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

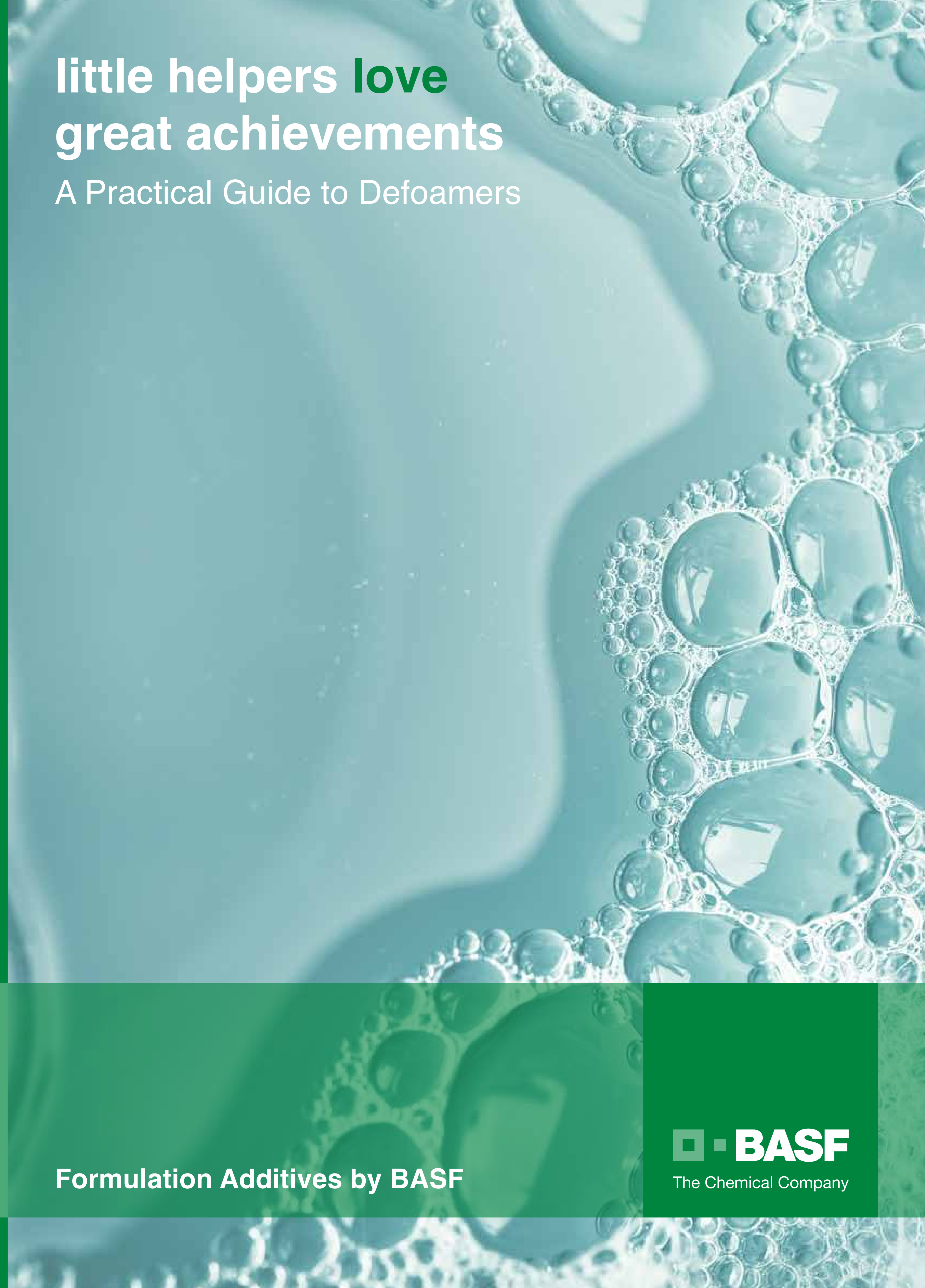
Europe
BASF SE
Formulation Additives
67056 Ludwigshafen
Germany
formulation-additives-europe@basf.com

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 Naçoes Unidas, 14.171
Morumbi - São Paulo-SP
Brazil
formulation-additives-south-america@basf.com

ED2 0414e

BASF SE
Formulation Additives
Dispersions & Pigments Division
67056 Ludwigshafen
Germany
www.basf.com/formulation-additives



little helpers love great achievements

A Practical Guide to Defoamers

Formulation Additives by BASF

BASF
The Chemical Company

We create chemistry

FOREWORD

BASF

is the world's leading chemical company and a premiere provider of innovative solutions for the paints and coatings industry – along with the know-how to solve formulation challenges and support the development of new coating concepts. The portfolio encompasses dispersions, pigments, resins and a broad range of additives such as light stabilizers and photoinitiators and formulation additives.

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

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

This booklet has been developed in order to give paint formulators and technicians first-hand guidance on the use of defoamers from BASF and to help make the most out of their performance characteristics.

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

BASF – The Chemical Company

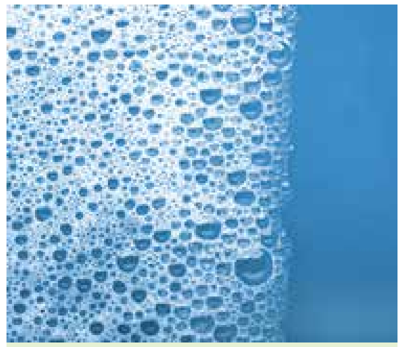
Table of Contents

Defoamers: An Introduction

It is difficult to get through a single day without coming in contact with foaming materials like beverages, soap or insulation foams. In these cases foam is a desired property and well accepted in our daily life.

For paint manufacturers and applicators however, control of foam is one of the major tasks to ensure a smooth and even appearance of the paint film. Thus, high performing defoamers are needed to prevent the formation of bubbles in liquid paints. They reduce foam and avoid foam-formation during the production, application and transport of paint formulations.

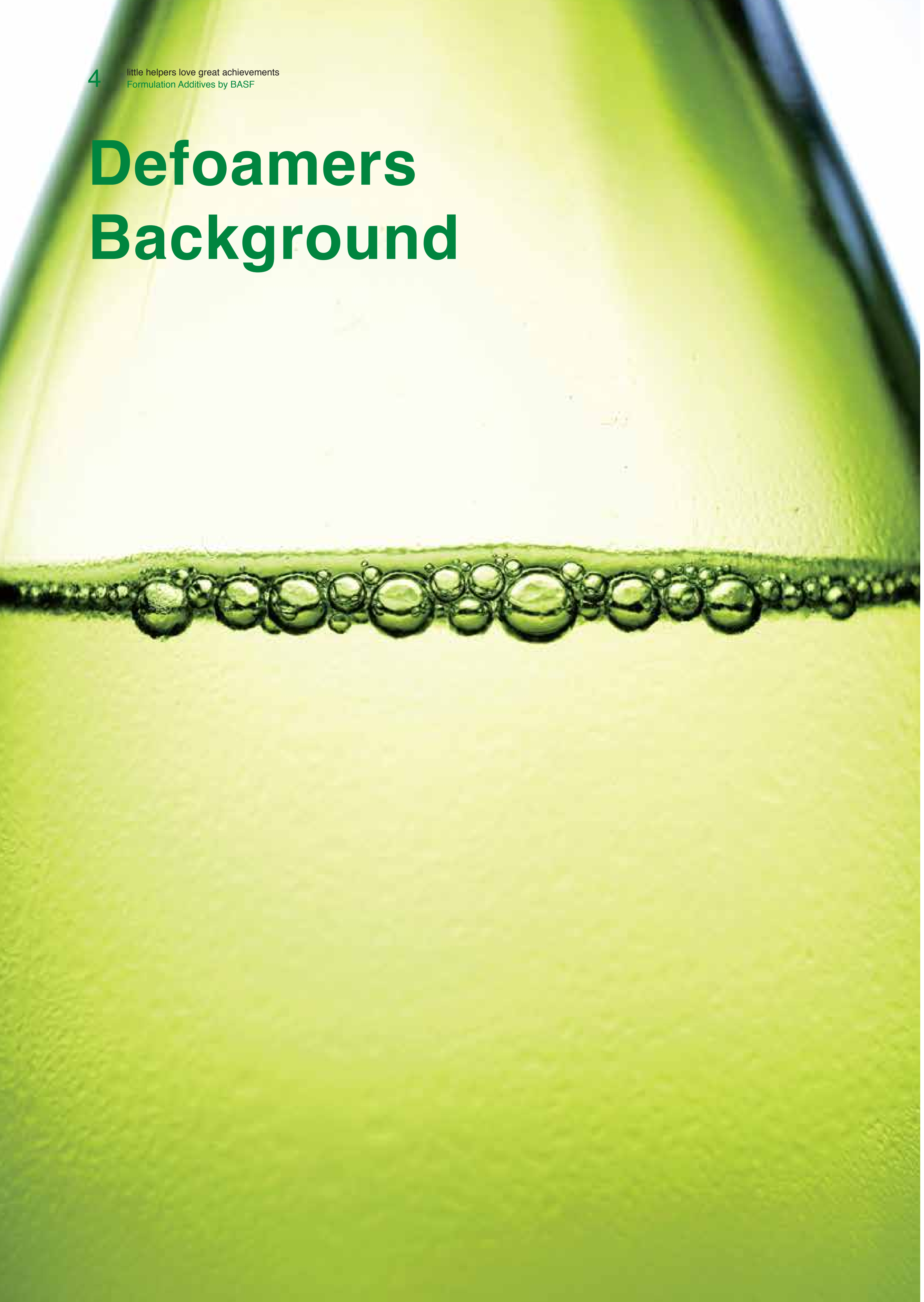
Especially in industrial surroundings, foam is a very undesirable phenomenon that can emerge during dispersing processes, pumping, stirring operations or while applying paints. This foam can for example increase the production time, create difficulties in filling vessels, reduce the efficiency of many high speed operations and promote surface defects like craters, fish eyes, pinholes and weak points in the dried film.



Good to know:

- **Defoamer:** a surface-active agent that destroys foam after it has been formed, as a knock-down effect (post-defoaming)
- **Anti-foam agent:** a surface-active agent that prevents foam formation (pre-defoaming)
- **Air release agent:** removes (micro-) air bubbles from a liquid and helps them to rise to the surface

Different denominations like "defoamer", "anti-foaming agent" or "air release agent" are used interchangeably to describe products designed to control or to prevent foaming. The distinction between the different terms is somewhat blurred since most foam controlling products can serve either role.



Defoamers Background

Defoamers Background

Foam and foam control: What is foam?

Foam can be defined as gas dispersed in a liquid. In pure liquids foam is thermodynamically unstable; the bubbles rise rapidly to the surface and burst immediately.

Surfactants or other surface active ingredients (for example: detergents, wetting agents, emulsifiers or dispersants) which are commonly used in the coating industry lower the surface tension (see Table 1) of a liquid and tend – due to their amphiphilic nature (see Fig. 1) – to accumulate on interfacial surfaces (e.g. air/liquid interface) (see Fig. 2). They retard the coalescence of gas bubbles and thus stabilize foam.

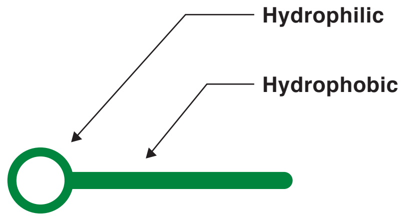


Figure 1:
Schematic drawing of a surfactant molecule with polar (hydrophilic) head group and unpolar (hydrophobic) tail.

Polar groups can be based on carboxylates, sulphates/sulphonates, phosphates, amines or polyethylenglycol chains. Unpolar groups on the other hand could be based on natural fats and oils, alkyl chains (linear or branched) or synthetic polymers.

Good to know:

Foam is defined as dispersed air or gas in a liquid.

Surfactants or surface active ingredients tend to stabilize foam in paints and coatings.

In **pure liquids** foam is thermodynamically unstable.

Surface tension of different liquids:	
water:	72.7 mN/m
xylene:	30 mN/m
butyl acetate:	25 mN/m
white spirit:	24 mN/m
Surface tension of different aqueous surfactant solutions (0.5%):	
fluorinated surfactant:	22 mN/m
silicone wetting agent:	24 mN/m
sulfosuccinate:	27 mN/m
fattyalkohol ethoxylate:	24 mN/m

Table 1:
Overview about surface tensions of liquids and surfactant solutions.

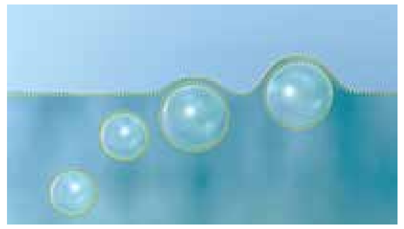


Figure 2:
Orientation of surfactant molecules around foam bubbles. Foam bubbles on top of a liquid exhibit a surfactant double layer around the foam bubbles.

It is interesting to know that surfactants do not strengthen foam bubbles, actually they stabilize them. If a foam lamella is stretched, the local surface concentration of surfactants decreases, which in turn causes the surface tension to increase locally (Gibbs-Marangoni elasticity). This way the surfactants selectively stabilize the weakest parts of the foam bubble and tend to prevent them from stretching further. In addition, the surfactants reduce evaporation of the liquid so the bubbles last longer, although this effect is relatively small.

By drainage, foams are dehydrated and thus water escapes between the bubbles. The spherical foam bubbles are distorted into dry, hexagonal (polyhedral) foam (see Fig. 3).

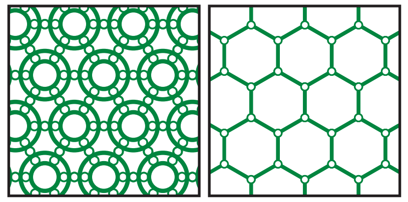


Figure 3:
Schematic drawing of spherical and polyhedral foam.

Defoamers Background

How to destroy foam?

Unfortunately, there is no single overarching defoamer theory in the scientific literature. However, for aqueous systems all theories have some explanations and prerequisites in common. It is generally accepted that a defoamer active should:

- Possess a “controlled incompatibility” with the formulation to be defoamed. This “controlled incompatibility” must remain even after long term storage.
- Have a low surface tension.
- Exhibit a de-wetting effect.
- Have the capability to penetrate into foam lamellae and to spread effectively on the liquid/gas interface.

All defoamers are characterized by a certain balance between compatibility and incompatibility in a given system. On one hand, the active ingredient in the defoamer must be almost insoluble in the paint formulation. A defoamer must form small defoamer droplets which are able to migrate into the foam lamellae. In order to ensure long term defoaming efficiency the defoamer droplets have to be stable in the system and should not dissolve upon storage.

On the other hand, no surface defects such as craters should be generated in the final paint film due to defoamer incompatibility. The defoamer must therefore be sufficiently compatible with the binder. Thus, every defoamer is formulated on a tightrope between compatibility and targeted incompatibility (see Fig. 4):

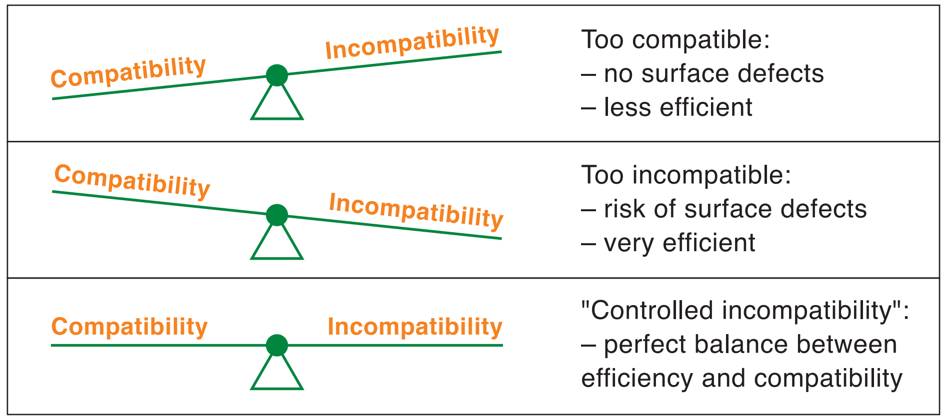


Figure 4:
Schematic drawing of balance between defoamer incompatibility and compatibility. The incompatibility of the defoamer should not lead to surface defects in the final paint film.

Also, a defoamer should exhibit pronounced surface active properties. An essential feature of a defoamer product is its capability to spread rapidly on the gas/liquid interface.

Additionally, the defoamer must have a lower cohesion energy density than the stabilizing surfactants in order to reverse or prevent the Marangoni effect, i.e., causing fast thinning and collapse of the lamella.

Figure 5:
Schematic drawing of entering, spreading and destabilizing a surfactant layer by a defoamer droplet.

Figure 5 depicts a possible working mechanism of a defoamer droplet. The working mechanism of a defoamer can be characterized by three steps. First, a defoamer droplet has to enter the foam lamella. Due to its highly surface active properties the defoamer droplet has a strong tendency to migrate to the air/water/surfactant interface. Second, the defoamer droplet spreads and pushes aside the stabilizing surfactants. Without the stabilizing surfactants the foam lamella locally becomes much less elastic (“reverse Marangoni effect”). A weak spot is formed. Third, this kind of destabilization facilitates rupture of the foam lamella.

To increase defoamer efficiency, it is a common approach to add finely divided hydrophobic particles, such as hydrophobic silica or waxes, to the formulation. The reason for this is that the hydrophobic solid particles are able to destabilize the foam lamella by a de-wetting process. In simple terms, the surfactant film which stabilizes the foam lamella is not able to wet the hydrophobic solids and “shrinks back”. An unstable area results where the lamella is thus destabilized.

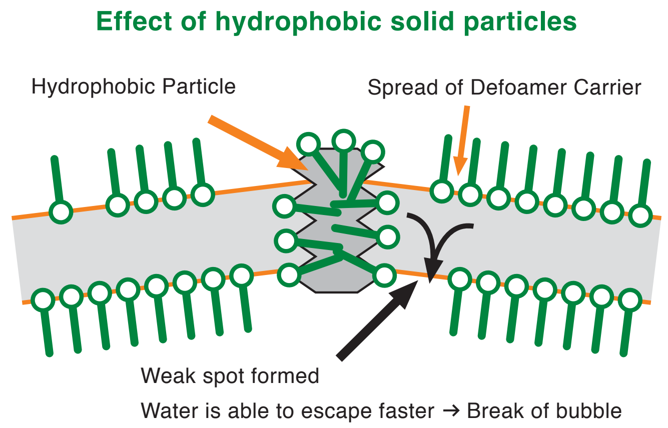


Figure 6:
Schematic drawing of de-wetting properties of hydrophobic particles in a defoamer formulation.

A defoamer’s point of action is the foam lamella. Therefore it must be insoluble in the paint system and the defoamer droplets must be rather mobile so they can enter the lamella and develop the defoaming action.

Good to know:

Three steps of defoamer action are:

- Entering of a defoamer droplet into a foam lamella
- Spreading on the air / liquid / surfactant interface
- Destabilization and rupture of the foam lamella

Defoamers Background

Defoamer evaluation

BASF experts have a high degree of experience in selecting the right defoamer product for a specific application or paint formulation. They will assist customers in order to select and test the right defoamer for their individual formulation needs.

When testing the performance of defoamers the choice of test methods depend on the intended area of use and application method (e.g. brushing, spraying, dipping, printing, rolling). Defoamers can cause surface defects such as cratering which are just as undesired as problems caused by foam bubbles. Potential side effects have to be taken into account and should be investigated by suitable test methods.

Stirring Test (Density Test):

The stirring test allows the evaluation of the efficiency and the separation tendency of a defoamer in liquid systems:

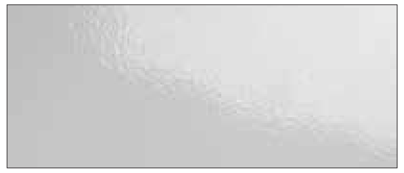
The complete formulation (including the defoamer) is stirred with a toothed dissolver at high speed (e.g. 3 min at 4000 rpm). Then the density of the formulation – which gives information about the efficiency of the antifoam – is determined by weight.

The test is repeated after storage (e.g. 2 weeks at 50°C) which gives important information about the long term defoaming efficiency in the specific formulation.

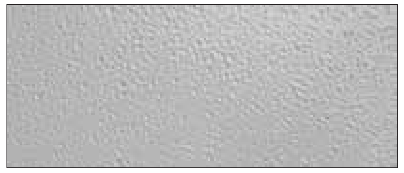
Figure 7:
Dissolver and pycnometers to determine density after stirring.

Compatibility Test:

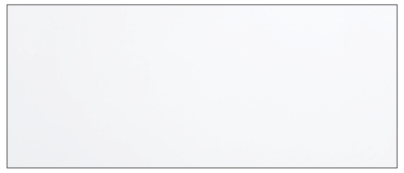
Defoamer incompatibility in a given coating system can provoke film defects like orange peel, fisheyes and wetting problems.



Orange peel



Fisheyes



No defect

A visual evaluation of the surface aspect on a glass panel is carried out to evaluate the adequacy of the defoamer used. For this, the complete formulation (including the defoamer) is applied on a glass plate (wet film: 100-150 µm) and a visual comparison with a blank sample (without defoamer) is done.

Sponge Roller Test:

In order to simulate the paint application on a wall, a certain amount of test system (including the defoamer) is applied on 0.4m^2 of polyester film and distributed with a high porosity sponge roller. The knock-down effect during and after application and the surface aspect of the dried film illustrate the efficiency of the defoamer used.

Gloss measurement

The gloss of a dried coating film on a glass panel is measured to give an indication of the compatibility of tested defoamers in the paint; the less influence on gloss, the more compatible the defoamer.

Depending on the coating system and the customer requirements, various other additional tests like spray application (e.g. air-less or air-mix), shaking tests or circulation foam tests may be carried out to simulate industrial application conditions or to adapt the test methods to the specific needs of a customer.

Chemistry of Defoamers

Chemistry of Defoamers

BASF offers a broad selection of defoamer technologies to the paint and coatings market. The portfolio ranges from standard mineral oil defoamer technologies to aqueous emulsion defoamers and up to our innovative FoamStar technology.

Today, most defoamers are sophisticated formulations designed to fit in together with paint and coating formulations in the best possible way. Usually the formulations are based on raw materials with a low surface tension such as silicone, mineral oils, fatty acids and fluorocarbons.

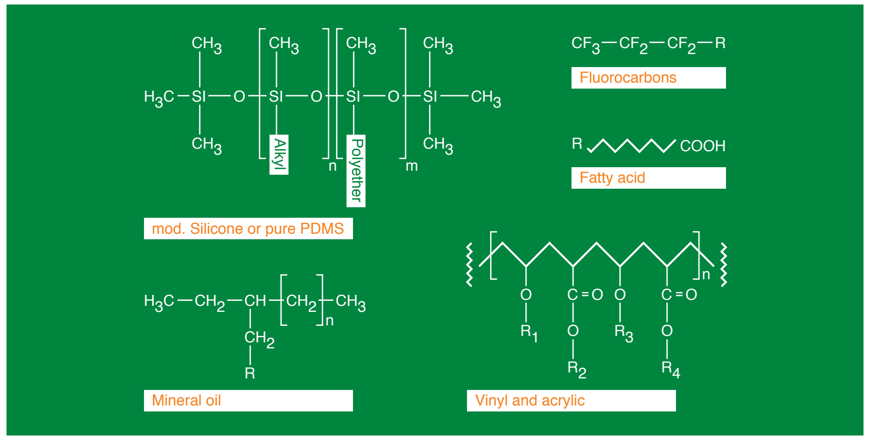


Figure 8:
Chemical structures of organomodified silicones, fluorocarbons, fatty acids, mineral oil and vinyl/acrylic polymers.

To increase the defoaming efficiency, solid particles can be included, such as hydrophobic silica, metallic soaps or waxes.

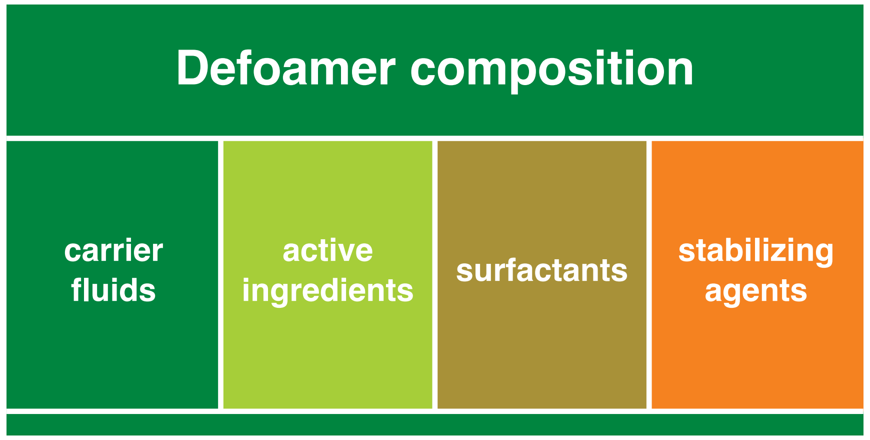


Figure 9:
General overview of defoamer ingredients.

These materials can be incorporated into carriers such as water and organic solvents, in order to give easier addition and faster distribution of the active substance in the liquid paint. 100% active defoamers are suitable for systems which have to perform under shear stress such as grinding, which ensures the distribution and activity of the defoamer.

BASF's Defoamers Product Range

BASF's Defoamers Product Range

BASF defoamers for water-based systems

BASF Formulation Additives offer a broad defoamer portfolio for water-based systems including products based on mineral oils, natural oils, aqueous emulsions, (organo-) silicones or other polymers.

- **Defoamer product range for water-based systems**
  - **Silicone based defoamers** – FoamStar® SI
  - **Emulsion defoamers** – FoamStar® ED
  - **(Star-) Polymer based defoamers** – FoamStar® ST
  - **Powder defoamers** – FoamStar® PB
  - **Oil based defomers** – Foamaster® MO/NO/WO*

Foamaster® **MO** = Mineral oil based defoamers
NO = Native oil based defoamers
WO = White oil based defoamers

BASF's Defoamers Product Range

Oil based defoamers for water-based systems

Foamaster® MO/NO/WO

The oil based Foamaster® MO/NO/WO defoamer products are either based on mineral oils (MO), vegetable or native oils (NO) or on white oils (WO).

The most important carrier oils are paraffinic and naphthenic mineral oils. These mineral oils are excellent base fluids to formulate effective defoamers and to achieve a reliable long term defoaming effect at an optimum cost/performance ratio.

Vegetable or native oils (NO) and white oils (WO) offer various advantages over conventional mineral oils. Vegetable oils, for example, have excellent sustainability characteristics because they come from renewable resources. Highly purified (medical) white oils even allow the formulation of products with a comprehensive range of food contact approvals.

Most oil based defoamers also contain waxes and/or hydrophobic silica to boost their performance. This product class may also contain surfactants to improve emulsification and spreading in foaming media. This is of special importance in emulsion polymerization processes.

Oil based defoamers	Advantages	Limitations
Mineral oil (MO)	• Excellent result against macro foam • Universal • Excellent cost/performance ratio	• Gloss reduction in high gloss systems • Typical odor
White oil (WO)	• Similar efficiency to mineral oil defoamers • Odor improvement • Low fogging • Food contact compliance	• Gloss reduction in high gloss systems
Native oil (NO)	• High efficiency • Low S-VOC • Renewable raw material	• Gloss reduction in high gloss systems • Typical odor

Examples of application areas of Foamaster® MO/NO/WO defoamers

- High PVC and flat emulsion paints
- Wood coatings
- Primers
- Adhesives
- Plasters
- Inks

BASF's Defoamers Product Range

Silicone based defoamers for water-based systems

FoamStar® SI

FoamStar® SI types are highly efficient defoamers for emulsion paints and coatings. They are based on organically modified polydimethylsiloxane (PDMS).

Polydimethylsiloxane is a particularly efficient defoamer ingredient because of its low surface tension, spreading capability, thermal stability, chemical inertness and water insolubility. Organic modification of the polydimethylsiloxane with polyethers or other organic groups renders the products more compatible and allows the formulation of highly efficient defoamers with excellent compatibility characteristics for high performance applications.

Silicone based defoamers can be formulated as 100% liquid products ("silicone compounds"), as solutions and as aqueous emulsions. The silicone compound often contains hydrophobic silica dispersed in an organomodified silicone fluid. Emulsifiers can be added to ensure that the silicone is well dispersed in the foaming medium.

Silicone based defoamers	Advantages
Organomodified silicone types	• High performance • Excellent compatibility • Excellent long term efficiency

Examples of application areas of FoamStar® SI defoamers

- High gloss architectural and industrial coatings
- Silk and glossy emulsion paints
- Wood paints and stains
- Inks and overprint varnishes
- Clear coats
- Pigment concentrates
- Adhesives

BASF's Defoamers Product Range

Emulsion based defoamers for water-based systems

FoamStar® ED

FoamStar® ED products are aqueous defoamer emulsions based on oils, polymers and/or organomodified silicones. An aqueous emulsion is a very elegant way of delivering a defoamer. Plain water is used as a carrier fluid. Volatile organic compounds (VOC) and even semi-volatile organic compounds (S-VOC) are reduced to an absolute minimum, which makes them well suited for use in paints with eco-labels.

In the aqueous emulsion, the defoamer droplets have been formed already in the right size. The low viscous emulsions are easy to handle. Incorporation with high shear mixing equipment is not required. This minimizes the risk of inhomogeneities in the formulation.

Emulsion based defoamers	Advantages	Limitations
Oil	• Easy incorporation • Quick foam suppression • Good cost performance ratio	• Moderate persistency • Contain mineral oil • Moderate stability
Polymer	• Easy incorporation • Highly compatible • Good cost/performance ratio • Minimized odor • Ultra low S-VOC	• Moderate to good efficiency
Organomodified silicone	• Easy incorporation • Mineral oil free	

Examples of application areas of Foamaster® ED defoamers
Depending on the defoamer emulsion composition, all application areas mentioned below can be covered with the FoamStar® ED range.

- Architectural coatings
- Industrial coatings
- Clear coats
- Inks
- Adhesives

BASF's Defoamers Product Range

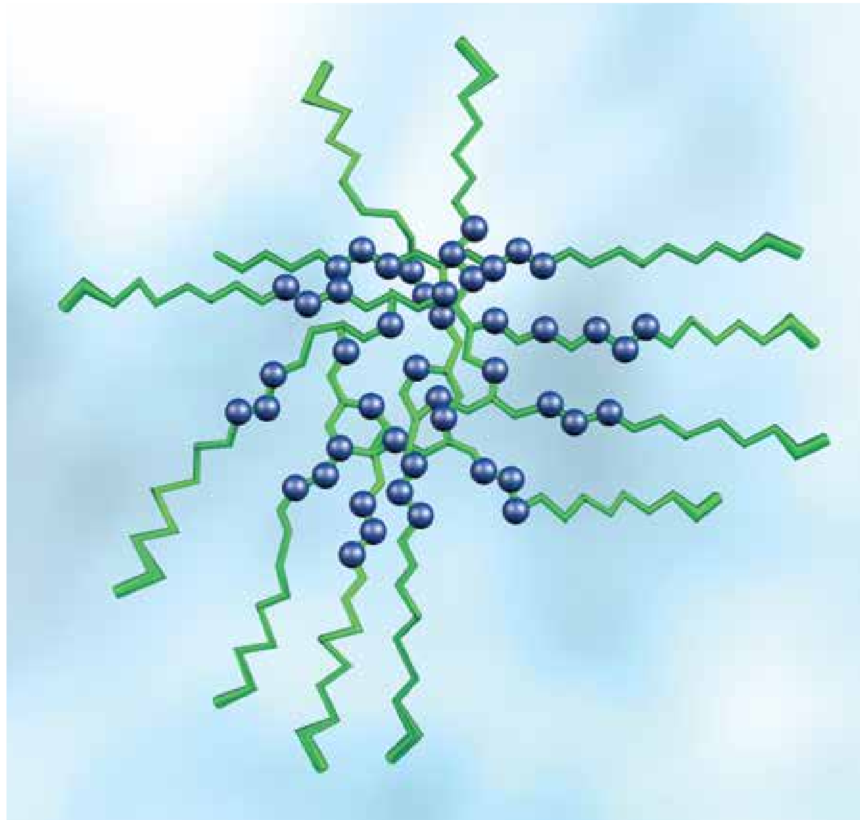
Star-polymer based defoamers for water-based systems

FoamStar® ST

Star-polymer is a hyper-branched polymer with a 3D star-shaped structure, containing hydrophilic as well as hydrophobic elements.

Unlike conventional mineral oil and silicone defoamers, the FoamStar® molecule defoams on a molecular level. It acts as a unique surfactant interacting with the foam-stabilizing surfactants and destabilizes the foam bubbles. When combined with conventional defoamer types it yields faster bubble-break times and improves the overall efficiency. Bubble-break time is the time in seconds needed to break all macro bubbles in a paint film; the shorter the time the better the defoamer.

Star-Polymer types	Advantages
	• Multifunctional (defoaming and wetting) • Improved bubble-break time compared to conventional defoamers • Excellent defoaming persistence • Effective against microfoam • Easy to incorporate

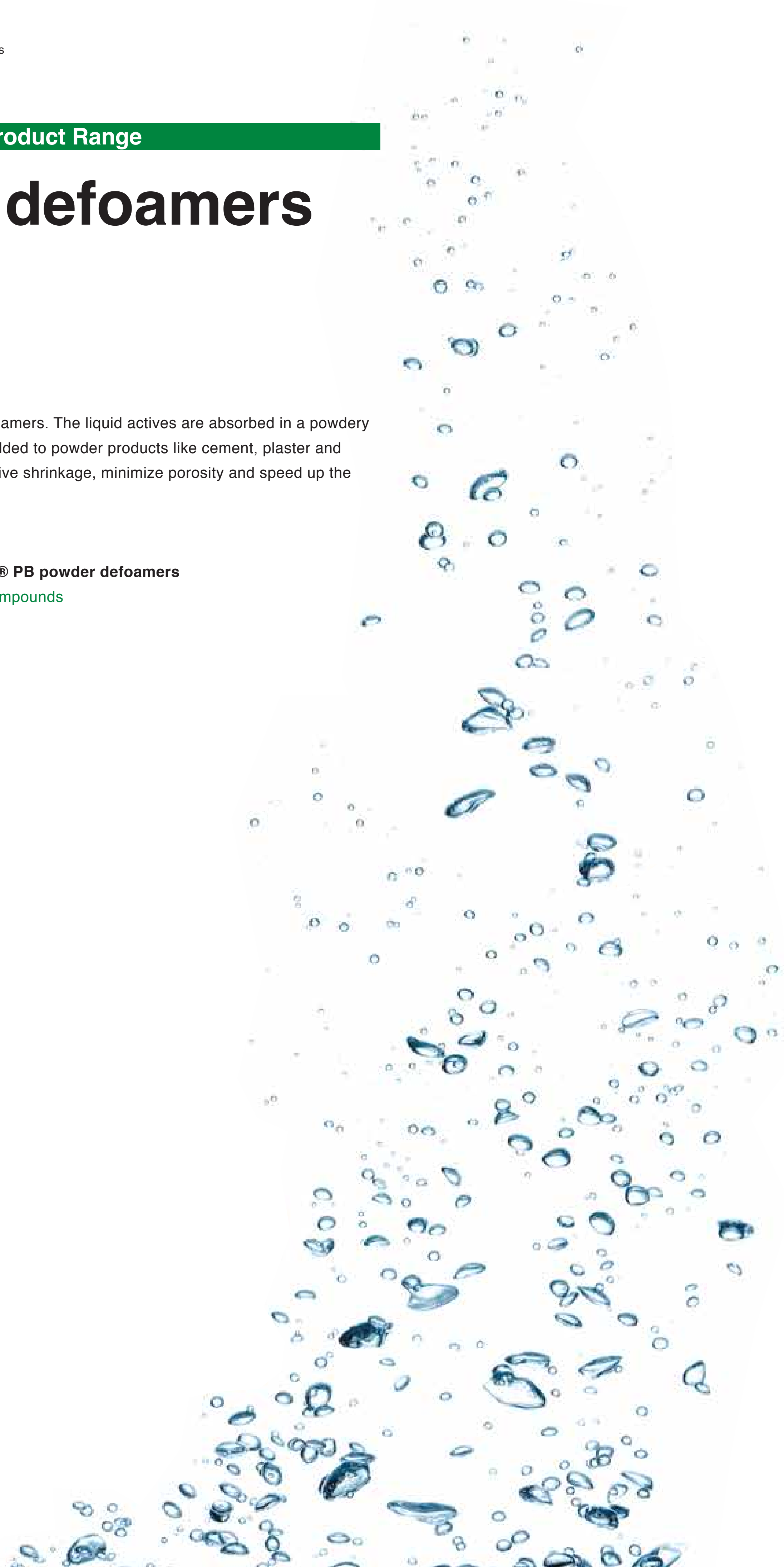


Examples of application areas of FoamStar® ST defoamers

- High gloss paints and coatings
- Flat to semi-gloss paints and coatings
- Industrial water based coatings
- Excellent for difficult-to-defoam coatings

BASF's Defoamers Product Range

Powder defoamers



FoamStar® PB

BASF offers several powder defoamers. The liquid actives are absorbed in a powdery carrier and are designed to be added to powder products like cement, plaster and detergents. They prevent excessive shrinkage, minimize porosity and speed up the wetting of dry mix products.

Application areas of FoamStar® PB powder defoamers

- Cement based self-leveling compounds
- Cement based floor screeds
- Repair mortars
- Tile adhesives
- Tile grouts

BASF's Defoamers Product Range

BASF defoamers for solvent-based systems

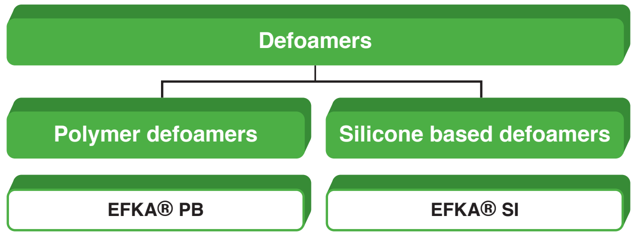
Depending on the requirements and the request of the customers, two different classes are in use – silicone and polymer based products.

Polymers like Polyacrylates and others are suitable actives for use as defoamers/deaerators in non-aqueous systems where air release is more important than the breakdown of surface foam. These defoamers/deaerators are often delivered in a solvent carrier like petroleum distillates, but due to most recent regulations more and more VOC free carriers are used. Modification of such polymers with fluorine gives even lower surface tensions and therefore improves wetting and leveling significantly.

Pure PDMS type defoamers/deaerators show excellent performance, but can show certain incompatibility (depending on the system).

Therefore organomodification of PDMS is used to give products an improved compatibility.

BASF offers a complete range of defoamers and deaerators for all classes of solvent based and 100% systems based, on a broad technology portfolio of polysiloxanes, polyacrylates and/or other organic polymers.



Application areas of polymer based defoamers for solvent borne systems EFKA® PB

- 2-pack polyurethane coatings
- Epoxy systems
- Nitrocellulose lacquers
- NC/alkyd lacquers, air-drying and baking paints
- Acrylic resin finishes
- Acid-curing systems
- Unsaturated Polyester (UPE) systems

Application areas of silicone based defoamers for solvent-borne systems EFKA® SI

- 2-pack polyurethane coatings
- Epoxy systems
- Nitrocellulose lacquers
- NC/alkyd lacquers, air-drying and baking paints
- Acrylic resin finishes
- Acid-curing systems
- Unsaturated Polyester (UPE) systems