSTMENTS OF POLYACRYLATE PRESSURE SENSITIVE ADHESIVES

The physicochemical and mechanical properties of PSAs are determined to a high degree by type and concentration of the crosslinker used.

Multifunctional conventional photoinitiators

This group of substances consists of saturated photoinitiators, which contain at least two photoreactive structures in the molecule and form crosslinkage with the polymer by UV radiation. It is possible to obtain so called migration-free photoinitiators by specific construction, for example, from multifunctional benzophenones (Figure 7).

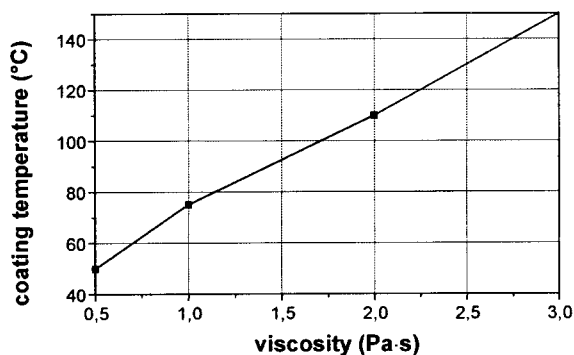


Figure 6 Molecular weight of polyacrylate pressure-sensitive adhesives versus the viscosity of the solvent-containing systems and versus the process temperature of the hot melt.

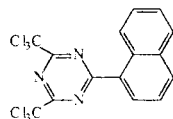


Figure 8 2,4-bisTrichloromethyl-6(1-naphthyl)-triazine (absorption wavelength, 363 nm).

There is the possibility of matching the multifunctional photoinitiators regarding the chemical structure to the commonly used UV sources because of the different UV characteristics. The anchoring in the polymer takes place at protruding alkyl sidechains as in typical H-abstractors.

Photosensitive crosslinkers

This group consists of UV-activating crosslinkers that have absorption maxima at wavelengths between 330 and 380 nm. The best known example of this group is the group of chromophoric substituted bischloromethyl-*s*-triazine⁷ (Figure 8), which function simultaneously as photoinitiator and photocrosslinker.

Sidechain modification with derivatives containing double bonds

One possibility to introduce photoreactive unsaturated groups is synthesizing the bulk PSA first without photosensitive groups and then introducing them after the polymerization into the polymer structure by distinct chemical methods. A typical example of the latter is the acrylation of the hydroxy group containing PSAs on a polyester or polyacrylate base. In practice, the incorporation of an unsaturated architecture is achieved by reaction of OH-, COOH-, or NH₂-groups of a polymer with corresponding isocyanate compounds allylisocyanate,⁸ isocianoethylmethacrylate, or *m*-TMI⁹ (Figure 9). The pressure sensitive adhesives obtained in this way are actually suitable for EBC. For UV crosslinking purposes, commercial photoinitiators are added.

Photoinitiators suitable for polymerization

The idea to use a photoinitiator suitable for copolymerization in the process of UV radiation evolved ~30 years ago, however, was not utilized at that time.

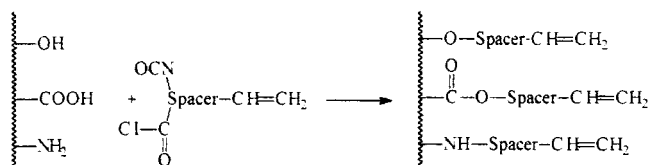


Figure 9 Introduction of photoreactive groups into the pressure-sensitive adhesive structure.

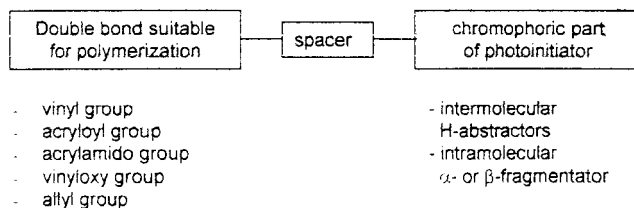


Figure 10 Schematic of photoinitiators suitable for polymerization.

Later developments in this area of PSAs suitable for radiation curing focused on this idea again and resulted in >100 patents that describe the concept and application of photoinitiators suitable for polymerization and the PSAs that contain photoinitiators. Photoinitiators suitable for polymerization should be very soluble, should react completely in the polymerization process, should be highly temperature resistant, and should not form photolytic fragments that tend to migrate with a strong specific odor after the UV radiation. Substances of this type include ethane-unsaturated UV-reactive benzophenones, benzoines, and acetophenones with the structure shown in Figure 10.¹⁰

The spacer and substituents at the basic photoinitiator molecule influence the photoreactivity of the photoinitiator suitable for polymerization as well as influence the effectiveness of the intermolecular crosslinking reaction by mobility of the chromophoric part. The most important photoinitiators suitable for polymerization are shown in Figure 11.

Photoinitiators suitable for addition

Photoinitiators suitable for addition are from a new group of compounds.¹¹ On one side is a conventional photoreactive group (e.g., benzophenone rest) and on the other side are groups that tend to addition reaction, such as compounds from the aziridine group (Figure 12).

The transformation of the carboxyl group of the copolymer takes place after the polymerization by addition reaction in the polymerization media without

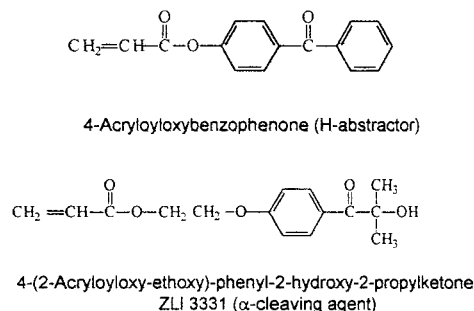


Figure 11 Typical photoinitiators suitable for polymerization.

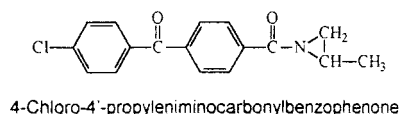


Figure 12 4-Chloro-4'-propyleniminocarbonylbenzophenone.

side products and leads to UV crosslinkable highly efficient PSAs (Figure 13).¹³

MODIFICATION OF HMP SA BASED ON POLYACRYLATES SUITABLE FOR UV CROSSLINKING

Normally, the additives used interfere with the reaction of the crosslinking position in the polymer by getting placed between these positions. Furthermore they can react with the incorporated photoinitiator despite their UV transparency. The additional consumption of photoinitiator decreases the effect of the UV crosslinking.

In some applications it is advantageous to add primarily UV inert tackifiers to the photoreactive PSAs (e.g., hydrated colophonium derivatives, terpene phenolic resins, or hydrocarbon resins) in the amount of up to 30%. Furthermore pigments that contain UV gaps, plasticizing homopolyacrylates, or polyester plasticizer can be considered.

REMOVAL OF VOLATILE COMPONENTS

The solvent is distilled from the polymer under vacuum at elevated temperature after the polymerization is finished. It is used again as polymerization media after condensation. Volatile components are unreacted monomers and the rest of the solvents that are present in the hot melt bulk after distillation.

In extruder

Such a process is conducted in practice by the company Belland/Switzerland and results in solvent-free plastics. The question is to what extent this process can be used in PSAs and how much the volatile components can be removed in the degassing zone.

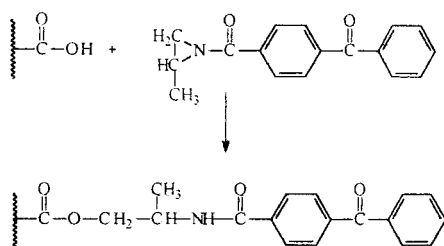


Figure 13 Transformation of carboxyl groups with photoinitiator tending to addition reaction.

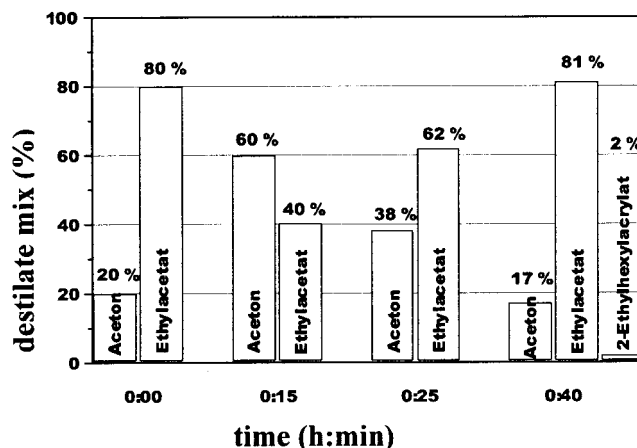


Figure 14 Composition of recovered volatile components.

In thin layer evaporator

The goal of the tests was the reduction of the volatile components to <1.0% and the optimization of the process parameters. Furthermore, medical quality with an amount of <0.3% residual volatiles was attempted by use of a vacuum. The implemented amount of solvent containing polyacrylate was 50 kg/h, the evaporation temperature was 120–180°C. No problems occurred with unmodified polyacrylates, however, gelling was observed with resin-containing formulations.

In polymerization reactors

Such a concept is based on tested techniques and brings the lowest risks in production. At a first glance it utilizes a pseudo-hot-melt technology because it cannot be done without solvents. The advantage of this process is the removal of large quantities of solvents from the solvent-containing PSA within a short time. The recovered solvent is used again in the polymerization process.

After finishing the polymerization in solvent, the solvent is first removed from the polymerization reactor under normal temperature and then at decreased pressure at elevated temperature. A solvent-free PSA is obtained. In one example, the removal of volatile components is done in two steps with a copolymer consisting of 2-ethylhexylacrylate (bp > 230°C) and acrylic acid (bp 141°C) that is formulated in a solvent mix of acetone (bp 56°C) and ethylacetate (bp 77 °C).

- First step: distillation under normal pressure at ~100–120°C (determination of yield, distillation time, and composition of condensate).
- Second step: distillation under vacuum (≤ 20 –30 mmHg) at a maximum temperature of 150°C (similar analysis as in step 1).

TABLE III
Manufacture of Solvent-Free Polyacrylate Pressure-Sensitive Adhesives

Parameter	Polymerization Reactor	Thin Layer Evaporator	Extruder
Volatiles [%]	0.3–0.5	1.5–2.0	>3.0
Yield [kg/h]	125	50	15

With increasing temperature, a final amount of $\sim 0.3\%$ of volatile components was reached at 160°C . A gas chromatogram of the recovered distillate showed that the largest part consisted of the used solvents ethylacetate and acetone. The final amount of 2-ethylhexylacrylate is of lesser importance (Figure 14). The recovered solvent and the unreacted monomers (in this case 2-ethylhexylacrylate) can be used again without problems.

All processes conducted for manufacturing of solvent-free polyacrylate PSAs are compiled in Table III. The presented values do not need any comment.

RELEVANT PROPERTIES OF UV CROSSLINKED HMPSA

The most important parameters of UV crosslinkable polyacrylate PSAs overlap often and depend on each other. These parameters are characterized as follows:

- melt viscosity: used for the flowability of non-crosslinked PSAs in the molten state
- Williams plasticity: allows determination of the increase of cohesion from non-crosslinked to crosslinked status
- K value: a parameter for the average molecular weight of non-crosslinked PSAs
- average molecular weight M_w : provides information about possible cohesion level before and after UV radiation (Figure 15)

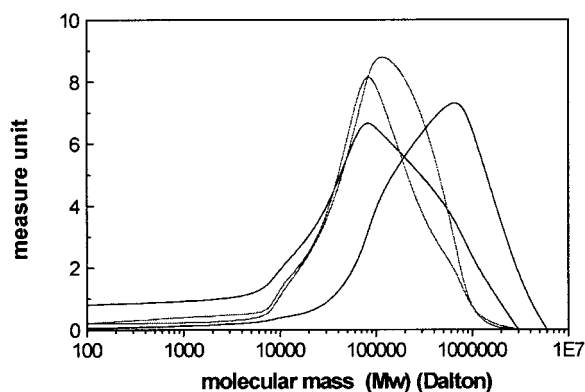


Figure 15 Molecular weight of different polyacrylate hot-melt-pressure-sensitive adhesives.

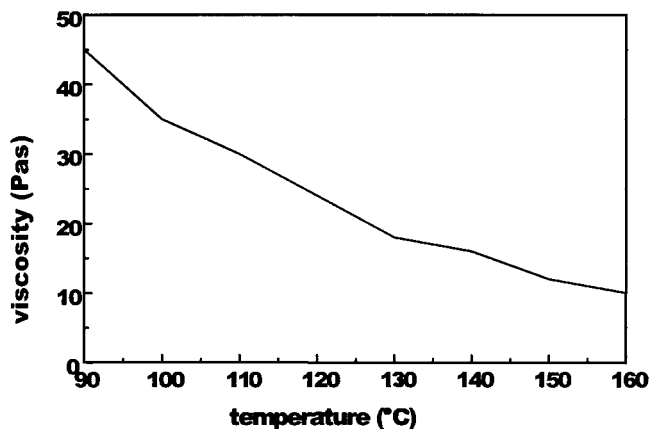


Figure 16 Melt viscosity of UV-crosslinked hot-melt pressure-sensitive adhesives.

- iodine value: provides information about $\text{C}=\text{C}$ double bonds in the PSA structure
- reduced viscosity: refers to degree of polymerization
- gel part: determination of non-melting part of pressure sensitive adhesive
- concentration of volatile components: provides hints at quality of polyacrylate hot melt

After coating and UV crosslinking the following AFERA (Association der Fabricants Europeens de Rubans Auto-Adhesifs) application related properties are determined.

- tack (adhesion to the touch)
- adhesive strength (peel resistance)
- shear strength (cohesion)
- specific adhesion on various substrates with different surface energy.

COATING OF POLYACRYLATE HOT-MELT PRESSURE-SENSITIVE ADHESIVES

Application conditions of a hot-melt PSA are primarily determined by the melting and flowing characteristics (Figure 16). The combination of extruder/wide slit nozzle constitutes an interesting variation of the coating of solvent-free PSAs. Such a process allows one to modify the PSAs with various additives. Furthermore, the application of UV-crosslinked PSAs can be conducted with barrel and tank melting equipment by the slit nozzle coating, as already mentioned, or by the actually known method of heatable coating heads, doctor blade, or roll coater.

The UV crosslinkable hot-melt PSAs have good thermostorage stability; the viscosity stays relatively constant at elevated temperatures.

RADIATION-INITIATED CROSSLINKING

EBC-station

Because the tendency in general goes towards saturated radiation crosslinkable hot-melt PSA systems, the UV technology has to be preferred. EBC-technology is more and more favored in the area of radiation crosslinkable rubber systems.

Mechanism of UV crosslinkage

During UV exposure, the intermolecular H-abstractor structures are excited and react with the neighboring C—H positions of polymer sidechains. The crosslinking mechanism of UV-reactive HMPSA has been thoroughly investigated and is presented schematically in Figure 17. UV crosslinkable HMPSA possess excellent oxidation resistance, which allows one to work without inert gas atmosphere.

Normally, polyacrylates absorb the entire radiation at <300 nm. To accomplish acceptable crosslinking with transparent PSA layers, only UV wavelengths $>\sim 300$ nm are of importance. Because, in general, energy of 350–410 kJ/mol is required for stimulation of H-abstractors (benzophenone derivatives), a UV wavelength range of ~ 300 to 410 nm is required. Such UV radiation is emitted with common UV lamps.

UV lamps (spectral)

The most important properties of the crosslinked polyacrylate PSA layer, such as tack, peel strength, and shear resistance, can be controlled by the UV dosage. The solvent-free UV-curable polyacrylates are coated directly or in a transfer process depending on the carrier material. With the PSA layers starting at ~ 60 g/m², which are primarily used for the manufacture of double-sided PSA tapes, a tendency of hardening can be observed.

The curing with UV light can be done directly after the application or after passing a cooling zone. Mercury lamps (low, medium, high pressure) are used with power between 80 and 120 W/cm, which in-

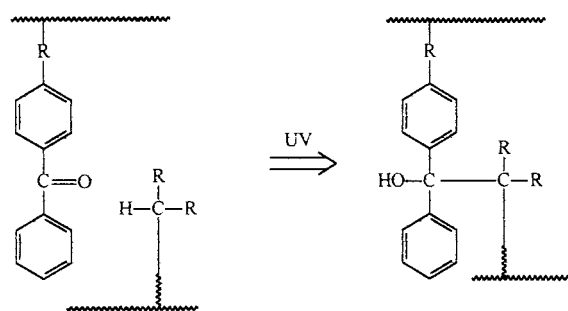


Figure 17 UV-initiated crosslinking reaction with HMPSA based on polyacrylates.

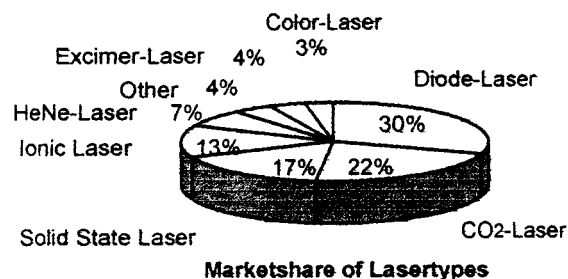


Figure 18 Distribution of various LASER types.

cludes UV stations with six and more UV lamps as the state of the art with a power of 120–250 W/cm.

The A wavelengths, responsible for UV curing, are in the range 320–400 nm. Spectral emissions of common UV A radiators for this application also contain other wavelengths, for example, that IR shares.

UV laser (monochromatic)

The word LASER (Light Amplification by Stimulated Emission of Radiation) reveals a technology existing since about 40 years ago. In 1990, Japan had a 43% share the world market of LASER systems, USA had 31%, and Western Europe had 26%. Figure 18 is a pie chart of how the world market for LASER in 1989 was distributed over the various LASER types. The reason for the distribution is found in part in the historical introduction of systems, but primarily in the various application fields that the LASER types have conquered.

Regarding the PSA technology, the excimer LASERS have the highest chance to be used. The excimer LASER was invented in 1975, and is considered in comparison to Nd:YAG-LASER the youngest LASER with high radiation power. Still, only a few practice related application areas for excimer LASERS are found because of the relatively short development time. The most important field is the electronic industry, and interesting new technology includes photo- and polymer chemistry.

Excimer LASERS are very intense pulsed light sources that radiate UV wavelengths between 170 and 351 nm, depending on the noble gas-halogen mixture, and provide a high energy, MW-power that is in the ns-range of radiation times (Table IV).

TABLE IV
Wavelengths of Excimer LASER

Active Medium	Wavelength (nm)
ArCl	170
ArF	193
KrCl	222
KrF	248
XeCl	308
XeF	351

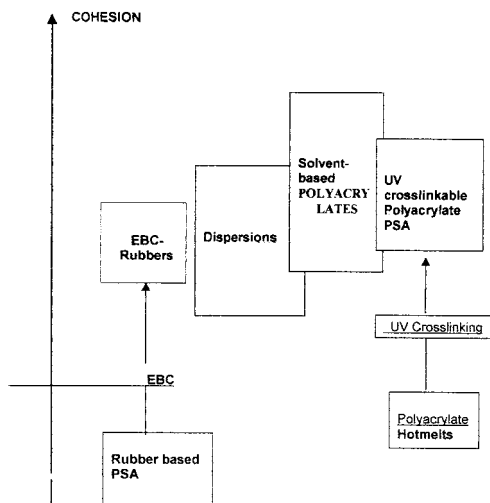


Figure 19 Adhesive characteristics of UV-cured pressure-sensitive adhesives.

The advantage of UV radiation from excimer LASERS lies primarily in the tailored UV light spectrum. The excimer LASER with monochromatic UV light offers in comparison to commercial UV lamps with spectral UV light significant advantages in the application possibility of chemical synthesis of macromolecules, in particular in LASER-induced polymerization¹² and/or LASER-initiated crosslinking.¹³

The introduction of LASER technology requires new demands to the development of photoinitiators, which are incorporated in the main or sidechain. The LASER optic producers also are confronted with a number of tasks. The investment costs of the LASER equipment still constitutes the largest application hurdle.

The application of LASER equipment in comparison to conventional UV lamps provides the following advantages:

- a monochromatic wavelength instead of a spectral one guarantees high reaction speeds
- the distance between the reflected laser beam and the PSA surface that is radiated is not relevant in comparison to the distance of UV lamp/PSA layer when conventional UV equipment is used
- the LASER beam is monochromatic and contains no IR parts (no additional heating of the PSA layer or the coated substrate)
- UV curing of "thick" PSA layers (up to 3 mm)
- no problems with the UV curing of PSA containing suitable tackifiers, plasticizers, fillers, and other additives.

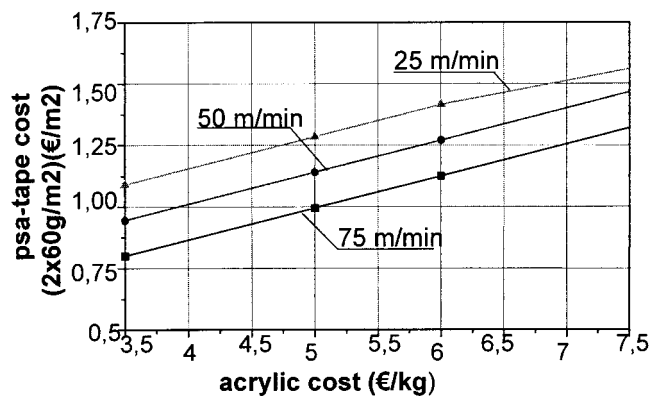


Figure 20 Manufacturing cost versus raw material cost.

UV-CURED POLYACRYLATE PRESSURE-SENSITIVE ADHESIVES IN COMPARISON WITH COMMERCIAL PRESSURE-SENSITIVE ADHESIVES

The extremely important characteristic "cohesion" was used here (Figure 19). Regarding the cohesion, there are the UV-cured polyacrylate HMPSA positioned presently between polyacrylate dispersions with average performance level and solvent-based polyacrylate PSAs. Depending on the photoinitiator used, the PSA coating weight, the type of UV source, and the coating speed/radiation time, there high cohesion values achievable with certain UV-crosslinking polyacrylate PASs.

APPLICATION OF UV CROSSLINKABLE POLYACRYLATE HOT MELT

Pressure sensitive adhesives

There is a broad spectrum of application for UV-crosslinkable polyacrylate hot-melt PSAs. Several types with <3.0% of volatile components can be used without problem for medical or hygiene products, such as band aids, first aid, incision foils, or hydrogels, or for PSA design of various bioelectrodes and slip-pad because of their excellent adhesion, good skin compatibility, and physiological safety.

TABLE V
Cost for Manufacturing Pressure-Sensitive Adhesive Tapes at Constant Coating Speeds in Linear Relationship of Cost for Polyacrylate Hotmelts Used

UV Crosslinkable Pressure-Sensitive Adhesive [DM/kg]	Pressure-Sensitive Adhesive Tape Manufacturing Cost ($2 \times 60 \text{ g/m}^2$) at Various Coating Speeds [DM/m ²]		
	25 m/min	50 m/min	75 m/min
7	2.17	1.88	1.60
10	2.57	2.27	1.99
12	2.83	2.54	2.25
15	3.22	2.93	2.64

Within the technical qualities (residual volatile compounds between 0.3 and 0.6%), the application area includes PSA labels, PSA decor films, protective films, construction support in the form of holding labels, PSA photopaper, insulation tapes, post its, PSA adhesive wall covers, a variety of double-sided PSA tapes, etc.

As a specific application, the lamination of lead glass and the use in shielding of LCD-displays has been reported,¹⁴ where conventional polyacrylate hot-melt systems fail because of insufficient chemical resistance. The manufacturing costs of a double-sided PSA tape are presented in Table V to show the rentability calculation in the use of solvent-free systems. The costs for manufacturing PSA tapes at constant coating speeds in linear relationship to the cost for the polyacrylate hot melts used are shown in Figure 20. From the data in Table V, three linear performance equations result that present the manufacturing cost for PSA tapes in relation to the cost of the PSA:

$$KP = 0.13 \times KK + 1.27 \text{ at } 25 \text{ m/min}$$

$$KP = 0.13 \times KK + 0.98 \text{ at } 50 \text{ m/min}$$

$$KP = 0.13 \times KK + 0.69 \text{ at } 75 \text{ m/min} \quad (1)$$

where KP is the PSA tape price in DM/m² and KK is the PSA cost in DM/m².

FUTURE ASPECTS

The next decade will show how the newly developed UV-crosslinkable polyacrylate hot-melt PSA systems will position themselves in the market. Despite some weaknesses, such as cohesion, which have to be improved, these systems are characterized, in addition to good tack and good adhesion, with high light, air, moisture, and solvent resistance in the crosslinked state. Because of environmentally conscious economy politics, such a system surely will be on the market more often. Interesting sales opportunities will arise in the future for water soluble UV-crosslinkable hot melts based on polyacrylates.¹⁵⁻¹⁷

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