R&D Item

1. Integration of In-Body CA

Progress until FY2024

1. Outline of the project

In this R&D Item, we will research and develop elemental technologies related to the main functions of small cybernetic avatars, which are necessary to realize in-body cybernetic avatars (In-body CAs). In addition, design, prototyping, and basic experiments will be conducted considering system integration for the distributed remote control type (Distributed CA) and the cooperative remote control type (Cooperated CA) as application issues.

2. Outcome so far

The Distributed CA classified the possible forms for in-body use and clarified the technological challenges for dynamic and accurate measurement and monitoring of the in-body environment and pinpoint dosing as needed. We developed the basic technologies for capsule, helical ring, and stent types, and developed the hardware for devices, sensing, communication, processing, and materials necessary to dynamically and accurately measure and monitor the body's environment and administer pinpoint dosing as needed.

We have developed temperature, pH, and image sensing technology with the world's smallest class size and power consumption. We developed temperature and pH sensing for stent mounting with a size of less than 0.3 mm square. 22nm ULL (ultra-low standby power) CMOS process was used to develop temperature and pH sensing circuits with a size of 0.000005 mm^2, which is one of the smallest in the world.

We have developed a position measurement system that measures quasi-static magnetic fields with high sensitivity using a magnetic impedance sensor (Figure 1), and have achieved position measurement accuracy of less than 1 cm. Furthermore, for the position measurement of multiple in-body CAs, we developed a signal technology that effectively separates the quasi-static magnetic field signals.

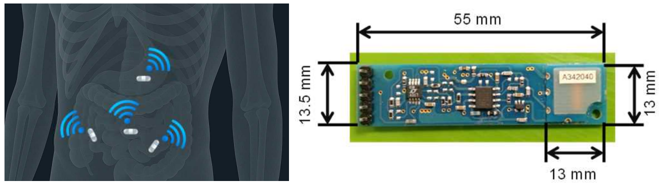

Figure 1: Concept of Position Measurement and Photo of Magnetic Impedance Sensor

We have developed a drug carrier with a size of less than 200 nm that can be implemented in a pinpoint dosing system for stent-type CAs. We have succeeded in encapsulating anticancer drugs with an internal inclusion rate of more than 80%.

As for Distributed CA, we have successfully developed a digital tablet (Figure 2) with gastric acid charge-driven pH and temperature monitoring functions using a 65nm LP (low power consumption) CMOS process. We implemented it in a 1 mm square chip, which is equivalent to the size of a digital tablet used for medication monitoring. The power consumption is extremely low, achieving the world's smallest class compared to conventional fully integrated wireless transmission function sensor chips.

As for Cooperative CA, we developed fundamental technologies for mechanisms, measurement, control, communication, energy supply, and materials for biological diagnosis of tissues and cells that are usually difficult to harvest. We have developed basic technology to improve operability when collecting tissue using a traction mechanism (Figure 3). We also developed a technology to operate the device remotely via in-body wireless communication, and evaluated the communication through animal experiments using living pigs.

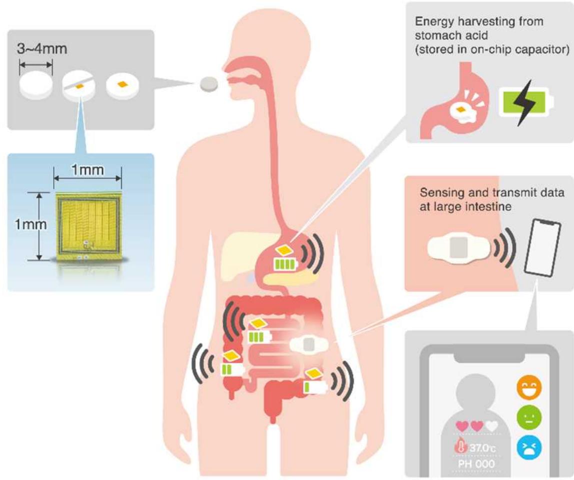

Figure 2: Temperature Sensing and Wireless Data Transmission Device

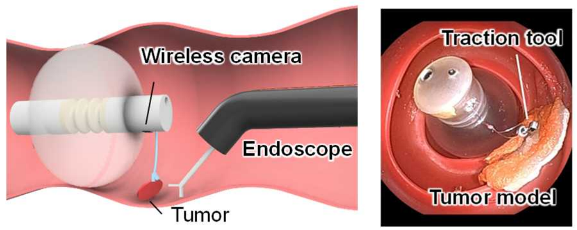

Figure 3: In-body Manipulation of Tissue with Coordinated CA: Traction Force Adjustment and Visual Field Expansion

3. Future plans

We have developed the elemental technologies necessary to build small CAs on the millimeter, micro, and nanoscale. We will continue to research and develop elemental technologies and promote system integration.