Gustatory (taste) sensor and its applications

May 8th, 2024

Today's Key Words

- Chemical sensor.
- Chemically decorated surface of sensor device with sensing film for selection / recognition of molecules.
- Multi-sensor system and Multivariate data analysis.
- Suitable measurement method based on the characteristics of measuring object in order to acquisition of desired data.

Our taste sense

- Sensation about “good taste or bad taste”.
- Important tool to judge chemicals to be safe or not for us.

Important sense which affects life maintenance

Taste receptor

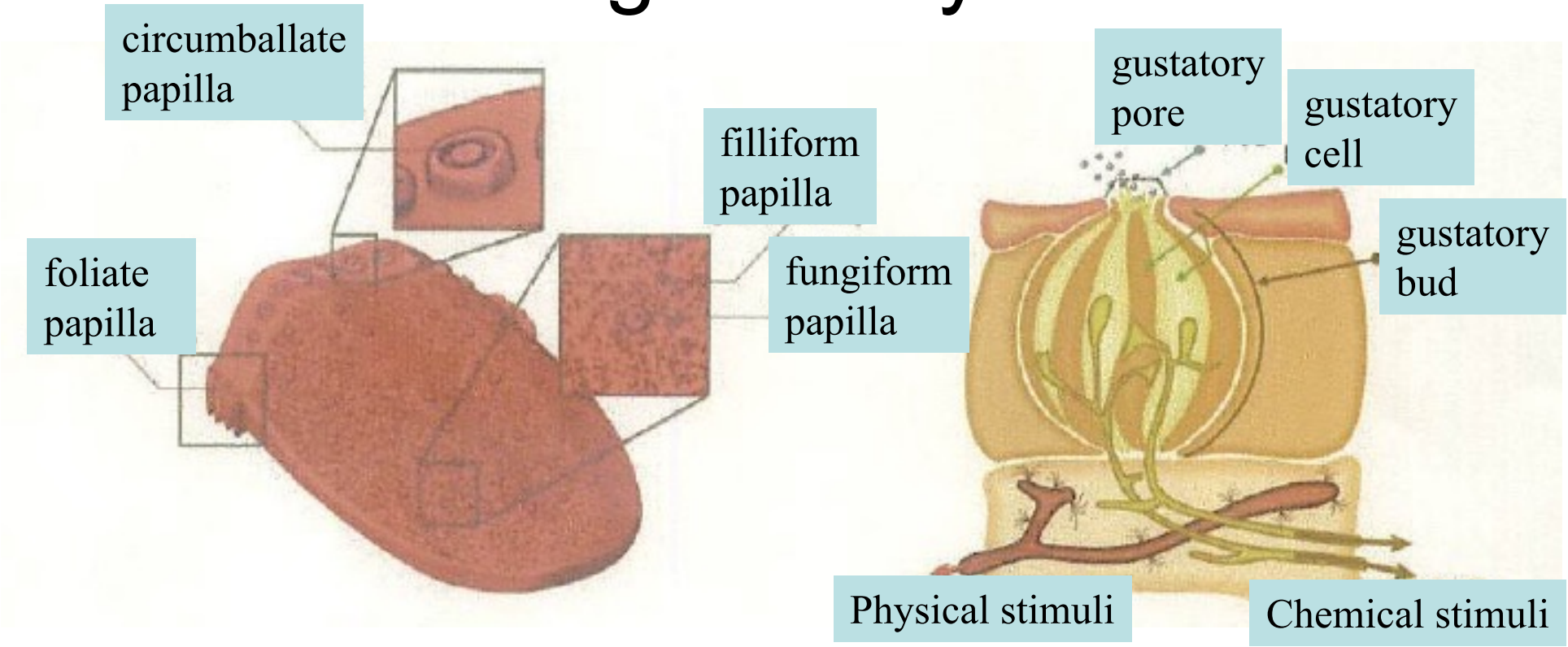
⇒ Cell group which is specialized to adopt taste substances. = Gustatory bud
⇒ Shape and Size of gustatory bud: bud-like shape, Diameter 50μm, Length 60μm.
⇒ The number of gusatory bud : About 6,000 ～ 8,000 for adult.
⇒ Existance position : surface of tongue and gular region (throat).

5 fundamental tatste

- Salty taste: sodium chloride (NaCl)
- Sour taste: acetic acid
- Sweet taste: sucrose
- Bitter taste: quinine
- Umami (delicious taste): sodium glutaminate

But…, Two or more tastes are caused by one taste substance.
So, We cannot easily relate the taste material and the taste.

Our tongue, mammary papilla, and gustatory bud



※ Gustatory bud is aggregation of gustatory cells
⇒ Gustatory cell junction is strong and thick.
Any taste substances can not go into the inside of tongue.
※ Gustatory buds concentrate onto tongue and exist into papillas.
※ Each gustatory cell can respond several taste substances, but with different sensitivity.

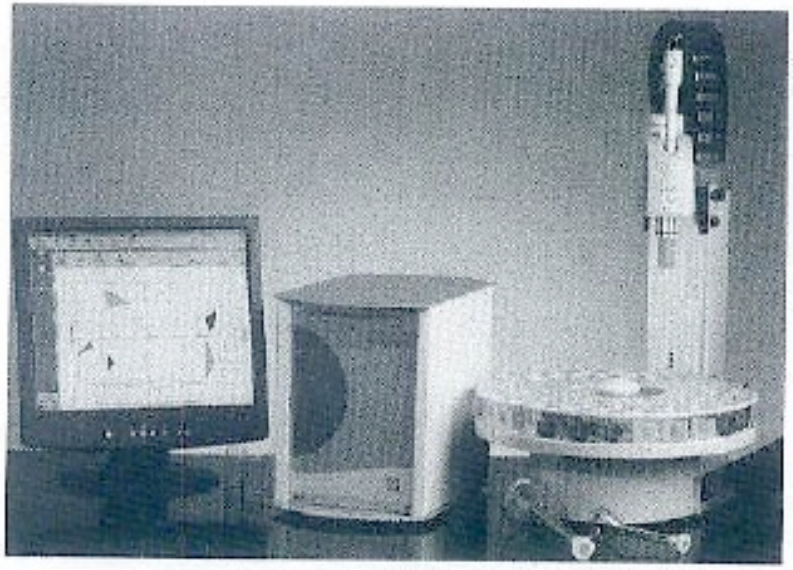
Artificial Gustatory Sensors

- CHEMFET + Sensing film
- Ion selective electrode + Sensing film
- Quartz crystal resonator + Sensing film

Applications of Gustatory Sensors

- Evaluation of food, drink.
  - taste, safety, sustenance, and so on.
- Medical Applications
  - Development and Evaluation of taste masking substance.
- Clarification of our taste recognition mechanism using biomimetic gustatory sensing system.

CHEMFET + Sensing Film



Taste Recognition System
"α ASTREE"
(Alpha M.O.S. Co. Ltd., France)

Gustatory Sensor using CHEMFET

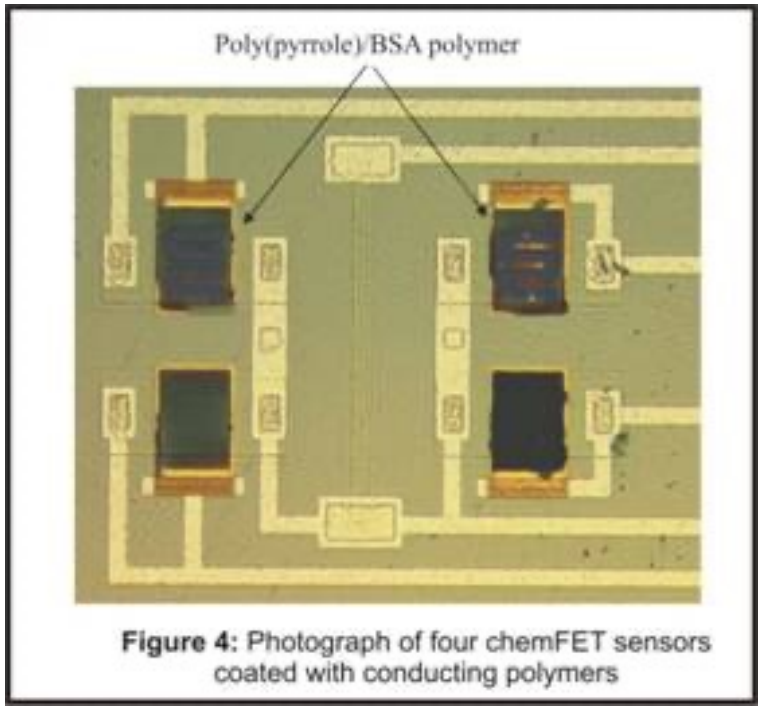


Figure 4: Photograph of four chemFET sensors coated with conducting polymers

Chemical Sensitive FET：CHEMFET

出展：Microsensor & Bioelectronics Lab.,
Univ. of Warwic, UK.

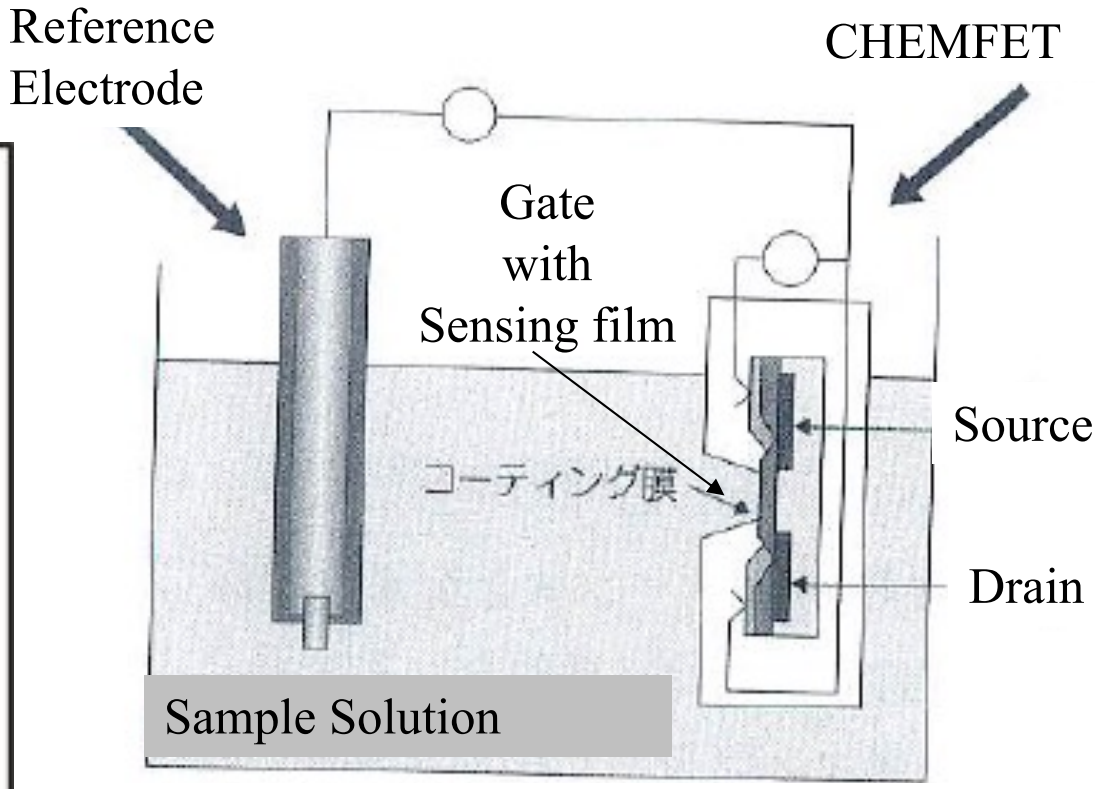


Fig. Measurement system
using CHEMFET Sensor

Response property of CHEMFET used in αASTREE

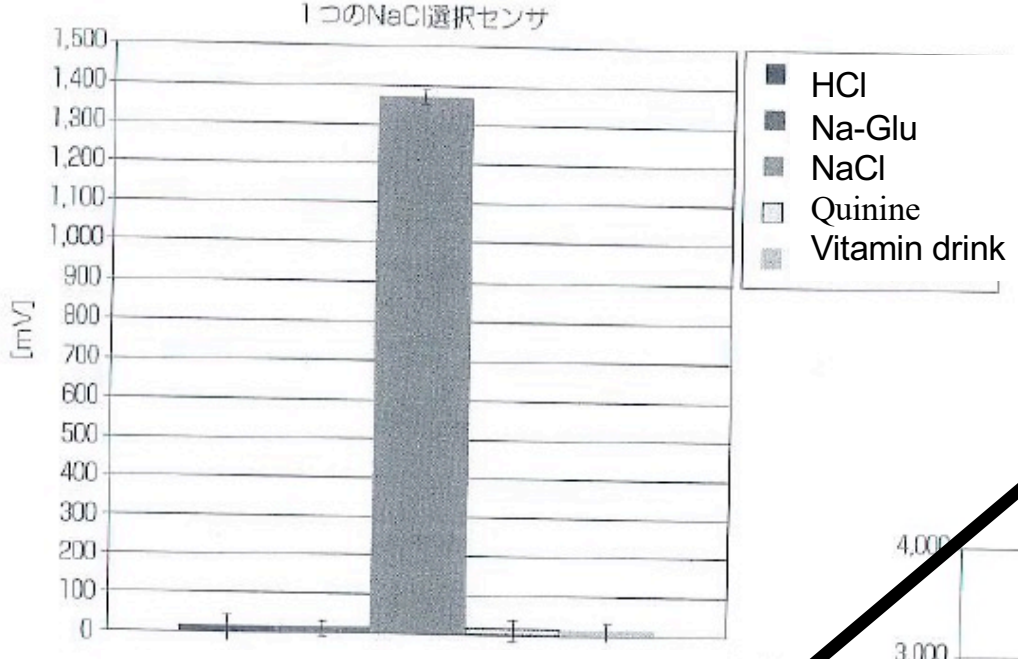


Fig. Response of commonly used CHEMFET

Attenuation of selectivity

=> Biomimetics

Human's gustatory bud doesn't have perfect selectivity.

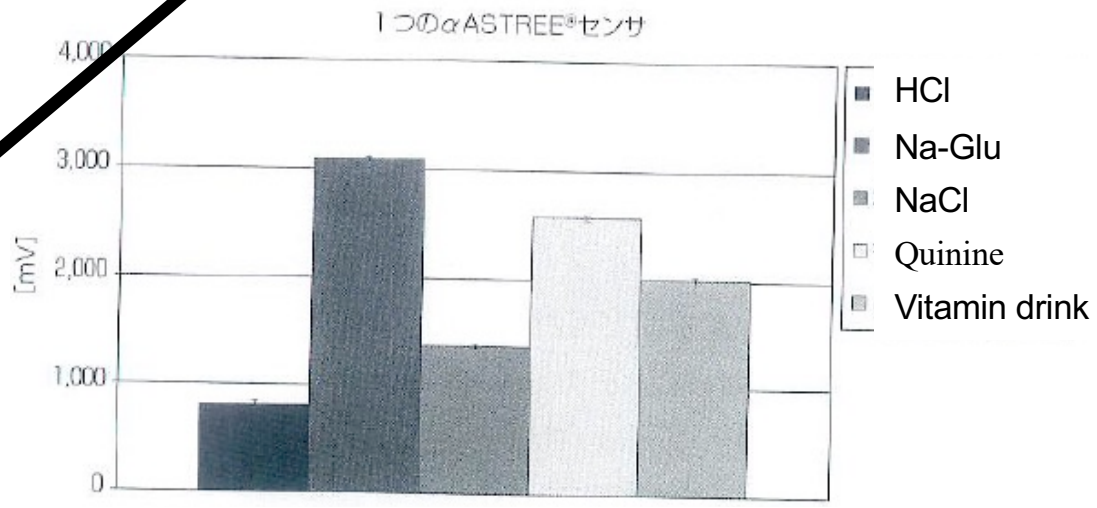


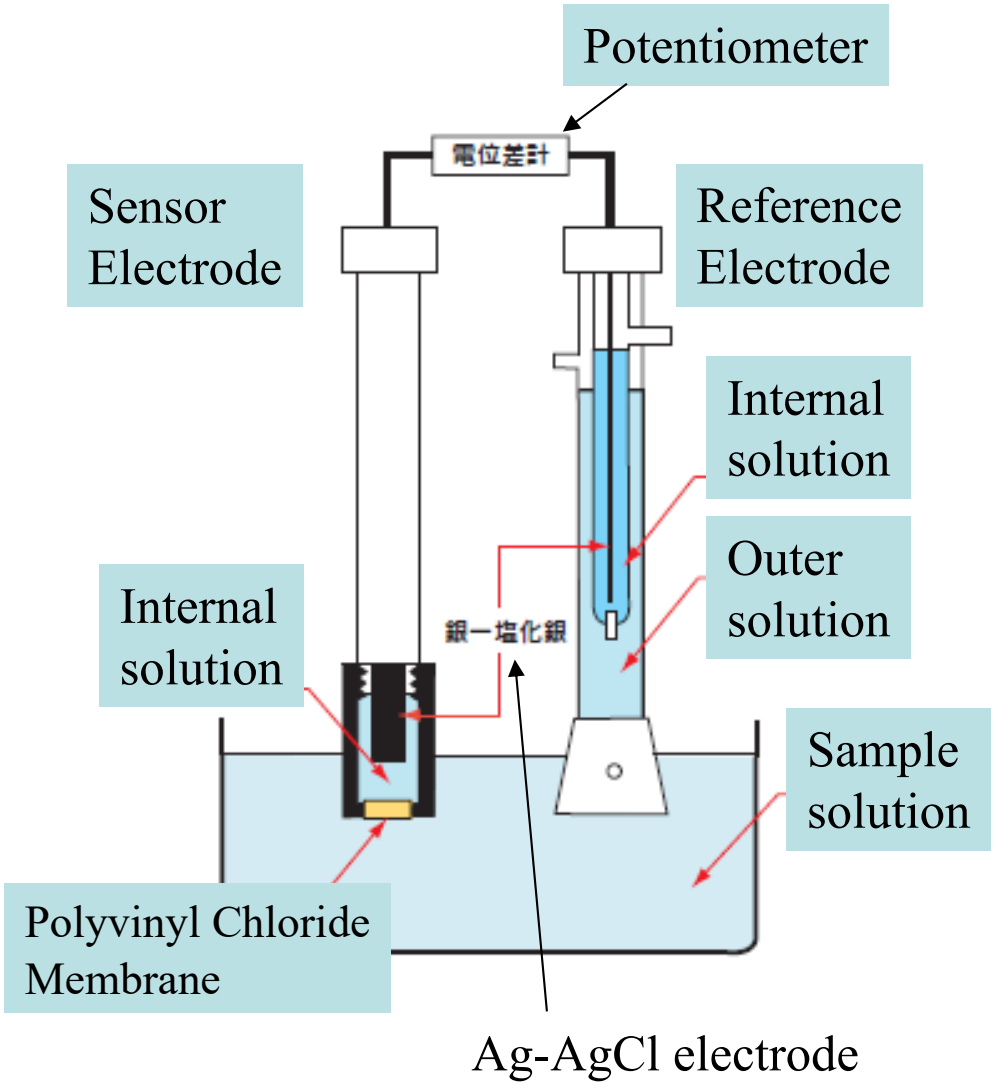
Fig. Response of a CHEMFET used in aASTREE

Ion selective electrode

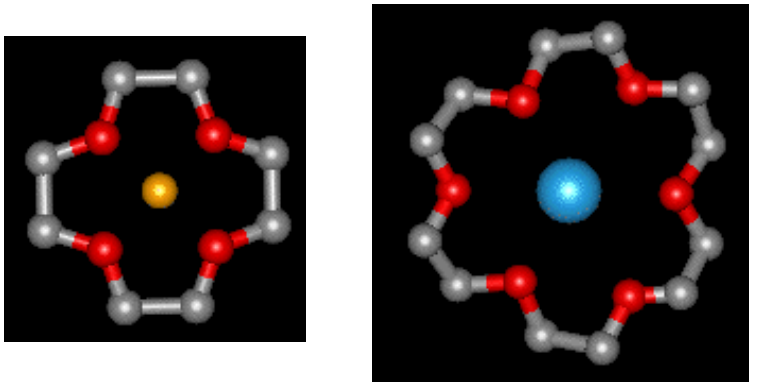
+

Sensing Film

Gustatory Sensor using Ion selective electrode

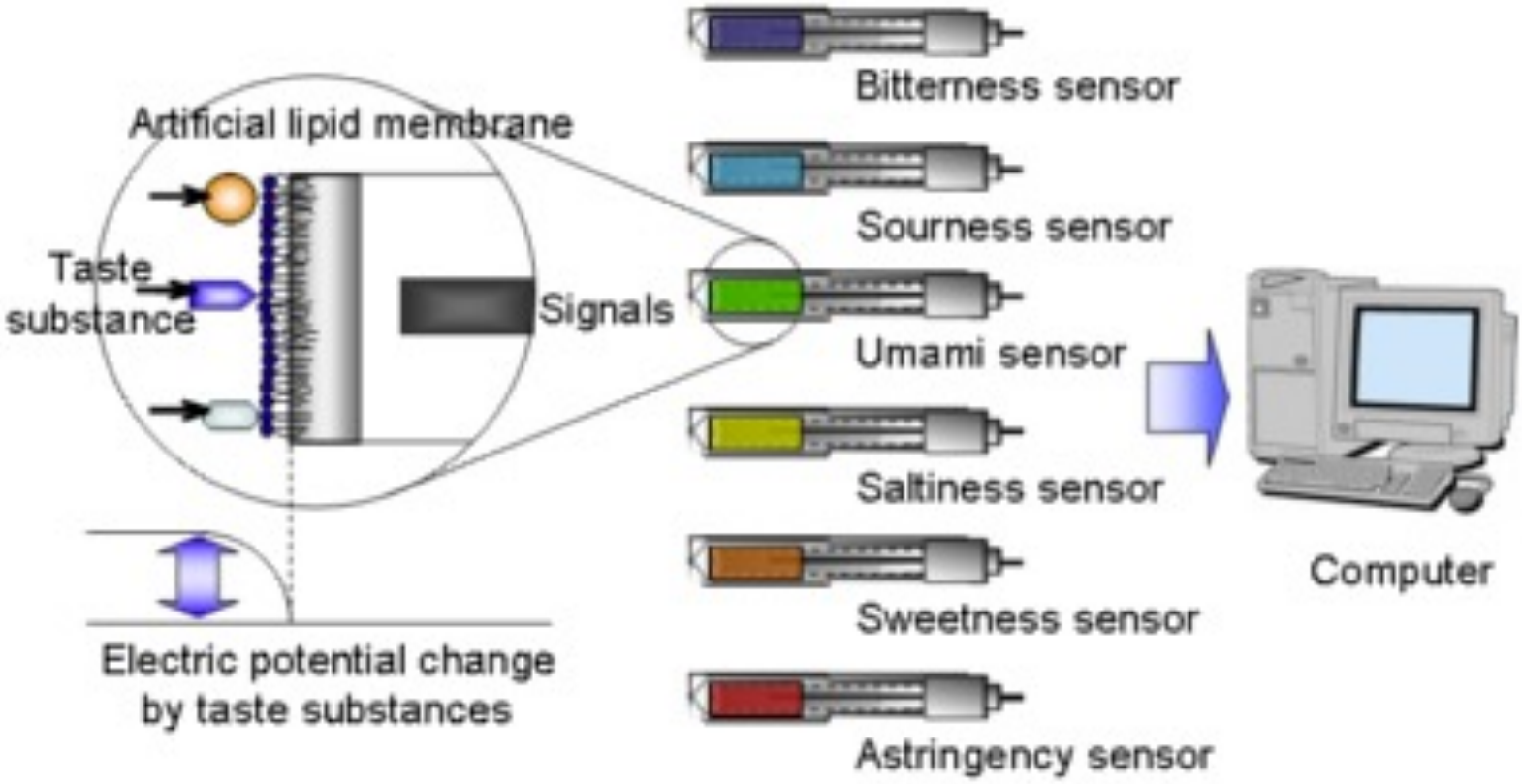


- Selectiveness of Ion is realized by “ionophore” which has specific molecular shape.



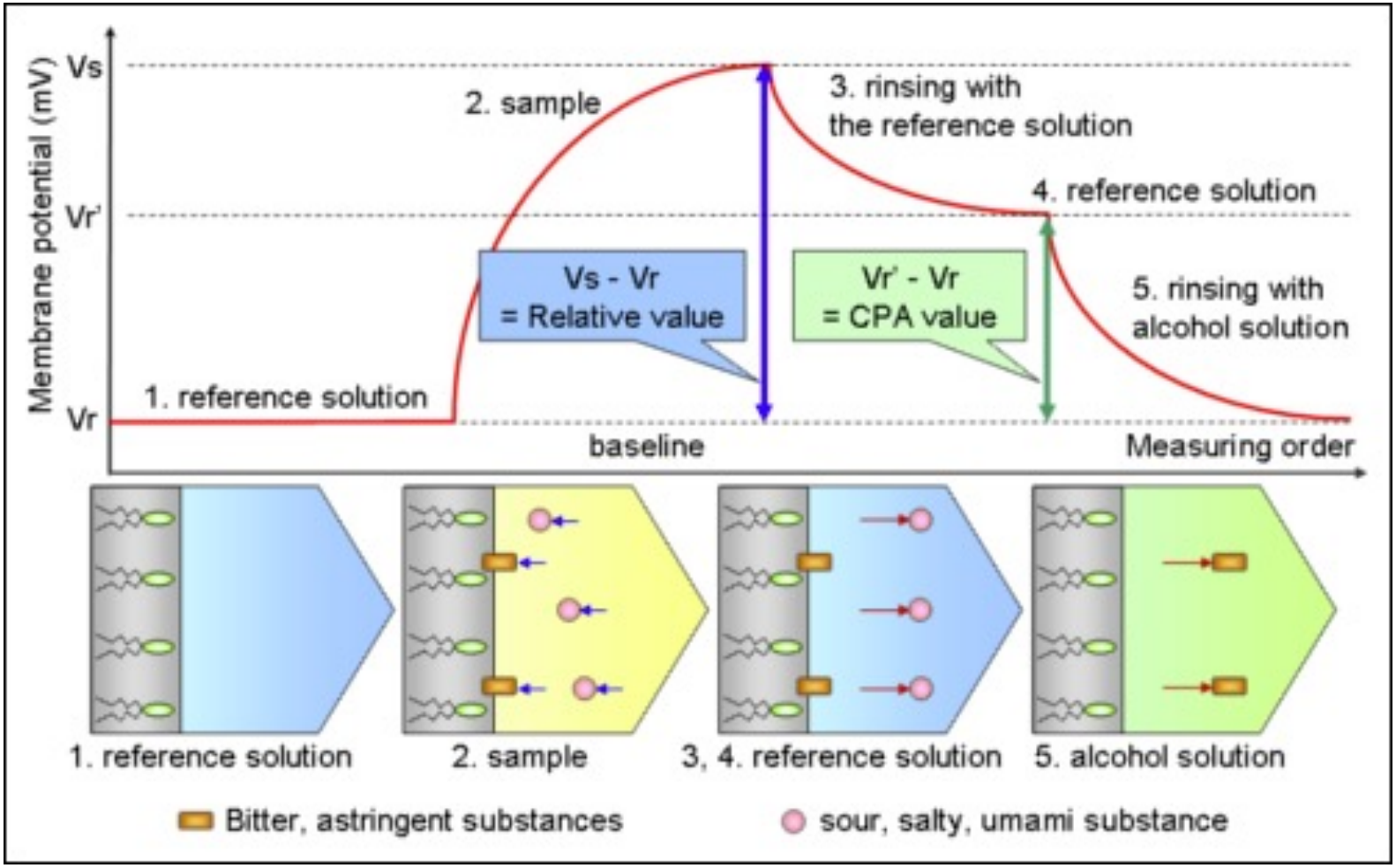
Example of ionophore（Crown ether）

Response principle of gustatory sensor using ion selective electrode



* From “Intelligent Sensor Technology, Inc.’s web site”

Measurement procedure for gustatory sensor using ion selective electrode



* From “Intelligent Sensor Technology, Inc.’s web site”

* CPA value: “Change of membrane Potential by Adsorption”

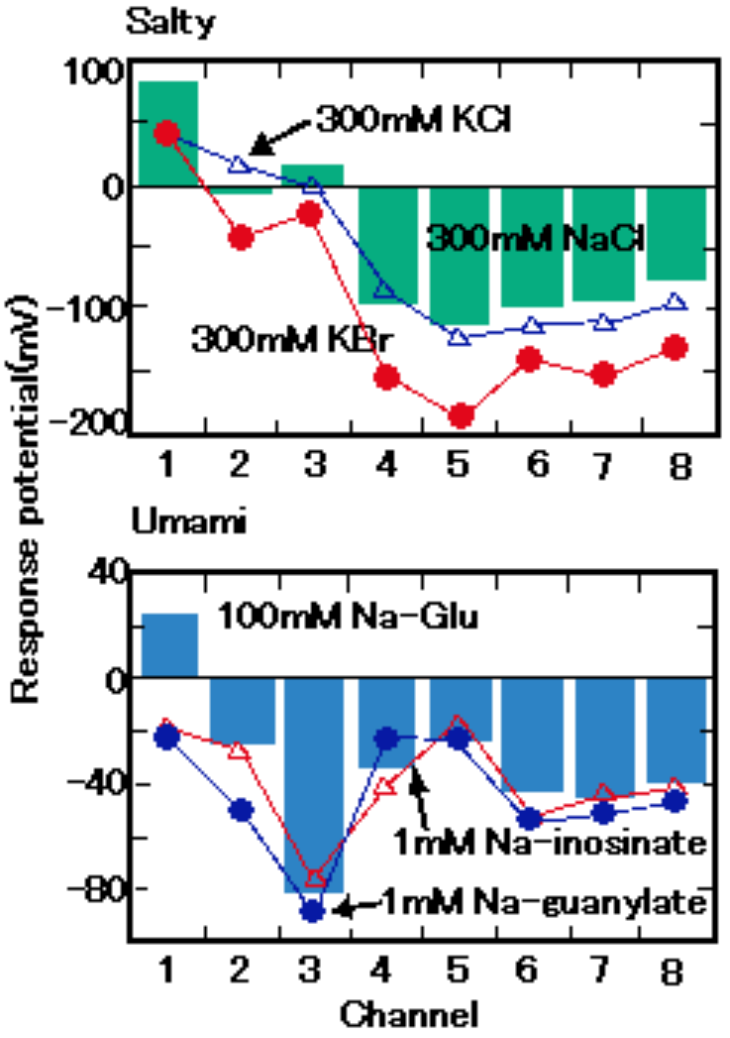
Developed gustatory sensors using ion selective electrode

Taste information		Sensor	Characteristic	Targets
Initial taste (Relative value)	Sourness	CA0	sourness produced by citric acid and tartaric acid	beer, coffee
	Saltiness	CT0	saltiness evoked by dietary salts	soy sauce, soup, stock sauce
	Umami	AAE	umami (savoriness) by amino acids and nucleic acids	soup, stock sauce, meat
	Acidic bitterness	C00	bitterness derived by bitter substances found in foodstuffs and beverages, but can also be perceived richness with its concentration being low	bean curd, stock sauce, soup
	Astringency	AE1	pungent taste by astringent taste materials	wine, tea
	Sweetness	GL1	sweetness produced by sugars and sugar alcohols	sweets, drink

Taste information		Sensor	Characteristic	Targets
Aftertaste (CPA value)	Aftertaste from acidic bitterness	C00	aftertaste by bitter taste materials	beer, coffee
	Aftertaste from astringency	AE1	aftertaste by astringent taste materials	wine, tea
	Richness	AAE	richness, also called "continuity," evoked by umami substances	soup, stock sauce, meat
	Aftertaste from basic bitterness	AC0 AN0	bitterness of medicines	basic drugs (such as quinine hydrochloride, famotidine)
	Aftertaste from hydrochloride salts	BT0	bitterness of medicines	hydrochloride drugs

* From "Intelligent Sensor Technology, Inc.'s web site"

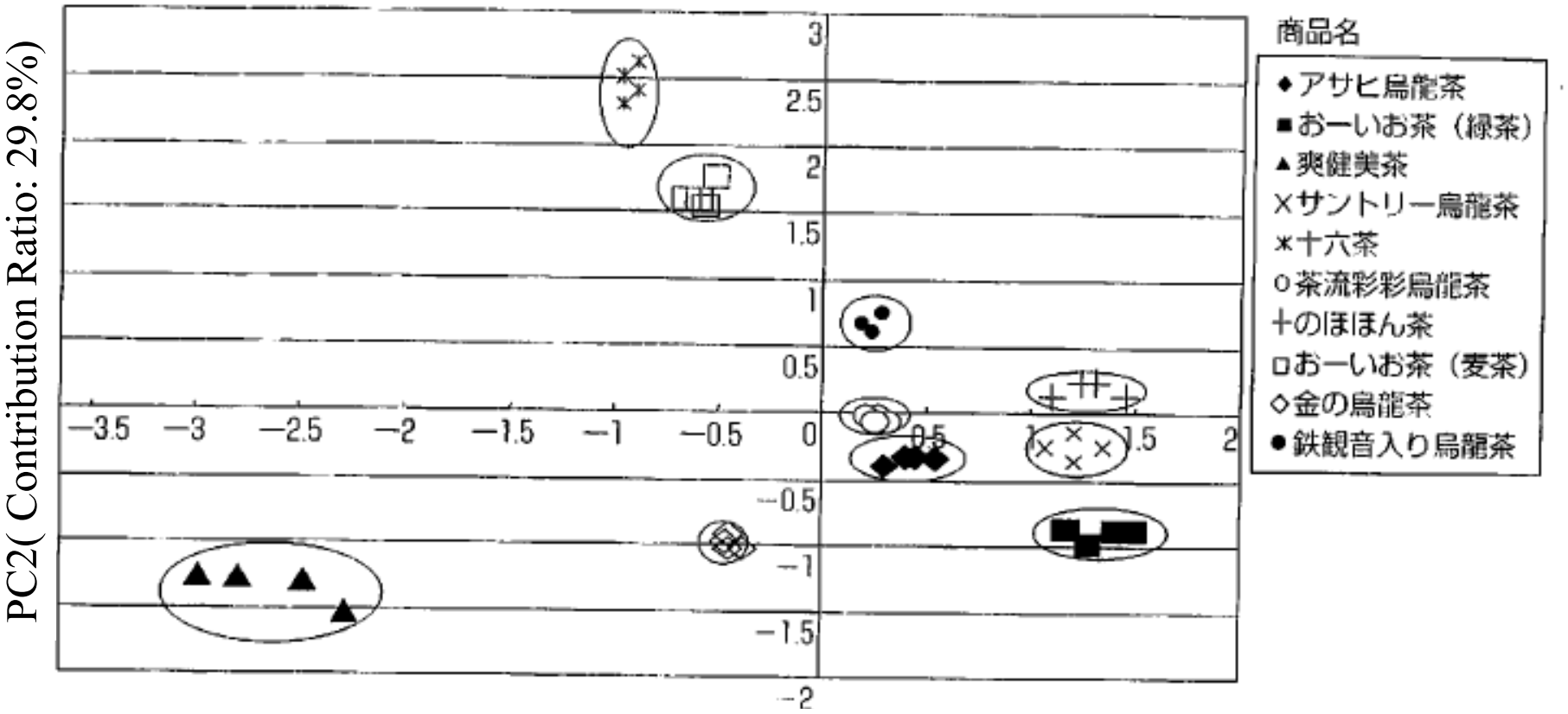
Measurement Results from ion selective electrode



※ Toko et al., Kyusyu Univ.

- **What do those responses means?**
- **What is excellent feature of these sensors as taste sensor?**

Classification of teas

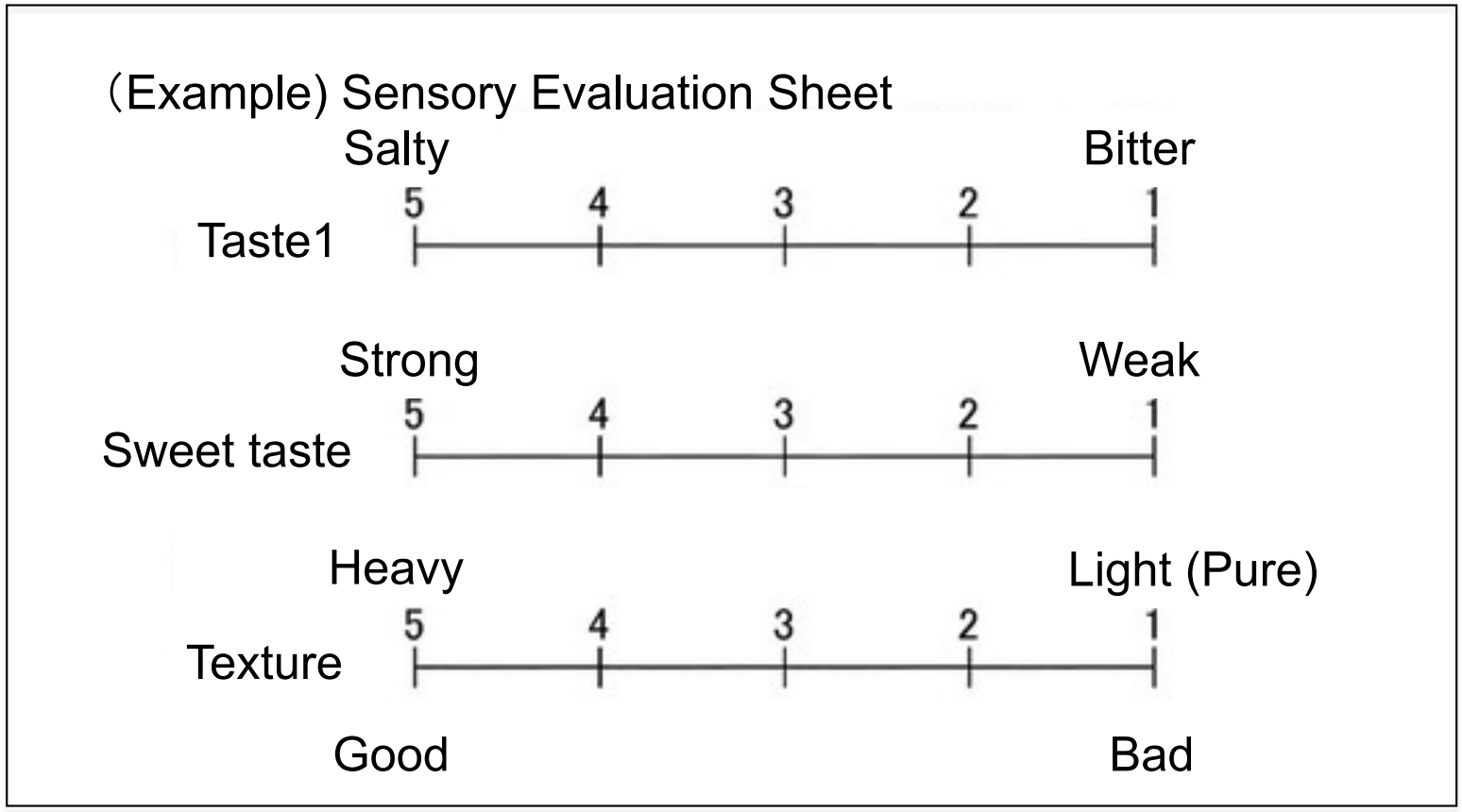


※PCA: Principal component analysis

“PCA” method transforms a number of possibly correlated variables
into a smaller number of uncorrelated variables called principal components.
⇒ From 8 dimensional data (the number of sensor) space to 2 dimensional data space

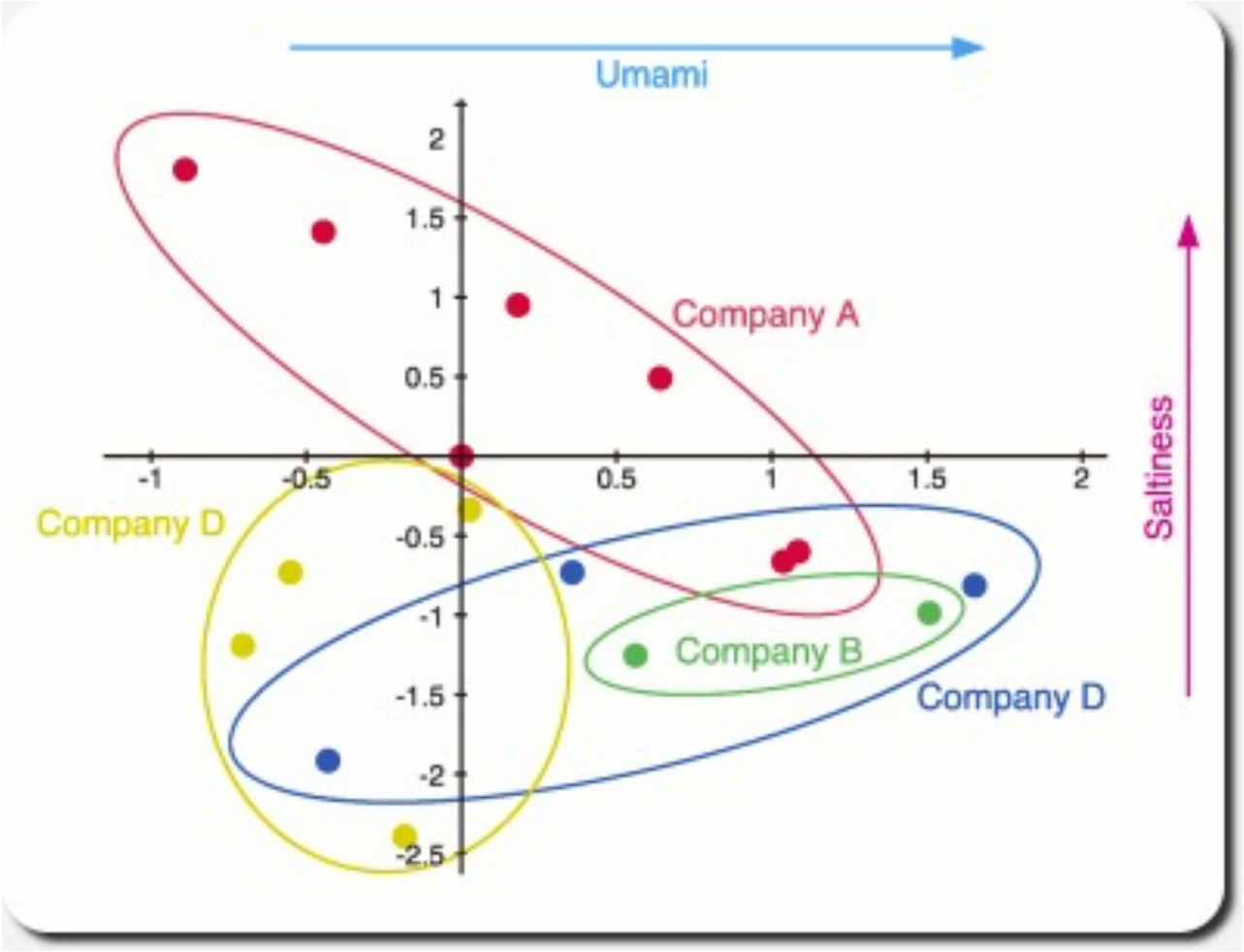
Sensory Evaluation

- An inspection that determines the quality of a product using human senses (visual, auditory, taste, smell, tactile sense, etc.) and is used for evaluation of foods, perfumes, and industrial products.
  * It may also be used to study sensory characteristics of a human sensation.
- We can get important data of human sensation by the evaluation, in order to make meaning for the data from sensor system.



Classification and Evaluation of Beers

Evaluation of instant soups



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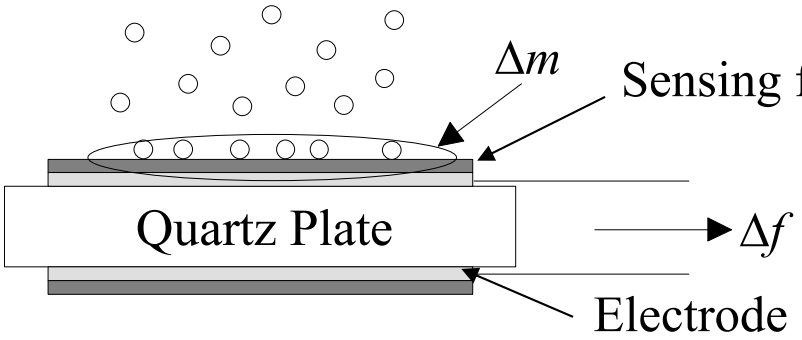
Quartz Crystal Microbalance
+
Sensing Film

Gustatory Sensor based on Quartz Crystal Microbalance



Quartz plate : AT-cut substrate

zero temperature coefficient
at room temperature

Mass Loading Effect:
Δm are transformed to Δf.

$$\Delta f = -\frac{f^2 \Delta m}{N \rho A}$$

N : frequency constant (Hz·cm)

Δf : resonant frequency change (Hz)

f : fundamental frequency(10MHz)

Δm : mass change (g)

ρ : density of quartz $(2.648 g/cm^3)$

A : electrode's area (cm^2)

[Repost] Piezo electric effect

Mechanical load to a material
⇒ Strain of the material
⇒ Slight changes of crystal structure due to material deformation
⇒ The position of the positive charge and the position of the negative charge in the crystal deviate from each other.
⇒ Generation of electrical field in the material.

Generation electrical field by Piezo electric effect

Normal state
⇒ Positive and negative charges are centrally located.

Applying compression load
⇒ Changes of positive and negative charges

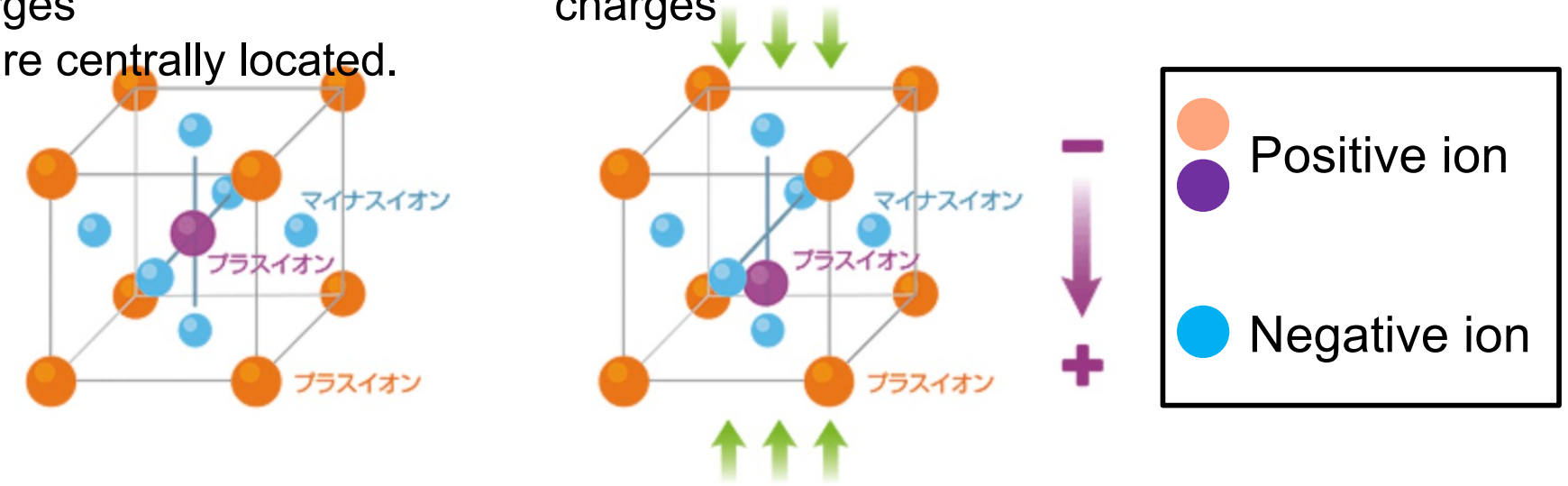
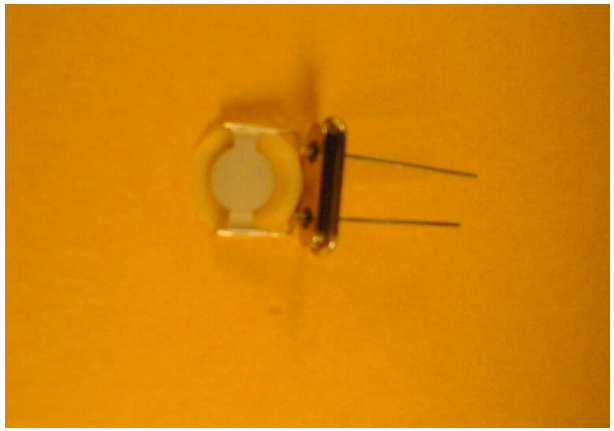
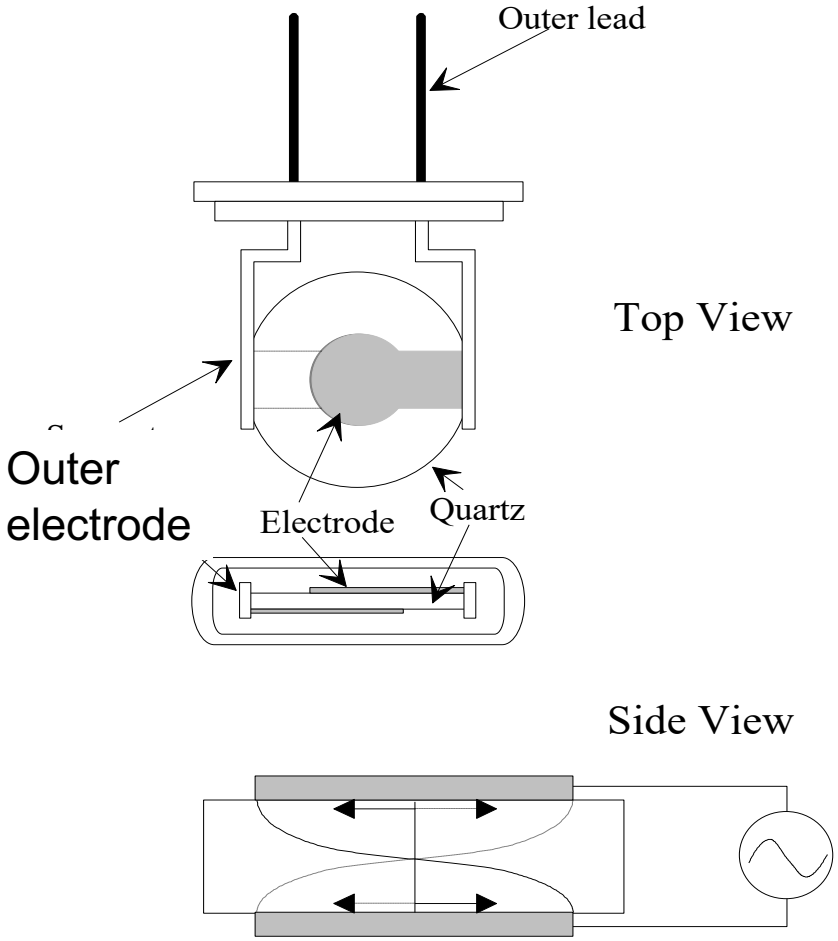


Fig. Piezo electric effect（TDK Co,. Ltd.）

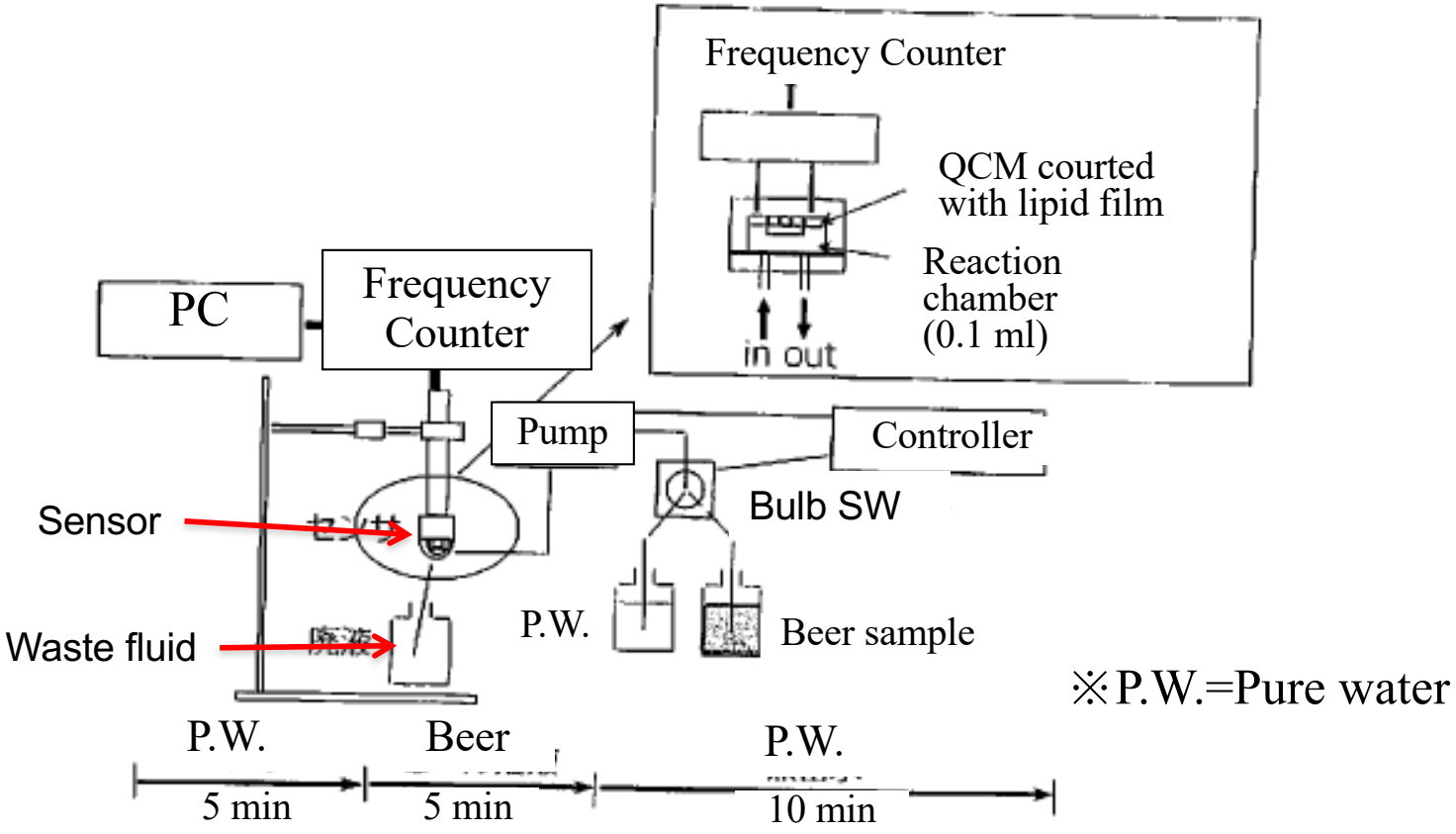
Quartz Crystal Resonator

Quartz Resonator



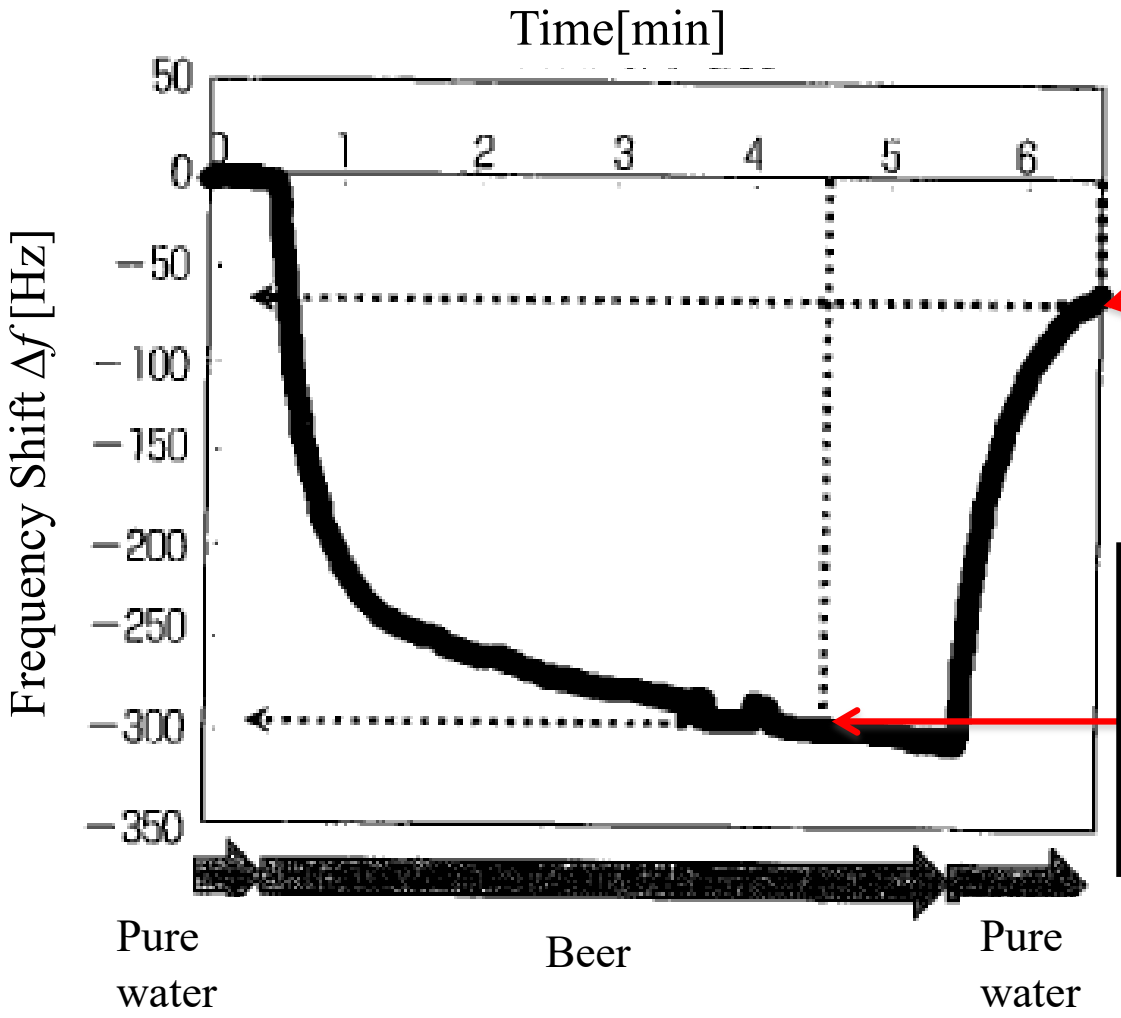


Evaluation System about Richness and Coolness of Beer using QCM gustatory sensor



Measurement Sequence

Evaluation concept for Richness and Coolness of beer



Remaining response after refreshing sensor

↓

Amount of remaining taste substances

Response intensity for a beer

↓

Amount of adsorbed taste substances

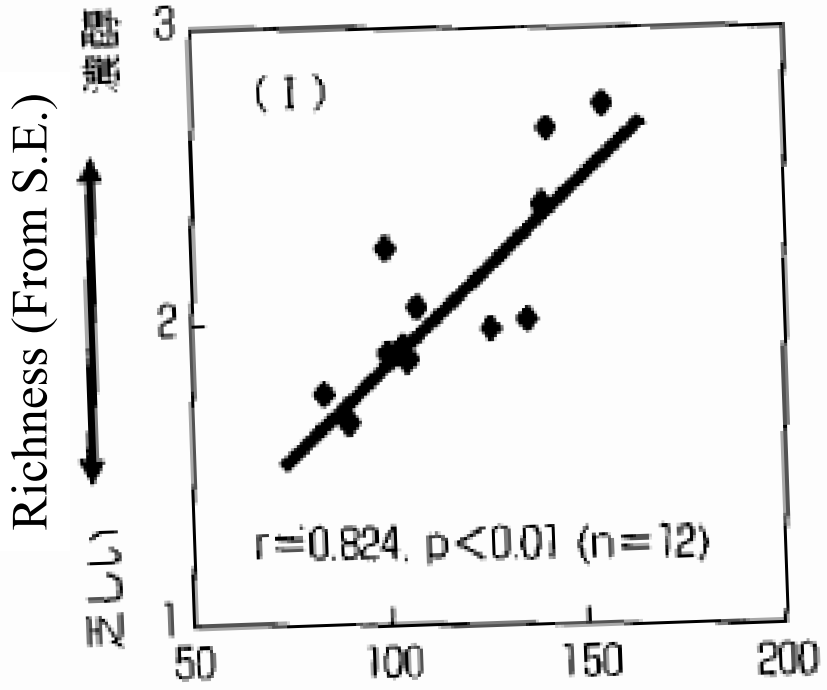
f_0 : Resonant frequency in pure water

f_B : Resonant frequency in beer

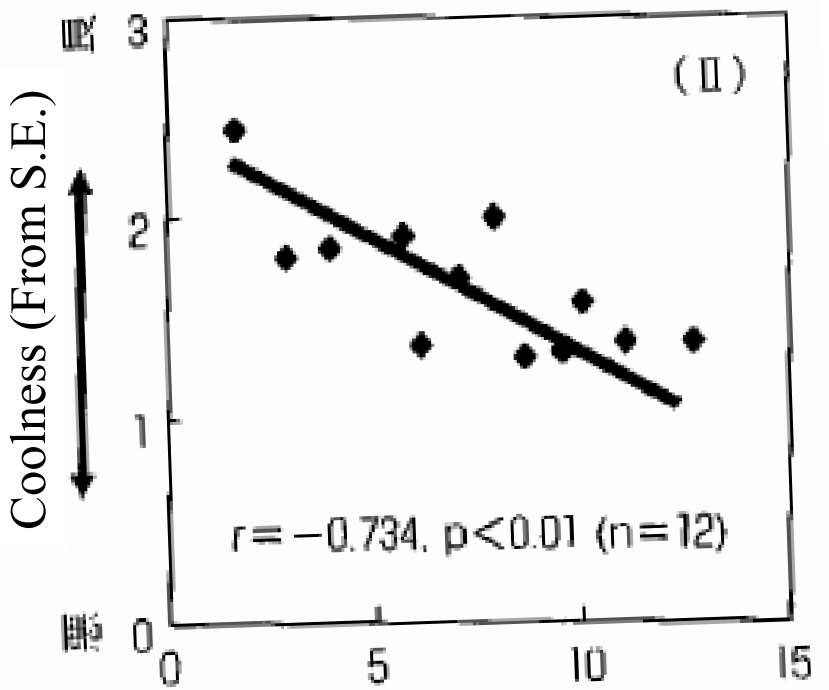
$$\Delta f = f_B - f_0$$

Evaluation concept for Richness and Coolness of a beer

－ Comparison between Sensory Evaluation － and Sensor response



Response by adsorption amount [Hz]



Response for remaining amount [Hz]

※ S.E. = sensory evaluation by human.

Today's summary

- Gustatory sensor and Its application
- A gustatory sensor responds to a wide range of chemicals with different sensitivities.
  => Biomimetics
- Multi sensor system and multivariate data analysis
  => Biomimetics
- Study on suitable measurement method to get desired information