**NANOBUBBLE SIZE AND CONCENTRATION ANALYSIS WITH MULTI-LASER NANOPARTICLE TRACKING ANALYSIS (NTA)**

**Introduction**

Nanobubbles are submicron gas-filled cavities in an aqueous medium. By virtue of formulation and manufacturing, they remain suspended in liquid for a long time. There are over 18,000 scientific articles on nanobubbles covering an extensive range of applications. From mitigating the excess toxins in lakes to enhancing the health benefit of your everyday beverages, scrub-free cleaning to wellness and health applications [1], nanobubbles are set to disrupt industrial norms with their unique physiochemical characteristics. See Table 1 for some possible applications. With proper understanding and control of nanobubble formation and stability, applications that are traditionally impossible can now be reached.

**Background**

There are several ways to create nanobubbles and a few are listed below:

1. Acoustic cavitation/ultrasound
2. High shear mechanical agitation [3]
3. Electrolysis

Nanobubble stability depends on five main factors [5]:

1. Van der Waals forces
2. Electrostatic forces
3. Hydration forces
4. Hydrophobic interaction
5. Steric forces

In some cases, in order to increase the stability of the nanobubbles in a liquid, suitable surfactants are used to achieve stable suspension conditions.

This note analyzes carbon dioxide (CO\textsubscript{2}) and oxygen (O\textsubscript{2}) gas nanobubbles used for pain management to demonstrate multi-laser Nanoparticle Tracking Analysis’s (NTA) ability to characterize a mixture of nano and microbubbles without sample manipulation. The results of this analysis, specifically bubble mean size and concentration, helped determine the best techniques and formulation to generate stable gas nanobubbles in distilled water.

**Materials and Method**

Samples were prepared by a company using a proprietary nanobubbler and formulations. Neither the sample composition nor the bubble generating process were disclosed. Samples were analyzed as received with the ViewSizer 3000 multi-laser Nanoparticle Tracking Analyzer (NTA) to determine bubble size and concentration.

Multi-laser NTA is a novel technique incorporating three lasers with different wavelengths and a color camera to visualize the displacement of particles from 10 nm to 15 microns. Displacement is interpreted as Brownian
motion, or, for larger particles, settling or creaming and can therefore be readily converted to particle size for each bubble, allowing high-resolution size distribution analysis.

Each sample was transferred directly into the system cuvette without further preparation (Figure 1). In this study, we collected 100 videos per sample. Temperature was controlled at 22°C throughout each measurement.

Results and Discussion

The results in Table 2 below confirmed the existence of nanobubbles in the aqueous environment at concentrations well over 3E+07 nanobubble particles/mL. Using ViewSizer 3000 the manufacturer was able to optimize the process in order to increase the particle concentration from 2.77E+06 particles/mL (Sample A) to 2.90E+07 particles/mL (Sample B).

Since NTA is an individual particle-by-particle method, a handful of larger particles did not adversely affect the measurement of the smaller particles like in dynamic light scattering (DLS) measurements. The mean diameter was 542 nm and the total particle concentration was 2.89E+07 particles/mL.

Comparing Sample A with Sample B with respect to the nanobubbles mean size one can observe that the mean size of Sample B is 10% lower than the mean size of Sample A. Larger mean size results in less stable gas nanobubbled aqueous solutions due to the Ostwald ripening effect [7].

Conclusions

The ViewSizer 3000 successfully determined the size, size distribution, and concentration of nanobubbles in suspension. Hence, offering information on nanobubble longevity. The data collected shows that these nanobubbles remain stable in liquid for a long time, from production to shipment to lab analysis. The results from the ViewSizer 3000 also provided insights to improve nanobubbles generation methodology.
References


