Defoamer

Mark Heekeren, Lab Manager Technical Service Automotive Coatings
Wesel, 12. August 2015
Content

- What is foam – foam stabilization
- Mode of action of defoamers
- Defoamer classes
- Defoamer test methods
Effect of Foam / Air

- Poor visual appearance
- Long production time (e.g. filling of drums)
- Decreased water resistance
- Poor application properties

Defoamers are used, in order to avoid it!!!
Types of Foam –
Foam is an emulsion of a gas in a liquid

- Wet Foam
- Dry Foam
- Microfoam (10 µm - 70µm)
- Macrofoam (>100 µm)
Causes for Foam

- Adsorbed air (pigments, extenders)
- Reaction bubbles (e.g., carbon dioxide in PU systems)
- Incorporated air (production, application)
- Air from the substrate (wood, concrete, ...)

7/20/2015, Page 5, Defoamer
Bubbles Break at Surface*

Lamella = double wall interface

Drainage effect

Pure liquids do not foam!
Foam Stabilization

- Hydrophobic non-polar
- Hydrophilic polar

Surfactant
Mechanisms of Foam Stabilization:

- Gibbs-Marangoni-Effect
- Formation of electrostatic/steric repulsing double layers
- Gasdiffusion
- Foam stabilization through solid particles
- Influence of viscosity
Gibbs-Marangoni-Effect (elasticity)

\[ \gamma + \Delta \gamma \]

\[ \gamma \]

\[ \gamma - \Delta \gamma \]

Transport of surfactant/water mixtures in the direction of the arrows shown

Higher elastic behavior is stronger foam stabilization
Electrostatic Repulsion

>10 nm
Gasdiffusion

The size of neighbouring foam bubbles differs:

- Inner pressure in small bubbles is higher then in large bubbles
- Under high pressure more gas is dissolved as under low pressure

Gas diffusion: large bubbles grow at the expense of small bubbles

  Gas diffusion can stop because of saturation of the interface with surfactant molecules

Air and CO$_2$ dissolve better into the liquid phase then nitrogen
Bubbles Rise to Surface

Foam is a dispersion of a gas in a liquid, stabilized by surface active substances.

\[ V \sim \frac{r^2}{\eta} \]

- \( V \) = Velocity of rise
- \( r \) = Bubble radius
- \( \eta \) = Viscosity of liquid
Mode of Action

Properties of a defoamer:

• Low Surface Tension

• Good spreading ability

• Insoluble / Incompatible in the surrounding medium

silicones, mineral oils and certain polymers fulfill these criteria's
Spreading of Defoamer

- Marking water surface with inert powder
- Adding one droplet of defoamer

→ Rapid spreading
Defoamer Selection

![Diagram showing the relationship between defoaming, foam stabilization, and compatibility/solubility.](image-url)

- Defoaming
- Optimum
- Defects
- Foam
- Foam stabilization
- compatible/soluble
- incompatible/insoluble
Mode of Action of Hydrophobic Particles

- Synergy between hydrophobic particles and defoamer oil
- Rough, structured particles are more efficient than ball shaped particles
- Destabilization of lamella through high hydrophobicity and dewetting of the particles
- Chemistry: hydrophobic silica, polyurea, waxes polyamides and metal salts
- Only used in water-borne systems
Defoamers - Air Release Additives

Defoamers
Act at the surface

Air Release Additives
Act in the resin

No clear differentiation!
Deaeration - Mode of action inside the liquid
Increasing speed of gas diffusion

Different mechanism compared to bubble rupture at the surface!

- Formation of microfoam after application
- Removal of surfactants and covering of the bubble surface by defoamer molecules
- Increased speed of gas diffusion into the liquid phase
  → Microfoam disappears
Incorporation / Emulsification of Defoamers
Droplet Size Distribution

- **Too incompatible poor emulsification:**
  - Strong defoaming
  - Poor substrate wetting
  - cratering

- **Good compatibility good emulsification:**
  - Strong defoaming
  - Good substrate wetting
  - no cratering

- **Too compatible over emulsification:**
  - Weak defoaming
  - Good substrate wetting
  - no cratering

Shear Force
Incorporation time

BYK
Additives & Instruments
Foam Prevention

Before adding a defoamer the possible reasons for foam stabilization should be eliminated:

- Optimization of production process
- Wetting of solid particles
- Minimize utilization of foam stabilizing components
- Adjusting application conditions (if possible)
Defoamer for Aqueous Systems
Defoamer Classes for Aqueous Systems

- Mineral oil defoamers
- Silicone defoamers
- Silicone-free polymeric defoamers
## Composition of Mineral Oil Defoamers

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil</td>
<td>85 - 95</td>
</tr>
<tr>
<td>Hydrophobic particles</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Emulsifier</td>
<td>3 - 6</td>
</tr>
<tr>
<td>Modified polysiloxanes</td>
<td>0.5 - 3</td>
</tr>
</tbody>
</table>
## Mineral Oil Defoamers for Emulsion Paints and Plasters

<table>
<thead>
<tr>
<th></th>
<th>Interior paints</th>
<th>Industrial emulsions</th>
<th>Gloss and semigloss paints</th>
<th>Emulsion production</th>
<th>Emulsion type</th>
<th>Contains silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-035*</td>
<td>good</td>
<td></td>
<td>good</td>
<td>100%</td>
<td>100%</td>
<td>Yes</td>
</tr>
<tr>
<td>BYK-037*</td>
<td>good</td>
<td></td>
<td>good</td>
<td>w/o</td>
<td>100%</td>
<td>Yes</td>
</tr>
<tr>
<td>BYK-038*</td>
<td>good</td>
<td></td>
<td>excellent</td>
<td>100%</td>
<td>100%</td>
<td>Yes</td>
</tr>
<tr>
<td>BYK-039*</td>
<td>good</td>
<td></td>
<td>excellent</td>
<td>100%</td>
<td>100%</td>
<td>No</td>
</tr>
</tbody>
</table>

*Alkylphenol-ethoxylate-free
Defoamer Classes for Aqueous Systems

- Mineral oil defoamers
- Silicone defoamers
- Silicone-free polymeric defoamers
## Composition of Silicone Oil Defoamer

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone Oil</td>
<td>5-90</td>
</tr>
<tr>
<td>Hydrophobic particles</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Emulsifier</td>
<td>3 - 6</td>
</tr>
<tr>
<td>Polyglycol or Water</td>
<td>0-85</td>
</tr>
</tbody>
</table>
Polydimethylsiloxane

![Polydimethylsiloxane structure](image)

- **Not used in Aqueous Paint Systems**

<table>
<thead>
<tr>
<th>Property</th>
<th>Compatible Range</th>
<th>Incompatible Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leveling</td>
<td>2 - 30</td>
<td>45 - 230</td>
</tr>
<tr>
<td>Slip</td>
<td>380 - 1500</td>
<td>1800 - 2900</td>
</tr>
<tr>
<td>Defoaming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammertone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Silicone Defoamers

Polyether: EO, PO, EO/PO
Silicone Defoamers for Emulsion Paints and Plasters

- Suitable
- Recommended

VOC-free
Low dosage (0.1 – 0.5%)
Suitable for PVC range between 30-85%
APEO-free
No “Fogging”

<table>
<thead>
<tr>
<th></th>
<th>Interior paints, Plasters</th>
<th>Gloss and semigloss paints</th>
<th>Sealers, transparent systems</th>
<th>Emulsion production</th>
<th>Solids [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-023</td>
<td>18.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYK-1610</td>
<td>17.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYK-1615</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Silicone Defoamers for Architectural and Wood Coatings

<table>
<thead>
<tr>
<th></th>
<th>Architectural coatings and Joinery</th>
<th>Wood and furniture coatings</th>
<th>Solids [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-1730</td>
<td>suitable</td>
<td>For pigmented high gloss systems, PVC 18-25</td>
<td>100</td>
</tr>
<tr>
<td>BYK-1770</td>
<td></td>
<td>Airless/Airmix</td>
<td>100</td>
</tr>
<tr>
<td>BYK-1780</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>BYK-1785</td>
<td></td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

*suitable* and *recommended*
Defoamer selection for waterborne systems
General overview

- Silicone defoamer with hydrophobic particles
- Silicone defoamer w/o hydrophobic particles

Shear Force

<table>
<thead>
<tr>
<th>Millbase</th>
<th>BYK-044</th>
<th>BYK-1730</th>
<th>BYK-017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letdown</td>
<td>BYK-1780</td>
<td>BYK-021</td>
<td>BYK-018</td>
</tr>
<tr>
<td></td>
<td>BYK-1785</td>
<td>BYK-022</td>
<td>BYK-019</td>
</tr>
<tr>
<td>Post</td>
<td>BYK-094</td>
<td>BYK-094</td>
<td>BYK-1650</td>
</tr>
<tr>
<td>Addition</td>
<td>BYK-1770</td>
<td>BYK-023</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYK-1610</td>
<td>BYK-024</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYK-1615</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYK-093</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYK-028</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYK-025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Silicone Defoamers for Aqueous Systems

<table>
<thead>
<tr>
<th>Solids %</th>
<th>Hydrophobic Particles</th>
<th>Carrier/Solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-017</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>BYK-018</td>
<td>100</td>
<td>Polyglycol MW &gt;1000, hydrophobic</td>
</tr>
<tr>
<td>BYK-019</td>
<td>60</td>
<td>Dipropylenglycol monomethylether</td>
</tr>
<tr>
<td>BYK-1719</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>BYK-021</td>
<td>100</td>
<td>Polyglycol MW &gt;1000, hydrophobic</td>
</tr>
<tr>
<td>BYK-022</td>
<td>100</td>
<td>Polyglycol MW &gt;1000, hydrophobic</td>
</tr>
<tr>
<td>BYK-023</td>
<td>18.5</td>
<td>Water/Emulsion</td>
</tr>
</tbody>
</table>

Polyether = PO
## Silicone Defoamers for Aqueous Systems

<table>
<thead>
<tr>
<th>Solids %</th>
<th>Hydrophobic Particles</th>
<th>Carrier/Solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-024</td>
<td>100</td>
<td>Polyglycol MW &lt;1000, hydrophilic/hydrophobic: emulsifiable</td>
</tr>
<tr>
<td>BYK-1650</td>
<td>27</td>
<td>Water/Emulsion</td>
</tr>
<tr>
<td>BYK-025</td>
<td>20</td>
<td>Dipropylenglycol-monomethylether</td>
</tr>
<tr>
<td>BYK-028</td>
<td>100</td>
<td>Polyglycol MW &gt;2000, hydrophilic</td>
</tr>
<tr>
<td>BYK-044</td>
<td>57</td>
<td>Water/Emulsion</td>
</tr>
<tr>
<td>BYK-093</td>
<td>100</td>
<td>Polyglycol MW &gt;2000, hydrophilic</td>
</tr>
<tr>
<td>BYK-094</td>
<td>100</td>
<td>Polyglycol MW &lt;1000, hydrophilic/hydrophobic</td>
</tr>
</tbody>
</table>

Polyether = EO or EO/PO
Defoamer Classes for Aqueous Systems

• Mineral oil defoamers
• Silicone defoamers
• Silicone-free polymeric defoamers
Silicone- and Mineraloil-free Polymeric Defoamers for Water-Borne Systems

Polymeric defoamers are chemically stable in a pH range from 3-12

<table>
<thead>
<tr>
<th></th>
<th>Emulsion Paints and Plaster PVC 30-85</th>
<th>Alkyd-emulsions</th>
<th>Emulsion-polymerisation process</th>
<th>Printing Inks and OPV</th>
<th>Acrylic/Melamine Pigmented</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-012</td>
<td>suitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05 - 0.5%</td>
</tr>
<tr>
<td>BYK-014</td>
<td>suitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05 - 0.5%</td>
</tr>
<tr>
<td>BYK-016</td>
<td>suitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 - 2%</td>
</tr>
<tr>
<td>BYK-1640</td>
<td>suitable</td>
<td></td>
<td>recommended</td>
<td></td>
<td></td>
<td>0.05 - 0.5%</td>
</tr>
<tr>
<td>BYK-1740</td>
<td>suitable</td>
<td></td>
<td>recommended</td>
<td></td>
<td></td>
<td>0.2-0.5%</td>
</tr>
</tbody>
</table>

BYK-1740: Green Defoamer Based on Eco-friendly and Sustainable Raw Materials

BYK-016: FDA § 175.105, 175.300, 175.320, 176.200, 176.21 approved

BYK-1640: Polymer-Emulsion, Polyamid particles; FDA § 175.105, 175.300 approved
Polymeric defoamers are chemically stable in a pH range from 3-12

<table>
<thead>
<tr>
<th></th>
<th>2K PU</th>
<th>2K Epoxy</th>
<th>Alkyd Emulsion</th>
<th>Water soluble Alkyd resins</th>
<th>PU Emulsion</th>
<th>Water-Based UV</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYK-011</td>
<td>✅</td>
<td>✅</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-2%</td>
</tr>
<tr>
<td>BYK-015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2 - 1%</td>
</tr>
<tr>
<td>BYK-1710</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1 – 0.5%</td>
</tr>
<tr>
<td>BYK-1711</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1 – 0.5%</td>
</tr>
</tbody>
</table>

- **Suitable**
- **Recommended**

BYK-015: Anti Popping additive with defoaming properties

BYK-1710: VOC-free. AGBB Conform

Polymeric-Defoamers for Waterborne Systems

*FDA-approved, specifically for printing inks and paper coatings
Silicone-free and Mineral Oil Free Anti Popping Additives for Aqueous Systems

- Increase the popping limit of water borne paints
- No influence on recoat ability
- Reduce the crater sensitivity
- Can improve the levelling

<table>
<thead>
<tr>
<th></th>
<th>2K-PU</th>
<th>Acrylate/ Melamine pigmented</th>
<th>Alkyd emulsions</th>
<th>HAPS-free</th>
<th>APEO-free</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYKETOL-WS</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>No</td>
<td>0,5 – 3,0%</td>
</tr>
<tr>
<td>BYKETOL-AQ</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>0,5 – 3,0%</td>
</tr>
</tbody>
</table>

- good
- excellent
Defoamers for Solvent-borne and Solvent-free Systems

- Silicone defoamers
- Silicone-free polymer defoamers
- Silicone/polymer defoamers
- Silicones and acrylates with defoaming properties
Defoamer Selection

Defoaming

Optimum

Defects

compatible/soluble

incompatible/insoluble

Foam

Foam stabilization
Influence of Compatibility
One Defoamer in Three Different Solvents

Left: too incompatible
→ turbid

Middle: too compatible
→ foam stabilization

Right: good balance
→ clear, no foam
Defoamer Selection for Solvent borne and Solvent free systems
General Overview

- Silicone defoamer: BYK-065, BYK-A535, BYK-055, BYK-088, BYK-072
- Silicone/Polymer defoamer: BYK-051, BYK-052, BYK-054, BYK-057, BYK-A535, BYK-1791, BYK-1798
- Silicone free Polymer defoamer: BYK-066N, BYK-081, BYK-1790, BYK-077, BYK-085, BYK-070, BYK-141

The chart illustrates the selection of defoamers based on shear force and time of incorporation.
## Surface Additives with Defoaming Properties

<table>
<thead>
<tr>
<th>Silicons</th>
<th>Acrylates</th>
</tr>
</thead>
<tbody>
<tr>
<td>• BYK-077</td>
<td>• BYK-354</td>
</tr>
<tr>
<td>• BYK-322</td>
<td>• BYK-352</td>
</tr>
<tr>
<td>• BYK-323</td>
<td>• BYK-392</td>
</tr>
<tr>
<td>• BYK-320</td>
<td>• BYK-359</td>
</tr>
</tbody>
</table>
Test Methods
Defoamer Test Methods

• Shaking
• Stirring-in air by dissolver
• Introducing air by pump
• Rolling with porous foam roller
• Brush application
• Measurement of density
Defoamer Test Methods - Shaking
Defoamer Test Methods - Stirring-in of Air by Dissolver
Defoamer Test Methods - Rolling With Foam Roller
Defoamer Test Methods - Brush Application
Defoaming: Influencing Factors

- Point of addition
- Shear forces needed for incorporation
- Dosage
- Duration of incorporation
- Defoamer selection
Summary

• Foam prevention
  1. Production
  2. Application

• Correct additive selection
  1. Wetting and dispersing additives
  2. Surface additives

• Usage of defoamers
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