Detection of Soil Gravity Water with Hetero-Core Optical Fiber Sensor

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Keywords: soil gravity water, SPR, optic fiber, agriculture

It is well known that soil water at a farm land seriously affects on growth and quality of crops. Therefore, although several methods for monitoring of soil water have been developed, they still have many difficulties for a continual monitoring such as difficulty in an electrical supply at a farm. On the other hand, hetero-core optical fiber sensor has several advantages such as requiring no electricity supply to work in the sensing part and no ignition capability from breaking of optical fibers never occurring. In addition, the sensor is suitable for a continual monitoring because it is easy to be built in a network system.

Hetero-core optical fiber SPR sensor introduced in this research is used for sensing a drop of water. It takes hetero-core optical fiber construction by two types of an optical fiber with different core diameter and the 5µm core optical fiber is inserted between the 50µm core optical fibers (Fig. 1). Moreover, it is a hetero-core optical fiber SPR sensor which is evaporated thinly with Au on the surface of hetero-core optical fiber (Fig. 1). Sensing a drop of water is performed with measuring attenuation rates of light going through inside of the optical fibers caused by change of refraction index when water is exposed to the surface of the thin Au film. The purpose of this research is to detect soil gravity water with the sensor when watering.

The detection experiments are performed in our laboratory and a plastic container is used for the experiment which is holed on the bottom side (volume: 9.7L) and filled with all sorts of soils by approximately 20 cm from the bottom. The soil of the measuring object was made large granule soil, andosol and leaf mold. We set the sensor at 5 cm in depth from the top of the soil and connected it to both a LED light source and power meter. Watering the surface of the soil with a water pot, we kept to measure loss in light per 0.6 second to 1200 seconds.

As the result of that, in large granularity soil the loss in light going through inside of the optical fibers became from 0.62dB to 1.21dB in 40 seconds after watering, and the gain in light became from 0.10dB to 0.16dB in a matter of time (Fig. 2 (a)). In andosol the loss in light became from 0.07dB to 0.31dB in 60 seconds after watering, and the gain in light became from 0.06dB to 0.11dB in a matter of time (Fig. 2 (b)). In leaf mold the loss in light became from 0.51dB to 0.63dB in 30 seconds after watering, and the gain in light became from 0.08dB to 0.17dB in a matter of time (Fig. 2 (c)).

According to the result, it was proved that to detect soil gravity water is possible and in several soils the detection ability of the sensor can return which is caused by evaporating of water on the surface of the sensor by air in a soil. Therefore, if watering again in a served condition, loss in light was detected, so that repeated detection with the sensor is available. By contrast, in a few soil such as andosol and a leaf mold, the loss in light was sometimes unable or low to be detected soil gravity water. Therefore, modifying the form of the sensor, finally it was possible to detect a soil gravity water in those soils. From those results, the sensor can adequately detect soil gravity water in a soil.

![Fig. 1. Scheme of hetero-core optical fiber SPR sensor.]

![Fig. 2. Detection of soil gravity water with hetero-core optical fiber SPR sensor.](attachment)
Measurement of Electrical Conductivity into Tomato Cultivation Beds using Small Insertion Type Electrical Conductivity Sensor Designed for Agriculture

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Keywords : Electrical conductivity (EC), Insertion EC sensor for agriculture, Tomato culture in greenhouse, Substrate of tomato culture, Si integrated circuit technology

Our group has studied on-site monitoring sensor for agricultural field. An electrical conductivity (EC) sensor had been fabricated using Si integrated circuit technology. EC information of solutions shows ion concentration dissolving in water, and can be used as the index of nutrient concentration for plants. So, it is important to measure EC in real time and on site. Because our EC sensor (5mm×5mm in size) is smaller than other commercial ones (several centimeters), it is easy to insert and achieve measurement in rockwool (shown in Fig. 1, 2). In this study, our sensor measured long term EC values in tomato cultivation soil and rock wool medium. At first, we calibrated a relationship between output voltages and EC values on the sensor. The sensor was confirmed about enough EC measurement range from 8 to 969mS/m. In long period measurement, the sensor was confirmed about continuous operation for over five months and intermittent measurement for over a year. In measurement in the cultivation soil, the sensor indicated that water was kept and diffused in the soil (shown in Fig. 3, 4). In contrast, it was found that water diffused without keeping in it in rock wool medium (shown in Fig. 5, 6). We confirmed our small EC sensor is useful for on-site monitoring and analysis of solution concentration distribution in several kinds of plant bed in real time.

![EC Sensor electrodes (Pt/Ti/Al/SiO2/Si)](image1)

Fig. 1.  EC sensor Chip with Pt electrodes

![Insertion type EC sensor mounted on PCB base](image2)

Fig. 2.  Insertion type EC sensor mounted on PCB base

![Drip tube for irrigation](image3)

![Insertion type EC Sensor](image4)

Fig. 3.  Insertion type EC sensor insertion into the soil and drip tube

![EC output in the soil on tomato production](image5)

Fig. 4.  EC output in the soil on tomato production

![Insertion type EC sensor and tomato plant](image6)

Fig. 5.  Insertion type EC sensor and tomato plant

![EC output in the rock wool slab](image7)

Fig. 6.  EC output in the rock wool slab
Rapid Diagnostic Device for Subclinical Mastitis Based on Electrochemical Detection of Superoxide Produced from Neutrophils in Fresh Milk

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Keywords: Mastitis, Superoxide, Self-assembled monolayer, Superoxide dismutase

Mastitis, a persistent inflammatory reaction that occurs in the tissue of the udder, is the most common disease found in dairy cows. When dairy cows are infected with the disease, the number of neutrophils, a kind of white blood cell, in raw milk increases. Neutrophils are known to produce superoxide (O$_2^•$); therefore, O$_2^•$ may be used as an indicator to estimate the number of neutrophils and the seriousness of mastitis. To develop a diagnostic system based on this principle, we fabricated an electrochemical microdevice for the detection of O$_2^•$ using a superoxide dismutase (SOD) enzymatic reaction. A detection scheme using this enzyme alleviates the use of bulky spectroscopic instruments and provides more reliable data. We used the device on real milk samples to demonstrate its usefulness.

Fig. 1 shows the construction of the microdevice. The device consisted of a glass substrate with a three-electrode system and a polydimethylsiloxane (PDMS) substrate with a microchannel. Micropillars were formed on the gold working electrode area (1 mm × 2 mm) at the bottom of the microchannel, and gold was sputter-deposited on the micropillars. As shown in Fig. 1(b), the micropillars were 70 µm high, 50 µm (short axis), and 100 µm (long axis). The surface of the working electrode including the micropillars was modified with a self-assembled monolayer of cysteine. SOD and P-selectin were immobilized there using the carbodiimide coupling procedure. P-selectin is a molecule that is expressed on vascular endothelial cells and promotes the adhesion of neutrophils on blood vessels. Therefore, we used P-selectin to promote the adhesion of neutrophils onto the modified surface of micropillars and to concentrate neutrophils there. When a sample solution is flowed through the narrow space between micropillars, neutrophils are expected to make frequent contact with the sidewalls of the micropillars and to adhere.

Raw milk samples containing neutrophils activated by opsonized zymosan were introduced into the flow channel at 1 µl min$^{-1}$ for 1 h. The numbers of neutrophils were approximately $8 \times 10^4$ ml$^{-1}$ in the normal raw milk and $8 \times 10^6$, $7 \times 10^6$, and $9 \times 10^5$ ml$^{-1}$ in the mastitic milk. In a preliminary experiment, we found that only a few neutrophils were trapped around micropillars with surfaces not modified with P-selectin; furthermore, it was difficult to collect neutrophils on a working electrode without the micropillars. Therefore, micropillars modified with P-selectin are essential for our system to perform optimally. To detect the O$_2^•$ produced by the neutrophils, +0.3 V was applied to the micropillar electrode with respect to the on-chip Ag/AgCl electrode. A distinct difference in the detection current was observed between samples from mastitic and normal cows (Fig. 2). We are currently developing an auxiliary device to further promote the concentration of neutrophils.

Fig. 2. Response curves observed using the type II device. (a)–(c) Mastitic milk samples containing $8 \times 10^6$ ml$^{-1}$ (a), $7 \times 10^6$ ml$^{-1}$ (b), and $9 \times 10^5$ ml$^{-1}$ (c) neutrophils. (d) Normal milk sample containing $8 \times 10^3$ ml$^{-1}$ neutrophils. (e) Blank phosphate buffer solution without neutrophils.
Recognition of Daily Activity in Living Space based on Indoor Ambient Atmosphere and Acquiring Localized Information for Improvement of Recognition Accuracy

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Keywords : Indoor ambient atmosphere changes, Multi-sensor unit, Recognition of resident’s activity

Japan is a super-aged society. Therefore, senior citizen’s lonely death becomes a big social trouble. Moreover, the nursing problem of an elder person which lives alone is also similar. Under the circumstance, it is necessary to develop the system in order to watch the life of an elder person.

For the purpose, we have proposed a method to recognize the resident’s daily activity in a room using indoor environmental changes.

This method acquires the information about an indoor environment (temperature, humidity, gas, brightness) that change by resident’s daily activities by multiple sensors. Then, we developed a multi-sensor unit. In the unit, astable multi vibrator was used as a resistance-frequency converter for getting sensor response data of a resistance change type sensor, and frequency counter was used for the measurement of sensor response. The unit has merits as follows: 1) sensor is exchangeable easily and 2) the sensitivity of each sensor can adjust in pseudo only by exchanging the capacitance in the oscillation circuit. Those features are useful for the measurement about the environment which changes by resident’s preference and season.

We measured the indoor environment changes in a room by using above mentioned multi-sensor unit. As a result, we could classify the resident’s daily activity roughy by one multi-sensor unit. Fig. 1 shows result of classification by Self-Organized Map. However, classified data have a little error. Then, to classify the resident’s daily activity more in detail, we introduced one more sensor unit which was able to get localized information around a table.

Generally, an activity and a place in a room have a relation. For example, “eating” is done at a dining table and “cooking” is done at a kitchen. Therefore, if the information about local environment in room such as “around dining table” can be acquired, daily activities would be recognized more in detail by using the relationship between the sensor response and the place.

To acquiring environmental changes at a specific local place where a resident acts specific daily activity, we used above mentioned multi-sensor unit which was added with active sensing function. The active sensing function was realized by equipping the wind tunnel and micro-fan to sensor device. The micro-fan was switched by the signal from human detector using pyroelectric sensor. Therefore, the air around the unit is pulled toward gas sensor, when human is around the unit. In the basic experiment for acquiring local information, we focused on the active sensing of local gas environment, because a lot of activities were featured in the change of the gas environment.

We assumed the experimental situation of having a meal at a table. The situation was realized by using naturally evaporating ethanol gas. Fig. 2 shows experimental situation, and Fig. 3 shows result of the experiment.

It was found that the gas sensor in the wind tunnel was more stable (Green solid line plot: no remarkable response) than other gas sensors in the case of OFF state of the micro-fan. And when the micro-fan is ON, the gas sensor in the wind tunnel respond clearly comparison with other sensors. As a result, we could distinguish between the environmental changes by the resident’s daily activity at a specific place and the others. This technique will make a big contribution to the recognition the resident’s daily activity more in detail by analyzing the acquired data.
Mist Ejection of Silicon Microparticle Using a Silicon Nozzle

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Keywords : Mist-jet technology, Ultrasonic wave, Silicon microparticle

The novel mist-jet technology using a silicon nozzle and a silicon reflector has been developed. Ejection of water mist containing the silicon microparticles is demonstrated. Impurities of the silicon microparticles ejected on the substrate are analyzed. It has been verified for the first time that the contamination is reduced by the silicon head. The silicon pattern drawn by the head is successfully formed.

The development target of this work is to form a film of silicon using the combining technique of ejection of silicon microparticles ejection and non-vacuum deposition by plasma enhanced chemical transport under the atmospheric pressure.

The mist-jet technology is different from ink-jet technology where the solution is ejected by single droplet. The mechanism of mist-jet technology is to employ high-density ultrasonic energy to atomize water and to eject the mist from the nozzle as shown in Fig. 1(d). Ejected silicon microparticles should be free from impurities since the contamination decreases the performance of the functional film. Therefore the reflector and the nozzle have been made of silicon instead of stainless-steel as shown in Fig. 1. The continuously ejection of the mist from the silicon head is confirmed, though a detailed ruggedness is seen in the silicon reflector and nozzle.

The mist diameter is approximately 3.7 µm using the ultrasonic frequency of 5 MHz. The measurement is performed by a particle size distribution measuring device based on laser scattering. The mist ejection is examined using water containing the silicon microparticles (diameter of 50 nm - 100 nm). Impurities of ejected silicon microparticles are analyzed by SIMS (Secondary Ion Mass Spectrometer). The result of using the silicon head is shown in Fig. 2. The decreasing amount of Fe is detected.

Using the mist-jet system with the head, the letters “BEANS” are drawn on the glass substrate without surface treatment as illustrated in Fig. 3. The basic driving frequency of the mist-jet head at 5 MHz is used. The speed and the temperature of the motorized stage for moving substrate is 60 mm/s and 80 °C, respectively. Figure 3(b) shows that silicon microparticles are aggregated.

For the future outlook, the aggregation of silicon microparticles will be solved. In addition, combination of mist-jet technique and non-vacuum deposition technique will be achieved.

This work was supported by New Energy and Industrial Technology Development Organization (NEDO).

Fig. 2. Impurity analysis results of silicon microparticle using mist-jet technology

Fig. 3. Drawing by the mist-jet head