

Kai Steenweg, Susanne Struck and Thomas Veit, Evonik Tego Chemie, explore the new generation of substrate wetting – a siloxane-based Gemini surfactant tailored to the latest coatings requirements

# New generation of substrate wetting

Creating a closed, defect-free coating film is not only a problem on low-energy substrates like plastics but can also be difficult on many other surfaces. For example, metal is not always perfectly degreased, wood can be critical since it needs to be penetrated well and often contains oil. Printed paper or cardboard often creates major wetting problems, since the actual substrate for the ink to wet is not paper but a previously applied layer of ink, and of course any substrate can be contaminated by dirt, dust, fingerprints and more.

## SUBSTRATE WETTING ADDITIVES

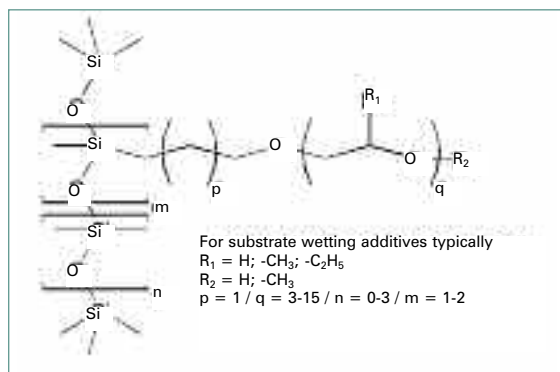
To overcome these wetting problems, substrate wetting additives are commonly being used. They are special surfactants that reduce the surface tension of a coating or an ink to a homogeneously low level, enabling the coating or ink to wet the substrate.

Very strong surface tension reduction is required to wet surfaces with oily and greasy contamination. This strong surface activity, however, often goes along with foam stabilisation.

A lot of different technologies<sup>1,2</sup> are currently being used to supply the coatings and inks industry with effective substrate wetting additives. For powerful wetting properties siloxane based surfactants are most commonly used. They reduce surface tension to a very low level with dosages of 0.2% or 0.3%.

All substrate wetting additives, including siloxane-based surfactants, contain a non-polar hydrophobic and a polar hydrophilic part. In contrast to simple organic substrate wetting additives, the hydrophobic part of the molecule is a siloxane backbone, which usually is hydrophilically modified with polyethers in a hydrosilylation reaction (figure 1).

Fig 1. Simplified chemical structure of a siloxane surfactant



In the manufacture of this kind of substrate wetting additives, it is of the highest importance to have strict and reliable control over functionalisation of silox-

anes to guarantee reproducible properties in coating systems since unmodified molecules may lead to defects.

The polarity of polyethers can be varied by the appropriate selection of their building blocks.

The hydrophilic-hydrophobic-balance of a siloxane-based substrate wetting additive may then be achieved by tailoring the length of the siloxane backbone and the length of the polyether as well as the density of functional siloxane units<sup>3</sup>.

## GEMINI SURFACTANTS

In the search for new improved structures, Evonik Tego Chemie's Research and Development chemists investigated a special surfactant structure called 'Gemini surfactant' that is often quoted in scientific literature.

Gemini surfactants are also often referred to as bis- or double-tailed surfactants<sup>4,5,6</sup>. They are characterised by at least two hydrophobic chains and two ionic or polar groups and the presence of a spacer. The spacer can be of various chemical natures; such as a simple alkyl chain, a polyoxyalkylene segment or an aromatic unit. Most Gemini surfactants are symmetrical structures (figure 2).

Compared to conventional surfactants, Gemini surfactants display a very different aggregation behaviour. This results in a significantly lower critical micelle concentration (CMC) and a far higher surface activity (factor up to 100x/1000x) making them very efficient<sup>7,8,9</sup>. Depending on their structure they can also show significantly reduced foam stabilisation.

In application tests in coatings or inks, however, purely organic Gemini surfactants did not show a sufficiently strong surface tension reduction that would ensure wetting of contaminations or very low energy substrates.

## SILOXANE GEMINI SURFACTANTS

The innovative approach was to utilise siloxane chemistry in order to build Gemini structures.

Combining different in-house technologies siloxane-

Fig 2. Comparison of a conventional single-tailed surfactant with a Gemini surfactant



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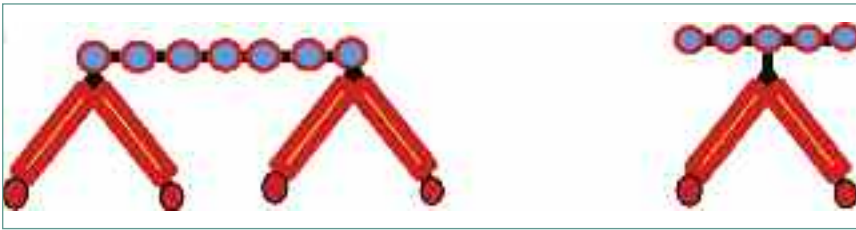


Fig 3. Examples for structures of siloxane-based Gemini surfactants



Figure 6: Microscopic view on waterbased Acrylic wood coating  
Above: With 0.3% Tego Airex 902 W  
Below: 0.3% Tego Airex 902 W + 0.3% Tego Twin 4100



Fig 4. Illustration of foam prevention after 15min of high shear stirring.  
Above: Control (without any additives)  
Below: Sample siloxane-gemini surfactant



Fig 5. Substrate wetting improvement on wet litho-offset ink.  
Above: Blank sample  
Below: With Siloxane Gemini surfactant



These new structures combine the strengths of both technologies. They:

- Provide a strong surface tension reduction – resulting in good substrate wetting properties
- Are effective at very low addition levels
- Provide a distinct defoaming effect in most water-based coatings and inks
- Are 100% active matter and free of organic solvents.

**THE FIRST COMMERCIAL PRODUCT**

The first commercially available siloxane Gemini surfactant created a lot of interest a few years ago. Tego Twin 4000

based Gemini surfactants were created in which the siloxane chain forms the spacer resp hydrophobic backbone (figure 3).

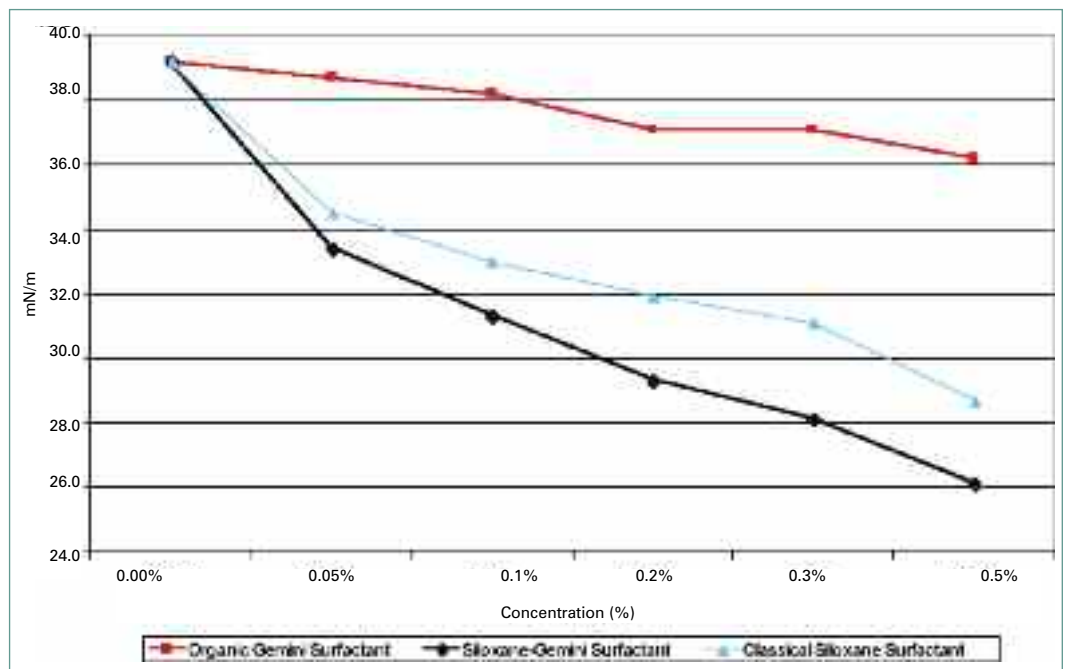


Fig 7. Static surface tension measurement with increasing dosage level of different surfactants

displays a combination of foam prevention, defoaming and substrate wetting.

This hydrophobic substrate wetting agent today is used successfully in a variety of applications, including waterborne industrial coatings, wood coatings and printing inks.

Its most unique property, besides a very powerful surface tension reduction, is its good foam prevention even under high shear conditions. When performing a high shear test with an aqueous varnish for 15min, the control built up a lot of microfoam, literally turning into 'whipped cream'. The sample containing the siloxane-based Gemini only showed moderate foam build-up (figure 4).

Another interesting property with regards to foaming is the much faster foam break-down that could be observed in water-based coatings and inks containing the siloxane-based Gemini surfactant.

## SECOND GENERATION

During the last few years, the trend within the water-based industrial and wood coatings industries continues to lower cosolvent contents and incorporate new high performance binder systems.

A second generation siloxane Gemini surfactant has now been developed tailored to these modern formulation needs. Tego Twin 4100 displays superior substrate wetting properties, superior flow and levelling promotion and compatibility even with sensitive aqueous binders. At the same time it does not stabilise foam, in most formulations it actually accelerates foam break.

It can be used as a combination partner in coating and ink

formulations. Traditionally, substrate wetting additives and defoamers are used in combination to achieve consistently good results in the final application. These conventional substrate wetting surfactants are normally known for causing foam, which has to be controlled by defoamers.

The new siloxane Gemini surfactant technology behaves completely differently. It supports the defoaming/deaeration, prevents defoamer craters and ensures good coating appearance (figure 6).

Siloxane Gemini technology is an economic way of effectively lowering the surface tension of water-based coatings and inks. Figure 7 shows the surface tension results highlighting the superior performance of Tego second generation siloxane Gemini technology compared to classical siloxane surfactants and organic Gemini surfactants.

Finally is Tego siloxane Gemini technology also suitable for solventborne formulations? Application tests have shown that the Tego Twin products offer good performance in waterborne formulations, where low surface tension is a key factor towards good substrate wetting. However, in solventborne coatings and inks Tego siloxane Gemini technology is also about to achieve improvements in substrate wetting, flow and levelling.

## CONCLUSION

With the combined approach of using siloxane chemistry and Gemini technology, it has become possible to create substrate wetting additives with detailed unique property profiles.

In conclusion, outstanding substrate wetting can now be achieved in waterborne coatings – without any foam stabilisation. ■

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