ULTRAPACKED ELECTRODE ASSEMBLY AND METHOD OF MAKING THE SAME

Field of the Invention

[0001] The present invention generally relates to bipolar electrode assembly suitable for various sensors, and more particularly to an ultrapacked electrode assembly and the method of making the same.

Background of the Invention

[0002] Bipolar electrodes have been used in diversified fields including research and industry applications. In neuroscience, neurological electrodes have been used for acute or chronic extracellular stimulation and recordings. In addition, many hand tools utilize electrodes to detect electrical changes. For example, surgical hand tools used in drilling of bones include electrodes that enable the sensors contained in the hand tool to provide prior warning to surgeons of close proximity with soft tissues such as nerves.

[0003] There were disclosed many electrode assemblies for special purposes. For example, EP 0281272A1 disclosed a high pressure electrode assembly, wherein the assembly comprised a stainless steel rod as a first electrode, a stainless steel sheath as a second electrode surrounding the rod, and an insulating collar spacing apart of the rod and the sheath. In addition, EP 0524752A1 disclosed one bipolar electrode assembly suitable for monitoring radiation, wherein the bipolar electrode assembly comprised a metal tube as an outer electrode and an electrically conductive wire as an inner electrode extending along a central axis of the tube. However, the electrodes in the disclosed electrode assembly were separated by gases so that they were not tightly packed against each other. Moreover, EP0709669A1 disclosed one pH measuring electrode assembly, wherein the assembly comprised concentric inner, outer and intermediate outer glass tubes with a pH measuring electrode in the space between the inner tube and the intermediate tube and a reference electrode in the space between the intermediate tube and the outer tube. However, the electrodes in the disclosed assembly were suspended between the glass tubes so that the assembly was not tightly packed.

[0004] It is evident that all the disclosed electrode assemblies inherit many problems from their structures. For example, the first electrode and the second electrode were separated by empty spaces or a separate insulating layer so that the assembly lacked integrity and physical strength. It is more apparent when an inner electrode is suspended within an outer electrode where the inner electrode is supported solely by the tension exerted on the inner electrode. Furthermore, the spaces between two electrodes must be large enough to maintain the separation of the electrodes, so that the sizes of the electrode assemblies cannot be reduced as desired.

[0005] Therefore, there is an imperative need to have an assembly of electrodes that have great integrity, high strength and reduced sizes. This invention satisfies this need by disclosing an assembly of electrodes that has all the desired features and a method for the making the same. Other advantages of this invention will be apparent with reference to the detailed description.

Summary of the Invention

[0006] The present invention provides an ultrapacked assembly of electrodes for being used as a part of a sensor. The assembly comprises a core rod as one electrode of the assembly, an insulating layer, wherein the core rod is coated by the insulating layer and a shell having an internal channel for accommodating the coated core rod; wherein the coated core rod is inserted into the channel of the shell, thereby the shell can grip the coated core rod, resulting a tightly packed assembly of electrodes. In certain embodiments, the electrical conductive materials used for the electrodes include stainless steel, platinum, platinum alloys, iridium and iridium alloys. In certain other embodiments, the insulating material is an aluminium oxide, a boron nitride, a lithium oxide, or a magnesium oxide.

[0007] The present invention also provides methods for manufacturing the ultrapacked assembly of electrodes. The manufacturing method includes the steps of drilling a central channel through the shell, coating the core rod with the insulating layer, heating the shell with the central channel to a temperature higher than that of the core rod, and inserting the coated core rod into the central channel of the shell while the shell is hot; wherein when the shell is cooling, the shell grips the coated core rod; thereby a tightly

packed assembly of electrodes is formed. The preferred method for depositing the insulating layer onto the core rod is physical vapor deposition.

[0008] Accordingly, one object of the present invention is to provide an assembly of electrodes with great integrity, high strength and reduced size.

[0009] The objectives and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0010] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0011] FIG 1 is a cross-sectional view of the assembly of electrodes.

Detailed Description of the Invention

[0012] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0013] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0014] Now referring to FIG 1, there is provided a cross-sectional view of an illustrative assembly of electrodes in accordance with the present invention. The assembly of electrodes **10** comprises a core rod **20**, an insulating layer **30**, and a shell **40**. As seen from FIG 1, the core rod **20** is coated by the insulating layer **30**, the shell **40** has a central channel for accommodating the coated core rod, and a tightly packed assembly of electrodes is formed when the coated core rod **20, 30** is inserted into the channel of the shell and the shell **40** grips the coated core rod **20,30**.

[0015] The core rod **20** can be made from any preferred metal for specific applications. In one embodiment, the preferred metal in forming the core rod **20** is stainless steel for its high corrosion resistance. The other suitable metals for making the

core rod include platinum, platinum alloys, Iridium, gold, and copper. The core rod **20** is preferably substantially cylindrical. Other shapes are also contemplated for the core rod **20**. In certain embodiments, the core rod **20** has a tapered tip at one or both ends so that the electrode may be inserted into tissues when the electrodes are used for live measurement. When the desired features and parameters of the core rod are chosen, the core rod **20** can be made by any ways known to one skilled in the art including. In certain embodiments, the core rod **20** is a wire of fine gauge. While the dimension of the core rod is not a limiting factor in the present invention, the core rod **20** in certain embodiments has preferable dimensions of length of 50 mm and diameter of 1.0mm.

[0016] The shell **40** can be made from a rod that has a larger diameter than the core rod **20**. The electrical conductive metals suitable for the shell **40** includes stainless steel, platinum, platinum alloys, iridium and iridium alloys. The shell **40** preferably has the same metal as the core rod **20**. However, the shell **40** could have different metals than the core rod **20** in certain circumstances. The electrical conductive materials used for the core rod **20** and the shell **40** must match the application of the sensor and the environment the electrodes are used for. For instance, electrodes for medical uses are preferably made of stainless steel, platinum and iridium.

[0017] The shell **40** is formed when the central channel is drilled through the shell-forming rod. The diameter of the central channel depends upon the desired gripping force exerted by the shell upon the core rod **20**. In certain embodiments, the central channel has a diameter that is substantially the same as the diameter of the sum of the core rod **20** and the insulating layer **30** coated upon the core rod **20**. In other embodiments, the central channel has a diameter that is smaller than that of sum of the core rod and the insulating layer. The central channel can be drilled by any means known to one skilled in the art including gun drill and wire drill. The central channel can also be made by the method of tube extrusion. The roundness of the hole is not critical. Instead, the major consideration is that the feature of the hole should correspond with the cross section shape of the core rod **20**. While the dimension of the shell **40** is not a limiting factor in the present invention, the shell **40** in certain embodiments has preferable dimensions of length of 50 mm and diameter of 5 mm.

[0018] The insulating layer **30** is coated onto the core rod **20** before the core rod **20** is inserted into the shell **40**. The coating process will be detailed later. The consideration

of an insulating material for the insulating layer **30** depends upon specific applications of the assembly of electrodes. In certain embodiments, the material coated between the electrodes can also be selected to achieve other desired properties such as dielectric. The preferred insulating layer **30** is mainly formed by one of a boron nitride (BN), a lithium oxide (Li2O), an aluminium oxide (Al2O3), or a magnesium oxide (MgO) having a superior insulating characteristics and thermal conductivity. Here, a member "mainly formed by one of a boron nitride (BN), a lithium oxide (Li2O), an aluminium oxide (Al2O3), or a magnesium oxide (MgO)" is defined as a member which contains at least one of these members by 70 weight % or more.

[0019] In one embodiment of the present invention, the preferred insulating material is alumina. It is well known that alumina is an excellent electrical insulator because its high volume resistivity and dielectric strength. In addition, alumina has excellent corrosion resistance, durability in uses in high temperature environment. More importantly, high purity aluminas are also used for its biocompatibility as orthopaedic implants particularly in hip replacement surgery. It is preferable that the alumina layer is about at least 0.4μm. It is more preferable that the alumina layer is about 2.0 μm.

[0020] The assembly of electrodes of the present invention can be manufactured by any methods known to one skilled in the art. The preferred method for the making of the assembly of the electrode in accordance with the disclosure of the present invention is described herein in detail. The known techniques including the making of the rod and central channel will be omitted herein so as not to obscure the present invention.

[0021] The core rod is coated with an insulating layer before it is inserted into the shell for final assembly. In certain embodiments, the insulating layer is comprised of aluminum oxide (Al2O3). The coating of the insulating layer onto the core rod can be done by any suitable technique known to one skilled in the art. The consideration for any preferred coating technique includes the porosity of deposited coating layer and the consistence of the coating thickness. A coating layer being less porous has greater level of insulation. And a coating layer with a consistent thickness has higher integrity and better performance.

[0022] In one embodiment, the preferred coating material for the present invention is Al2O3. The deposited Al2O3 provides a great level of insulation because it forms an insulating layer with low porosity and consistent thickness. One preferred depositing

method for coating the core rod with Al2O3 is physical vapor deposition (PVD) process. PVD process ensures the high purity of the deposited layer. While the purity is not a limiting factor for the present invention, its high level resulting from the PVD process makes the assembly of electrodes to pass the FDA requirement for medical uses. PVD is well known in the art. Briefly, PVD processes are carried out under vacuum conditions with four steps: evaporation, transportation, reaction and deposition. During the evaporation, Al2O3 as a target is bombarded by a high energy source such as a beam of electrons or ions. This dislodges atoms from the surface of the target, "vaporizing" them. Then, the "vaporized" atoms are moved from the target to the core rod to be coated. The reaction step is optional depending upon specific applications. If the coating consists of only the target material, the reaction step would not be part of the process. Here, for Al2O3, there is no reaction step. Finally, the deposition step is the process of coating built up on the core rod surface.

[0023] The thickness of the coating is dependent on electrical characteristics desired for specific application. In certain embodiments, the interference fit between the core rod and the shell can reach 250 bar or higher. As discussed above, it is preferable that the alumina layer is about at least 0.4μm. It is more preferable that the alumina layer is about 2.0 μm.

[0024] Before the assembly of the electrodes, the shell **40** is heated to a temperature higher than that of the core rod **20** to expand the dimension of the central channel. The expanded dimension of the central channel will be larger than the diameter of the sum of the core rod **20** and the insulating layer **30**. After the shell **40** is heated as desired, the core rod **20** with the insulating layer **30** is inserted into the shell **40** while the shell **40** is hot. Upon cooling, the shell **40** will contract and hold the core rod securely while maintaining the consistent thickness of the insulating layer **30**. Higher holding force can be designed based on interference fit between the core rod and the shell.

[0025] The assembled electrodes can be further processed to be used in a variety of sensors. For example, the electrodes of the present invention can be used in sensors for nerve and muscular monitoring.

[0026] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the invention scope is not so limited. Alternative embodiments of the present invention will

become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

Claims:

1. An assembly of electrodes for use as a part of a sensor, the assembly comprising:
a metallic core rod as one electrode of the assembly;
an insulating layer operable to be coated on the metallic core rod; and
a metallic shell having a central channel for accommodating the coated core rod; wherein the central channel of the shell is operable to be thermally expanded to accommodate the coated metallic core rod and then operable to be cooled to grip the coated metallic core rod to form a tightly packed assembly of electrodes.

2. The assembly of electrodes of claim 1, wherein the core rod is made of an electrical conductive material selected from the group consisting of stainless steel, platinum, platinum alloys, Iridium, and iridium alloys.

3. The assembly of electrodes of claim 1, wherein the core rod is made of stainless steel.

4. The assembly of electrodes of claim 1, wherein the core rod has substantial dimensions of length of 50 mm and diameter of 1.0mm.

5. The assembly of electrodes of claim 1, wherein the shell is made of an electrical conductive material selected from the group consisting of stainless steel, platinum, platinum alloys, Iridium, and iridium alloys.

6. The assembly of electrodes of claim 1, wherein the shell is made of stainless steel.

7. The assembly of electrodes of claim 1, wherein the shell has preferable dimensions of length of 50 mm and diameter of 5 mm with the central channel having the diameter that is substantially the same as or smaller than the diameter of sum of the core rod and the insulating layer depending on the gripping force desired.

8. The assembly of electrodes of claim 1, wherein the insulating layer is selected from the group consisting of boron nitride, lithium oxide, aluminium oxide, and magnesium oxide.

9. The assembly of electrodes of claim 1, wherein the insulating layer is aluminium oxide.

10. The assembly of electrodes of claim 9, wherein the insulating layer of aluminium oxide is about at least 0.4μm.

11. An assembly of electrodes for use as a part of a sensor, the assembly comprising:

a stainless steel core rod as one electrode of the assembly;

an aluminium oxide insulating layer operable to be coated on the core rod; and

a stainless steel shell having a central channel; wherein the central channel of the shell is operable to be thermally expanded to accommodate the coated core rod and then operable to be cooled to grip the coated core rod to form a tightly packed assembly of electrodes.

12. A sensor for measuring a desired parameter, comprising an assembly of electrodes disclosed in any one of claims 1-11.

13. A method for producing an assembly of electrodes, wherein the assembly of electrodes comprises a metallic core rod, an insulating layer and a metallic shell, said method comprising the steps of:

drilling a central channel through the shell;

coating the metallic core rod with the insulating layer;

heating the metallic shell with the central channel to a temperature higher than that of the metallic core rod; and

inserting the coated metallic core rod into the central channel of the metallic shell while the metallic shell is hot; wherein when the metallic shell is cooled, the metallic shell grips the coated metallic core rod to form a tightly packed assembly of electrodes.

14. The method of claim 13, wherein the core rod is made of an electrical conductive material selected from the group consisting of stainless steel, platinum, platinum alloys, Iridium, and iridium alloys.

15. The method of claim 13, wherein the core rod is made of stainless steel.

16. The method of claim 13, wherein the core rod has substantial dimensions of length of 50 mm and diameter of 1.0mm.

17. The method of claim 13, wherein the shell is made of an electrical conductive material selected from the group consisting of stainless steel, platinum, platinum alloys, Iridium, and iridium alloys.

18. The method of claim 13, wherein the shell is made of stainless steel.

19. The method of claim 13, wherein the shell has preferable dimensions of length of 50 mm and diameter of 5 mm with the central channel having the diameter that is substantially the same as or smaller than the diameter of sum of the core rod and the insulating layer depending on the gripping force desired.

20. The method of claim 13, wherein the insulating layer is selected from the group consisting of boron nitride, lithium oxide, aluminium oxide, and magnesium oxide.

21. The method of claim 13, wherein the insulating layer is aluminium oxide.

22. The method of claim 21, wherein the insulating layer of aluminium oxide is about at least 0.4μm.