Biocompatible, Adhesive and Small Sized Electrode for EEG Signal Measurements Made of CNT and Adhesive PDMS

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COMFORT and biocompatible electroencephalography (EEG) recording is essential for advance in brain-computer-interface (BCI) technology. Normally conventional EEG electrode is attached on scalp using conductive gel or paste which leaves residue and cause skin irritations. To solve this problem, many researchers introduced dry electrodes, capacitive typed electrodes or pin type electrodes. Although these electrodes have shown high performances with gel or paste, still fixation is a big challenge that most electrodes for EEG was fixed on a hat or hair band. Moreover, biocompatibility is also one of major issues as the subjects who need BCI technique should wear the electrodes for a long time in daily life. With these senses, EEG measurement using adhesive polydimethylsiloxane (PDMS) is very attractive as it is one of the highly biocompatible materials which was approved by U.S Food and Drug Administration (FDA). However, beside the adhesive property and biocompatibility, it has poor conductivity that will lower the signal quality.

In this study, we newly developed conductive, biocompatible, adhesive and small-sized EEG electrode which could be attached on the scalp without any preparation. This electrode is cylindrical, with a 6mm diameter, and 1mm height. Due to its small size and adhesive property, the electrode can be perfectly hidden by hair when attached on the scalp, making it aesthetically pleasing. Moreover, this electrode leaves no residue as it does not need conducting paste or gel. To increase the conductivity, this electrode is made of PDMS and the mixture of adhesive PDMS and carbon nano tube (CNT) and polyimide based Au/Ti metal was inserted between them. CNT was mixed 2.5% by weight, then dispersed in adhesive PDMS uniformly by home-made stirring machine.[1] The impedance of adhesive PDMS was measured as 38kΩ at 10 Hz and adhesion force was maintained after mixing. The PDMS was used for base mold and Au/Ti metal was for interface between the adhesive PDMS with CNT and wire which was connected customized measurement system. The adhesion force was decreased with usage several times due to dust or secretion from the scalp. However, it was recovered by cleaning process with alcohol so this electrode is reusable and semi-permanent. Furthermore, adhesive PDMS with CNT has very low modulus (950kPa) that can penetrate the rugged surface of the scalp, which lowered the contact impedance, resulting in high signal to noise ratio (SNR). After comparing the contact impedance to a dry electrode, the developed EEG electrode showed less than 50% to the dry one due to comfort contact to the scalp. To verify the feasibility, commonly used EEG signals for BCI was measured. Alpha wave and steady state visually evoked potential (SSVEP) were measured with flickering four LEDs in 13Hz while the developed electrode was placed O_z. N100 peak for auditory evoked potential (AEP) was also measured at Cz by beep sound signals which has the frequency of 1.3Hz and 300ms duration. All EEG signals were filtered from 0.5 to 40 Hz and amplified 5000 times. The alpha wave was observed when eyes were closed and the dominant peak at frequency domain of 13Hz was also observed for SSVEP test. For the AEP experiment, N100 was observed after signal averaging and its *p*-value was decreased to lower than 0.01 after 27 trials of 500Hz beep sound stimuli. For biocompatibility test, developed electrode was attached for a week and we found that it was not associated with any adverse effects-including erythema-at the attached sites. Live and dead test was also performed on the fibroblast cells (1×10^4 cells ml^{-1}) that were also seeded directly onto the electrode, and we found that most cell cultured within the electrode remained alive for more than three days.

REFERENCES

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