Full Spectrum of Defoamer Offerings

Foam Control in Waterborne Coatings, Inks and Adhesives

EVONIK
POWER TO CREATE

Determining the best defoamer for a given formulation is a matter of finding a balance between the defoaming power (strength) of the defoamer and its compatibility in the system. Defoamers that are highly incompatible may give very effective foam control but may also cause surface defects, whereas more compatible defoamers may not give sufficient foam control.

Evonik offers a full spectrum of defoamer chemistries, including organic oil, siloxane and our own unique molecular defoamers, so that formulators can quickly find the proper product needed to achieve defect-free foam control in a broad range of systems and applications.

Contents

Foam and Defoamer Basics

Water, like all pure liquids, does not foam; bubbles form quickly, rise to the surface and burst. The liquid drains out of the bubble lamellae until the bubble walls becomes too thin and break, releasing the trapped air **(Figure 1)**.

However, as everyone has experienced when adding soap to water, the presence of the soap (surfactant) promotes formation and stabilization of foam. The wetting agents and emulsifiers present in waterborne coating, ink and adhesive formulations are also surfactants, and, as such, they prevent small bubbles beneath the air-liquid interface from coalescing, which slows their rise to the surface and results in microfoam. For air bubbles that do reach the air-water interface, the surfactant bilayer stabilizes the macrofoam bubbles **(Figure 2)**.

FIGURE 1
Unstabilized air bubbles in pure liquids burst quickly

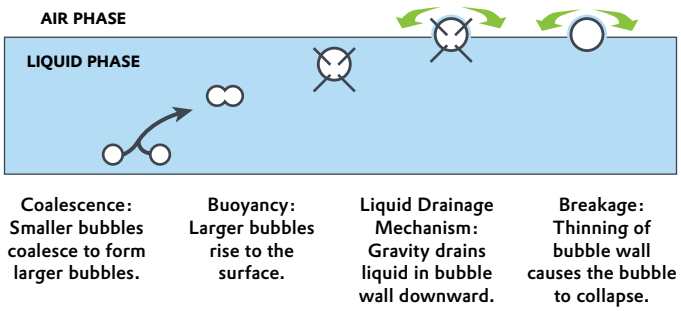
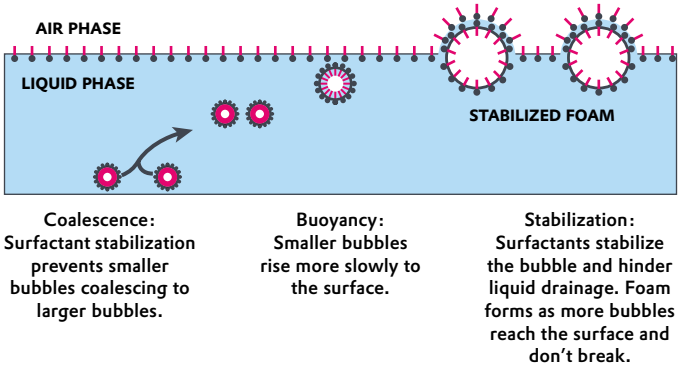


FIGURE 2
Surfactants can stabilize air bubbles, inhibit coalescence of smaller bubbles, slow bubble rise and prevent foam collapse



Conventional Defoaming and Deaeration Mechanisms

A defoamer is an additive that acts to disrupt the surfactant bilayer that surrounds the air bubble, destabilizing the bubble wall in order for the bubble to break and release the trapped air. Conventional defoamers, such as silicones, mineral and other organic oil based defoamers, are formulated products that contain insoluble, low surface tension materials that are capable of entering and spreading across bubble surfaces. These hydrophobic materials displace the stabilizing surfactants and form an unstable film at the bubble surface; the destabilized lamellae easily rupture, bursting the bubbles and collapsing the foam **(Figure 3)**. Hydrophobic particles present in some defoamers can also adsorb excess surfactant from the bubble, reducing the stabilization effect and assisting bubble breakdown.

However, the hydrophobic oils and particles contained in conventional defoamers are highly insoluble in waterborne systems, and they must be added at low enough use levels and properly dispersed or emulsified in the formulation in order to prevent the insoluble material from phase separating. When insoluble oils or particles are not sufficiently incorporated, they can migrate to the air-water interface and cause film defects, such as craters and fisheyes, in the waterborne coating or ink because the drying film dewets around the insoluble droplets or particles. This is illustrated in **Figure 4** where the extremely low surface tension (γ) material (red droplet) repels the higher surface tension coating (yellow), resulting in a crater once the film dries.

FIGURE 3
Conventional defoamers function via an incompatibility mechanism

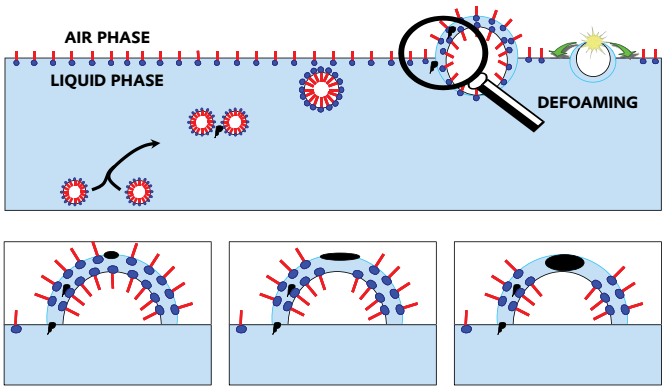


FIGURE 4
Use of an incompatible defoamer results in defects (craters) in this polyurethane-acrylic parquet floor lacquer

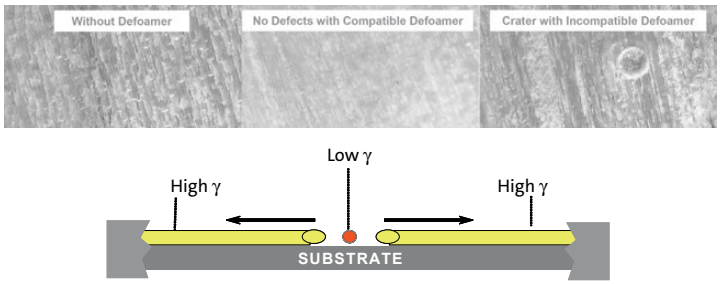
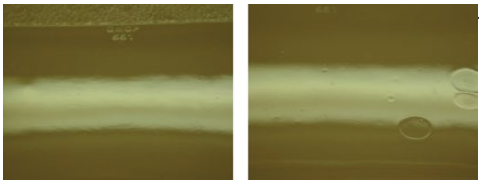


FIGURE 5
A waterborne self-cross-linking acrylic clear coat on plastic employing Surfynol® DF-62 defoamer (left) and a less compatible competitive siloxane defoamer (right)



Careful molecular engineering and formulation can be used to produce siloxane and oil-based defoamers with varying degrees of defoaming strength and compatibility in aqueous formulations; however, defoamer predictability can be a challenge with defoamers that function via this incompatibility mechanism. As can be seen in **Figure 5**, both conventional defoamers are very effective in controlling the foam in this waterborne self-crosslinking acrylic clear coat. Using a compatible siloxane defoamer like Surfynol DF-62 defoamer (left) results in a defect-free film, while use of a less compatible competitive siloxane defoamer (right) eliminates the foam but the insoluble siloxane migrates to the film surface and causes craters.

Defoaming and deaeration differ from one another because each is related to a specific type of foam. Defoaming describes the action of breaking the air bubbles which are stabilized at the air-liquid interface or the surface of the applied coating (macrofoam). Deaeration is the elimination of small bubbles trapped beneath the liquid surface or in the bulk of a liquid formulation. Because the microfoam bubbles are so tiny, they may escape visual inspection and might only be recognized when the formulation's density is lower than expected. Deaerators function by enabling smaller bubbles to coalesce to larger bubbles that can escape the liquid more quickly. Conventional defoamers and deaerators are both designed to be incompatible to some extent with the aqueous phase and are active at the air-liquid interface, which can be either microfoam or macrofoam; however, deaerators need to have molecular structures that enable them to remain in the bulk of the liquid where they can access the microfoam bubbles **(Figure 6)**.

As can be seen in **Figure 7**, highly effective yet very compatible siloxane deaerators like Evonik's Airase® 8070 deaerator can be used to eliminate microfoam in sensitive coatings applied by methods, like airless spray, that are notorious for introducing microfoam.

FIGURE 6
Deaeration mechanism for a conventional deaerator

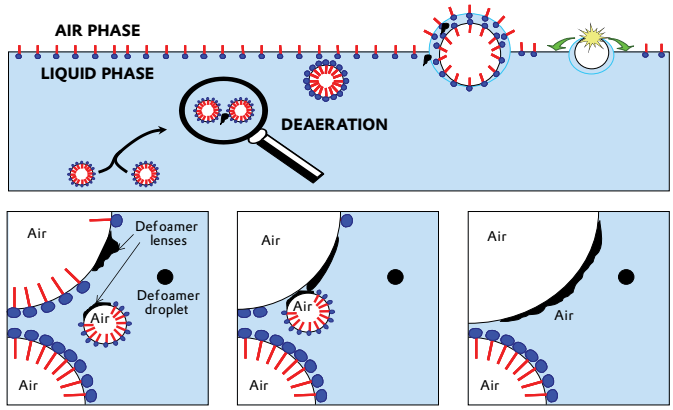
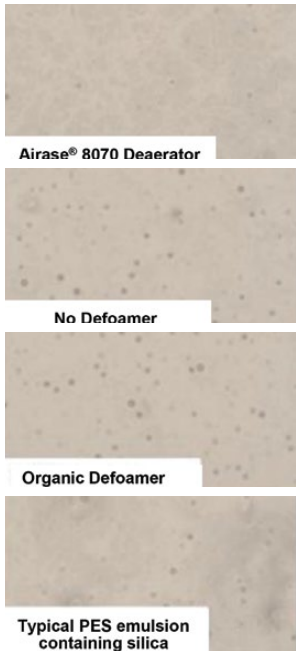


FIGURE 7
The novel siloxane-based Airase 8070 deaerator (top) effectively eliminates microfoam in an airless spray-applied, two-component waterborne polyurethane topcoat



Molecular Defoaming and Deaeration Mechanisms

Molecular defoamers are non-micellar, nonionic surfactants that are designed to compete with and displace the foam stabilizing surfactants within the bubble lamella. These unique surfactants do not stabilize foam and allow normal liquid flow so that the bubbles can break naturally **(Figure 8)**.

Molecular defoamers are also very effective at controlling microfoam (small bubbles trapped within the liquid) because they are partially water soluble and are available to migrate to bubbles beneath the liquid surface to aid in deaeration **(Figure 9)**. Many conventional defoamers are not effective at controlling microfoam because the oil is insoluble and remains at the liquid surface. However, molecular defoamers can prevent stabilization of foam bubbles so that they can escape the liquid more quickly. As a result, molecular defoamers can act as anti-foam agents. As surfactants, molecular defoamers are compatible with most systems and do not cause the incompatibility problems of oil-based defoamers. They can also provide additional dynamic wetting properties to the formulation. Evonik provides unique products based on Gemini surfactant technology that allows them to act as both surfactants (enhancing compatibility) and defoamers at the same time.

FIGURE 8
Defoaming Mechanism for Molecular Defoamers

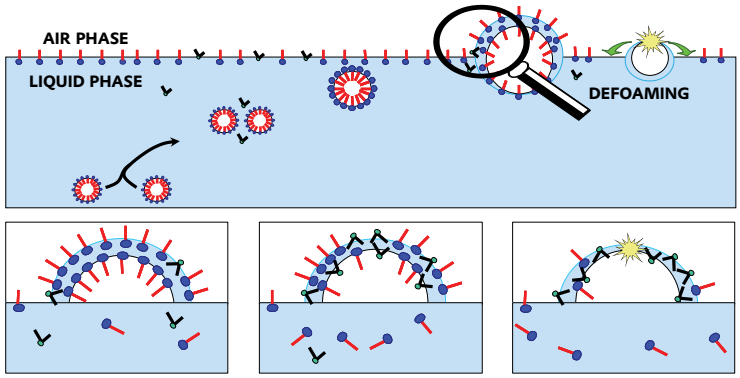
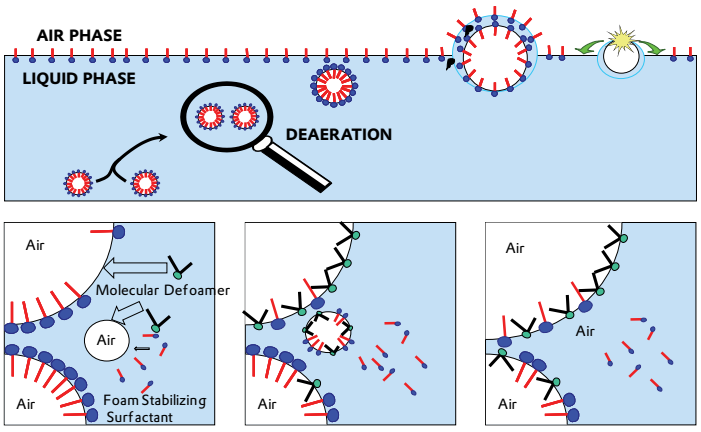


FIGURE 9
Deaeration Mechanism for Molecular Defoamers



How to Select a Defoamer

Determining the correct defoamer is a process of finding the balance between defoaming strength and compatibility that will provide optimal results in a specific system. Many factors influence the selection of an appropriate defoamer; therefore, we have developed a process to help determine the correct strength/compatibility balance of defoamers that are most likely to be effective in particular formulations.

1 One should start by understanding the formulation's viscosity. High viscosity (build) systems are harder to defoam and need stronger defoamers. Low viscosity systems tend to release air bubbles more quickly but are often more sensitive to defects, demanding a more compatible defoamer.

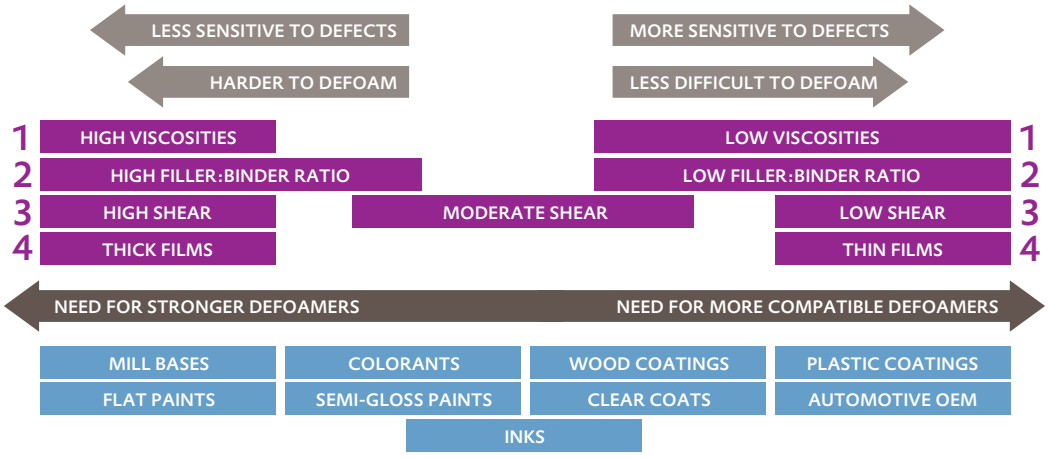
2 The second property that should be understood is the filler-to-binder ratio of the formulation. High filler-to-binder ratio systems are less sensitive to defects because there is sufficient surface area to adsorb incompatible liquids, and strong defoamers, including siloxanes and mineral oils, are generally more effective. Low filler-to-binder ratio systems and clear coats can be very sensitive to defects caused by insoluble species; thus, weaker defoamers with greater formulation compatibility are usually most effective.

3 If high shear can be used during defoamer addition, a stronger, less compatible defoamer may be effectively incorporated in a manner that minimizes any incompatible material that could cause defects in later application. But, if the defoamer must be incorporated using low shear, care must be taken to choose a more compatible defoamer so that defects are avoided.

4 Finally, the application details also need to be considered when selecting a defoamer. Thick films and application techniques that introduce air into a formulation will demand stronger defoamers, whereas thin films and coatings applied to less absorbent substrates can be quite sensitive to surface defects and require very compatible defoamers.

NOTE: Defoamer effectiveness and compatibility is influenced by binder type, rheology modifiers and other system components; however, the interactions between these components are highly complex and difficult to predict. Therefore, we recommend that, whenever possible, a formulator evaluate at least one defoamer from each chemical type (molecular, oil-based and siloxane) that fits within the strength/compatibility zone identified throughout steps 1-4 of the process. In this way, the formulator will best be able to identify the optimum defoamer or deaerator for the system.

FIGURE 10 Factors to be considered when selecting a defoamer



Benefits of Each Defoamer Type

Molecular defoamers are surfactant-based defoamers and deaerators that are highly effective against both macro- and microfoam. Because they are surfactants, they usually provide good compatibility; therefore, they often provide the sought after balance between good defoaming and excellent compatibility. Molecular defoamers are suitable for low viscosity, high gloss, low PVC (Pigment Volume Concentration) formulations and clear coats that are highly sensitive to craters and pinholes; they are also shear stable and highly effective in pigment grinding. Molecular defoamers can also be used in combination with other defoamers to improve microfoam control. Typical use levels for molecular defoamers range from 0.1-1.0 wt.%.

Figure 11 illustrates the benefits of using a molecular defoamer rather than a conventional defoamer. Unlike conventional defoamers, Surfynol MD-20 molecular defoamer demonstrates its ability to eliminate microfoam and surface defects. Water-based inks were printed on oriented polypropylene film using a flexo handproofer and photographs were taken under a microscope with 10X magnification. The ink without defoamer (left) had print defects caused by microfoam. When a conventional siloxane defoamer containing hydrophobic silica was used (center), the print showed pinholes and fisheyes. However, the ink containing Surfynol MD-20 molecular defoamer (right) was able to produce defect-free prints by eliminating the microfoam without causing craters or fisheyes; moreover, the molecular defoamer actually enhanced the print by improving the wetting and transfer of the ink.

Oil-based defoamers typically contain an oil carrier and hydrophobic particles that can be emulsified in water to create oil-in-water (O/W) emulsion defoamers or 100% active "self-emulsifiable" products. The carrier can be based on mineral oil or other organic oils such as esters, glycols or even vegetable oils. These types of defoamers can also be formulated to exhibit a broader range of behaviors, enabling different oil-based defoamers to be effective in diverse applications that range from inks and adhesives to architectural coatings (from matte to semi-gloss). Typical use levels for oil-based defoamers range from 0.1-1.0 wt.%.

Figure 12 demonstrates the performance of organic oil-based Airase® 4500 defoamer relative to stronger siloxane defoamers when used at 0.18 wt.% in both the grind and letdown in a 100% acrylic exterior flat architectural paint (PVC 45%).

Siloxane defoamers can be emulsions of simpler silicone oils or more sophisticated 100% active products that contain tailored polyether-modified siloxanes that have been formulated to provide a desired balance between defoaming effectiveness and system compatibility. While the low compatibility of a mineral oil defoamer could cause loss of gloss or other surface defects, siloxane defoamers can be suitable for higher gloss coatings and printing inks. In fact, a very wide breadth of applications can benefit from specific properties achievable with the diversity of performance that can be obtained through synthesis and formulation of polyether-modified siloxane chemistries. Typical use levels for siloxane defoamers range from 0.05-1.0 wt.%.

FIGURE 11
The benefits of using Surfynol MD-20 molecular defoamer (right) to eliminate microfoam in a waterborne ink applied to OPP film

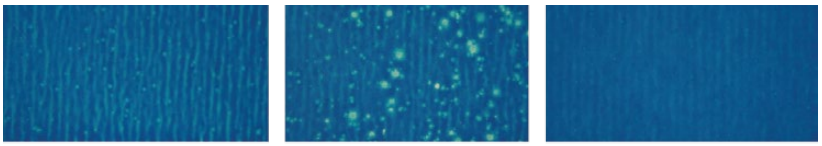
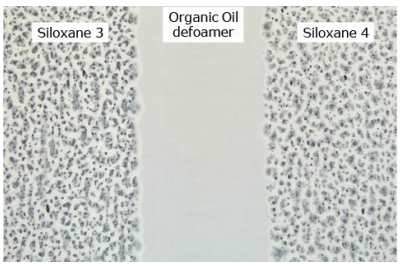
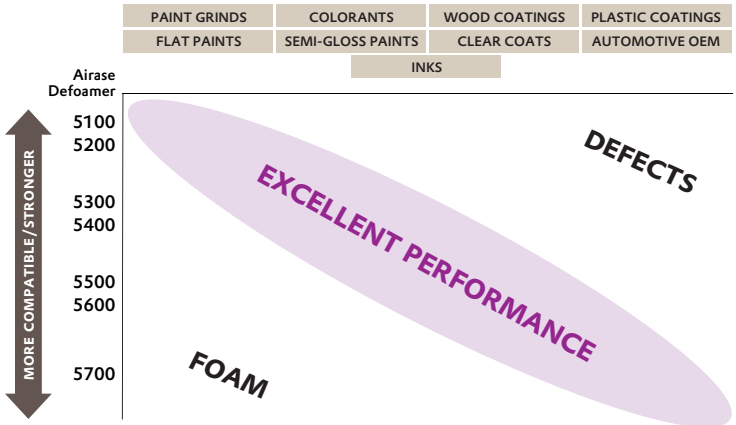


FIGURE 12
Due to its optimized formulation, organic oil-based Airase® 4500 defoamer (center) out-performs stronger siloxane defoamers (right and left) in this 100% acrylic exterior flat architectural paint.



The Airase Structured Siloxane Defoamer Line (SSDL) Approach

FIGURE 13
The Airase SSDL approach to quickly and systematically identify an optimal defoamer

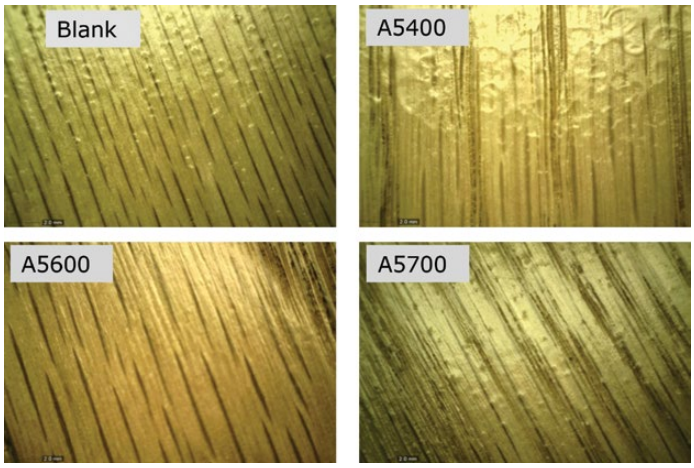


Evonik's original Surfynol DF-Series siloxane defoamers have proven themselves to be outstanding performers within the siloxane defoamer space. However, more recently, we recognized the market need for a series of defoamers with a higher level of predictability that could facilitate a customer's ability to rapidly identify the optimum defoamer for a formulation. Therefore, we developed a new line of unique formulated siloxane-based defoamers to enable formulators of coatings, inks and adhesives to find a defoaming solution more quickly. These products have been designed to have reproducibly predictable performance relative to one another in order to enable formulators to take a systematic approach to defoamer selection. Each product in the SSDL line has a different balance of defoaming strength and formulation compatibility for optimal defoaming performance in particular types of formulations, and each product's number reflects where it falls on this spectrum. Thus, if one product in the line does not give sufficient foam control in a given system, the formulator can try the next product in the line (lower number) for stronger defoaming performance. Similarly, if a product in the line gives film defects, such as craters or fisheyes, the next product in the line (higher number) should be more compatible in the formulation **(Figure 13)**.

The Airase Structured Siloxane Defoamer Line (SSDL) consists of seven defoamers. Airase 5100 and 5200 defoamers are both very strong defoamers, designed for applications where strong defoaming is required but compatibility is not an issue or the defoamers can be incorporated using high shear. Airase 5300 and 5400 defoamers are strong defoamers with good compatibility for applications where shear stability is required. Airase 5500 and 5600 defoamers have good compatibility for applications where a balance between defoaming and defect-free surface appearance is needed, while Airase 5700 defoamer is designed for applications that are very sensitive to craters and other surface defects.

Figure 14 illustrates the simplicity of using the Airase SSDL approach to identify the best defoamer for a self-crosslinking, modified acrylic-aliphatic urethane clear coat applied to red oak. When no defoamer is used (top left), the coating shows severe foam trapped in the film. Adding a relatively strong defoamer like Airase 5400 defoamer (top right) eliminates all traces of foam but results in severe cratering of the film. The much weaker but very compatible Airase 5700 defoamer (bottom right) is unable to control the foam which remains trapped in the film. However, using slightly stronger Airase 5600 defoamer (bottom left), provides a much improved appearance with no entrapped air.

FIGURE 14
Using the Airase SSDL approach to identify the best defoamer for a polyurethane-acrylic clear coat applied to red oak



Evonik's Full Spectrum of Airase and Surfynol Defoamers and Deaerators

When looking for a defoamer having the optimal balance between defoaming strength and system compatibility, think of Evonik and our full spectrum of defoamer chemistries and offerings. With our broad portfolio of defoamers and deaerators, we offer quick and effective solutions to your toughest foam control challenges **(Figure 15)**.

FIGURE 15
Evonik's Full Line of Airase and Surfynol Defoamer Chemistries

	SILOXANES	OIL-BASED	MOLECULAR
STRONGER DEFOAMING ▶	Airase 5100		
	Airase 5200		
	Airase 5300		
	Airase 5355		
	Surfynol DF695	Airase 4500	
	Airase 5400	Airase 4655	
		Surfynol DF220	
	Surfynol DF58		
	Airase 8070*		
	Airase 5500		
	Surfynol DF62	Surfynol DF37*	
	Surfynol DF66		
	Airase 5600		
	Airase 5655		
	Surfynol DF178		
◀ MORE COMPATIBLE	Airase 5700		Surfynol DF110*
			Surfynol AD01*
			Surfynol 107L*
			Surfynol MD20*
			Surfynol 104*
			Surfynol 420*
			Surfynol PC*

* These products are superb deaerators, suitable for eliminating microfoam.

Product descriptions

CARRIER TYPE	PRODUCT	DESCRIPTION
Siloxane	Airase 5100 defoamer	The strongest defoamer of the SSDL series. Designed for applications where strong defoaming is required and the formulations are not sensitive to cratering.
Siloxane	Airase 5200 defoamer	Designed for applications where strong defoaming is required and the formulations are not particularly sensitive to cratering. Provides excellent long-term, persistent defoaming in formulations. Better film compatibility than Airase 5100 defoamer.
Siloxane	Airase 5300 defoamer	Designed for applications where strong defoaming is required with good long-term persistency, especially in high shear applications.
Siloxane	Airase 5355 defoamer	A strong siloxane based defoamer designed to control and quickly eliminate foam without generating defects in waterbased pigment grinds, inks, overprint varnishes, and coatings. It can be incorporated into the grind or letdown, depending on the formulation requirement. It does not contain added mineral oils, hazardous air pollutants (HAPs), alkyl phenol ethoxylates (APEs) or acetylenic diols. The product has multiple regional food contact compliances.
Siloxane	Surfynol DF-695 defoamer	A siloxane emulsion defoamer requiring high shear incorporation for pigment grinds and paint applications.
Oil	Airase 4500 defoamer	An organic oil defoamer designed to eliminate foam, pinholes and entrapped air in water-based paints without generating surface defects. Contains no added mineral oils, hazardous air pollutants (HAPs) or alkyl phenol ethoxylates (APEs). Has several US FDA 21CFR 175 and 176 compliances.
Siloxane	Airase 5400 defoamer	Designed for applications where strong defoaming is required with good long-term persistency, especially in high shear applications. Better film compatibility than Airase 5300 defoamer.
Oil	Airase 4655 defoamer	A relatively compatible organic oil-based defoamer designed to control and eliminate foam in a broad range of waterbased systems, with particular advantages in adhesives end-use applications as well as in inks, pigment grinds, overprint varnishes and coatings systems. It is easy to incorporate and provides excellent compatibility with high shear stability. It does not contain added mineral oils, hazardous air pollutants (HAPs), alkyl phenol ethoxylates (APEs) or acetylenic diols. The product has multiple regional food contact compliances.
Mineral Oil	Surfynol DF-220 defoamer	A shear-stable, oil-based defoamer that provides excellent long-term foam control for medium to high pigment volume concentration paints and coatings. Also useful for formulation for application over absorbent substrates.
Siloxane	Surfynol DF-58 defoamer	A highly efficient, shear stable, siloxane-based defoamer that provides fast action foam control in water-based paints and industrial coatings.
Siloxane	Airase 8070 deaerator	A proprietary deaerator designed to eliminate microfoam, pinholes, and solvent popping problems in water-based coatings applied by airless (or air assisted) spray technologies and without generating surface defects.
Vegetable Oil	Airase 4750V defoamer	A proprietary vegetable oil based defoamer designed to control foam, bubbles, and entrapped air without generating surface defects. It does not contain added mineral oils, HAPs, or APEs. This defoamer combines good efficiency with excellent film compatibility and sustained defoaming performance, suitable for a wide range of waterborne applications.
Siloxane	Airase 5500 defoamer	Can be incorporated in the grind or used as a letdown defoamer. Designed for applications where good defoaming is required with good long-term persistency and film compatibility.
Mineral Oil	Airase 4800 defoamer	100% active, mineral oil based defoamer for a variety of water-based formulations. It does not contain added HAPs or APEs. This defoamer combines good film compatibility with sustained, long term defoaming performance.

NOTE: Surfynol DF-110 and Surfynol 104 are available diluted in different solvents.
All products may not be available in all regions. Please contact your local supplier for availability.

CARRIER TYPE	PRODUCT	DESCRIPTION
Siloxane	Surfynol DF-62 defoamer	A shear stable, polysiloxane defoamer that provides an excellent balance of initial foam knockdown and persistency in water-based paints and industrial coatings.
Oil	Surfynol DF-37 defoamer	A formulated organic defoamer for both macrofoam and microfoam control that can also provide additional substrate wetting.
Siloxane	Surfynol DF-66 defoamer	A self-emulsifiable, formulated polysiloxane defoamer with good compatibility in waterborne coatings formulations.
Siloxane	Airase 5600 defoamer	Can be incorporated in the letdown of a coating or ink. Airase 5600 defoamer provides an excellent balance of effective defoaming and film compatibility.
Siloxane	Airase 5655 defoamer	A compatible siloxane based letdown defoamer designed to control and quickly eliminate foam without generating defects in waterbased inks, overprint varnishes, and coatings. It does not contain added mineral oils, hazardous air pollutants (HAPs), alkyl phenol ethoxylates (APEs) or acetylenic diols. The product has multiple regional food contact compliances.
Siloxane	Surfynol DF-178 defoamer	A formulated siloxane-based defoamer and deaerator combining strong defoaming and microfoam control for spray applications.
Molecular	Surfynol DF-110 defoamer	A powerful, silicone-free, acetylenic diol-based defoamer that provides defect-free foam control and deaeration of aqueous formulations.
Siloxane	Airase 5700 defoamer	Formulated for incorporation in the letdown of a coating or ink and has the best compatibility in the SSDL series. Airase 5700 defoamer provides an excellent balance of effective defoaming and film compatibility.
Molecular	Surfynol AD01 surfactant	A 100% active liquid dynamic wetting agent and molecular defoamer that can function as a deaerator to eliminate microfoam in aqueous dispersions and many other formulations. Compared to Surfynol 104 surfactant, the patented Surfynol AD01 surfactant can offer stronger molecular defoaming and deaeration. Additionally, it can act as a coalescing surfactant by lowering the minimum film formation temperature of low or zero VOC waterborne coatings.
Molecular	Surfynol 107L surfactant	A molecular defoamer and nonionic wetting agent that combines strong defoaming performance with efficiency substrate wetting and improved film formulation in water-based adhesives, coatings, and inks as well as good deaeration in construction systems.
Molecular	Surfynol MD-20 defoamer	A nonionic, organic defoaming/deaerating molecular defoamer that provides both foam and microfoam control without surface defects.
Molecular	Surfynol 104 surfactant	A high performance surfactant that offers both dynamic surface wetting and excellent antifoaming properties in waterborne paints and coatings. Dilutions in other solvents are also available.
Molecular	Surfynol 420 surfactant	A 100% active liquid dynamic wetting agent and molecular defoamer that can function as a deaerator in aqueous dispersions and other formulations. Compared to Surfynol 104 surfactant, Surfynol 420 surfactant can offer better wetting with a higher degree of compatibility but with a slightly weaker molecular defoaming ability. Additionally, this Surfynol 420 surfactant complies with several food contact regulations in the US, Europe and Asia.
Molecular	Surfynol PC defoamer	A liquid molecular defoamer designed specifically to provide foam control and pigment shock reduction in paper coating formulations. It provides long-lasting defoamer activity and is stable through continued recycling of the formulation.

NOTE: Surfynol DF-110 and Surfynol 104 are available diluted in different solvents.
All products may not be available in all regions. Please contact your local supplier for availability.

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