Technical Information AS-TI 6

Additives for Aqueous Pressure-sensitive Adhesives

A member of ALTANA

Additives for Aqueous Pressure-sensitive Adhesives

About BYK

BYK additives offer broadly diversified, cross-industry applications for adhesives and sealants. They improve product properties, optimize production processes and provide perfect applications and the best possible property profiles in the final application.

BYK is your technology partner when it concerns improving the properties of your adhesives and sealants, and offers additives for all kinds of adhesive systems. Starting with products for the area of aqueous dispersion adhesives, such as acrylate and polyurethane dispersions, to solvent-borne systems or solvent-free reactive systems such as polyurethanes, epoxides, acrylates and silane-terminated systems.

The use of BYK additives has a distinct positive effect on the processing of systems, mechanical properties, application behavior and, finally, the quality of your end product. BYK's product portfolio includes rheology additives for the targeted control of rheology behavior, surface additives and defoamers for defect-free applications and optimized manufacturing processes, wetting and dispersing additives, and process additives as well as wax additives and adhesion promoters.

Contents

Introduction

Pressure-sensitive adhesives are used to produce adhesive tapes and self-adhesive labels. They are characterized by their lasting adhesion which enables permanent or detachable adhesive connections to be formed with light contact pressure.

Typical applications for aqueous pressure-sensitive adhesive systems range from adhesive tapes for the packaging industry to removable labels and permanent adhesive products for bonding mirrors or skirting boards. Aqueous pressure-sensitive adhesive systems are based on acrylate or polyurethane dispersions.

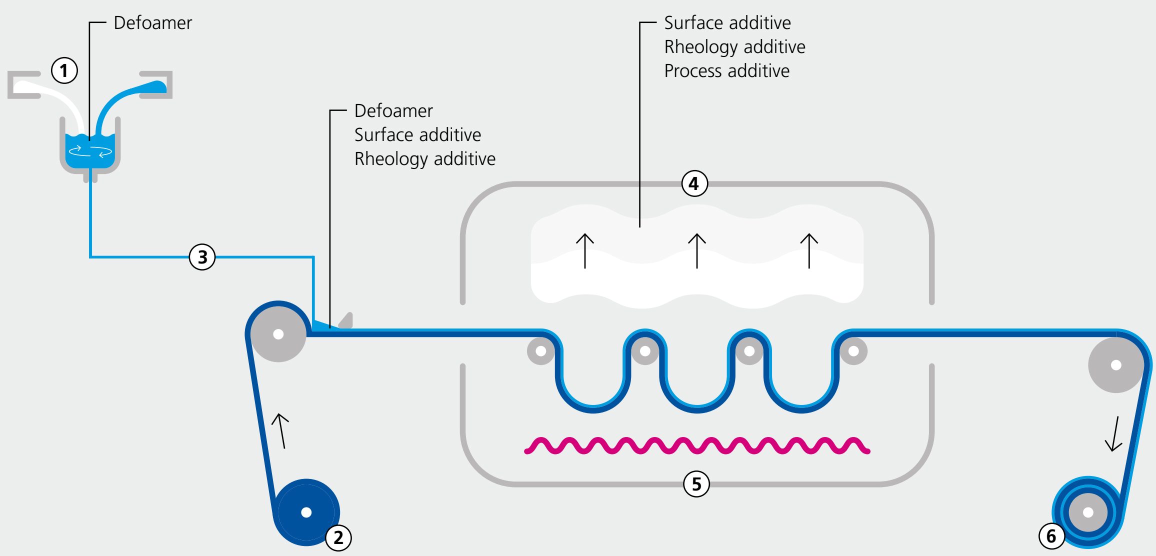
BYK additives optimize the production and application process of aqueous pressure-sensitive adhesives, and improve the application properties.

Defoamers reduce or avoid the formation of foam during production and application processes.

Surface additives optimize the wetting on the pressure-sensitive adhesive carrier and the separating foil.

Rheology additives adjust the flow behavior of aqueous dispersions, enabling a spatter-free application and good wetting on the carrier.

Effect of Additives in the Production Process



1. Production of the aqueous pressure-sensitive adhesive dispersion
2. Providing of the carrier
3. Application of the dispersion on the carrier
4. Evaporation of the water
5. Heating
6. Winding the PSA product

Figure 1

Defoamers for Pressure-sensitive Adhesives

Aqueous pressure-sensitive adhesive dispersions can develop foam during the mixing and production process, impeding mixing, and extending transfer and filling times. Foam can also form when processing with spray, nozzle or roller applications. This formation can lead to surface defects, craters and a reduction in adhesion.

Defoamers prevent and destroy the foam bubbles, enabling improved processing, a perfect surface and optimum product properties.

Creation of Foam and Effect of Defoamers

The generation of stable foam bubbles requires **foam-stabilizing substances** to be present in the liquid phase. Generally speaking, these are surface-active substances (surfactants), which are characterized by having hydrophobic and hydrophilic chemical domains in the molecule. Due to this structure, they orientate themselves at the interfaces the liquid and the gaseous phase, **reduce the surface tension** and create the requirements for a stable foam. Every aqueous pressure-sensitive adhesive dispersion contains a multitude of such surface-active substances which encourage foam formation and stabilize the foam.

Defoamers are used to prevent foam formation or to destabilize foam bubbles that arise despite the presence of foam-stabilizing substances, and to destroy foam as quickly as possible.

A key feature of all defoamers is their targeted and **controlled incompatibility** with the medium that is to be defoamed. A defoamer that is too compatible does not migrate into the foam lamella specifically, it is distributed evenly in the pressure-sensitive adhesive film; the defoaming effect is either low or non-existent.

Foam Stabilization by Surfactants

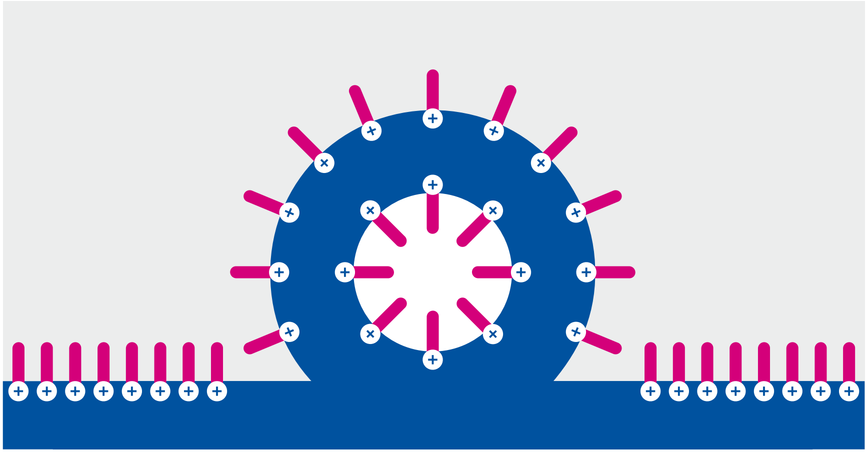


Figure 2

Too much incompatibility causes defects such as turbidity or cratering. Choosing the correct defoamer is a "balancing act" between compatibility and incompatibility. The term "incompatibility" generally does not mean that a reduction in adhesion can be expected after the pressure-sensitive adhesive has been applied. When using a suitable defoamer, and provided the recommendations for incorporation and dosage are followed, there is no reduction in the adhesion and performance of the pressure-sensitive adhesive.

To adjust the optimum defoaming in aqueous pressure-sensitive adhesive dispersions, differentiation is made between three defoamer groups:

- Mineral oil defoamers
- Silicone defoamers
- Silicone-free polymer defoamers

Mineral oil defoamers consist of approximately 85–95 % mineral oil and 1–3 % hydrophobic particles. They can also contain emulsifiers, biocides and other performance-enhancing ingredients such as modified polysiloxanes. Aliphatic mineral oils are used as the carrier oil.

Silicone defoamers are defoamer fluids with a particularly low surface tension, which contain polysiloxanes as the primary active substance. However, when selecting a polysiloxane, its structure is critical. For instance, the relatively short-chained polysiloxanes that are used as silicone surface additives stabilize foam but have no defoaming effect. Whether a polysiloxane has a defoaming or foam-stabilizing effect depends on its compatibility and solubility in the medium: only incompatible and insoluble polysiloxanes have a defoaming effect.

Polymer defoamers also have a defoaming effect due to their incompatibility. Finding the right balance between "incompatible" and "compatible" is achieved by making selective changes to the polarity and molecular weight (molecular weight distribution) of the polymer structures. In polymeric defoamers for water-borne systems, hydrophobic particles are used to enhance the defoaming efficiency. Chemically, the particles are based on hydrophobic silicas, polyurea or polyamide.

Defoamers for Acrylate Pressure-sensitive Adhesive Dispersions

To evaluate the efficiency of the defoamer in the specific pressure-sensitive adhesive dispersions, the systems are modified using defoamers and are then precisely foamed. The foam volume is assessed. The following graphic provides an overview of typical defoamers and their efficiency in aqueous acrylate dispersions.

Defoamers for Pressure-sensitive Adhesive-acrylate Dispersions

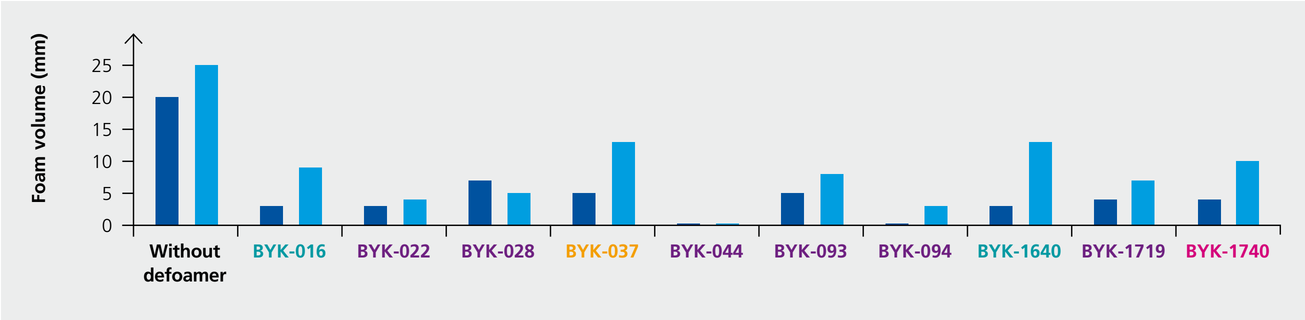


Figure 3

Test method: The defoamer is incorporated in the acrylate dispersion with a dissolver. The modified dispersion is then foamed using a dissolver disc at a defined speed and for a defined period of time. Directly after foaming, the initial filling height is compared and assessed against the foam height. The influence on the speed of the foam destruction is measured by reassessing the foam height after a defined period of time. The parameters such as agitation speed, agitation duration, choice of agitating disk and receptacle used are adapted according to the system that is to be tested.

Evaluation: The effectiveness and choice of defoamer depends on the system. For example, the polymer defoamer BYK-1640 is highly effective in the acrylate dispersion 1, whereas the foam height in the acrylate dispersion 2 is higher. In both test systems, BYK-094 and BYK-044 show very effective defoaming. Good efficiency of the defoamer depends on a targeted incompatibility of the additives in the system. A strong defoaming effect with too much incompatibility can cause surface defects or problems with the substrate wetting. It is important to assess and exclude this by carrying out tests.

Surface defects can also be minimized by modification with surface additives.

Food Contact

With pressure-sensitive adhesive dispersions, especially for packaging and label applications, both performance and legal requirements, with legal provisions must be ensured. BYK provides a multitude of additives which are suitable for direct food contact. Please contact us with any food contact legal status queries:
foodcontact.byk@altana.com
www.byk.com/foodcontact

Acrylate Dispersion

Without defoamer **With BYK defoamer**

Figure 4

Defoamer Recommendations for Aqueous pressure-sensitive Adhesive Dispersions

Defoamer class	Recommendation
Polymer defoamers	**BYK-016** **BYK-017** **BYK-1640**
Silicone defoamers	**BYK-022** **BYK-028** **BYK-093** **BYK-094** **BYK-1719**
Mineral oil defoamers	**BYK-037** **BYK-039**
Defoamers based on renewable resources	**BYK-1740**

Figure 5

Surface Additives for Pressure-sensitive Adhesives

Wetting as a Function of Adhesive and Cohesive Forces

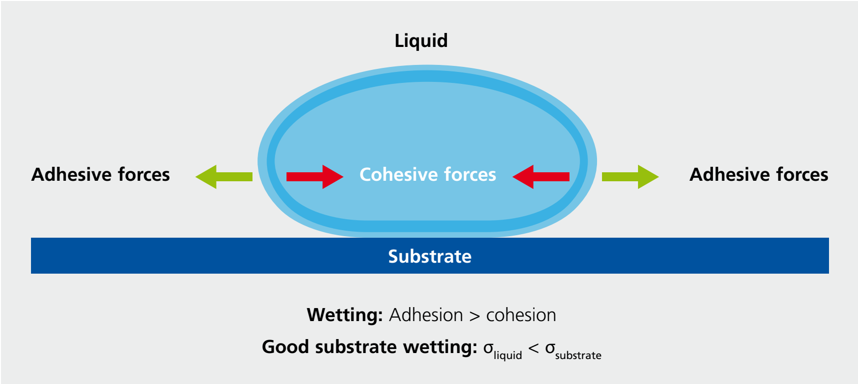
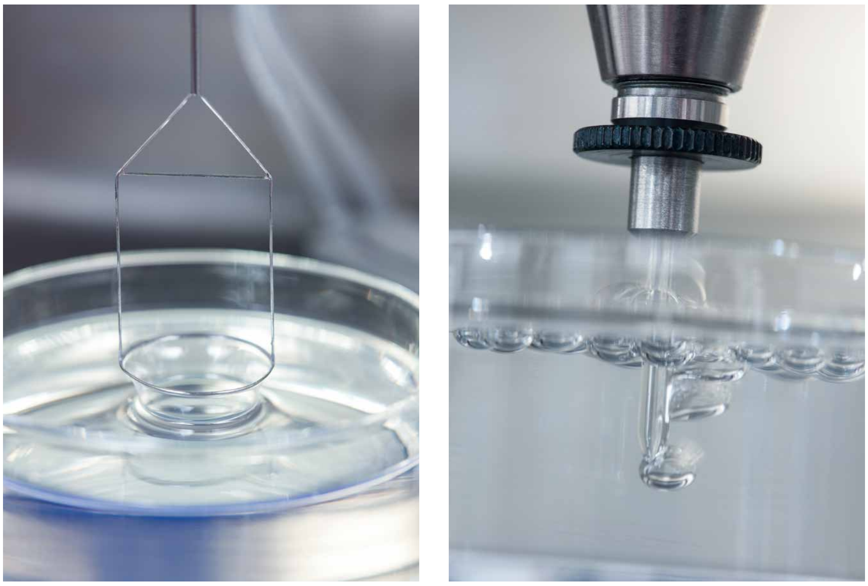


Figure 6

Measuring the Surface Tension



Ring method **Bubble pressure tensiometer**

Figure 7

The production of pressure-sensitive adhesive products such as labels and adhesive tapes requires good wetting and good leveling of the dispersion on the carrier. Surface defects on the applied film are undesirable as they affect the visual appearance and the adhesion. Typical surface defects are poor substrate wetting, cratering and insufficient leveling. A key parameter is the **surface tension** or surface tension differences between the materials involved, which lead to surface defects. To avoid these faults, additives are used which influence the surface tension of the adhesive dispersion and minimize surface tension differences. Mostly, these additives are based on polysiloxanes (silicones), which – depending on their chemical structure – reduce the surface tension of the dispersion. Alongside an improvement in the substrate wetting and outstanding anti-cratering properties, polysiloxane surface additives can also improve the surface slip of the pressure-sensitive adhesive film.

Generally speaking, a good substrate wetting is achieved as soon as the surface tension of the dispersion is lower than the surface energy of the substrate that is to be wetted.

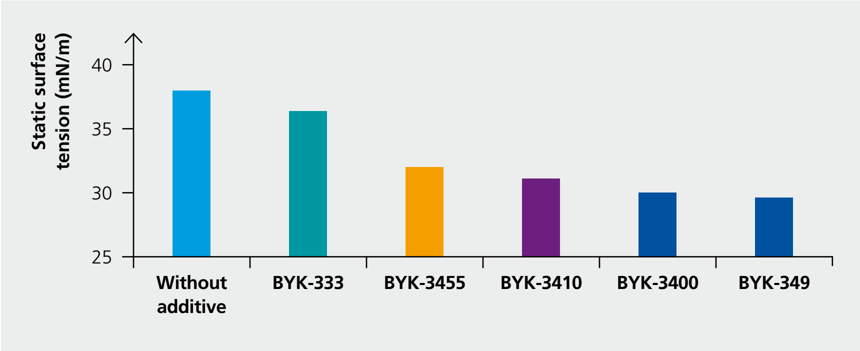
The surface tension of the liquid pressure-sensitive adhesive dispersion can be determined statically by the Du Noüy ring method, and dynamically by the bubble pressure tensiometer. The test methods can be seen in Figure 7.

With the ring method, during the measurement no energy is applied to the liquid, and the surface-active substances involved are in a thermodynamic equilibrium. This represents the state after application of the dispersion (static surface tension). When measuring using the bubble pressure tensiometer, the measuring process is based on continuously and rapidly forming gas bubbles, which is how this method determines the surface tension for, e.g., the application of the dispersion (dynamic surface tension). So as to characterize the dispersion in full, both measuring principles should be applied.

The determination of the surface energy of the substrate that is to be wetted is carried out by evaluating the contact angle of different liquids on the respective substrate. In doing so, the contact angle is an indication for the wettability of the substrate.

Good wetting of pressure-sensitive adhesive dispersions on the respective substrates is essential. Polysiloxane-based surface additives reduce the surface tension of the pressure-sensitive adhesive dispersions and therefore enable a defect- and crater-free draw down even on those substrates which are difficult to wet, such as PET or polyolefin-based plastics. Figure 8 provides an overview of the efficiency of different surface additives for pressure-sensitive adhesive applications.

Acrylate Dispersion – Modified with 0.3 % Surface Additive



Polymeric silicone
Silicone surfactant with polyether modification
Silicone-free variant of BYK-3400
Standard silicone surfactants

Figure 8

The Surface Tension can be Adapted by Adjusting the Dosage to the Required Level

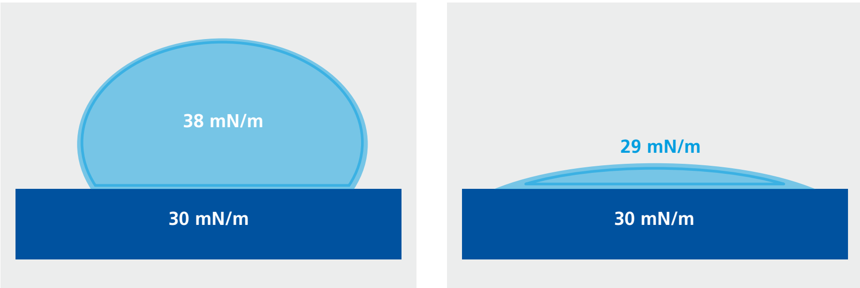
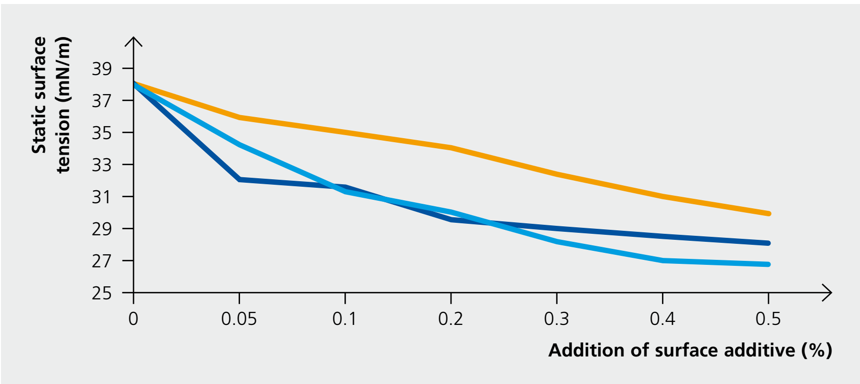


Figure 9

A significant reduction in the surface tension even at a low dosage and with a good spreading on the low-energy substrates is achieved by the modification with special trisiloxane-based surface additives. The effect is shown in Figure 10.

Dependency of Static Surface Tension on the Addition of Silicone Surfactants



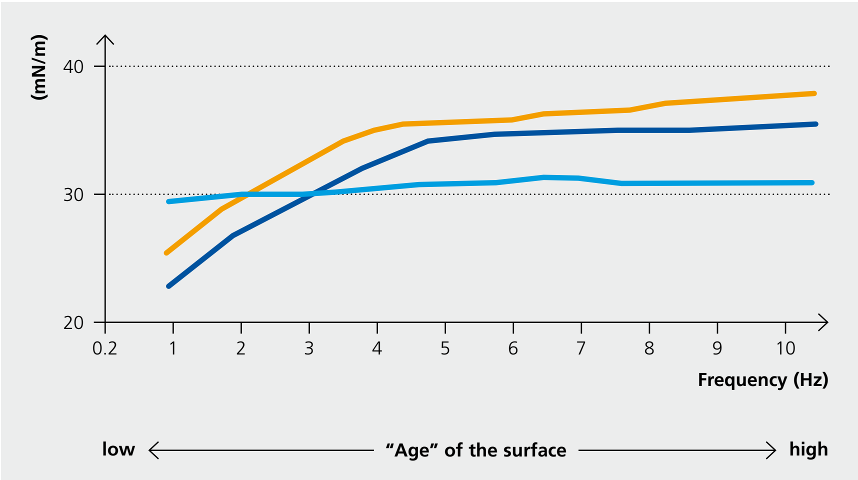
Standard silicone surfactant
BYK-3450
BYK-3451

Figure 10

Surface Additives for Pressure-sensitive Adhesives

The dynamic surface tension is essential for fast application processes, as the interfaces are generated very quickly. Alongside the static surface tension, the kinetics of the interface formation also have a significant influence. BYK-DYNWET 800 creates a considerable reduction in surface tension across the entire kinetics of the interface formation.

Dynamic Surface Tension of an Acrylate Dispersion Depending on the Frequency, 0.2 % Additive Addition



BYK-345 BYK-349 BYK-DYNWET 800

Figure 11

Surface Additive Recommendations for Aqueous Pressure-sensitive Adhesive Dispersions

Reduction of static surface tension	**BYK-3400** **BYK-3410** **BYK-3450** **BYK-3451**
Reduction of dynamic surface tension	**BYK-3450** **BYK-3451** **BYK-DYNWET 800**

Figure 12

Surface Wetting on a Silicone Paper

Insufficient wetting without surface additive

Optimum wetting with surface additive BYK-349

Figure 13

Combination of Defoamers and Surface Additives

For optimum production, filling and application of pressure-sensitive adhesive dispersions, it is often necessary to use a combination of surface additives and defoamers. Due to their incompatibility, defoamers can encourage surface defects, while specific surface additives can promote the stabilization of foam. Combining the two additive classes can address both defect causes, and achieve an application with both good leveling and the absence of foam.

The efficiency of the defoamer and surface additives as well as the targeted and necessary incompatibility of the defoaming additives depends on the system. The evaluation of suitable system-specific additive combinations is required (Figure 14).

Typical additive combinations for optimum pressure-sensitive adhesive dispersion properties can be seen in Figure 15.

Reduction in Surface Tension and Foam Stabilization by Combination with Defoamers

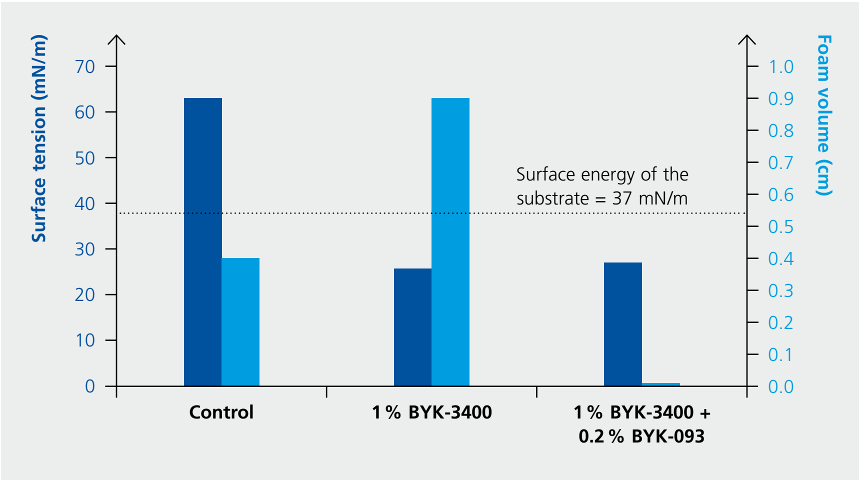


Figure 14

Defoamer	Surface additive
BYK-016	BYK-3400
BYK-093	BYK-3410
BYK-094	BYK-3450
BYK-1640	BYK-3451
BYK-1740	

Figure 15

Influence of Defoamers and Surface Additives on Mechanical Properties

Essential assessment criteria for pressure-sensitive adhesives are the adhesion testing in a 180° peel test and the test of shear strength. The process-optimized modification of the aqueous pressure-sensitive adhesive dispersions with surface additives and defoamers enables a defect-free substrate wetting, preventing technical adhesive defects. It must also be checked whether necessary incompatibilities of the defoamer in the binder matrix will influence the adhesion. Figure 16 shows that the peel strength of an aqueous acrylate pressure-sensitive adhesive is not influenced by the modification with defoamers. The defined incompatibility of the defoamer doesn't have a negative impact on the mechanics of the adhesive bond.

No Influence of Defoamers on the Peel Strength

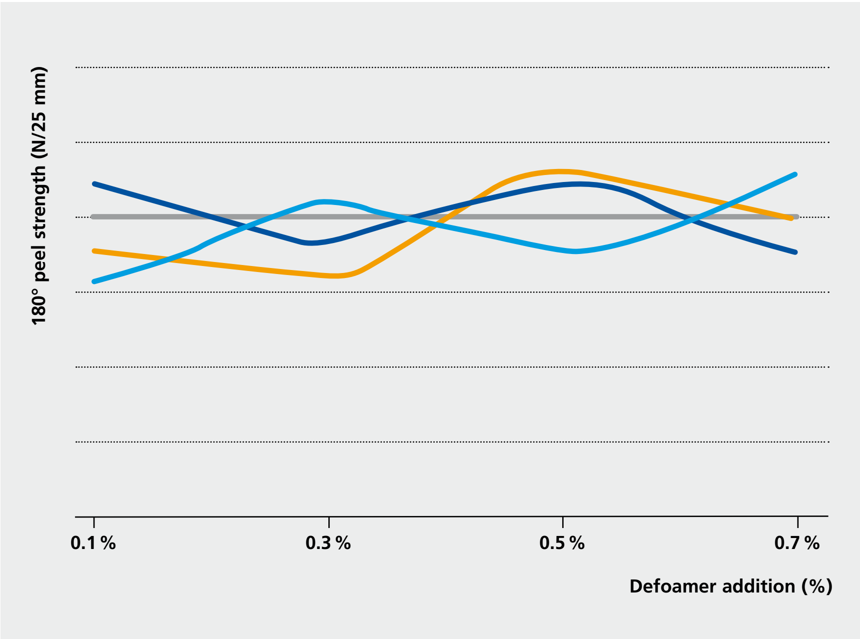


Figure 16

180° Peel Test

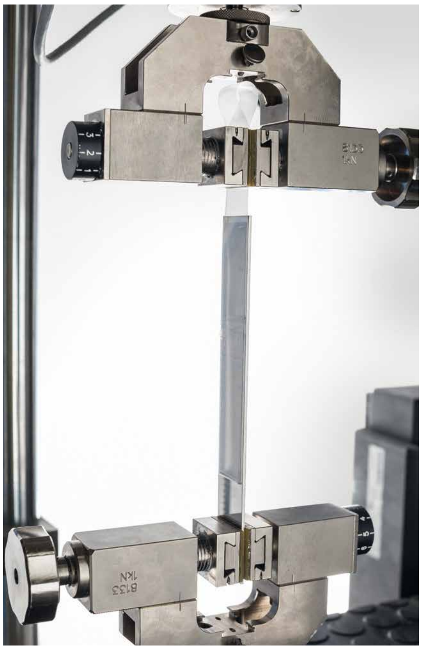


Figure 17

Rheology Additives for Pressure-sensitive Adhesives

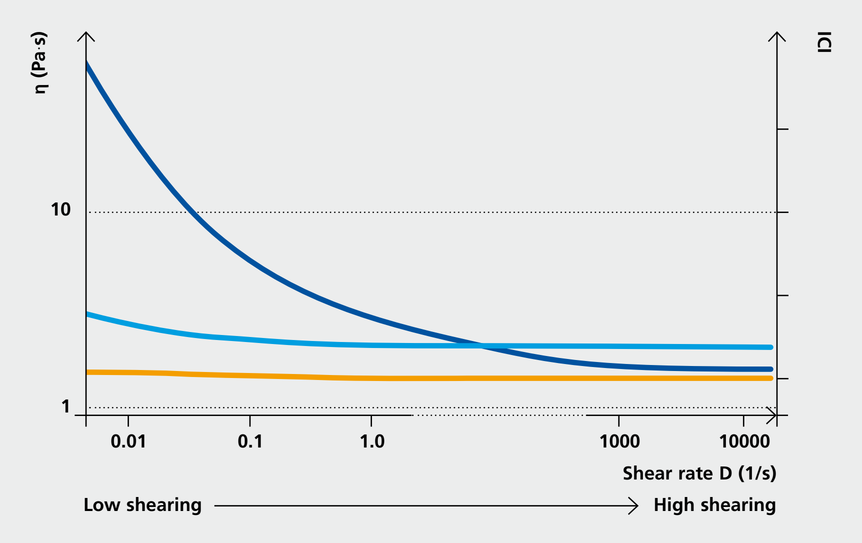
When formulating pressure-sensitive adhesive dispersions, a defined rheology behavior is desired.

A high viscosity in the low shear range prevents the settling of solids and any phase formation of different formulation components. Furthermore, the wetting of the dispersion adhesives on the pressure-sensitive adhesive carrier is optimized. When applying high shear forces, e.g. during stirring, pumping and processing, the viscosity is reduced which ensures good applicability and processing.

If, however, this shear thinning effect is too strong, the viscosity during application is reduced to such an extent that spattering and other undesirable effects can occur. By using a rheology additive for the high shear range, also referred to as a "Newtonian thickener", this effect can be avoided. The additive increases the viscosity in the low shear range only negligibly, but in the high shear range it increases the viscosity considerably. This increased viscosity level at high shear forces can significantly reduce or even completely prevent the spraying when applying.

An increased viscosity across the entire shear range with Newtonian flow behavior improves the anti-spattering effect at high application speeds. Figure 19 shows the spattering behavior of an acrylate pressure-sensitive adhesive dispersion with no additive on the left and 0.3 % addition of RHEOBYK-T 1010 (0.3 % based on the active substance) on the right.

Mode of Action of Associative Thickeners



Dispersion (control)
RHEOBYK "H" (pseudoplastic thickener for low/medium shear ranges)
RHEOBYK "L" and "T" (thickener for the high shear range)

Figure 18

Reducing Spattering During Application

Without additive

0.3 % RHEOBYK-T 1010

Figure 19

Rheology Additive Recommendations for Pressure-sensitive Adhesive Dispersions

Newtonian rheology behavior/ high-shear thickener	Pseudoplastic rheology behavior/ low-shear thickener
RHEOBYK-L 1400 RHEOBYK-T 1000 RHEOBYK-T 1010	RHEOBYK-H 3300 VF RHEOBYK-H 7500 VF

Figure 20

Detailed information about our additives and sample orders can be found at:

www.byk.com

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Additive Guide

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