10 February 2014

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Press Release

"The world's first flexible wireless organic sensor system" Disposable sensors that can electrically functionalize a Band-Aid or diapers

1. Achievements

- ✓ A flexible wireless organic sensor system that transmits power and data wirelessly has been constructed by integrating organic devices on plastic films.
- ✓ This sensor will be used in new applications in the currently expanding healthcare and nursing-care fields. An example application is a diaper that detects liquid electronically.

2. Summary

Within the framework of the Strategic Basic Research Program of the Japan Science and Technology Agency (JST), a research team led by Professor Takayasu Sakurai and Professor Takao Someya at The University of Tokyo has succeeded in developing the first flexible wireless organic sensor system in the world. The feasibility of this wireless system has been demonstrated by wirelessly supplying power and wirelessly transmitting data from a wet sensor.

Because of the recent significant progress of wireless sensors, they are expected to be widely in use to measure various physical information in a real space. Recently, the measurement targets of sensors are expanding swiftly from objects to humans. In order to extract biological information from sensors that physically interact with the human body, we are facing issues that have not been required of conventional sensors, such as imperceptible softness and disposability from a hygienic perspective.

The team has succeeded in developing a wirelessly powered flexible wet sensor sheet that transmits data wirelessly by implementing an organic integrated circuit (IC) (glossary 1) on top of a polymeric film. Introducing an electromagnetic-resonance method (glossary 2) in power transmission for the operation of an organic IC for the first time in the field was key to this achievement. This method enabled them to effectively transmit power and data wirelessly between the reader and the sensor, which are far apart. This organic IC is structured with three circuitry blocks. The first block receives a wireless power supply with the magnetic-resonance method at a rectifier circuit (glossary 3) using organic diodes. The second block is placed on an organic ring oscillator (glossary 4) with oscillating frequencies that change with the resistance. The ring oscillator transmits the data of the resistance changes caused by moisture or the presence of liquid. The third block is an electrostatic discharge (ESD) circuit (glossary 5) comprising organic diodes that enable to protect the device from damage when touched by a charged human body (2-kV electrostatic discharge).

The principle of this research could be applied to sensors to detect humidity or pressure, other than moisture. This result will be applied to disposable sensors such as sticking-plaster-type sensors.

This achievement was presented at the 2014 IEEE International Solid-State Circuits Conference (ISSCC) in San Francisco, U.S.A, on February 12, 2014.

This result is an accomplishment of the Exploratory Research for Advanced Technology (ERATO) research funding program of the Japan Science and Technology Agency (JST).

Project Name	**Someya Bio-Harmonized Electronics Project**
Research Director	Takao Someya, Professor, School of Engineering, The University of Tokyo
Project Period	August 2011 - March 2017
Project Objective	The aim of the project is to realize brand new electronic devices that seamlessly merge biological tissues and electronics together, by making the best use of the unique features of soft and bio-harmonized organic materials, and to subsequently open up new bio-harmonized electronics markets that are closed to conventional electronics relying on inorganic rigid materials represented by silicon.

3. Detailed Information

//Background//

Because of the recent significant progress of wireless sensors, they are expected to be widely in use to measure various physical information in a real space. Wireless sensors monitor the power consumption of the apparatus, environmental information such as temperature or humidity, and the locations of people. Using this information taken from a real space, an energy management or human monitoring system (“mimamori”) is being performed globally. Furthermore, recent targets of wireless sensors are expanding rapidly from objects to humans.

Conventional wireless or sensing technology has been implemented on rigid electronic materials such as silicon, and medical sensors have been developed on top of conventional rigid sensors. However, in order to extract biological information from sensors that physically interact with the human body, there are issues that have not been required of conventional sensors, including imperceptible softness and disposability from a hygienic perspective.

With this background, organic devices such as organic transistors or organic diodes that are easily printed by an inkjet on a polymeric film are simultaneously expected to realize a large area, cost effectiveness, lightness, and flexibility. Organic integrated circuits (ICs) (glossary 1) have been utilized for flexible displays or wireless tags up until now.

However, flexible wireless sensors integrate various electronic circuits, and it has been considered quite difficult to accomplish this integration on a single polymeric film. Further, the sensor sheet tends to become thick and unbendable when external components such as batteries are attached. It is an urgent issue to establish technologies to implement all electronic circuits with organic devices without embedding external components.

//Research//

The research team succeeded in developing a flexible wet sensor sheet that transmits power and data wirelessly by building several organic ICs on top of a 12.5-μm-thick polyimide film. The sensor sends signals of several hertz when it detects moisture. When an oscillation frequency of the sensor was 3 Hz, the power consumption was only 1.4 μW.

The key to this success was the adaptation of an electromagnetic-resonance method (glossary 2) for the transmission of electricity for operating the organic IC. The electromagnetic-resonance method has been drawing attention as a new effective way to transfer electricity to electronics over a long distance. For the first time, the electromagnetic-resonance method has proven to be appropriate for organic ICs. With this new technology, flexible sensors have also become capable of effective wireless power transmission and wireless data transmission from a distance.

The organic IC is an implementation of various electronics such as organic Schottky diodes, organic transistors, and capacitors. All the apparatuses mentioned above are soft; thus, the system as a whole possesses softness and flexible features as well.

Our organic IC is structured in three circuitry blocks. The first block receives a wireless power supply with the magnetic-resonance method at a rectifier circuit (glossary 3) using organic diodes. The organic diodes created on this rectifier circuit have large current drivability (20 mA) at a low driving voltage (10 V or less) with frequencies of approximately 13.56 MHz, the frequency widely used by wireless tags.

The second block is placed on an organic ring oscillation circuit (glossary 4) with oscillating frequencies that change with the resistance. The ring oscillator transmits the data of the resistance changes caused by moisture or the presence of liquid. The circuit is equipped with a mechanism within itself to adjust the transmission voltage so that the sensor steadily extracts data at an optimal condition, even when the reader coil of the wireless sensor is bent. As such, we managed to reduce the power consumption of the reader, which reads and extracts data from a wireless sensor, by 92% at most.

The third block is an electrostatic discharge (ESD) protection circuit (glossary 5) consisting of organic diodes. It protects the flexible sensors from being damaged by the static electricity of a human body. It has been proven that the electrostatic discharge protection circuit remains undamaged even with 2 kV of static electricity. The novel organic diode has a large current drivability (greater than 10 mA) at the low driving voltage (8V or less) for organic transistors. There have been investigations into electrostatic discharge (ESD) protection circuits; however, we accomplished the global testing standard (level 1 of IEC61000-4-2) for the first time in the world for this type of circuit.

//Outlook//

Although the structure is simple, a completely wireless sheet sensor system will open up various kinds of novel applications. Indeed, the soft sensor system will operate on the basis of the present principle, when any data extracted by a sensor is transferred to a change in resistance. This sensor system can be applied to various sensors such as temperature or pressure sensors. The new wireless sensor will realize an accurate monitoring at multiple points over large area. The data measured at multiple points are more reliable than data monitored at a single point. As such, multipoint sensors are suitable for medical and healthcare use, as these fields require reliability and accuracy of data. The system is also capable of sensing diaphoretic skin; thus, a diaphoresis sensing system is expected to become a unique biosensor.

Furthermore, high throughput and an environmentally friendly process by which organic devices are manufactured, such as inkjet printing, may lead to a significant reduction in manufacturing cost. Cost effectiveness is ideal for disposable hygienic sensors, for example, a Band-Aid sensor.

In the next stages of this work, the reliability and reduction in power consumption will be improved. As for the reliability, by investigating materials and structures of organic diodes used for the electrostatic discharge protection circuit, circuits will withstand at the higher voltage. The further power reductions will be possible by decreasing the operation voltage of the organic diodes in a rectifier circuit.

Figures

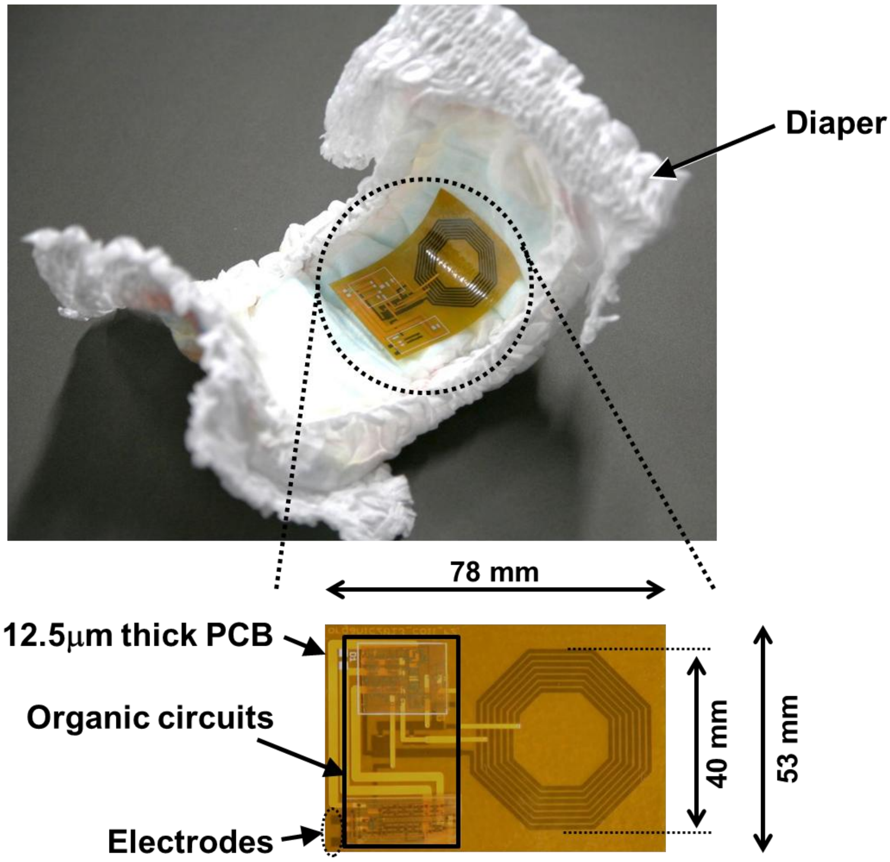


Figure 1: The world's first soft wireless organic sensor system detects liquid and wirelessly transmits data. The sensor is powered wirelessly and can be mounted to diapers or Band-Aids for disposable use.

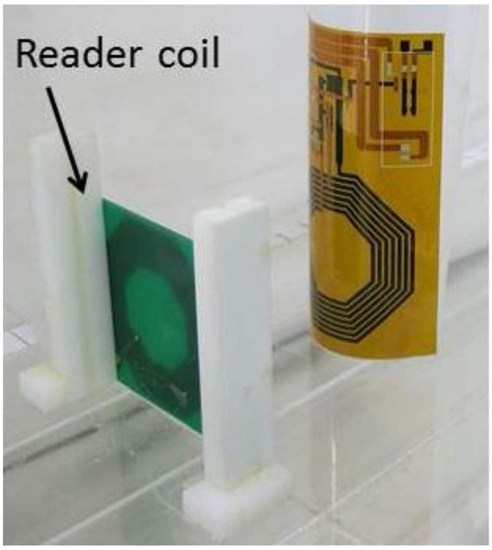
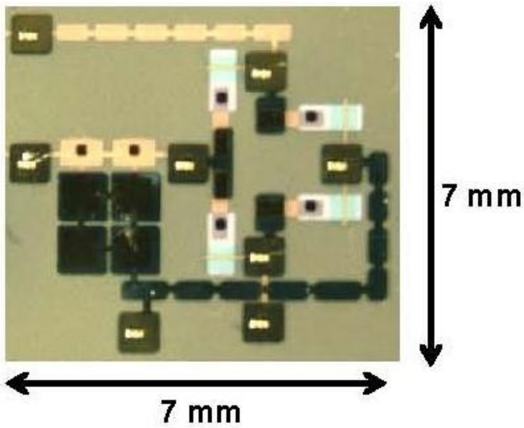
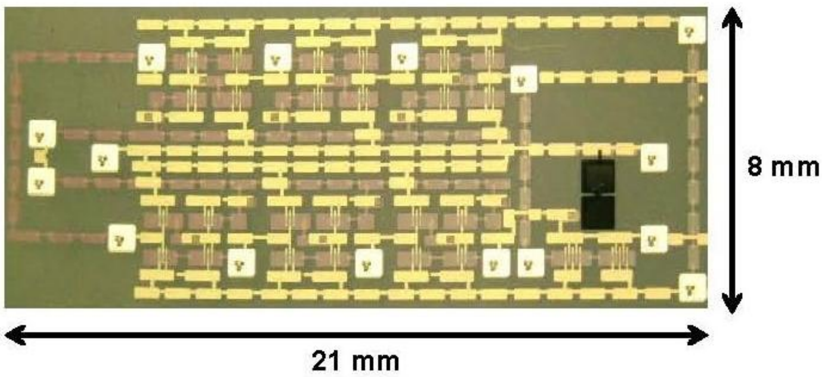


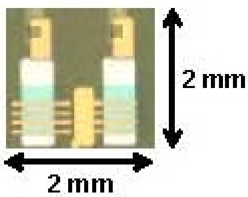
Figure 2: The wireless flexible wet sensor sheet with an ESD protection circuit operates even when the coil is bent.



(a) A rectifier circuit using organic diodes



(b) An organic ring oscillator (wet sensor)



(C) ESD circuit using organic diodes

Figure 3: Three circuitry blocks that structure the organic IC.

(a) A rectifier circuit using organic diodes that receives a wireless power supply with the magnetic-resonance method

(b) An organic ring oscillator with oscillating frequencies that change with the resistance. The ring oscillator wirelessly transmits the data of the resistance changes caused by moisture or the presence of liquid.

(c) The third block is an ESD circuit created with organic diodes that protects the device from damage when touched by a charged human body (2-kV ESD).

Glossary

1) Organic integrated circuits (ICs)
An organic integrated circuit is a set of organic electronic components such as organic transistors, organic diodes, and capacitors.

2) Electromagnetic resonance method
The electromagnetic resonance method is a power transmission system. Compared with the electromagnetic induction type of power transmission system, this system can transmit power over a longer distance. In addition, this system transmits power wirelessly.

3) Rectifier circuit
A rectifier is an electrical circuit that converts alternating current (AC) to direct current (DC). Normally, a rectifier consists of diodes.

4) Ring oscillator
A ring oscillator is an oscillation circuit composed of an odd number of inverters. The inverters are attached in a chain.

5) Electrostatic discharge (ESD) circuit
An electrostatic discharge circuit is the circuit for protecting semiconductor devices, such as an LSI and IC, from ESD. By passing a high-voltage pulse that occurs from the ESD to an electrostatic protection circuit, the ESD circuit prevents the internal circuit from damage by high voltage.

Conference presentation

Hiroshi Fuketa, Kazuaki Yoshioka, Tomoyuki Yokota, Wakako Yukita, Mari Koizumi, Masaki Sekino, Tsuyoshi Sekitani, Makoto Takamiya, Takao Someya, and Takayasu Sakurai, "Organic Transistor Based 2kV ESD Tolerant Flexible Wet Sensor Sheet for Biomedical Applications with Wireless Power and Data Transmission Using 13.56MHz Magnetic Resonance", IEEE International Solid-State Circuits Conference, San Francisco, CA, USA, February 9-12, 2014.

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