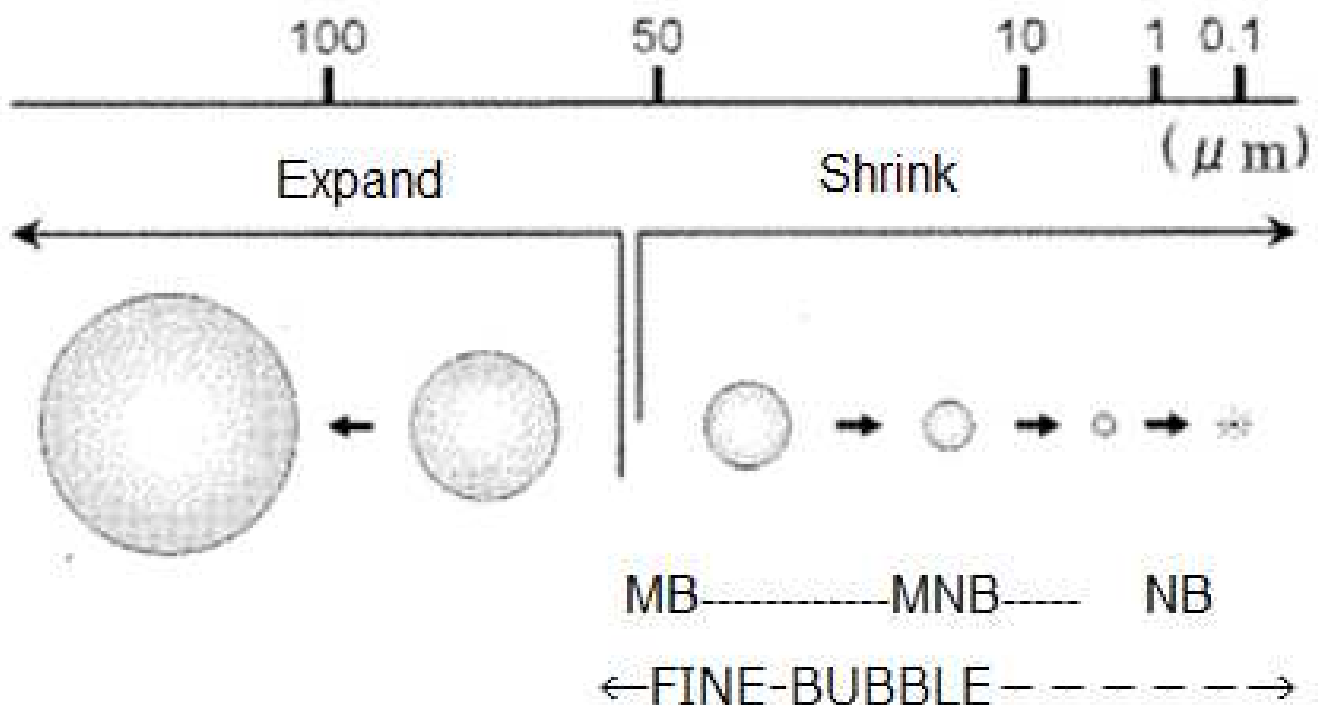


What is Fine-bubble? What is Micro-bubble ? What is Nano-bubble?

1. DEFINITION

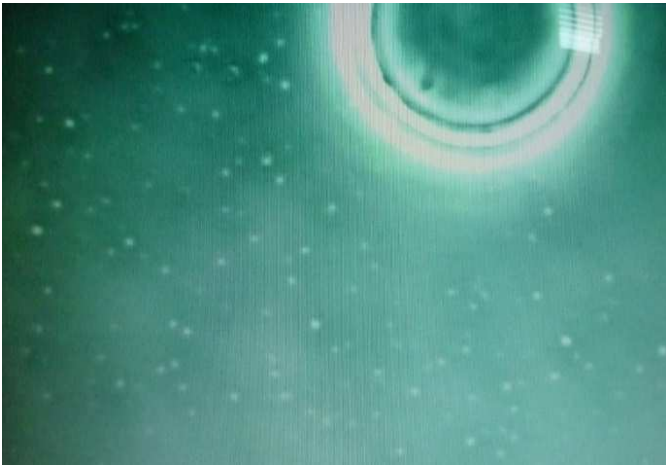


Bubble of less than diameter $1\mu\text{m}$ is called a Nano-bubble(NB).

$50\mu\text{m}$ diameter of Bubble and less is called a micro-bubble(MB) or micro-nano-bubble(MNB).

Fine-bubble(FB) includes nano-bubble, micro-bubble and nano-

2. VARIETY OF BUBBLES



Observation of nano-bubbles by phase contrast microscopy

You can observe bubbles of approximately $12\mu\text{m}$ in left photo in upper right. Other tiny white spots are nano-bubbles diameter of about $100 \sim 300\text{nm}$.

«Micro-bubble»

Bubble diameter of $50\mu\text{m}$ or less, floating in the water

They look like a cloud.



«Millimeter-Centimeter-bubble»

0. 2 ~ 2 Millimeter Over 2 ~ 10 Millimeter



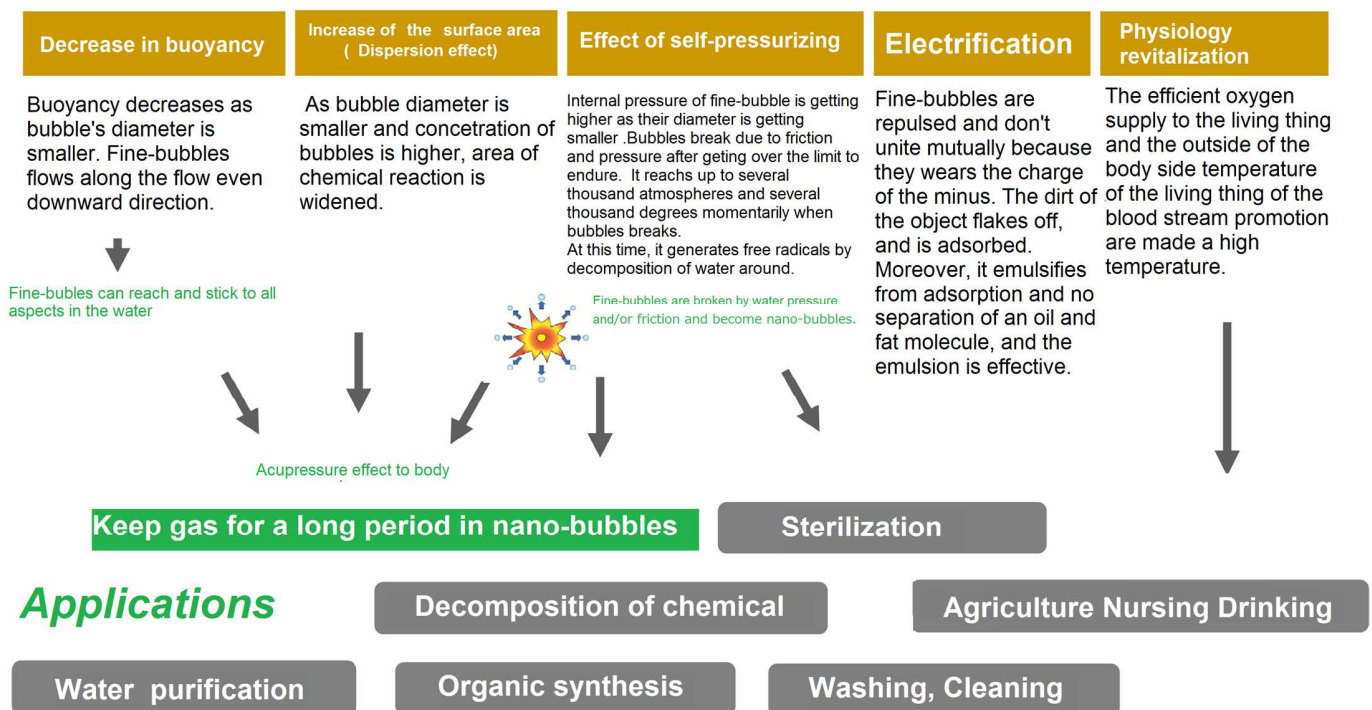
【Reference 1】

Nano-bubble water (left) visualized by freezing looks like fine mist freeze. Freezing of pure water (right)



3. BASIC CHARACTERISTIC AND BEHAVIOR OF FINE-BUBBLES

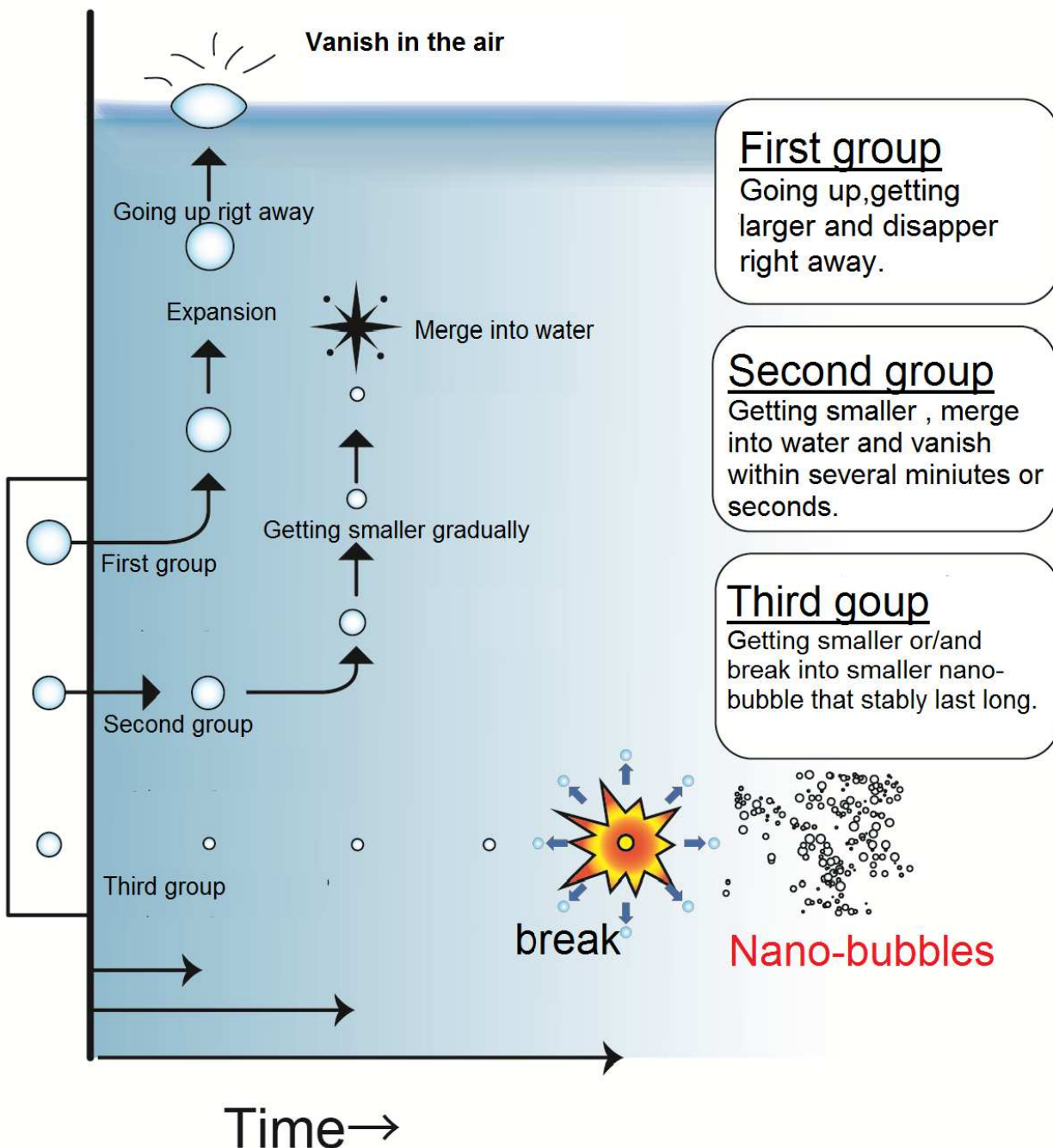
Basic characteristic



Why fine-bubble break ?

Fine-bubbles are under pressure in water. They can stand to some extent but some are crushed and merge into water beyond the limit, others survive and are stable such a long period.

Behavior of fine-bubbles



First group

Going up, getting larger and disappearing right away.

Second group

Getting smaller, merge into water and vanish within several minutes or seconds.

Third group

Getting smaller or/and break into smaller nano-bubbles that stably last long.

Nano-bubbles

【Reference 3】

Just before breaking micro-bubble



Micro-sized fine-bubble shows three behavior.

● **First group** •••• Relatively large bubbles approximately more than 50 microns diameter bubbles

Bubbles of this group expand and rise toward the liquid surface gradually, and they are scattered into the atmosphere.

● **Second group** •••• Bubbles approximately between the first group and the third group

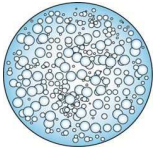
Bubbles of this group float in water and balance internal pressure and surface tension for minutes or seconds, but finally melt into water and disappear.

● **Third group** ···· Bubbles approximately less than 20 microns diameter

Bubbles of this group receive the strong surface tension as gas-liquid interface area is large in spite of small bubble volume. They are not crushed soon because their internal pressure is also high, but some are crushed by pressure and/or friction over the limit in the end. Inside of bubble just before breaking is in the ultra-high heat and ultra-high-temperature state that generate free radicals when they break.

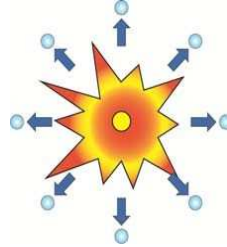
4. POSSIBLE APPLICATIONS

Micro-bubble



Dissolution Contact
Mixing and stirring

Break



Emission
High-temperature
High-pressure
Shock wave

Organic synthesis
Cancer treatment

Nano-bubble



Ozone dissolution
Hydrogen dissolution
Semiconductor cleaning...
Agricultural water
Nursing

Freezing nano-bubble



Keep freshness of food
Storage gas
Freezing point lowering

Emerged filtration
Bathing
Visualization of fluid Medical equipment cleaning and eradication bacteria
Washing (instruments, parts, foods etc.)
Soil cleanup
Liquefaction prevention
Friction-reducing
Removal of flow electrification
Floor cleaning
Deodorizing
Water purification
Emulsification
Gas-liquid mixing

5. REFERENCE DATA

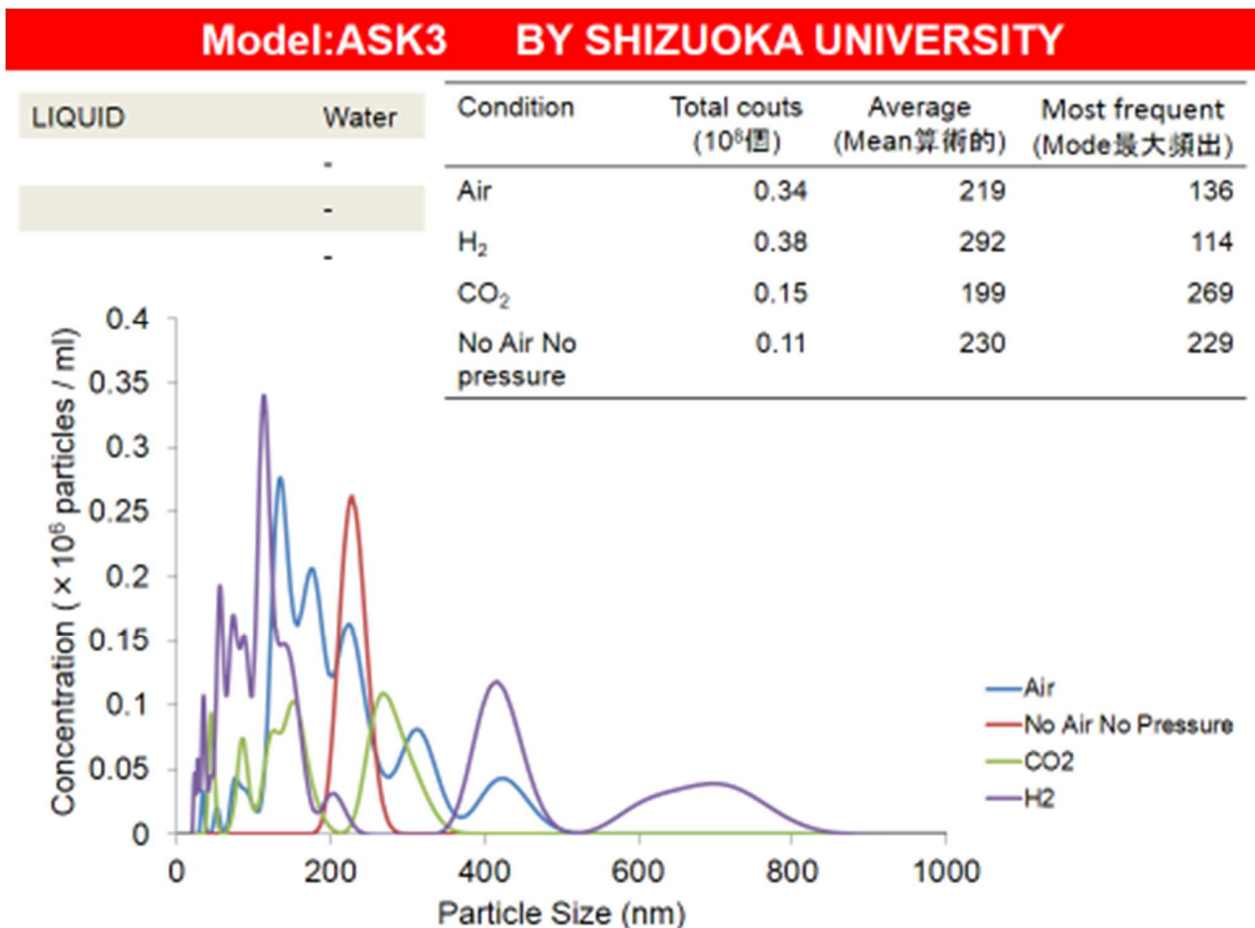
I. «24 hours after the generation by ASUPU's hybrid system»

Nanometer sized bubbles are stable for a long period of time

【Mase laboratory, Faculty of Engineering, Shizuoka University】

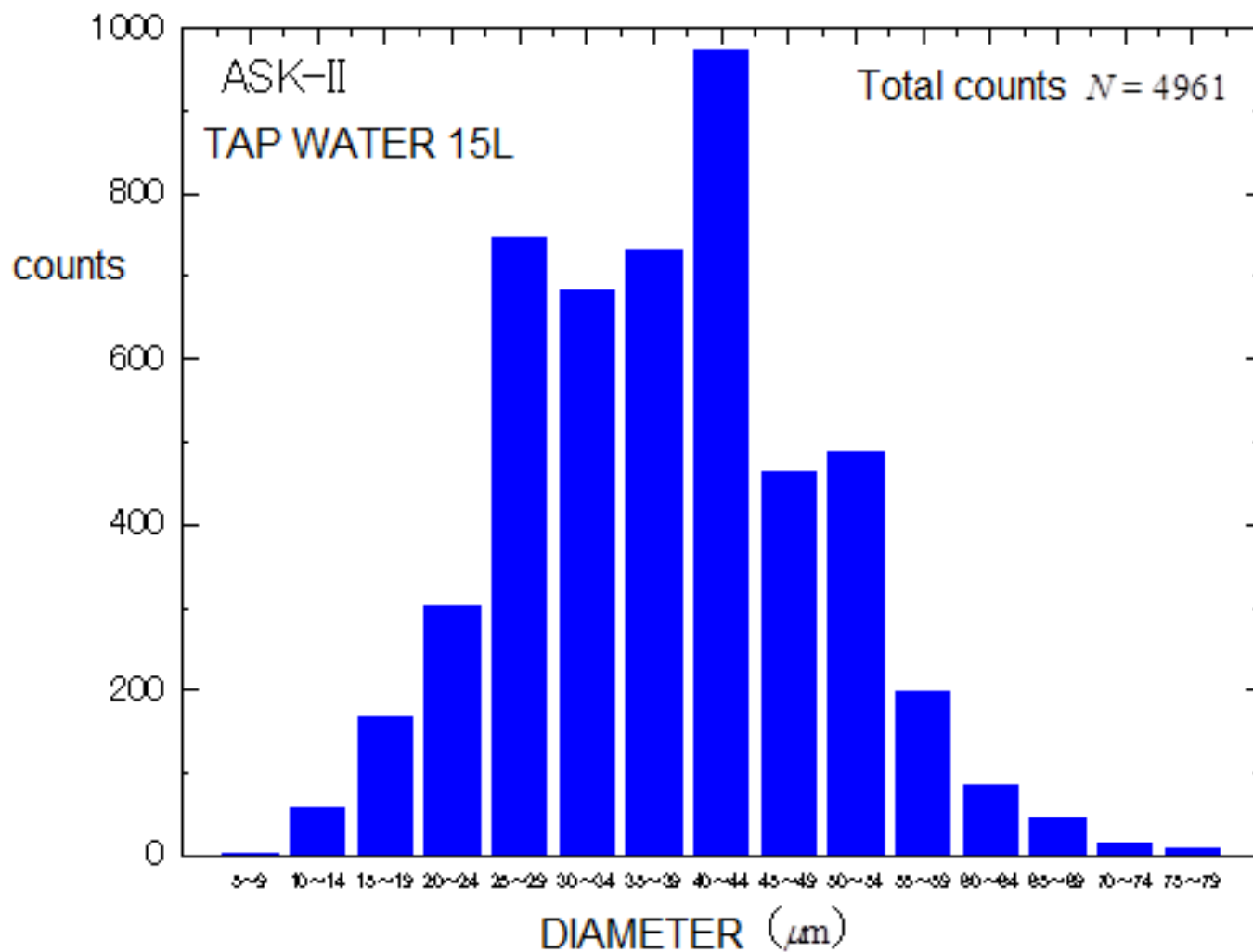
【Measurement device : Nanometer particle analyzer "Nanosight".】

① Generator: Model ASK3



II. Counts of Micro-bubble just after generated

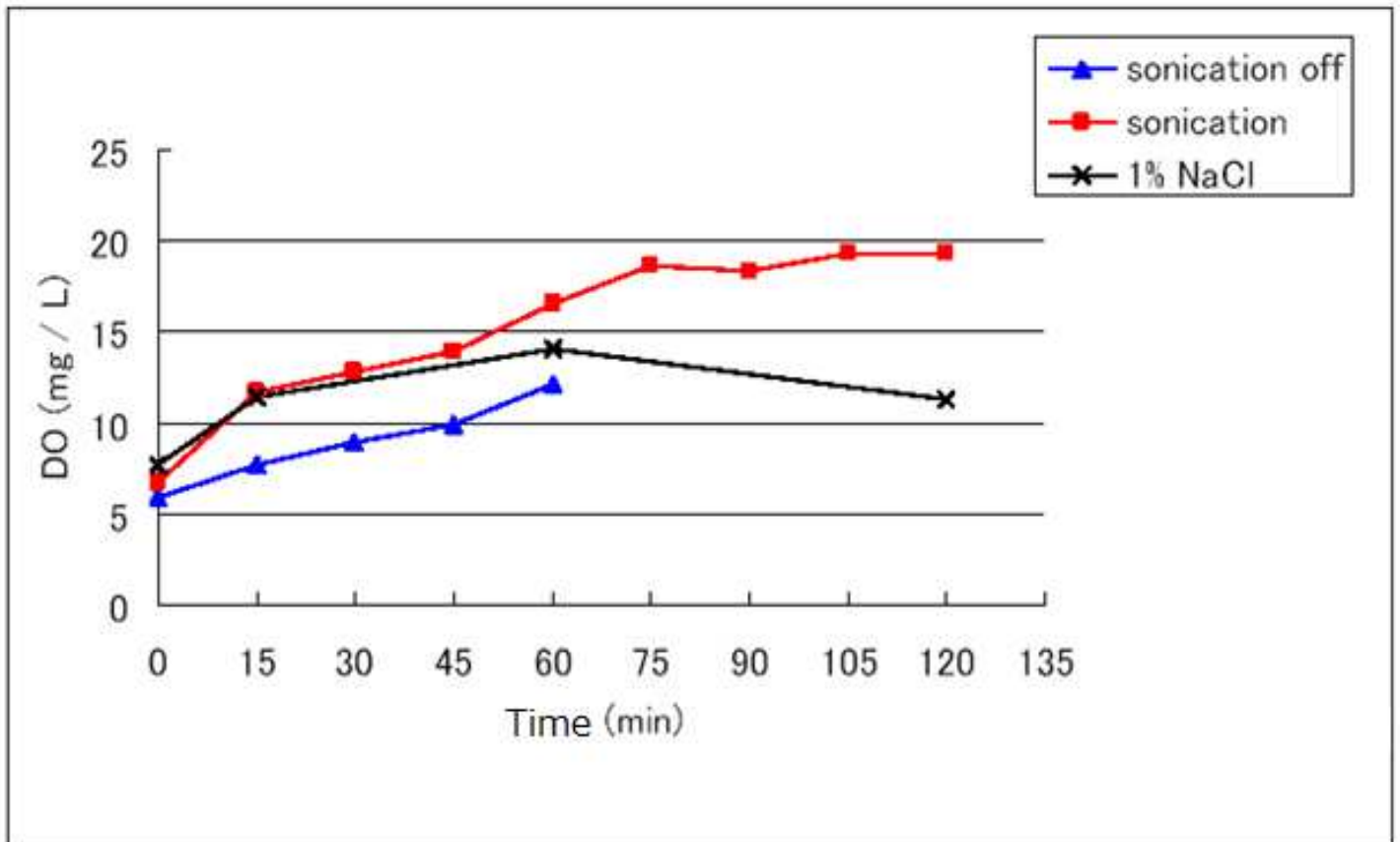
Hori laboratory, Okayama University of Science



III Dissolved oxygen

Professor Inomata, Tohoku Pharmaceutical University

Amount of dissolved oxygen in water under the sonicated condition



Super tiny bubbles create a new world



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