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[54] **THUMBTACK MICROELECTRODE AND METHOD OF MAKING SAME**

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[52] **U.S. Cl.** ..... **128/2.1 E,** 29/630 R, 128/DIG. 4

[51] **Int. Cl.** **A61b 5/04**

[58] **Field of Search** ..... 128/2 E, 2.06 B, 2.06 E, 128/2.06 R, 2.1 E, 2.1 R, 404, 418, DIG. 4, 2 R; 29/630 R

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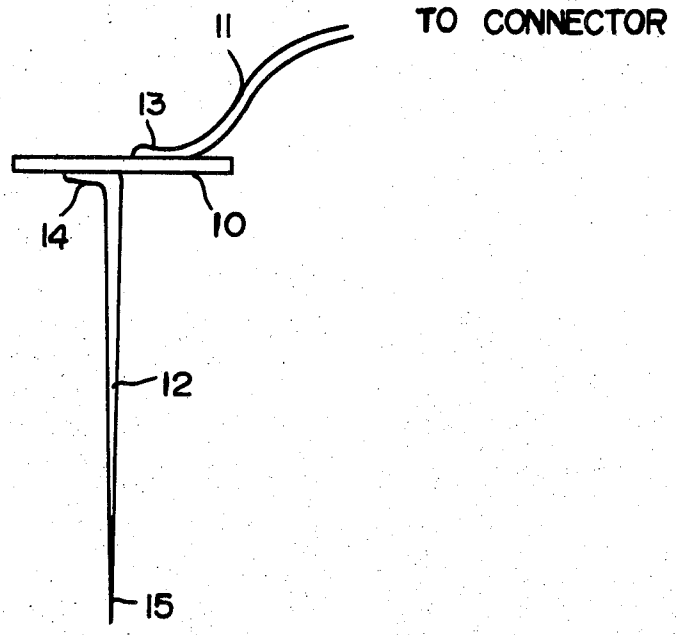
Primary Examiner—William E. Kamm

[57] **ABSTRACT**

A thumbtack microelectrode for making extracellular chronic recordings from single nerve cells in the cerebral cortex in unrestrained animals over prolonged periods of time comprises a rigid electrode shaft, which is microwelded to one side of a tack head-like disc, and a flexible electrical conductor which is microwelded to the opposite side of the tack head-like disc. After a cleaning operation including ultrasonic desiccation the entire microwelded assembly is electrically insulated. The insulation covering the recording tip of the electrode shaft which is tapered, prior to the cleaning and insulating operations, by electrolytic etching, is then removed so as to expose a small area for use as the recording surface.

14 Claims, 2 Drawing Figures



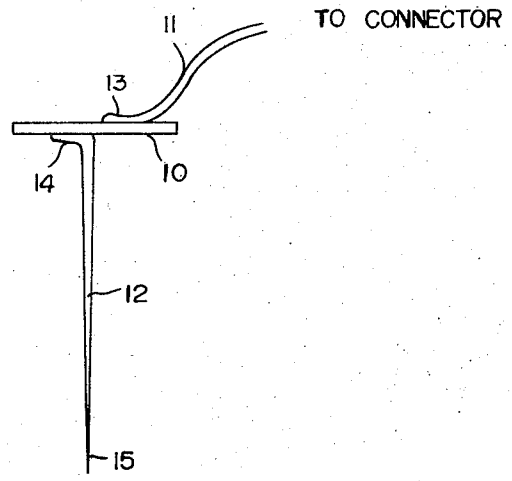


FIG. 1

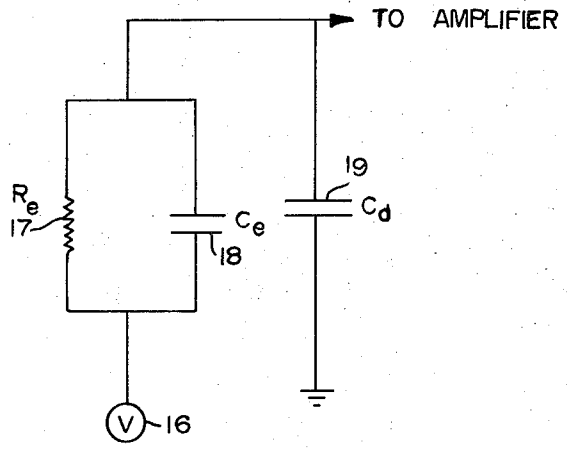


FIG. 2

THUMBTACK MICROELECTRODE AND METHOD OF MAKING SAME

FIELD OF THE INVENTION

The present invention relates to measuring intracortical brain waves and, more particularly, to microelectrodes for making chronic recordings of electrical discharges from single cells in the cerebral cortex of an animal's brain.

BACKGROUND OF THE INVENTION

In defining chronic recording from single cells of the brain, it is essential to accurately locate the electrode. One technique has required the attachment of a special chamber to the animal's head through which new electrodes are inserted on each successive recording day while the animal's head is rigidly bolted to prevent any movement. However, such techniques are highly undesirable for a number of reasons including the fact that they are difficult, are extremely uncomfortable to the animal, and are less accurate than desirable.

In all truly chronic recording techniques the following design conditions are essential:

a. the electrodes must be implanted once during surgery, remain fixed in position, and then must not be subjected to further external manipulation;

b. during recording sessions, the head of the animal must be unrestrained except for the connecting cable where telemetry is not possible;

c. The animal must be awake and unmedicated; and

d. through the use of spike discriminators, statistical measures, continual visual monitoring and other stringent criteria, the identity of a single nerve cell must be established and the cell successfully monitored for several hours to many days.

Although prior art devices which meet these design requirements do exist they suffer from a variety of deficiencies. Most pertinently, such prior art devices have been successfully employed only in deep structures, such as the basal nuclei, hypothalamus, brain stem, etc., because they comprise a comparatively long length of wire, the electrode, which is cemented directly to the skull. Since the rotational acceleration of the head results in displacements of the brain relative to the skull, an electrode rigidly connected to the skull is certain to move within the substance of the superficial cortex.

Therefore, prior art microelectrodes for recording from single cells in the brains of unrestrained animals are not capable of successfully recording electrical discharges from single cells in the cerebral cortex over prolonged periods of time. Further, such devices are of comparatively large diameter (e.g., 80 micrometers) and do not provide means for limiting the entry of the electrode into the cortex.

SUMMARY OF THE INVENTION

The shortcomings of the prior art microelectrodes for recording from single cells in the cerebral cortex of the brain are satisfactorily overcome by the present invention. It is, accordingly, an object of the present invention to thus overcome the defects of the prior art, such as indicated above.

Another object of the present invention is to provide for improved brain wave recording of single brain cells.

Another object is to provide an improved technique of brain wave measurement.

Another object of the present invention is to provide a microelectrode capable of extracellular chronic recording from single nerve cells in the superficial layers of the cerebral cortex in unrestrained animals over prolonged periods of time.

Another object is to provide a microelectrode which makes chronic recordings of electrical discharge from single cells with minimal tissue reaction.

A further object is to provide a chronic recording microelectrode having maximal fidelity.

In furtherance of these and other objects, a principal feature of the present invention is a microelectrode capable of detecting electrical discharges from a single cell in the cerebral cortex of the brain over prolonged periods of time due to the flexible connection and stabilizing influence of the microelectrode (tack) head on the pial surface of the brain. The tack head of the microelectrode provides an anchoring surface for a mechanical inserter or micromanipulator and, therefore, dispenses with the need for manual insertion. Also, the tack head limits the entry of the microelectrode into the cortex and provides a good surface for attachment of pia by the application of isobutyl cyanoacrylate.

Another feature of the invention is that minimum tissue damage is achieved through the use of a small diameter tip (1–3 micrometers) and electrode shaft which, depending upon the animal to be studied, may be as short as one-half mm. Although small, the electrode is strong enough to pierce the intact pial membrane, thus leaving superficial circulation undisturbed and decreasing the incidence of meningocerebral adhesions.

A further optional feature is the incorporation of preamplifiers into the tack head of the microelectrode, thus reducing cable problems, such as stray capacitance, pickup, etc., to an absolute minimum.

According to the preferred manufacturing method, a microelectrode component is formed by microwelding an electrode shaft of bare iridium wire, which is approximately 0.001 inch in diameter, to the intended undersurface of a platinum disc-like tack head 0.005 inch thick and 1 mm in diameter. After welding, the electrode shaft is bent at a right angle to the intended undersurface of the tack head and cut to the appropriate length. A flexible lead which electrically attaches the tack head to a connector fixedly attached to the skull is similarly welded to the dorsal or upper surface of the tack head.

The electrode shaft is then electrolytically etched until the desired tip configuration is achieved. After cleaning, the electrode shaft is coated with an insulator (e.g., parylene). The final step in the fabrication involves the removal of a small amount of parylene from the very tip of the electrode shaft so as to expose a small area of iridium for use as the recording surface.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention a possible embodiment thereof will now be described with reference to the attached drawing, it being understood that the embodiment is to be intended as merely exemplary and in no way limitative.

FIG. 1 is an elevational view of an embodiment of a completed thumbtack microelectrode.

FIG. 2 is a schematic diagram of the electrical components of the thumbtack microelectrode of FIG. 1.

DETAILED DESCRIPTION

Referring to FIG. 1, there is shown a preferred embodiment of the thumbtack microelectrode, here provided in the form of a disc-like tack head **10**, a flexible lead wire **11**, and an electrode shaft **12**. The head **10** is, preferably, a platinum disc 0.005 inch thick and 1 mm in diameter.

One end of the flexible lead **11** is microwelded to the approximate center of the intended dorsal or upper surface of tack head **10** as indicated at **13**. The other end of the flexible lead **11** is attached to a connector (not shown) which is fixedly attached to the surface of the skull. The connector, in turn, is attached by a cable to an amplifier system, thereby permitting daily recordings of single nerve cells to be made. The flexible lead **11** is, preferably, a Teflon-coated platinum-iridium (90/10) wire.

The electrode shaft **12** is microwelded to the approximate center of the opposite or lower surface of the tack head **10** as indicated at **14** and subsequently bent perpendicularly to that surface. The very tip **15** of the end of the electrode shaft **12** furthest from the tack head **10** is electrolytically etched to a fine point. The entire shaft **12** except for the tip **15** is coated with an insulator such as parylene or Teflon.

Referring now to FIG. **2**, there is shown a schematic diagram of the electrical components of the preferred embodiment of the thumbtack microelectrode shown in FIG. **1**. The electrical discharge of the single nerve cell is designated generally by **16** and corresponds to the biological source voltage. In series with the biological source voltage **16** are the resistance and capacitance **17** and **18**, respectively, of the electrode recording tip which are in parallel with one another. Numeral **19** designates the grounded shunt capacitance of the tack head which is in parallel with the equivalent electrical components (**16, 17** and **18**) which are, also, grounded by the body of the animal.

The resistance and capacitance **17** and **18**, respectively, of the electrode recording tip correspond to the impedance of the interface between the intestitial fluid and the recording surface of the electrode shaft. Since the shunt capacitance of the thumbtack microelectrode which corresponds to the total capacitance associated with all of the metallic components and the dielectric outer insulation is considerable, the amplifier circuit must have the capability of cancelling out the distortion introduced in this manner.

The fabrication of the preferred embodiment of the thumbtack electrode shown in FIG. **1** includes the following steps. The head **10** of the microelectrode is a platinum disk 0.005 inch thick and 1 mm in diameter which may be obtained in any convenient manner, e.g., punched from a sheet of platinum with a steel die against a wood block.

The flexible lead **11** is a 4 inch length of platinum-iridium (90/10) Teflon-coated wire, 0.001 inch in diameter. It is microwelded to the approximate center of the intended dorsal or upper surface of the tack head **10** by any suitable precision welding instrument, such as a Weltek Model 410E, under direct visual control through a dissecting microscope. The microwelding operation is performed right through the Teflon insulation.

The electrode shaft **12** is a length of bare iridium (e.g. 100 percent) wire which is 0.001 inch in diameter. It is microwelded to the approximate center of the opposite or lower surface of the tack head **10**, also, under direct microscopic control. After microwelding, the shaft is cut to the appropriate length (for cat visual cortex—about 2 mm) and bent at substantially a right angle to the lower surface of the tack head by a pair of fine watchmaker's forceps.

To facilitate the handling of the microelectrode, the flexible lead is loaded into a blank micropipette previously drawn on a vertical micropipette puller with the fine end broken off. Again under direct microscopic control, the iridium electrode shaft is electrolytically etched in a bath of supersaturated sodium cyanide—30 percent sodium hydroxide until the desired tip configuration is achieved. In the case of the preferred embodiment of FIG. **1** the diameter of tip **15** is approximately 1–3 micrometers and increases slowly to 10 micrometers at a distance of 100 micrometers from the tip.

After etching, the microelectrode is rinsed in hydrochloric acid and then distilled water. After being placed in an acetone bath, the microelectrode is subjected to approximately 15 seconds of ultrasonic desiccation in distilled water and then approximately 15 seconds of ultrasonic desiccation in methanol in a device similar to that manufactured by Ultrasonics Inc. Following the above cleaning steps the microelectrode is oven dried at 60°C.

Once the microelectrode has been sufficiently dried, it is placed in a low vacuum (about 1 torr), room temperature chamber and coated with a 3 micrometer layer of parylene. The coating process is carried out by vaporizing 2 gm of the parylene dimer at 260°C and subsequent polymerization in the chamber mentioned above. The microelectrode emerges from the chamber with a uniform coating of 3 micrometers of parylene along the entire length of the etched electrode shaft and over both surfaces of the tack head. Parylene is used because it is a superior insulator with negligble water uptake and excellent conformability. Also, its biological toxicity is almost nil. It should be noted that Teflon or (glass) could be used in place of the parylene.

The final step in the fabrication process involves the removal of a small amount of parylene from the very tip of the electrode shaft so as to expose a small area of iridium for use as the recording surface. This step may be carried out by several methods. The first method involves burning away the parylene by bringing the 0.003 inch heating element of a specially designed microforge (See: Dolde and Burke, EEG *Clin. Neurophysiol.* 1972) in close proximity to the tip of the electrode shaft. Secondly, the parylene may be melted with the beam of a ruby laser. The final method involves abrading the parylene off with oxygen or argonions through the use of a micromilling device. The first and second methods may be repeated until a desired tip impedance is

achieved, about 1 megohm in the case of the preferred embodiment of FIG. 1.

In operation, the microelectrode is attached to a connector which is then cemented to the surface of the skull. The microelectrode is then attached to the nose of a vacuum electrode inserter and is driven into the cortex by positive pressure acting on the piston of the electrode inserter. The piston rides on sapphire jewel bearings and a vacuum is delivered to the head of the thumbtack through the centerbore of the piston. After insertion, the microelectrode is cemented to the pial surface of the cortex by isobutyl cyanoacrylate.

A chamber is built up around the bony incision in the skull and after all of the air is evacuated, the chamber is filled with a saline solution, thereby maintaining a constant pressure in the skull cavity and preventing leakage of fluid therefrom.

The connector which is located remote from the incision and, therefore, not enclosed by the chamber is attached by a cable to the amplifier system and daily recordings are made of the same single nerve cell for many hours. As mentioned above, the shunt capacitance of the tack head is relatively large and, therefore, the amplitude circuit must have the capability of cancelling out the distortion introduced in this manner. Displacement of the brain relative to the skull during movement of the animal are absorbed by the flexibility of the microelectrode lead, without movement of the microelectrode tip which stays in contact with the selected brain cell.

The foregoing description of the specific embodiment will so fully reveal the general nature of the invention that others can, by applying current knowledge, readily modify such specific embodiment and/or adapt it for various applications without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiment.

It should be noted that the instant device is not necessarily limited to use in the cortex of an animal. Also, other suitable materials, dimensions, or processes besides those recited herein may be adapted without departing from the inventive concept of the instant invention.

It is to be understood that the phraseology or terminology employed herein is for the purposes of description and not of limitation.

What is claimed is:

1. A thumbtack microelectrode for use in the chronic recording of electrical discharges from single nerve cells in the cortex of the brain of an animal comprising:

a first electrical conductor means adapted to be imbedded in a single nerve cell of the cortex of the brain of an animal for detecting electrical discharges from the single nerve cell, said first electrical conductor means having a blunt end and a tapered end;

a second electrical conductor means for anchoring and limiting the entry of said first electrical conductor means within the cortex, said second electrical conductor means having an upper and lower surface, the lower surface being substantially perpendicularly attached to the blunt end of said first electrical conductor means and adapted to be cemented to the outer surface of the cortex;

a third electrical conductor means fixedly attached to the upper surface of said second electrical conductor means for transmitting the detected electrical discharges from the cortex to the exterior of the skull of the animal; and

insulation means totally encompassing the outer surface of said second and third electrical conductor means and all of said first electrical conductor means except the tapered end thereof for insulating the covered areas when the microelectrode is inserted in the cortex.

2. The device of claim 1 wherein said first electrical conductor means is a rigid elongated iridium shaft.

3. The device of claim 1 wherein said second electrical conductor means is a rigid platinum disc.

4. The device of claim 1 wherein said third electrical conductor means is a flexible platinum-iridium wire.

5. The device of claim 1 wherein said insulation means includes:

a Teflon covering for said third electrical conductor means; and

a parylene covering for said first and second electrical conductor means.

6. The device of claim 1 wherein the non-insulated tapered end of said first electrical conductor means is from 10 to 20 micrometers in length and from 1 to 3 micrometers in diameter.

7. A thumbtack microelectrode for use in the chronic recording of electrical discharges from single nerve cells in the cortex of the brain of an animal comprising:

a rigid, elongated, electrically conducting electrode shaft having a blunt end and a tapered end, the tapered end being the only portion of said electrode shaft not electrically insulated;

a rigid electrically insulated, electrical conducting disc having an upper and lower surface, the lower surface being substantially perpendicularly attached to the blunt end of said electrode shaft; and

a flexible, electrically insulated, elongated wire fixedly attached to the upper surface of said disc for transmitting the detected electrical discharge from the cortex to the exterior of the skull of the animal.

8. A method of making a thumbtack microelectrode comprising the steps of:

providing a disc of an upper and lower surface;

microwelding to the upper surface of said disc an elongated, flexible, insulated electrical conductor;

microwelding to the lower surface of said disc one end of an elongated, rigid, bare electrical conductor;

bending said bare electrical conductor at substantially a right angle to the lower surface of said disc;

electrolytically etching the free end of said bare electrical conductor until the desired tip configuration is achieved;

cleaning the microwelded assembly;

vacuum depositing a layer of insulating material of low biological toxicity over said disc and said bare electrical conductor; and

removing a small amount of the insulating material from the electrolytically etched tip of said bare electrical conductor.

9. The method of claim 8 wherein the bare electrical conductor is electrolytically etched in a bath of supersaturated sodium cyanide—30 percent sodium hydroxide.

10. The method of claim 8 wherein the cleaning step includes:

rinsing the microwelded assembly in hydrochloric acid, then in distilled water;

placing the microwelded assembly in an acetone bath;

ultrasonicly desiccating the microwelded assembly for 15 seconds in distilled water, then for another 15 seconds in methanol; and

oven drying the microwelded assembly at 60℃.

11. The method of claim 8 wherein the vacuum deposition step includes:

vaporizing 2 gm of parylene dimer at 260℃;

pyrolysizing the parylene at 700℃; and

subsequent polymerization of the parylene.

12. The method of claim 8 wherein the insulation removal is achieved by burning away the insulation.

13. The method of claim 8 wherein the insulation removal is achieved by melting the insulation with the beam of a ruby laser.

14. The method of claim 8 wherein the insulation removal is achieved by abrading off the insulation.

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