FOREARM MOVEMENT DETECTION USING CARBON BASED COMPOSITE FILM

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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 flexion and finger flexion, 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 flexion and finger flexion. 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 conductivelayer changes surface resistance with the degree offlexion when worn on human body. When a strip-shaped film whose surface is coated with aconductive layer is bent in the longitudinal direction,cracks are created in the conductive layer, therebychanging 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 sensor module comprising two mechanical parts, as shown in Fig. 2, one mechanical part inserted on the inside is connected to the other mechanism 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.

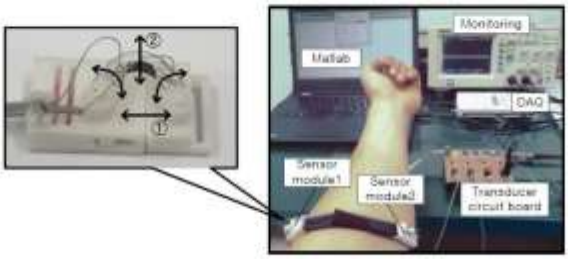

Fig. 2 Fabricated form of sensor module

Thus, when the muscles of the area touching the sensor module contract and the surface of the skin protrudes, the sensor module is stretched (Ⓒ in Fig. 2) in the longitudinal direction and the resistance of the conductive layer decreases because the bending of film is slightly released and closing effect of crack gaps in the conductive layer (Ⓒ 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 (Ⓒ 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 flexion and finger flexion were worn to around forearm as shown in Fig. 2. Wrist flexion and finger flexion motion are shown in Fig. 3.

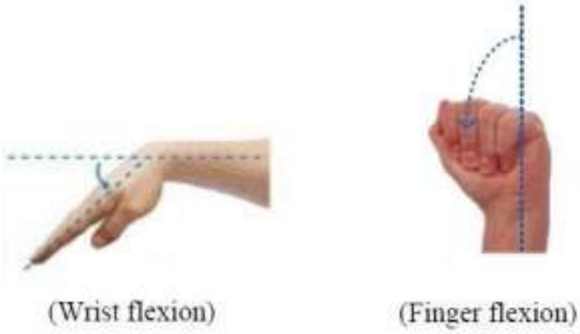

Fig. 3 Image of forearm movements

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.

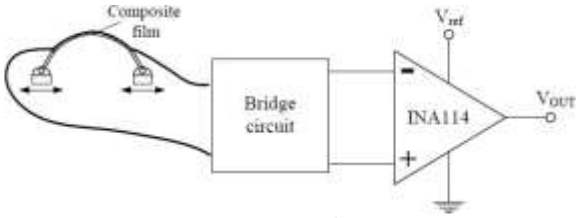

Fig. 4 Transducer circuit of bracelet sensor

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 wearable sensor, while wrist flexion(Fig. 5(a)) and finger flexion motion (Fig. 5(b)). During both wrist flexion and finger flexion motion, the muscles of the area touching the sensor modules become depressed, resulting in the sensor modules are contracted in the longitudinal direction. Therefore, the resistances of the conductive layers in the composite films increase, as shown in Fig. 5.

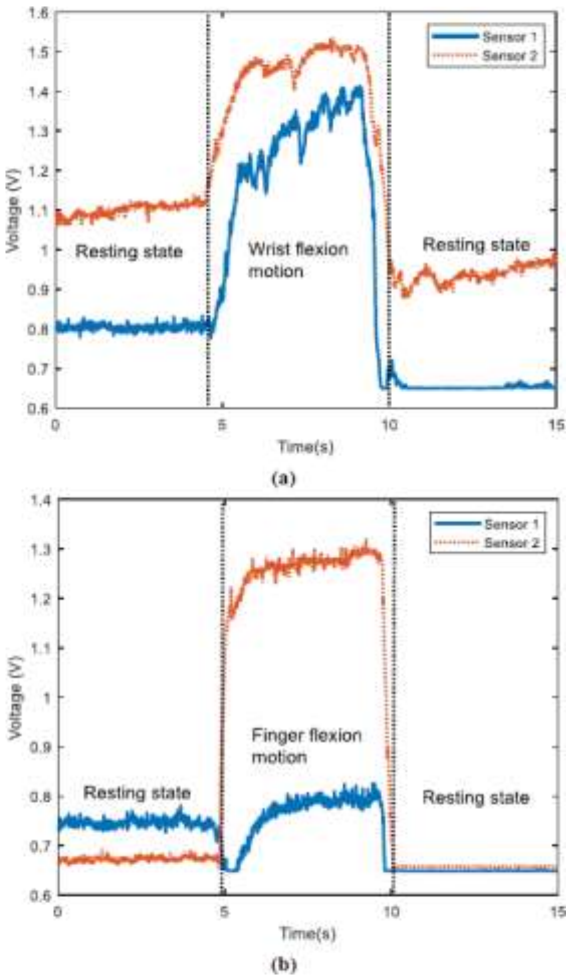

Fig. 5 Measured signals from bracelet sensor: (a) signals from wrist flexion motion, (b) signals from finger flexion motion.

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 at the beginning and finishing of each motion. Also, during maintaining each 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 different level.

In wrist flexion, the signal variance from sensor 1 is greater than the signal variance from sensor 1. Conversely, In finger flexion, the signal variance from sensor 2 is much greater than the signal variance from sensor 1. Thus, the difference of two motions were accurately detected.

IV. CONCLUSION

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 flexion and finger flexion.

REFERENCE

[1] S. C. Mukhopadhyay, “Wearable Sensors for Human Activity Monitoring: A Review,” IEEE SENSORS JOURNAL, VOL. 15, NO. 3, MARCH 2015.

[2] G. Li and T. A. Kuiken, “EMG Pattern Recognition Control of Multifunctional Prostheses by Transradial Amputees,” IEEE 10. 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2-6, 2009.

[3] E. Park, S. G. Meek, “fatigue compensation of the electromyographic signal for prosthetic control and force estimation,” IEEE transactions on biomedical engineering, vol. 40, no. 10, October 1993.

[4] Srđan Đorđević , Sašo Tomažič, Marco Narici, Rado Pišot, and Andrej Meglič, “In-Vivo Measurement of Muscle Tension: Dynamic Properties of the MC Sensor during Isometric Muscle Contraction,” Sensors 2014, 14, 17848-17863; doi:10.3390/s140917848,

[5] L. H. Smith, T. A. Kuiken, and L. J. Hargrove, “Real-time simultaneous and proportional myoelectric control using intramuscular EMG,” J. Neural Eng. 11 (2014) 066013 (13pp).

[6] Soares, A. Andrade, E. Lamounier, “The Development of a Virtual Myoelectric Prosthesis Controlled by an EMG Pattern Recognition System Based on Neural Networks,” Journal of Intelligent Information Systems, 21:2, 127–141, 2003.

[7] S. Micera, J. Carpaneto, and Stanisa Raspopovic, “Control of Hand Prostheses Using Peripheral Information,” IEEE reviews in biomedical engineering, Vol. 3, 2010.

[8] D. A. Yungher, M. T. Wininger, J.B. Barr, W. Craelius, A. J. Threlkeldb, “Surface muscle pressure as a measure of active and passive behavior of muscles during gait,” Medical Engineering & Physics, 33, 464–471, 2011.

[9] M. R. Al-Mulla, F. Sepulveda, and M. Colley, “A Review of Non-Invasive Techniques to Detect and Predict Localised Muscle Fatigue,” Sensors, 11, 3545-3594; doi:10.3390/s110403545, 2011.

[10] B. Ajiboye and R. F. ff. Weir, “A Heuristic Fuzzy Logic Approach to EMG Pattern Recognition for Multifunctional Prosthesis Control,” IEEE transactions on neural systems and rehabilitation engineering, Vol. 13, No. 3, September 2005.

[11] Zizoua, M. Raison, S. Boukhenous, M. Attari, and S. Achiche, “Development of a Bracelet With Strain-Gauge Matrix for Movement Intention Identification in Traumatic Amputees,” IEEE Sensors Journal, Vol. 17, Issue: 8, April 15, 2017.

[12] K. Park , M. Yoon, S. Lee, J. Choi, and M. Thubrikar, “Effects of electrode degradation and solvent evaporation on the performance of ionic-polymer–metal composite sensors,” Smart Mater. Struct. 19 (2010) 075002 (13pp).