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A Real Time Monitoring System using a Multi-Modal Sensor with EC Sensor Areas and a Temperature Sensor Area for Cows' Health Control

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1. Introduction

Living body information of animals has been carefully watched for health controls during recent years. Milk yield, milk quality and body weight are, in general, measured periodically of milking cows. And first stomach of cows, which is called "rumen", is needed to keep good condition. However, information can't be measured simply, quickly, and continuously of a rumen, because it is in a body. Continuously measurements (of pH, electrical conductivity (EC) and temperature) of the rumen contributed to a control of all-around feeding system [1] [2]. In particular, EC measurement makes it possible to study stomach contents in the rumen [3], and temperature measurement makes it possible to study health conditions. Our group has proposed a multi-modal sensor which includes several kinds of sensors using LSI technologies, and we have fabricated an EC sensor using Pt electrodes on a Si substrate [4]. The sensor has measured EC inside of soils for agriculture applications. In this research, we fabricated multi-modal sensor including the EC sensor and a Temp sensor in a same sensing chip. A wireless measurement system with the multi-modal sensor chip was also realized for continuously measuring of the rumen conditions in real time.

2. Structures and measurement methods

The multi-modal sensor including EC sensing areas and a temperature sensing area fabricated on a Si substrate (Fig. 1 and Fig. 2). At first, a p-type diffusion layer, which was used as shielding layer for cutoff noise, was formed. A p-n junction diode at temperature sensing part was formed into the shielding layer. SiO_2 layer used as an insulating layer was formed, because leak currents between the EC sensing areas in the Si substrate were necessary to decrease. After Al layer was formed, Pt was patterned on the EC sensing area. We deposited and patterned SiO and SiN layers which were for passivity layers. After that, the multi-modal sensor was successful including the EC sensing areas and the temperature area, after the chip was covered except the EC sensing areas.

For example, "water into soil" and "fluid into rumen" were possible to measure using an EC sensor which measured conductivity between Pt electrodes (Fig. 3 (a)). The sensor needed to use alternator (wave pattern: 10 kHz sine wave, amplitude: 250 mV). The temperature sensor measured a change in voltage using a constant current source (value: 1 mA).

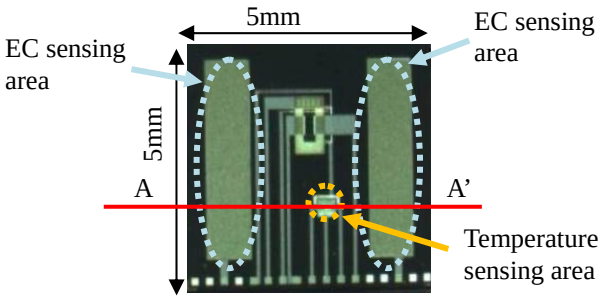


Fig. 1 EC and temperature sensors on the same chip fabricated by compatible LSI technology.

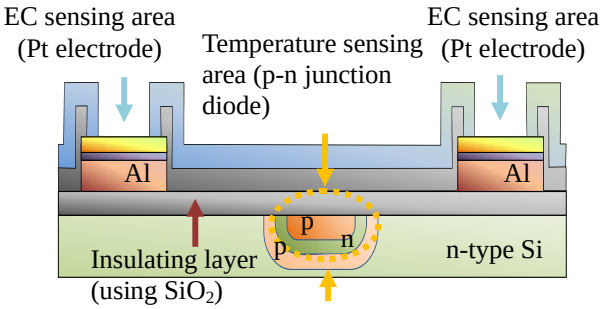
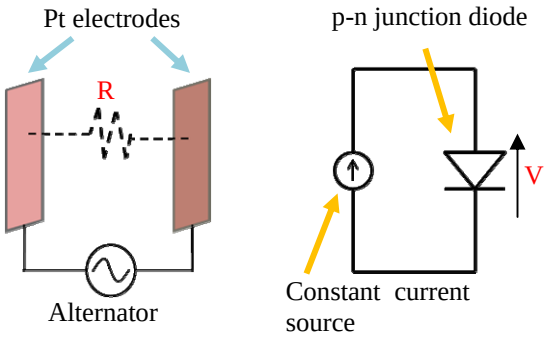


Fig. 2 Fig1 A-A' Cross sectional structure image of multi-modal sensor chip with EC sensor and temperature sensor.



(a) Measurement of EC sensor (b) Measurement of temperature sensor

Fig. 3 Measurement circuits of EC sensor and temperature sensor.

3. Applications

We fabricated a digital wireless system, including a sensor unit (Fig. 4), for real time measurement of a rumen. The sensor unit had waterproof case, because the unit was continuously set in the rumen (Fig. 5). In the unit, there was a battery (3 V), an antenna and some boards which were an analog signal processing circuit board, an A/D converter board and a receiver-transmitter board. The multi-modal sensor was bonded outside the case, because the sensor needed to touch the fluid in the rumen.

We were successful that the EC and temperature measured in the rumen in the real time (Fig. 6). For we needed to check positions of sensor unit in the rumen, we tried the rumen measurements using on examination cow, which was called “rumen cow”. And we received signals (EC and temperature) using the wireless system when a rumen cap was closed. After that, we opened the cap and measured the rumen temperature using an infra-red heat gauge, because the temperature measurements of a multi-modal sensor were possible to confirm accuracy.

The temperature measurements were confirmed accurate because variation of the sensor measurements was similar to variation of the gauge measurements. The EC sensor measurements were accurate because the measurements were possible to check the value of the rumen mat.

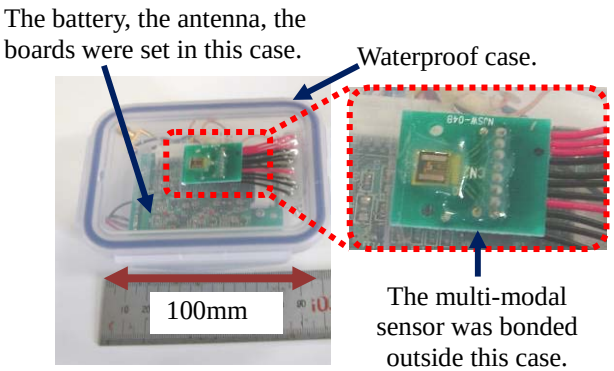
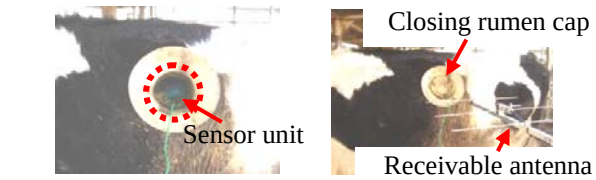


Fig. 4 The sensor unit including multi-modal sensor, the battery, the analog signal processing circuit board, the A/D converter board, the receiver-transmitter board and the antenna.



(a) Inserting the sensor unit into the rumen cow.

(b) Appearance of measurement using a wireless system.

Fig. 5 The examination of the rumen measurement using a wireless system.

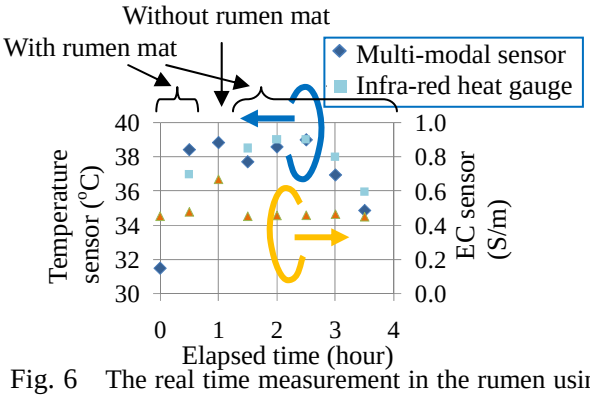


Fig. 6 The real time measurement in the rumen using a wireless system.

4. Conclusions

A multimodal sensor including the EC and the temperature sensor on the same chip was successfully fabricated by using a compatible CMOS LSI technology. The real time measurements of EC and temperature using the multi-modal sensor unit were successful in the rumen of a cow. The wireless system was successful to receive continuously the unit measurements, and it was successful to observe the rumen conditions in real time.

Acknowledgements

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Appendix

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