Biopotential Electrodes

Introduction

Biopotential electrodes provide a means of interfacing a biological system with an electronic system [1], such that electrical signals in the biological system may be amplified, filtered, and recorded. Biopotential electrodes are most commonly used in the medical domain to gather data on heart rhythms (electrocardiogram or, ECG/EKG) or brain wave activity (electroencephalography or, EEG). Although the underlying physics of biopotential electrodes remains unchanged, various advances and improvements are continually being implemented allowing for more accurate data, and as a result, better patient care. This paper serves to briefly examine the commercial applications and state of the technology for biopotential electrodes.

Commercial Applications of Biopotential Electrodes

Perhaps the most common applications of biopotential electrodes are the EKG and EEG, although they are also used in pacemakers [2], monitoring retina activity (electrooculography or, EOG), and monitoring muscle activity (electromyography or, EMG) [3]. Four major types of bioelectrodes are currently on the market, each with specific characteristics and benefits. Metal plate electrodes consist of a metal plate with adhesive attached to a foam pad and are the most commonly used type of electrode in the EKG and EEG, as they are cheap (disposable) and easy to apply to a patient [4]. Metal-plate electrodes are made by biomedical suppliers all over the world, and can be purchased from companies such as BIOPAC for $42 for a set of 25 [5], or Kendall for $120 for a set of 600 [6]. Suction electrodes require no adhesive and operate by using a suction mechanism with electrolyte gel. Unlike metal-plate electrodes, suction electrodes may be reused, however, prolonged suction force may irritate the skin [4]. The EL254 4 mm reusable suction electrode is available from BIOPAC for $35 [5]. Floating electrodes contain a metal disk immersed in electrolyte gel, allowing it to never directly come into contact with the skin, thereby reducing unwanted noise and motion artifact [4]. The TSD203 set can be purchased from BIOPAC for $125 [5]. Flexible electrodes are made of conductive rubber and contain a thin film of mylar and are ideal for infants or persons with irregular body shape, where the rigid metal electrodes will not attach properly [4]. The EL506 flexible electrodes can be purchased from BIOPAC for $25 for 8 [5].

Technology of Biopotential Electrodes

Operation

Biopotential electrodes serve as an interface between biological systems (where currents travel along neurons) and electronic systems (where currents travel along metal wires). This conversion is made possible by utilizing oxidation-reduction electrochemical reactions via a connection between a metal and electrolyte solution. Typically, a metal such as silver (Ag) is used as the electrode and is coated with a layer of silver chloride (AgCl). Biological fluids are rich in chloride ions, allowing the flow of chloride ions from the body to the silver metal electrode via the silver chloride layer. The redox reaction between silver metal and chloride ions is spontaneous, generating a voltage that can be manipulated and read electronically [4].

Advances

One of the biggest problems with biopotential electrodes is the fact that they are only slightly attached to the skin and have a tendency to peel off due to sweat or the drying of the adhesive, and in such an instance, provide poor data [3]. To combat this problem, a class of capacitive biosensors have been introduced by Quantum Applied Science and Research, where the electrodes are coupled to the capacitance of the human body and have an input impedance on the order of 10^{12}, allowing for accurate monitoring of biological signals without direct contact with the skin. These breakthroughs would allow for performing EKGs through clothing in emergency situations, or through sheets in hospital beds [3].

Research is also being done to investigate the use of carbon nanotubes and biopolymers to construct biopotential electrodes for use inside the human body. Typically, electrodes have a high surface area conductivity at the expense of mechanical strength, but research has shown that electrodes made out of single walled carbon nanotubes and biopolymers such as DNA can exhibit conductivity on the order of 300 S/cm, strength up to 145 MPa, and capacitance from 19-27 F/g [2]. “These composites exhibit sufficient conductivity, electrochemical capacitance, and suitable mechanical properties to allow for their use as implanted electrodes for the purpose of sensing and stimulation, for example as pacemaker electrodes or ECG pads.” [2]

Implementation of Biopotential Electrodes

The implementation of metal-plate biopotential electrodes to an EKG or EEG system is fairly simple and cheap. Metal-plate electrodes are most commonly used in such applications, and can be purchased in bulk for as low as $0.20 each [6]. The use of floating or flexible electrodes is equally simple, but generally costs more [5], while the use of suction electrodes could potentially be cheaper as they are reusable, but could also provide the patient with discomfort [4]. The electrodes are directly applied to the skin of the patient and attached to wires which feed into an electronic system where the signal is amplified and filtered. If floating electrodes are used, less filtering would be required as less noise would be introduced into the system [4].

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