A floating 5-μm-diameter needle-electrode on the tissue for damage -reduced chronic neuronal recording in mice*

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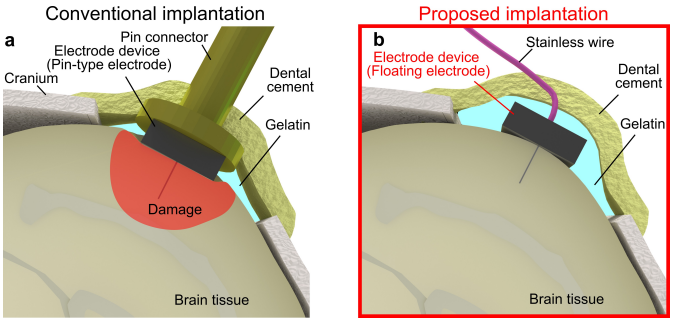
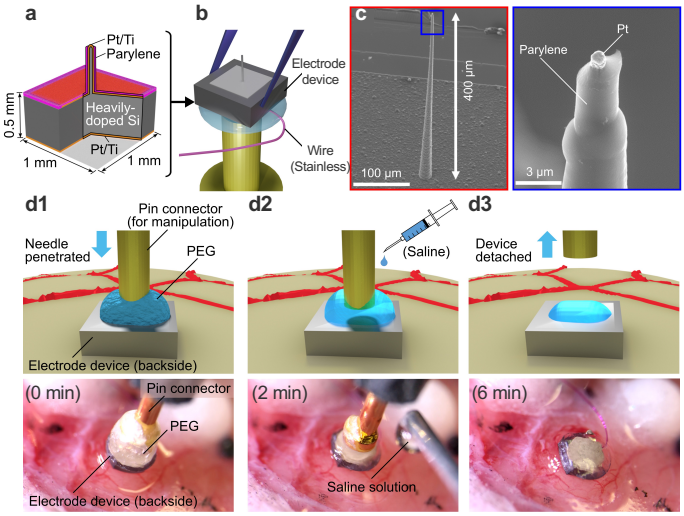
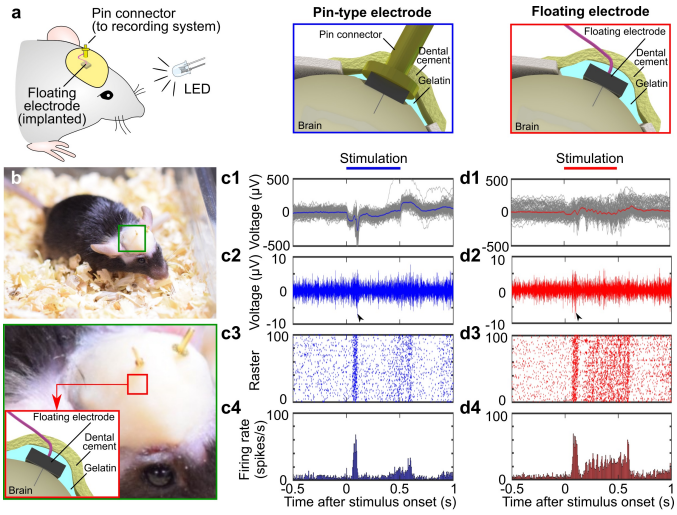
Abstract Microelectrode technology is essential in electrophysiology and has made contributions to neuroscience as well as to medical applications. However, it is necessary to minimize tissue damage associated with needle-like electrode into the brain tissue and the implantation surgery, which make the stable chronic recording impossible. Here, we report on an approach to use a 5-μm-diameter needle electrode, which enables the following of tissue motions by the surgical method. The electrode is placed on the brain tissue of the mouse with a dissolvable material while reducing the physical stress to the tissue; this is followed by implantation of the device in the brain without fixing it to the cranium while achieving a floating electrode on the tissue. The electrode shows the stable recording with no significant degradation of the signal-to-noise ratios for 6 months, and minimized tissue damage is confirmed compared to that when using the other cranium-fixed electrodes with the same needle geometry.

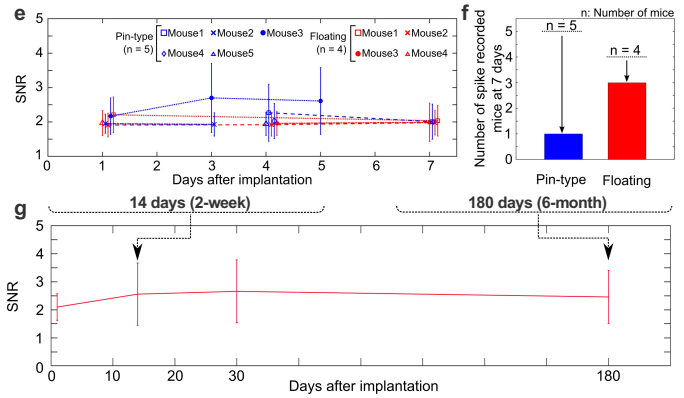


Comparison of electrode implantation. a) Schematic showing conventional implantation, in which the electrode is fixed to the cranium of the brain. b) Schematic showing the proposed implantation, in which the electrode packaged with a flexible lead is implanted in the brain without fixing to the cranium, achieving a "floating electrode" on the tissue.

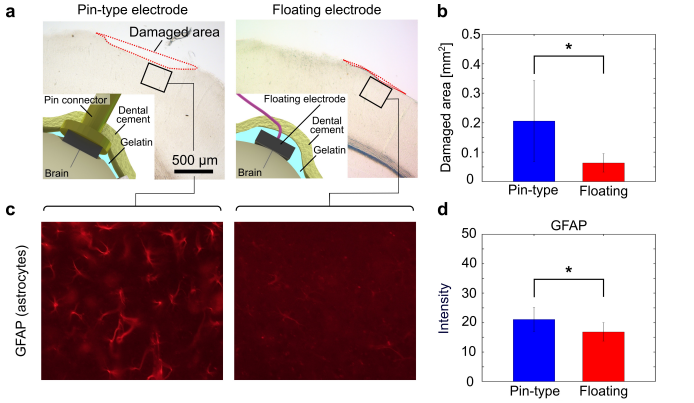


An electrode device. a) Schematic of the electrode device, containing a needle electrode with a diameter of 5-μm and length of 400-μm. b) Assembly of the electrode device on a pin connector via the PEG paste. c) SEM images of the overall needle and the needle tip portion. d) Placement of the floating electrode on the brain tissue of a mouse.





Chronic in vivo neuronal recording. a) Schematic of the recording with visual stimulation provided by a light-emitting diode b) Photographs of a mouse implanted with a floating electrode. Each device is implanted into the mouse's visual cortex. c1–4) Waveforms recorded from the pin-type electrode 1 day after implantation; c1) an average waveform of low-frequency band signals (filtering=10–80 Hz, n=100 trials), c2) a single high-frequency band signal from a single trial (filtering=500–1,000 Hz), and c3, 4) raster plot diagrams and PSTHs extracted from the high-frequency band signals, respectively (n=100 trials). d1–4) Waveforms recorded from the floating electrode 1 day after implantation. e) SNR of spike detected on each electrode implanted mouse for 7 days. f) Numbers of electrodes detecting spike from each mouse 7 days after implantation. g) SNR of spike detected for 180 days.



Histological comparison of the tissue response to two-week chronically implanted conventional pin type and floating electrodes. a) Photograph of the brain tissues. b) Quantitative comparison of damaged areas. c) Tissue responses. Tissues are labeled for reactive astrocytes (GFAP). d) Quantitative comparisons of astrocytes.

Conclusion

In summary, we proposed a method for chronic neuronal recording in mice in which a 5-μm-diameter microneedle electrode penetrates brain tissue via dissolvable material-based detachment and remains on it without being fixed to the cranium, resulting in a floating electrode architecture. Although the electrode device requires further advancements such as miniaturization and wireless recording system, the proposed recording technology showed clear advantages in terms of the high SNR during implantation and less tissue damage. These findings show that the proposed method will enable stable and safe chronic recording in not only the mice demonstrated in this study but also other animals, including rats and monkeys.

Acknowledgements

We acknowledge support from JSPS KAKENHI Grant Numbers 17H03250, 26709024, and 20H00244, for the Strategic Advancement of Multi-Purpose Ultra-Human Robot and Artificial Intelligence Technologies program from NEDO, Adaptable and Seamless Technology transfer Program through Target-driven R&D (A-STEP) from JST, and Nagai Foundation for Science & Technology. R. N. was supported by Takeda Science Foundation. K. K. was supported by JSPS KAKENHI Grant Number 15H05917, 20H00614.

***Journal information**

K. Yamashita et al., Lab on a Chip, Issue 2, 2022. *in press*