Multi-electrode Recording System in the Brain Activities

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Abstract- **In electrophysiology, field potential (FP) recordings give us macroview information of the brain activities. In this research, the tail of the rat was stimulated and the evoked FP at the thalamus was recorded. In order to record the neural activities in thalamus that is deeper than cortex, it is provided the multi-electrode probing, based on the new microfabrication with high-density, recording simultaneously in a group of neural tissue. A multi-channel recording system was also developed to process a huge FPs. According to the Possion equation, FPs were further analyzed to obtain current source density (CSD) mapping to locate the responsive area. The developed contour or CSD mapping software for FP was a valuably tool for neuroscience research.**

***Keywords* - Field potential, Multi-electrode probe, Current source density**

I. INTRODUCTION

The sensory information is generated by the integral electrical signals, compromising numerous time and special variation, and collected from volume conduction of many neural activities simultaneously.

Therefore, it is necessary to develop the multi-electrode recording techniques to observe the activity of a large number of cells simultaneously. These techniques include multi-electrode probe development, multi-channel recording system design and the neural signals analysis software kit development. The neural signals analysis software kit can display accurately the spatial distribution of the neural responses. The analysis of current source density (CSD) [1] could tell the location where the post-synaptic potential of the neuron occurs (that is, the responding center), so that the changes in conditions of the time and location of neuron could be understood.

II. METHODOLOGY

The overall schematic for the lab-designed neural ensemble recording system containing three parts comprising the A) probe, B) the recording system, C) the CSD analysis software is summarized in Fig. 1.

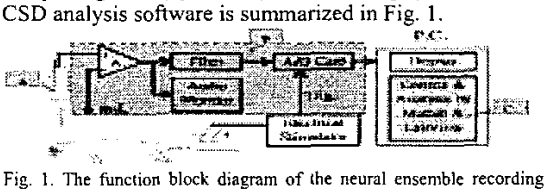

Fig. 1. The function block diagram of the neural ensemble recording system.

1) Probe design and fabrication

The current designs support 16 electrodes placed near the tip of the shaft. The shaft width is 220μm. The shaft length is 6mm and the shaft thickness is 25μm. The tip angle is 40° and the conductor line width is 10μm. The electrode sites are 10μm x 10μm and are distributed with 50μm pitch.

The process technology for multi-electrode probe based on silicon substrate is described in detail in Fig. 2.

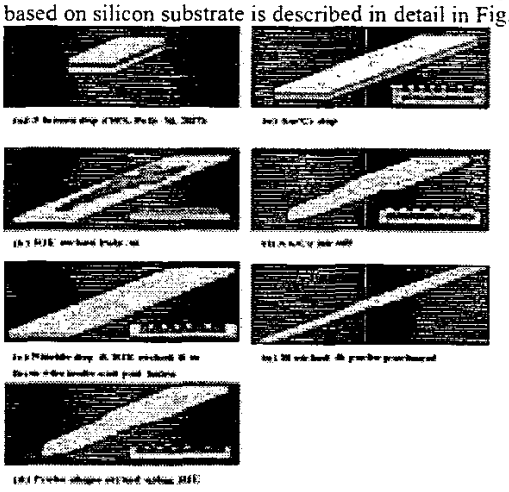

Fig.2. Schematic procedure of the fabrication process.

2) Recording system setup

The recording process of FP includes: (1) Amplification, (2) filtration and (3) the saving of digital signals into the hardware from the A/D converter.

For the signal amplification, alternating amplifier circuit is used to magnify the signals to the strength required by the A/D converter. Hence, The Lab-designed non-reverse amplifier in the series will increase the gaining to 2500 times.

For the low-pass filtration, the main function of the filter is to eliminate the noises, which exceed the FP spectrum. As a result, according to the spectrum analysis of the potential [2], making use of a 2-stage Butterworth low-pass filter, its cutoff frequency is within 300 Hz gained by 1.

For the signal acquirement system, a 16-channel A/D card (NI PCI-MIO-16E-4) was used because of letting signals passing through the low-pass filter, which will confine the high frequency signals at 300 Hz and below (to eliminate the action potential of the single cell), the sampling frequency set is 3k Hz and the length of each sample obtained by every period is 512 points.

3) CSD analysis

The analysis of CSD provides the information of the current changes of the cell membrane, especially at the location after the synapse occurs [3]. When current flows out of the neuron, this is where 'sink' is produced. Ironically, when current flows into the neuron, this is also where the 'source' is produced. The CSD function is quite useful to locating the sites of synaptic input in dendrites or the sites of action potential initiation.

The gathered data were then analyzed with program to calculate the CSD mapping. This off-line program was

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developed under the MATLAB environment on PC platform [4].

III. RESULTS

1) Electrode characterization

A typical set of impedance spectroscopy is shown in Fig. 3. We found that the measured electrode impedance was 1.7 MΩ at 1 kHz with a phase -93°.

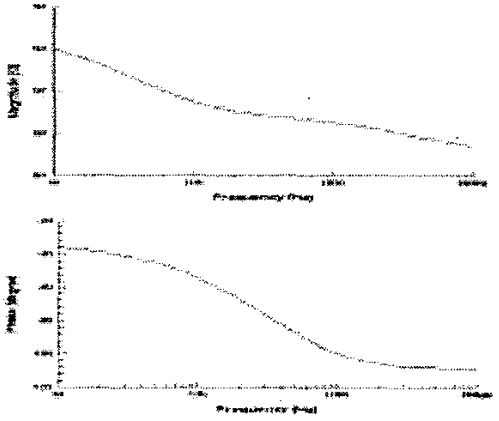

Fig. 3. Impedance spectroscopy.

2) Electrophysiology experiments

The multi-electrode probe was used for the electrophysiology experiments to record the FPs in the brain. Adult Wistar rats weighing from 350 to 450g were used. During the experiment an animal was anesthetized with continuous delivery of pentobarbital with an infusion pump at a lower dosage (5mg/ml; 1ml/h; i.v.). Then the dura mater of the brain was carefully removed under the microscope. The exposed brain was covered with warm liquid, paraffinin (34°C) oil pools formed with the cut skin. A probe assembly was mounted on the manipulator, positioned over the exposed brain, and inserted into the responsive area in thalamus VPL, which responds to the S3 segment of rat tail applied electrical stimuli. Fig. 4A is shown the recording FP contour which was constructed of 16x4 recording sites. Fig.4B is CSD analysis due to the previous. The analysis of 2D field potential used previously has found out that the negative respondent centers produce changes in strength and location.

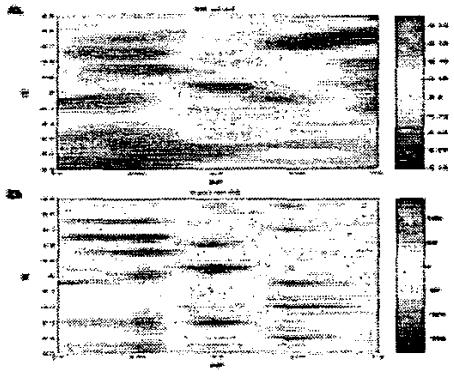

Fig. 4. Part (A) is the 2D field potential (AP = 3.55mm). Part (B) is CSD analysis due to the previous.

IV. DISCUSSION

The new multi-electrode probing fabrication was used for etching polysilicon to form the electrode sites, interconnect lines and connection pads with Poly-RIE but not evaporating and patterning the metallization layer. During this process, it should reduce the sheet resistance (10Ω/square) of poly-silicon with $POCl_3$ doping because the interconnecting lines and connection pads were conductors with lower impedance (20 kΩ). But there was still one metallization layer to be evaporated and patterned with lift off to form electrode and bonding pads. In other probe designing [5] two metallization layers evaporating were used to fabricate the inter-circuit and electrode sites.

When the 1st layer silicon nitride was deposited on the substrate, there were fine cracks happening on the silicon nitride layer. There were two possibilities caused this situation: (1) the difference in thermal expansion coefficients was between Si (2.6×10^{-6}/℃) and Si_3N_4 (2.8×10^{-6}/℃). The solution was adopted to deposit the thin oxide film (350~500 Å) on substrate firstly and then reduce the thickness (2500 Å) of the silicon nitride layer deposited upon the oxide layer. (2) the thickness of the 1st layer silicon nitride deposited was too thick(7500 Å). Now it has been modified to deposit less silicon nitride (1500 Å~2000 Å) on the substrate. We found there are few cracks on the silicon nitride layer after depositing.

V. CONCLUSION

The multi-electrode probe could be simply fabricated and its characterization is suitable to recording field potential and multi-unit in the neural tissue. Now the recording system should improve the ability to process different type neural signals and the analysis software kit also extends more functions to handle different application requirements.

ACKNOWLEDGMENT

This research was supported by the National Science Council of R.O.C. under Grant No. NSC-91-2213-E-002-119.

REFERENCES

[1] J. A. Freeman and C. Nicholson, "Experimental optimization of current source density technique for anuran cerebellum," J. Neurophysiol., vol. 38, pp. 369-382, 1975.

[2] F. S. Jaw, "Analysis of compound action potential and field potential of the nervous system, and development of a recording system," PhD thesis, National Taiwan Univ., Taipei , Taiwan, Jan., 1992.

[3] R Rodrguez and L. B. Haberly, "Analysis of synaptic events in the opossum piriform cortex with improved current source-density techniques," J. Neuralphysiol., vol.61, pp.702-718, 1989.

[4] Y.Y. Chen, "Current source density of field potential," in the Brain, M. S. thesis National Taiwan Univ., Taipei, Taiwan, June 1998.

[5] D.T. Kewly, M. D. Hill, D. A. Borkholder, I. E. Opris, N. I. Manluf, C.W. Storment, J. M. Bower and Gregory T E. Kovacs, "Plasma-etched neural probe," Sensors and Actuators, vol. A58, pp.27-35, 1997.