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2.2.3: Peripheral Electrodes

A flexible method for fabrication of nerve cuff electrodes

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Abstract **A method for construction of cuff electrodes is presented. The method is based on using platinum foil electrodes fixed by rubber bands on a Teflon coated mandrel, that is then dip-coated with silicone. The method allows for design of cuff electrodes of practically any size, shape and electrode configuration, and simple cuffs can be built in less than one hour of work. Cuff electrodes have been built that range in size from 0.5 to 10 mm ID and 5 to 70 mm length and number of electrodes from one to twelve. Tri-polar recording electrodes have been tested in more than 30 chronic implantations in rabbits (tibial nerve) and for various acute experiments, where different electrode configurations were investigated. None of the chronic implants have failed and impedances have been stable for one year.**

INTRODUCTION

Nerve cuff electrodes have been shown in several studies to be able to provide a stable interface between a nerve and an electronical device, either a stimulator or an amplifier. Several designs have been developed reviewed by e.g. [1,2]. A much used design for recording of neural activity has been to use short lengths of pre-formed tubes with de-insulated multistranded stainless steel wires sewn into the inside wall of the tube. With this design it is difficult to control the exact position and size of the electrodes, and lose wires may act as constrictions of the nerve. Another method has been to use platinum foil electrodes. Since platinum foil does not adhere to silicone, it has been necessary to mount the foil inside the wall of the cuff, e.g. between two sheets of silicone glued to each other and then cut windows in the silicone to form the conducting path to the nerve. These windows can be difficult to produce and tend to change the mechanical properties of the cuff wall when they are large, as they must be for recording electrodes.

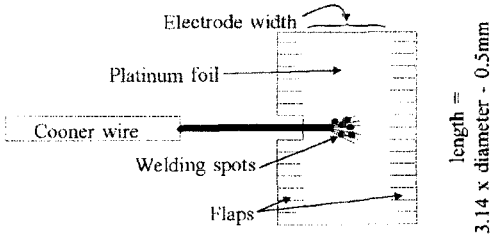
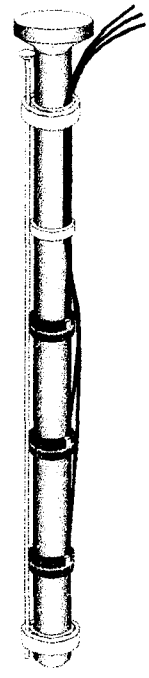


Figure 1: Platinum foil with anchor-flaps cut along the edge and lead wire spot-welded onto the back.

METHODS

The principle in the method presented here is to use platinum foil electrodes, embedded into the wall of a silicone cuff, that is produced by dip-coating a Teflon coated mandrel. For a typical tri-polar cuff, three rectangular pieces of 25µm platinum foil are cut. The width of these must be equal to the preferred width of each electrode (e.g. 1mm) plus about 1 mm to form the flaps that will secure the electrode in the wall of the cuff. The length should be about 0.5mm shorter than the diameter of the mandrel multiplied with π (3.14).



Since silicone does not stick very well to platinum, it is necessary to produce a series of flaps on either of the long edges of the electrode. To do this, the electrode is placed in a holder with the same width as the electrodes should be on the inside of the cuff and letting the edges of the electrode sit free symmetrically on either side. Micro-scissors are then used to cut the flaps, that should be about 0.25 to 0.5 mm wide (Fig. 1).

Figure 2: Mandrel with electrodes, wires and locking-pin mounted, ready for dip-coating.

Now the lead wires (e.g. Cooner Wire, AS 632) are welded onto the back of each electrode. This is done by deinsulating about 4mm of the wire and spot weld the tip onto the foil. The long deinsulated part is necessary to anchor the wire to the silicone and thereby release some of the stress that might appear at the welding site (since silicone does not stick to Teflon).

The platinum electrodes are now mounted on the mandrel by first wrapping the electrode around the mandrel and fixing it in place by a "rubber band". The rubber band is made out of a piece of silicone tubing with a diameter about 20% smaller than the mandrel and a width equal to the width of the recording surface of the platinum. When this is done, the flaps of the platinum foil are bent back and in over the rubber band. The electrodes can now be pushed around on the mandrel and placed at their final position (Fig. 2).

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To prevent the dipcoat solution from covering the inner surface of the electrodes, a barrier of undiluted silicone is placed along the edges of each electrode (Fig. 3). A syringe with a blunt needle is used for this.

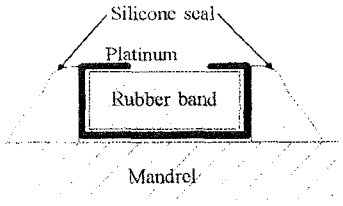

Figure 3: Cut-away view of electrode, rubber band and silicone seal. The wings of the platinum foil are wrapped around the rubber band, to form an anchor in the silicone.

If a locking mechanism as the "interdigitating tubes" invented by Kallesøe et al, [5] is to be made, a 0.5mm Teflon coated pin is mounted on the mandrel, lying on top of the rubber bands holding the electrodes (Fig. 2). It is fixed by means of three rubber bands. When the mandrel is coated with silicone and the pin is removed, it will form the channel through which the locking suture is passed.

Now the mandrel is dipped into a mixture of Medical Adhesive Type A (NuSil) and heptane. The heptane dilutes the silicone and makes it suitable for dip-coating. After curing and perhaps one or two more coatings, the cuff is removed from the mandrel. This can be done by simply pulling it off, because of the Teflon surface of the mandrel. Then excess silicone is cut off at the ends. The cuff is now cut open with a sharp knife, e.g. a piece of a razorblade, about 2,5mm wide. By cutting the opening as shown in Fig. 4, a closing mechanism similar to the "interdigitating tubes" can be produced.

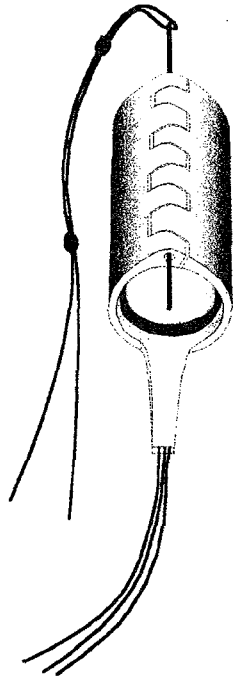

Figure 4: Finished cuff electrode, locking-suture being inserted.

RESULTS

The resulting cuff will look as shown on Fig. 4. The "fingers" at the opening contain the hole produced by the 0.5mm pin. After mounting the nerve in the cuff, the closing is locked by inserting a 2-0 suture, laid double, into the hole. This is easiest done by mounting it on a thin needle. Two drops of silicone are placed on the sutures with a distance equal to the length of the cuff. The one drop of silicone can be pulled through the holes by just a little extra force, but will stop the suture from sliding out.

At the moment we have used electrodes fabricated with this technique for about two years. In an ongoing study of nerve damage, we have implanted more than 30 cuffs on rabbit tibial nerves. Some of these animals have now been implanted for more than a year. None of the electrodes have failed so far. Impedances of the electrodes have been stable from a few days after implant until they were terminated.

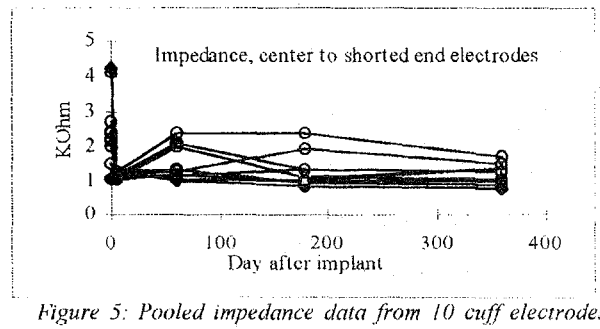

Figure 5: Pooled impedance data from 10 cuff electrodes implanted in rabbits for a year. Measured at 1KHz.

DISCUSSION AND CONCLUSIONS

The method presented here has been used for construction of several different designs of cuffs, used for different purposes, some with oval or rectangular shape and 12 point electrodes [3], some spiral with one or more electrodes [4] and some small (0.5mm ID) and others large (8 circ. electrodes, 7cm long).

The advantage of dip-coating is that practically any (internal) shape can be produced easily. The use of silicone rubber bands makes it possible to accurately mount many electrodes. If prototypes are to be made rapidly, it can be done by simply shaping a piece of Teflon (PTFE) with a knife. In this way (simple) cuffs can be made in less than an hour of work (ex. curing time).

ACKNOWLEDGEMENTS

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REFERENCES

[1] J.A. Hoffer, "Techniques to study spinal-cord, peripheral nerve, and muscle activity in freely moving animals", Neuromethods, Neurophys. techniques: Applications to neural systems, vol. 15, pp. 65-145, 1990.

[2] G.E. Loeb, R.A. Peck, "Cuff electrodes for chronic stimulation and recording of peripheral nerve activity", J. Neuroscience Methods, 64, pp. 95-103, 1996.

[3] J.J. Struijk, M. Haugland, M. Thomsen, "Fascicle selective recording with a nerve cuff electrode", *this meeting*

[4] M. Thomsen, J.J. Struijk, "Artifact reduction with monopolar nerve cuff recording electrode", *this meeting*

[5] K. Kallesøe, J.A. Hoffer, K. Strange, I. Valenzuela, "Implantable cuff having improved closure" U.S. Patent #5.487.756, 30. jan 1996.