Wireless neural interface based on an aluminum electrode array

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Abstract

This abstract proposes a method for wireless acquisition of neural signal using an invasive neural microelectrode needle array based on aluminum. The fabricated electrode array is composed by 100 individualized micropillars in a 10 x 10 matrix with 3.0 mm pillars' length and a pyramidal profile.

The fabrication method of the microelectrode array is illustrated in Figure 1. The electrodes are based on an aluminum substrate (Fig. 1a). The aluminum is a cost-effective metal, with the required mechanical and electrical characteristics. It is ductile, reducing the risk of breaking the microelectrodes at the implantation moment, and it is an inherently excellent electrical conductor. Despite all advantages, aluminum is a biotoxic material and therefore, special care was taken in the encapsulation process.

The fabrication process starts with pads regions dicing (0.2 x 0.2 x 0.2 mm^3) in the backside of the aluminum substrate (Fig. 1b). Then, they are filled with epoxy resin to electrically isolate the microelectrodes and to support the final needles (Fig. 1c). Afterwards, the substrate is diced to produce a 10 x 10 matrix of micropillars with dimensions of 0.25 x 0.25 x 3.0 mm^3 (Fig. 1d). In this stage, the pillars present a straight square profile that need to be sharpened to facilitate the implantation (Fig. 2e). In order to clean the aluminum debris in the space between the pillars, an etching step is performed, immerging the pillars on type-A aluminum etchant at 50 ºC for 30 minutes (Fig. 1f). In order to perform the charge transduction, a 270 nm thin film of iridium oxide over each needle's tip is deposited by pulsed DC magnetron sputtering (Fig. 1g). Finally, the encapsulation step is accomplished with a biocompatible layer of alumina (Al_2O_3) by anodization of the aluminum-based microelectrodes at 40 mA in 15% sulfuric acid solution for 15 minutes (Fig. 1h). Both iridium oxide and alumina are biocompatible materials.

After the microelectrode array fabrication, it is performed the assembly of the microelectrode array and the acquisition-signal electronics and RF transmitter (Fig. 2). A male connector with the electrodes structure is plugged in a female connector with the electronic circuits and the RF transmitter [1,2]. The electronics has an ADC ADS1298 with 16 bits resolution and sampling rate of 1000 samples per second. Also, the electronics has an ARM core of OMAP (Open Multimedia Architecture Platform) embedded system. Once the data arrives in the processing unit, they are saved in SD-card and sent by 802.11g TCP/IP-socket protocols with minimum delay.

Figure 3 represents the mechanical *in vivo* tests, which demonstrated the electrode implantation effectiveness on the rat's brain without surface dumpling. This avoids the use of high-velocity insertion devices [3]. The 10 x 10 electrode matrix is shown in Figure 4.

The proposed fabrication method is simple, cost-effective, being mainly characterized by the deep pillars heights (maximum 3 mm) and by the effective implantation on neural tissue. The microelectrode array, the signal processing electronics and the RF wireless communications were tested for recording neural signals, processing and transmitting them wirelessly.

Acknowledgments

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References

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Figures

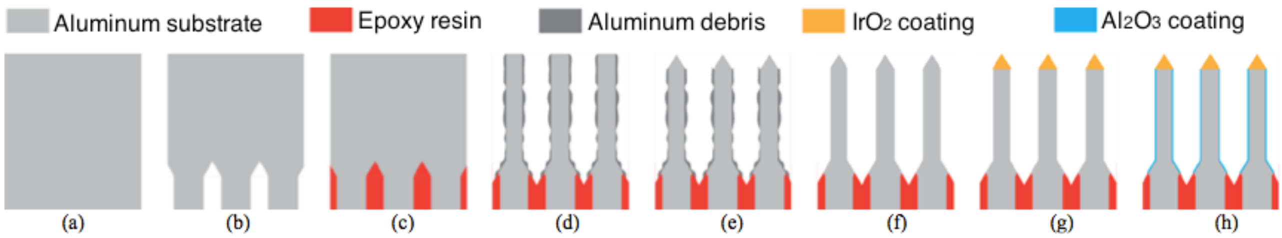

Figure 1 – Microelectrodes array fabrication steps: a) Aluminum substrate; b) Pads region delimitation; c) Pads' grooves filling with epoxy resin; d) Pillars cutting stage; e) Pillars sharpening; f) Pillars cleaning by etching stage; g) IrO_2 coating at the pillars' tips; h) Electrodes passivation by Al_2O_3 coating.

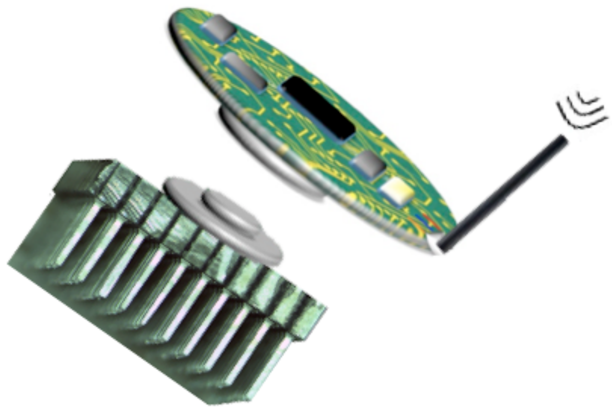

Figure 2 – An artist view of the wireless neural-signal acquisition system using an aluminum-based microelectrode array. The array is connected with the circular PCB (10 mm of diameter) containing the electronic circuits and the RF data transmitter.

Figure 3 – Mechanical insertion tests on a male Wistar rat.

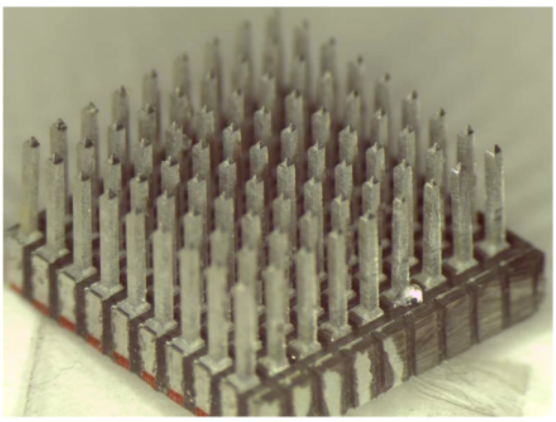

Figure 4 – Photography of the electrode matrix structure. The pillars' dimensions are 0.25 x 0.25 x 3.0 mm^3.