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CHARACTERISATION OF A PASTE LESS ECG ELECTRODE

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ABSTRACT

For better understanding of the activity of the heart, the Electrocardiograph needs to be studied for which the electrodes are an inevitable part of the measuring system. Generally electrodes are used with some paste called electrode jelly. Recently, for constant use and ease of using the pasteless electrodes are replacing the previous one. In the present work, an attempt has been made to fabricate different types of pasteless electrode and characterize them by measuring their skin-to-electrode impedance at various frequencies and in presence and as well as in absence of perspiration. Such measurements are necessary in order to design the ECG preamplifier. The results thus obtained have been plotted and from which the best can be chosen for the use.

KEYWORDS: Bio-Electrodes, Half Cell Potential, Electrolysis Process

INTRODUCTION

Bio-electric potentials are generated at cellular levels through continuous polarization and non-polarization of the cells and due to a physiological activity called "Sodium Pump" [1]. The excited cell passes such potential to the neighbouring cell and thus is propagated throughout the body. The wave of excitation when propagating through the muscle causes contraction. Every contraction of a muscle results in producing an ionic voltage. The potentials occur in such a way that the moving muscle section is always at a negative potential with respect to its surroundings. The bio-electric signals are thus very much significant for diagnosis and therapy. These are often recorded and are produced by the co-ordinated activity of the large group of cells. In this type of synchronised excitation of many cells, the charges tend to migrate through the body fluids towards the still unexcited areas.

Such charge migration constitutes an electric current and hence sets up potential differences between various parts of the body in its outer surface. The nature of such potentials will definitely depend on the source of generation and type of cells generating them. Such ionic potentials can be converted into electronic voltage with the help of electrodes and these electrodes will be termed as Bio-electrodes. Thus the electronic voltages can be measured by some sensitive instruments placed across two different electrodes placed at two different locations of the body.

OPERATION OF ELECTRODES

The bio-electric potentials generated in the body are ionic in nature and need to be converted into electronic voltages. Devices that convert ionic potentials into electronic potentials are called Electrodes. The voltage developed at an electrode-electrolyte interface is designated as the "Half Cell Potential" or "Electrode Potential".

In the case of a metal solution interface, an electrode potential results from the difference in rates between two opposing processes, viz., i) the passage of ions from the metal into the solution and ii) the combination of metallic ion in solution with electron in the metal to form the atoms of the metal[2].

So when a metal electrode comes in contact with an electrolyte (body fluid), there is a tendency for the electrode to discharge ions into solution and for ions in the electrolyte to combine with the electrodes. The net result is the creation of a charge gradient, the spatial arrangement of which is called the "Electric Double Layer". Electrodes in which no net transfer of charge occurs across the metal electrolyte interface are called "Perfectly Polarised Electrodes". Electrodes I which unhindered exchange of charge is possible across the metal electrolyte interface are known as "Perfectly Non Polarised Electrodes". Practical electrodes have the properties that lie between these two idealised limits. The following circuit shows the electrical equivalent circuit of a surface electrode when it is in contact with the body surface.

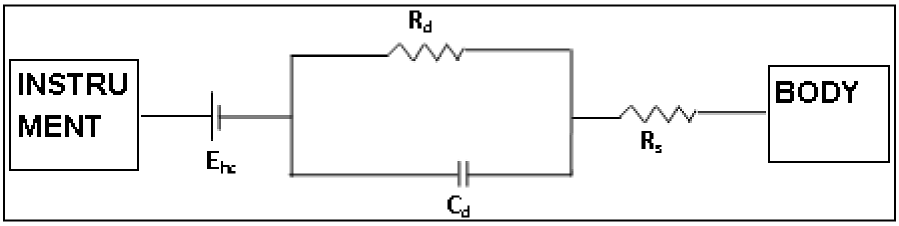

Figure 1: Equivalent Circuit of an ECG Electrode

The electrode electrolyte interface resembles a voltage surface having half cell potential "E_{hc}" which is developed due to charge gradient and a capacitor "C_d" in parallel with a leakage resistance "R_d". The series resistance in the equivalent "R_s " represents the series electrolyte and skin resistance under equilibrium conditions. The impedance of this equivalent circuit can be put as[2]:

$$Z = R_s + \frac{\dfrac{R_d}{j2\pi C_d}}{R_d + \dfrac{1}{j2\pi f C_d}}$$

i.e., $Z = R_s + \dfrac{R_d}{1 + j2\pi f C_d R_d}$

Thus it is obvious from the above expression that the impedance will largely depend upon the electrode metal, its area, the electrolyte, charge density and frequency of the ionic current which is to be converted into electronic potential. The capacitance represents the charge developed at the phase boundary whereas the resistance depends upon the conditions associated with ion migrating along phase boundaries and inside the diaphragm.

However, due to above arrangement there is a possibility of the presence of voltages of non-physiological origin. These voltages are called "Contact Potentials". The electrical equivalent circuit of the surface electrode suggests that voltage applied to the measuring instrument from the electrode consists of two main components[3]: Contact Potential and the Biological signal of interest. The contact potential is found to be a function of the type of skin, skin preparation and composition of the electrolyte. Therefore the differences in skin characteristics can vary widely even on the same body. The emotional state of the patient also affects the electrode potential. When bioelectric events are recorded, interference signals are produced by the differences of metal electrolyte and the electrolyte skin interface. Therefore, in order to minimize this contact potential two electrodes are connected in the opposite directions at two different parts of the body.

PURPOSE OF THE ELECTRODE PASTE

The outer skin of the body is highly non-conductive and can not establish a good electrical contact with an electrode. The skin should therefore be cleaned thoroughly and rubbed briskly to remove some of the outer cells. This area should then be coated with an electrically conductive paste called "Electrode Paste" that should be "worked in" by further rubbing. The electrode is then applied to the prepared site and held in place with a rubber strap or a length of tape. Thus the electrode paste decreases the impedance of the contact and it also reduces the artefacts resulting from movement of the electrode or the patient[4].

PASTELESS ECG RECORDING ELECTRODES

The ECG monitoring electrodes – in a majority of cases, are metal plates applied to the skin after preliminary preparation of the skin. Such preliminary preparation may some time rise to poor baseline drift and poor quality signals[5]. Another disadvantage of using electrode paste is that during long term monitoring there is likely to be patient skin reactions as the electrode-skin interface dries out in few hours the electrodes need to be periodically removed for paste replacements., thus causing further discomfort due to repetitive worn over long periods. Also, in conductive electrodes, shift in electrode position at the electrode site causes a drift in the baseline particularly when the subject moves. Therefore the present work of using a dry electrode may dispense with the preparation of skin would definitely look attractive.

FABRICATION OF DRY ELECTRODE (PASTELESS ELECTRODE)[6]

Anodization: Anodization is a process where by a hard, non-corroding oxide film is deposited on to the pure aluminium. This film is harder and far more scratch-resistant than the pure aluminium itself. It also protects against finger prints which can be areal nuisance.

Ingredients and Equipments Required: Caustic Soda lye (1:10), Nitric acid, Sulphuric acid (1:7), distilled water, a piece of lead, suitable tank, a variable mains power supply or a heavy duty battery.

Processing: First the aluminium is smoothed with grade 400 wet and dry emery paper. Proper care should be taken for not to overheat the aluminium for not more than 10 minutes in the caustic Soda lye to remove al the grease. Decolouration often occurs, but this can be removed if etched in 1:10 nitric soda solution. Electrolysis process is to be carried out in a solution of sulphuric acid with a sheet of lead suspended and connected to negative terminal of the battery. The electrolysis process is to be carried out for about an hour at a constant temperature of 16 – 20^{0}C. The aluminium work piece is then to be rinsed thoroughly with distilled water. Finally the aluminium is to be condensate for about 15 minutes in boiling water.

Measurement: In order to determine the electrode impedance, a suitable skin-contact electrodes of 2.5 cm diameter were constructed of various materials like Copper and Aluminium. The skin to electrode impedance of these surfaces were measured as shown in figure 2 where 'B' represents the disk under test and 'A' and 'C' are two standard

Silver-Silver chloride electrodes used for all impedance tests and located 5 cm apart and proximal to the test disk on the forearm of the subject. The Silver-Silver chloride electrodes were used with electrode paste. The two voltmeters shown have input impedances in excess of 250 MΩ. A sinusoidal voltage was applied between electrode disks 'A' and 'B' through series resistor 'R'. By measuring e_{a-b}, the current through the 'B', i_B can be calculated by

$$i_B = \frac{e_{a-b}}{R} \quad \text{with } R << 250\ \text{M}\Omega$$

The very high impedance of the voltmeters eliminates any appreciable flow of sinusoidal test current between electrode disk 'B' and 'C', hence any voltage appearing between these two electrodes is due to the voltage drop across Z_B, the skin – to electrode impedance at the junction of disk 'B' and the skin, caused by the applied current i_B. Thus Z_B is given by

$$Z_B = \frac{e_{b-c}}{i_B} = \frac{R.e_{b-c}}{e_{a-b}}$$

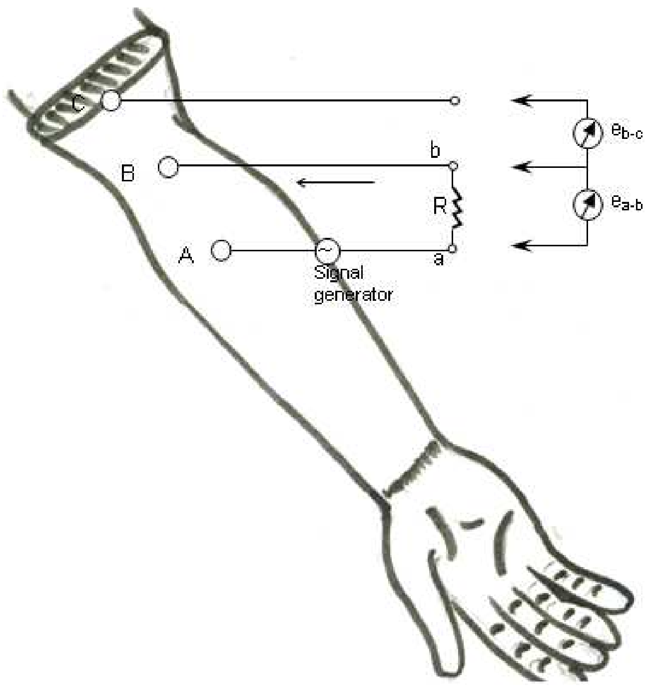

Figure 2: Arrangement for Measuring the Impedance

RESULTS AND CONCLUSIONS

The results of these measurements of skin-to-electrode impedance on one subject for test disks constructed of anodized copper and anodized aluminium over the frequency range of 1 Hz to 1 KHz has been shown in figure 3. Measurements were made within 10 minutes after the application of the electrode disk being tested. It is clear from the results that the impedance offered by the anodized copper almost maintains a constant value over the frequency range mentioned whereas that for the anodized aluminium varies a lot and also the impedance offered by anodized aluminium electrode is much higher than that of anodized copper.

Figure 4 illustrates the effect of perspiration on the skin-to-electrode impedance of anodized copper and anodized aluminium disk those were placed first on the forearm and then on the palm of the subject, where perspiration was profuse. As depicted in the graph of figure 4, the magnitude of the skin-to-electrode impedance reduced mostly at low frequencies due to the presence of perspiration at the skin-electrode interface but at the higher frequencies the impedance almost remains the same. Thus it may be concluded that the little effect of the presence of perspiration is noted and thus become useful in both the presence as well as absence of perspiration.

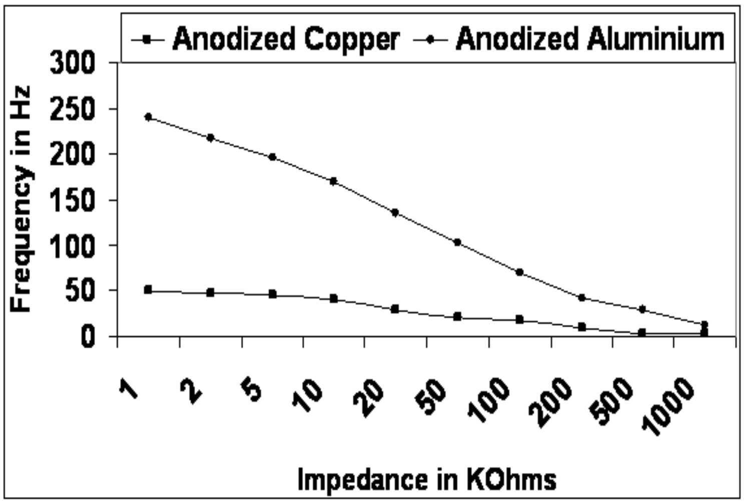

Figure 3: Impedance of the Tests Disks at Various Frequencies in the Absence of Perspiration

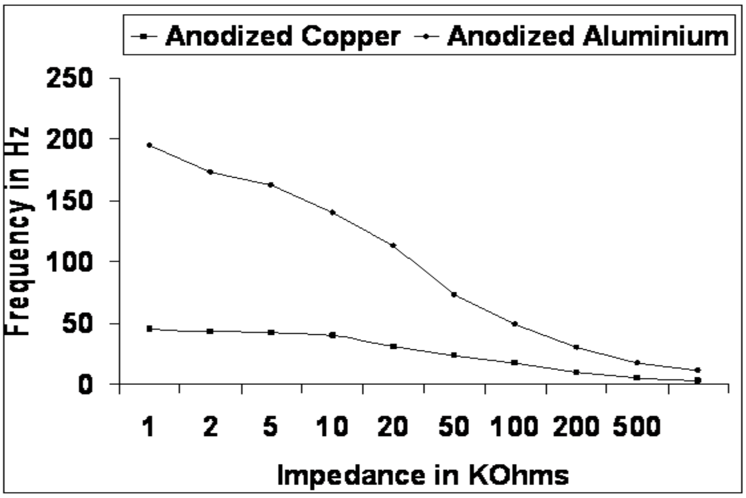

Figure 4: Impedance of the Tests Disks at Various Frequencies in the Presence of Perspiration

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