

## Contacts worldwide

Asia  
BASF East Asia Regional Headquarters Ltd.  
45/F, Jardine House  
No. 1 Connaught Place  
Central  
Hong Kong  
formulation-additives-asia@basf.com

Europe  
BASF SE  
Formulation Additives  
67056 Ludwigshafen  
Germany  
formulation-additives-europe@basf.com

North America  
BASF Corporation  
11501 Steele Creek Road  
Charlotte, NC 28273  
USA  
formulation-additives-nafta@basf.com

South America  
BASF S.A.  
Rochaverá - Crystal Tower  
Av. das Nações Unidas, 14.171  
Morumbi - São Paulo-SP  
Brazil  
formulation-additives-south-america@basf.com



BASF SE  
Formulation Additives  
Dispersions & Pigments Division  
67056 Ludwigshafen  
Germany  
[www.basf.com/formulation-additives](http://www.basf.com/formulation-additives)

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out their own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights, etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. The agreed contractual quality of the product results exclusively from the statements made in the product specification. It is the responsibility of the recipient of our product to ensure that any proprietary rights and existing laws and legislation are observed. When handling these products, advice and information given in the safety data sheet must be complied with. Further, protective and workplace hygiene measures adequate for handling chemicals must be observed.

® = registered trademark of the BASF Group

# Additives for Thermoset Composites

## Formulation Additives by BASF

ED2 0319e

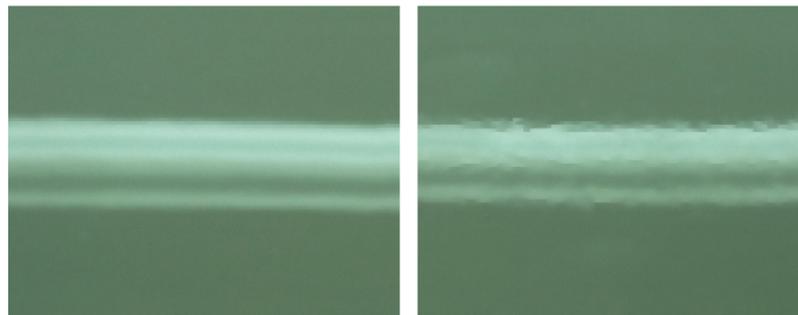
 **BASF**  
We create chemistry

Europe, March 2019

**We create chemistry**



Leveling is defined as the ability of a coating to flow out after application in order to reduce any surface irregularities such as brush and roller marks, orange peel, peaks or craters.

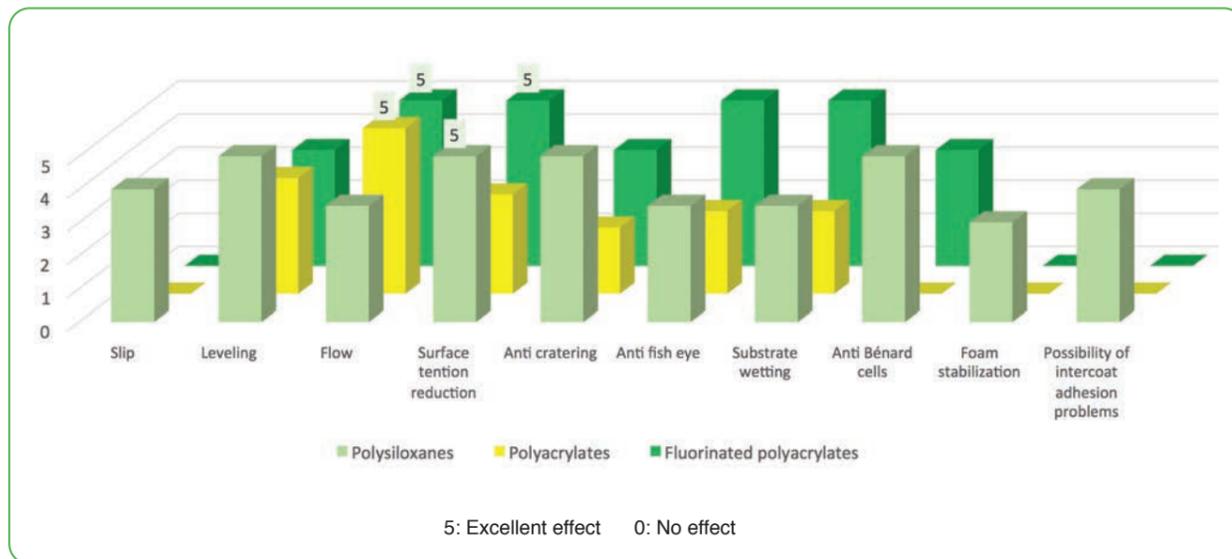


### Good to know

**Orange peel** is a surface bumpiness or waviness that is often caused by poor leveling and resembles skin of an orange.

**Figure 12:**  
Good and bad leveling (“orange peel”)

BASF serves the composites industry with three major classes of wetting agents and surface modifiers which includes products based on polysiloxanes, polyacrylates and fluorinated polyacrylates. The properties of wetting agents and surface modifiers by chemistry are illustrated in Figure 13.



**Figure 13:**  
Properties of wetting agents and surface modifiers by chemistry

## PREAMBLE

# BASF

is the world's leading chemical company and a premier provider of innovative solutions for the paints and coatings industry. BASF offers virtually every ingredient needed to make high-quality coatings and has the know-how to solve formulation challenges and support the development of new coating concepts. Our portfolio encompasses dispersions, pigments, resins and a broad range of additives such as light stabilizers and formulation additives.

When it comes to formulation additives, BASF offers a strong portfolio of industry-leading products that help to enable sustainable and performance-driven solutions. Our offer is comprised of the broadest technology base of dispersing agents, wetting agents, surface modifiers, defoamers, rheology modifiers and film forming agents.

We prioritize our understanding, listening and collaboration skills to serve our customers' needs. With global manufacturing capabilities, a strong research and development platform, full-service regional technical laboratories, pre-screening capabilities and a team of experienced and knowledgeable experts, BASF can help make your coatings better and your business more successful.

This brochure has been developed to give composites and gelcoat producers, molding companies and assemblers first-hand guidance on the use of formulation additives from BASF and on making the most out of their performance characteristics.

Looking for innovative solutions where little helpers make all the difference for your high-quality composites?

**BASF – We create chemistry**

# Table of Contents

- Composites: An Introduction \_\_\_\_\_ 3
- Manufacturing Processes for Thermoset Composites \_\_\_\_\_ 4
- BASF Formulation Additives for Composites \_\_\_\_\_ 8
  - Air Release Agents \_\_\_\_\_ 10
  - Dispersing Agents \_\_\_\_\_ 12
  - Wetting Agents and Surface Modifiers \_\_\_\_\_ 14

## Composites: An Introduction

Composites materials are clearly established in nearly all significant economic sectors. Innovative developments for new applications, or as substitutes for metallic alloys, are key elements in demanding markets like aerospace, automotive, energy, sports and military.

Traditional composites typically consist of combinations of different components:

**Matrix** is generally a thermosetting resin as unsaturated polyesters or epoxies that binds the reinforcement together, keeps it firmly in place and protects it from environmental influences.

**Reinforcements** are usually in the form of fibers or particles that enhance the mechanical and physical properties of the parts.

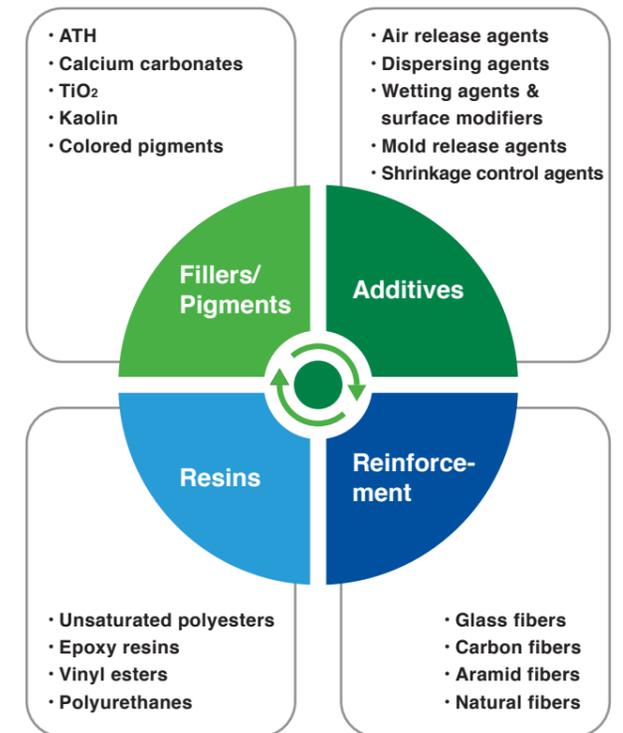
**Fillers and pigments** are used to enhance coloristic and other physical properties. Fillers are typically the least expensive components of major ingredients. They improve functional properties such as water and temperature resistance and can help control shrinkage.

**Formulation Additives** are applied to optimize composite properties like shrinkage, rheology, flow and wetting behavior and adhesion.

Additives are used in low quantities by weight but help improve the cost performance ratio of the final composite part.

As composite materials can be tailored to meet specific needs, several properties like strength, stiffness, weight, aesthetics, resistance to corrosion and chemical stability can be considerably improved through proper choice of additives.

Finding accurate raw materials is one of the most important steps for developing the ideal composite part. Commonly used raw materials for composite formulations are shown in Figure 1.

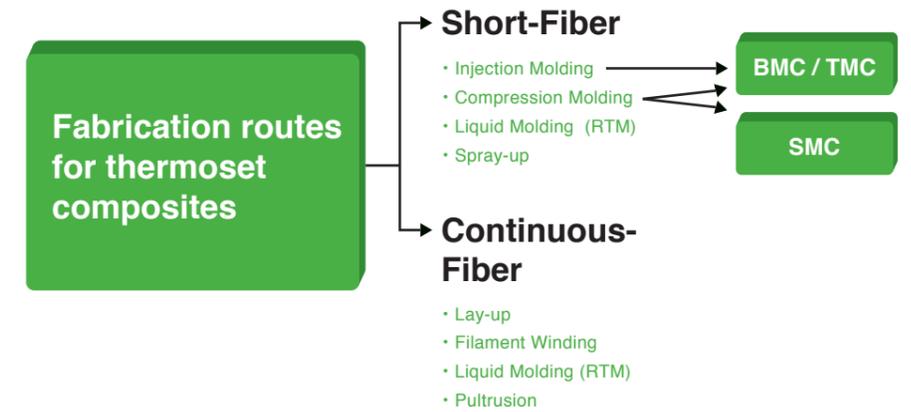


**Figure 1:**  
Example formulation components for thermoset composites.

# Manufacturing Processes for Thermoset Composites

## Manufacturing Processes for Thermoset Composites

The matrix nature, reinforcement type and the designated end application of the designed composite part are crucial selection elements for the fabrication process. The basic manufacturing methods used to fabricate composites include: lay-up, spray-up, filament winding, pultrusion and resin transfer molding. The major fabrication routes for thermoset composites are shown in Figure 2.



**Figure 2:**  
Fabrication routes for thermoset composites

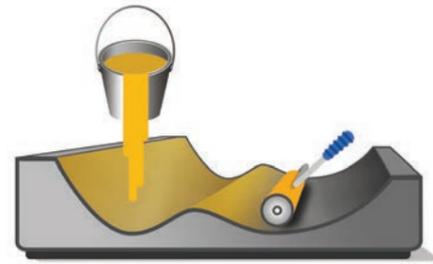
### SMC/BMC/TMC (Sheet/Bulk/Thick Molding Compounds):

SMC, BMC and TMC are premixes made up of thermoset resins, mineral fillers and additives. The compounds are further formed into complex shapes through high volume injection or compression molding processes at high temperatures of around 150°C. The resulting composite parts compete with steel parts in their mechanical properties, ensure pronounced chemical and, corrosion resistance and allow very high design freedom.

SMC	BMC	TMC
Fiber content: 10-60%	Fiber content: 10-30%	Fiber content: 10-20%
Fiber length: 25-50 mm	Fiber length: 6-12 mm	Fiber length: 12-50 mm
Characteristics: Superior mechanical properties due to the longer fibers	Characteristics: Better flow and temperature resistance than SMC due to the shorter fibers and higher filler content	Characteristics: Combined properties of BMC (good flow) and SMC (best mechanical properties)

**Figure 3:**  
Composition and characteristics of SMC/BMC/TMC compounds

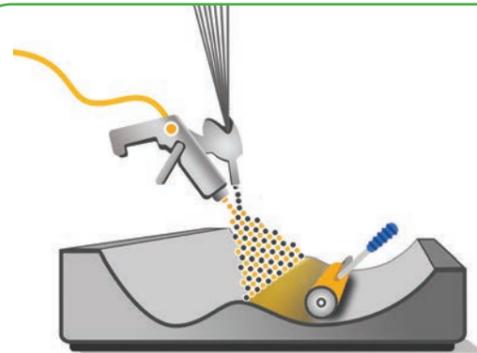
## Manufacturing Processes for Thermoset Composites



Hand Lay-Up

### Hand Lay-up

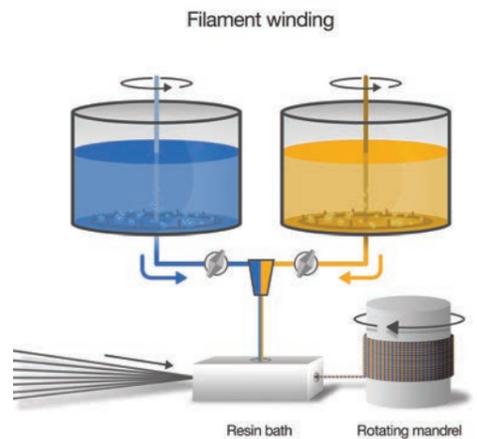
Hand lay-up consists of manual positioning of fiber reinforced mats or prepreg plies onto a prepared mold. Thermosetting resins are then applied by brushing, spraying or resin infusion. Entrapped air can be removed with the aid of rolling, and the laminate can be left to dry at room temperature. Curing can be accelerated in ovens or by vacuum. Hand lay-up is a simple and relatively low cost processing method for large components such as wind turbine parts and boats.



Spray-Up

### Spray Lay-up

Spray lay-up is a conventional open mold process. Gelcoat is applied as a first layer onto a previously waxed mold and then cured. Chopped reinforcements and thermoset resins are then sprayed onto the mold and left to cure at room temperature in ovens or autoclaves. Spray lay-up allows more shape complexity and a quicker production time than hand lay-up. This process is suitable for large components with less complex geometries such as boats and bath tubs.

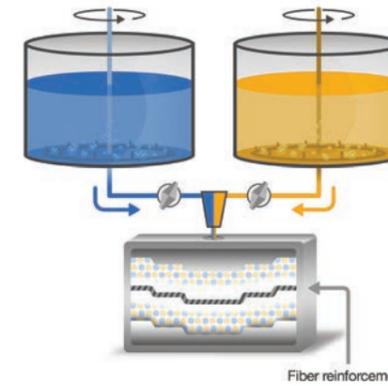


Filament winding

### Filament Winding

Filament winding refers to the winding of thermoset resin impregnated fiber rovings under tension around a rotating mandrel. These fabricated circular composite products with a hollow core are then cured at room temperature or in ovens and used in applications where weight, chemical resistance, pressure and temperature are an important concern. Pipelines, tanks and vessels are example applications of filament winding produced composite parts.

Resin transfer molding (RTM)

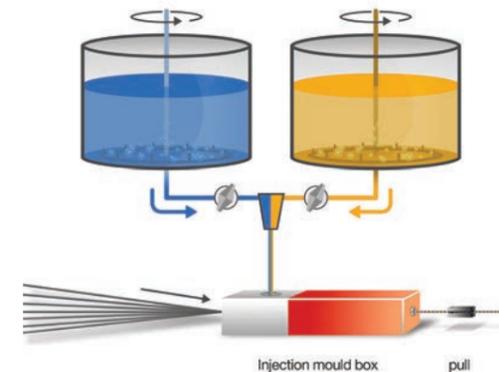


Fiber reinforcement

### RTM (Resin Transfer Molding)

RTM is a vacuum-assisted closed mold process. Fiber reinforcements are positioned in a matched male and female mold, which is then closed and clamped. The matrix is injected under pressure until the mold is filled. The parts cured in the mold are normally heated by controller. RTM is a fast and clean process to produce composites with large surface areas, complex shapes and smooth finishes like boat hulls and wind turbine blades.

Pultrusion



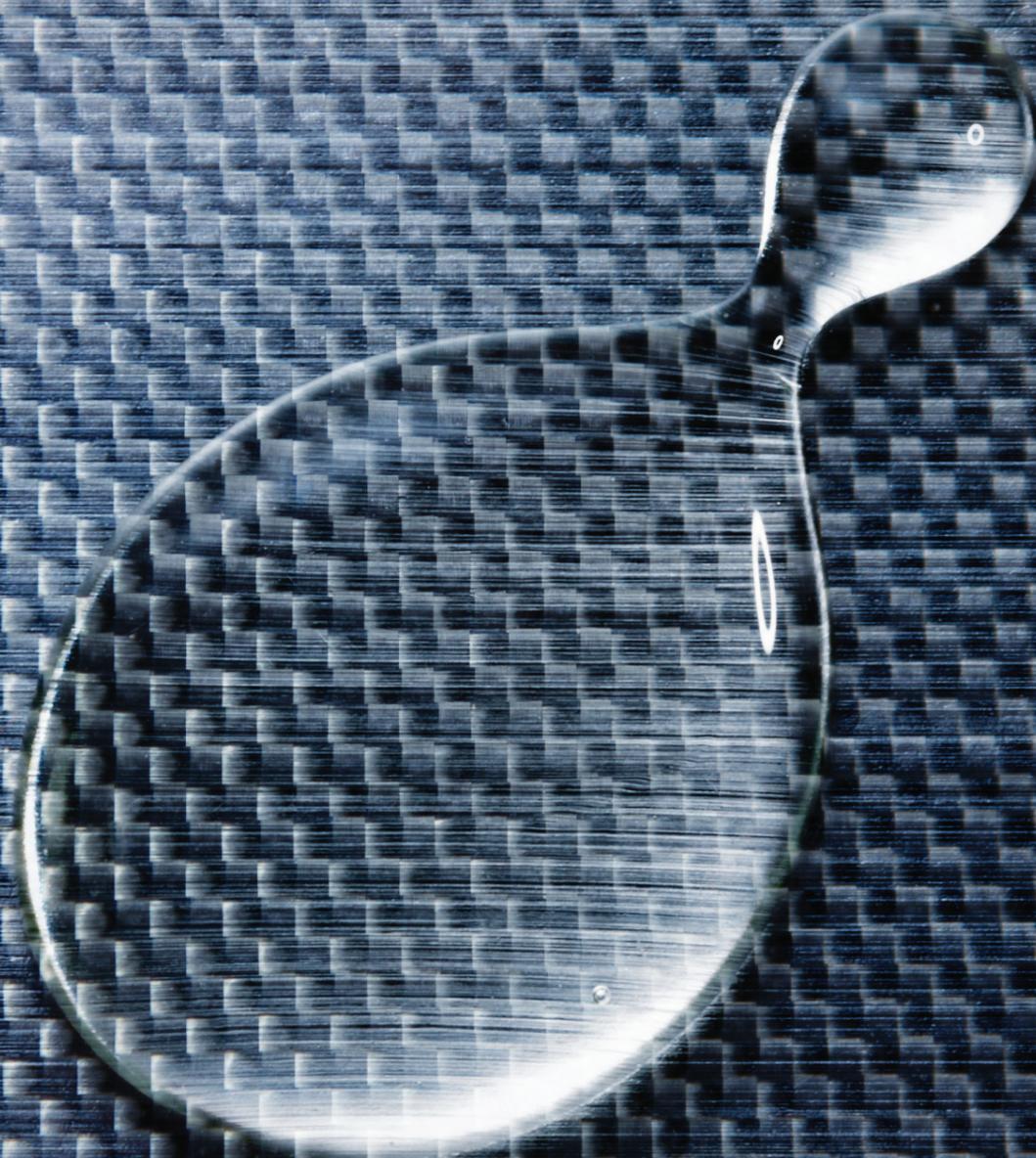
Injection mould box

pull

### Pultrusion

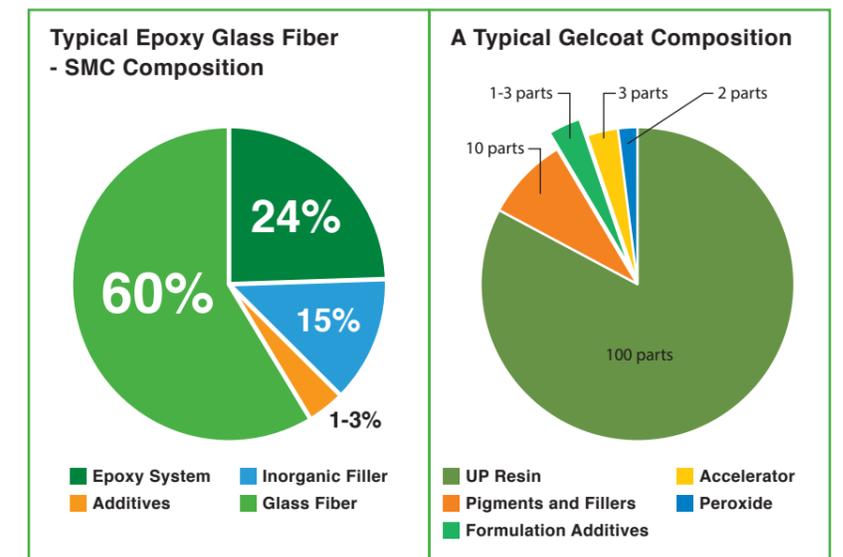
Pultrusion is a high-volume production process for composite profiles. Reinforcement materials (long fibers, mats or fabrics) are pulled and guided through a bath of matrix for impregnation, passed through a heated die for curing and cut at the end of the line into various tubes and flat sheets with excellent mechanical and chemical properties.

# BASF Formulation Additives for Composites



## BASF Formulation Additives for Composites

Formulation additives are essential formulation components of composite materials. They are used to optimize the matrix properties and adapt the reinforcements for particular applications. Additives stabilize pigments and fillers to prevent their sedimentation in composite formulations. They also improve the flow, slip and rheology behavior and contribute to proper fiber wetting. Formulation additives are significant raw materials which enhance the quality of the laminate's finish and extend the product durability of the composite parts.



**Figure 4:**  
Formulation additives content in typical composite formulations

BASF offers a number of solutions for the composites industry and a wide range of formulation additives including air release agents, low to medium molecular weight dispersing agents, high molecular weight dispersing agents and wetting agents, and surface modifiers.

### Nomenclature

**Efka® PB:**  
Polymer based defoamers

**Efka® SI:**  
Silicone based defoamers

**Dispex® Ultra FA / Efka® FA:**  
Low molecular weight dispersing agents

**Efka® PU:**  
Polyurethane based dispersing agents

**Efka® PX:**  
Controlled or advanced polymers

**Efka® PA:**  
Polyacrylic based dispersing agents

**Efka® SL:**  
Slip and mar agents

**Efka® FL:**  
Flow and leveling agents

### Air release agents

Efka® PB

Efka® SI

### Low/medium molecular weight dispersing agents

Dispex® Ultra FA

Efka® FA

### High molecular weight dispersing agents

Efka® PU

Efka® PX

Efka® PA

### Wetting agents & surface modifiers

Efka® SL

Efka® FL

**Figure 5:**  
BASF Formulation Additives for Composites

# Air Release Agents



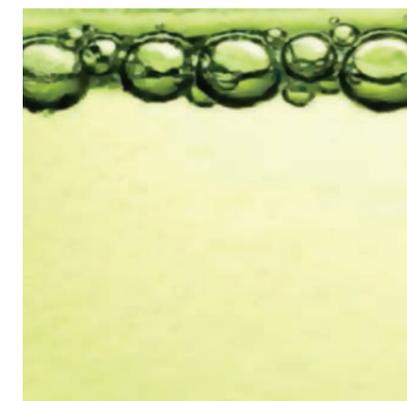
## Air Release Agents

Matrices used in compound formulations and gelcoats often include soluble impurities as surface active substances that stabilize entrapped air during the processing and application of the parts.

Entrapped and stabilized air remains as micro- or macro-foam in the system after curing and can be a considerable source of porosity, weak points, insufficient fiber wetting and poor mechanical properties in composite materials.

Removing incorporated air from the mostly highly viscous systems make the use of air release agents imperative.

Air release agents take effect by destroying foam or preventing its formation, enabling coalescence of air bubbles, increasing their diameter and making them rise easily to the surface and collapsing.

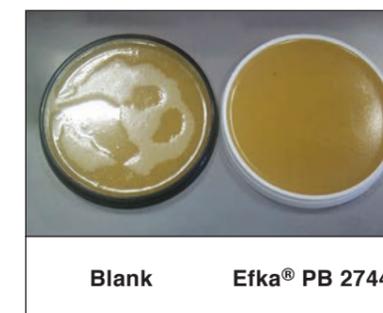


### Good to know

Different denominations like “defoamer”, “antifoaming agent” or “air release agent” are used interchangeably to describe products designed to control or prevent foaming. The distinction between the different terms is blurred since most foam controlling products can serve all three roles.

Depending on the application and customer needs, BASF offers a complete range of air release agents for thermoset resins-based composite formulations.

The products are based on a broad technology portfolio of polysiloxanes, polyacrylates and/or other organic polymers.



**Figure 6:**  
Air release performance of Efka® PB 2744 in a solvent-free 2-pack polyurethane



**Figure 7:**  
Air release performance of Efka® SI 2009 in a clear unsaturated polyester system

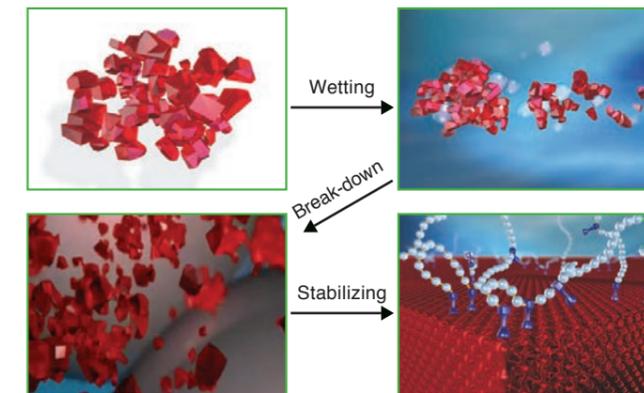
# Dispersing Agents



## Dispersing Agents

The use of dispersing agents results in reduced viscosity, increased filler and pigment loading, improved color strength and a stable dispersion of the compound.

The dispersing process takes place in three steps: **Wetting** of the particle surface by the surrounding liquid; **break-down** of the particle agglomerates using high shear mixers; and **stabilization** of the finely milled pigments.



**Figure 8:**  
Wetting, agglomerate break-down and pigment stabilization process

Insufficient stability might provoke flocculation that leads to an increase in particle size, loss of gloss and color strength and to a settling tendency. A side effect is a higher viscosity that precludes reasonable fiber wetting.

For unsaturated polyester-based composites, control of shrinkage control is an important factor. The shrinkage of the pure resin and styrene increases the internal stress of the molded parts and causes surface waviness, geometry changes and crack formation in the composites part.

For this reason, resin incompatible low-shrink additives are very often used in, for example, SMC/BMC compounds and have to be stabilized. Commonly used shrink control technologies used in UP resins are shown in Figure 9.

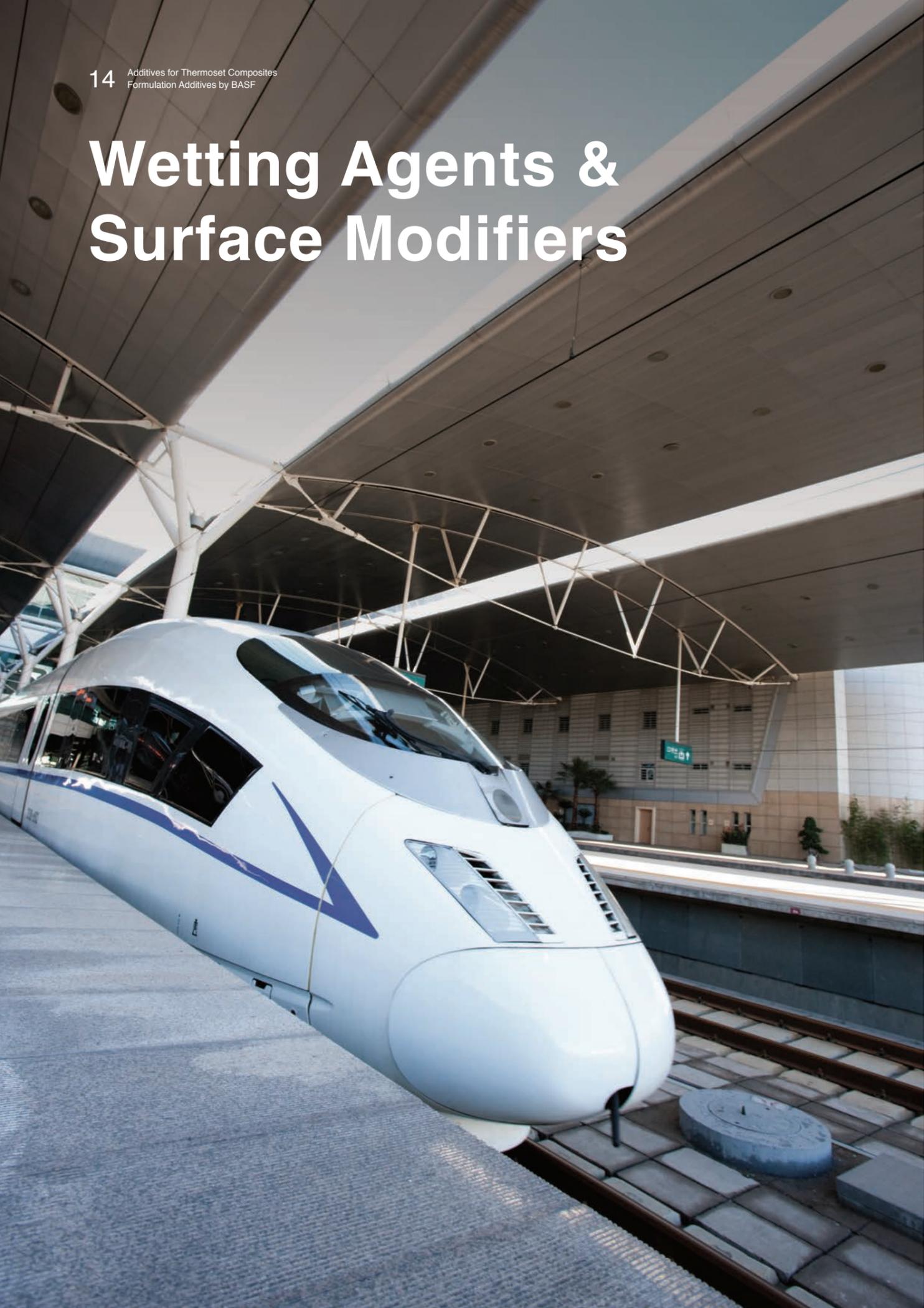
<p><b>LDPE (Low density polyethylene)</b></p> <ul style="list-style-type: none"> <li>• Less crack formation in composite parts</li> </ul> <p><b>LS (Low shrink formulations)</b></p> <ul style="list-style-type: none"> <li>➔ PS, HIPS (high-impact polystyrene), PMMA</li> <li>• Dimension stability</li> <li>• Lower internal stress</li> </ul> <p><b>LP (Low profile formulations)</b></p> <ul style="list-style-type: none"> <li>➔ PVAc and UP in Styrene</li> <li>• High shrink control</li> <li>• Class A surfaces → coating without surface treatment</li> </ul>	<p>Blank      Efka® PU 4061</p>
---	-------------------------------------

**Figure 9:**  
Common shrink control additives

**Figure 10:**  
Stabilization performance of Efka®  
PU 4061 in an LS containing UP resin

BASF high molecular weight dispersing agents comprise a high number of anchoring groups along the polymer backbone. The resin-like character allows for excellent compatibility with both the UP resin and the shrink control agents enhancing homogeneity and stabilization of the compounds. Figure 10 shows the stabilization effect of Efka® PU 4061 in an LS Formulation.

# Wetting Agents & Surface Modifiers



## Wetting Agents & Surface Modifiers

Substrate wetting and the profile of the cured surface of composite materials depend heavily on the nature of the substrate, surface tension of the compounds and coating applied on the top of the parts.

Wetting agents and surface modifiers are often used in composite systems to balance surface tension differences as well as to prevent surface defects such as bad substrate wetting, fish eyes, leveling or slip-related effects.

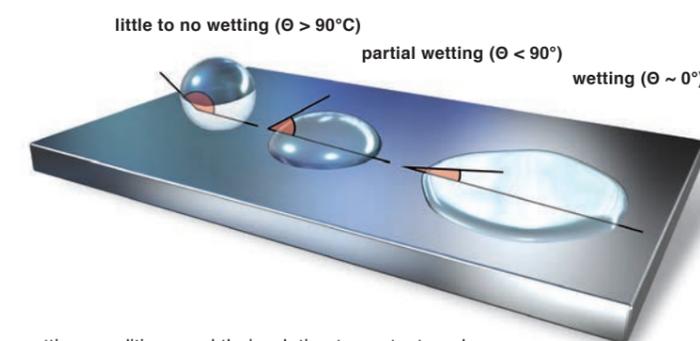
### Substrate wetting

**Main influencing factors**

Compound's surface tension  
Substrate's surface tension

**Related defects**

Craters, edge crawling, de-wetting, fish eyes



Three wetting conditions and their relation to contact angles

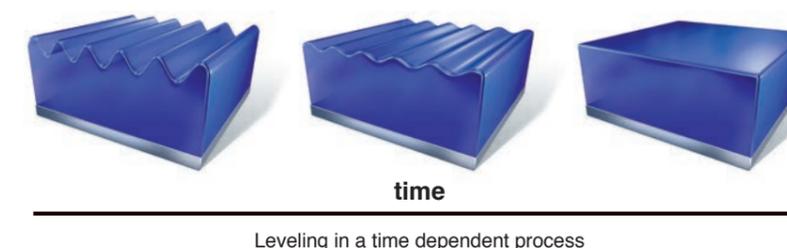
### Leveling

**Main influencing factors**

Compound's rheology  
Compound's surface tension

**Related defects**

Orange peel, waviness, pinholes, decreased gloss



Leveling in a time dependent process

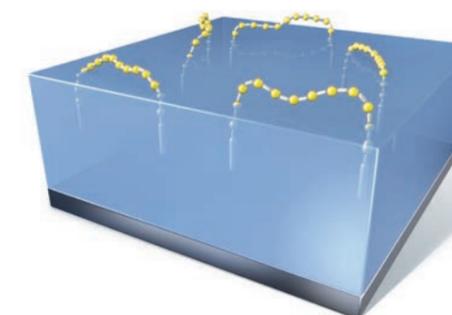
### Slip

**Main influencing factors**

Additives chemistry and its positioning within the compound

**Related defects**

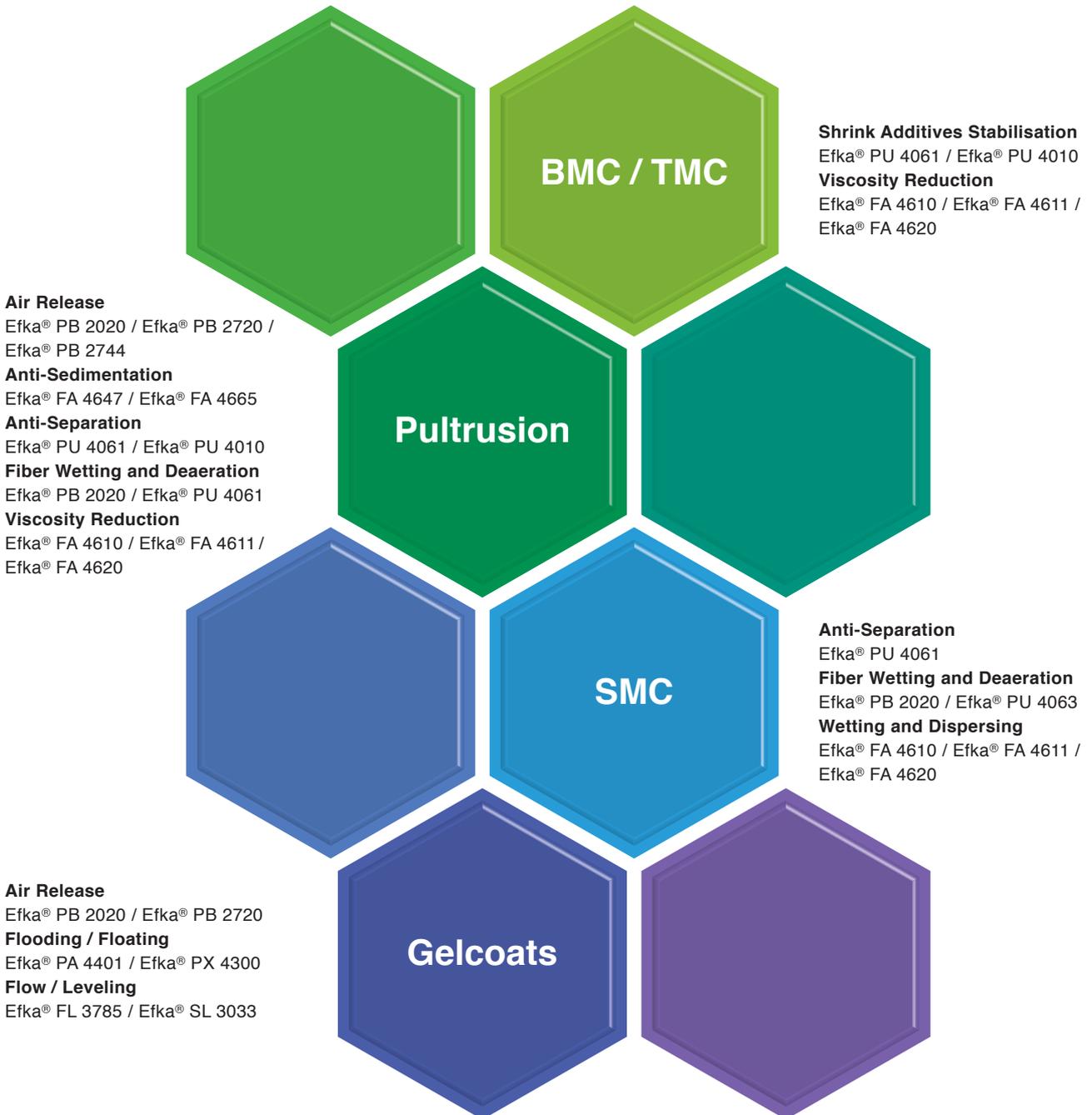
Blocking, decreased mar resistance, intercoat adhesion



Orientation of organomodified silicones at a surface

**Figure 11:**  
Theoretical aspects of substrate wetting, leveling and slip

# BASF's Formulation Additives Focus Portfolio for Composites



BASF SE  
Formulation Additives  
Dispersions & Pigments Division  
67056 Ludwigshafen  
Germany  
[www.basf.com/formulation-additives](http://www.basf.com/formulation-additives)

**BASF**  
We create chemistry

## Air Release Agents

Applications		Unsaturated Polyester					Epoxyes / Polyurethanes					
Product Name	Features	Gelcoats	Pultrusion	SMC/BMC	Casting	Laminating	Putties	Gelcoats	Pultrusion	Casting	Laminating	Flooring/Lining
<b>Polymer based Air Release Agents</b>												
Efka® PB 2001	Brings fast de-aeration even in viscous compounds	■	■		■	■	■	■		■		
Efka® PB 2010	Most suitable air release agent for transparent systems up to medium thicknesses	■	■		■	■		■	■	■	■	■
Efka® PB 2020	Brings fast de-aeration while increasing wetting (e.g. towards fibres), even in viscous compounds	■	■		■	■	■	■				■
Efka® PB 2720	Most efficient air release agent combined with broad applicability. Suitable for pigmented compounds	■	■	■		■	■		■		■	■
Efka® PB 2744	Ultra low VOC de-aerator with excellent and fast performance against micro and macro foam	■	■	■	■	■	■	■	■	■	■	■
<b>Silicone based Air Release Agents</b>												
Efka® SI 2040	Designed for ambient cured systems and low shear forces				■	■	■			■	■	■
Efka® SI 2722	Efka® SI 2722 can be used in pigmented or non-pigmented resin systems				■	■	■	■	■	■	■	■
Efka® SI 2723	Low odour version of Efka® SI 2722				■	■	■	■	■	■	■	■

■ Excellent ■ Good

## Substrate Wetting Agents and Surface Modifiers

Applications		Unsaturated Polyester		Epoxyes / Polyurethanes				
Product Name	Features	Gelcoats	Laminating	Gelcoats	Pultrusion	Casting	Laminating	Flooring/Lining
<b>Fluorinated Polyacrylates</b>								
Efka® FL 3277	Provides additional substrate wetting as well as anti-cratering over straight polyacrylate additives	■	■	■				
<b>Straight Polyacrylates</b>								
Efka® FL 3740 EH	Flow agent with higher de-aeration properties compared to Efka® FL 3741	■	■	■	■		■	■
Efka® FL 3741	Highly compatible flow agent with additional air release effect	■	■	■	■		■	■
Efka® FL 3778	Brings leveling without slip, supports the action of air release agent Efka® PB 2720	■	■	■	■		■	■
Efka® FL 3785	Brings leveling, no slip and contributes to deaeration	■	■	■	■		■	■
<b>Modified Polysiloxanes</b>								
Efka® SL 3031	Slip & leveling agent with good substrate wetting and anti-cratering properties			■	■	■	■	
Efka® SL 3033	Slip & leveling agent with good substrate wetting and anti-cratering properties	■	■	■	■	■		■
Efka® SL 3035	Leveling agent with moderate slip	■						
Efka® SL 3200	Solvent-free slip and leveling agent with a strong reduction of surface tension	■		■				
Efka® SL 3236	Slip & leveling agent with additional air release effect			■	■	■		

■ Excellent ■ Good

## Low molecular weight dispersing agents

Applications		Unsaturated Polyester							Epoxyes / Polyurethanes				
Product Name	Features	Filler Loading	Gelcoats	SMC/BMC	Pultrusion	Casting	Laminating	Putties	Gelcoats	Pultrusion	Casting	Laminating	Flooring/Lining
Dispex Ultra® FA 4420	Increases colour acceptance of inorganic pigments	100-150 pHr	■	■		■	■	■	■		■		■
Dispex Ultra® FA 4425	Increases colour acceptance and reduces floatation	100-150 pHr	■	■			■	■	■				
Dispex Ultra® FA 4431	For fillers. Possible fluidizing by post addition	100-150 pHr	■	■	■	■	■	■	■			■	■
Efka® FA 4610	Standard choice for fillers and inorganic pigments (e.g. 200 phr of CaCO <sub>3</sub> ). Antisettling properties are inherent	>170 pHr	■	■	■	■	■	■			■		
Efka® FA 4611	Broad compatibility in a wide range of resin systems. Very efficient in wetting and dispersing of titanium dioxide and other inorganic pigments. High pigment and filler loading possible. Strong reduction of mill base viscosity	>170 pHr	■	■	■		■	■	■	■	■	■	
Efka® FA 4620	For inorganic pigments and fillers in cobalt catalyst free compounds. Able to wet 275 phr of ATH. Same anchoring group as Efka® FA 4612. Antisettling properties are inherent	>170 pHr	■	■	■		■	■	■	■	■	■	■
Efka® FA 4644	For fillers such as ATH or CaCO <sub>3</sub> . Antisettling properties are inherent	100-150 pHr	■	■			■		■				
Efka® FA 4647	For fillers in fiber-reinforced thermosetting systems. Antisettling properties are inherent	100-150 pHr	■	■	■				■	■	■		■
Efka® FA 4665	For fillers and inorganic pigments. Prevents settling and improves color separation. Antisettling properties are inherent	ca. 150 pHr		■	■								
Efka® FA 4666	For fillers and inorganic pigments. Prevents settling and improves color separation. Efka® FA 4666 can be used in pastes. Antisettling properties are inherent	ca. 150 pHr	■	■	■	■	■		■	■	■	■	■
Efka® FA 4672	For inorganic pigments and extenders such as talc, ATH and quartz	above 170 pHr	■	■		■		■	■		■		■

■ Excellent ■ Good

## High molecular weight dispersing agents

Applications		Unsaturated Polyester		Epoxyes / Polyurethanes		
Product Name	Features	Gelcoats	Pultrusion	Gelcoat	Pultrusion	Flooring/Lining
Efka® PA 4401	Efka® PA 4401 is a polymeric dispersant for stabilizing inorganic and organic pigments in high quality systems	■		■		■
Efka® PA 4402	Conventional for all standard inorganic and organic pigments (e.g. Irgalite® range); suited for colourants (higher pigment loading)	■		■		■
Efka® PU 4009	Stabilizes TiO <sub>2</sub> and standard organic pigments as found in our Irgalite® range			■		■
Efka® PU 4010	Stabilizes TiO <sub>2</sub> , matting agents and usual organic pigments. Improves anti sag resistance in UPE	■	■		■	■
Efka® PU 4047	Stabilizes inorganic and organic pigments such as our Heliogen® Blue and Green and carbon black pigments	■				
Efka® PU 4050	Stabilizes all kinds of pigments and is particularly effective with pigments such as our DPP reds	■		■		■
Efka® PU 4061	Stabilizes TiO <sub>2</sub> , matting agents and usual organic pigments. Improved anti-separation effect in UPE	■	■		■	■
Efka® PU 4063	Stabilizes all kinds of pigments and is particularly effective with red pigments such as our DPP reds	■		■		■
Efka® PX 4300	Efka® PX 4300 is a controlled polymer by the use against flooding, floating and flocculation in high quality systems and difficult organic pigments	■		■		■
Efka® PX 4340	Controlled polymer with higher efficiency towards pigment stabilization and viscosity reduction. Specific of high performance organic pigments (e.g. Palitol®, Cromophthal®, Irgazin®)	■				
Efka® PX 4701	Efka® PX 4701 is made by Controlled Free Radical Polymerization. It provides a combination of strong viscosity suppression and excellent storage stability	■		■		■
Efka® PX 4733	Highly efficient dispersing agent which shows excellent performance in stabilizing organic pigments in low viscosity systems. It has been specifically developed to provide the challenging combination of strong viscosity suppression, excellent storage stability and improved color strength	■		■		■
Efka® PX 4780	Efka® PX 4780 is a high molecular weight dispersing agent designed to disperse and stabilize organic pigments and carbon-blacks, especially where resin-matrix reactive dispersants are desired	■		■		■

■ Excellent ■ Good