Dry Electrode Design and Performance Evaluation for EEG based BCI systems

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***Abstract*— For the design of electroencephalography (EEG) based BCI systems, crucial issues are to acquire high fidelity EEG signals and to provide convenient installation to users. Electrodes are the key components which measure EEG signals from user's scalp. In this paper, we introduce a design of dry electrodes for BCI systems. The proposed electrodes are equipped with six spring loaded probes. They are capable of acquiring EEG signals of good enough quality without usage of conductive gels. To verify the performance of proposed electrodes, we measure contact impedance and compare them with those of conventional wet electrodes and G.tec Sahara dry electrodes. From the results, the impedance of proposed electrodes is shown to be satisfied without conductive gels. In future research, we will improve the design of proposed electrodes by adding active circuits.**

Keywords- EEG, Dry electrode, Impedance

I. INTRODUCTION

Brain-Computer Interface (BCI) systems can translate user's intentions and generate control signals which computer or external machine can understand, by analyzing the neurophysiological signals. Recently, EEG based BCI systems have been released for BCI applications such as cursor controls and speller applications.

In these systems, electrodes are the most important part because they may affect the signal quality severely. EEG signals are very sensitive because their amplitude are very small and thus the signals are easy to be affected by various noise sources such as physiological interference, e.g., electrooculograms (EOG). These unfavorable conditions influence the measured signal quality. Poor signal quality may lead to poor accuracy in a BCI application. Moreover, electrode installation is also inconvenient and time-consuming. Because conductive gels are viscid, the users can easily be irritated. Therefore, development of improved EEG electrodes which provide high fidelity EEG signals and easy installation is one of the most important challenges.

Recently, researchers have studied dry electrodes. Dry electrodes are defined as those that do not require the use of conductive gels for installation process. Thus, a user can conveniently attach the electrodes to its scalp without any hair arrangement. To contact electrodes without conductive gels at the scalp, researchers employ special materials or shapes in the design of dry electrodes. Extensive research has produced a variety of electrode materials and structures, including finger [1], bristle structure [2], and micro-tip structure [3].

In this paper, we aim to introduce our design of dry electrodes. We employed a set of probe which looks like fingers for making dry contact. For performance evaluation, we show performance of proposed dry electrodes in terms of contact impedance, and compare them with those of wet electrodes and G.tec Sahara dry electrodes [4].

II. DESIGN AND TEST

A. *Dry electrode design*

Our dry electrodes are equipped with six probes of spring loaded type. These probes contract their length when compressed. This structure provides flexibility and geometric adaptation between the sensor and the irregular scalp surface. Because the probes are easy to touch with the user's scalp through the hairs, any hair preparation is not needed in their installation process. Figure 1 is a picture of the proposed electrode and a diagram showing its structure.

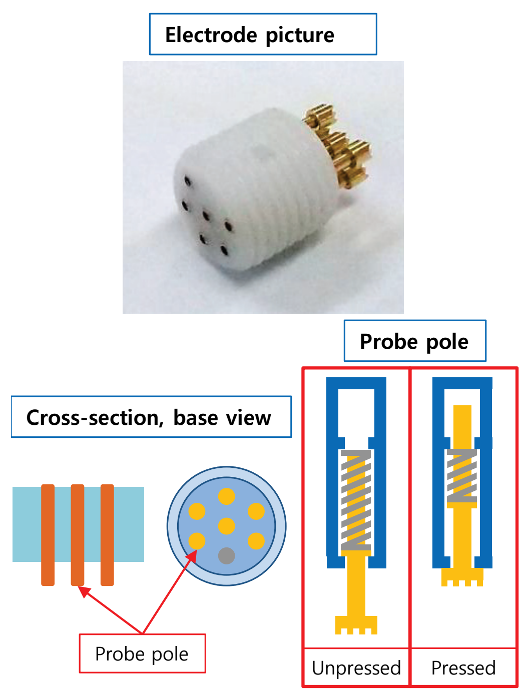


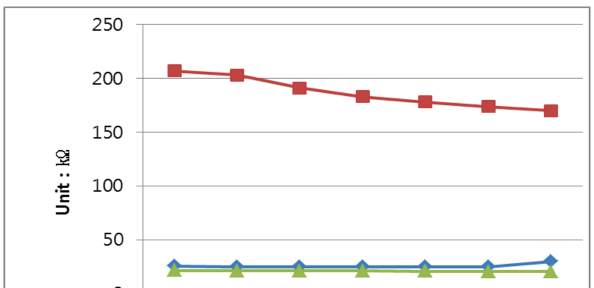
Figure 1. Dry electrode picture and structure diagram.

B. Impedance test

To verify the performance of the electrode, we measure the contact impedance and compare that with those of conventional wet electrodes and G.tec Sahara dry electrodes. The impedance can be obtained by measuring the voltage difference between a reference electrode and a target electrode [5]. Lower impedance means a higher contact capability, and a better contact capability implies the possibility of high quality EEG signal acquisition without noise and distortions.

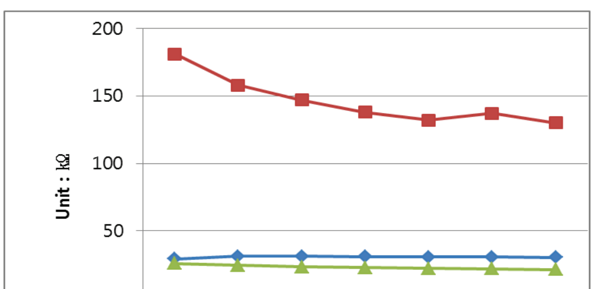
To measure the electrode impedance, we utilize EEG acquisition system named RZ5 neurophysiology workstation, PZ3 low impedance preamplifier and impedance check application (made by Tucker-Davis Technology). Comparison targets are general wet electrodes named StarDisk(made by Hurev)[6] and commercial dry electrodes named Sahara electrodes(made by G.tec). While wet electrodes use the conductive gels for adhesion and high conductivity, proposed dry electrodes and Sahara electrodes do not use conductive gels for electrode installation. In the impedance test, we used a single male subject. We measured the electrode impedance at Cz, and Pz positions based on international 10/20 system. We also recorded the change in impedance from 2 seconds up to 60 seconds. Reference and ground electrodes are installed on the right and the left ear lobe respectively.

III. Results



	2s	10s	20s	30s	40s	50s	60s
Dry	26	25	25	25	25	25	30
g.tec Dry	207	203	191	183	178	174	170
Wet	21.6	21.4	21.2	21.2	20.8	20.5	20.4

Figure 2. Electrode impedance comparison at Cz position



	2s	10s	20s	30s	40s	50s	60s
Dry	29	31	31	30.8	30.5	30.6	30.2
g.tec Dry	181	158	147	138	132	137	130
Wet	25.8	24.2	23.1	22.5	22.2	21.7	21.1

Figure 3. Electrode impedance comparison at Pz position

Figure 2 and Figure 3 are results of impedance comparison at Cz and Pz electrode positions respectively. Owing to the usage of conductive gels, the impedances of wet electrodes shows the lowest impedance performance. However, the impedance difference between proposed dry electrodes and wet electrodes is shown to be insignificant. According to impedance values at Cz electrode position, the impedance values of proposed electrodes are comparable to the wet electrodes without conductive gels. Comparing with G.tec Sahara electrodes, proposed electrodes show quite lower impedance.

IV. Discussions

From the results, we have shown satisfied impedance values of proposed electrodes. It is because we employed spring loaded probes which can contract their length by pressure. Therefore, this design significantly improves contact capability compared to G.tec Sahara electrodes.

Although the impedance values of proposed electrodes are slightly higher than those of the wet electrodes, these impedance values are good enough to measure EEG signals practically. In addition, proposed electrodes have advantages such as convenient installation and feasibility of long-term monitoring. Impedance problem of dry electrodes can be improved by equipping an active circuit. It will be our future research.

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