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Fabrication and acute *in-vivo* study of a ECoG/intracortical hybrid electrode array

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***Abstract*— Neural interfaces have been widely used to understand the function and connectivity of the brain. Many different types of neural electrodes have been developed for the purpose from single neuron recording to cortical activity recording. In this study, we fabricated a hybrid electrode array, in which two different types of microelectrodes are combined for multi-site recordings. We also conducted preliminary animal experiments for validation of the developed hybrid electrodes.**

I. Introduction

Neural interfaces have been widely used to understand the function and connectivity of the brain. To detect brain signals with high resolution, it is necessary to use invasive electrodes that are implanted by surgical procedures. Invasive electrodes include electrocorticography (ECoG) electrodes, intracortical electrodes, and deep brain stimulation (DBS) electrodes. Each of them has differences in target area of interest, spatial resolution, and extent of tissue damage. In this study, we present a hybrid electrode array based on a flexible substrate, having both ECoG electrodes and intracortical electrodes in a device. We developed a fabrication process to integrate ECoG and intracortical electrodes. The developed hybrid multisite electrode array was evaluated in terms of electrical characteristics and *in-vivo* application.

II. Methods

The hybrid electrode array was fabricated by integrating a flexible penetrating microelectrode array (FPMA) and a parylene-C based ECoG electrodes (Fig. 1). The fabrication of the FPMA is explained in a previous study [1]. To improve the electrical characteristics of the FPMA, the electrode tip was coated with activated iridium oxide. The ECoG electrodes were fabricated by stacking parylene-C – metal – parylene-C layers. First, the sacrificial layer was sputtered on a wafer and 6 µm of parylene-C was deposited. The ECoG electrodes, made of Au/Cr (200nm/50nm), were sputtered and patterned. The insulation parylene-C layer was deposited on the patterned conductive lines and pads. Lastly, the electrode sites were opened and the mesh structure of parylene-C was created. The ECoG electrodes' substrate also functioned as interconnections for the FPMA. The FPMA and the ECoG electrode array were integrated by using conductive epoxy. The fabricated hybrid electrode array was implanted at the somatosensory cortex of 4 rats. Simultaneous recording through ECoG electrodes and stimulation through the FPMA was conducted using signal recording & stimulation system (RHS Stimulation/Recording System, Intan technologies, California, USA).

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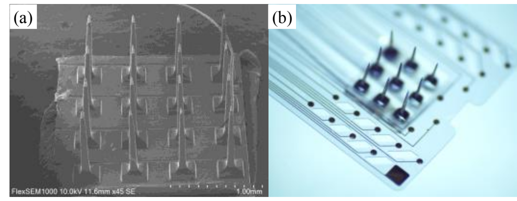

Figure 1. (a) Fabricated FPMA, and (b) hybrid electrode array in which FPMA (9 channels) and ECoG electrodes (23 channels) are integrated.

III. Results & Discussion

The hybrid electrode array was evaluated through electrochemical impedance spectroscopy (EIS) and *in-vivo* experiment. The impedance at 1kHz was 4.41 ± 0.62 kΩ for FPMA electrodes and 960.4 ± 180.8 kΩ for ECoG electrodes. For stimulation, biphasic cathodic pulses were applied with current amplitudes from 5 µA to 100 µA through one of the FPMA electrodes. Low-frequency neural signals were detected from ECoG electrodes at the stimulation amplitude of 60 µA and higher (Fig. 2(a), red). The analysis was performed by dividing the area that was covered by the ECoG electrodes according to the distance from the stimulating electrode (Area 1 to 4). The amplitude of responses decreased as the distance from the stimulating electrode increased, as shown in Fig. 2(b). The latencies of P1 and N1 peaks increased along the distance from the stimulating electrode, which was speculated to be due to signal transmission through synapses (Fig. 2(c)).

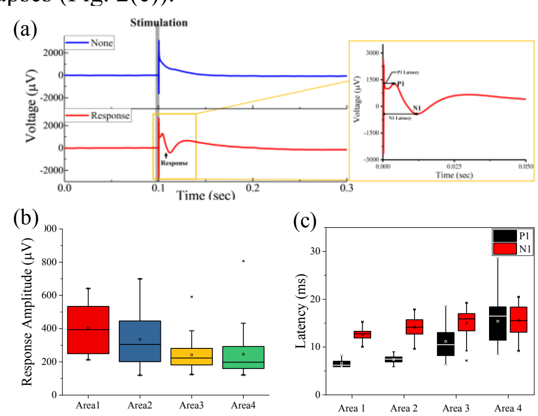

Figure 2. (a) Recorded ECoG signal upon stimulation, (b) the peak to peak amplitude of reponses and (c) the latency of P1 and N1 peaks.

IV. Conclusion

The fabricated hybrid electrode array could record brain signals upon simultaneous stimulation. The propagation of neural responses was also observed. We will continue in vivo experiments for multi-site recordings and simultaneous stimulation/recording using the developed hybrid electrodes.

References

[1] D. Byun, Fabrication of a flexible penetrating microelectrode array for use on curved surfaces of neural tissues. Journal of Micromechanics and Microengineering, 2013, Vol.23, No.12, 125010.