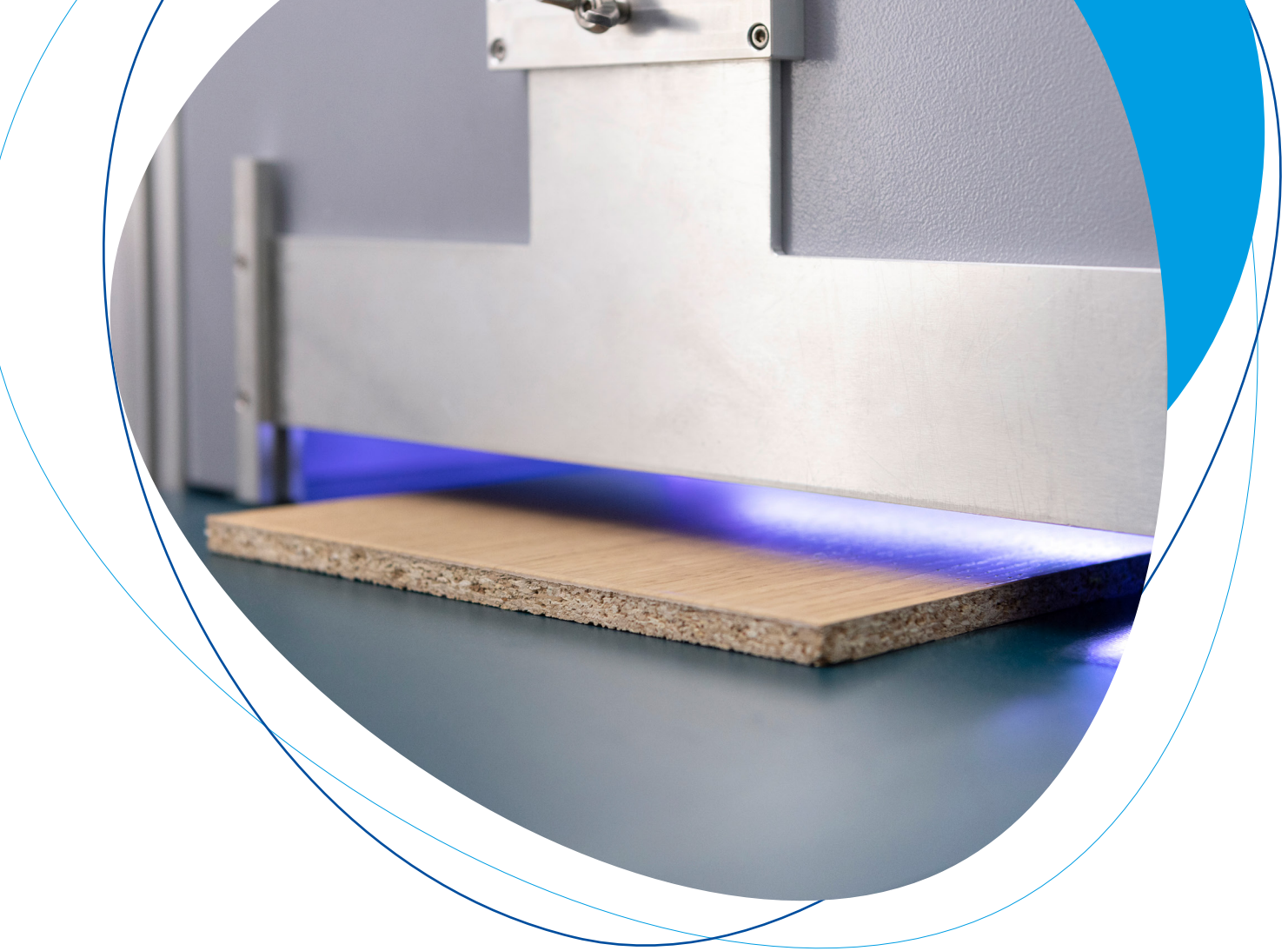


BYK

TECHNICAL INFORMATION

SOLVENT-FREE RADIATION-CURING WOOD AND FURNITURE COATINGS

L-TI 7

A member of ALTANA

Contents

Introduction

Solvent-free, radiation-curing coating systems have been in use in industrial applications since the 1970s. These systems and the coating machinery have undergone a process of continuous improvement, and the curing mechanisms have been optimized. Nevertheless, owing to the absence of solvents and increasingly faster curing mechanisms, the challenge of meeting formulation parameters and making the optimum selection of additives has become ever more apparent. Balancing the individual components is essential and forms the basis for fulfilling current standards with respect to quality and durability.

Note

To ensure the best appearance and full functionality, please open in Adobe Acrobat.

Wetting and stabilization of pigments

The effective wetting and stabilization of inorganic and organic pigments for solvent-free, radiation-curing wood and furniture coatings requires the use of wetting and dispersing additives that both exhibit broad compatibility with all commonly used monomers and oligomers and ensure long-lasting deflocculation of the pigment particles in the liquid matrix.

These characteristics are the prerequisites for:

- An excellent viscosity-reducing effect and the reduction of thixotropic flow behavior combined with the potential for increasing pigment load
- The best possible coloristic properties in the form of maximum tinting strength, excellent hiding power or transparency, and improved gloss with minimal haze
- Long-term storage-stable pigment concentrates and pigmented radiation-curing coating systems

The specific formulation of solvent-free radiation-curing coating systems increasingly requires that all raw materials used, including the wetting and dispersing additives, are solvent-free. Accordingly, product recommendations and developments are focused on solvent-free wetting and dispersing additives.

Transparency of a coating system as a result of different pigment stabilization

Excellent transparency in a coating based on a phthalocyanine pigment as the result of an optimum selection of additives (right) in comparison with the transparency of a coating with insufficient pigment stabilization (left).

G.01

DISPERBYK-111 is a solvent-free wetting and dispersing additive with acidic pigment affinity groups, which makes it particularly suitable for use with titanium dioxide and other inorganic pigments. Through steric stabilization, DISPERBYK-111 ensures highly effective deflocculation of the pigment particles, which is reflected in a very strong reduction in viscosity accompanied by improved flow behavior and increased hiding power.

For the best possible deflocculation and stabilization of organic pigments and carbon blacks in solvent-free, radiation-curing coating systems, wetting and dispersing additives with aminic pigment-affinic groups have proven effective in practice. However, in order to keep these aminic groups from producing unintended interactions with the monomers and oligomers used (e.g. resulting in insufficient storage stability of the coating systems), tailor-made additive structures are required, such as those achieved in DISPERBYK-2013 and DISPERBYK-2155.

DISPERBYK-2013 and **DISPERBYK-2155** are high-molecular weight, solvent-free wetting and dispersing additives that are highly effective in stabilizing organic pigments and carbon blacks thanks to steric stabilization. These products have proven satisfactory owing to their strong viscosity-reducing effect and simultaneously reducing thixotropic flow behavior. The long-term stability of coating systems formulated with DISPERBYK-2013 or DISPERBYK-2155 is also significantly improved. The highly deflocculating effect makes it possible to formulate radiation-curing coating systems with excellent optical properties. The improvement in color strength and transparency is particularly significant. DISPERBYK-2155 is also available as a tin-free variant: **DISPERBYK-2155 TF.**

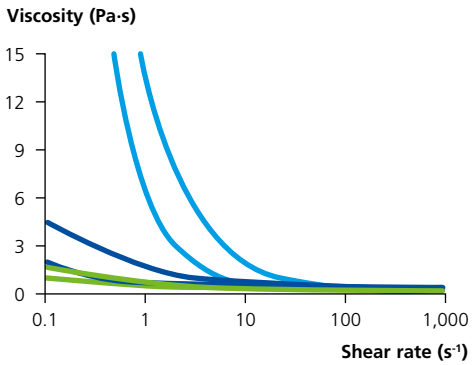
The new "TF" alternative corresponds to the standard additive in terms of application technology, has the same delivery form, and is produced on the basis of the same raw materials.

Along with the targeted selection of products, the amount of wetting and dispersing additives used is also critical to success. Depending on the fillers or pigments dispersed, the recommended levels (additive as supplied based on pigment) are as follows:

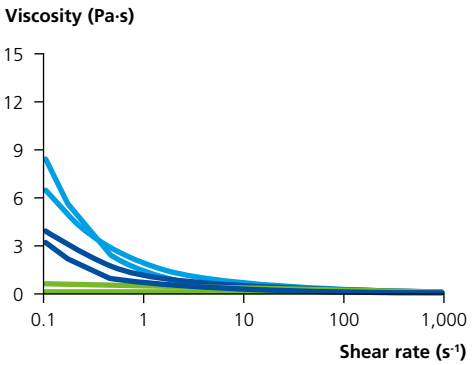
- Fillers: ≤ 1 %
- Titanium dioxide: 2–4 %
- Inorganic pigments: 5–8 %
- Organic pigments: 15–25 %
- Carbon blacks: 30–80 %

Viscosity reduction with DISPERBYK-2013 and DISPERBYK-2155 for a representative range of pigments dispersed in dipropylene glycol diacrylate (DPGDA)

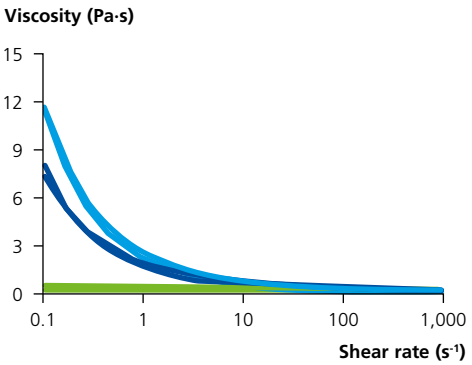
65 % KRONOS 2310 (Kronos International) in DPGDA; 2 % additive (solid) on pigment



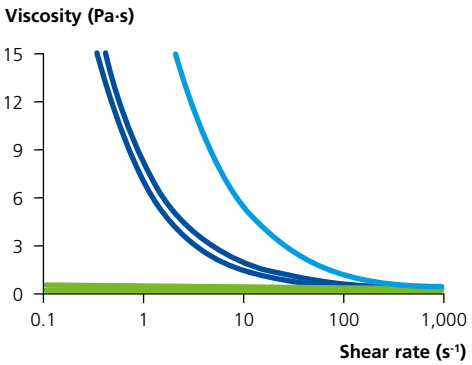
20 % Hostaperm Yellow H4G (Heubach) in DPGDA; 30 % additive (solid) on pigment



20 % Irgazin Red L 3660 HD (Sun Chemical) in DPGDA; 45 % additive (solid) on pigment



20 % Heliogen Blue L 7101 F (Sun Chemical) in DPGDA; 30 % additive (solid) on pigment



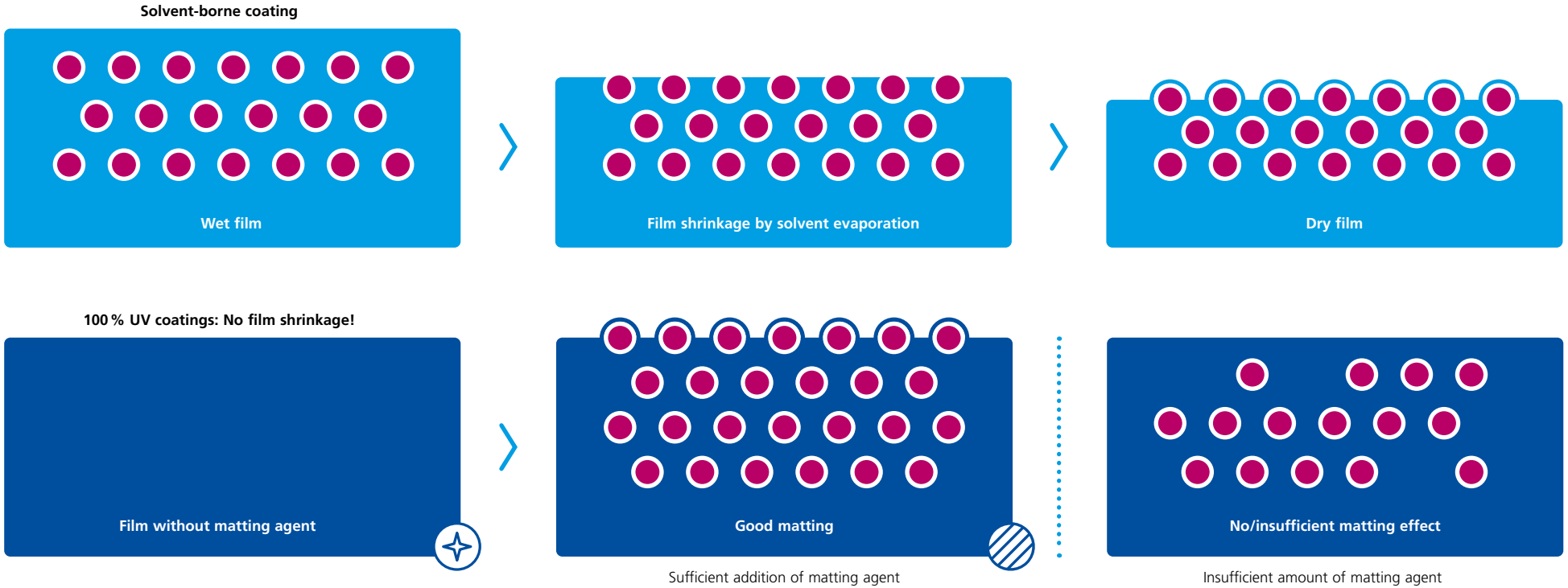
Internal standard DISPERBYK-2155 DISPERBYK-2013

G. 02

Gloss reduction/matting

Radiation-curing coating systems that are fast curing and either solvent-free or high-solid have very low or no film shrinkage due to a lack of volatile matter, which makes matting these systems extremely challenging. It is a matter of finding suitable methods and additives that, for example, allow for an increased use of matting agent in the application technology without affecting coating properties as a result.

Influence of the system and the evaporation of volatile matter on matting



Sufficient addition of matting agent

Insufficient amount of matting agent

Depending on the characteristics of the formulation and the application conditions chosen, there are suitable wetting and dispersing additives or micronized wax additives that allow for the desired effect of optimum matting.

In particular, **DISPERBYK-2008, DISPERBYK-2009 R, DISPERBYK-2158, DISPERBYK-2159, CERAFLOUR 929 N, CERAFLOUR 988, CERAFLOUR 1000,** and **CERAFLOUR 1010** have proven effective in practice for the optimization of matting in radiation-curing systems or were developed specifically for this field of application.

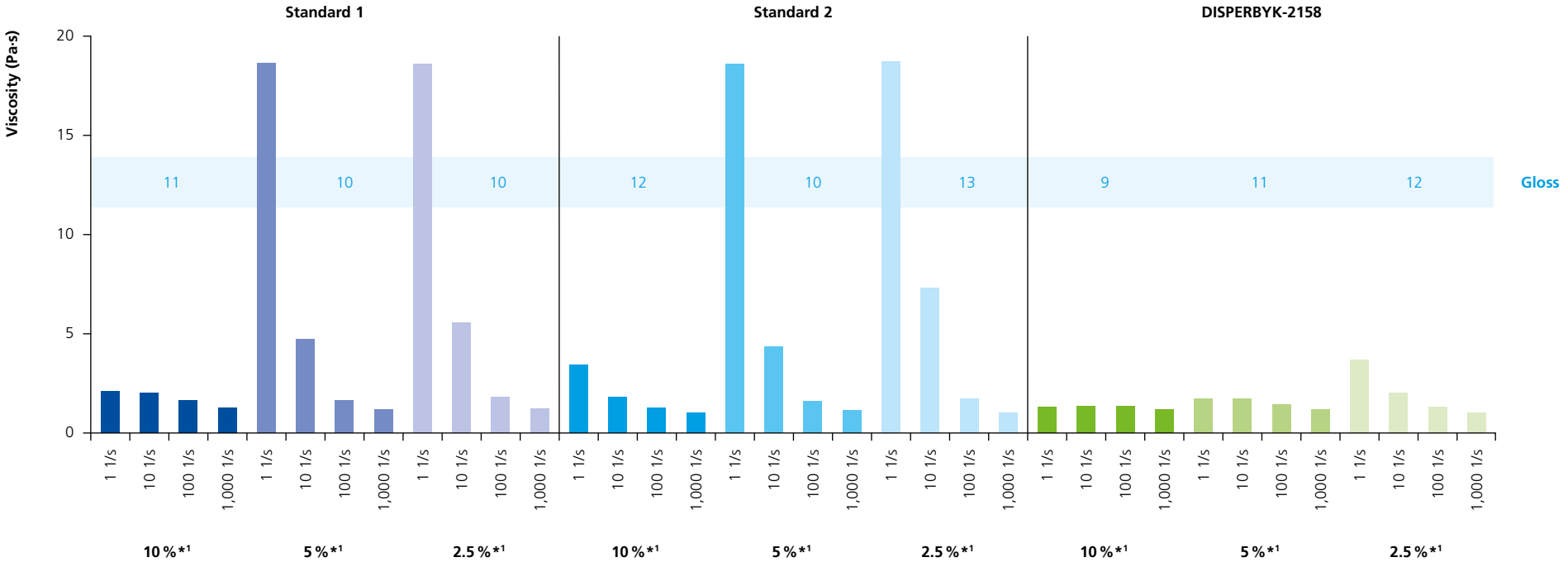
DISPERBYK-2158, for example, is a copolymer with pigment-affinic groups in reactive co-solvent (DPGDA) in order to ensure chemical curing in 100 % UV systems. With this wetting and dispersing additive, one can achieve a high dispersing and stabilization effect for untreated and treated silica-based matting agents. Moreover, it produces excellent viscosity reduction with practically Newtonian flow behavior at maximum load of matting agent.

Selection of wetting and dispersing additives for the effective dispersion of silica-based matting agents

Product data	DISPERBYK-2008	DISPERBYK-2009 R	DISPERBYK-2158	DISPERBYK-2159
Amine value	66 mg KOH/g	4 mg KOH/g	13 mg KOH/g	13 mg KOH/g
Density (20 °C)	1.04 g/ml	1.02 g/ml	1.08 g/ml	1.05 g/ml
Active substance	60 %	43 %	60 %	60 %
Solvent	Polypropylene glycol	Methoxypropanol/methoxypropyl acetate 2/1	Dipropylene glycol diacrylate (DPGDA)	Methoxypropyl acetate
Flash point	99 °C	34 °C	143 °C	45 °C

T. 01

Viscosity and gloss reduction for selected wetting and dispersing additives as a function of dosage



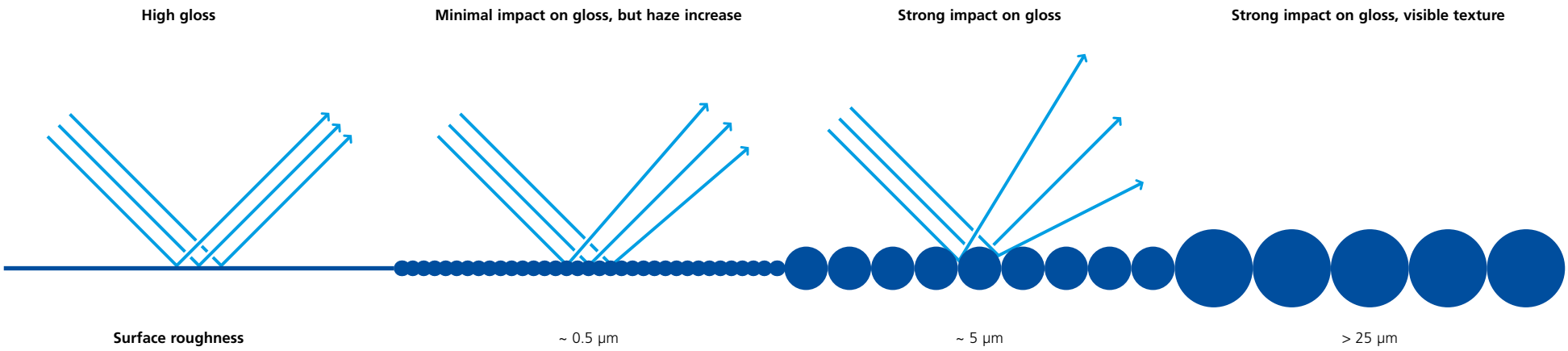
*1 Additive solid on pigment

G.04

The effect on viscosity by DISPERBYK-2158 in a solvent-free radiation-curing system based on an unsaturated polyester and a matting agent amount of 15 % (Acematt HK 440); application 25 µm wet film thickness; gloss measurement at 85°.

Micronized wax additives achieve the maximum light refraction possible and therefore the greatest effect on matting of UV systems thanks to their particle size distribution in the 2–8 µm range.

Effect of particle size in terms of light refraction and therefore on gloss



G.05

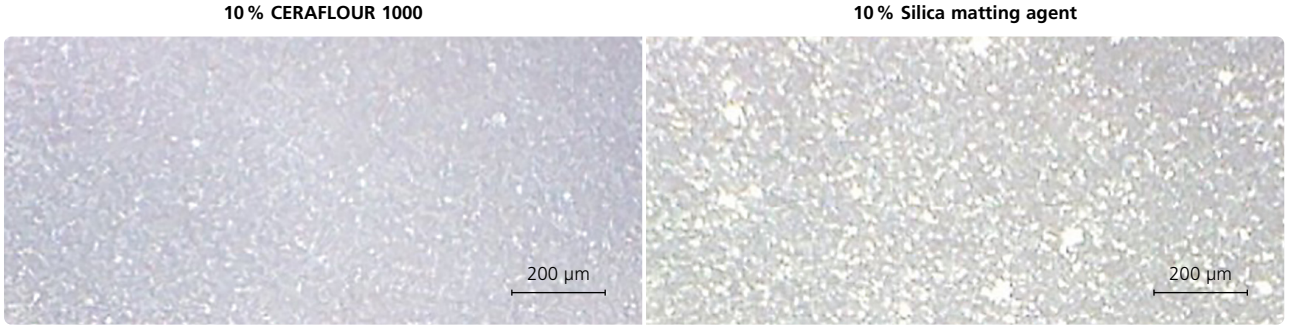
Selection of wax additives for solvent-free radiation-curing wood and furniture coatings

Product data	CERAFLOUR 929 N	CERAFLOUR 988	CERAFLOUR 1000	CERAFLOUR 1001	CERAFLOUR 1002	CERAFLOUR 1010
Density (20 °C)	1.06 g/cm^3	0.97 g/cm^3	1.25 g/cm^3	1.25 g/cm^3	1.25 g/cm^3	0.91 g/cm^3
Particle size D50	8 µm	6 µm	5 µm	3 µm	6 µm	6 µm

T.02

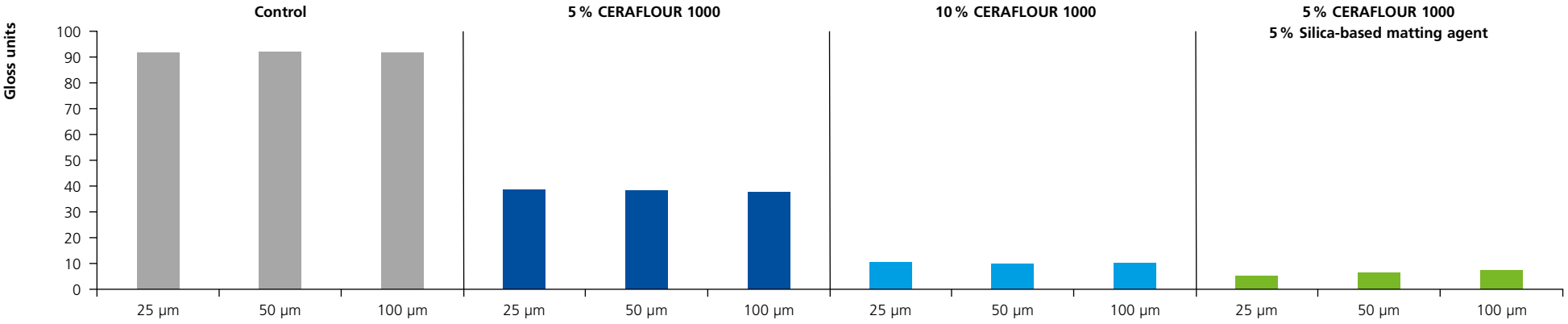
CERAFLOUR 1000, for example, is a biodegradable, micronized polymer with wax-like properties based on renewable resources. The additive has a matting effect, especially in radiation-curing systems, and produces highly transparent coatings. It has no effect on viscosity and slip and does not stabilize foam.

Distribution and particle size of CERAFLOUR 1000 in a coating system



G.06

Matting with CERAFLOUR 1000



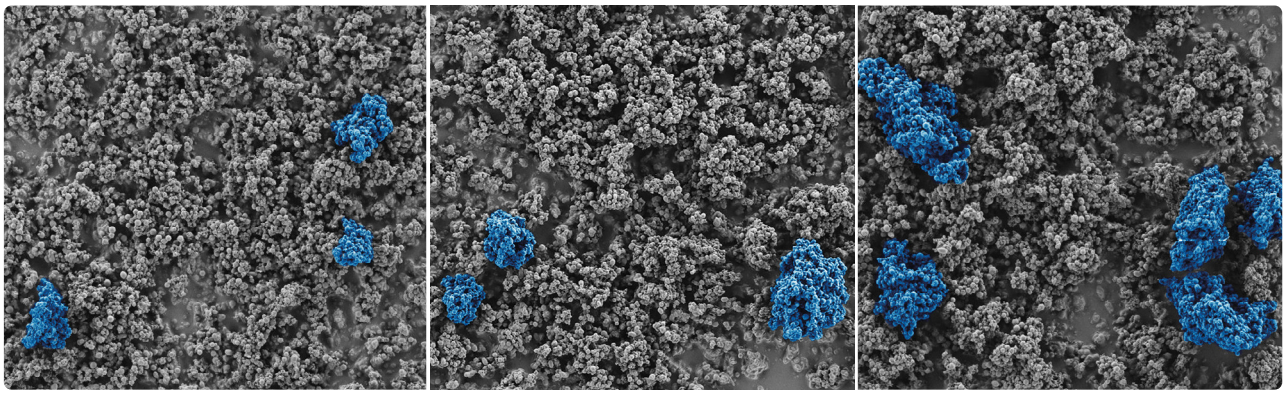
Consistent matting with CERAFLOUR 1000 regardless of the wet film thickness in a solvent-free UV system based on polyester acrylate, gloss measurement at 60°.

G.07

This successful approach is complemented by two other biopolymers that use the same raw material: **CERAFLOUR 1001** with very fine particles for excellent matting and optimum transparency, and **CERAFLOUR 1002** with larger particles for creating a surface structure and high transparency with the best matting effect. All **CERAFLOUR 1000 grades** moderately increase scratch resistance, offer pleasant haptic properties (soft-feel effect) and can be used in UV systems as well as in aqueous, solvent-born, or solvent-free systems.

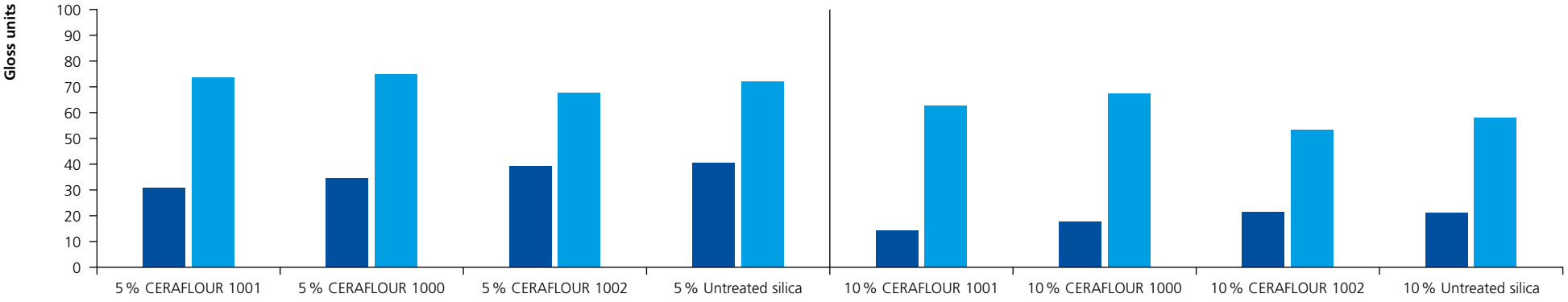
Particle size distribution

CERAFLOUR 1001 – Very fine particles | **CERAFLOUR 1000 –** Fine particles | **CERAFLOUR 1002 –** Larger particles



G.08

Matting in 100 % UV system



Gloss at 60° measurement Gloss at 85° measurement

G.09

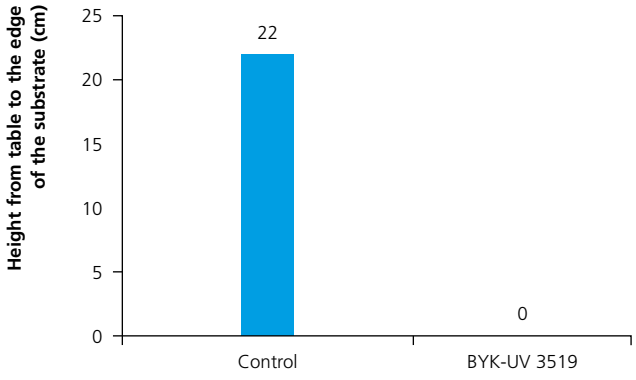
Mechanical resistance

In addition to matting, protecting surfaces against mechanical damage is also a recurring challenge. While an improvement in scratch and abrasion resistance as well as in burnishing resistance can be achieved in matted and semi-gloss coatings by using micronized waxes, this is particularly difficult in high-gloss coatings, as these wax-based products often have an influence on gloss that cannot be tolerated.

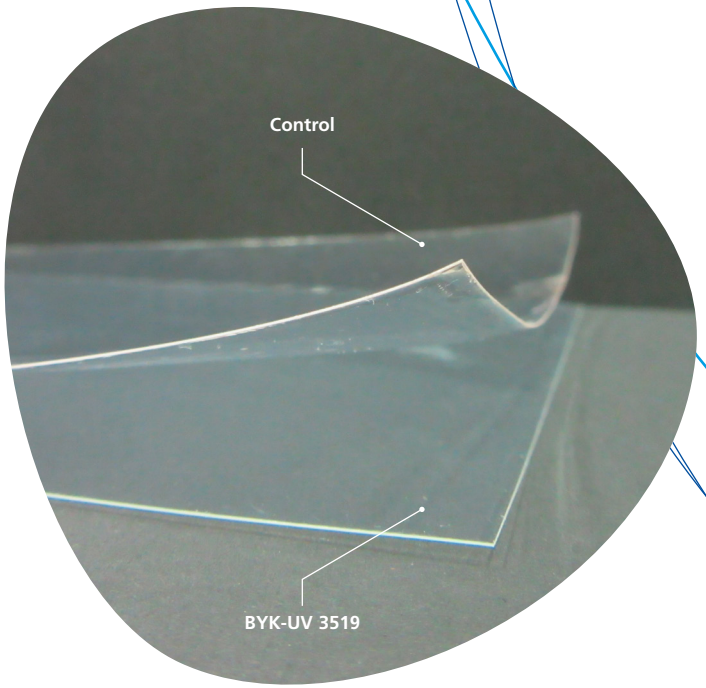
With **BYK-UV 3518** and **BYK-UV 3519,** two extraordinarily effective products for improving mechanical resistance are available for high-gloss systems.

BYK-UV 3518 and **BYK-UV 3519** also increase the flexibility of the coating and counteract the curling effect caused by film shrinkage, which often occurs with film coating.

Anti-curling effect with BYK-UV 3519



G. 10



Surface effects

To avoid surface defects and to select specific effects, the use of surface additives is essential to precisely adjust the surface tension of the coating system or to minimize differences in surface tension. In conventional coating systems, additives based on organically modified polysiloxanes (silicones) and polyacrylates (acrylate additives) have proven effective, and their use is also recommended for solvent-free radiation-curing coating systems. Moreover, surface additives have been developed especially for radiation-curing coating systems that react with the resin matrix owing to their acrylic functions.

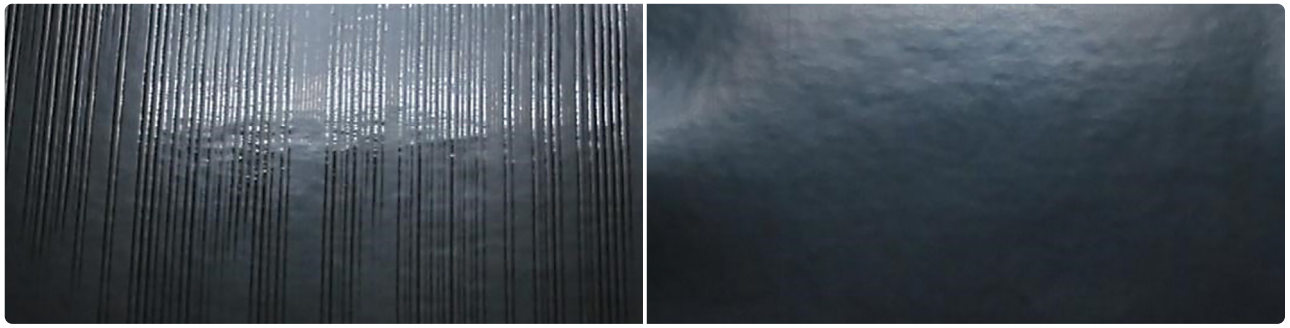
Substrate wetting

In order for adequate substrate wetting by the coating system, a basic requirement is that the surface tension of the coating system is below the surface energy of the substrate to be coated. This is why the use of active silicones has proven particularly effective, since it produces a significant reduction in surface tension even when very low quantities are added. Specifically, **BYK-UV 3500, BYK-UV 3505, BYK-379,** and **BYK-3760** are suitable for improving substrate wetting and avoiding surface defects (e.g. cratering) in radiation-curing wood coating systems.

Leveling

The leveling of coating systems can be positively affected especially by less active silicones or acrylate additives. For radiation-curing coating systems, solvent-free surface additives such as **BYK-UV 3535, BYK-3455, BYK-3456,** or **BYK-361 N** have proven particularly effective. In contrast to very active silicones, these products reduce surface tension much less significantly, but minimize the inhomogeneity of the surface tension at the coating/air interface, which has a very positive effect on the leveling of radiation-curing coating systems.

Leveling improvement by using a surface additive



Leveling improvements by using BYK-UV 3535 (right) in comparison to a coating system without leveling additive (left) for a solvent-free radiation-curing coating system applied by roller. **G. 11**

Surface slip

Very active silicones, in particular, demonstrate excellent orientation to the coated surface, which is a basic requirement in achieving exceptionally high surface slip. Alongside conventional organically modified polysiloxanes, in particular **BYK-333, BYK-379,** and **BYK-3760,** the additives **BYK-UV 3500** and **BYK-UV 3505** show a strong increase in surface slip. Because of their acrylic functionality, these two surface additives react with the resin matrix, which results in a long-lasting positive effect on surface slip.

Easy-to-clean and tape-release properties

Along with the very significant reduction in surface slip, the use of **BYK-UV 3500** and **BYK-UV 3505** result in other special properties, such as easy-to-clean or tape-release properties. Here as well the reactivity of these two products constitutes a significant advantage in achieving long-lasting effects. Alongside these surface additives developed specially for radiation-curing coating systems, conventional silicones such as **BYK-379** and **BYK-3760** are likewise suitable for improving easy-to-clean or tape-release properties.

BYK-UV 3505

Even at lower dosages, **BYK-UV 3505** demonstrates a significant reduction of surface tension and improves substrate even on difficult substrates. Surface slip is significantly increased even at lower dosages. This results, among other things, in an improvement of scratch resistance and easy-to-clean properties. Because of its multiple acrylic functions, **BYK-UV 3505** reacts with radiation-curing systems, thereby producing long-lasting effects without migration. The recoatability must be checked and sanding of the surface is recommended. The product is highly compatible and does not cause any turbidity in the coating system.

BYK-UV 3535

BYK-UV 3535 improves the leveling of radiation-curing systems. The product is highly compatible and does not cause any turbidity in the coating system. In many cases, it demonstrates a deaerating effect. Owing to its multiple acrylic functions, **BYK-UV 3535** reacts with radiation-curing systems, thereby producing long-lasting effects with no migration.

BYK-379

BYK-379 provides a strong increase in surface slip, thereby also improving scratch resistance. It results in a moderate to strong reduction of surface tension, and therefore very good substrate wetting and a good anti-cratering effect. **BYK-379** displays a high effectiveness at low dosage and only stabilizes foam very slightly.

BYK-3760

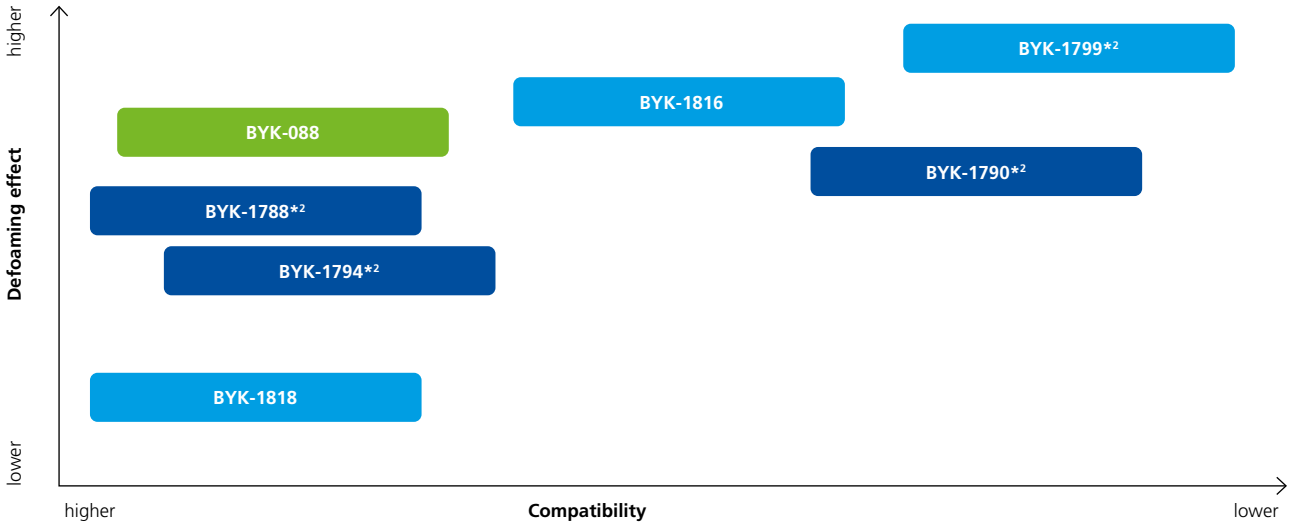
BYK-3760 provides a significant reduction of the surface tension of coating systems. It therefore especially improves substrate wetting and prevents cratering. **BYK-3760** strongly increases surface slip, which likewise has a positive effect on the scratch resistance of coating systems. **BYK-3760** is less foam stabilizing than other highly active additives containing silicone and is effective even at low dosages.

Defoaming

Solvent-free coating systems and, in particular, radiation-curing coatings are difficult to defoam because of their often high application viscosity. If matting agent or pigments are also contained in the formulation, defoaming becomes even more challenging. Moreover, more demanding application conditions, such as high-speed roller application, can require instant and efficient defoaming.

Depending on the specific formulation characteristics and the choice of application conditions, defoamers with a variety of application profiles with respect to their defoaming properties and system compatibility are available for the effective defoaming of solvent-free radiation-curing wood and furniture coatings. In particular, **BYK-088, BYK-1788, BYK-1790, BYK-1794, BYK-1799, BYK-1816,** and **BYK-1818** have proven effective for the defoaming of radiation-curing systems or were specifically developed for this field of application.

Selection of defoamers for solvent-free, radiation-curing wood and furniture coatings



Silicone defoamer · Silicone/polymer defoamer · Silicone-free polymer defoamer

G. 12

*2 100 % non-volatile compounds

Defoamer recommendations for solvent-free radiation-curing wood and furniture coating systems as a function of defoamer compatibility and the resulting defoaming effect (representative selection of products).

BYK-1788, for example, is a solvent- and silicone-free polymer defoamer that demonstrates a well-balanced relationship between defoaming effect and system compatibility, which makes it especially well suited to clear coating systems that require high gloss and transparency.

Spontaneous defoaming during paint preparation

Spontaneous defoaming in the production process for a solvent-free urethane acrylate-based coating system (left: without the use of a defoamer; right: using BYK-1788 with a dosage of 0.3 % based on total formulation). G. 13

BYK-1799, by contrast, is a solvent-free defoamer based on an organically modified polydimethyl siloxane with a very strong defoaming effect, which makes it excellent for use in matted or pigmented UV-curing systems. It eliminates both macrofoam and microfoam and, thanks to its spontaneous and very effective defoaming effect, is quite suitable for demanding application methods such as roller application.

Defoaming effect after application with a foam roller

Defoaming effect of BYK-1799 (right), used at 0.05 % based on total formulation, compared with a system without defoamer (left) for a 100 % UV-cured transparent coating system, applied with a foam roller. G. 14

When testing and selecting defoamers, it is important to take into consideration the system-dependent and application-specific effect of the individual products. For this reason, it is always useful to conduct a test series while using realistic application methods.

System-dependent defoamer efficiency demonstrated with a matted coating system

Control
Macro = 1; Micro = 1

BYK-1788
Macro = 2; Micro = 3

BYK-1799
Macro = 4.5; Micro = 4

Different effectiveness of selected defoamers in a matt, radiation-curing coating system based on unsaturated polyester; rating of macro- and micro-foam from 5 = excellent to 1 = unsatisfactory.

G. 15

Adjustment of flow properties

The rheology profile is one of the most important application properties of a coating system. It is highly important for the applicability and practicability of the coating material. The most important variable in describing flow behavior is viscosity. For most coating systems, viscosity is not constant, but instead depends on various parameters. Alongside a dependence on temperature, the most important thing from an application perspective is the shear force applied to the coating system. Rheology describes the (sometimes) quite complex relationships between viscosity and applied shear forces.

Depending on the characteristics of the formulation and the application conditions chosen, suitable rheology additives are available that can achieve the desired effects.

In particular, **RHEOBYK-410, RHEOBYK-7410 ET, GARAMITE-1958,** and **GARAMITE-7303** have proven in practice to be effective in influencing the rheological properties of radiation-curing systems.

RHEOBYK-410, RHEOBYK-D 410, and **RHEOBYK-7410 ET,** for example, are solutions of a modified urea for medium-polar, solvent-free UV systems. The additives create highly thixotropic flow behavior, and consequently improve the anti-sagging and anti-settling properties. Post-addition is possible.

GARAMITE-1958 and **GARAMITE-7303** are a blend of phyllosilicates with pseudo-plastic flow behavior. This property is especially helpful in UV systems, where it is critical to have the right balance between anti-settling properties and storage stability as well as shear thinning flow behavior during final application. These products are easy to incorporate, do not require an activation temperature, do not generate dust during incorporation, and therefore represent an outstanding alternative to fumed silica.

Rheology additives for 100 % UV-systems

Additives	Delivery form			System		Incorporation				Rheology effect					
	Liquid	Paste	Powder	Water	Solvent/solid	Post	Medium shear	High shear	Pre-mix	Low shear	Medium shear	High shear	Newtonian	Pseudoplastic	Thixotropic
Urea-based additives	■			■	■	●	○	○		■					■
Organophilic phylosilicates			■		■			●	○	■	■			■	

● Especially recommended ○ Recommended

T. 03

Overview of urea-based additives

Product data	RHEOBYK-410	RHEOBYK-D 410	RHEOBYK-7410 ET
Active substance (%)	52	52	40
Solvent	N-methylpyrrolidone	Dimethyl sulfoxide	Amide ether
Flash point (°C)	91	99	118

T. 04

Rheological effect of RHEOBYK-410, RHEOBYK-D 410, and RHEOBYK-7410 ET in DPGDA

Additive	Additive on total formulation (%)	Gel after 1 hour	Trubidity	Gel after 5 hours
Control			1	
RHEOBYK-410	0.5	+	2	+
RHEOBYK-410	1.0	+	4	+
RHEOBYK-D 410	0.5	+	2	+
RHEOBYK-D 410	1.0	+	3	+
RHEOBYK-7410 ET	0.5	○	3	○
RHEOBYK-7410 ET	1.0	○	4	○

Turbidity: 1 = no turbidity, 5 = strong turbidity; **Gel:** + = strong rheological effect, ○ = weak rheological effect

After 1 hour

Control
0.5 % RHEOBYK-410
1 % RHEOBYK-410
0.5 % RHEOBYK-D 410
1 % RHEOBYK-D 410
0.5 % RHEOBYK-7410 ET
1 % RHEOBYK-7410 ET

After 5 hours

Control
0.5 % RHEOBYK-410
1 % RHEOBYK-410
0.5 % RHEOBYK-D 410
1 % RHEOBYK-D 410
0.5 % RHEOBYK-7410 ET
1 % RHEOBYK-7410 ET

Product recommendation chart – Wood and furniture coatings/ decorative film systems (1/2)

Application	Solvent-free radiation-curing systems
Wetting and stabilization of matting agents	DISPERBYK-2009 R ● DISPERBYK-2158 ● DISPERBYK-2159 ○
Wetting and stabilization of pigments	DISPERBYK-111 ● DISPERBYK-2013 ● DISPERBYK-2155 TF*3 ●
Anti-settling	GARAMITE-1958 ● GARAMITE-7303 ● RHEOBYK-D 410 ● RHEOBYK-7410 ET ○
Substrate wetting	Silicone: BYK-3760 ● BYK-UV 3500*4, 5 ● BYK-UV 3505*5 ● BYK-379 ○
Leveling	Silicone: BYK-3455 ● BYK-3456 ● BYK-333 ○ Silicone-free: BYK-361 N ● BYK-UV 3535*5 ●

Application	Solvent-free radiation-curing systems
Surface slip	Silicone: BYK-333 ● BYK-379 ● BYK-3760 ● BYK-UV 3500*4, 5 ● BYK-UV 3505*5 ● Wax: CERAFLOUR 988 ●
Anti-slip	Wax: CERAFLOUR 970 ● Silicone-free: BYK-UV 3535*5 ●
Tape release	Silicone: BYK-379 ● BYK-UV 3500*4, 5 ● BYK-UV 3505*5 ● BYK-377*4, 5/BYK-3771*5 ○ BYK-3760 ○
Easy-to-clean	Silicone: BYK-UV 3500*4, 5 ●

● First recommendation ○ Second recommendation

Unless otherwise stated, all silicone-containing additives have a cyclic siloxane content (D4, D5, D6) of less than 0.1 % each.

*3 (Organo) Tin-free version: Future-oriented variant of the original product. Originals are still available.

*4 Content of cyclic siloxanes ≥ 0.1 %.

*5 Contains functional groups

*6 To be combined with a polysiloxane additive such as BYK-UV 3500

Product recommendation chart – Wood and furniture coatings/ decorative film systems (2/2)

Application	Solvent-free radiation-curing systems
Mechanical resistance	BYK-UV 3519*5 ● NANOBYK-3605*5, 6 ● BYK-UV 3518*5 ○ Wax: CERAFLOUR 929 N ● CERAFLOUR 988 ● CERAFLOUR 1010 ●
Defoaming	Silicone: BYK-1799 ● BYK-1816 ● BYK-088 ○ BYK-1818 ○ BYK-A 530 ○ Silicone-free: BYK-1788 ● BYK-1791 ● BYK-1794 ● BYK-1790 ○
Matting	CERAFLOUR 1000 ● CERAFLOUR 1010 ● CERAFLOUR 929 N ○ CERAFLOUR 950 ○ CERAFLOUR 988 ○ CERAFLOUR 1001 ○ CERAFLOUR 1002 ○

Application	Solvent-free radiation-curing systems
Orientation of silica matting agents	Silicone: BYK-3760 ● BYK-UV 3500*4, 5 ● BYK-UV 3505*5 ● BYK-379 ○
Curtain stability	Silicone: BYK-307*4/BYK-3762 ●
Haptic effects	Texture: CERAFLOUR 913 ● CERAFLOUR 914 ● CERAFLOUR 915 ● CERAFLOUR 916 ● CERAFLOUR 917 ● Soft-feel effect: CERAFLOUR 994 ● CERAFLOUR 1000 ● CERAFLOUR 1001 ●

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● First recommendation ○ Second recommendation

Unless otherwise stated, all silicone-containing additives have a cyclic siloxane content (D4, D5, D6) of less than 0.1 % each.

*3 (Organo) Tin-free version: Future-oriented variant of the original product. Originals are still available.

*4 Content of cyclic siloxanes ≥ 0.1 %.

*5 Contains functional groups

*6 To be combined with a polysiloxane additive such as BYK-UV 3500

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