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Intelligent Neural Implant Microsystem Fabricated Using Multi-Chip Bonding Technique

Taiichiro Watanabe[1], Keita Motonami[1], Kazuhiro Sakamoto[2], Jun Deguchi[1], Risato Kobayashi[1], Ken Komiya[1], Keiji Okumura[1], Takafumi Fukushima[1], Hiroyuki Kurino[1], Hajime Mushiake[3], and Mitsumasa Koyanagi[1]

[1]Dept. of Bioengineering and Robotics, Tohoku Univ., 6-6-01 Aza Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan
Phone: +81-22-795-6906 E-mail: sdlab@sd.mech.tohoku.ac.jp
[2]Research Institute of Electrical Communication, Tohoku Univ., 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
[3]Dept. of Physiology, Tohoku Univ. School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan

1. Introduction

Aiming to develop a new information processing system or cure brain diseases such as blindness, deafness, paralysis, epilepsy, and Parkinson's disease, many research programs for revealing cerebral nervous system have been progressing in the world. Most neurophysiologists currently use conventional single neural recording techniques with an electrode made of an electrolytically etched tungsten wire [1]. Therefore, simultaneous multipoint recording techniques of neurons in the brain has attracted considerable attention in neurophysiology due to its high measurement efficiency [2]. As opportunity for a more thorough exploration of neural and cellular functions increase, further functional systems, which we call intelligent neural implant, are required. Using this system, neurophysiologists can always precisely record the electrical response from individual neuron without causing the animals pain. In order to realize the intelligent neural implant, we developed a new multipoint recording Si microelectrode using a multi-chip bonding technique with biocompatible resin and biocompatible flexible cable. Furthermore we also tried to integrate photo-diode and LED on the neural implant microsystem to obtain the tomogram of the micro blood flow.

2. Intelligent neural implant microsystem with blood flow measurement function

Figure 1 illustrates the configuration of intelligent neural implant microsystem which consists of a multi-electrode array, blood flow detectors, on-electrode circuits (Stimulation circuit, MUX, AMP, and DAC), a flexible cable with secondary coil for inductive link, main control circuits and external units. Figure 2 shows the block diagram of our intelligent neural implant, in which low noise amplifiers, multiplexers and D/A converters should be directly mounted on the multi-electrode array, because the neural signal is extremely low as ~10μV and consequently the signal-to-noise (S/N) ratio is very small. Then, in order to mount all of those circuits and devices on the multi-electrode array, we have developed multi-chip bonding technique with biocompatible resin [3]. Using this multi-chip bonding technique, we also tried to mount infrared-LED on the neural implant microsystem to obtain the tomogram of the micro blood flow simultaneously recoding electrical signals by the Si multi-electrode. Absorption of infrared light in tissues depends on the amount of oxygen in the blood. Therefore light intensity penetrated through tissue is measured by photo-diodes as shown in Fig. 3. Figure 4 shows a SEM micrograph of LED mounted on the neural implant microsystem using this multi-chip bonding technique. Figure 5 shows the *I-V* characteristics of LED mounted on the neural implant. The far field image and angle distribution of light emitted from LED mounted on the neural implant are shown in Fig. 6. Light emitted from LED spread widely between ±40degree.

3. Fabrication of Si microelectrode for intelligent neural implant mycrosystem

The overall structure of our Si microelectrode, which is a platform for the intelligent neural implant, is shown in Fig. 7. This needle-shaped Si microelectrode has the length of 40mm, the width of 140μm, and the thickness of 140μm. Electrodes with impedances of a few MΩ at 1kHz are indispensable to record the activities of neurons [4]. Then, the recording sites with circular pattern were made of tungsten/aluminum varying their diameters as 5, 10, 15, or 20μm to control the impedance of the Si microelectrode. Figure 8 shows the photograph of microelectrode with 8 recording sites covered with a stainless steel pipe to support the penetration of the Si microelectrode into the closed dura mater of animals. The impedance of the fabricated Si microelectrode in a saline solution was about 1MΩ at 1kHz. Figure 9 shows the photograph of assembled single microelectrode test system consisting of a stainless steel pipe for a puncture through the dura, a manipulator for control in positioning, and stainless steel lead wires for connection to amplifiers. We have monitored the nerve collective response from the monkey premotor cortex by using an electrode with impedance of 40kΩ [3]. We have also developed a multi-electrode test system for simultaneous multi-point recording of neural spikes from the monkey premotor cortex.

4. Conclusion

We proposed the intelligent neural implant microsystem with a blood flow measurement function which consists of a multi-electrode array, blood flow detectors, electronic circuits and a flexible cable. We also developed the multi-chip bonding technique to mount these circuits and devices on the multi-electrode array. Si microelectrode with 1MΩ at 1kHz in a saline solution was successfully fabricated.

Acknowledgements

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References

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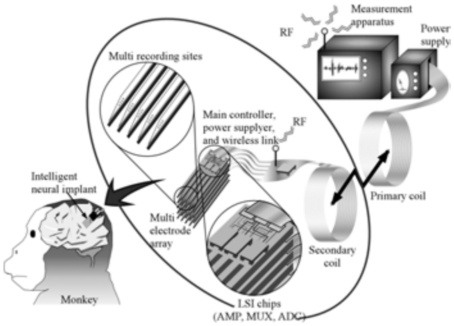

Fig. 1. Configuration of intelligent neural implant microsystem.

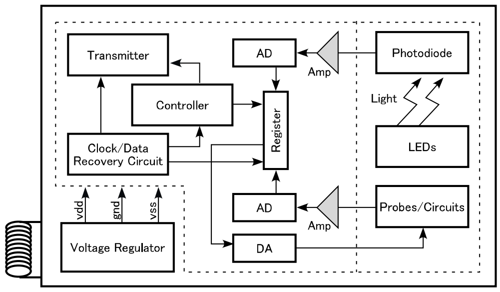

Fig. 2. Block diagram of intelligent neural implant microsystem.

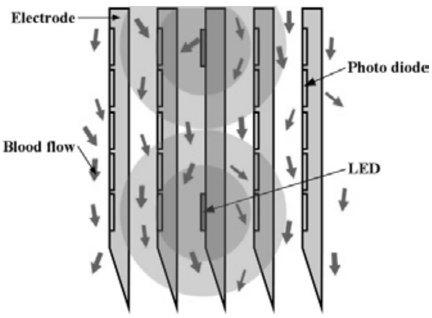

Fig. 3. Blood flow measurement using intelligent neural implant microsystem.

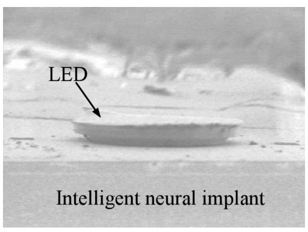

Fig. 4. SEM view of LED mounted on intelligent neural implant microsystem.

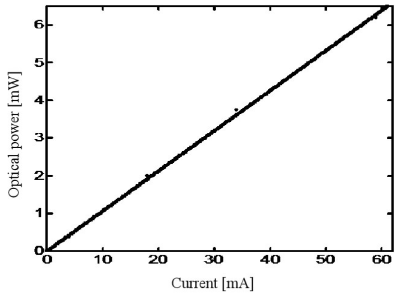

Fig. 5. *I-V* characteristics of LED mounted on intelligent neural implant microsystem.

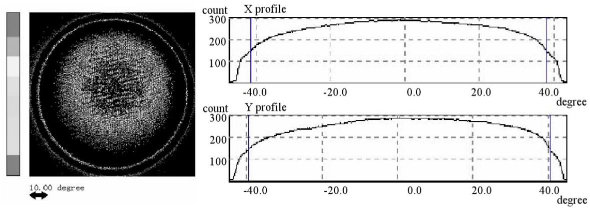

Fig. 6. Far field image of light emitted from LED mounted on intelligent neural implant microsystem.

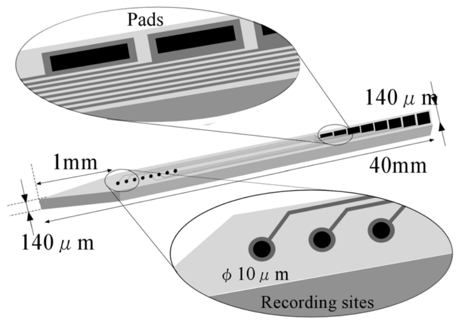

Fig. 7. Design of Si microelectrode with 8 recording sites.

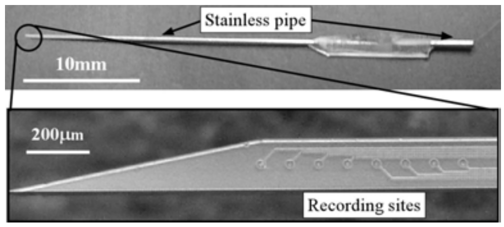

Fig. 8. Photograph of Si microelectrode with 8 recording sites.

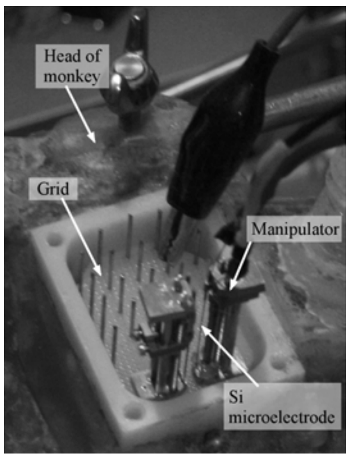

Fig. 9. Photograph of single microelectrode system assembled on the brain of monkey for the experiment.