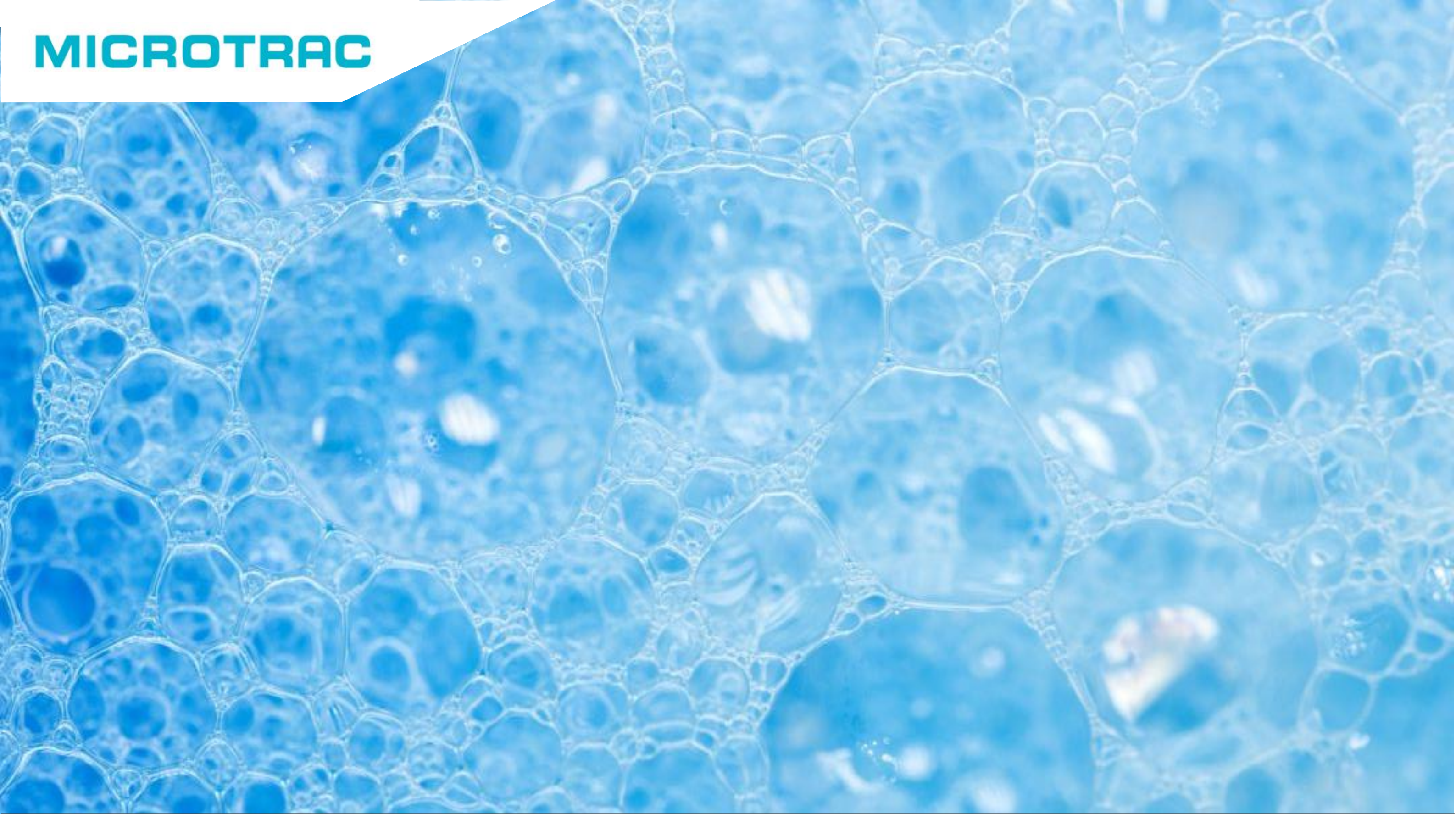
MICROTRAC



Foamability And Foam Stability With TURBISCAN

Context

Foams are very common in everyday life and found in many food products, cleaning products, hygiene, and health formulations as well as construction materials (heat and noise insulation, shock- absorbers) or for lightweight materials in aerospace/automotive fields. On the other hand, in some cases, foam is the undesired subproduct that needs to be limited (papermaking, printing). Measuring and analyzing foam remains a challenge due to the diversity of the phenomena involved. This note shows how Turbiscan, based on SMLS technology, provides a relevant and reliable method to fully characterize foam stability: foam height, bubble size, foamability…

Definition: Foam

Foam is a two-phase system that consists of a dispersion of gas in a condensed phase, which is typically an aqueous phase but can also be solid. Surfactants are adsorbed at the surface of the bubbles, reducing the surface tension of the interfaces between bubbles and lamellae. They play a crucial role in determining foamability, foam stability, and foam quality. Foamability is influenced by the surfactant's nature, concentration, and the liquid phase viscosity, and it relates to the amount of foam generated. It is essential to differentiate between foamability and foam stability, which are two separate properties. There are three primary processes involved in foam destabilization.

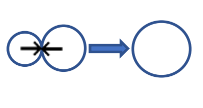
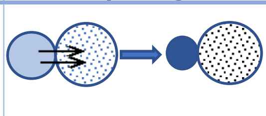
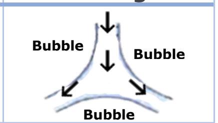
Bubble Coalescence	Bubble Ostwald ripening	Water drainage
		
Rupture of a film separating two bubbles	The smallest bubbles empty into the large ones by diffusion through the liquid films	Flow of the liquid out of the lamellae

Table 1. Foam destabilization phenomena

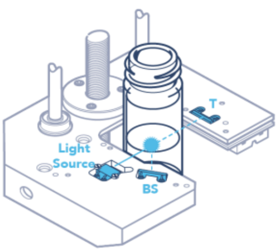
These phenomena, which are often interdependent, result in an increase in bubble size and phase separation between the liquid and gas over time. Water drainage, for instance, facilitates coalescence. The most common method for studying foam is visual observation, but it is user-dependent and not sensitive enough for short-lived systems. Some indirect methods involve analyzing the behaviour of an isolated film, but it is not always possible to correlate this behaviour with the overall foam behaviour.

Fortunately, the TURBISCAN is a reliable tool for precise foam study. It allows for precise measurement of foam height during formation and foam destabilization over time.

TURBISCAN: How it works

TURBISCAN technology, based on Static Multiple Light Scattering (SMLS), consists of sending light pulses (880 nm) into a sample along its height. The reading head scans the sample by moving vertically along the analysis cell and acquires data each 20 µm. Measurements are made over time and variations in the backscattering and transmission levels due to sample instability are recorded. The signal is directly linked to the evolution of particle concentration (φ) and size (d) by the Mie theory.

The signal is directly linked to the evolution of particle concentration (φ) and size (d) by the Mie theory. Samples with a particle concentration from 10^{-4} to 95% (v/v) and from **10nm to 1mm** in particle size can be measured as is.



$$BS = f\,(\varphi, d, np, nf)$$

Figure 1. TURBISCAN measurement head

The instrument enables to monitor of changes in physical stability (coalescence, creaming, sedimentation, phase separation, etc...) for any type of dispersion as well as foams without any dilution or any stress.

TURBISCAN profiles show the variation in recorded light intensity levels as a function of sample height (in mm) over time. The bottom of the sample is represented on the left of the graphic and the top of the sample is on the right. The color gradient on the time scale corresponds to each scan time lapse with the first scan in blue and the last scan in red.

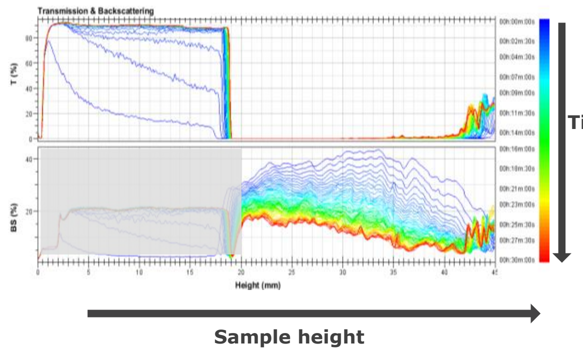


Figure 2. Foam on TURBISCAN profile

Fast foam analysis with TURBISCAN

As an example, the following profile shows a foaming agent (surfactant) that was previously foamed in a defined manner and analyzed using TURBISCAN.

❑ Foam height – Single scan

The graph below shows the initial scan just after the foaming process (30s). In only 30 seconds, the TURBISCAN can provide information about the foamability (ability of the surfactant to create foam) & foam height as well as the initial bubble size.

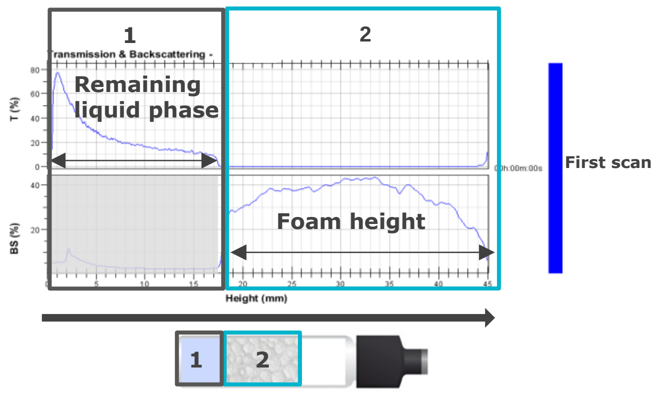


Figure 3. Initial generated Foam

- **Zone (1)**: Bottom of the sample – Transmission signal. A transmission peak is detected, which corresponds to the remaining water phase.

- **Zone (2)**: Top and middle of the sample – Backscattering signal. The incident light is scattered by the air bubbles, and the foam is identified on the backscattering signal. The Foam height is easily measured (27.4mm). Finally, knowing the initial liquid height, the foamability can easily be determined (foam volume/ initial liquid volume) as well as the initial bubble size (here 450µm).

❑ Foam stability – Multiple scans over time

The scans are repeated over time to observe changes in the foam parameters, such as air bubble size, foam loss, and air bubble coalescence rate. The graph below shows the TURBISCAN profile's evolution over 30 minutes, with the first scan indicated in blue and the last scan in red.

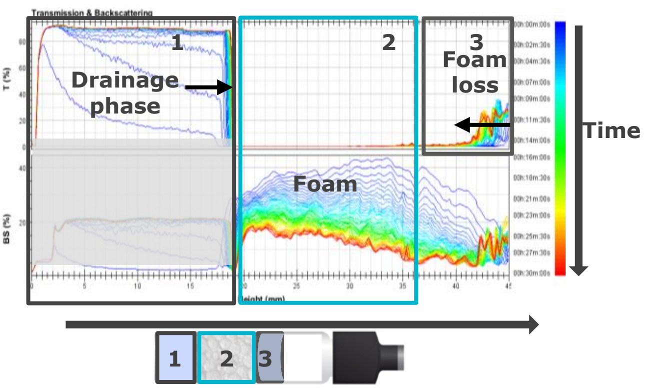


Figure 4. Foam destabilization over 30 minutes

- **Zone (1):** Bottom of the sample – Transmission signal. With foam destabilization over time, the transmission signal increases at the bottom corresponding to the increase of the bottom liquid phase (drainage phase).

- **Zone (2)**: Middle of the sample – Backscattering signal. Over time, the backscattering signal decreases and corresponds to the increase of the size of scatterers (bubbles), i.e: the coalescence of the foam.
- **Zone (3)**: Top of the sample – Backscattering signal. A transmission peak appears on the right (top of the sample) and evolves from the right to the left. This corresponds to the foam collapse. The sample is losing the foam from the top to the middle.

In addition to faster and more reliable identification of foam destabilization compared to the visual observation, TURBISCAN technology enables to follow foam stability over time.

Direct foam studies with the mixing tool

The TURBISCAN Mixing Tool can be used to generate the foam directly inside the measurement cell allowing to characterize the foam properties at every stage.

The direct characterization enables screening of surfactants (type and concentration) and the environment (pH, temperature, water hardness…) to rapidly evaluate the efficiency of various additives and thus to optimize the formulation. In this study, three foaming agents (surfactant A, B, C – 10%wt in water) have been studied. The stability measurement was performed for 10 minutes.

❑ Foaming and foamability with TURBISCAN

Once the foam is generated, the foam height and volume can easily be measured with the TURBISCAN and the foamability can be determined:

$$Foamability\ (\%) = \frac{\text{Volume of the foam}}{Initial\ Volume\ of\ the\ liquid}$$

Sample	Initial liquid volume	Foam height generated	Foam volume generated	foama bility
Surf.A	10 mL	27.4 mm	13.4 mL	134%
Surf.B	10 mL	18.2 mm	8.9 mL	89%
Surf.C	10 mL	17.8 mm	8.7 mL	87%

Table 1. Foamability of the three foams

The surfactant A generates more foam than the surfactant B and C

❑ Air bubbles diameter

From backscattering measurements and based on the Mie theory, the TURBISCAN enables to calculate the bubble's mean diameter in function of time and without any sample preparation. Initial bubble size and coalescence kinetics can be monitored only by the input of 3 parameters (refractive indexes of both phases and volume fraction).

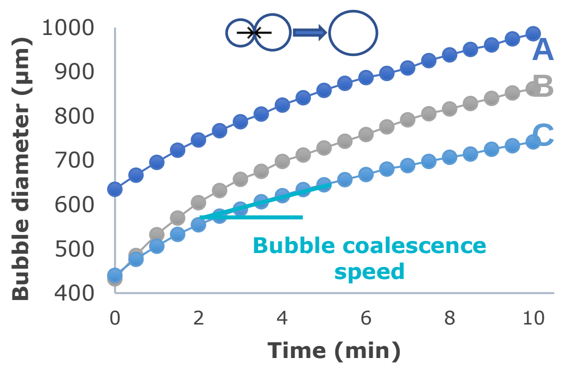


Figure 5. Bubbles diameter over time

The bubble coalescence rate can easily be obtained by determining the slope of the kinetics:

Sample	Initial bubble size	Coalescence speed
Surf.A	635 µm	31.6 µm/min
Surf.B	432 µm	38.6 µm/min
Surf.C	440 µm	27.4 µm/min

Table 2. Coalescence speed of the three foams

The initial bubble sizes are different for surfactants B and C compared to surfactant A (~430µm vs 630µm) and different foam quality can be expected. Furthermore, the foam made of the surfactant C shows the slowest coalescence speed.

❑ Foam stability & half-life

The foam height evolution can easily be recorded.

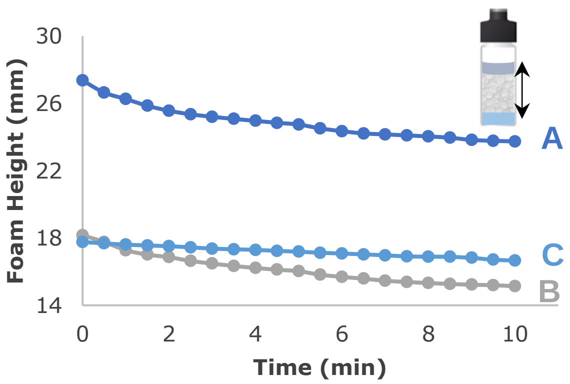


Figure 6. Foam height evolution over time

From the previous graph, the initial amount of foam can also be determined as well as the speed of foam loss (slope of the curve), thus the foams stability can be easily evaluated.

Sample	Initial foam amount	Foam loss speed
Surf.A	27.4 mm	-0.30 mm/min
Surf. B	18.2 mm	-0.27 mm/min
Surf. C	17.8 mm	-0.10 mm/min

Table 3. Foam loss speed of the three foams

Note: Foam stability can be expressed in terms of foam half-life. Half-life is defined as the time required for half of the initial foam volume/height has collapse and can easily be determined using this technique.

❑ Drainage phase

Gravity causes the liquid phase to drain down, which increases the volume of the bottom liquid phase, known as the drainage phase. The thickness of the peak in transmission at the bottom of the sample is precisely and quickly measured over time to determine the volume of the drainage phase.

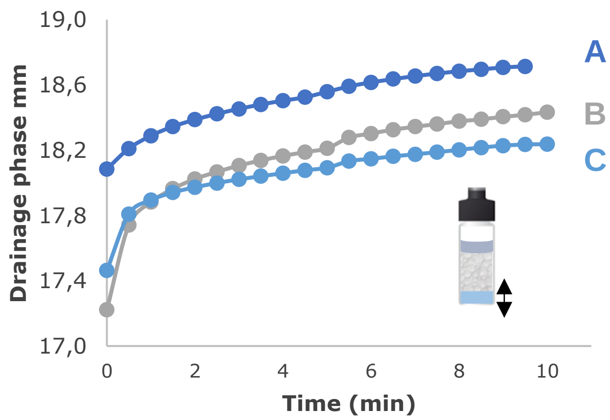


Figure 7. Drainage phase over time

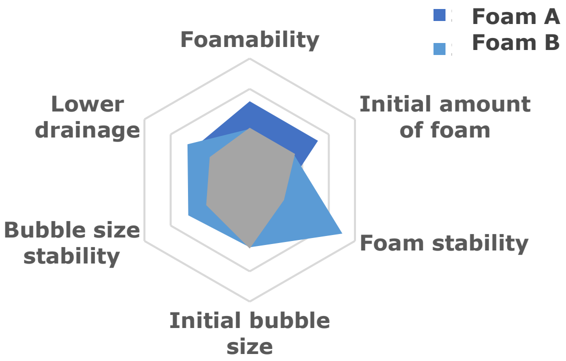
Sample	Initial drainage phase	Drainage speed
Surf.A	18.1 mm	3.42 mm/hr
Surf.B	17.2 mm	4.8 mm/hr
Surf.C	17.5 mm	3.1 mm/hr

Table 4. Drainage phase speed of the three foams

The foam generated by the surfactant C has the slowest drainage speed, which must be related to the bubble size (the smallest) and the stability of the foam.

❑ Data interpretation

Foam analysis with the SMLS technology provides a broad range of precise metric for foam: from foamability, to bubble size, and foam stability measurement. All the data can be summarized in the radar chart for comparing the different formulations and select the best formulation.



Surfactant B is surpassed in all the parameters by surfactant A and C and can be considered as the least efficient foaming agent. For **foam generation**, **surfactant A** is the most appropriate foaming agent, it generates the most amount of foam. However, the foam is not as **fine** and as **stable** as the foam generated by **surfactant C**. So, for stability and the finest foam, surfactant C is the surfactant of choice.

Conclusion

The TURBISCAN allows to study the entire foam life, from the generation to its collapse and monitor key parameters: stability, air bubble size, and coalescence rate... Thus, it is perfectly adapted to accurately evaluate the quality of foam products and make the right decision to optimize product efficiency and quality.