

Technical Information AS-TI 2

# Rheology Additives for Adhesives and Sealants

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## Overview of Rheology Additives

System	Additive	Effect
Solvent-borne, solvent-free systems	BYK-7410 ET BYK-7411 ES BYK-D 410	Thixotropic behavior
	BYK-430 BYK-431	Pseudoplastic behavior
	BYK-R 605 BYK-R 606 BYK-R 607	Stronger thixotropy when combined with fumed silica or organoclays
Aqueous systems	BYK-7420 ES BYK-D 420	Thixotropic behavior
	BYK-425	Pseudoplastic behavior
	OPTIFLO-T 1000	High-shear thickener

The rheology additives from BYK listed above are always liquid and therefore easy to incorporate into the system.

figure 1

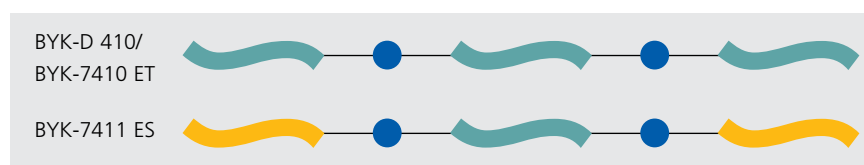
## Liquid Rheology Additives for Solvent-borne and Solvent-free Systems

BYK-D 410, BYK-7410 ET and BYK-7411 ES are rheology additives for diverse applications. They are based on modified urea products in a solvent (figure 2). Depending on the additive, the following solvents are included:

- Dimethylsulfoxide
- an amide ester
- an amide ether.

The active substances are insoluble in conventional adhesive systems, which is what the rheological effect is based on. When incorporated in the resin system, the additive is precipitated in a controlled manner while forming very fine needle-like microcrystals, which then use hydrogen bonds to create a three-dimensional network structure (figure 3). The initial formation of this structure can take several hours. In the application of such a system, the network structures are already destroyed by low shear forces and the material exhibits a (desired) low application viscosity. The reformation of the structure after the application occurs rapidly and leads to a quick increase of the viscosity in the wet film.

## Structure BYK-D 410/BYK-7410 ET and BYK-7411 ES



● Urea groups

Modifying groups:  medium-polar  low-polar

figure 2

## Incorporation of BYK-D 410/BYK-7410 ET and BYK-7411 ES

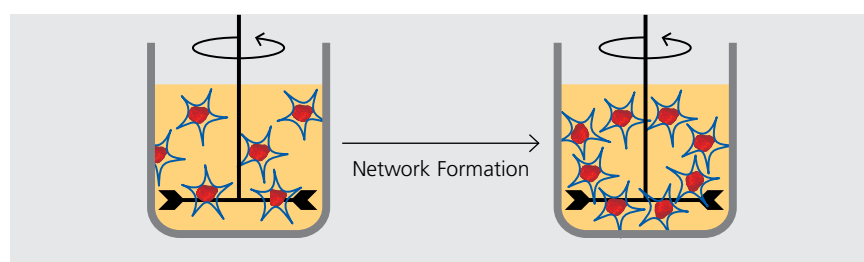


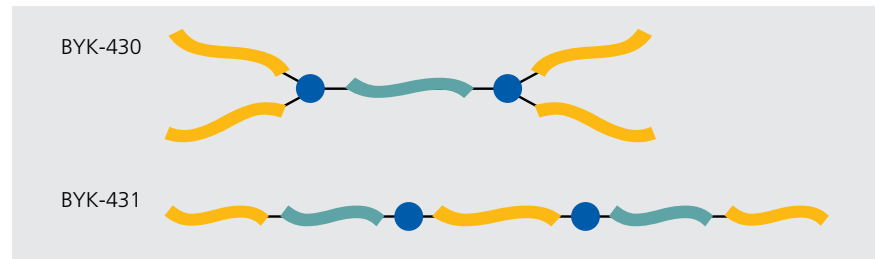
figure 3

BYK-D 410/BYK-7410 ET and BYK-7411 ES specifically generate a strong thixotropy which results in a significantly delayed structural build-up after shearing. These rheology additives are mainly used in adhesives and sealants when the settling of fillers has to be prevented. At low shear rates, e.g. during storage and transportation, the three-dimensional network structure builds up a yield point, or respectively a viscosity that is high enough to avoid sedimentation. Under shear forces the network structure is destroyed and a strong shear thinning effect with a low application viscosity can be observed. This is particularly advantageous when the adhesive must be able to flow easily (e.g. into a porous substrate), or when bubbles should rise to the surface.

In contrast, if increased layer thickness on a vertical surface is required, the pseudoplastic rheology additives BYK-430 and BYK-431 should be used. Both additives are urea-modified polyamides dissolved in different solvents (figure 4). These additives cause an immediate structure recovery after shearing. The anti-sagging properties are greatly improved, further flowing or sagging (figure 6) of the adhesive are avoided. Additionally the additives have a positive influence on storage stability and prevent the sedimentation of pigments and fillers.

Figure 5 shows the effects of BYK-D 410 and BYK-430/BYK-431 compared to other rheology additives.

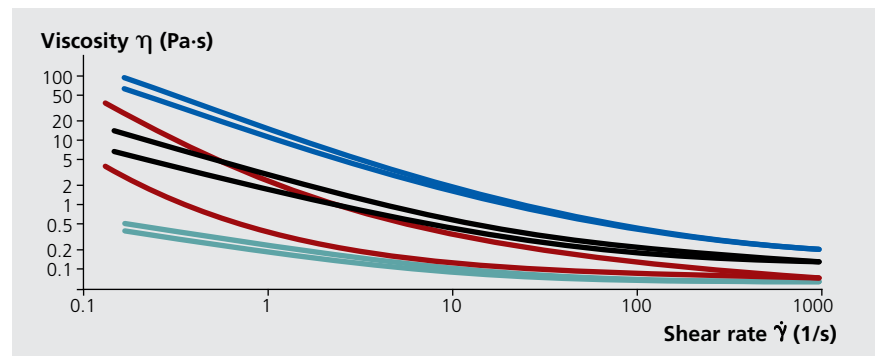
## Composition



- Urea groups
- Polyamide
- Compatibility-improving structures (Alkyl, polyether)

figure 4

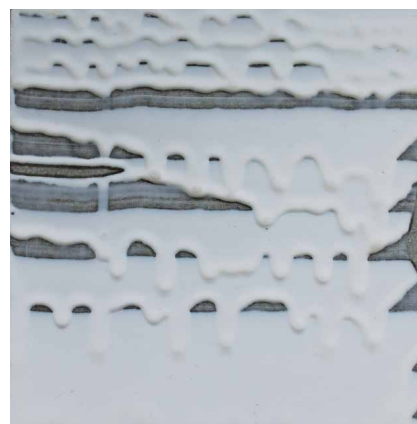
## Comparison of Various Rheology Additives



- BYK-430/BYK-431
- BYK-D 410
- Polyamide
- Control

figure 5

## Stability of an Adhesive



With standard additive



With 1 % BYK-D 410

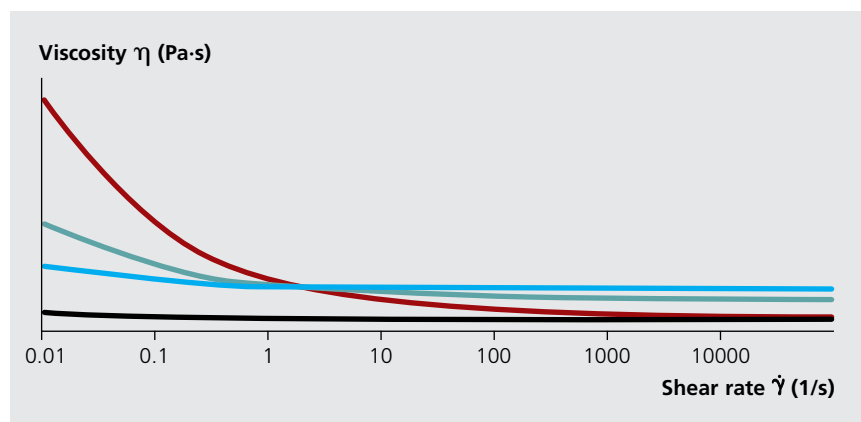
figure 6

### Liquid Rheology Additives for Aqueous Systems

BYK-7420 ES is based on the chemistry shown in figure 2. The urea-modified additive is dissolved in the solvent variants N-methylpyrrolidone, N-ethylpyrrolidone and dimethyl sulfoxide. It is compatible with water due to its high-polar end-groups. BYK-7420 ES increases the low-shear viscosity and can also be incorporated into pure water. Like BYK-D 410/BYK-7410 ET, it creates a thixotropic flow behavior, which leads to a delayed structure recovery. BYK-425 and OPTIFLO-T 1000 take a slightly different approach. The additives utilize the familiar chemistry of hydrophobic-modified urea thickeners in combination with the resin chemistry of BYK-420.

Through this combination, the effectiveness against settling and sagging in most aqueous resin systems is improved. Figure 8 shows both mechanisms: association of the hydrophobic additive segments among each other (forming of micelles) or with the resin, and at the same time, formation of hydrogen bonds between the urea groups of the additive. This results in a highly effective low-shear thickener, especially for the low and middle shear ranges. Should higher viscosity at high shear forces be necessary, the high-shear thickener OPTIFLO-T 1000 is recommended. The structure in figure 9 displays a high amount of hydrophobic groups. The formed network remains stable even at high shear, because a sufficient amount of interacting groups are always present. OPTIFLO-T 1000 provides a Newtonian viscosity increase over the entire shear range (figure 7). In practice, it is customary to use combinations of high-shear and low-shear thickeners.

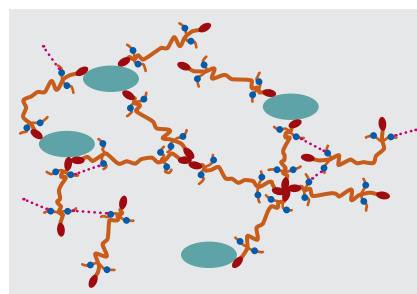
### High-shear/Low-shear Thickener



■ BYK-428 ■ Thickener combination ■ BYK-7420 ES ■ Without thickener

figure 7

### Mechanism of BYK-425



● Dispersion resin

figure 8

### Structure of BYK-428



● Hydrophobic group

figure 9

### GARAMITE – Mixed Mineral Thixotropes

GARAMITE additives are the culmination of a concerted development effort to design a product that would answer the rheological needs of a number of industries that have used fumed silica as their primary thixotrope. The result of this development effort was the creation of Mixed Mineral Thixotrope (MMT) technology for which a patent has been issued to BYK.

MMT technology involves the blending of acicular and platey minerals that are then surface modified for resin compatibility. The combination of different mineral morphologies promotes particle spacing creating a product that disperses very easily. The commercialization of the MMT technology spawned the GARAMITE brand of additives. GARAMITE additives differ from other organically modified mineral thixotropes by exhibiting unparalleled ease of dispersion, ease of use, high efficiency, and high performance without unwanted viscosity.

GARAMITE additives have several distinct and quantifiable advantages compared to fumed silica additives:

- Higher bulk density
- Less dust during handling
- Less storage space required
- Reduced order frequency
- Easier incorporation into resin or solvent
- Higher efficiency in use (typically 30–40 % more efficient) than fumed silica
- Higher sag and slump resistance

### Delivery Forms – Fumed Silica and GARAMITE-1958



The volume of 10 grams each of fumed silica and GARAMITE-1958. Due to its higher bulk density, GARAMITE-1958 reduces dust, reduces storage space required, and reduces order frequency versus fumed silica additives.

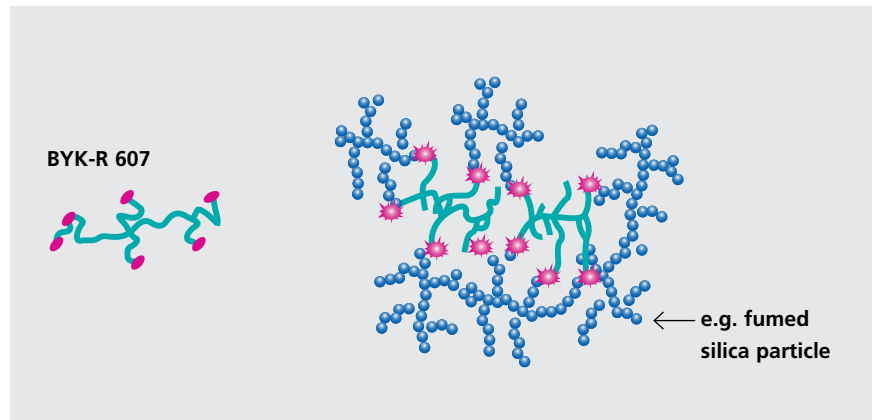
figure 10



### BYK-R 607, the Thixotropy Enhancer

Nowadays, epoxy resins are included in a multitude of applications. They are generally used in protective coatings, fiber reinforced composites, electrical castings, prototyping and tooling systems, and adhesives. Optimum processability of the respective system requires an optimally adjusted rheology profile. Often fumed silica or clay additives are used for this. The problem, however, is that when the amine hardener is added, the viscosity spontaneously drops. Consequently at present, more expensive hydrophobic fumed silica, for instance, is applied in the resin and hydrophilic fumed silica in the curing agent. Although this solution has disadvantages. The user must accept higher viscosities, poorer deaeration and extended production times. BYK has found a better solution with its new thixotropy booster BYK-R 607. By adding BYK-R 607 to the curing agent, significantly cheaper clays or hydrophilic fumed silica can be applied in the resin. Both curing agents and resin components are less viscous and develop the required rheology profile only when being mixed. This ensures good processability, defoaming and outstanding anti-sagging properties.

### BYK-R 607 – Mode of Action



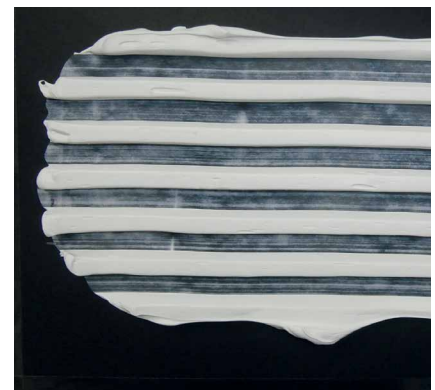
Multiple functional groups effectively enhance the solid thixotropic network.

figure 11

### Higher Sag Resistance with BYK-R 607 and a Clay-Based Additive



GARAMITE-7305



GARAMITE-7305 + BYK-R 607

Epoxy grout system

figure 12



### OPTIGEL and LAPONITE: Rheology Additives for Aqueous Systems

OPTIGEL and LAPONITE products are smectite based rheological additives for water-borne systems. Smectites are a group of layered silicate minerals, which occur naturally, but can also be produced synthetically. Smectites have a platelet structure. The platelets are very thin, about 1 nm. The platelet diameter is about 500–1000 nm (1  $\mu\text{m}$ ) for natural smectites (OPTIGEL products) and 25–50 nm for synthetic smectites (LAPONITE products). These stacks then separate into their individual platelets when added to water and dispersed under high shear conditions.

#### House-of-cards Structure

The surfaces of individual OPTIGEL/ LAPONITE platelets are negatively charged, but their edges are either neutral or even positively charged. Because their overall charge is predominantly negative, the platelets repel each other in the suspension, a process that distributes them evenly throughout the solution. The difference in charge between their edges and their surfaces then generates a slight edge to face attraction between the platelets. Small amounts of divalent cations as  $\text{Ca}^{2+}$  or  $\text{Mg}^{2+}$  can further contribute to this interaction. These cations can link two platelets together at the edges this increasing the platelets size. This and the edge to face interaction produces a house-of-cardslike structure, which results in a gel formation.

### House-of-cards Structure/ Gel Formation

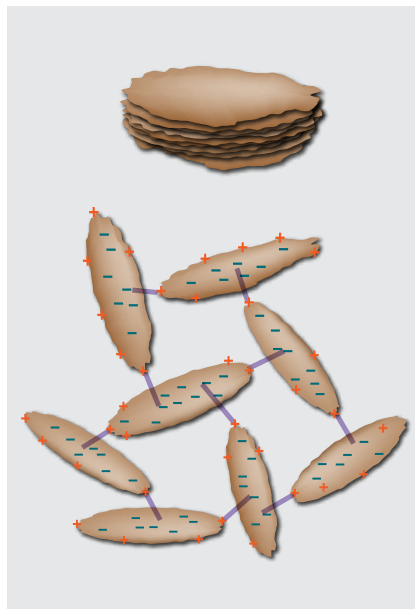


figure 13

#### Yield Point and Thixotropy

The stability of the gel reflects the bonding strength between platelets. When external forces act on the gel, the house of cards collapses and the gel returns to its fluid state. Once the external force is reduced, the card house reforms and the liquid again behaves like a gel. OPTIGEL/LAPONITE produce what is known as a yield point. This means, a minimum force is required before a substance starts to flow.

### Response of Gel to External Force

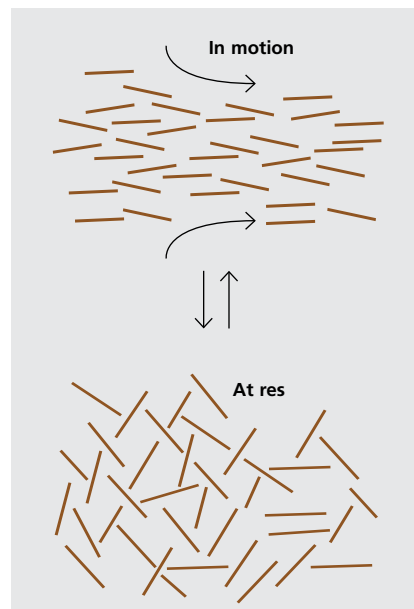


figure 14

Additionally, the gel exhibits thixotropic behavior. The greater the stirring force acting on the gel, the more completely the card-house structure will collapse, i.e., the thinner the liquid will become. After stirring, the card-house structure will reform within a short period of time and the viscosity will return to its original level.

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