A Multipolar Precision Hybrid Cuff Electrode for FES on Large Peripheral Nerves

*Martin Schuettler, Thomas Stieglitz, J.-Uwe Meyer
Fraunhofer Institute for Biomedical Engineering, Sensor Systems / Microsystems Department,
Ensheimer Str. 48, D-66386 St.Ingbert, Germany
*E-mail: schuettl@ibmt.fhg.de

***Abstract*- There are two different techniques that can be applied for fabricating a nerve cuff electrode: 1. traditionally used silicon rubber tubes or spirals and 2. micromechanical methods . Each technique has its own advantages and restrictions. A hybrid cuff combines desired properties of both: high flexibility, high possible numbers of integrated electrodes, high reproducibility and the ability to embrace nerves even with large diameters.**

***Keywords*- FES, MEMS, cuff electrode, large diameter, hybrid, multipolar, polyimide, silicone rubber**

I. INTRODUCTION

Cuff electrodes are the often used type of neural electrode for functional electrostimulation (FES) on peripheral nerves. Two different types of fabrication techniques lead to different products: (1.) cuffs made of silicone rubber tubes or spirals (electrical contact to the nerve is obtained by embedded platinum foils), that can be applied to nerves with large diameters [1] and (2.) polyimide-based cuffs, produced by micromechanical methods and with diameters restricted to about 4 mm [2]. A hybrid electrode can combine the advantages of silicone (mechanical properties) and micromechanical polymere processing (high precision batch fabrication of the multielectrodes).

II. MATERIALS AND METHODS

The hybrid cuff electrode is composed of two parts: (1) a micromechanical fabricated polyimide thin film structure which is about 10 µm thick (methode describtion in [2]). It has 12 platinum electrodes (1 mm in diameter, arranged as described in [1]) and integrated gold interconnects. After heat treatment, it is rolled to a compound of three rings, each carrying four electrodes. (2) a self-rolling silicone rubber sheet. It is made of two layers, both about 100 µm thick: layer A is stretched while layer B is glued unstretched to layer A. The tension of layer A rolls the sheet to a spiral cuff. The polyimide structure is glued to the inside of the cuff (Fig. 1). The fabricated hybrid cuff electrode is self-sizing in diameter. The range depends on the design of the thin film structure and on the stretching of the silicone sheet.

III. RESULTS

Several hybrid cuff electrodes were assembled. Three different designs were made and cuffs were fabricated with 6, 8 and 10 mm inner diameter, suitable for contacting large peripheral nerves (e.g. n.ulnaris, n.radialis). The cuffs fit close to the nerve which is uncritical because they are self-adjusting in diameter. So the gap between nerve and electrodes is kept at a minimum. The impedance of a single electrode (including the integrated interconnect) is about $|Z| = 1{,}5\ k\Omega$, $\varphi = -22°$ at 1 kHz, 100 mV measured in Ringer's solution at room temperature.

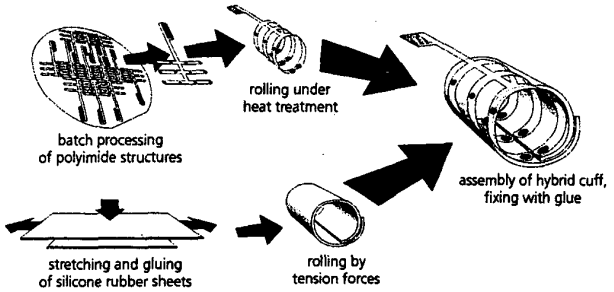

Fig.1 Schematic view of the fabrication process of a hybrid nerve cuff electrode

IV. DISCUSSION

For small nerves and implantation sites that are not strongly effected by muscular activity (e.g. sacral roots inside the spinal cord), pure polyimide micromachined cuff electrodes are advantageous. For larger nerves at mechanically strained locations and the need of only a few electrodes, conventional silicone techniques are sufficient. For other purposes (medium size / large nerves, high number of electrodes and even in regions under mechanically load) the new technology is promising.

V. CONCLUSION

The fabricated hybrid cuff electrode is a first version of a new generation of nerve electrodes. The fabrication process is less critical than that of the conventional silicone cuffs and the batch processing of the polyimide electrode structures on silicon wafers makes the new electrodes cost-effective and reproducible in shape and electrical properties. In future designs it is possible to realize large flexible cuffs with a very high number of electrodes without increasing effort.

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