Ultrafine bubble characterization

Stability monitoring by S-MLS

Introduction

Ultrafine bubbles are defined by their size (less than 1 µm), they offer additional features compared to ordinary bubbles: they stay longer in a liquid and lower the surface tension. Their properties have long been used but the technology keeps on expanding to new applications in various fields such as toilet detergency, cosmetics, medical, semi-conductor, and agriculture for vegetables growing acceleration.

The challenge is the detection and characterization of these very fine bubbles to highlight their efficiency. Static Multiple Light Scattering is proposed to monitor ultrafine bubble stability in water, but also to determine bubble size and concentration.

KEY BENEFITS

- FAST
- NO DILUTION
- SENSITIVE

Reminder on the technique

Turbiscan® technology, based on Static Multiple Light Scattering, consists on sending a light source (880 nm) on a sample and acquiring backscattered (BS) and transmitted (T) signal all over the height of a sample.
By repeating this measurement over time at adapted frequency, the instrument enables to monitor physical stability.

The technology also enables to measure directly the mean spherical equivalent diameter (d), with the signal intensity and knowing refractive index of continuous (n_f) and dispersed phase (n_p) and the particle concentration (φ) according to the Mie theory:

$$BS = f(d, \varphi, n_p, n_f)$$

with BS for Backscattering Intensity and T for Transmission Intensity. In return, the volume fraction can be computed knowing refractive indexes and diameter.

Method

Samples of ultrapure water were analyzed and results compared with samples charged with ultrafine air bubbles at two concentrations (low LC and high HC).

Ultrafine bubbles signal sensitivity

The samples analyzed are transparent, thus only transmission signal is to be taken into account. Figure 1 shows the transmission level for ultrapure water and ultrafine bubbles in water. Since Turbiscan® signal reproducibility is 0.1%, any variation greater than 0.1% is to be considered significant.

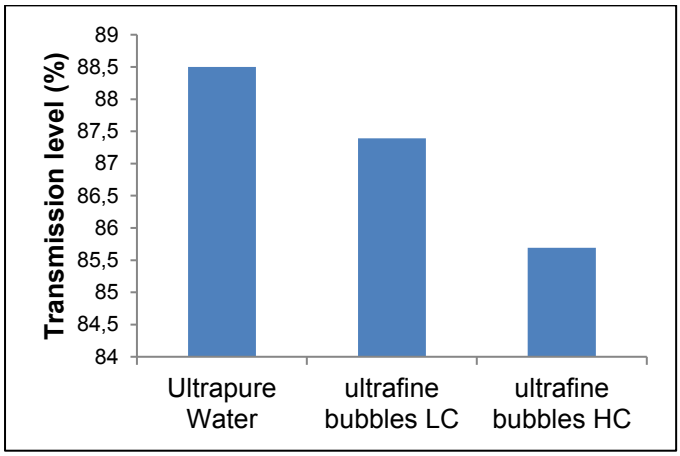

Figure 1: Transmission level (%) for ultrapure water and water with ultrafine bubbles at low (LC) and high concentration (HC)

The transmission signal measured with Turbiscan® is sensitive to differentiate ultrafine bubbles at different concentrations. The transmission intensity decreases with higher air bubble concentration.

Ultrafine bubbles stability

Samples have been monitored during 30 days at 25°C to study ultrafine bubbles stability in water. Figure 2 shows the transmission evolution of studied samples over time.

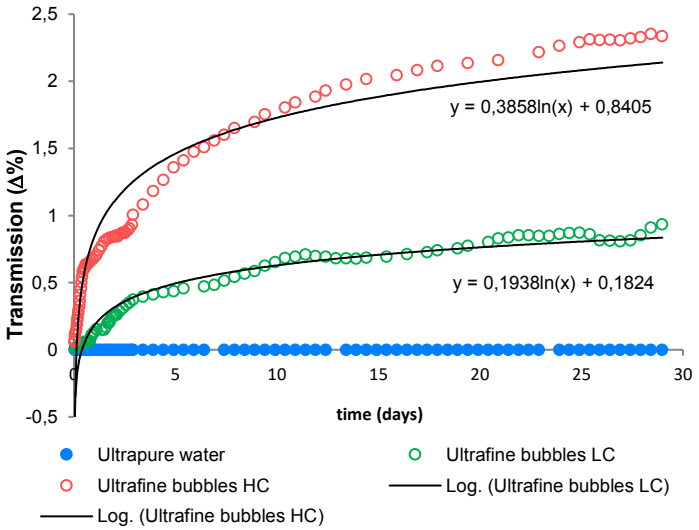

Figure 2: Stability versus time for samples at 25°C during 1 month

The transmission signal remains constant for water but increases versus time for ultrafine bubbles samples showing that bubble concentration evolves and more specifically decreases with time.

Extrapolation of the curves enables to determine the time required to reach the transmission level corresponding to ultrapure water, this time corresponds to the stability time of ultrafine bubbles

Sample	Time to reach ultrapure water level (extrapolation)
Low Concentration (LC)	68 days
High Concentration (HC)	96 days

The higher the initial concentration of ultrafine bubbles, the longer it takes to reach water level.

Ultrafine bubbles size and concentration measurement

Size measurement:

The size of ultrafine bubbles was measured on the example of High Concentration sample (HC) with known number concentration of bubbles generated with IDEC device.

Sample	Refractive index bubbles	Refractive index water	Number concentration (bubbles/mL)	Diameter(nm)
HC	1	1.33	10^{11}	**100**

(non underlined = known, underlined = measured)

Concentration measurement:

The concentration of ultrafine bubbles was determined on the example of Low Concentration sample (LC) knowing the initial bubbles size.

Sample	Refractive index bubbles	Refractive index water	Diameter (nm)	Number concentration (bubbles/mL)
LC	1	1.33	100	**10^{10}**

(non underlined = known, underlined = measured)

CONCLUSION

Turbiscan technology is proposed to monitor ultrafine bubbles stability compared to ultrapure water. The transmission signal is sensitive to detect ultrafine bubbles presence in water and allows the monitoring of the evolution of ultrafine bubble concentration with time in the very same sample. This technology can also measure bubbles size and concentration without sample preparation or dilution.