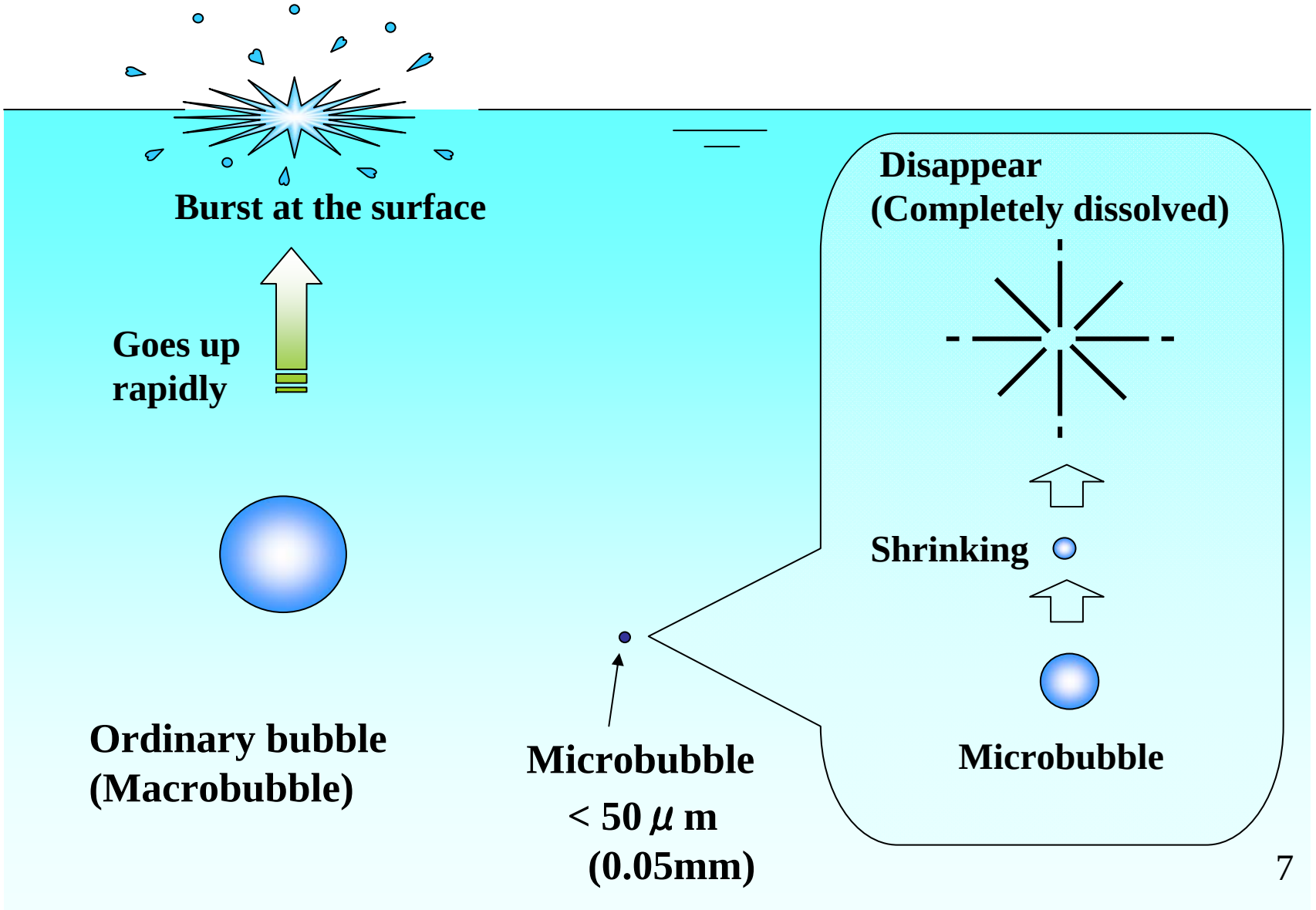
Fantastic properties of Microbubbles

AIST　Dr.Masayoshi Takahashi

Contents of the presentation

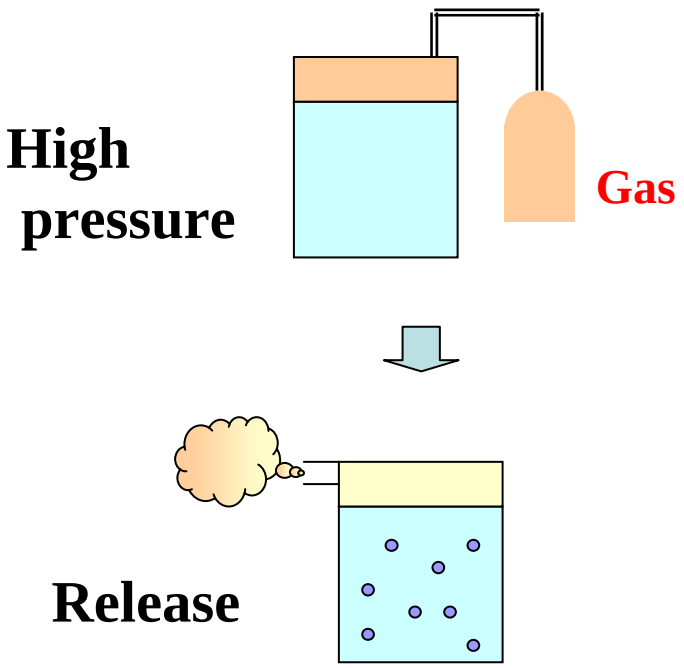
- Fundamental properties of microbubble
- Gas hydrate formation
- Water remediation
- Waste water treatment

---- What is microbubble ? ----

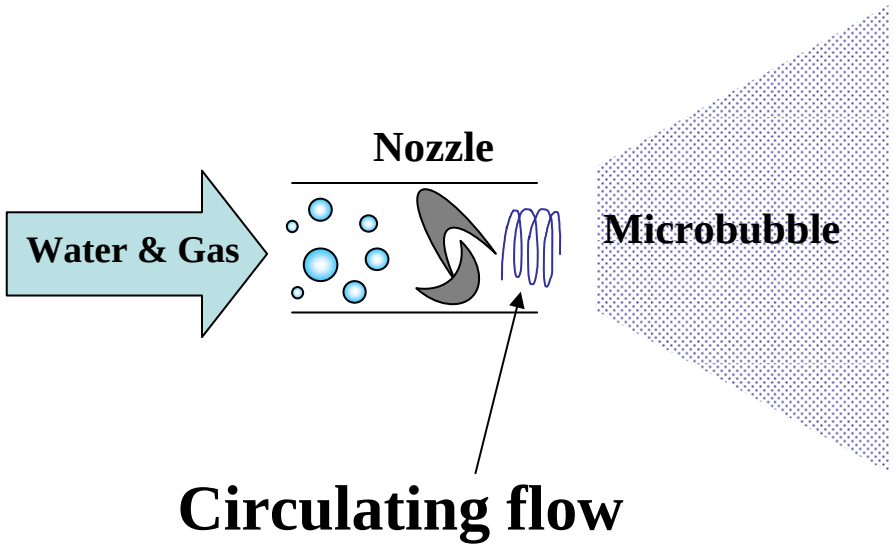


How to make microbubbles （Examples）

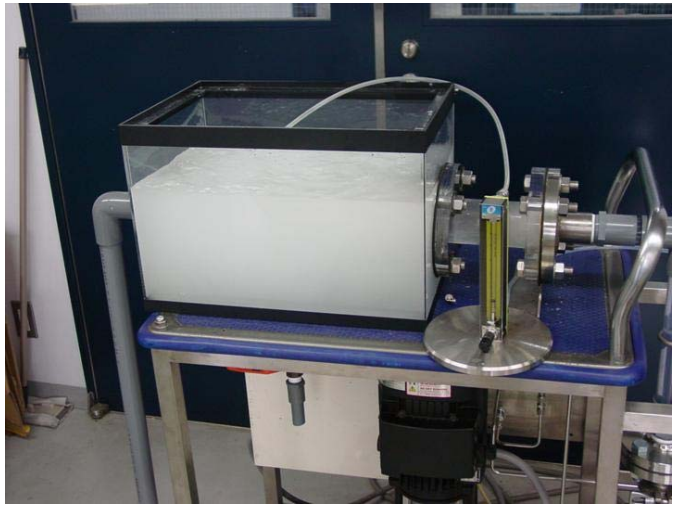
Dissolved gas type



Hydrodynamic Type

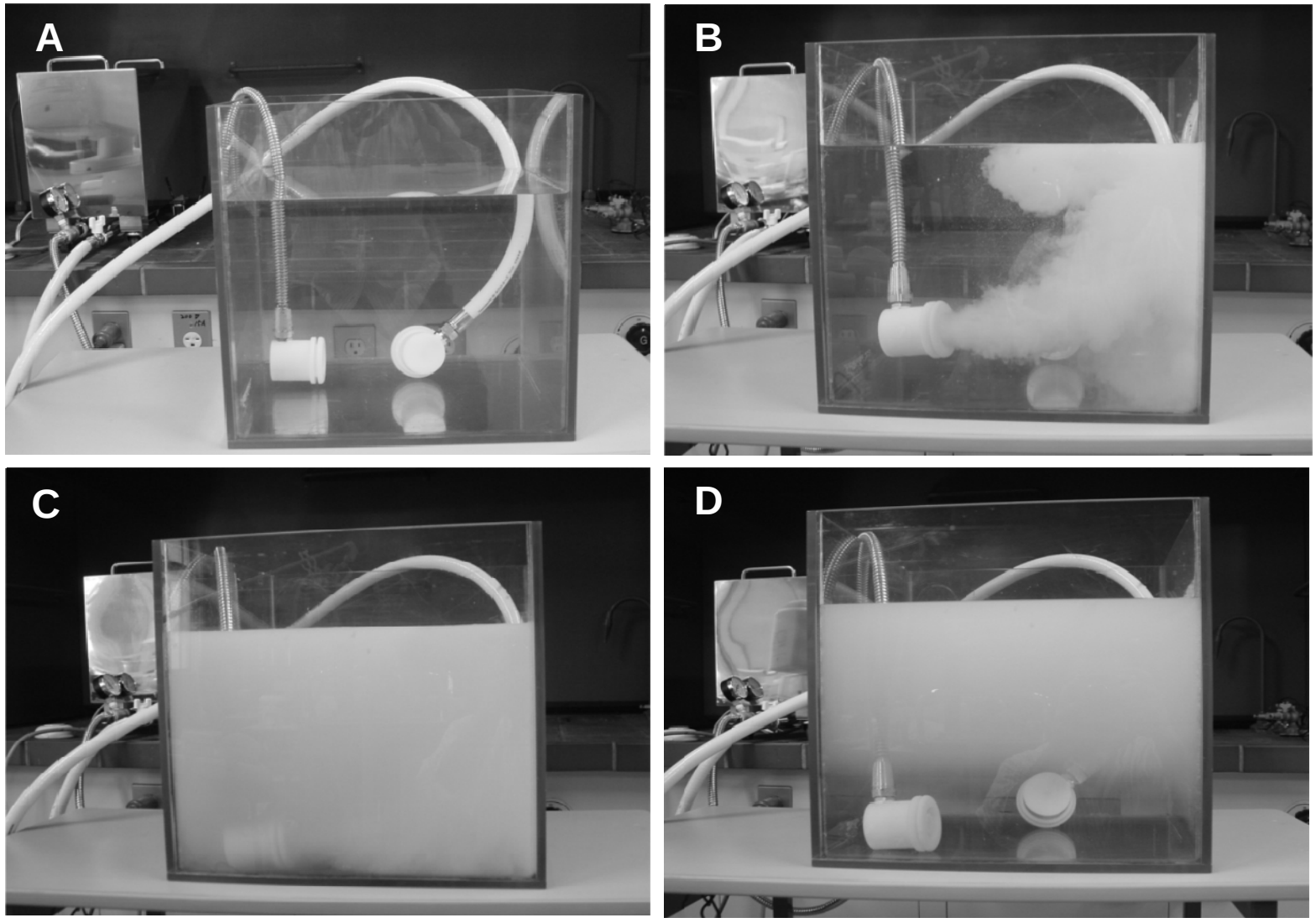


Hydrodynamic type (High density type)

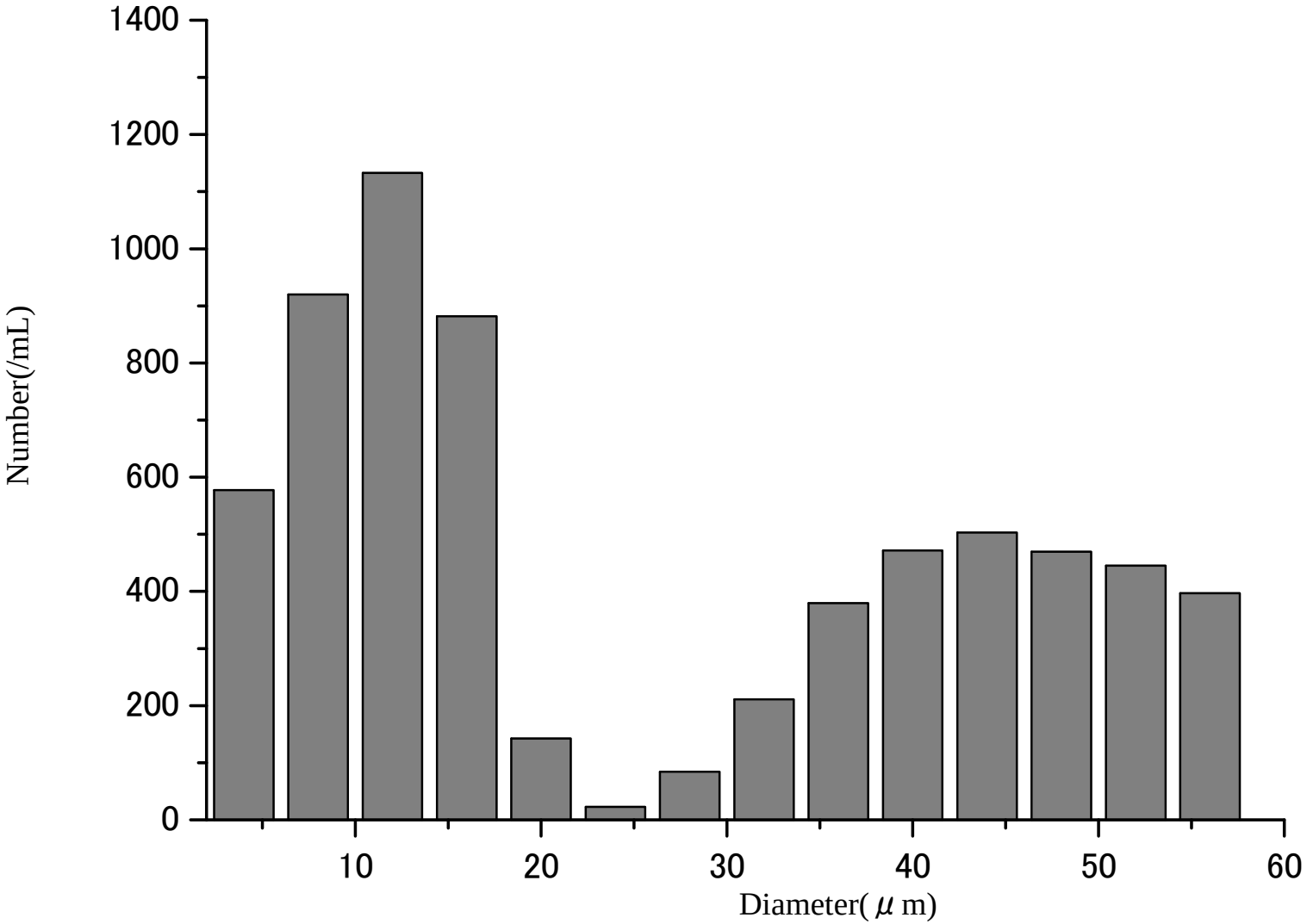


distilled water

Dissolved gas type



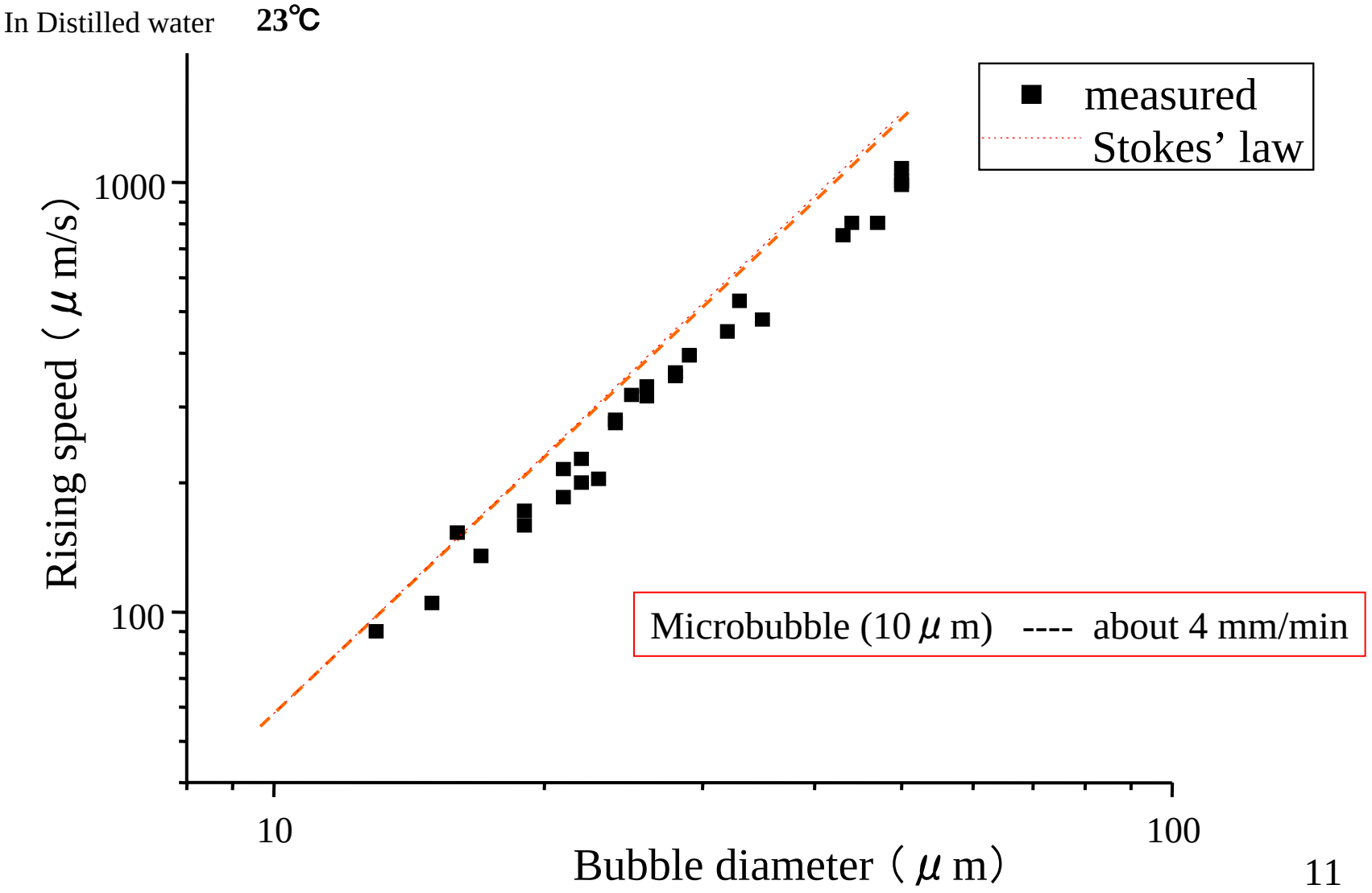
Bubble-size distribution (High density type)



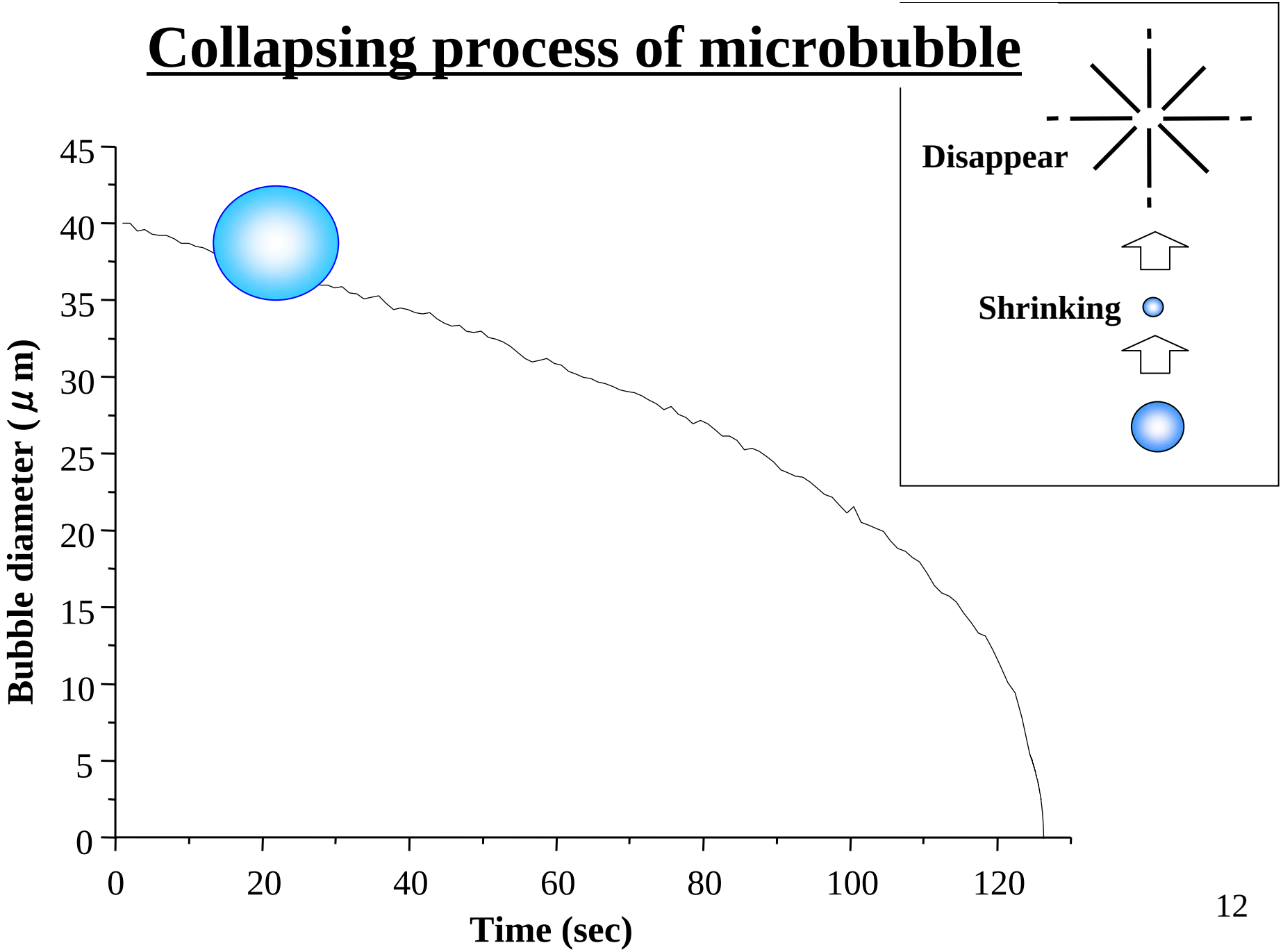
-- Distilled water --

(by a liquid particle counter)

Rising speed of microbubbles



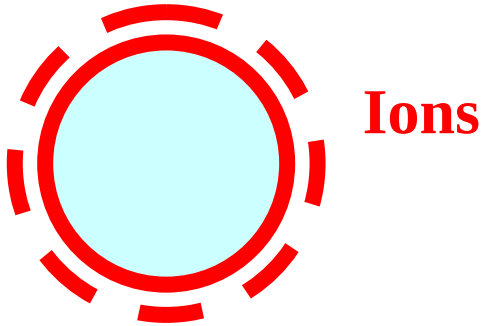
Collapsing process of microbubble



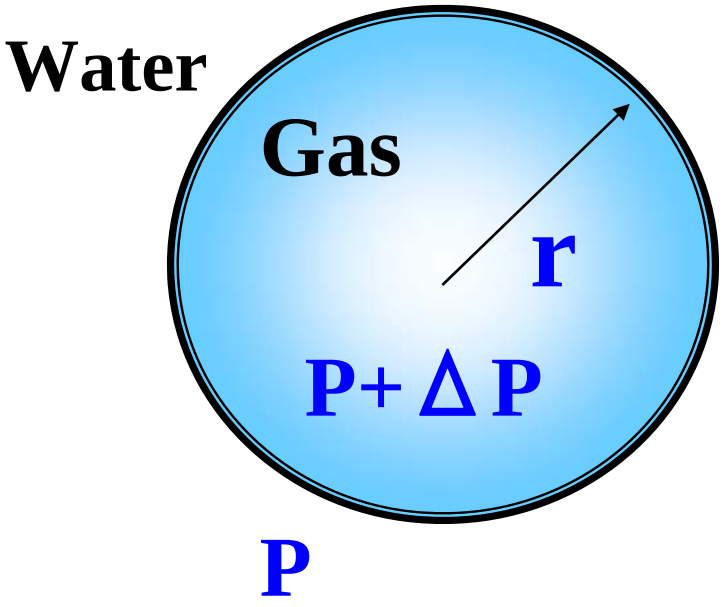
Fundamental properties of microbubble for practical application

1. Increase in interior gas pressure

2. Increase in ion concentration around the gas-water interface



1. Increase in interior gas pressure

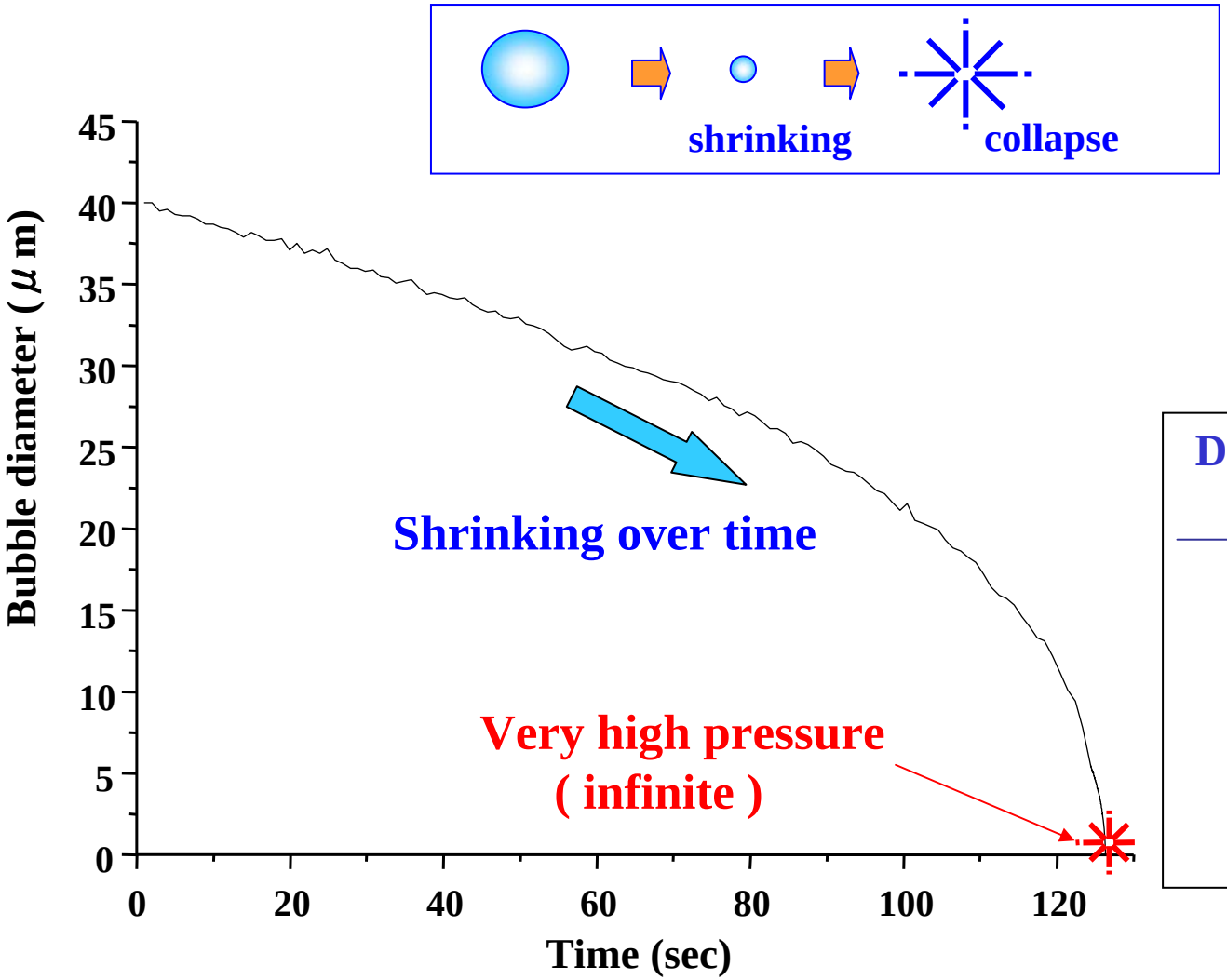


Surface tension

Young-Laplace equation

$$\Delta P = 2\sigma / r$$

Increase in interior gas pressure

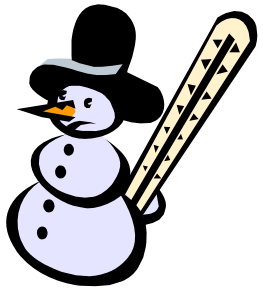


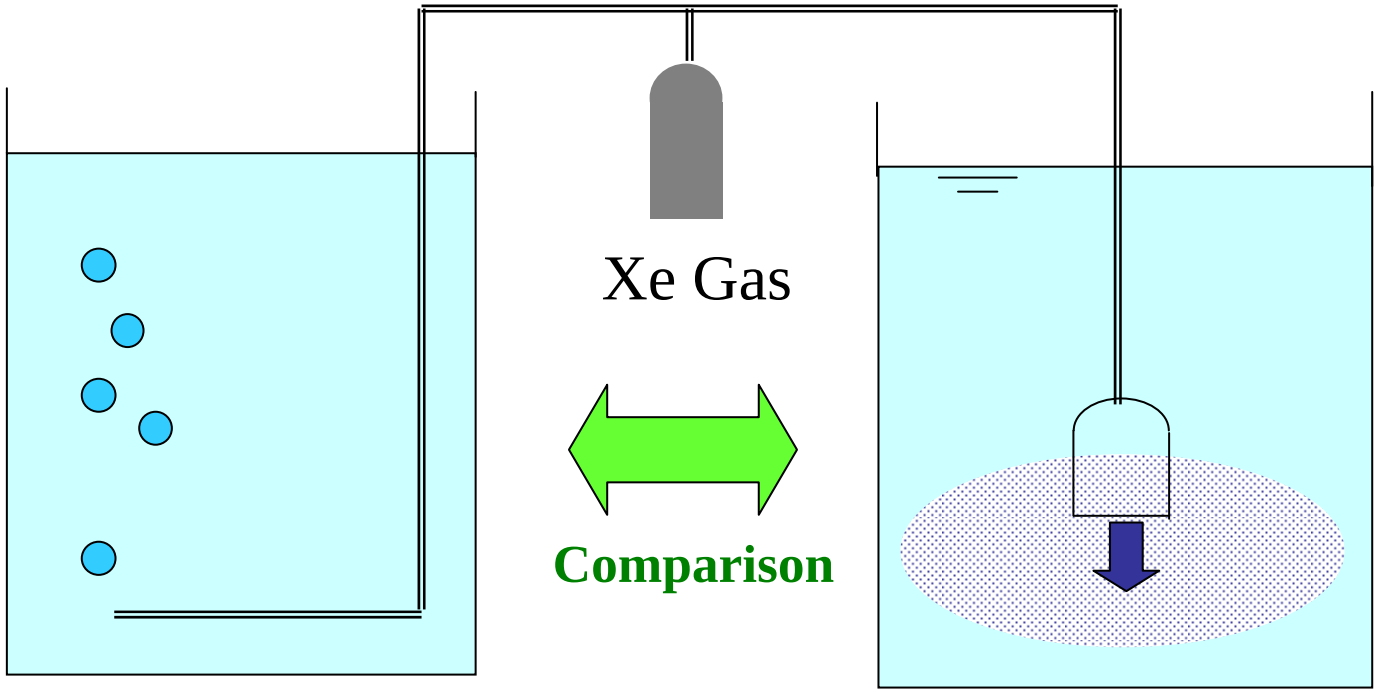
Diameter μ m	ΔP atm
10	0.3
1	3
0.1	30
↓	↓
0	∞

Gas hydrate formation

Gas hydrate = Ice-like material (with gas molecule)

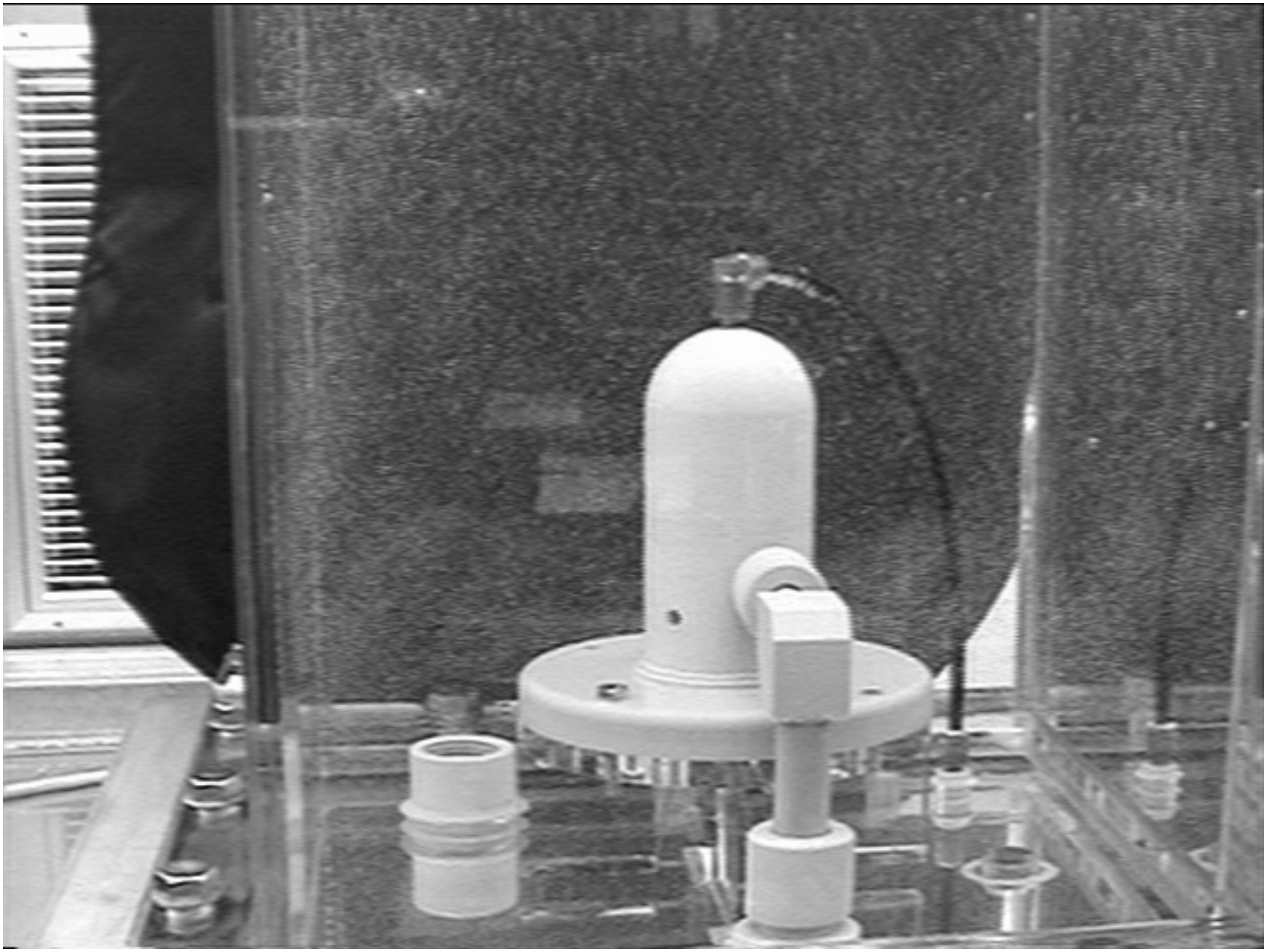
--- Low temperature / High pressure ---



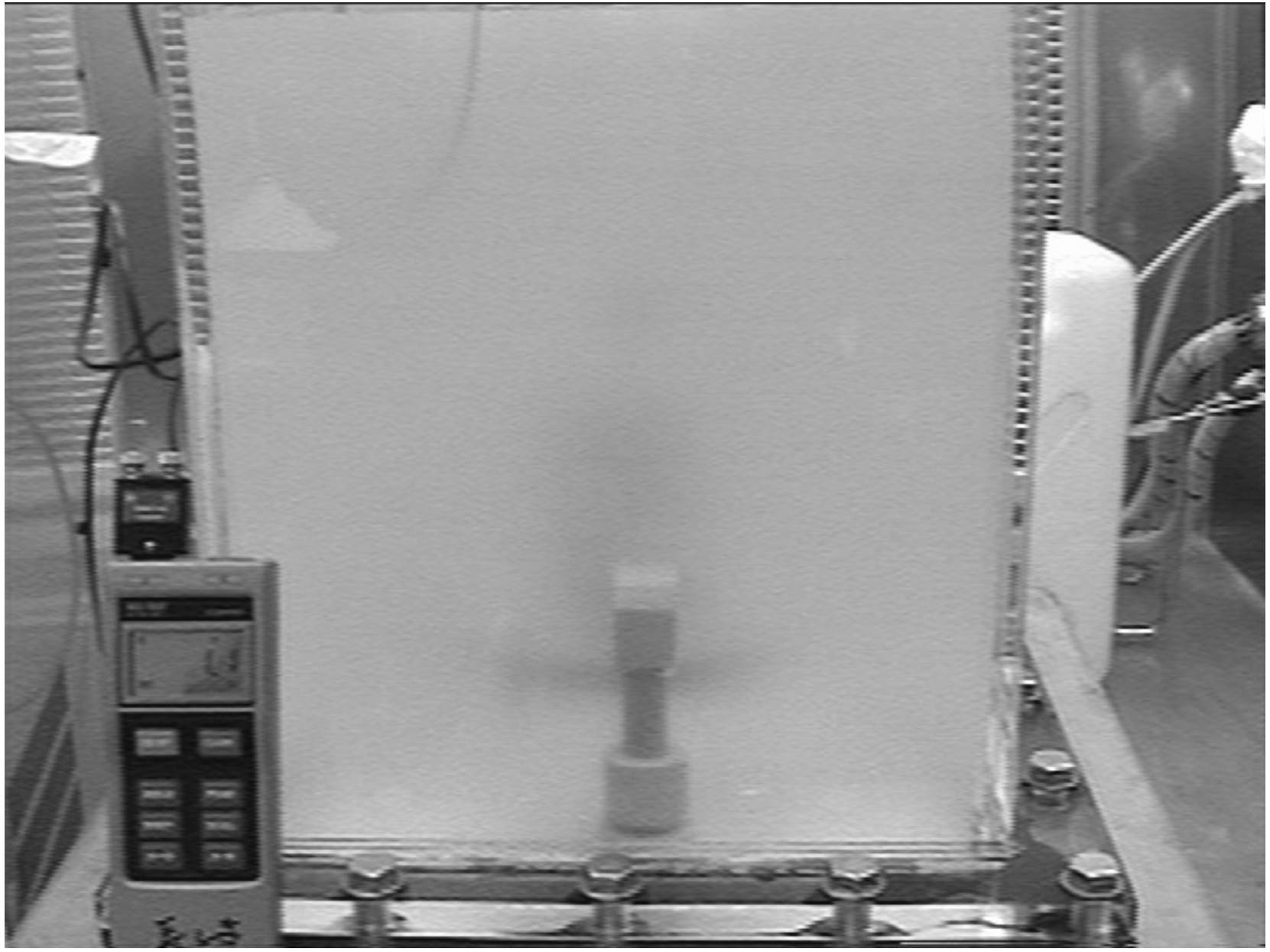


Normal bubble
(Conventional)

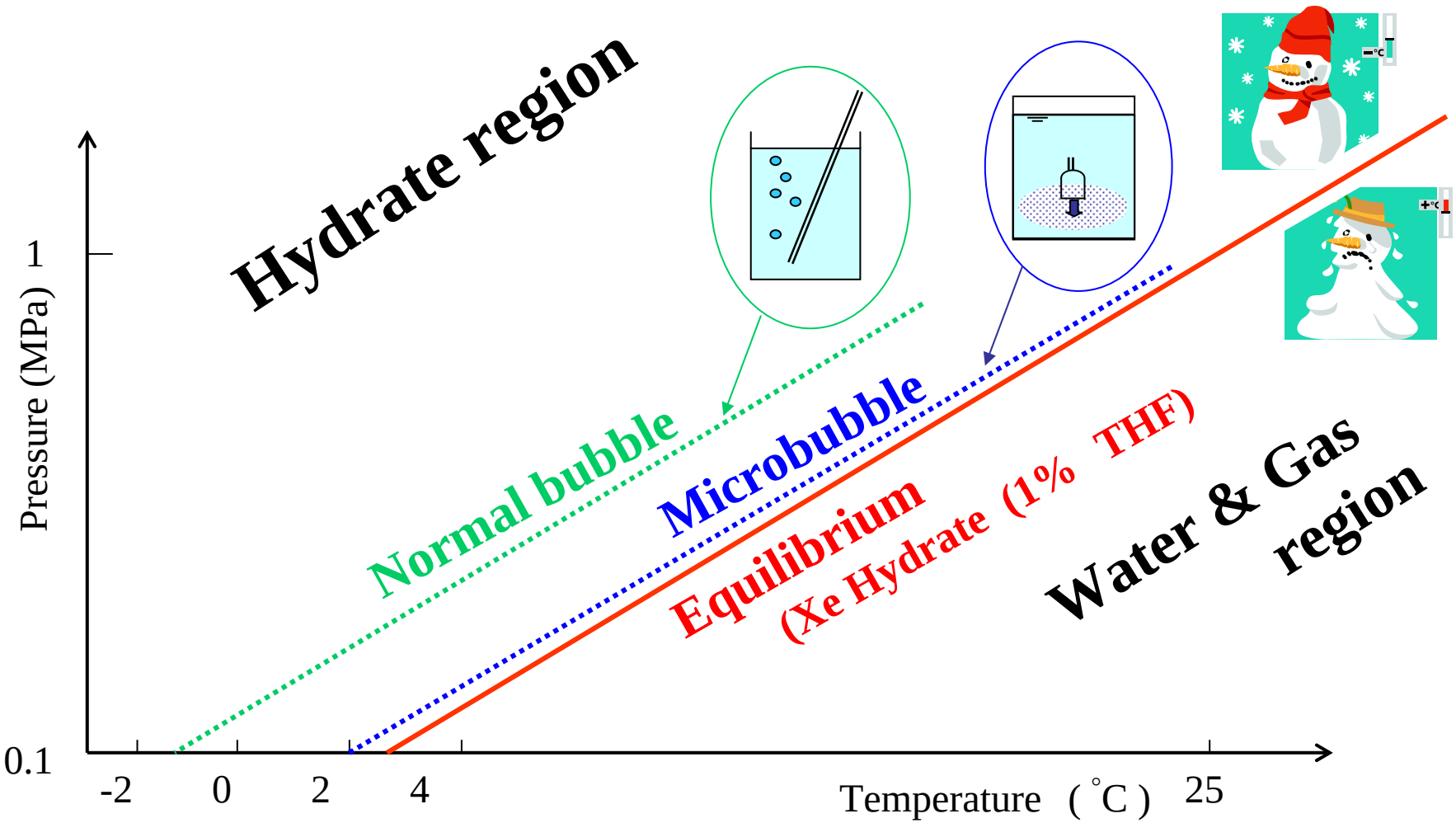
Microbubble



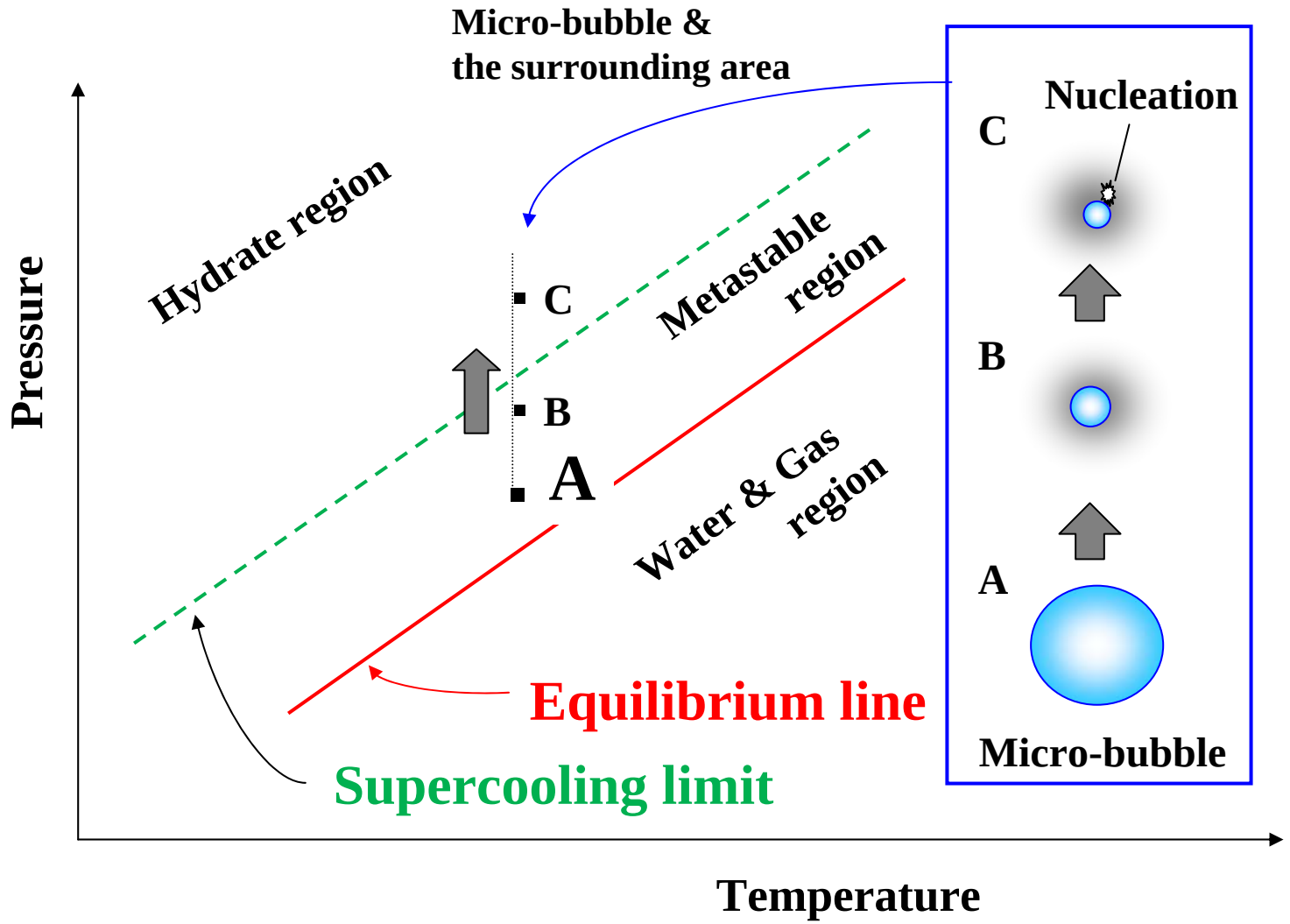
Temperature = 3 ºC / 1 Atm.



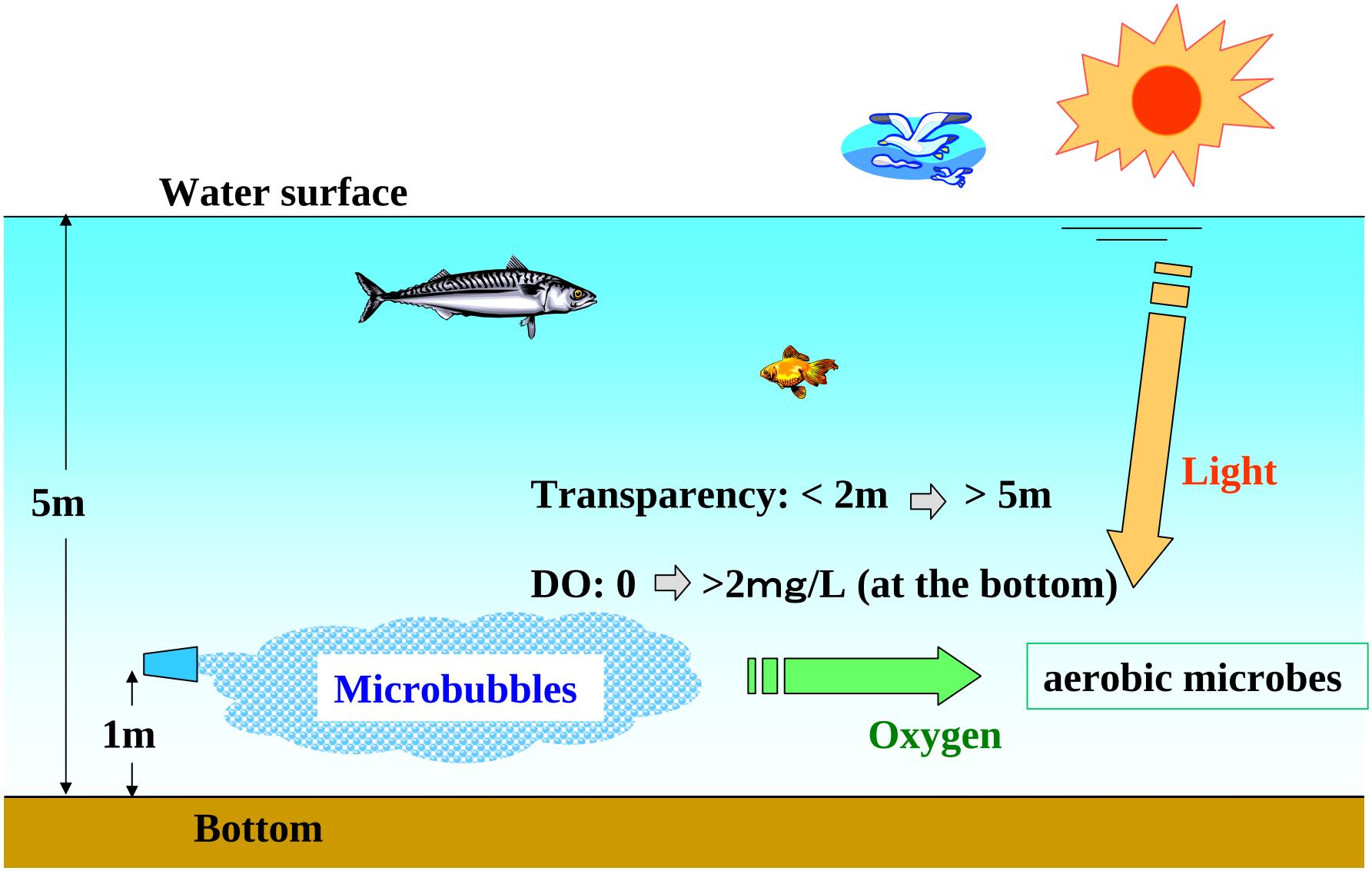
Temperature = 1.1 ºC / 1 Atm.



Pressure – Temperature diagram of Xe hydrate


Micro-bubble &
the surrounding area
Nucleation
C
B
A
Micro-bubble
Hydrate region
Metastable
region
Water & Gas
region
Equilibrium line
Supercooling limit
Pressure
Temperature

Remediation of water environmental by microbubble



Environmental remediation

Shio-Ashiya Port (Osaka bay area, Japan)

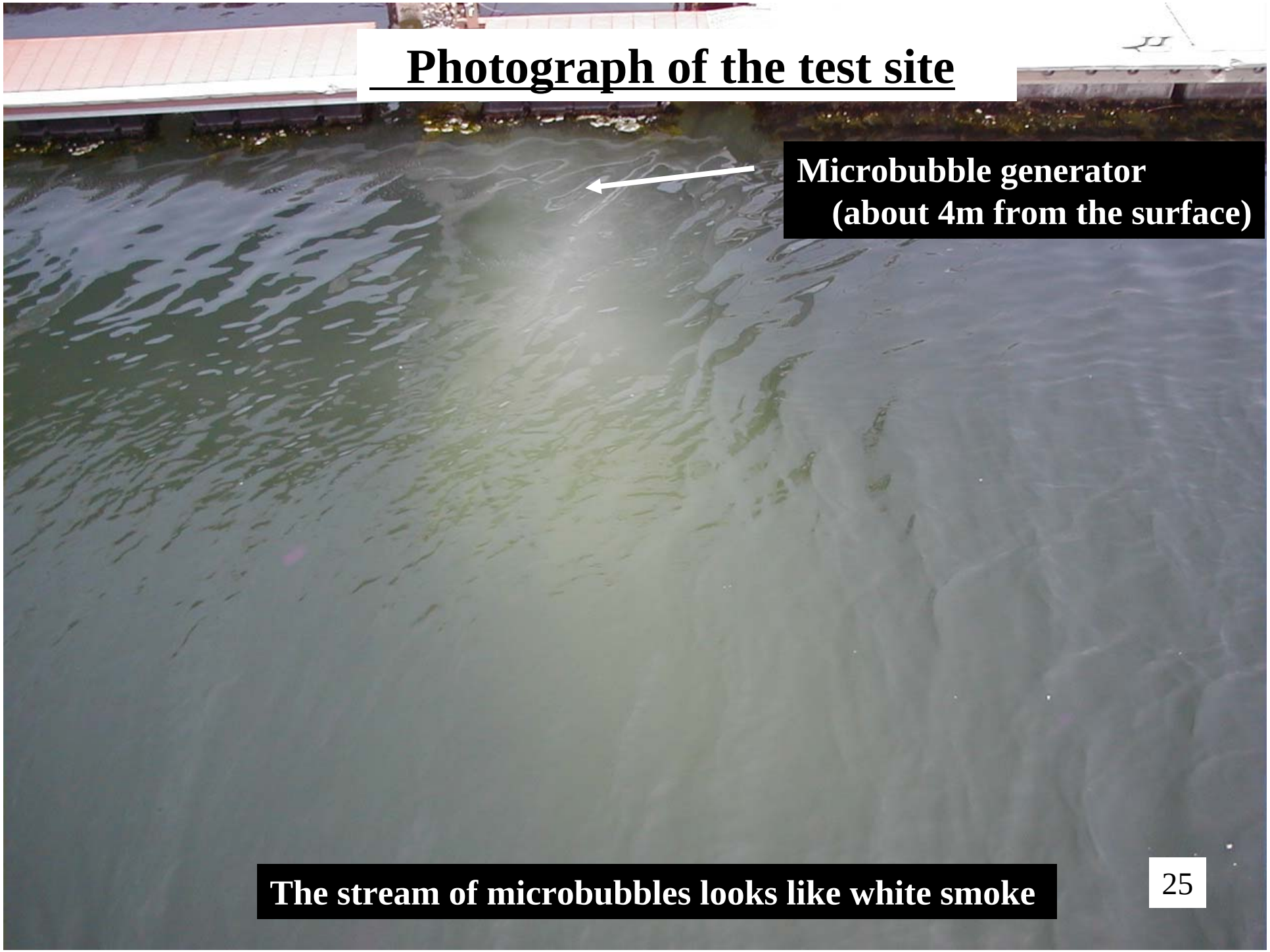
Microbubble generator for this test

Power :1.5 kW Water flow : 400L/min. Air supply : 10L/min.

The microbubble generator under sea

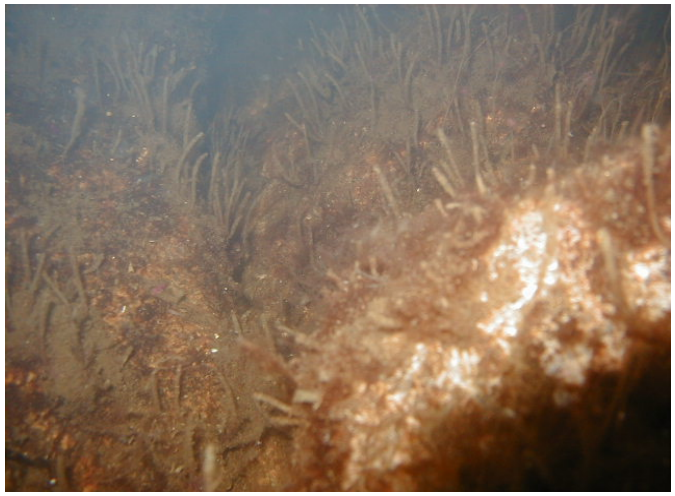
about 4m from the surface (1m from the bottom)

Photograph of the test site

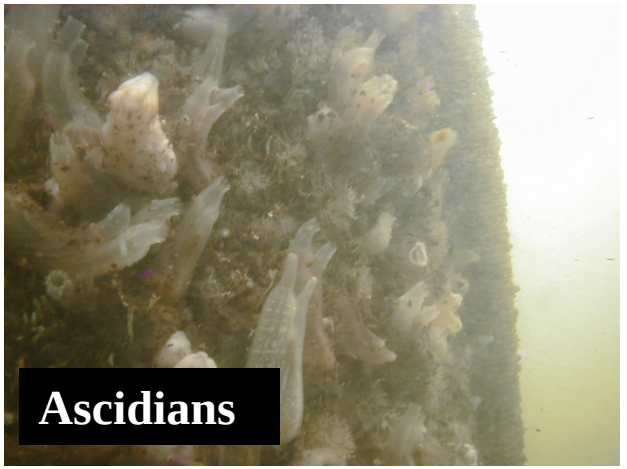


Before and after the microbubble treatment

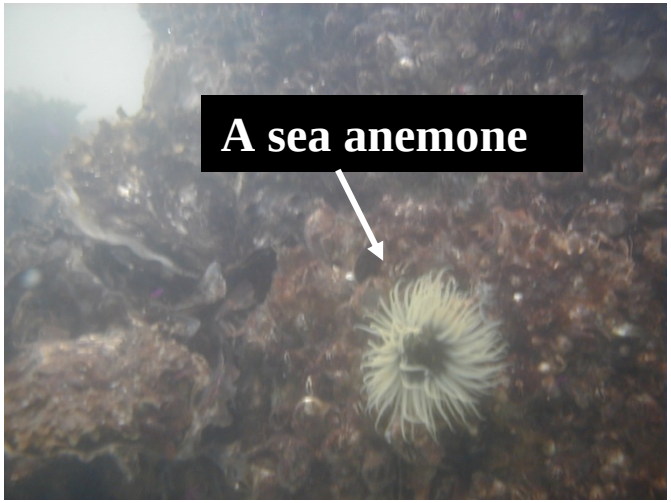
At the bottom of the sea (-5m)



Before / The world of death (with flash light)



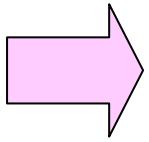
After about 3 months (without flash light)



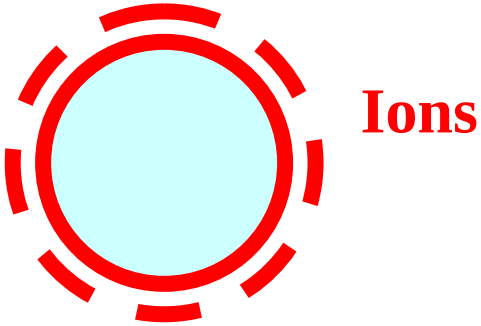
Fundamental properties of microbubble for practical application

1. Increase in interior gas pressure

2. Increase in ion concentration around the gas-water interface

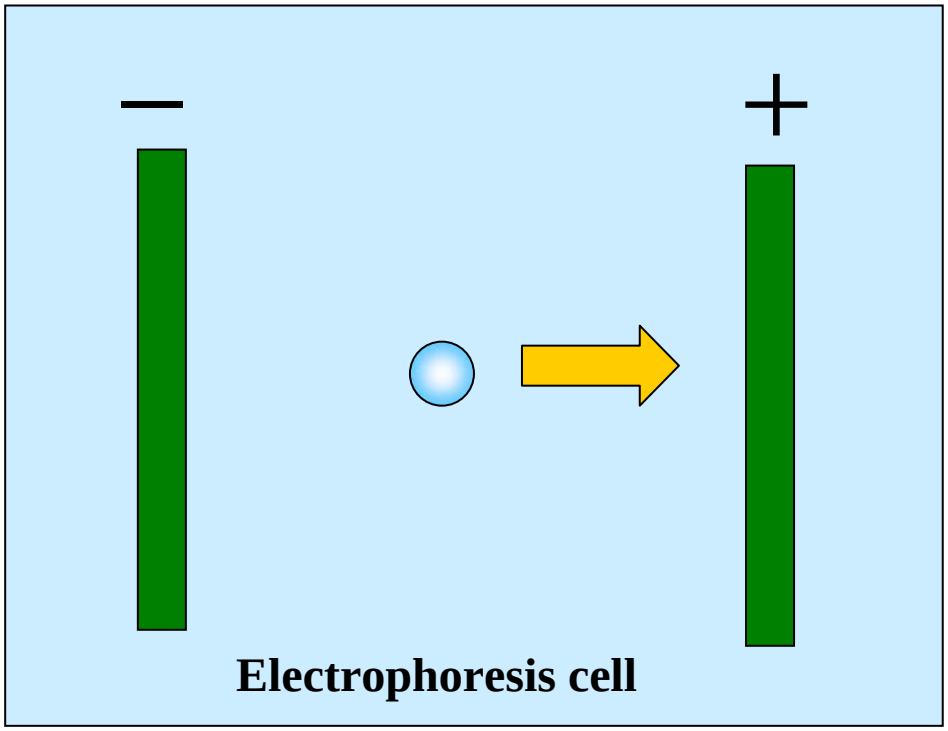


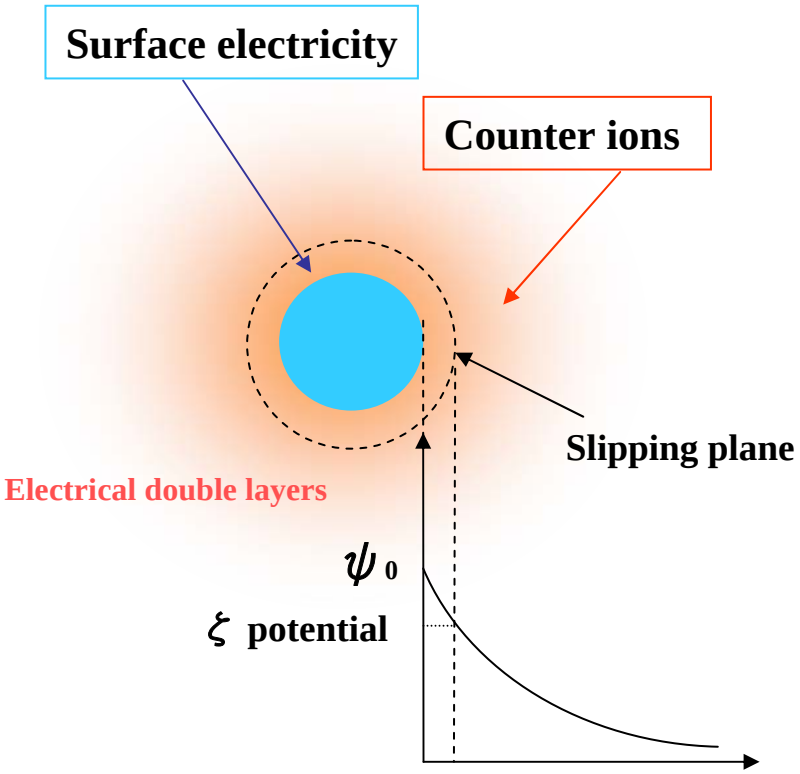
- Generation of free-radicals
- Generation of Nano-bubble



Electrical property of microbubble

ζ potential





Smoluchowski's equation

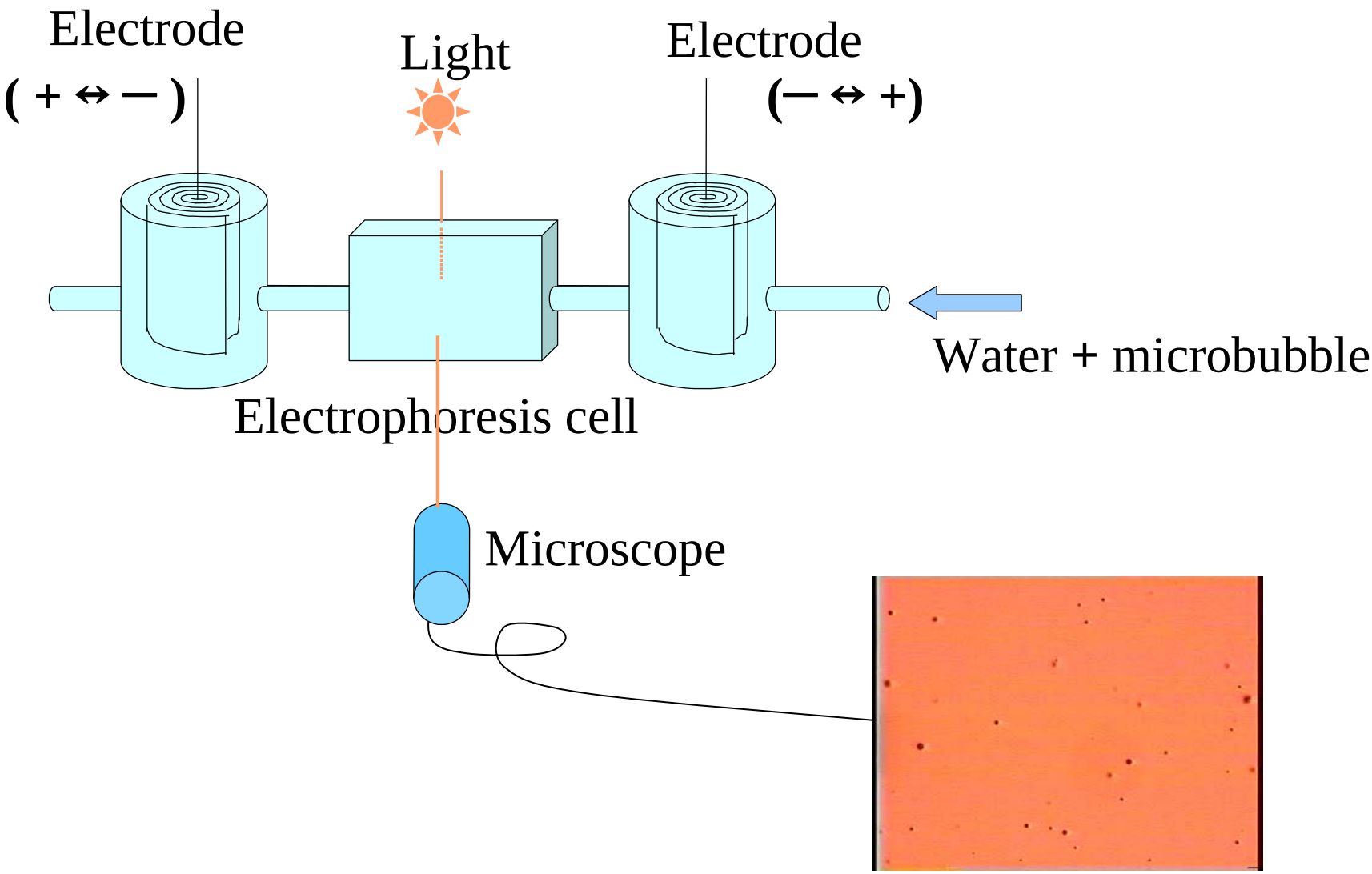
$\zeta = \eta \mu / \varepsilon$

μ : the mobility ($m^2s^{-1}V^{-1}$)

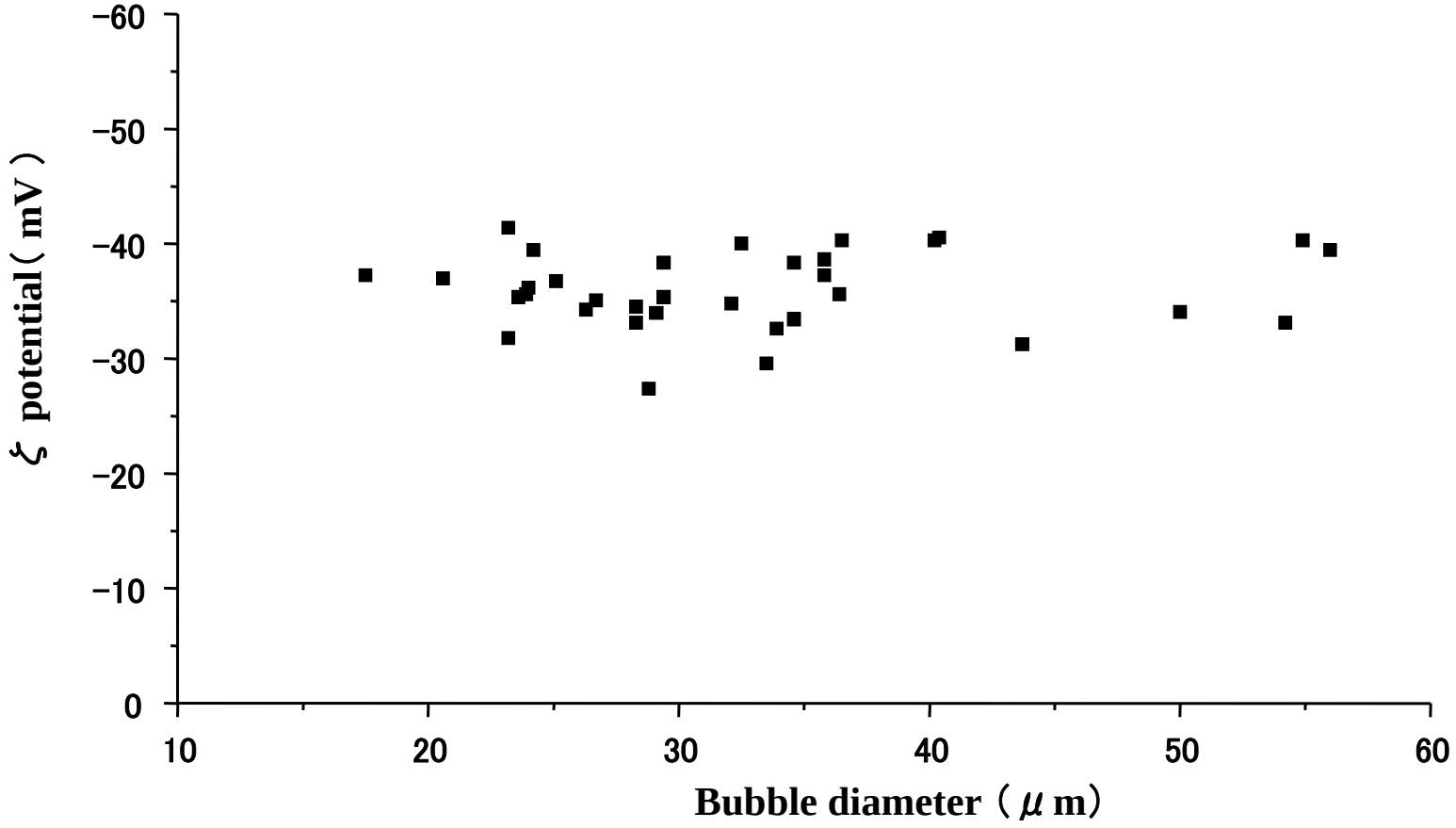
ε : the dielectric constant ($JV^{-2}cm^{-1}$)

η : the viscosity of water ($gcm^{-1}s^{-1}$)

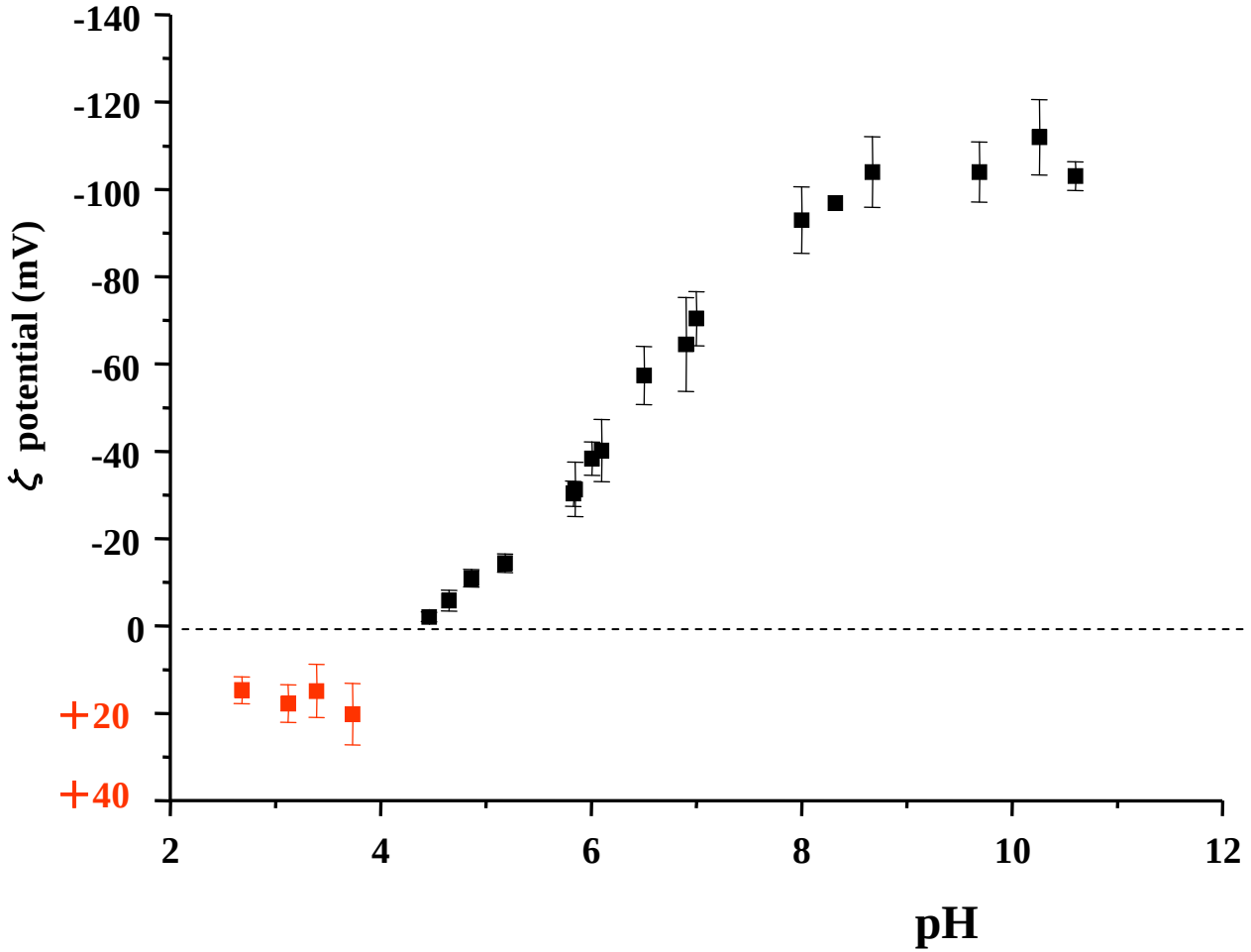
Movement of microbubbles in electrophoresis cell



ζ potential of microbubble in distilled water

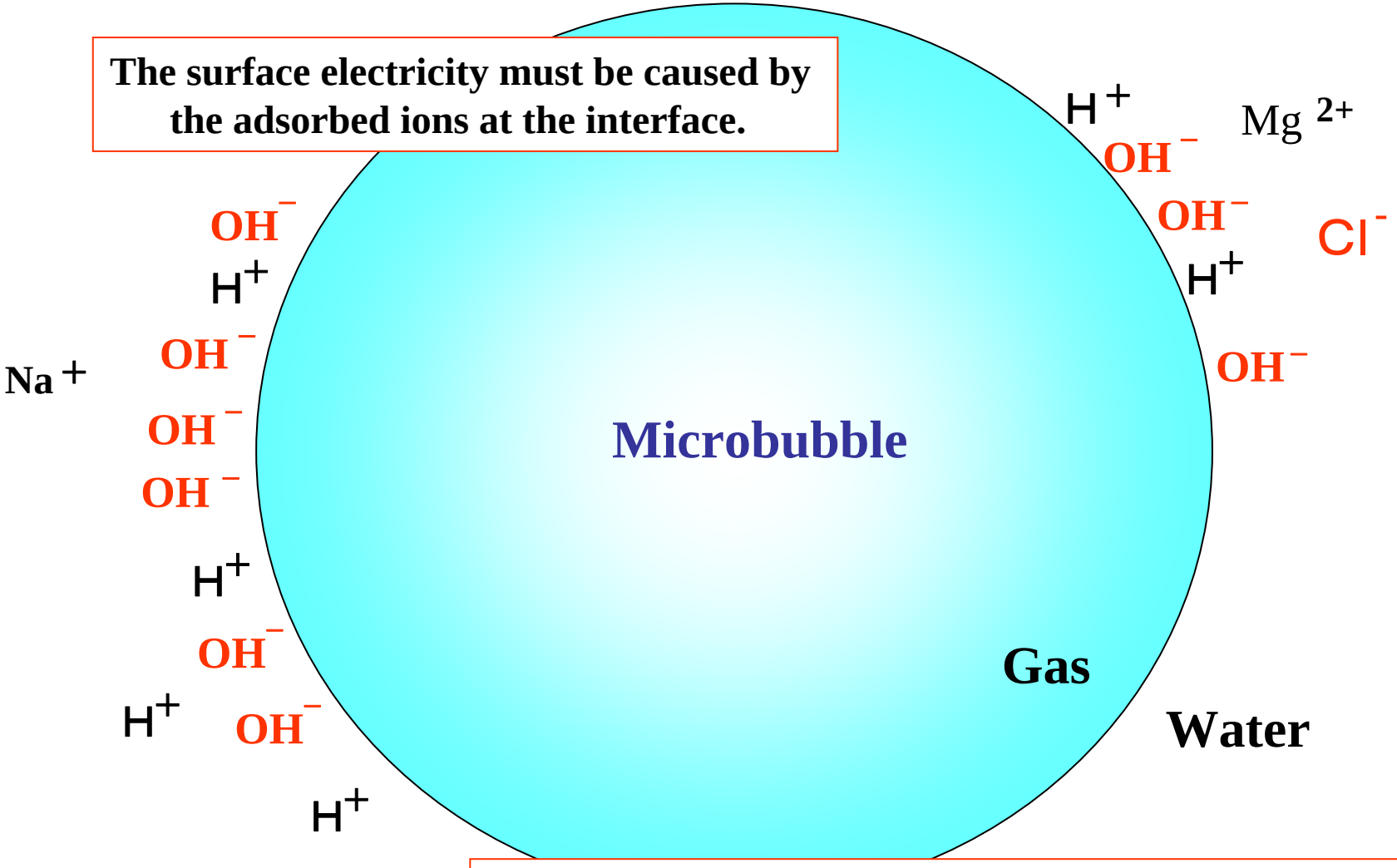


The relationship between ζ potential and pH of the water

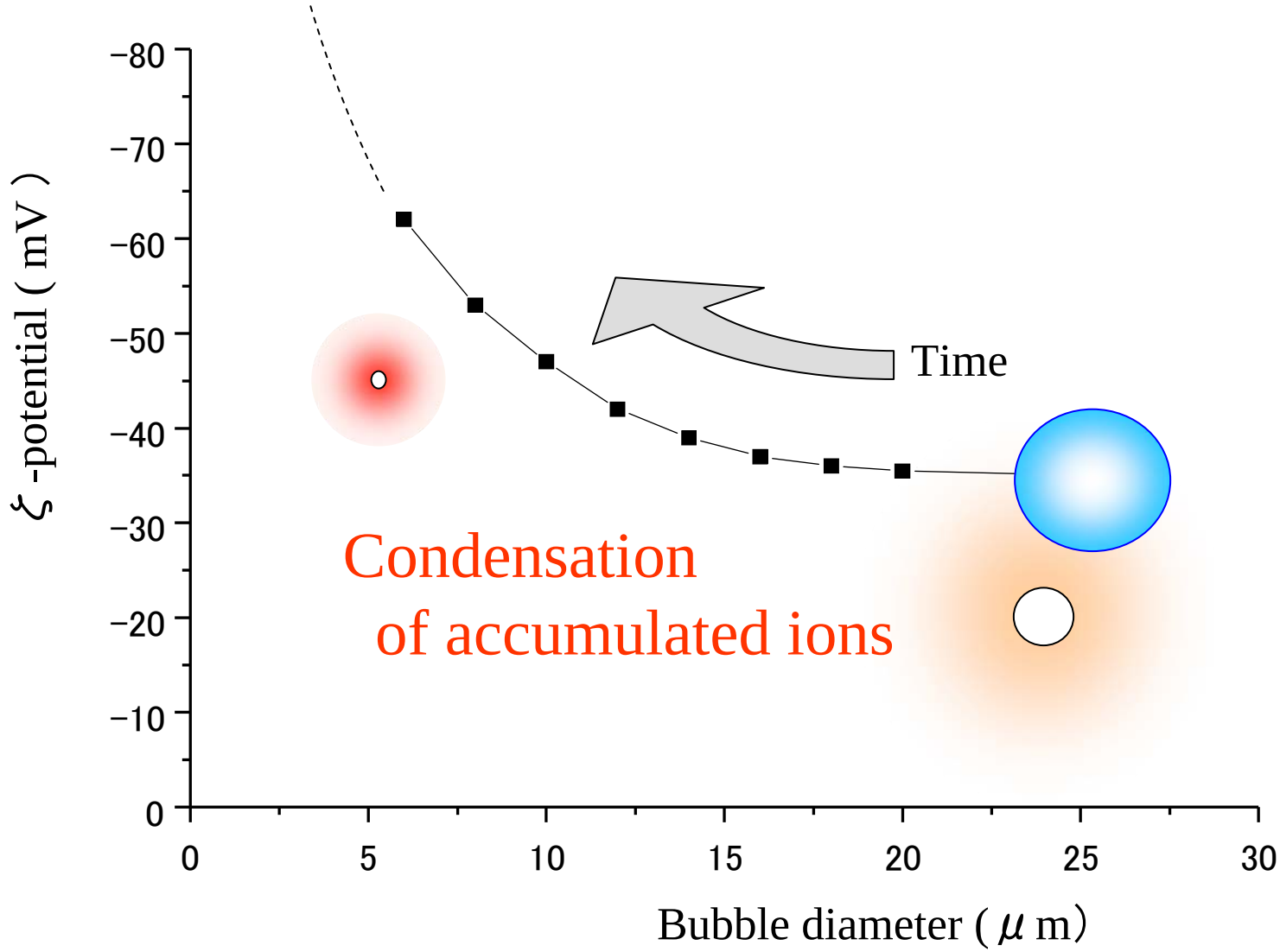


(adjustment by NaOH and NaCl)

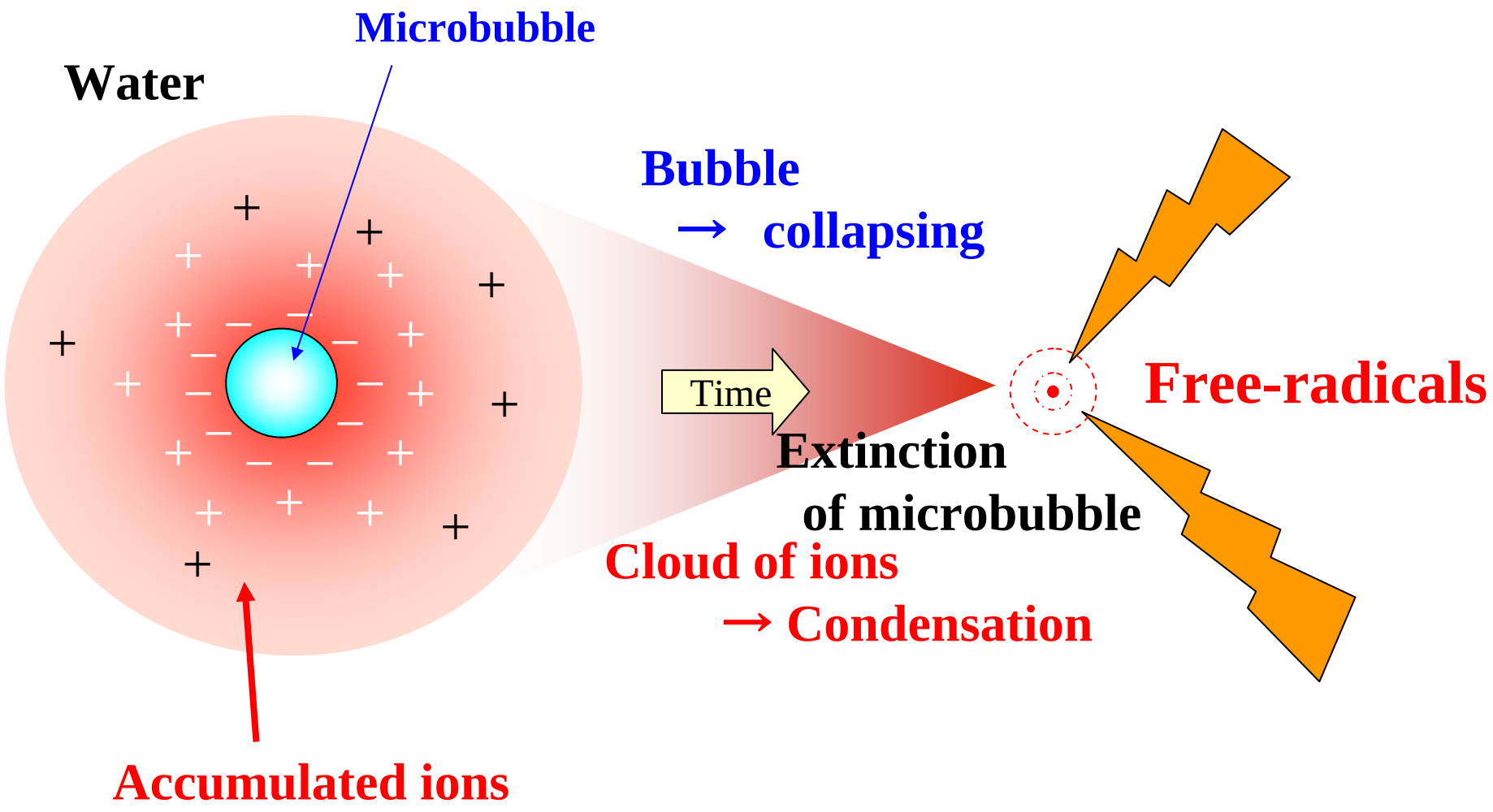
Mechanism of bubble electricity



Change in ζ potential of microbubble during collapsing process



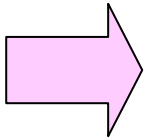
Free-radical generation by collapsing microbubble



Fundamental properties of microbubble for practical application

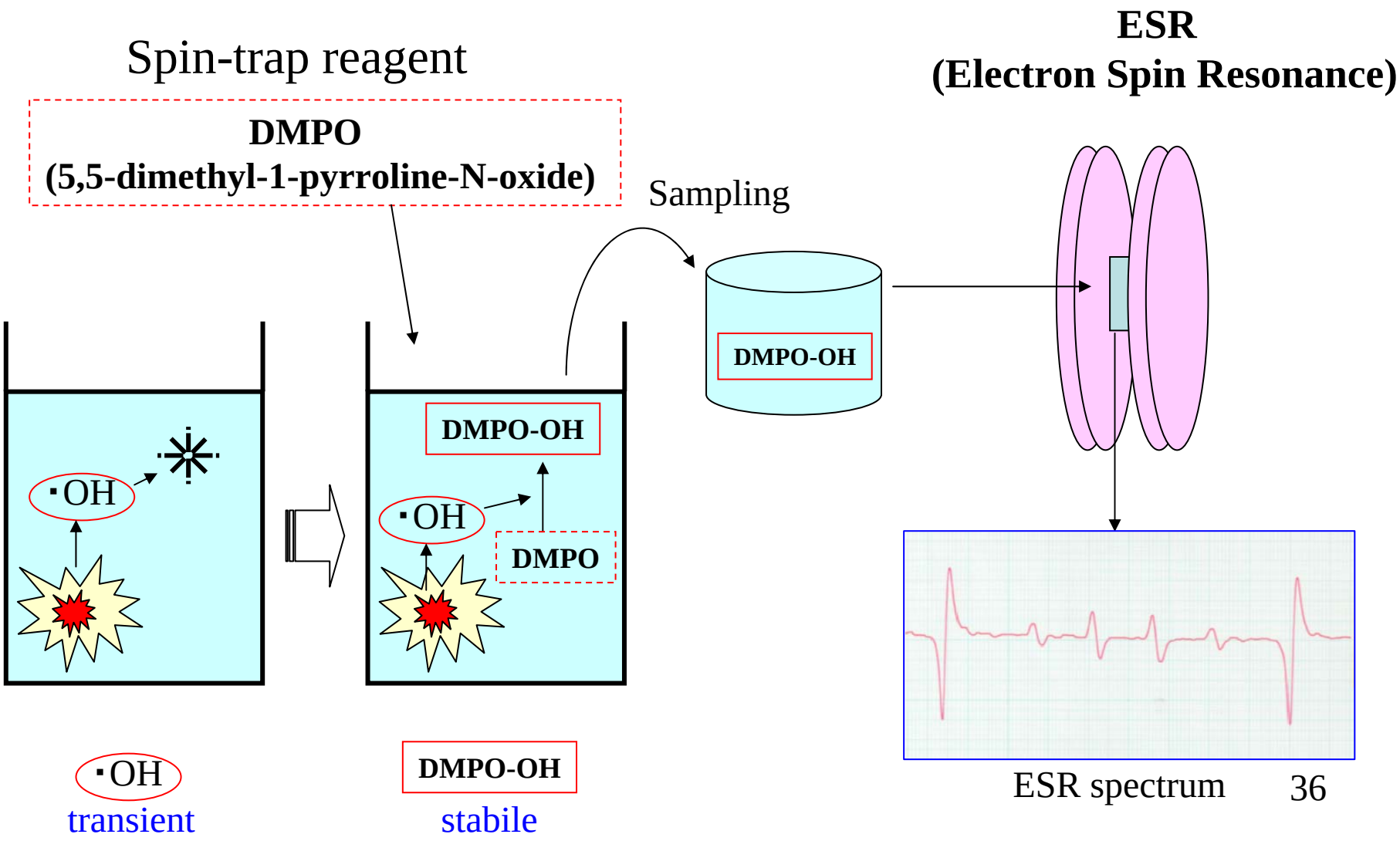
1. Increase in interior gas pressure

2. Increase in ion concentration around the gas-water interface

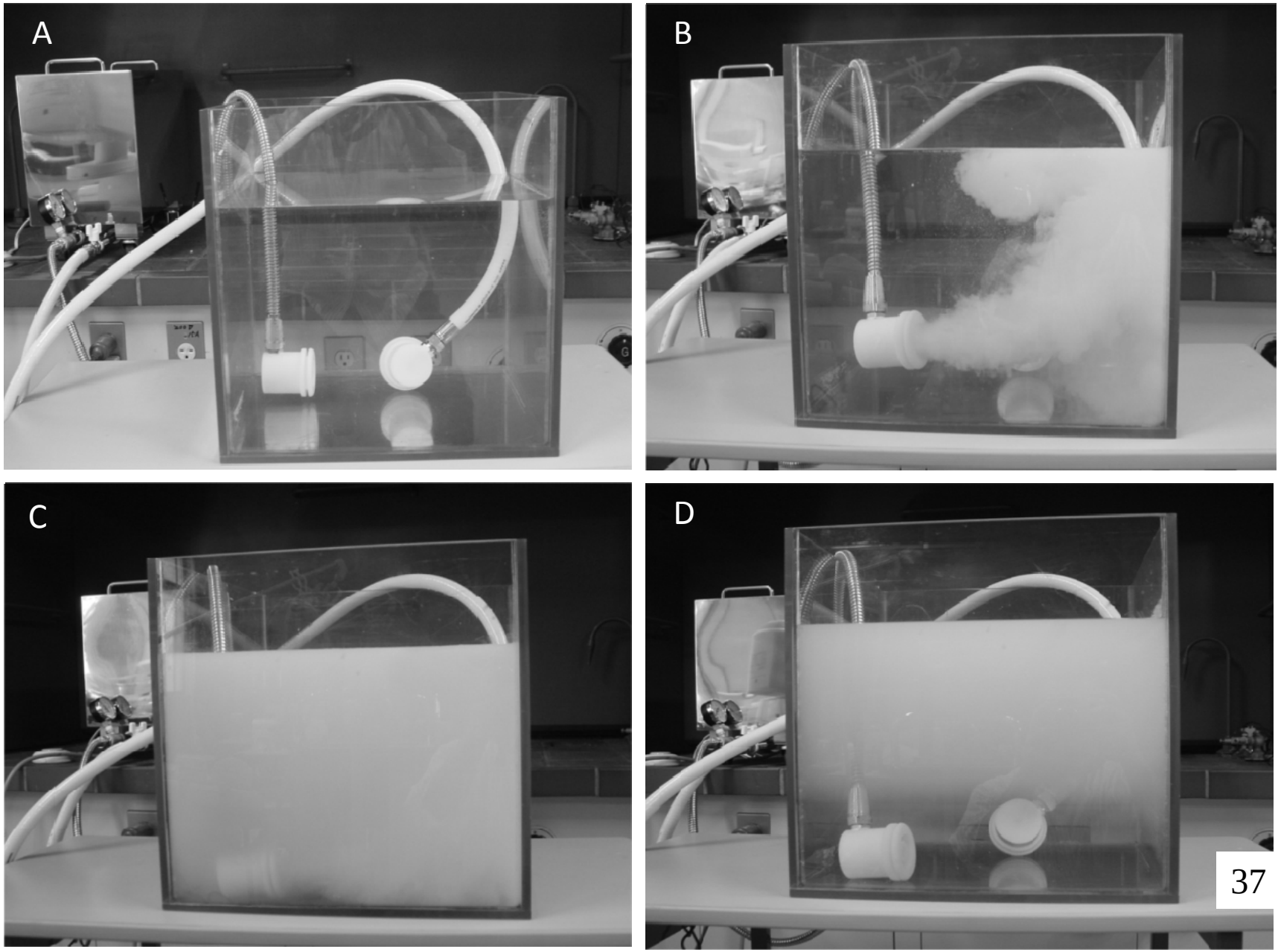


- **Generation of free-radicals**
- Generation of Nano-bubble

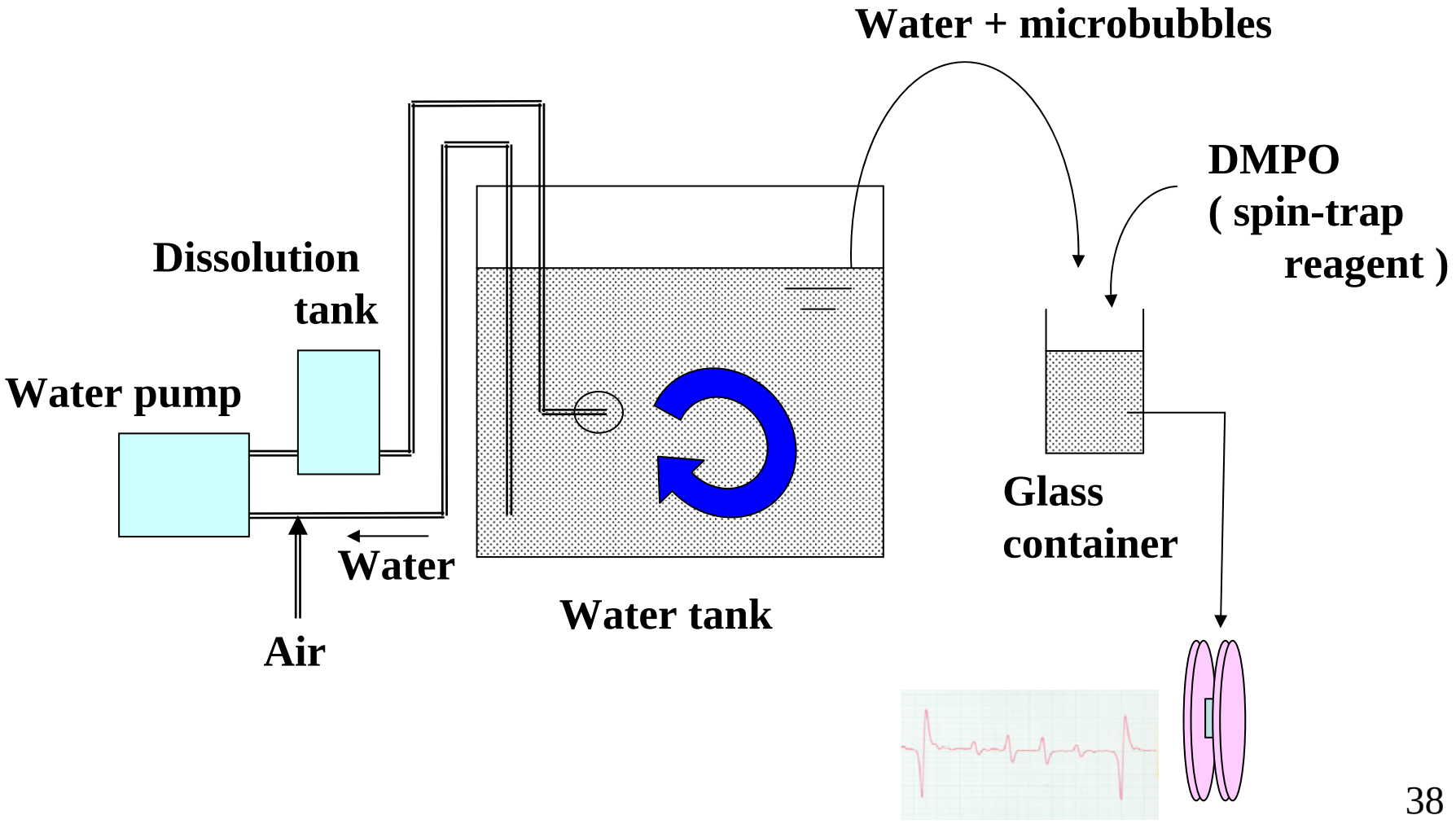
Measurement of free-radicals by ESR



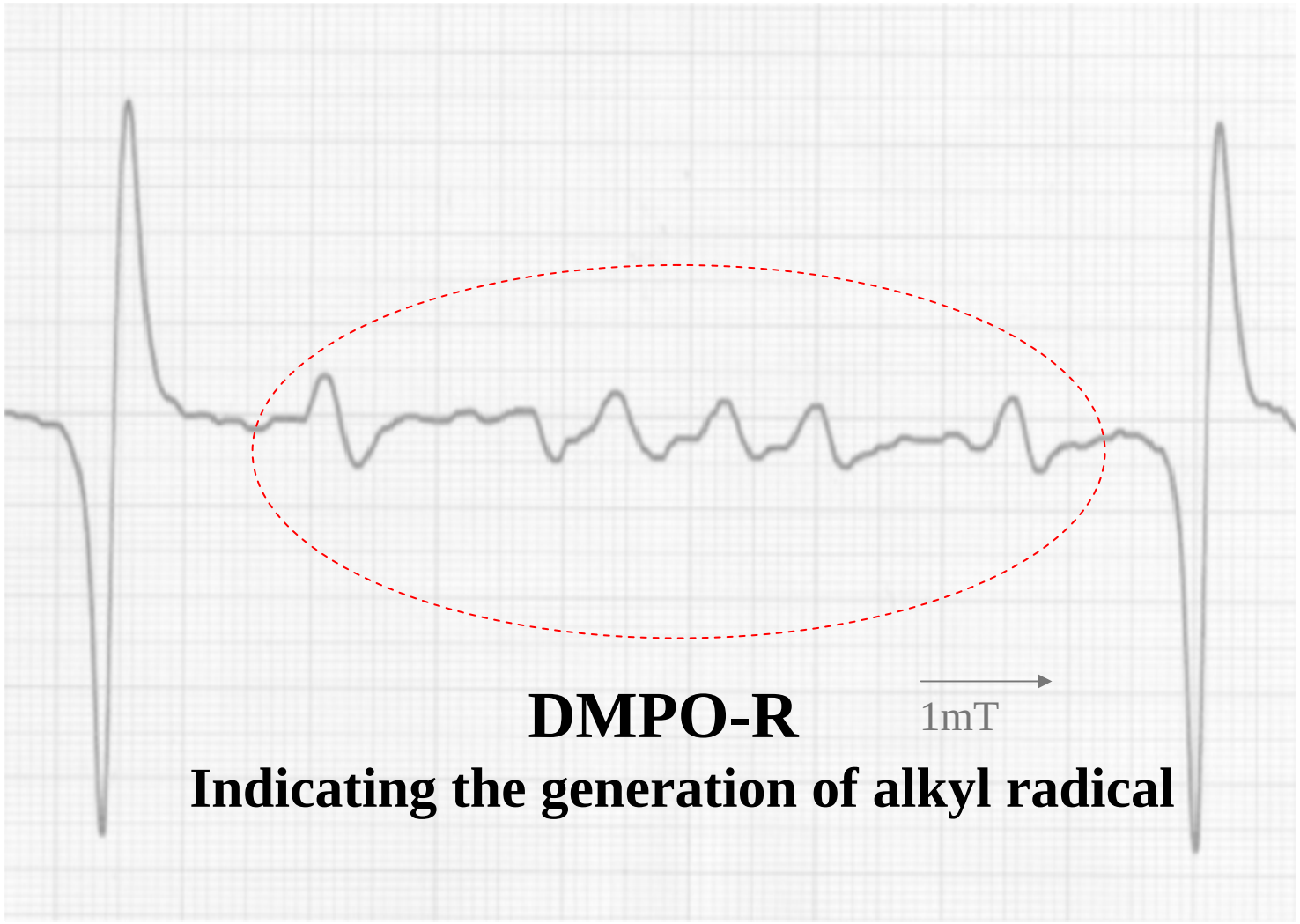
Free-radical generation during collapsing process of microbubble



Experimental setup of radical generation

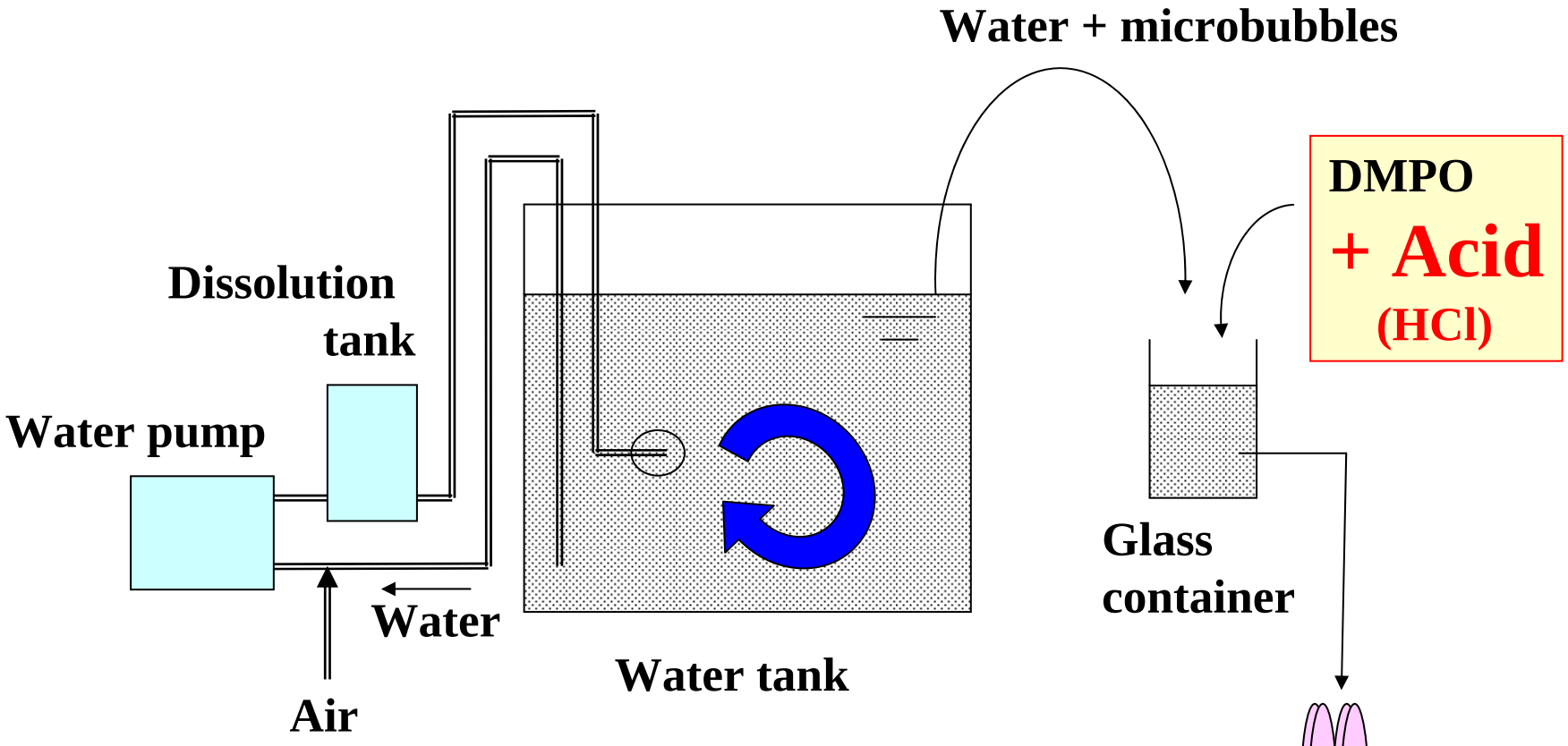


ESR spectrum

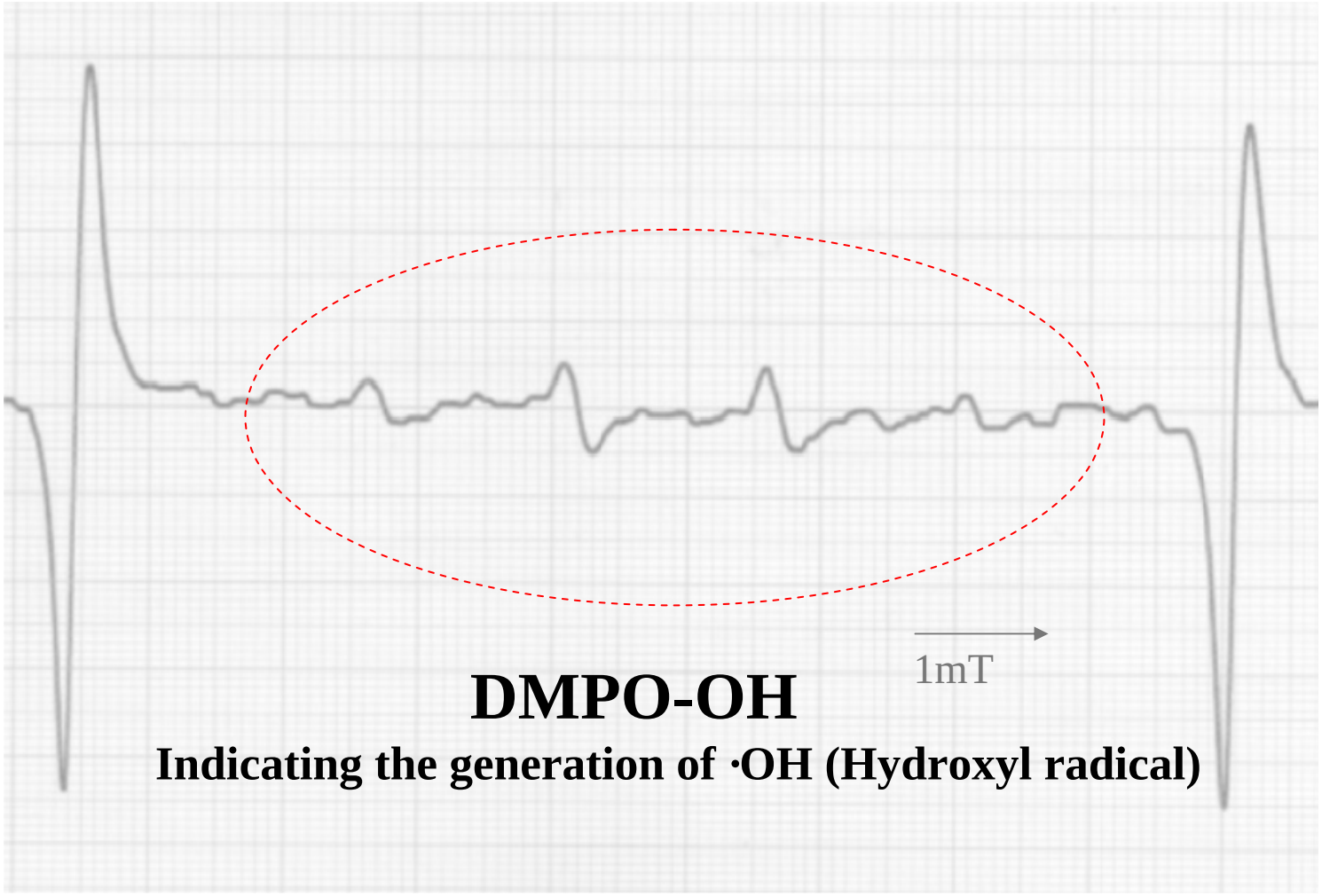


Indicating the generation of alkyl radical

Experimental setup of radical generation



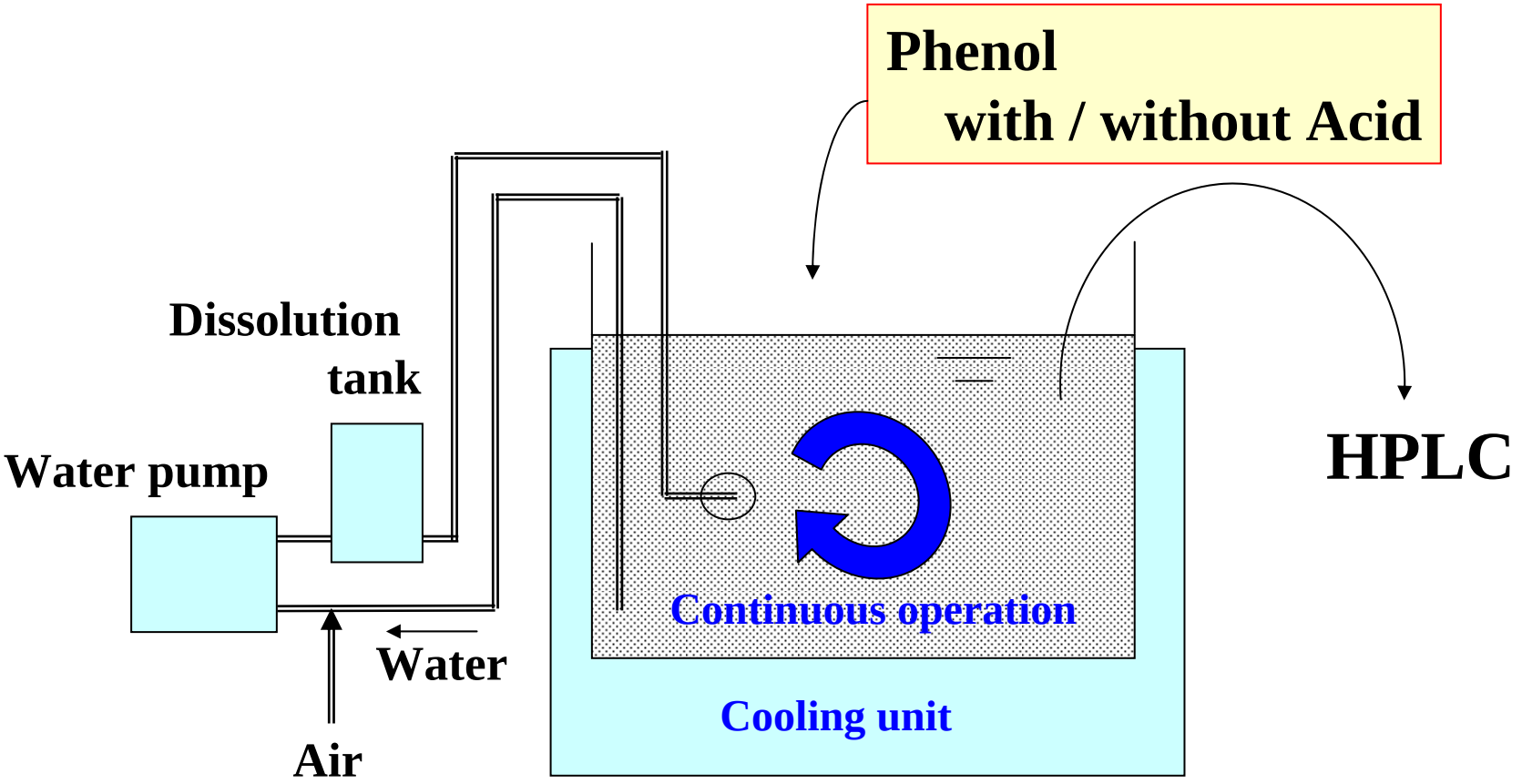
ESR spectrum



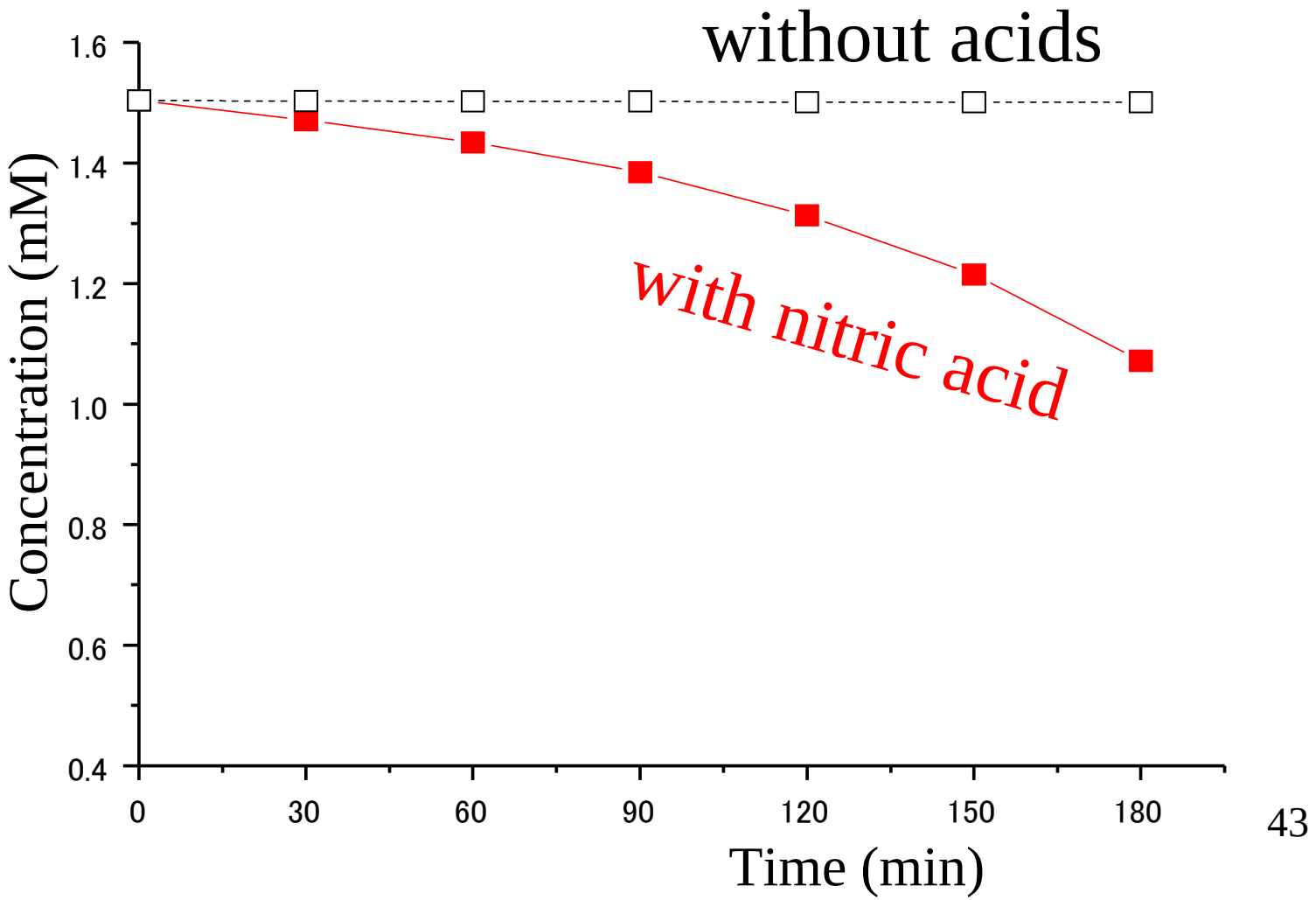
DMPO-OH

Indicating the generation of ·OH (Hydroxyl radical)

Experimental setup of phenol degradation

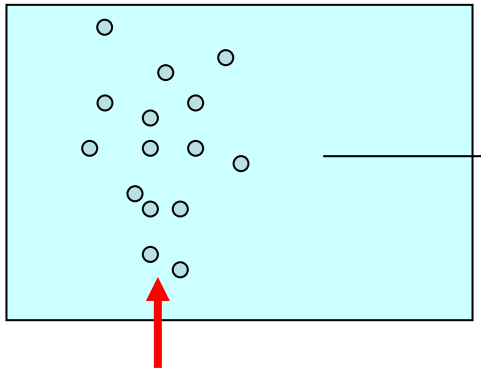


Degradation of phenol by collapsing air microbubble



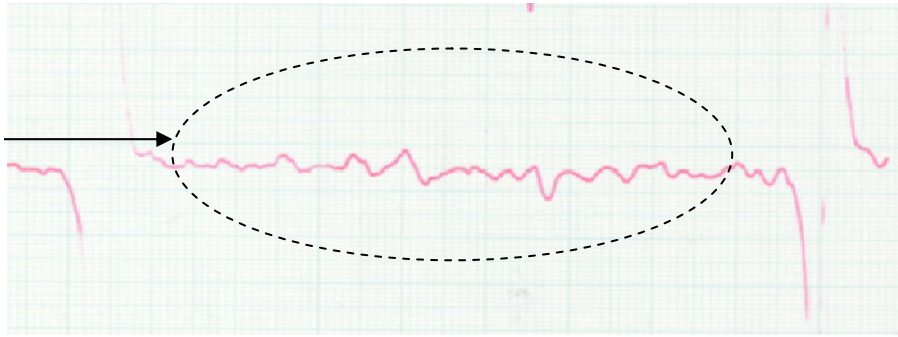
The results of ESR test of ozone microbubble

Macrobubble

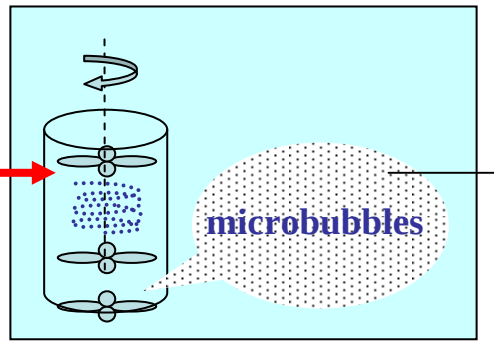


Ozone

ESR/ DMPO

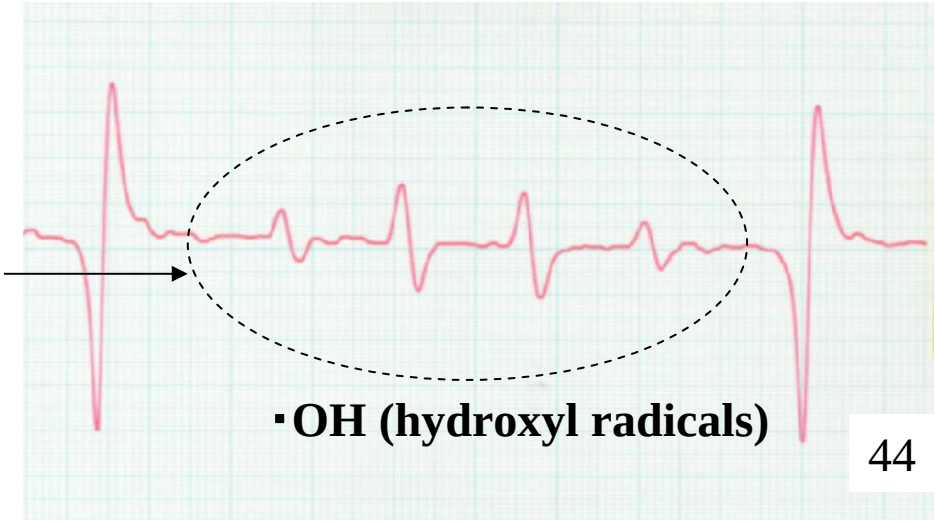


Microbubble



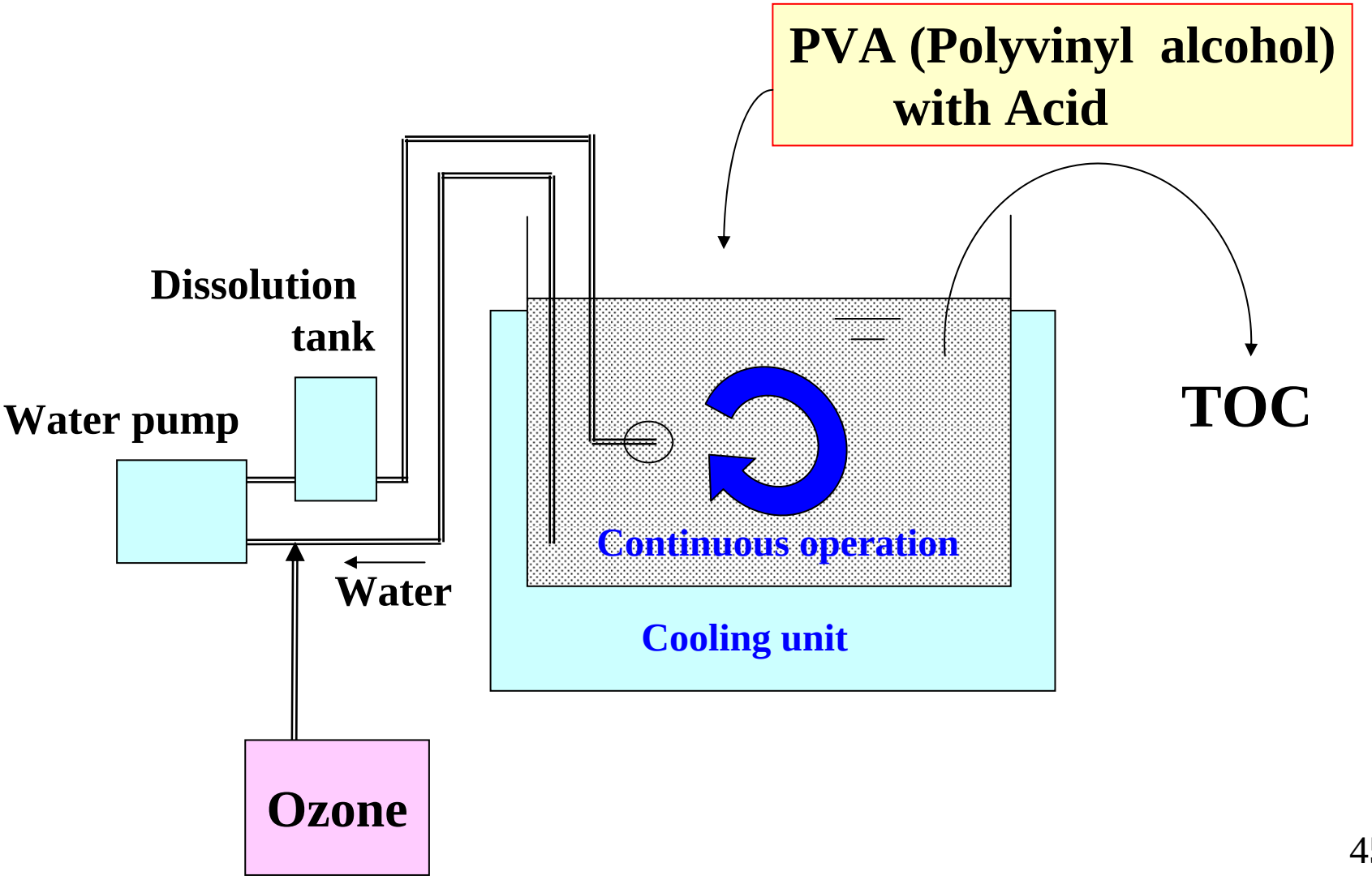
Ozone

ESR/ DMPO

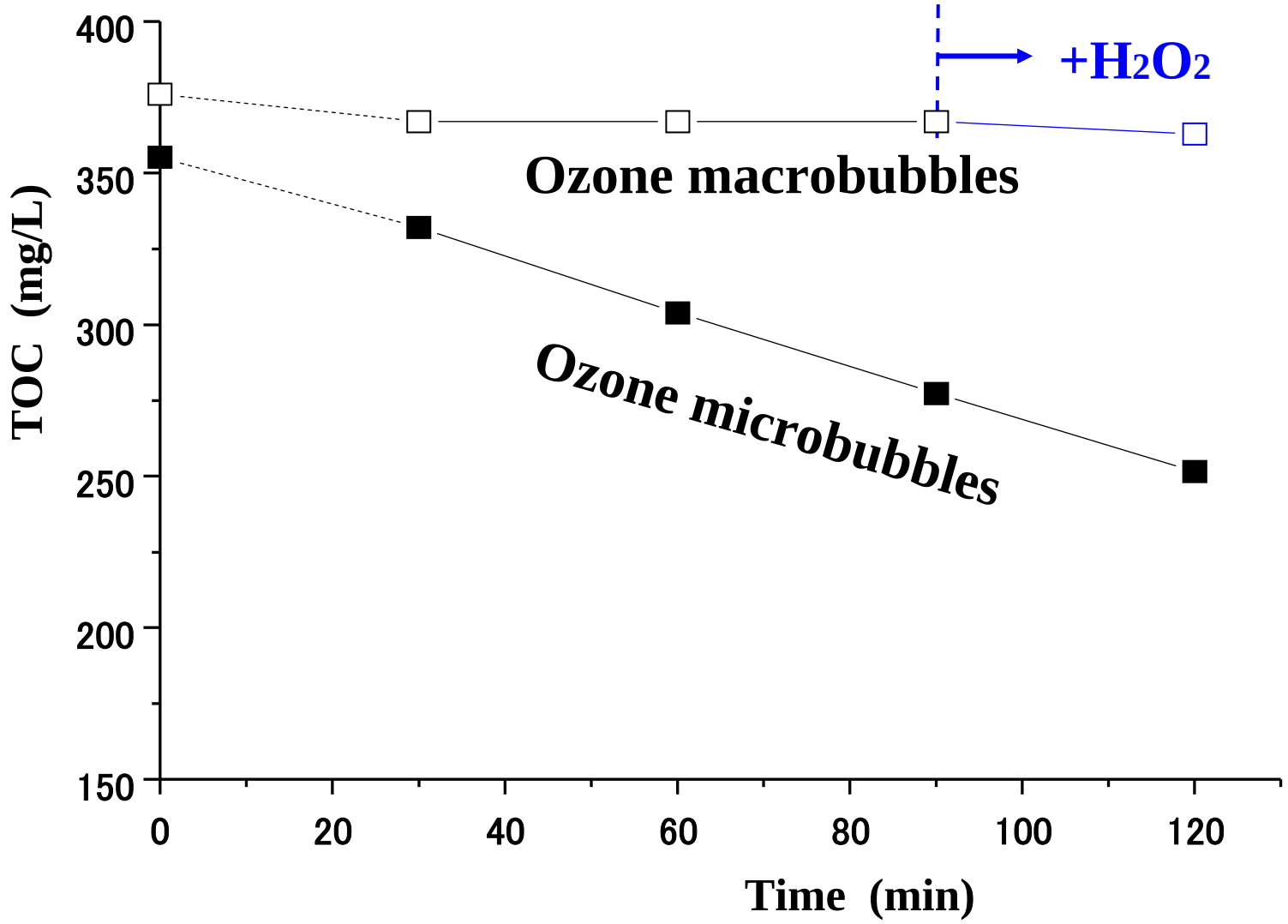


·OH (hydroxyl radicals)

Experimental setup of PVA degradation

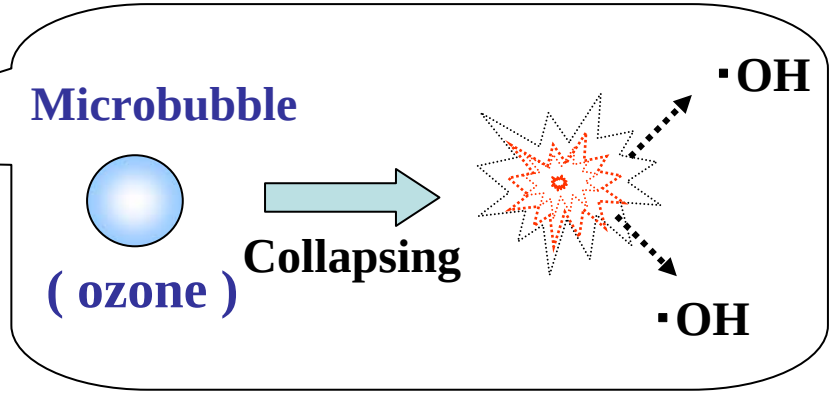


Degradation of PVA by ozone microbubble



Practical application of collapsing microbubble

waste water treatment



Food industry (fishery product) :
(200～300t/day)

Collapse of ozone microbubble

COD : 2500～2800mg/L
SS : 300～400mg/L
HEM (oil and grease) : > 800mg/L

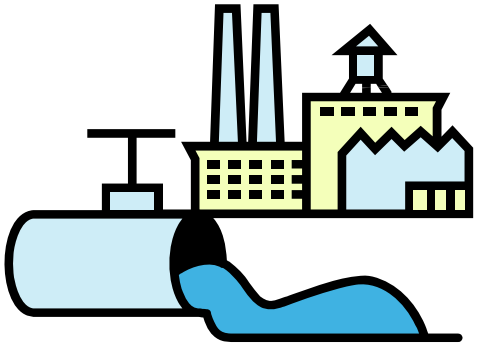
・OH

COD : <10mg/L
SS : tr.
HEM : tr.
sludge : < 10 t / year

N-Hexane Extractable Material

To treat waste water from chemical factory

A phenol factory



Content	Waste water
Phenol	0.32 %
Formalin	0.56 %
Methanol	1.90 %
Acetone	0.08 %
n-butanol	0.03 %
nonvolatile	1.70 %

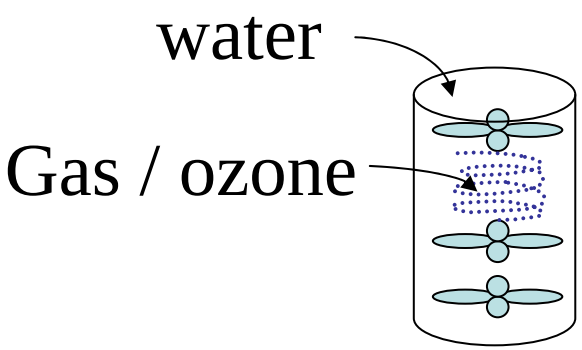
Not easy to treat by conventional methods

Collapse of ozone microbubble

Treatment of waste water from phenol factory

Development of new system to collapse microbubbles

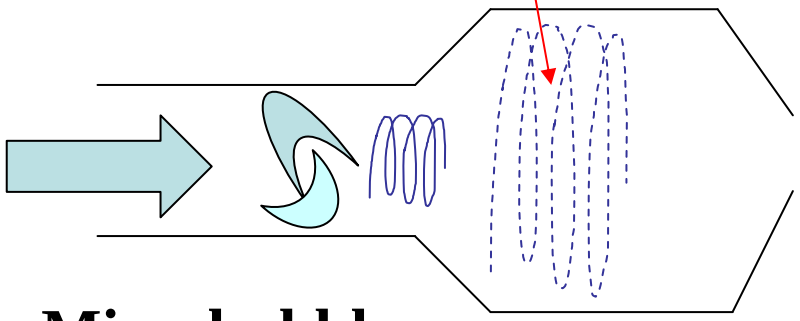
Previous system



Microbubble generator

New system

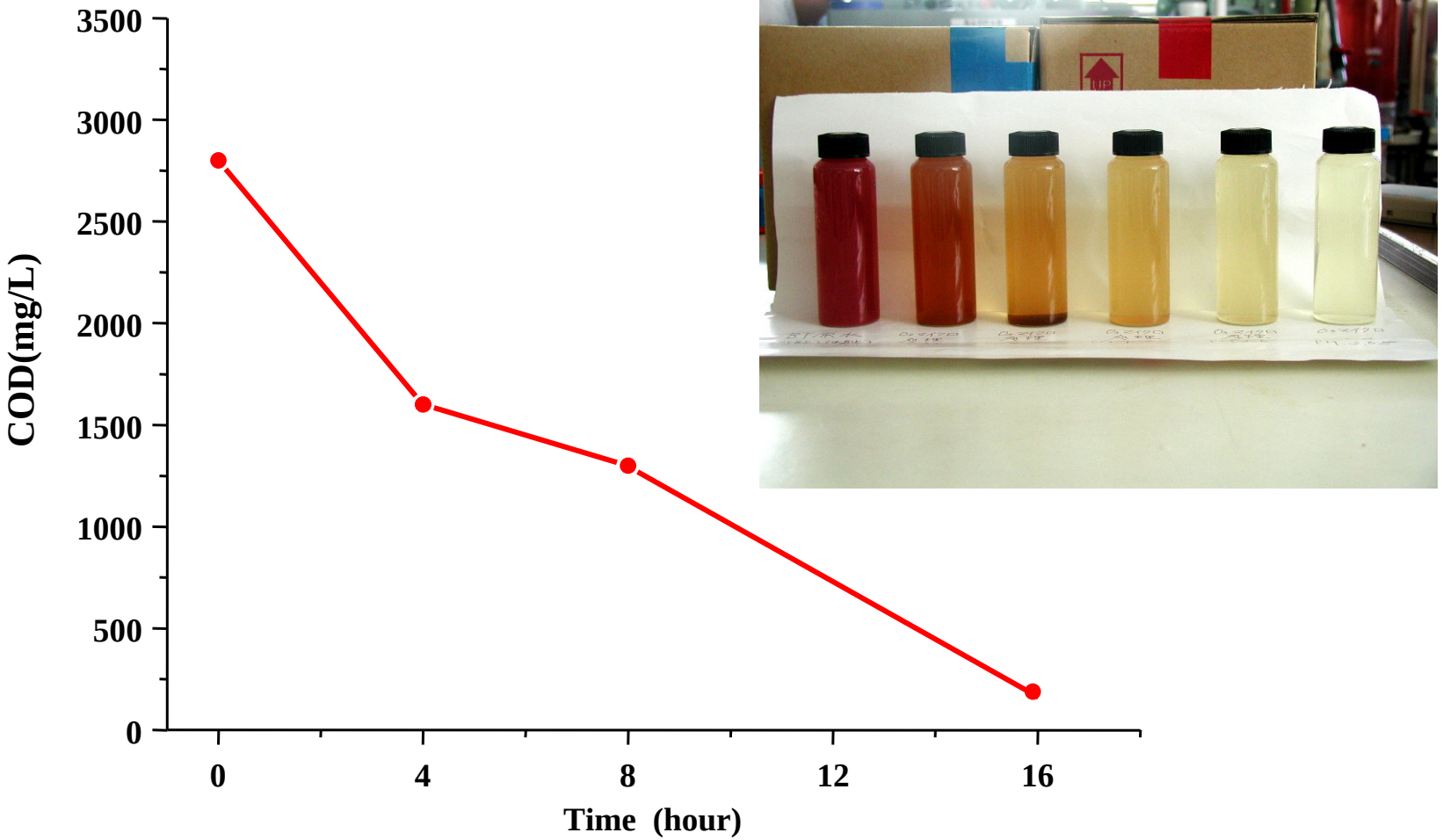
Collapsing microbubble intentionally



Microbubble generator

Introduction of new collapsing system

Result of the test of microbubble treatment



Summary

Microbubble

- **Increase in the interior gas pressure**
- **Increase in the ion concentration around the gas-water interface**

→ **Gas hydrate formation**

→ **Environmental remediation**

Collapse of microbubble

- **Free-radical generation**
- **Generation of Nano-bubble**

→ **Waist water treatment**

References

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