ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
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DEPARTMENT OF BIOMEDICAL ENGINEERING

BM3491 Biomedical Instrumentation

UNIT-I ELECTRODE CONFIGURATIONS

1.4 Classifications of electrodes

A wide variety of electrodes can be used to measure bioelectric events, but nearly all can be classified as belonging to one of three basic types:

1. **Microelectrodes**: Electrodes used to measure bioelectric potentials near or within a single cell.
2. **Skin surface electrodes**: Electrodes used to measure ECG, EEG, and EMG potentials from the surface of the skin.
3. **Needle electrodes**: Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG potentials from a specific group of muscles.

- All three types of biopotential electrodes have the metal-electrolyte interface described in the previous section. In each case, an electrode potential is developed across the interface, proportional to the exchange of ions between the metal and the electrolytes of the body.
- The double layer of charge at the interface acts as a capacitor. Thus, the equivalent circuit of biopotential electrode in contact with the body consists of a voltage in series with a resistance-capacitance network of the type shown in Figure.
- Since measurement of bioelectric potentials requires two electrodes, the voltage measured is really the difference between the instantaneous potentials of the two electrodes, as shown in Figure.
- If the two electrodes are of the same type, the difference is usually small and depends essentially on the actual difference of ionic potential between the two

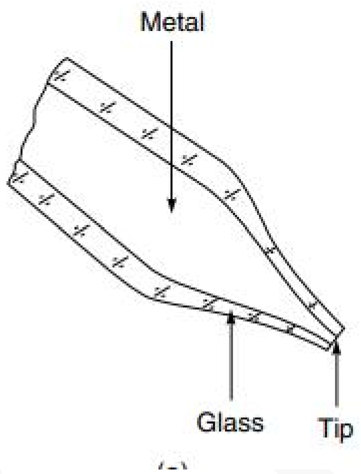
points of the body from which measurements are being taken. If the two electrodes are different, however, they may produce a significant dc voltage that can cause current to flow through both electrodes as well as through the input circuit of the amplifier to which they are connected.

- The dc voltage due to the difference in electrode potentials is called the electrode offset voltage. The resulting current is often mistaken for a true physiological event. Even two electrodes of the same material may produce a small electrode offset voltage.
- In addition to the electrode offset voltage, experiments have shown that the chemical activity that takes place within an electrode can cause voltage fluctuations to appear without any physiological input. Such variations may appear as noise on a bioelectric signal.
- This noise can be reduced by proper choice of materials or, in most cases, by special treatment, such as coating the electrodes by some electrolytic method to improve stability. It has been found that, electrochemically, the silver-silver chloride electrode very stable.
- This type of electrode is prepared by electrolytically coating a piece of pure silver with silver chloride. The coating is normally done by placing a cleaned piece of silver into a bromide-free sodium chloride solution.
- A second piece of silver is also placed in the solution, and the two are connected to a voltage source such that the electrode to be chlorided is made positive with respect to the other. The silver ions combine with the chloride ions from the salt to produce neutral silver chloride molecules that coat the silver electrode. Some variations in the process are used to produce electrodes with specific characteristics.

1.4.2 Microelectrodes:

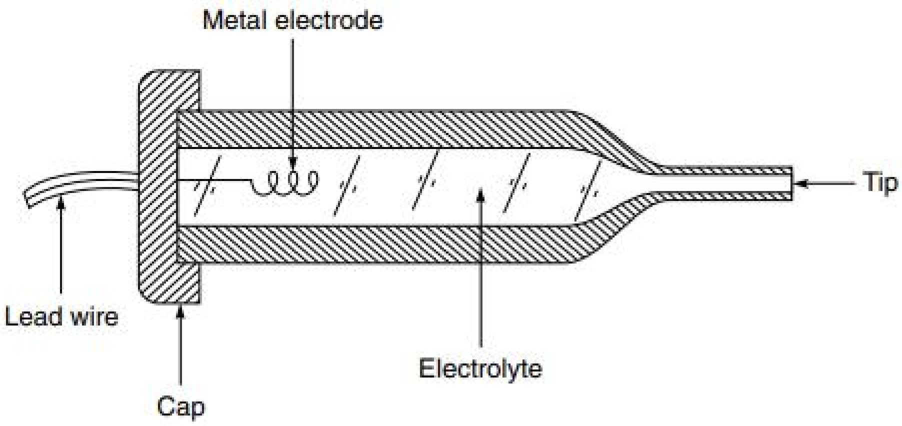
1. Microelectrodes are electrodes with tips sufficiently small to penetrate a single cell in order to obtain readings from within the cell.
2. The tip must be small enough to permit penetration without damaging the cell.
3. This action is usually complicated by the difficulty of accurately positioning an electrode with respect to a cell.
4. Microelectrodes are generally of two types: metal and micropipet.

5. Metal microelectrodes are formed by electrolytically etching the tip of a fine tungsten or stainless-steel wire to the desired size. Then the wire is coated almost to the tip with an insulating material. Some electrolytic processing can also be performed on the tip to lower the impedance. The metal-ion interface takes place where the metal tip contacts the electrolytes either in- side or outside the cell.



Microelectrodes—metal microelectrodes

6. The micropipet type of microelectrode is a glass micropipet with the tip drawn out to the desired size [usually about 1 micron (now more commonly called micrometer, μm) in diameter]. The micropipet is filled with an electrolyte compatible with the cellular fluids. This type of microelectrode has a dual interface. One interface consists of a metal wire in contact with the electrolyte solution inside the micropipet, while the other is the interface between the electrolyte inside the pipet and the fluids inside or immediately outside the cell.



Microelectrodes—micropipette or micro capillaries electrode

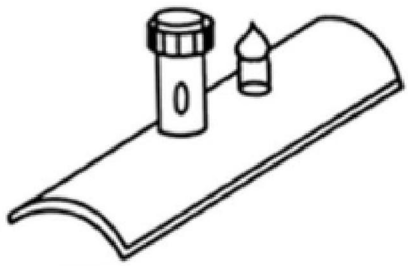
7. A commercial type of microelectrode is shown in Figure. In this electrode a thin film of precious metal is bonded to the outside of a drawn glass microelectrode. The manufacturer claims such advantages as lower impedance than the micropipet electrode, infinite shelf life, repeatable and reproducible performance, and easy cleaning and maintenance. The metalelectrolyte interface is between the metal film and the el performance, and easy cleaning and maintenance. The metal electrolyte interface is between the metal film and the electrolyte of the cell.
8. Microelectrodes, because of their small surface areas, have impedances well up into the megohms. For this reason, amplifiers with extremely high impedances are required to avoid loading the circuit and to minimize the effects of small changes in interface impedance.

1.4.3. Body Surface Electrodes:

1. Electrodes used to obtain bioelectric potentials from the surface of the body are found in many sizes and forms.
2. Although any type of surface electrode can be used to sense EGG, EEG, or EMG potentials, the larger electrodes are usually associated with EGG, since localization of the measurement is not important, whereas smaller electrodes are used in EEG and EMG measurements.
3. The earliest bioelectric potential measurements used **immersion electrodes**, which were simply buckets of saline solution into which the subject placed his hands and feet, one bucket for each extremity. As might be expected, this type

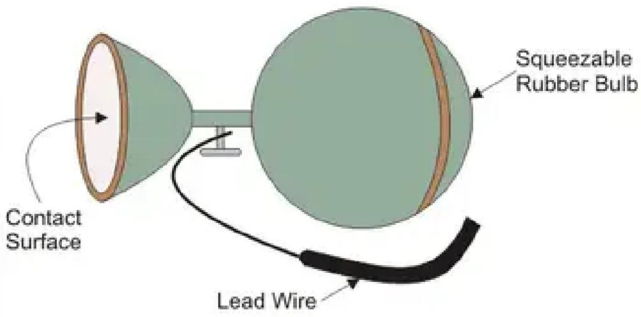
of electrode (Figure 4.4) presented many difficulties, such as restricted position of the subject and danger of electrolyte spillage.

4. A great improvement over the immersion electrodes were the **plate electrodes**, first introduced about 1917. Originally, these electrodes were separated from the subject's skin by cotton or felt pads soaked in a strong saline solution. Later a conductive jelly or paste (an electrolyte) replaced the soaked pads and metal was allowed to contact the skin through a thin coat of jelly. Plate electrodes of this type are still in use today.



Metal plate electrodes

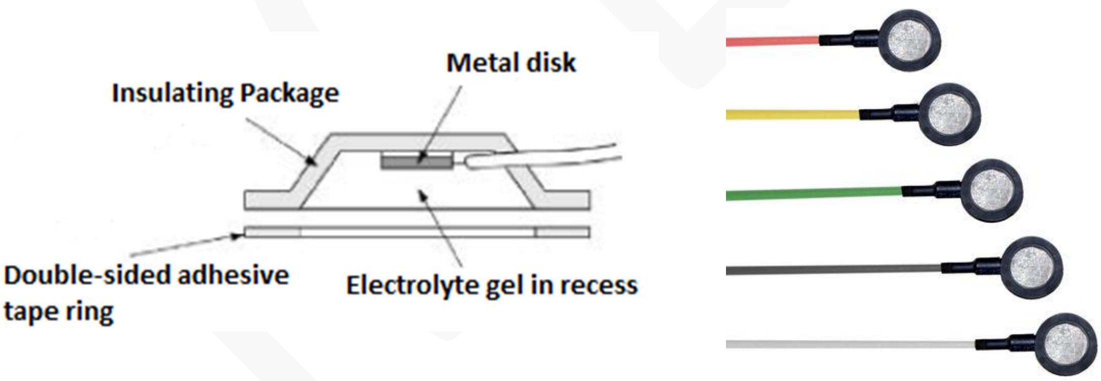
5. Another fairly old type of electrode still in use is the **suction-cup electrode** shown in Figure. In this type, only the rim actually contacts the skin.



Suction-cup electrode

6. One of the difficulties in using plate electrodes is the possibility of electrode slippage or movement. This also occurs with the suction-cup electrode after a sufficient length of time. A number of attempts were made to overcome this problem, including the use of adhesive backing and a surface resembling a nutmeg grater that penetrates the skin to lower the contact impedance and reduce the likelihood of slippage.

7. All the preceding electrodes suffer from a **common problem**. They are all **sensitive to movement**, some to a greater degree than others. Even the slightest movement changes the thickness of the thin film of electrolyte between metal and skin and thus causes changes in the electrode potential and impedance. In many cases, the potential changes are so severe that they completely block the bioelectric potentials the electrodes attempt to measure. The adhesive tape and **nutmeg grater" electrodes reduce this movement artefact by limiting electrode movement and reducing interface impedance, but neither is satisfactorily insensitive to movement.
8. Later, a new type of electrode, the **floating electrode**, was introduced in varying forms by several manufacturers. The principle of this electrode is to practically eliminate movement artifact by avoiding any direct contact of the metal with the skin. The only conductive path between metal and skin is the electrolyte paste or jelly, which forms an electrolyte bridge. Even with the electrode surface held at a right angle with the skin surface, performance is not impaired as long as the electrolyte bridge maintains contact with both the skin and the metal.



Floating type biopotential electrodes

9. Floating electrodes are generally attached to the skin by means of two-sided adhesive collars (or rings), which adhere to both the plastic surface of the electrode and the skin. Figure shows an electrode in position for biopotential measurement.

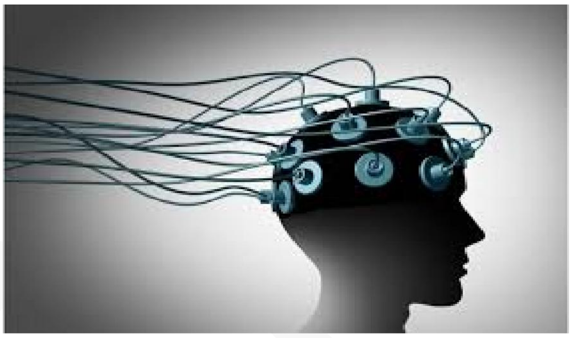
10. Special problems encountered in the monitoring of the ECG of astronauts during long periods of time, and under conditions of perspiration and considerable movement, led to the development of **spray-on electrodes**, in which a small spot of conductive adhesive is sprayed or painted over the skin, which had previously been treated with an electrolyte coating.

11. Various types of **disposable electrodes** have been introduced in recent years to eliminate the requirement for cleaning and care after each use. An example is shown in Figure. Primarily intended for ECG monitoring, these electrodes can also be used for EEC and EMG as well. In general, disposable electrodes are of the floating type with simple snap connectors by which the leads, which are reusable, are attached. Although some disposable electrodes can be reused several times, their cost is usually low enough that cleaning for reuse is not warranted. They come pregelled, ready for immediate use.

Disposable electrodes

12. Special types of surface electrodes have been developed for other applications. For example, a special **ear-clip electrode** (Figure 4.11) was developed for use as a reference electrode for EEG measurements. Scalp surface electrodes for EEG are usually small disks about 7 mm in diameter or small solder pellets that are placed on the cleaned scalp, using an electrolyte paste. This type of electrode is shown in Figure.

Ear-clip electrode



EEG Scalp Surface Electrode

1.4.4 Needle Electrodes:

To reduce interface impedance and, consequently, movement artifacts, some electroencephalographers use small subdermal needles to penetrate the scalp for EEG measurements. These needle electrodes, shown in Figure, are not inserted into the brain; they merely penetrate the skin. Generally, they are simply inserted through a small section of the skin just beneath the surface and parallel to it.

Subdermal needle electrodes

Needle electrodes for EMG- consist merely of fine insulated wires, placed so that their tips, which are bare, are in contact with the nerve, muscle, or other tissue from which the measurement is made. The remainder of the wire is covered with some form of insulation to prevent shorting. Wire electrodes of copper or platinum are often used for EMG pickup from specific muscles. The wires are either surgically implanted or introduced by means of a hypodermic needle that is later withdrawn, leaving the wire electrode in place.

A single wire inside the needle serves as a **unipolar electrode** which measures the potentials at the point of contact with respect to some indifferent reference. If two wires are placed inside the needle, the measurement is called **bipolar** and provides a very localized measurement between the two wire tips.

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