Development of Electronic Nose "FlavoTone®"

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What is electronic nose (e-Nose)?

(1) What is scent / smell?

We sense smells in our daily lives. The essence of a smell lies in the diverse odorants that stimulate olfactory cells, with as many as approximately 400,000 different chemicals reported to exist. Often, smells consist of complex blends of these various chemicals, and the perception of different smells is typically influenced by variations in the types and concentrations of chemicals present in the inhaled gases **(Figure 1)**.

(2) Mechanism of the sense of smell (olfaction)

Deep within the nasal cavity lie cells known as olfactory cells, which are triggered by chemicals. These olfactory cells feature proteins called olfactory receptors (approximately 400 types in humans[1]) on their surfaces. When chemicals bind to these olfactory receptors, they stimulate the olfactory cells, sending electrical signals to the brain.

Due to the unique three-dimensional structure of each olfactory receptor, the degree of binding (affinity) for odorants varies across receptors, resulting in different stimulations of the olfactory cells.

The brain processes the signals from the olfactory cells into patterns, as illustrated in **Figure 2**, enabling us to perceive differences in smell.

In this way, olfactory receptors, olfactory cells, and the brain work together, we can recognize the presence or absence of smells and distinguish among different smells.

(3) Functions provided by e-Nose

Our sense of smell is highly sophisticated, capable of discerning emotional cues such as deliciousness and comfort, as well as alerting us to potential hazards like spoiled food and toxic gases.

The "FlavoTone®"* e-Nose we're developing functions

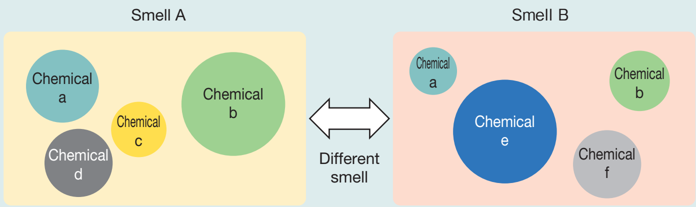


Fig. 1 Image of the difference in smell

(The color indicates the type of chemicals and the size of the circle indicates the concentration)

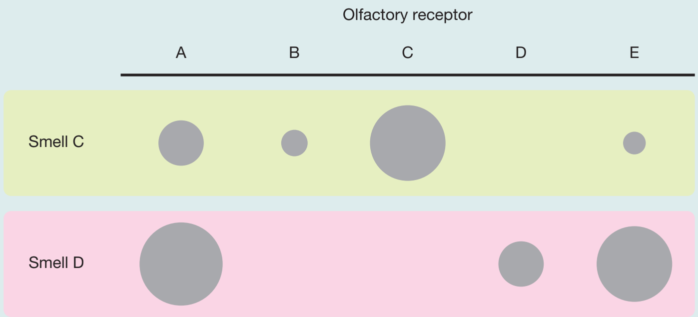


Fig. 2 Image of smell discrimination by the sense of smell

(The intensity of stimulation of each olfactory cell is represented by the size of the circle. The electrical signals emitted by the olfactory cells are smell to the brain as a pattern as shown in the figure, and the brain recognizes the differences in the pattern as differences in smell) much like our sense of smell, detecting variations in smell. By translating the capabilities of our sense of smell into a device, we can digitally capture smell profiles, standardize individual differences in smell perception, and provide continuous smell monitoring, 24 hours a day, 365 days a year, providing new value that has been difficult for humans to achieve.

* The functionality provided by technologies and products labeled as "smell sensors" may vary in definition, so caution is advised to avoid confusion. In this context, the term "smell sensor" refers to technologies and products designed to sense differences in smells.

Measurement mechanism of e-Nose

(1) Principle of smell detection

In "FlavoTone®," we utilize resin materials, additives, and conductive materials based on our proprietary design to serve as the "smell responsive materials," which correspond to olfactory receptors. These responsive materials exhibit a characteristic of increasing electrical resistance upon adsorption of chemicals. By leveraging this property, our "probes," equivalent to olfactory cells, can detect information corresponding to the intensity of the smell (≈ concentration of odorants) **(Figure 3)**.
Chemicals adsorbed onto the smell responsive materials gradually detach from the materials as the surroundings return to a clean state, causing the electrical resistance of the device to revert to its initial state. This allows "FlavoTone®" to measure various samples continuously in a short period, or continuously measure for a long time in an environment with changing smells **(Figure 4)**.

(2) Mechanism of smell recognition

As previously mentioned, "FlavoTone®" is equipped with multiple "probes," each with different properties for adsorbing chemicals. This corresponds to that human nose possess numerous olfactory receptors.
The "FlavoTone®" measures the electrical resistance changes of each probe, allowing for the recording of smell patterns similar to the electrical signals transmitted by olfactory cells to the brain. By subjecting the sensor data obtained in this way to various numerical processing techniques using AI technology, it offers the ability to detect differences in smells, equivalent to our sense of smell. **Table 1** summarizes the comparison with the sense of smell.

How to use "FlavoTone®"

(1) Measurement of liquid and solid smells

When measuring the smell of samples with various shapes such as liquids like beverages and pharmaceuticals, and solids like foods and industrial products in sheet, powder, lump, or film forms, a "table-top machine" **(Figure 5)** can be used for measurement following the steps outlined in Figures (1) to (4).
<Measurement case 1: Measurement of coffee beans>
We conducted measurements on three types of commercially available roasted coffee beans (Kilimanjaro, Mandelin, Guatemala). The analysis

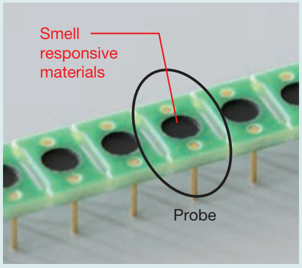
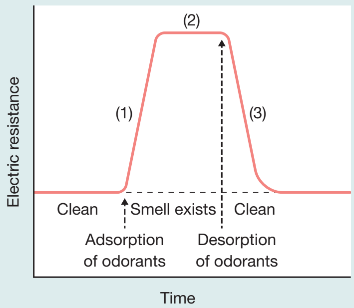


Fig. 3 "Probe" using our uniquely designed "smell responsive material"



(1) Chemical is adsorbed and resistance increases.
(2) Chemical concentration becomes constant and resistance stabilizes.
(3) Chemical is desorbed and resistance decreases and returned to initial state.

Fig. 4 Change in electrical resistance of our conductive material over time in response to the adsorption and desorption of chemicals

Table 1 Comparison of the mechanism human sense of smell and our e-Nose

	Human sense of smell	e-Nose (FlavoTone®)
Smell detection	Olfactory receptor + cells	Smell responsive material + probe
Smell identification	Brain processes electrical signals generated by olfactory cells	AI processes the electrical resistance changes in the probe

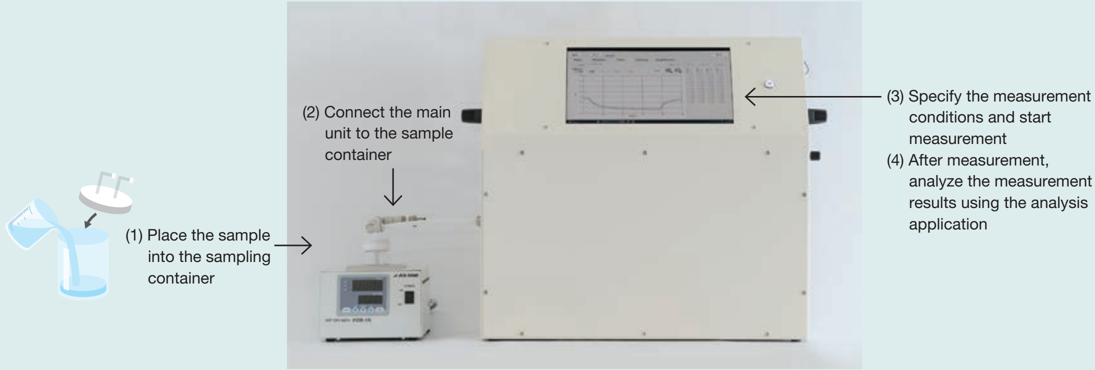


Fig. 5 FlavoTone® tabletop machine appearance and measurement procedure

results allowed us to capture the differences among the three samples. In **Figure 6-a**, the plots are color-coded by sample type. Repeat measurement points are represented by plots of the same color, and the larger the distance between groups of plots of the same color, the more distinct the differences in smell. Moreover, the larger the distance between the same-colored plots, the more distinct the differences in smell components.

<Measurement case 2: Smell comparison of recycled plastics>

In recent years, there has been growing consideration of using recycled plastics due to the need for decarbonization. However, it is known that recycled plastics emit unpleasant odors different from those of new plastics. When pellets of new polypropylene (PP) and recycled PP were measured and compared with a blank (odorless sample), it was confirmed that new PP is nearly odorless while recycled PP emits a different odor from new PP **(Figure 6-b)**.

(2) Measurement of smell spread over a space

Unlike the aforementioned measurement of smell generated from a sample, we propose measurement using a "compact machine (under prototyping)" **(Figure 7)** for measurement aimed at detecting changes in smell that occur in a relatively

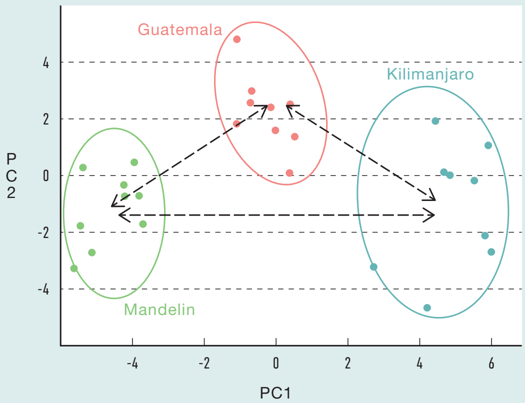


Fig. 6-a Case 1: Measurement of coffee beans

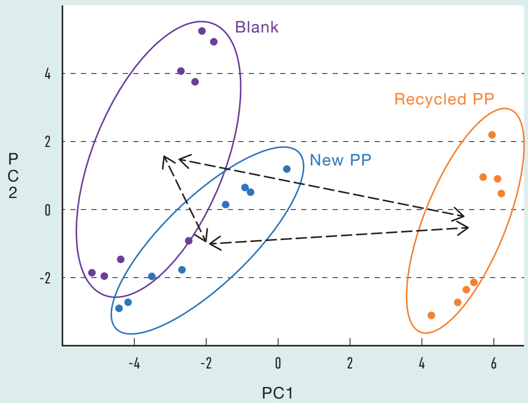


Fig. 6-b Case 2: Odor comparison of recycled plastics

How to see the figure:
(1) Plots are far apart ⇒ Low similarity in smell
(2) The plots are diagonally displaced from each other ⇒ Large differences in smell components

The x-axis (PC1) and y-axis (PC2) in the figure are axes obtained by statistically processing the responses of multiple probes. They correspond to a dimensional scale of the principal differences in chemicals present in the samples.

large space, such as inside a room, and recognizing the state of the smell.

<Measurement case 3: Odor measurement in a restroom>

We experimentally installed a sensor near the urinal in the men's restroom in our laboratory, and conducted an experiment in which samples simulating urine, stool, and vomit were sprayed on the floor around the sensor with the goal of recognizing among normal (no odor), urine, stool, and vomit odors **(Figure 8)**. The measurement and analysis flow is shown in **Figure 9**. As a result of the measurement and analysis, we have confirmed that the sensor can recognizing between odorless and urine odor, although this is still in the development stage. By monitoring toilet odors with our e-Nose, it is possible to propose efficient cleaning according to the sanitary conditions at the appropriate time. Development is currently underway to make the sensor smaller and more energy-efficient, and to expand the range of odors that can be handled.

Future plans

In addition to “FlavoTone®” rental and contracted analysis, we are also proposing solutions to individual issues. In response to diversifying consumer needs and increasingly complex social issues, we will contribute to the creation of a better social infrastructure through co-creation with our customers.

References (This is a machine translation of Japanese references)

1) Seiji Shiota et al., “Smell sensing, analysis, and its visualization and quantification”: Chapter 1, Section 1: The olfactory reception mechanism based on the anatomy and physiology of smell, Technical Information Institute, p3-9 (2021)

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In Japan
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Fig. 7 Compact machine (left) & prototype (right)

Fig. 8 Odor experimental measurement in a restroom

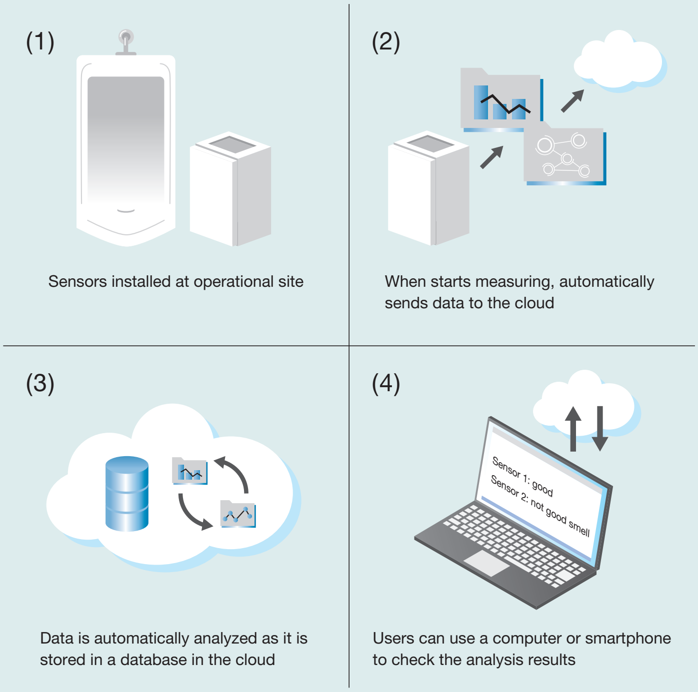

Fig. 9 Image of compact machine in use