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Wearable Respiratory Sensor Measuring Capacitance Constructed Across Skin Allowing Walking Motion

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Abstract

A wearable respiratory sensor is developed based on the capacitance sensing. The conductive cloth electrodes are sewn inside the belly band. The respiration is measured by the capacitance change at the abdomen skin due to its expansion or contraction. The noise caused by other body motions are decreased by (1) the movable magnet electrode connectors releasing the stress from the cable and (2) the coaxial electrode layout being insensitive to the body twisting motion. The respiration during 6-minnute walk is well monitored.

1. Introduction

In the world, COPD (Chronic Obstructive Pulmonary Disease) will become the third leading cause of death[1]. There is no pain at the lung. The respiratory sensor useful in the daily life is required for finding the patients, and for checking the treatment effect in hospitals. The sensor has to keep the natural condition, since the respiration can change due to the subject's consciousness. The conventional spirometers and the piezoresistive fabric sensors[2] don't match with the weak-health subjects.

Figure 1(a) shows the skin model. The capacitance is constructed between the outside electrode and the inside electrolyte. Figure 1(b) shows the condition under the inhalation at the abdomen. With the body volume, the skin extends. The gap between electrodes decreases. The capacitance increases. Figure 1(c) shows the exhalation. The situation becomes opposite. The series capacitance between two outside electrodes is measured[3]. Figure 2 shows one capacitance signal. The respiration signal (about 4 cyclic change) suffered from the noise even though the walking speed is slow[4].

Here, the wearable respiratory sensor is described making it robust against the noise caused by the walking.

2. Experimental Setup

The electrodes of the conductive cloths are sewn inside the belly band. The noise comes from both outside and inside the body. Figure 3 is three connections tested between the electrode and the cable to the capacitance sensor. Compared to (a) the direct stitching and (b) the metal snap, (c) the magnet connector can reduce the noise allowing the smooth rotation. This can be the buffer against the body movement and the wire tension. This button enables the detachment of the sensor circuit from the belly band. So, the belly band becomes washable because it does not include the active circuit.

Figure 4 shows the new sensing electrode shape. The body motion usually includes twisting motion, which makes

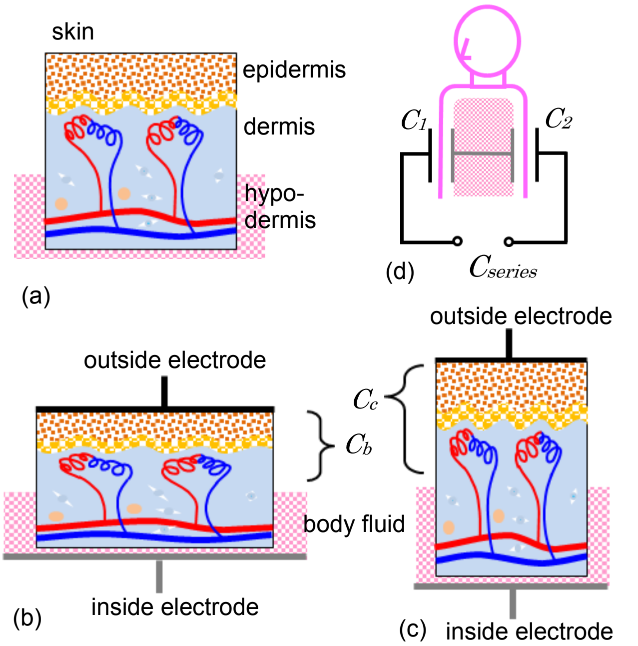

Fig. 1. (a) Skin structure. The capacitance across the abdomen skin at (b) inhaled and (c) exhaled conditions. (d) Two capacitances are considered to connect in series inside the body and measured by the outside circuit.

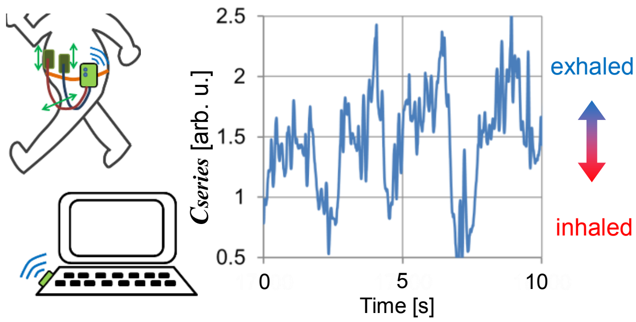

Fig. 2. Abdomen capacitance signals measured during slow walking using the previous setup. The capacitance sensing circuit used has the inverted amplifier showing the larger value to the smaller capacitance value.

Fig. 3. Connections between the metal wire and the conductive cloth using (a) stitching, (b) metal snap, and (c) magnet bottom.

the skin condition different between left and right. The previous layout in Fig. 4(a) is sensitive to this. The new coaxial layout is symmetric and insensitive to this twisting. The obtained capacitance signal shows the larger respiration signal against the walking noise.

3. Results

Figure 5 shows the signal during 6-minute walk, which is used as the standard in hospital. The subject inhales during 2 steps and exhales during 4 steps. This breath control is recommended for COPD rehabilitation. The walking machine speed is set at 2km/h for Fig. 5(a) and 5(b). Figure 5(a) is measured grabbing the machine levers setting the standing posture stable. The major cyclic signal shows the respiration and the minor peaks show stepping. Figure 5(b) is measured during the normal walking. The cyclic signal is still major. 6 peaks in one respiration cycle agrees with the breath control. The respiration depth and rate are almost maintained indicating the gentle exercise. Figure 5(c) is measured running at a trot at 6km/h. The larger stepping peaks are seen in the magnified waveforms (i) and (ii) at 2 and 5.6min, respectively. The respiration cycle is still recognizable. With time, the respiration amplitude increases and its waveform changes. These features can be attributed to the subject's metabolism.

4. Conclusions

Based on the understanding that the capacitive signal comes from the electrical skin thickness, the good quality of the respiration signal is obtained fitting the electrodes on the skin being compliant against the body movement. Sensing respiration during 6-minute walking is demonstrated showing the natural features of the subject's metabolism.

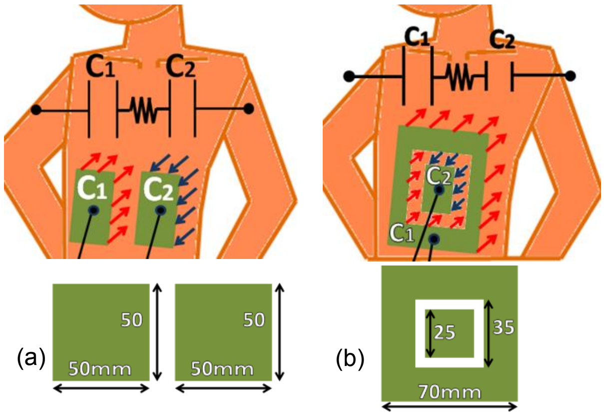

Fig. 4. Two electrode shapes for measuring the capacitance at the abdomen. (a) Conventional layout uses 2 sheets having the area of 5000mm^2. (b) The coaxial layout only uses 4300mm^2.

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References

[1] Chronic respiratory diseases, http://www.who.int/respiratory/copd/en/

[2] E. P. Scilingo, A. Gemignani, R. Paradiso, N. Taccini, B. Ghelarducci, D. D. Rossi, *IEEE Trans. Inf. Technol. Biomed.* **9** (2005) 345.

[3] M. Terasawa, S. Kumagai, M. Sasaki, *Jpn. J. Appl. Phys.* **55** (2016) 04EM13.

[4] M. Terazawa, M. Karita, S. Kumagai, M. Sasaki, *Micromachines* **9** (2018) 543.

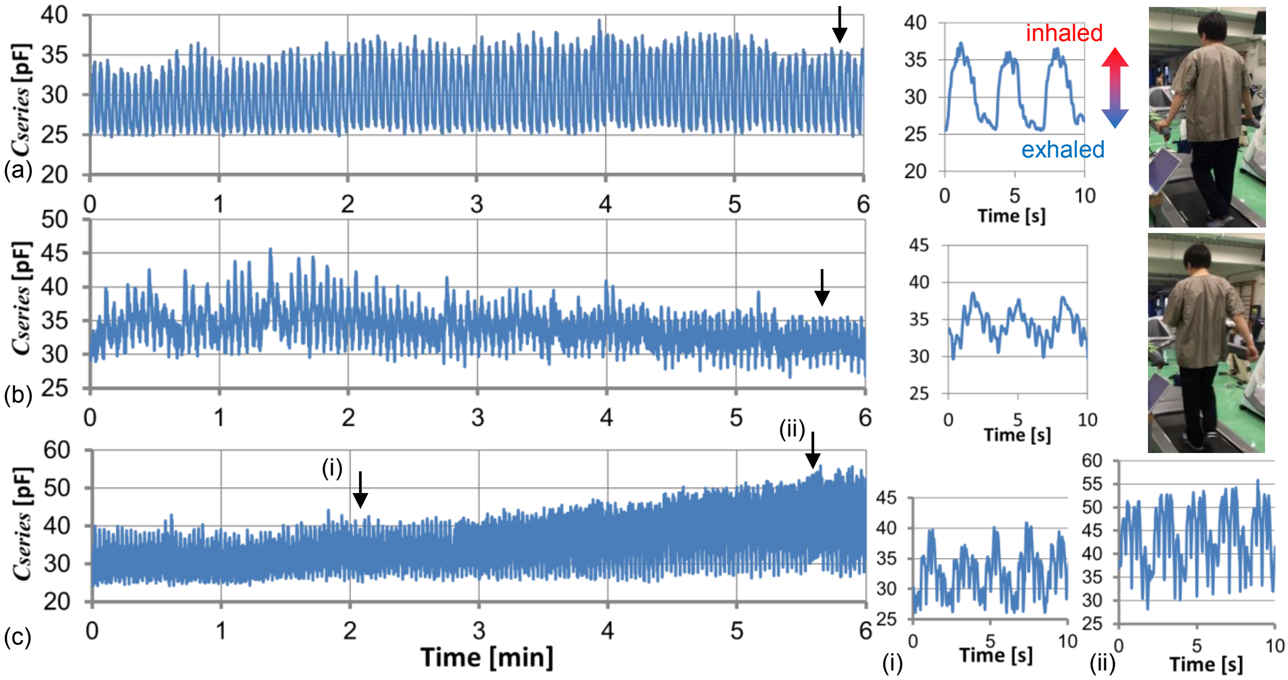

Fig. 5. Abdomen capacitance signals measured during (a) walking with grabbing the machine levers, (b) normal walking, and (c)running at a trot for 6 minutes. Down arrows indicate the timing of the magnified curves shown left. The signal drift in (b) is attributed to the posture change of the subject during walking.