

Breakthrough Sensors

Japanese manufacturers have developed highly reliable sensors that have contributed to upholding the high quality standards of their products. Japan Echo reports on two SMEs that have taken sensor technologies one step further to develop devices capable of quantifying what had previously been considered difficult to measure objectively.

Intelligent Sensor Technology

Recreating the Mechanisms of the Human Tongue

Taste tests of food products by food makers have traditionally been conducted by trained human testers based on their experience and designated standards. They score flavors by ranking each product into predetermined categories. There are individual differences from one tester to the next, though, and the conclusions may be affected by their physical condition or emotional state. It has thus been difficult to score taste objectively.

Many machines have been developed utilizing chemical analysis to identify individual taste-giving

substances. They evaluate flavors by measuring the amount of each substance in a food product. There are innumerable taste substances in foods and drinks, however, and many interact with one another. Ascertaining taste through chemical analysis has thus proven quite difficult.

Judging flavors objectively—either with the human tongue or by machine—has long been considered impossible. Overturning such conventional wisdom was Kyushu University and Intelligent Sensor Technology, Inc., a company based in Atsugi, Kanagawa Prefecture, that succeeded in developing a taste-recognizing device that uses sensors to identify such tastes as bitter, astringent, *umami* (savory), sweet, salty, and sour. An added feature of the machine is that it can gauge whether a food or drink is “crisp” or “rich”—qualities usually associated with tastes that linger after consumption.

Quantifying Flavors

Intelligent Sensor President Hidekazu Ikezaki was researching bioelectronics at a major electronic measuring equipment manufacturer when he met Kyushu Univer-



President Hidekazu Ikezaki

sity Professor Kiyoshi Toko. Rather than pursuing the conventional approach of identifying individual taste-giving substances, Toko sought to quantify the very sensations felt by humans by utilizing the mechanisms of the human tongue. This was around 1985.

Humans discern taste by having a variety of tongue cells that react only to certain tastes. Taste cells are covered by cell membranes containing lipids and proteins. When food enters the mouth and adheres to the taste cells, the lipids and proteins inside the cell membrane undergo a chemical reaction, creating a difference in electric potential between the inside and outside of the membrane. This differential is carried by the nervous system to the brain, where it is interpreted as taste.

Toko and Ikezaki thus mixed



The TS-5000Z measures 47 centimeters across, 51 centimeters high, and costs ¥9.8 million.

lipids with polyvinyl chloride to create an artificial cell membrane that generated an electric signal when it came into contact with food. The signals were sent to a computer and analyzed. In 1990 they began joint research on applying this mechanism to a commercial product, and in 1993 they developed a prototype taste-sensing device.

They soon ran into problems, however. There are five widely recognized basic tastes, namely, sour, bitter, sweet, salty, and *umami*. The membranes used on the prototype device, though, inevitably reacted to several tastes. So they analyzed the patterns created by the signals from those membranes to ascertain which patterns corresponded to which taste. This turned out to be a highly complex task, as there was a mind-boggling array of patterns to identify.

In an attempt to enhance statistical accuracy, they turned to the large volumes of taste-test data accumulated by food makers and pharmaceutical companies. Such data, though, were based on varying sets of sensory criteria and could not be used as objective values. Having run up against a wall, Toko and Ikezaki decided to change their approach. Instead of using a number of membranes to

ascertain each taste, they focused their energies on developing membranes that reacted to only one basic taste.

At the time, little was known about the human stimulus-response mechanism, so researchers went through a process of trial and error. While endeavoring to improve the stability of the sensor, they discovered the mechanisms behind the absorption phenomenon. This enabled them to change the characteristics of the cell membrane at will and to create membranes that selectively responded to each basic taste.

Ikezaki took the prototype to public research institutes, food processing companies and pharmaceutical firms, which had large volumes of human taste-test data. Comparing these figures with those generated by the prototype, he analyzed the patterns to enhance accuracy. After 10 years of research and analysis, the world's first apparatus capable of gauging the five basic tastes as numerical data was developed.

"Rich" and "Crisp"

Ikezaki subsequently left his employer and set up Intelligent Sensor Technologies to turn the machine into a marketable product.

"We had to ensure stability, durability, and ease of use before it could be launched commercially," says Ikezaki. "This was not an easy task, as we had to completely remake the artificial membranes that we had initially developed for the prototype. We also needed to provide customers with technical advice to enable them to make effective use of the apparatus and also set up a system for meticulous after-sales service. This took more time than anticipated."

Ikezaki also began meeting

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Capital: ¥95 million
Employees: 33
Website: <http://www.insent.co.jp/english09/framepage.html>

food makers' requests for added features. A beer manufacturer, for example, asked that the machine be capable of assessing the "crispness" of the alcoholic beverage. Beer often leaves a bitter aftertaste; when the bitterness fades quickly, it is considered "crisp." The brewery wanted a machine that could measure this quality. Ikezaki met this request by first dipping the sensor in the beer, rinsing it quickly, and then taking another measurement. When there is little residual bitterness on the sensor, the beer is thought to be "crisp."

This same principle was applied to soup, although in this case, a lingering, "rich" savoriness was considered desirable.

In 2007 the company launched its first commercial product, the TS-5000Z, capable of measuring six initial tastes, namely, sweet, salty, *umami*, sour, bitter-harsh, and astringent-tangy, as well as three aftertastes, namely, bitter, astringent, and *umami*-rich. Over 200 TS-5000Zs have been adopted for use by food, beverage, and pharmaceutical companies, research organizations, and other entities. With the ability to analyze a full range of tastes and graphically represent the results on a chart, the technology is now being used in a wide range of applications, such as new product development, product marketing, quality control, and corporate communications.

"Food makers are naturally very concerned about the taste of their products. So we're listening



Taste sensors tipped with artificial taste cells.

very carefully to their needs and trying to meet their expectations as much as possible. By making such efforts on an ongoing basis, I

think we'll be able to identify even subtler tastes in the future."

With further improvements of the taste sensors, Ikezaki hopes to

market the devices overseas and contribute to taste culture and food safety by establishing international standards for various tastes.

Nitto Construction Company

Measuring the Strength of Concrete

The head office of Nitto Construction is located in the town of Oumu, facing the Sea of Okhotsk on Japan's northern island of Hokkaido. Winters there are very cold, with icebergs berthing along the sea coast and temperatures sometimes dipping below minus 20 degrees Celsius.

Civil engineering projects are the main business of Nitto Construction, the main sources of revenue being road construction and snow-clearing projects. With the decline in public-works projects from the late 1990s, though, the company had been looking for ways to use its redundant workers in other fields of business.

It was around that time that a television news story caught the eye of the company president, Hajime Kubo. In 1999 a 200-kilogram block of concrete fell from the tunnel wall onto a passing San'yo Shinkansen train. "Concrete starts to break down after around fifty years," Kubo thought. "Perhaps Japan's concrete structures are beginning to reach their limit. Since so many of them were built all around the country during the high-growth years, they may soon need to be rebuilt or reinforced. There's a need for a concrete testing device that is easy to use, portable, accurate, and inexpensive."

Overcoming Equipment Shortcomings

The life of a concrete structure is mainly determined by the compressive strength of and degree of deformation in its concrete. A traditional, nondestructive way to test concrete involves a test hammer containing a spring: the material's compressive strength is estimated based on the rebound when it is struck by the hammer's plunger. Deformation, meanwhile, is determined by the sound made by hitting the concrete surface with an ordinary hammer.



A CTS unit costs ¥550,000.

There were a number of drawbacks with these conventional techniques. Since the test hammer used a built-in spring, its accuracy could decline as the spring deteriorated. Corrections could also be



President Hajime Kubo

needed in the calculations depending on the angle at which the hammer was struck. The drawback of using ordinary hammers to check for deformations, meanwhile, was their reliance on the experience and skills of human technicians, making objective data difficult to obtain.

Kubo hoped to develop a single testing device that could overcome these problems and be used to easily measure the compressive strength and deformation of concrete. To meet this tall challenge, he sought the guidance of Kunio Gokudan, then an associate professor researching nondestructive concrete-testing methods at the Department of Civil Engineering in Tokai University, Kubo's alma mater, and Tomoaki Sakai, then a part-time lecturer in the graduate course of the same department. He cited the problems with conventional forms of concrete testing and discussed ways they could be overcome.

They soon focused their attention on “strike force waveforms.” The first half of such a waveform represents the time during which the hammer compresses the concrete in a strike; the second half is the time when the concrete rebounds and pushes the hammer back. When there are deformations, the hammer’s strike force takes more time to propagate as it travels through the deformed portions of the material. During the rebound, meanwhile, the only force acting on the hammer is the compressed concrete seeking to return to its original shape. In short, analysis of this waveform can produce highly accurate measurements of the concrete’s compressive strength and judge the degree of deformation. The men aimed to develop a device that could numerically represent these values.

This was a technically challenging task, but through a process of trial and error, in April 2005 Nitto developed the Concrete Tester (CTS) capable of simultaneously and automatically assessing the compressive strength of a concrete structure and the degree of deformation.

The CTS consists of a hammer

sensor and main body, which together weigh 940 grams. It is a compact, lightweight device, with the body measuring just 20 centimeters high and 10 centimeters across.

Just two seconds after the concrete is struck with the hammer, which contains an accelerometer, the results appear on the body’s display and are stored on a flash memory card. Once the data is copied from the card to a computer, it immediately appears in a table of results. What is more, the structure being tested can be displayed on the screen as a color-coded image showing its strength in different areas, thus allowing testers to visually confirm its overall condition. The result is more accurate identification of areas in the concrete requiring reinforcement than was possible with previous testing methods.

To ensure that the hammer is struck with appropriate force, the CTS does not respond to a tap that is too light and sounds an alarm when struck too forcefully. Such foolproof features are the result of efforts to create a device anyone, regardless of experience, can use in testing.

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President: Hajime Kubo

Business: Construction work, sale of nondestructive, elastic-wave concrete testing equipment and technical guidance for the use of this equipment in surveying concrete structures


Capital: ¥20 million

Employees: 48

Website: <http://www.nittokensetsu.co.jp/index.htm> (Japanese only)

Collaborative Effort

“It was fortuitous that we were able to work in a collaboration among industry, academia, and government,” Kubo says. “We were also fortunate to have our work recognized by the Hokkaido Bureau of Economy, Trade, and Industry as an ‘innovative technological development project,’ a citation conferred to unique undertakings by private companies in the prefecture. We were able to pursue the development of the CTS thanks to this grant, and so we’re very grateful, as research and development work among SMEs must be conducted in ways that do not constrict their main businesses.”

As of February 2010, Nitto Construction has sold 252 CTS units to various customers, including such public bodies as the Ministry of Land, Infrastructure, Transport, and Tourism and the Ministry of Agriculture, Forestry, and Fisheries, as well as the Japan Railways Group of companies and construction firms. Looking abroad, the firm has already sold 12 devices to customers in South Korea and is fielding inquiries from the United States and Vietnam as well. The reaction from overseas has been that the CTS is a breakthrough testing device that is easy to use and that instantaneously generates test results. 



Testing the compressive strength and deformation levels of concrete.