Additives

Micro-Foam in Waterborne Coatings and Printing Inks?

There is a Solution: TEGO® Airex 90X W!

Often it is only recognizable using a magnifying glass or a microscope: micro-foam! It consists of small gas bubbles, which remain in the applied film after application. In the end the micro-bubbles lead to surface defects in the coating. These defects cause damages, depending on the substrate: metallic substrates corrode ahead of time, wooden substrates have low weather stability and fungal decay, silk screen inks show bad printing results etc.

The elimination of micro-foam in coatings and printing inks is one of the big challenges formulators and processors of coatings have to meet. The Chemicals Business Area of Evonik Industries has been researching the field of micro-foam for years. Our aim is to eliminate and actively avoid micro-foam in coatings and printing inks. The products are known under the brand name TEGO® Airex 90X W. This deaerator family has been complemented by another product which is highly effective, but also very compatible in the coating: TEGO® Airex 904 W.

Micro- and Macro-foam

Foam is particularly important in waterborne formulations. Macro-foam, consisting of foam-bubbles on the coatings surface, is usually easy to recognize, as when foam bubbles form in a container after filling. Macro-foam is also clearly visible when applying a paint to a substrate by brush or by roller. However, micro-foam is often only visible through a magnifying glass or microscope in the dried or cured coating. It consists of very small bubbles of trapped air in the coating, which can affect the function of the coating. There are however effects where the connection with micro-foam is not immediately obvious.

Cause and Effect

- Pinholes encourage corrosion

  If the substrate for an industrial coating shows early signs of corrosion the cause may be pinholes in the paint. Pinholes are small channels in the coating which remain when micro-foam bubbles rise too slowly out of the drying paint layer. If these channels reach down to the metallic substrate, moisture and salts can penetrate unhindered resulting in progressive corrosion.

- Clouding and loss of gloss caused by small foam bubbles

  If a coating does not develop gloss or becomes cloudy immediately after application, the initial response is to suspect incompatibility of the components of the paint. However inspection using a microscope or even a simple magnifying glass reveals that cloudiness or low gloss is sometimes caused by extremely fine air bubbles trapped in the dry paint film.

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- Air inclusions inhibit optimal curing of radiation-curing coatings

  A great advantage of radiation-curing coatings is that they cure within a few seconds. However oxygen from the air can slow down curing. Inert gas can be used to avoid contact of the coating with air. In spite of this, curing can be affected if micro-foam bubbles containing air are present in the coating.

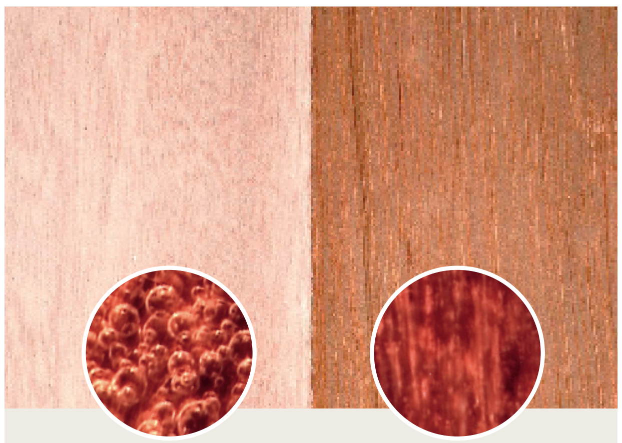

Figure 1: Waterborne wood coating, airless applied: left – without deaerator, right – with deaerator)

How is micro-foam formed?

Micro-foam is formed of small air or gas bubbles in the coating. When present, surfactants orient themselves at the air/liquid interface of the micro-bubble and stabilize it. Such surfactant structures are found in large numbers in coatings and printing inks through:

- the binder itself (particularly in emulsions and dispersions for waterborne formulations)
- wetting and dispersing additives
- surface or substrate wetting additives
- waxes and wax-dispersions or sanding like stearates

However, for micro-bubbles to occur, air or gas must first have been incorporated into the paint formulation. Air incorporation can occur by:

- stirring during paint manufacture
- stirring when adding curing agent in 2-pack systems
- application processes such as rolling, dipping, spraying and, most importantly, airless-/airmix-spraying
- release of gas by chemical processes during curing of the paint (e.g. reactions of isocyanate with moisture)
- application on porous substrates such as wood, stone or cement floors

Paint viscosity is responsible for foam problems

Viscosity also has a decisive effect on foam formation in paints, coatings and printing inks. For example, the speed at which foam bubbles rise depends on the viscosity of the paint formulations. According to the simplified form of Stoke's Law the relationship is: $V \sim r^2/h$.

This means that air bubbles in paint formulations with a relatively high viscosity h only rise very slowly (small rising speed n). As a consequence air bubbles do not reach the paint surface but remain in the paint layer while the paint cures further or dries physically – a great problem particularly in highly viscous floor coatings or high-build wood varnishes.

Micro-foam and macro-foam – size is the distinguishing feature

However another important relationship is indicated by Stoke's Law: the size of the air bubble has a very marked effect on the rising velocity as the radius of the bubble appears to the square in the equation.

Large air bubbles (>100 µm diameter, but depending on the viscosity) rise very quickly – sufficiently quickly that, during curing or drying, they reach the surface where they form macro-foam. In contrast, the rising velocity of air bubbles between about 10 and 100 µm diameter is so small that, same viscosity provided, they rise extremely slowly and finally remain in the coating. These small bubbles are called micro-foam.

Can micro-bubbles dissolve of their own accord?

Changes in micro-bubbles in a coating which has been applied by airless techniques can be observed under a microscope during the drying phase.

At first there is a mixture of micro-bubbles of different sizes. As drying occurs the picture alters. Large micro-bubbles become larger while small micro-bubbles become even smaller. They literally shrink until they are no longer recognizable.

The driving force for the shrinkage of the small micro-bubbles is the Laplace pressure of the micro-bubble. The Laplace pressure is given by the Young-Laplace equation. It relates the internal pressure of a micro-bubble to the external pressure of the surrounding medium.

Figure 2:
Rising speed depending on the radius of the bubble

$$v \sim r^2/\eta$$

v = rising speed of the foam bubble
r = radius of the foam bubble
η = viscosity of the paint

With small micro-bubbles the internal pressure is higher than the external pressure and this pressure difference causes air from the micro-bubble to diffuse into the surrounding medium and dissolve there. Diffusion, and with it, shrinking of the micro-bubble occurs. This becomes faster the smaller the micro-bubble so that small micro-bubbles dissolve.

The air from the small micro-bubbles either remains dissolved or diffuses into larger micro-bubbles whose internal pressure is markedly lower. Larger micro-bubbles can thus grow further.

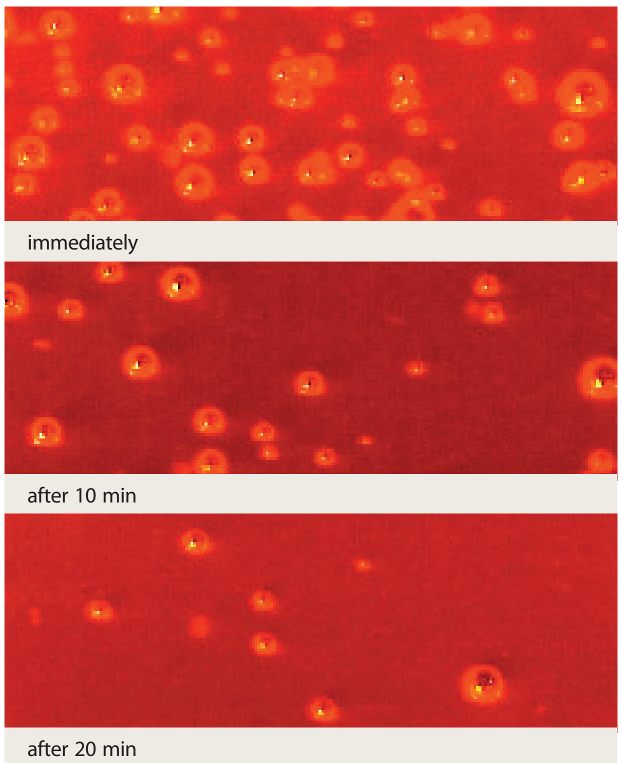

Figure 3: View through a microscope: dissolving of micro-bubbles with time proceeding, waterborne formulation on glass, airless applied

How do deaerators work?

Effective deaerators must have a targeted incompatibility with the paint formulation so that the deaerator immediately orients itself at the air/liquid interface, i.e. at the micro-bubbles. It is assumed that the deaerator displaces foam stabilizing surfactants there and so promotes diffusion of the air into the surrounding medium. The micro-bubbles become ever smaller until they completely dissolve.

Larger micro-bubbles grow further as air diffuses into them and can rise more quickly to the surface (Stoke's Law). There they break or form surfactant-stabilized foam bubbles (macro-foam).

With the development of deaerators it is always necessary to find a good balance between effectiveness and compatibility: if the compound is too compatible, it will not exhibit deaerating activity, but if it is too incompatible, there will be defects like craters, fish-eyes or turbidity. Particularly deaerating additives based on organically modified polysiloxanes show an excellent balance between effectiveness against micro-bubbles and compatibility within the medium that is to deaerate. Additionally we have found, that a combination of organically modified polysiloxanes and hydrophobical solids is essential.

TEGO® Airex 904 W: good effectiveness and compatibility

With the new TEGO® Airex 904 W it is possible to eliminate micro-foam effectively in waterborne formulations. With this the demand of the market on an effective but simultaneously having good com-

TEGO® Airex 904 W

- effective particularly in waterborne airless/airmix applied formulations
- 100 % active matter content, thus free of solvents
- suitable for formulations based on acrylic-, acrylic/polyurethanedispersions (Acrylat-, Acrylat/Polyurethandispersionen)
- effective in radiation-curing, waterborne and 2-pack PU formulations
- for clear and pigmented coatings
- application fields: industrial, wood, automotive and architectural coatings as well as printing inks

patibility additive was taken especially into account.
TEGO® Airex 904 W can be easily incorporated into waterborne coating formulations, without causing defects like craters.
TEGO® Airex 904 W ideally complements the already known deaerators such as TEGO® Airex 901 W and TEGO® Airex 902 W (fig 4). TEGO® Airex 901 W is characterized by highest effectiveness against micro-foam and is suitable particularly for relatively highly viscous coatings and printing inks. In middle to low viscosity coatings formulations – where often only low shear forces are available – TEGO® Airex 902 W had proved its outstanding worth. By all means the product can be classified as a universal micro-foam deaerator for waterborne formulations. The characteristics of new development TEGO® Airex 904 W close the gap between TEGO® Airex 901 W and 902 W.
Thus Tego, a Business Line of Evonik Industries, offers a complete package of deaerators for waterborne formulations, with which nearly each problem with micro-foam can be solved.
Besides TEGO® Airex 901 W, TEGO® Airex 902 W and the new TEGO® Airex 904 W there are many more products of the TEGO® Airex family. Problems with micro-foam can be optimally solved as well in solventborne, high solid and radiation-curing formulations.

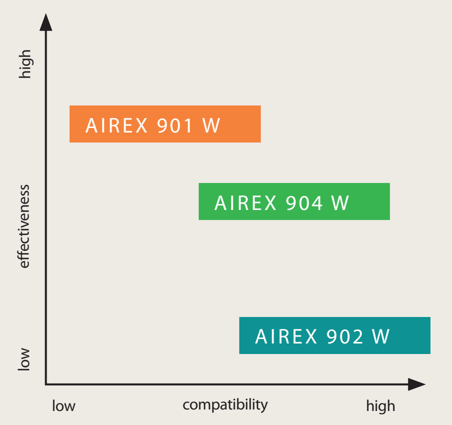

Figure 4: TEGO® Airex 90X W family for waterborne formulations.

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