Urine-activated Battery Using Conductive Yarn Electrodes with Folded Backstitch Structure for Self-powered Urinary Incontinence Sensor

Ami Tanaka[1], Shiyuya Imoto[1], and Takakuni Douseki[1]
[1] Ritsumeikan University, Shiga, Japan
a-tanaka@fc.ritsumei.ac.jp, ri0067sr@ed.ritsumei.ac.jp, douse@se.ritsumei.ac.jp

Abstract

Urinary incontinence is a common problem that affects many people around the world, particularly the elderly. Those who suffer from incontinence typically wear adult diapers; however, frequent diaper checks can be a nuisance for both the wearer and his or her caretaker. Thus, we propose a urine-activated battery for a self-powered urinary incontinence sensor system that detects when the diaper needs to be changed. The system consists of a urine-activated battery, a storage capacitor, an intermittent power-supply circuit, wireless transmitter, and a receiver. The battery consists of electrodes made of conductive sewing thread, one of which is sewn using running stitch on the front of the diaper and a backstitch with a folded structure on the backside. The structure makes it possible to detect if the entire diaper is soaked in urine because the generated current rapidly increases when part of the folded backstitch absorbs urine. We evaluated the system containing the battery with the folded backstitch structure using an adult diaper and determined that signals from the sensor were received when a certain amount of liquid had soaked into the diaper, showing that the system was able to detect when the diaper needed to be changed.

1 Introduction

Urinary incontinence is a problem that is estimated to affect millions of people, particularly the elderly, often diminishing their quality of life. Elderly people who suffer from cognitive impairments or are bedridden typically wear adult diapers or incontinence pads, and their caretakers frequently need to check whether the diapers needs to be changed. However, it is difficult and impractical for caregivers to constantly check the diaper. Furthermore, the frequent checks can be an affront to their dignity. A urinary incontinence sensor which automatically detects and notifies a caregiver of incontinence would eliminate unnecessary diaper checks. It would also aid in keeping a bladder diary.

In addition, using a diaper which has high water absorption makes it possible to reduce time to change the diaper since the diaper can absorb a few urinatiom. M. A. S. Tajin et al. developed a passive RFID-based diaper moisture sensor [1] which is able to detect if a diaper is wet. However, the sensor does not detect when the diaper needs to be changed because even a small amount of urine in the diaper.

We previously developed a self-powered wireless urinary incontinence sensor system with a urine-activated battery [2] [3] [4]. In addition to the battery, the system also consists of a storage capacitor, an intermittent-power-supply circuit, a wireless transmitter, and a receiver. The sensor system, which comprises activated carbon and aluminum electrodes, transmits wireless signals intermittently in accordance with the amount of urine in the diaper. It detects the amount of urine in the diaper and determines when it needs to be changed from the intervals between received sensing signals [5] [6]. However, an activated carbon electrode can break easily, so we propose a urine-activated battery made of conductive sewing thread electrodes, one of which is sewn using running stitch on the front of the diaper and the other using backstitch with a folded structure for the backside. The battery makes it possible to detect when the diaper needs to be changed.

2 Proposed Urine-activated Battery

The urine-activated battery (Fig. 1) comprises a piece of cotton cloth sewn with two types of conductive sewing thread used as electrodes. The battery is 520 mm × 20 mm in size. The Al thread (anode) is sewn in a straight line using running stitch. The Ag cathode is sewn using two types of stitches and has a folded structure 80 mm long at the end of the battery. 440 mm of the electrode is sewn in a straight line using running stitch and the rest is sewn using backstitch and folded five times. When the folded part of the backstitch absorbs urine, the current generated by the battery rapidly increases, making it possible to detect if the diaper is soaked to the edge.

Figure 2 shows the relationship between the generated current and the absorption distance of the urine-activated battery. A colored saline was used for the measurements instead of urine. The characteristics of a battery sewn using only running stitch and without folded structure are shown in the dotted line for comparison. This graph shows that as the absorption distance of the battery increases, the generated current also increases. In addition, the generated current of the battery with the folded backstitch structure was larger than that without when the absorption distance of the battery was 450 mm. This is because the folded stitch absorbed enough saline.

Figure 3 shows the charging voltage characteristics of the urine-activated battery when the absorption distance was 450 mm. The proposed battery reached a voltage of 0.6 V faster than the battery without the folded backstitch structure.

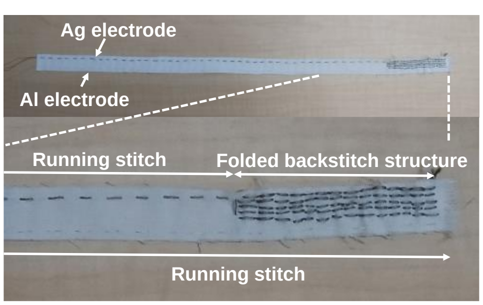


Figure 1: Photograph of urine-activated battery using conductive sewing thread electrodes with folded backstitch structure.

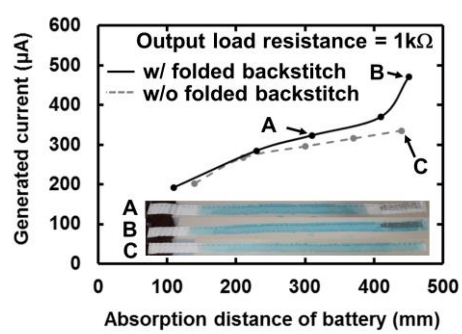


Figure 2: Relationship between generated current and absorption distance of urine-activated battery.

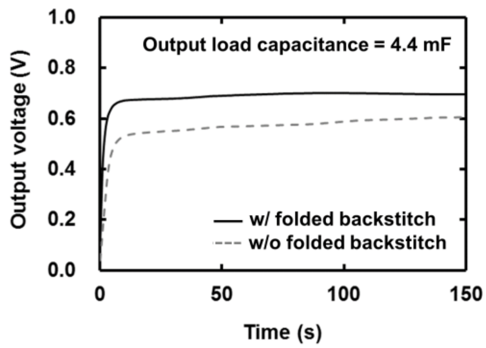


Figure 3: Measured charging voltage characteristics of urine-activated battery.

3 Self-powered Urinary Incontinence Sensor System with Proposed Battery

Figure 4 shows a block diagram of our self-powered urinary incontinence sensor system consisting of a urine-activated battery, a storage capacitor, an intermittent-power-supply circuit, a wireless transmitter comprising a BLE beacon, and a receiver. When the urine-activated battery absorbs urine, the transmitter sends wireless signals intermittently in accordance with the current generated by the urine-activated battery.

Figure 5 shows a cross section and a photograph of the diaper-shaped urine-activated battery containing conductive sewing thread electrodes with a folded backstitch structure between a sheet of absorbent material and a sheet of waterproof material from an adult diaper.

Figure 6 shows a photograph of the fabricated sensor board which is 45 mm × 25 mm × 6 mm (LWH) in size.

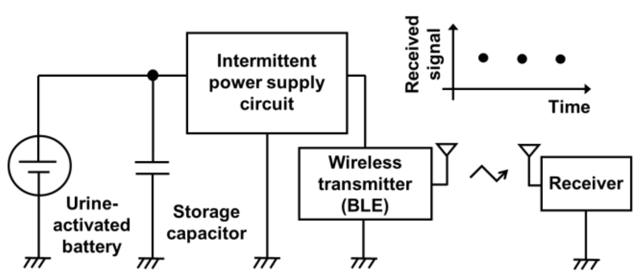
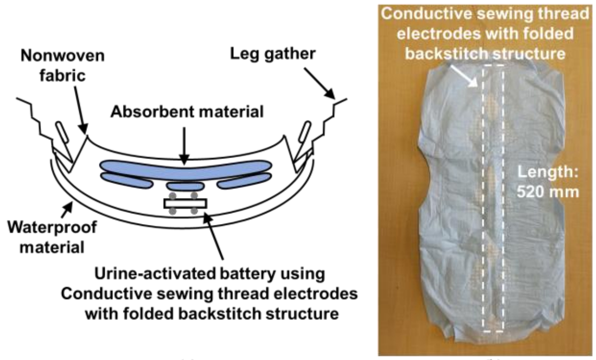


Figure 4: Block diagram of self-powered urinary incontinence sensor system.



(a) (b)

Figure 5: Diaper-shaped urine-activated battery using conductive sewing thread electrodes with folded backstitch structure. (a) Cross section. (b) Photograph of battery viewed from bottom.

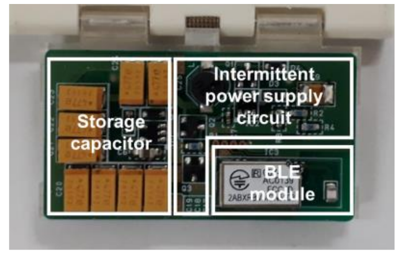


Figure 6: Photograph of fabricated sensor board.

4 Experiment

Figure 7 shows the fabricated self-powered urinary incontinence sensor system [6] [7] which can detect when the diaper needs to be changed. The system consists of a wireless sensor and a smartphone as a receiver. The sensor comprises the diaper-shaped urine-activated battery and the sensor board.

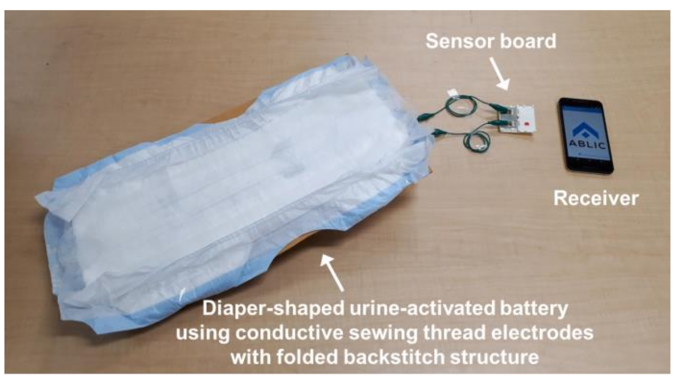


Figure 7: Photograph of self-powered urinary incontinence sensor system.

Figure 8 shows the relationship between the absorption distance of the battery and the total amount of saline in the diaper. For measurements, the battery was put on a board with an inclination of 10 degrees to make the saline flow toward the backside. The graph shows that as the total amount of saline in the diaper increases, the total absorption distance of the battery also increases. When the total amount of saline in the diaper was 600 ml, almost all of the battery was soaked with saline. In addition, the absorption distance of the folded backstitch part gradually increased when the total amount of saline was 300 ml. Given the relationship between the generated current and the absorption distance of the urine-activated battery (see Fig. 2), the absorption distance of the battery was over 400 mm when the generated current rapidly increased, so the intervals between the received sensing signals decreased substantially when the battery absorbed over 400 ml.

To verify the effectiveness of our system including the proposed battery, the characteristics of received sensing signals were measured (Fig. 9) by pouring 300 ml of saline onto the diaper-shaped urine-activated battery twice at least 10 minutes apart. When the saline was poured the first time, a sensing signal was received only once after 71 seconds. However, when saline was poured the second time, the total amount of saline in the diaper was 600 ml, and five sensing signals were received times within 10 minutes. This shows that the system with proposed the urine-activated battery was able to receive the sensing signals and detect when the diaper needed to be changed.

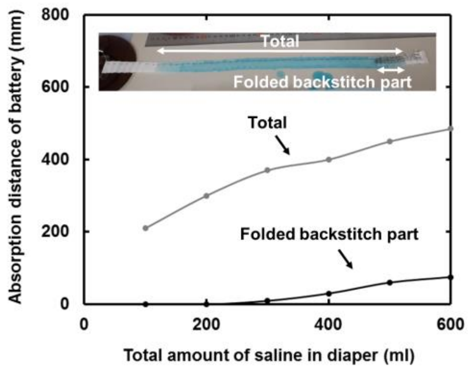


Figure 8: Relationship between absorption distance of battery and total amount of saline in diaper.

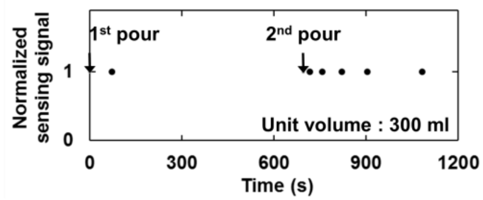


Figure 9: Characteristics of received sensing signals.

5 Conclusion

We developed a urine-activated battery using conductive sewing thread electrodes with a folded backstitch structure. The current generated by the battery rapidly increases when the folded backstitch part absorbs urine, so the battery can be embedded in an adult diaper to detect if the diaper has been soaked to the edge. By implementing the battery in our self-powered urinary incontinence sensor system, the system can determine from the received sensing signals if the diaper needs to be changed. We evaluated the effectiveness of our system including the proposed battery in an adult diaper. The results showed that only one sensing signal was received when the total amount of saline in the diaper was 300 ml, while five signals were received when the diaper absorbed 600 ml. Thus, our system with the battery was able to detect when the diaper needed to be changed.

References

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