MOVEMENT DETECTION OF FOREARM USING BRACELET SENSOR

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Abstract - In this research, a bracelet type wearable sensor was developed using PET polymer film with carbon based conductive layer. The mechanism of surface resistance variation of the composite film employed in this study was the relationship between the variations of surface resistance and the width variations of crack gaps in the conductive layer occur when the film was bent, resulted in the width of crack gaps significantly affect the resistance variation of conductive layer. The fabricated bracelet-type wearable sensor using the polymer film successfully detected the intention of forearm movement, wrist extension and ulnar deviation, without using complex pattern recognition algorithm.

Keywords - Carbon-Based Conductive Layer-Polymer Composite Film, Wearable Sensor, Sensor Fabrication

I. INTRODUCTION

One important technology in wearable devices involves the detection of human movement intention [1], of which the most common method utilizes the body's EMG signals [2-4]. An EMG signal is an electrical stimulus transmitted from the brain to a muscle fiber to contract the muscle. Signal measurement methods include an invasive method [5, 7] in which a needle-shaped electrode is inserted into the peripheral nervous system of the body and a non-painful, non-invasive method in which an electrode is attached to the surface of the skin to measure the signal [2, 4, 6, 8]. In general, a non-invasive method that quantitatively analyzes the overall synergistic activities of a set of muscular movement units has been utilized [17]. However, the sEMG signal measurement method has the following restrictions. First, a technique is needed to extract the motion intention from complex muscle noise signals generated from the movements of other muscles and inside and outside the body. Therefore, there are many studies applying fuzzy and neural networks with excellent effects on nonlinear signal processing [14, 17, 18]. Second, as the characteristics of the signal vary with the attachment position of the electrode and muscle fatigue, it is difficult to ensure reproducibility when used as a control signal for prosthetics over a long period of time [3, 9].

Third, multiple electrodes must be attached to the surface of the body; this is because two electrodes for differential amplification and one ground electrode in one muscle group must be attached [6, 9-11]. Due to these inconveniences of using sEMGs, researchers have been developing a sensor system to detect the motion intention of the body without using EMG signals. Most studies have used already commercialized sensors, such as acceleration, strain gauge, and tactile sensors, to develop sensor systems that can detect human movement. There is also research into developing sensors suitable for detecting human movement.

This study presents a method for fabricating the bracelet type wearable sensor module using a carbon- based conductive layer-polymer composite film to detect the movement intention of human body. The integral material used for the composite film is PET (polyethylene terephthalate) polymer film with a conductive layer made using a carbon paste, capable of detecting the changes in the resistance corresponding to the flexion changes of the surface of body due to muscle contraction and relaxation. The mechanism of surface resistance variation of the composite film employed in this study was previously investigated in [12], which identified the relationship between the variations of surface resistance and the width variations of crack gaps in the conductive layer occur when the film was bent, resulted in the width of crack gaps significantly affect the resistance variation of conductive layer. To minimize the external physical effects on the thin polymer film with a thickness of approximately 0.1mm, sensor modules mounting the polymer film were fabricated and connected each other by flexible bend. Then, the bracelet type sensor was worn on the subject’s forearm to detect the intention of forearm movement, wrist extension and ulnar deviation. The variations of surface resistance corresponding to forearm movement were converted into voltage signals and used to detect movement intention of upper arm.

II. SENSOR FABRICATION

2.1. Fabrication of conductive layer-polymer film

Fabricated composite material film with a conductive layer changes surface resistance with the degree of flexion when worn on human body. When a strip- shaped film whose surface is coated with a conductive layer is bent in the longitudinal direction, cracks are created in the conductive layer, thereby changing the resistance in the conductive layer.

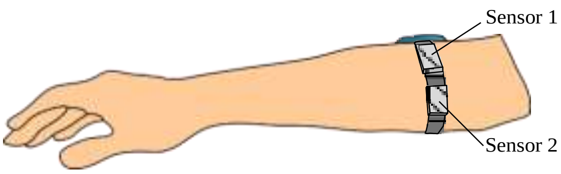
In this study, a graphite paste was used to form the conductive layer on the surface of the PET film with the thickness of approximately 0.1 mm. Fig. 1 shows the fabricated film.

Fig. 1 Fabricated composite film

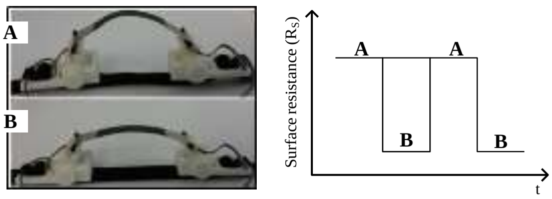
2.2. Fabrication of conductive layer-polymer film

When using a composite material film directly on the body with a thickness of approximately 0.1 mm, the conductive layer is easily damaged due to external physical effects, making it difficult to ensure the reproducibility of the sensor signal. Therefore, to minimize the external physical effects, we designed and fabricated a sensor module and implemented it in research on a data collection and movement detection.

In the final, a bracelet sensor in Fig. 2(a) was fabricated using two sensor modules comprising two mechanical parts, as shown in Fig. 2(b), one mechanical part is connected to the other mechanical part by the flexible band, causing sliding movement corresponding to the contraction and expansion of the skin surface. This causes flexion of the composite film connected to both mechanical parts to prevent the damage of surface electrode.



(a)



(b)

Fig. 2 Fabricated form of sensor module

Thus, when the muscles of the area touching the sensor module contract and the surface of the skin protrudes, the sensor module is stretched (B in Fig. 2(b)) in the longitudinal direction and the resistance of the conductive layer decreasesbecause the bending of film is slightly released and closing effect of crack gaps in the conductive layer (B in Fig. 2). Conversely, when the muscles of the area touching the sensor module expand and the skin surface becomes depressed, the sensor module is contracted in the longitudinal direction and the resistance of the conductive layer increases because the film is slightly bent more than resting state, and the width of crack gaps in the conductive layer increases (A in Fig. 2).

2.3. Signal measurement method

In the present study, the two sensor modules comprising a bracelet sensor developed to measure signals generated by wrist extension and ulnar deviation were worn to around forearm as shown in Fig. 2. Wrist extension and ulnar deviation motion are shown in Fig. 3.

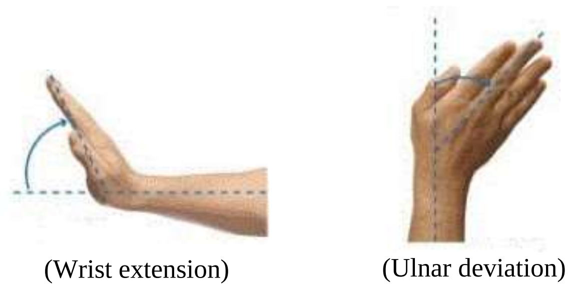


Fig. 3 Image of forearm movements

Fig 4 shows the transducer circuit, consisting of a bridge circuit and a differential amplifier IC (INA114) for each module to convert the surface resistance variations to voltage signals. The signals transmitted by each sensor module on the upper arm were collected by using NI-DAQ and analyzed through Matlab. The voltage signals from the electrodes attached to the upper arm for each of the four movements were measured at a sampling frequency of 1 kHz.

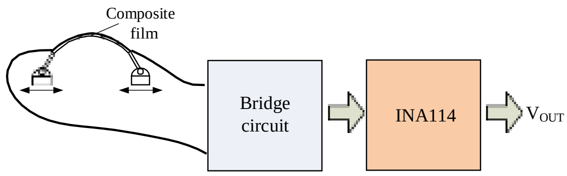


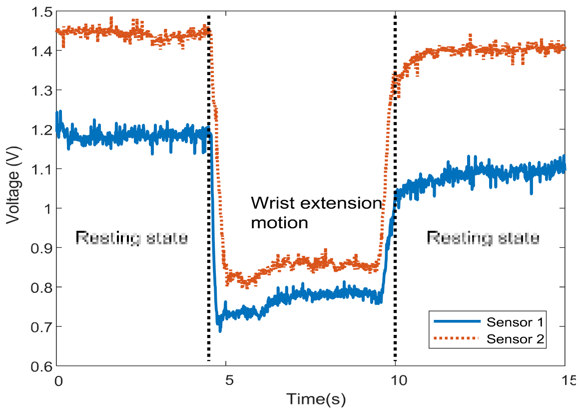
Fig. 4 Transducer circuit of bracelet sensor

The signal was measured for 15 seconds; during the first 5 seconds of data collection for each movement, the upper arm rested on the table without any movement. Afterward, each movement was performed and maintained for approximately 5 seconds, after which a resting state was maintained for the remaining 5 seconds.

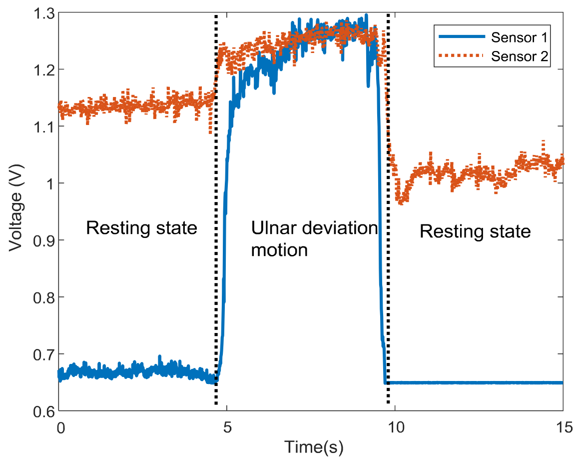
III. RESULTS

Fig. 5 shows the measured signals from two sensor modules in the bracelet sensor, while wrist extension (Fig. 5(a)) and ulnar deviation motion (Fig. 5(b)).

During the wrist extension, the muscles of the area touching the sensor modules contract and the surface of the skin protrudes, the sensor modules are stretched in the longitudinal direction and the resistance of the conductive layer decreases, resulting in the decrease of signals, as shown in Fig. 5 (a). Conversely, during the ulnar deviation, the muscles of the area touching the sensor module expand and the skin surface becomes depressed, the sensor module is contracted in the longitudinal direction and the resistance of the conductive layer increases, as shown in Fig. 5 (b).



(a)



(b)

Fig. 5 Measured signals from bracelet sensor: (a) signals fromwrist extension motion, (b) signals from ulnar deviation motion.

Based on the results of Fig. 5, during the resting state, the variance of signal is low in both motions, however the variance of signal is high during the active state. Also, during maintaining the motion, the magnitude of voltage shows discriminative level compared with resting state. Thus, the resting state and active state were accurately detected. In addition, it is observed that the two motions produce voltage signals in opposite direction. During wrist extension, the voltage signals decrease while the signals increase during ulnar deviation. Thus, the two motions were accurately detected.

IV. CONCLUSIONS

The present paper presented a method for fabricating a variable resistance bracelet sensor using a flexible polymer film-conductive layer composite film capable of detecting flexion changes in the surface of the human body due to muscle contraction and relaxation. In addition, this paper verified the successful performance of the sensor in the detection of two forearm movements: wrist extension and ulnar deviation.

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