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Trial of Continuous Measurement of Micro-Nano Bubbles in Water

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Motivation and Background

- Micro-nano-bubbles (MNBs) are tiny bubbles with diameters ranging from tens of nanometers to several tens of micrometers.
- Owing to their small diameter, MNBs have some characteristics. Compared with normal bubbles, MNBs have lower rising velocity and persist for long periods in the liquid phase.
- MNBs technology is proposed to use for various areas such as groundwater remediation, aquaculture, mass transfer.
- Although MNB generation methods and applied to problems are attracted, the continuous in-situ measurement technique has not researched well. An easy, continuous, and inexpensive method is desired for more efficiently using MNBs. In previous research, the dielectric constant of MNBs water was different from that of water (Ueda et al., 2015). Therefore we hypothesized that continuous measurement of dielectric constant could be used to estimate MNBs in the water.
- The purpose of this study is to investigate the attempt to continuous measurement for MNBs.

Materials & Methods

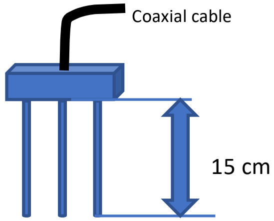

Fig. 1 The schematic of TDR probe.

Fig. 2 MNB generating and after.

- To measure dielectric constant, we used time domain reflectometry (TDR) (Topp et al., 1980). A TDR probe (0.15 m long) was used with a cable tester (Model 1502C, Tektronix Inc.) in this study (Fig. 1).
- We also used GS3 sensor (METER Group, Inc.) for water temperature measurement because the dielectric constant (ε) changed with temperature (below equation).

$$\varepsilon_T = 88.15 - 0.414t + 0.131\times10^{-2}t^2 - 0.046\times10^{-4}t^3$$

- Dielectric constant (ε) and water temperature (T) were measured every 1 min during before and after MNBs generation (Fig. 2). We conducted experiments with several MNBs generators.

Results & Discussion

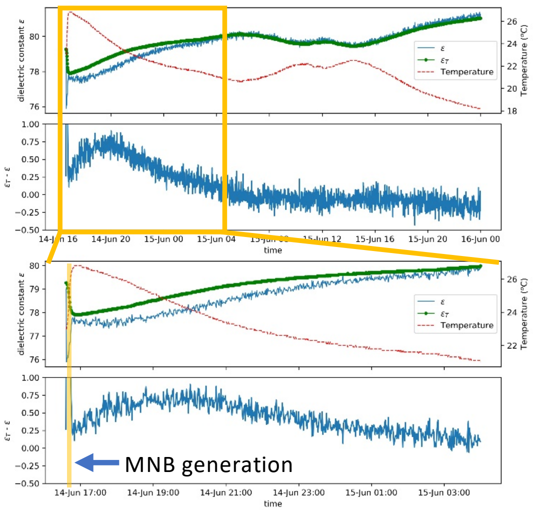

Fig. 3 Water temperature (T) and dielectric constant (measured ε, theoretical ε_T calculated from water temperature) before and after MNB generation. The upper column of each graph shows the change in temperature and dielectric constant, and the lower column shows the difference between the ε and ε_T.

Water temperature, T (°C)
The water temperature increased rapidly, which occurred immediately after the start of MNB formation.
This is because the MNB generator takes in the MNB air from the warm atmosphere.

Dielectric constant ε, ε_T
Measured dielectric constant changed before and after MNBs generation. The smaller dielectric constant ε than the relative permittivity ε_T calculated from the water temperature is considered to be due to the intake of air during MNB generation.

Estimation of relative MNBs
The difference dielectric constant disappeared (ε_T- $\varepsilon \approx 0$), 12 h after the generation of MNBs, indicating that the MNBs disappeared from the water.

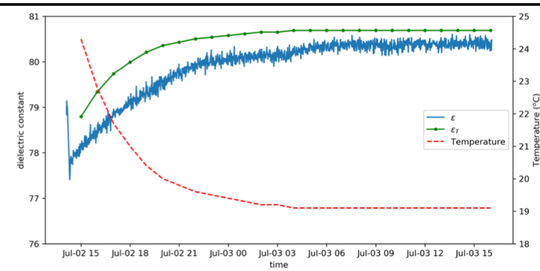

Fig. 4 Water temperature (T) and dielectric constant (measured ε, theoretical ε_T calculated from water temperature) before and after MNB generation. This results differed from Fig. 3 instrument.

- Our research suggested simultaneous measurement of temperature and dielectric constant can estimate the amount of MNB in water.
- This method is not universal at this time (e.g. Fig. 4), so we are continuing our research.

Reference
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- UEDA Yoshikatsu,TOKUDA Yomei,NIHEI Naoto,SUGIYAMA Akifum,OGAWA Yuichi, 2015, Fine Bubble Technology as an Adhesive Agent with Gasliquid Interface Journal of The Adhesion Society of Japan 0916-4812 The Adhesion Society of Japan. 51(2) 58-65 [in Japanese].
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