Scale-down and Package of Wireless Sensor Nodes for Biotelemetry

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***Abstract*—Biotelemetry and its applications have seen an explosive growth in recent years. This paper presents our recent research work on ultra-compact wireless sensor nodes from both system scale-down and packaging point-of-view for biotelemetry and MedTech innovation. In addition to the results of our work, we also present state-of-the-art technologies and challenges to better understand the market needs and the essential technologies for the coming new era of biotelemetry.**

Keywords- biotelemetry; wireless sensor node; scale-down; package; MedTech innovation.

I. INTRODUCTION

Decades before Internet of Things (IoT) and Wireless Sensor Network (WSN) came to our field of knowledge, biotelemetry systems have been developed for remote monitoring and gathering of various vital signs from animals and ambulatory patients [1]. However, the explosive growth in practical applications has happened in recent years because of the advances in wireless sensing technology, artificial intelligence, smart portable electronics devices, as well as medical diagnostic techniques. The so-called new era of biotelemetry aims at not only sick people, but also keeping people healthy, especially in the population aging societies [2]. Therefore, it requires more accurate and reliable data in real time, as well as acceptable production cost. In addition, a bio-compatible package and a user-friendly interface are essential requirements as well for ubiquitous applications.

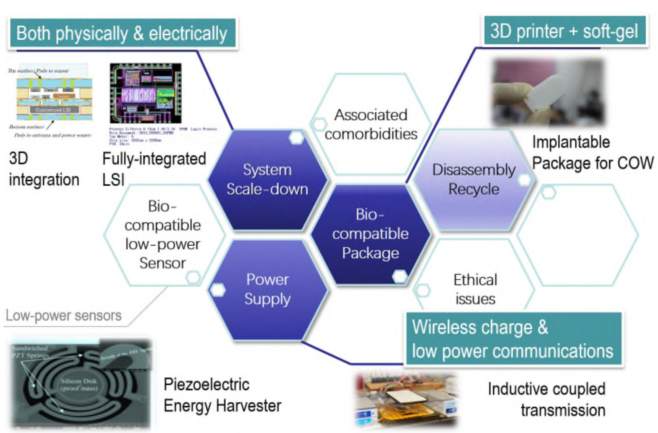

Figure 1. Challenges and some of our related works to scale-down wireless sensor nodes applicable to biotelemetry.

As shown in Figure 1, besides ethical and privacy matters, it is believed that the significant and major challenges associated with the devices for biotelemetry are scale-down of the device both physically and electrically, assembly of the device in a flexible and reliable way, and package of the device with sufficient compatibilities.

In this paper, we present our recent research works on ultra-compact wireless sensor nodes and their applications for biological information monitoring and MedTech innovation. The state-of-the-art technologies and challenges are discussed as well, along with the results of our works, for better understanding the market-needs and the key technologies for the new era of biotelemetry.

In Section II of this paper, the sensor node design and fabrication will be presented. Then, the experimental results will be discussed in Section III. Finally, this paper will be summarized with conclusions in Section IV.

II. SCALE-DOWN OF WIRELESS SENSOR NODES

System scale-down is extraordinary important to biotelemetry because most of the devices are designed as implantable to secure the data accuracy, as well as to avoid any influence from surrounding environments. Different from electronic system, scale-down in telemetry includes not only reducing module size and components counts, but also using the lowest possible power, or even energy harvesting devices, to power the system for a sufficient lifespan.

A highly integrated circuit chip, which has universal interfaces to various sensors, power management, and radio frequency communication functions, may contribute to reduce the components count. However, the development cost may exceed most of the acceptable market requests due to the small quantity. Therefore, in our work, a commercially available radio frequency integrated circuit (RFIC) transmitter (Si4010, Silicon Laboratories) with embedded microcontroller unit (MCU), clock, memory, and general input/output (I/O) interface was selected; by using this sensor, the size of a wireless temperature sensor node can be as small as 7 mm, with total component count of less than 10. The 3D assembly of integrated circuit (IC) chips and passive components is strongly expected to reduce the system volume [3], while it is clearly shown in Figure 2(a) that it may not be effective if the component count is small enough.

The carrier frequency was set as 920 MHz for the pursuit of lowest return-loss from the skin [4]. Then, an 8.3cm-long wire antenna was twisted round the sensor node to avoid package difficulties of the chip antenna which requires relatively large ground pattern. The detailed system blocks and diagrams have been published in a previous work [3].

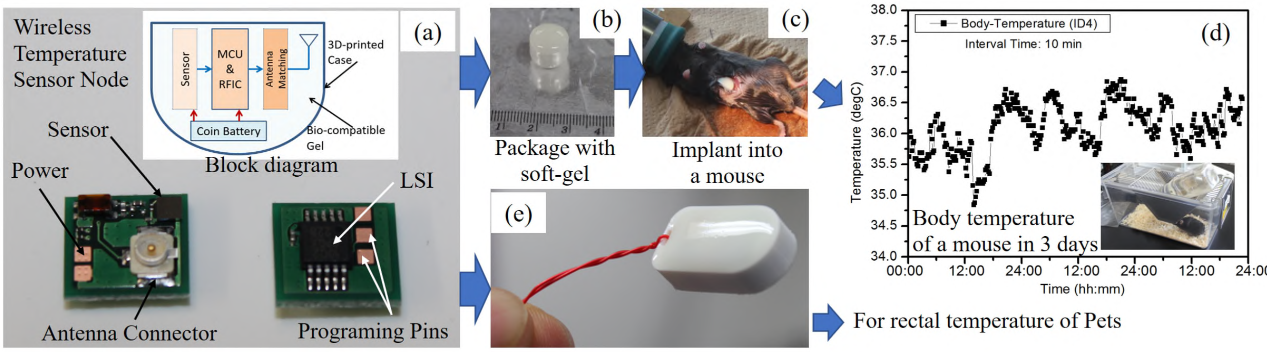

Figure 2. Photo of developed ultra-compact wireless temperature sensor nodes (a) and their packages (b)(e) for implantation (c) and rectal temperature monitoring, respectively. The recorded body temperature of a mouse for the duration of 3 days indicating excelllent repeatibility and accuracy (d).

By using RFIC transmitter instead of RFIC transceiver, it may compress standby current from a few mA to a few uA. Thus, the power consumption of the sensor node in Figure 2 (a) was measured as low as 50-100 uW depending on duty time. To change the measurement mode and switch the power ON/OFF especially after the implantation, a hybrid radio frequency identification (RFID) chip (LXMS2HACNF-165, Murata Manufacturing Co., Ltd.) was introduced in our 2nd prototype to communicate with MCU by shared memories, at the cost of 2 more components and 5x10 mm antenna ground pattern.

Besides saving the energy, inductive links between power source and sensor node may supply continuous power even after package and implantation. In our work, besides using battery CR1025, a wireless module was developed too for remote power delivery, in which super capacitors were used to quickly store electricity [5].

III. PACKAGE AND EVALUATION

The sensor node, battery, and antenna were finally assembled into a 3D printed case, and then packaged by bio-compatible soft-gel, i.e., silicon as shown in Figure 2 (b). Experimental results clearly demonstrate that temperature accuracy and communication distance were not affected by the package. The size of the sensor node was ϕ12mmX10mm, and the weight was around 1.6 gram. Figure 2(c) shows that the sensor can be successfully implanted into a mouse. Besides, as shown in Figure 2 (e), diffident package geometries were designed in our work too for various other applications, i.e., rectal temperature monitoring for pets.

The results in Figure (d) suggested that variation of the body temperature in a single day was surprisingly in between 34.5 ºC and 38.5 ºC (sensor accuracy: 0.05ºC). Body temperature is closely related to heart-rate, thus inter-activities of multiple mice in one cage can be recorded simply by the developed sensor nodes.

The sensor node with RFID and wireless power module was implanted into a cow to investigate its performance. The results indicate that the measurement mode can be changed by using a RFID writer at the distance of ~6 cm after implantation. Wireless power transmission module enables 1-2 weeks lifespan extension by a few minutes charge. However, the inductive receiver coil and the super capacitor still need improvements for the above applications, particularly the size, from a system scale-down point-of-view.

IV. CONCLUSIONS

This works summarized our recent efforts on wireless sensor nodes for biotelemetry and MedTech innovation. The preliminary results demonstrated its feasibilities and future necessary improvement to meet the market needs for the coming new era of biotelemetry.

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