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# Fine bubble technology — Guideline for indicating benefits —

## Part 1:
## Requirements for systematic classification of effective functions of fine bubbles



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# Foreword

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This document was prepared by Technical Committee ISO/TC 281, *Fine bubble technology*.

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# Introduction

Fine bubble technologies have been developed and introduced from the early 20$^{th}$ century. Especially, microbubbles have been actually introduced in various application areas such as the froth flotation, ultrasonic imaging, purification of contaminated water and the enhancement of growth of living things in the ocean. One reason of microbubble application is due to the visible character of microbubbles. Fine bubble technologies has been investigated academically since the late 20$^{th}$ century. As for the application of the ultrafine bubbles, investigation into their many usages has made great advances since the year 2000.

There have been various kinds of application technology of fine bubbles recently. The application fields include engineering application, environmental application, agro-aqua and food application and medical, living and cosmetic application.

From the viewpoints of effective functions of fine bubble technology, there are various kinds of effective functions. They include cleaning effect, water treatment effect, sterilizing promotion effect, growth promotion effect, lubrication effect, control of chemical reaction, improvement in food quality and control of material processing.

If the systematic classification of fine bubble technology from the viewpoints of the application fields and the effective functions has been established, the identification of each fine bubble technology is possible to be made, and be classified in the matrix and furthermore, the extension of the other application are imagined.

Therefore, the International Standards are made for the systematic classification of fine bubble technology from the viewpoints of application fields and the effective functions.

This document provides a path for fine bubble suppliers to contribute properly to the various application fields. Furthermore, by showing to fine bubble users and potential customers, it will be able to help them to bring the effective functions to the other important applications.

In addition, this document bears a guideline for standards developers to judge when expressing the contents of application fields and the effective functions of fine bubble technology and is not subject to the conformity assessment.



 

# Fine bubble technology — Guideline for indicating benefits —

# Part 1: Requirements for systematic classification of effective functions of fine bubbles



## 1 Scope

This document provides in detail how the standards of fine bubble technologies can contribute to establish the systematic classification of fine bubble technologies including the effective functions and the application fields of fine bubbles, which is useful for the users and the potential customers to optimize the application of fine bubble technologies..

This document also specifies the clauses required for fine bubble standards, including a description relating application fields and effective functions of fine bubble technologies.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20480-1, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 1: Terminology*

ISO 20480-2, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 2: Categorization of the attributes of fine bubbles*

ISO 20480-3, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 3: Methods for generating fine bubbles*

ISO 20480-4, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 4: Terminology related to microbubble beds*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20480-1, ISO 20480-2, ISO 20480-3, ISO 20480-4, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

**3.1**
**systematic classification**
tables and figures where fine bubble technologies are identified and explained from various kinds of viewpoints, such as application fields , effective functions

**3.2**
**application fields**
applied areas and fields of industry where fine bubble technologies are effectively used, demonstrated and commercialized

**3.3**
**effective function**
useful and characterized phenomena obtained successfully by the fine bubble technologies, which are used in the actual industrial applications

## 4 Effective functions of fine bubble technology

There are several effective functions of fine bubble technology demonstrated in the literature and described in Table 1 and Table 2. Since the fine bubble has been determined to be composed of microbubbles, which have the diameter between 1 µm and 100 µm, and ultrafine bubbles, which have the diameter less than 1 µm, the description of the effective functions would be discussed separately.

Microbubble applications: As for the effective functions of using micro bubbles, effective functions would be related to the froth floatation, ultrasonic imaging, purification of contaminated water and the enhancement of living things in the ocean as explained in the Annex A.

Froth floatation: The froth floatation would belong to one kind of control of chemical reaction by the separation of some kinds of metallic element. This floating method used micro bubbles and surface surfactants based on the mechanism that the bubble surfaces would attract the hydrophobic metallic element more than the hydrophilic rock element[1].

Fine Bubbles for Ultrasonic Imaging inside Body: The generation of ultrasonic contrast agent to the medical application has been established from the viewpoints of fine bubble formation and microcapsule generation[2][3].

Purification of Contaminated Water: Cleaning and purification of contaminated water in the lakes, ponds and dams with oil contamination and with the lack of oxygen have been used from about 1995.[4]

Enhancement of Growth of Oysters, Scallop and Pearls: These application technologies have been established for getting rid of the damages of HABs (Harmful Algal Blooms) around 1999.[5] These harmful algal blooms had made the red coloured sea water and the lack of oxygen for fishes and oysters. The injection of microbubbles included water has made the significant effects for decreasing the damages. Various application areas have been developed such as effective bathing, drag reduction of ships by using the microbubbles.

There were several challenges independently for clarifying the characteristics of ultrafine bubbles and investigating the applications of ultrafine bubbles from about 2000 to 2008. Then, many challenges have been made continuously in many application fields, as shown in Annex B.

The effective functions generated by ultrafine bubbles are explained in Table 1 as follows:

a) Cleaning effect.

b) Water treatment.

c) Sterilizing promotion effect.

d) Growth promotion.

e) Lubrication effect.

f) Control of chemical reaction.

g) Improvement in food quality.

h) Material processing.



 

**Table 1 — Effective functions related to the application of fine bubble technologies**

| No. | **Effective function** see ISO 20480-2, ISO 20480-3, ISO 24261-1, ISO 24261-2 | **Description of each effective function** |
|---|---|---|
| A | Cleaning effect, see ISO 21256-3, ISO 20480-2 and ISO 20480-3 | — Toilet cleaning<br>— Removal of salt from the bridges, see ISO/TS 21256-1<br>— Cleaning of vegetables<br>— Removal of contaminants on the semiconductor wafers<br>— Cleaning inside of mouth<br>— Cleaning of ceramic membrane<br>— Detergent free cleaning |
| B | Water treatment effect,<br>see ISO 20480-4 | — Dissolution of oxygen lack of ponds and lakes<br>— Floatation mining of minerals<br>— Water treatment of disposed and contaminated water<br>(minimizing the total amount of disposal in isolated area, promoting the growth of bacterium for disposal treatment), see ISO 24261-2, ISO 20304-1, ISO 21255, ISO 21910-1<br>— Removal of radioactive substances from the soil<br>— Soil treatment |
| C | Sterilizing promotion effect | — Minimize the total usage amount of ozone<br>— Maximize the effect of sterilizing liquid by changing the PH |
| D | Growth promotion effect | — Growth promotion of vegetables<br>(leaves such as lettuce, increase of total harvest and quality of tomato)<br>— Germination promotion<br>— Application of cell cultivation<br>— Growth promotion of fishes<br>— Prevention of oxygen lack of fishes in aquaculture |
| E | Lubrication effect | — Lubrication of semiconductor wafer transportation |
| F | Control of chemical reaction | — Control the limiting transport phenomena |
| G | Improvement in food quality | — Control of calorie of mayonnaise<br>— Freshness keeping of fishes<br>— Transportation, anestesi of fishes (aquaculture use)<br>— Fragrance addition |
| H | Material processing | — Size controlled synthesis<br>— Froth flotation |

## 5 Application fields of fine bubble technology

The application fields are categorized in Table 2 as follows:

— Engineering field.

— Environmental field.

— Agri-aquacultural and food field.

— Medical, living and cosmetic field.

**Table 2 — Application fields of fine bubble technologies**

| No. | **Application fields**<br>see ISO 20480-1, ISO/TR 24217-2 | **Description of each application fields** |
|---|---|---|
| 1 | Engineering applications see ISO 21256-2, ISO/TR 23015 | — Removal of contaminants on the semiconductor wafers (see A in Table 1)<br>— Cleaning of ceramic membrane (see A in Table 1)<br>— Floatation mining of minerals (see B in Table 1)<br>— Minimize the total usage amount of ozone (see C in Table 1)<br>— Maximize the effect of sterilizing liquid by changing the PH (see C in Table 1)<br>— Lubrication of semiconductor wafer transportation (see E in Table 1)<br>— Control the limiting transport phenomena (see F in Table 1)<br>— Dtergent free cleaning (see A in Table 1) |
| 2 | Environmental applica-tions | — Toilet cleaning (see A in Table 1)<br>— Removal of salt from the bridges (see A in Table 1)<br>— Dissolution of Oxygen lack of ponds and lakes (see B in Table 1)<br>— Water treatment of disposed and contaminated water (see B in Table 1)<br>— Removal of radioactive substances from the soil (see B in Table 1)<br>— Minimize the total usage amount of ozone (see C in Table 1)<br>— Application of cell cultivation (see D in Table 1)<br>— Detergent free cleaning (see A in Table 1) |

**Table 2** *(continued)*

| No. | Application fields see ISO 20480-1, ISO/TR 24217-2 | Description of each application fields |
|---|---|---|
| 3 | Agro-aqua and food applications | — Cleaning of vegetables (see A in Table 1)<br>— Water treatment of disposed and contaminated water (see B in Table 1)<br>— Minimize the total usage amount of ozone (see C in Table 1)<br>— Growth promotion of vegetables (see D in Table 1), see ISO/TS 23016-1<br>— Germination promotion (see D in Table 1), see ISO 23016-2, ISO/TR 23016-3<br>— Application of cell cultivation (see D in Table 1)<br>— Growth promotion of fishes (see D in Table 1)<br>— Prevention of oxygen lack of fishes in aquaculture (see D in Table 1)<br>— Control of calorie of mayonnaise (see G in Table 1)<br>— Freshness keeping of fishes (see G in Table 1)<br>— Transportation, anestesi of fishes (see G in Table 1)<br>— Fragrance addition (see G in Table 1) |
| 4 | Medical, living and cosmetic applications | — Cleaning inside of mouth (see A in Table 1)<br>— Minimize the total usage amount of ozone (see C in Table 1)<br>— Sterilizing medical equipment (medical grade use) (see C in Table 1)<br>— Oxygenated water, cancer treatment (medical treatment) (see C in Table 1) |



## 6 Systematic classification of fine bubble technology from the viewpoints of application fields and the effective functions

Fine bubble technologies have been systematically classified from the viewpoints of application fields and the effective functions in Table 3.

Existing application technology are symbolled by the circle in Table 3. They would have been meant to be already researched, developed, actually used or commercialized. Some typical literatures are shown in the table also as the reference. As the typical and successful challenges of applications, the following several kinds of ultrafine bubble technology have been researched and developed so far. The application to the higher performance of grinding has been researched[23] for the manufacturing application. The cleaning of the manufacturing tools has been developed[24]. The sterilizing equipment has been researched and developed for the medical applications[25]. As for the washing machine for the living application, the first commercial equipment has been developed using ultrafine bubbles[26]. For realizing the higher quality of living, the bath and shower have been developed and widely commercialized. For bathing using ultrafine bubbles and microbubbles the effect of the temperature rise of the body surface would have been observed[27]. For the shower in the living applications, the moisture content of the homy layer would have been observed to increase about 20 %[28]. For the environmental applications, the water treatment would have the large amount of application targets with the simple ultrafine bubble generators[29].

**Table 3 — Systematic classification of the challenged application fields and the effective functions of ultrafine bubbles**

| Systematic view of "application of fine bubble technology" | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application fields | | Effective functions | | | | | | | |
| | | A | B | C | D | E | F | G | H |
| | | Cleaning effect | Water treatment | Sterilizing promotion effect | Growth promotion | Lubrication effect | Control of chemical reaction | Improvement in food quality | Material processing |
| 1 | Engineering application | ○[11][18][19][24] | ○[29] | ○ | | ○[23] | ○[14][23] | | ○[1][37] |
| 2 | Environmental application | ○[13] | ○[15] | ○ | ○ | | ○[14] | | |
| 3 | Agri-aqua and food application | ○[13][18][20] | ○ | ○[18][20] | ○[21][22] | | | ○[17] | |
| 4 | Medical, living and cosmetic application | ○[13][26][27][28][29] | | ○[25] | | | | | |
| ○ Existing application technology (researched or developed or actually used or commercialized). | | | | | | | | | |

## 7 Assignment of systematic classification in standards

Every fine bubble technology shall be classified according to the application fields and the effective functions, which is necessary for the users and potential customers of fine bubble technology to decide the range of application fields and to optimize the applied effective functions of fine bubble technology.

Every new fine bubble technology shall be systematically classified according to the application fields and the effective functions of fine bubble technologies. Otherwise, due to the wide variety of fine bubble technologies, the systematic understanding of fine bubble technology cannot be made for the users and potential customers.

Consequently, every International Standard of fine bubble technologies is classified and named according to the application fields at the first step and the name of their application fields is written just after the “Fine bubble technology” in the title. Furthermore, the key words relating to the functions of fine bubble technologies is included in the following phrase of the title.

## 8 Review and revision of standards

At systematic and intermediate reviews, the special clause related to the identification should be appended.

Continuous research and development would be conducted for the fine bubble technology after the publication of this document. Therefore, the advanced and different systematic categorization would possibly be defined. Then, the revised and advanced systematic categorization would be discussed and established in the proceeding standards continuously. However, the discussion of systematic categorization would be very helpful and supportive for the advancement of fine bubble technology.



 

# Annex A
(informative)

# Brief history of micro bubble technology

Since microbubbles are visible, microbubbles have been actually introduced in various application areas in the early 20$^{th}$ century. The typical application areas are the froth flotation, ultrasonic imaging, purification of contaminated water and the enhancement of growth of living things in the ocean.

— Froth flotation

As the commercial and useful micro bubble applications, the froth floating method of producing various kinds of metals such as zinc has been established in 1905 at Broken Hill of Australia. This floating method used micro bubbles and surface surfactants based on the mechanism that the bubble surfaces would attract the hydrophobic metallic element more than the hydrophilic rock element. The mean bubble size would range between 50 µm and 650 µm[1]. The bubble size under 50 µm was also reported[35].

— Fine bubbles for ultrasonic imaging inside body

The generation of ultrasonic contrast agent to the medical application has been established from the viewpoints of fine bubble formation and microcapsule generation[2][3]. The diameter of fine bubbles would be about 2 µm and frequently absorbed the surfactant on the surface.

— Purification of contaminated water

Cleaning and purification of contaminated water in the lakes, ponds and dams with oil contamination and with the lack of oxygen have been used from about 1995[4].

The swirling flow bubble generators created the microbubbles having the diameter of about 20 µm.

— Enhancement of growth of oysters, scallop and pearls

These application technologies have been established for getting rid of the damages of HABs (Harmful Algal Blooms) around 1999[5]. These harmful algal blooms had made the red coloured sea water and the lack of oxygen for fishes and oysters. The injection of microbubbles included water has made the significant effects for decreasing the damages. Various application areas have been developed such as effective bathing, drag reduction of ships by using the microbubbles having the diameter between 10 µm and 30 µm.



 

# Annex B
(informative)

# Brief history of ultrafine bubble technology

There were several challenges independently for clarifying the characteristics of ultrafine bubbles and investigating the applications of ultrafine bubbles from about 2000 to 2008. Then, many challenges have been made continuously in many application fields. In this annex, various challenges are explained briefly.

— Measurement of ultrafine bubbles in water

Electro-generated hydrogen bubbles ranging from 20 and 300 nm were reported in 2001 in alkaline water from an Alkali-Ion-Water electrolyzer[36].

By using the ultrapure water and by minimizing the contaminated solid particles in the water, ultrafine bubbles generated by the supersonic wave cavitation in the water super saturated with air have been measured in 2004[11]. The measuring instruments were the particle counters for the ultrapure water. The measured values of the particles and the bubbles have increased for several tens and hundreds per ml after the initiation of supersonic wave cavitation and have decreased after the termination of the cavitation by passing through the membrane filters. The diameter of measured ultrafine bubbles would be in the range between 100 nm and 150 nm. Furthermore, the amount of produced ultrafine bubbles was revealed to depend on the dissolved oxygen concentration. The generation method of ultrafine bubbles by use of supersonic wave cavitation was patented[12].

— Cleaning effect of ultrafine bubbles for minute particle contamination on the wafers

Since the ultrafine bubbles have the smaller diameter below 1 µm, the contained air inside the bubbles would be compressed by the surface tension and the pressure inside the bubbles would be estimated larger than the atmospheric pressure. Therefore, by collapsing the ultrafine bubbles on the surface and by generating the pressure wave, the minute solid particles on the plate are expected to be removed from the surface.

Experimental research has been conducted to verify the cleaning effects of ultrafine bubbles. Consequently, minute particles, which had the diameter of about 50 nm and which were contained on the $SiO_2$ wafer, have been successfully removed from the wafer surface by impinging jet of ultrapure water containing ultrafine bubbles. By impinging ultrafine bubbles contained water jet for several tens of minutes, it was revealed that 98,9 % of particles were successfully removed in volume[11]. Utilization methods and apparatus of ultrafine bubbles were discussed systematically and various kinds of applications were patented[13].

— Shrinking microbubbles and ozone microbubbles

During the rising process of microbubbles which have the dimeter below 50 µm, the shrinking phenomena of microbubbles would occur in some cases and the generation of ultrafine bubbles would be estimated[14]. By use of ozone microbubbles the purification of water would become more effective for the smallest amount of ozone consumption. Various applications of the usage of ozone microbubbles have been tried and the actual proof tests have been made for the oyster farming. With the addition of some amount of electrolyte the microbubbles would be assumed to become bubbles with smaller diameter sizes below 1 µm[15].



 

— Transport of solar cell wafers, volume reduction of jellyfish disposal, vegetable cultivation and purification of soil

The generation devices of microbubbles have been developed from 1990 in several companies and some devices would have become to generate not only microbubbles but also ultrafine bubbles, of which diameters have been measured mainly between 100 nm and 200 nm, and have been measured at the first time in 2014[16]. The combination of microbubbles and ultrafine bubbles and in some cases the ultrafine bubbles have been used to promote the transport of solar cell wafers and to promote the volume reduction of disposed Jellyfish accumulated at the power plant cooling seawater system. Furthermore, the strawberry plants have been promoted to become higher quality as the example of successful applications of vegetable cultivation and the purification of soil has been realized by the liquid jets containing microbubbles and ultrafine bubbles. As the application to the field of food manufacturing the introduction of Sansho-pepper flavor to water has been realized by using ultrafine bubbles containing Sansho-pepper flavor[17].

— Cleaning of toilets in expressway service stations, cleaning of salt-stained bridges

In 2011, the cleaning of toilets in expressway service stations and parking areas by using the ultrafine bubbles started at the western part of Japan. The cleaning method of toilets and floors in restrooms using the ultrafine bubbles was to use the sprayed ultrafine bubbles contained water on the floor and on the toilets and to wipe the floor with the mop. Before the introduction of ultrafine bubble technology, the floor and the toilets have been cleaned by scrubbing with brushes and washing water and by absorbing the washing water with the vacuum. Therefore, the total amount of water consumption has been decreased to 1/100 and the usage of detergent has been decreased to 1/3 and the necessary cleaning time has been saved by 40 %. Due to these tremendous effects the cleaning method of toilets and restrooms using ultrafine bubbles have been spread and about 90 % of the western part expressway restrooms has become to use the ultrafine bubble technology in 2018.[18] The bridges along the expressway have been sprinkled by the salt in the winter season for dissolving the ice on the surface of the road. Therefore, in the spring season the bridges should have been washed to remove the salt from the surface of the bridges for preventing the deterioration due to the rust. For removing the salt from the bridge surface the usage of the ultrafine bubbles has been successfully used and the necessary time for removing the salt from the surface has been shortened to below 1/4 with the usage of water jet containing ultrafine bubbles[19].

— Cleaning and sanitizing of vegetables, enhancement of vegetable growth, promotion of seed germination

Vegetables washed with fine bubbles contained water would become more resident to food-borne pathogens than vegetables washed with normal water, which had been experimented in Thailand. Using fine bubble technology for vegetable would have reduced the microbial load on the surface of incoming produce or residual pesticide which impact the product's quality, self-life and safety[18][20]. The enhancement of growth of hydroponically grown lettuce by use of ultrafine bubbles contained water has been experimentally conducted in the large scale Japanese national project. By measuring over thousand stems of the lettuce, the 20 % enhancement of the lettuce has been actually obtained in weight for five weeks which would be the normal period for the harvest[21]. The promotion of the germination of barely seeds has been experimentally conducted to prove the enhancement of 46 % for the germination rate, which would meant that the necessary time would be shortened from 73 hours to 39 hours for 50 % germination[22].

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