LOW INVASIVE MEASUREMENT OF ELECTROCARDIOGRAM FOR NEWBORNS AND INFANTS

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Abstract-**In the present study, it is investigated whether capacitive electrode can detect electrocardiogram (ECG) at a condition where some cloth is interpolated between the electrode and body surface of an adult subject. The result showed that constructed devices could measure ECG when silk of 247μm thickness was mediated. Though there is room to improve measurement devices or signal processing for practical use, feasibility of capacitive electrode for low invasive measurement of ECG for newborns and infants is indicated.**

Keywords - **ECG, Capacitive Electrode, Barium Titanate**

I. INTRODUCTION

Cause of death in newborns and infants are mostly cardiovascular disease, respiratory disease or sudden infant death syndrome (SIDS) in Japan. For the purpose of diagnosis, medical treatment, or medical research of these diseases, electrocardiogram (ECG) is measured continuously from the newborns and infants when necessary. Metal electrodes are conventionally used and attached to the body surface with conducting paste or adhesive gel for detecting ECG. However adhesion of these paste and gel is so tight for newborns and infants that the skin is seriously damaged and, in some cases, the electrodes peel off the skin in detaching the electrodes from the body surface. In other case, metal electrode often cases allergic reaction on the skin where the electrode is attached. So it is desired to develop low invasive method for detecting ECG from newborns and infants.

In the present study, we investigated whether or not capacitive electrode can detect ECG at a condition where thin cloth is interpolated between the electrode and the body surface.

II. CAPACITIVE ELECTRODE

Capacitive electrode can detect alternating bioelectric signal as a capacitor by inserting impedance converter circuit posterior to the electrode. Since a small area of the body surface can be regarded as a conductive material in measuring bioelectric signal, one of the parallel plates of the capacitor may be substituted by the body surface. Thus, capacitive electrode can be constructed from a insulator mounted on a conducting plate. In this study, barium titanate is used as an insulator and silver is employed as a conducting plate, as can be seen in Fig.1.

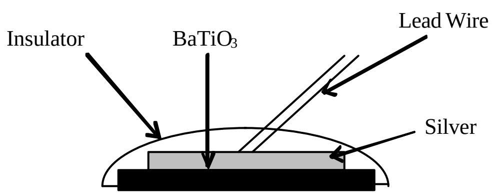


Fig.1 Fabrication of a capacitive electrode

III. MEASUREMENT SYSTEM

We constructed ECG measurement system (see in Fig.2). The system consists of 5 electronic circuits of impedance converter, instrumentation amplifier, high pass filter, low pass filter, and notch filter. The capacitive electrodes are connected to the impedance converter circuit and placed indirectly on the back of an adult subject at a condition where thin silk is interpolated between the electrode and the body surface. The subject was instructed to lie in supine position. The output signal of the system was digitized at 250Hz by A/D converter and stored in PC.

IV. RESULTS

A. Fundamental measurement of the capacitive electrode

Cross-sectional images of the barium titanate in the capacitive electrode and the interpolated silk are obtained by scanning electron spectroscopy. As can be seen in Fig.3, thickness of both materials was 247μm and 240μm respectively.

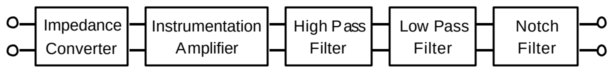
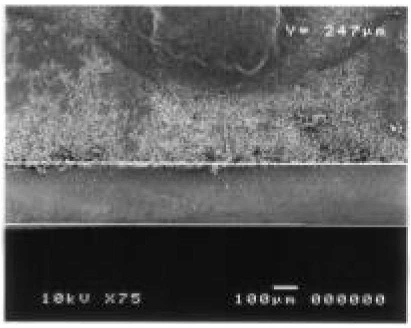
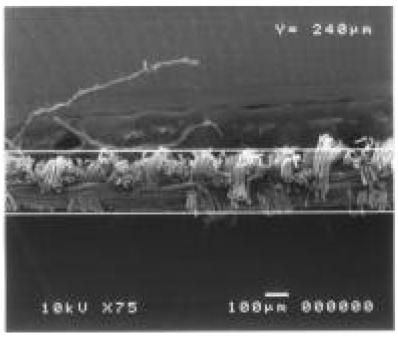


Fig.2 Block diagram of the system for ECG measurement



(a) Barium titanate in the capacitive electrode



(b) Silk mediated between the electrode and the skin

Fig.3 Cross-sectional images of the barium titanate in the capacitive electrode and the interpolated silk between the electrode and the body surface, which is observed by scanning electron microscope

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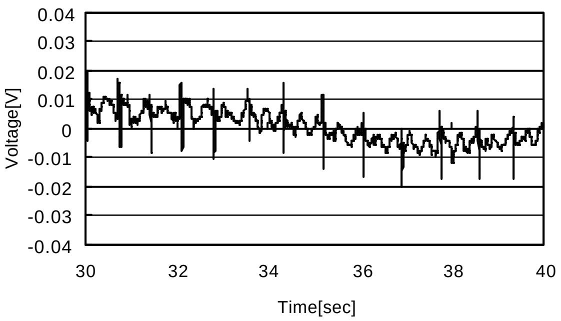

Fig.4 A record of ECG by the capacitive electrode with interpolation of the silk between the electrode and the body surface of the subject

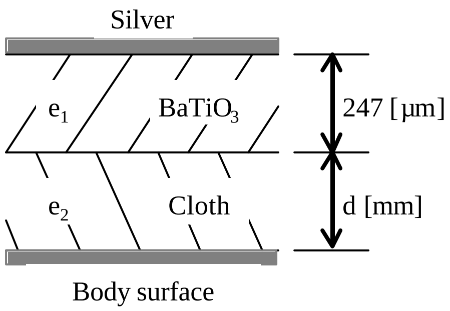

Fig.5 A model of the capacitive electrode interpolated by cloth

B. *ECG measurement by the capacitive electrode*

Result of ECG measurement by the capacitive electrode is shown in Fig. 5. Despite the interpolation of the silk between the electrode and the body surface, periodic R-wave potentials could be successfully detected. However, when thicker cloth such as cotton was interpolated, no effective signal could be observed. Furthermore, fluctuating base line was noticed and S/N ratio was insufficient for practical use. Thus, there are still some rooms to improve measurement devices or signal processing.

V. DISUCUSSION

Capacitance of the capacitive electrode including interpolated cloth can be estimated using a capacitor model in Fig.5 and Eq.(1). Since insulation between two parallel conducting materials has 2 layers of barium titanate and the cloth, capacitance of the electrode can be calculated as a capacitance of series-connected capacitor, so that

$$C = \frac{e_1 \times e_2 \times S}{e_1 \times d \times 10^{-3} + e_2 \times 2.47 \times 10^{-4}} \qquad (1)$$

where e_1 and e_2 are dielectric constants of the barium titanate and the cloth, *S* is area of the electrode face, and *d* is thickness of the cloth.

Substituting 1.06×10^{-7} F/m for e_1 and 5.03×10^{-5} m^2 for *S*, the capacitance *C* can be treated as a function of e_2 and *d*. Then Fig.6 is calculated according to this function. The simulated data shows that capacitance of the capacitive electrode are significantly small of the order of 10^{-12} F. Also capacitive reactance (impedance on this

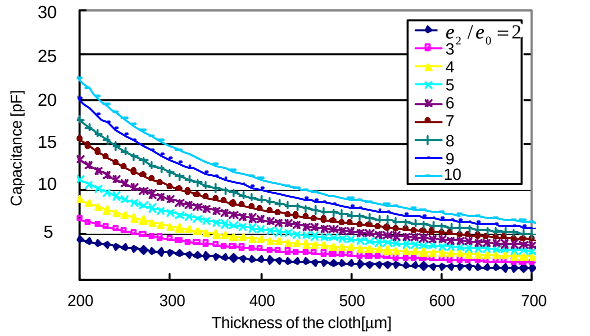

Fig.6 Thickness-capacitance characteristic of the capacitive electrode

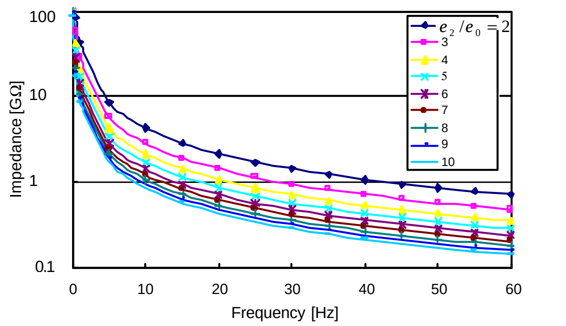

Fig.7 Frequency-impedance characteristic of the capacitive electrode

occasion) of the capacitive electrode is derived by dividing reciprocal of the *C* by angular frequency $w = 2pf$, so that

$$Z = \frac{1}{2pfC} = \frac{1.06 \times 10^{-10} \times d + 2.47 \times 10^{-4} \times e_2}{3.35 \times 10^{-11} \times f \times e_2} \qquad (2)$$

If the thickness of the silk (2.40×10^{-4} m) is substituted for *d*, impedance of the capacitive electrode is regarded as a function of *f* and e_2. As can be seen in Fig.7, impedance of the capacitive electrode including interpolated silk is assumed to of the order of $10^{12}\,\Omega$ at a frequency of 10 Hz. Consequently, input impedance of the impedance converter circuit should be equal to or more than $10^{12}\,\Omega$ in order to detect stable ECG.

VI. CONCLUSION

We experimentally observed that the capacitive electrode could detect ECG even when thin silk was interpolated between the electrode and the body surface of the subject. Though there is room to improve measurement devices or signal processing for practical use, the result implies that capacitive electrode is feasible for low invasive measurement of ECG for newborns and infants.

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