IRES²プロジェクト研究

A self-insertable 5-µm-diameter flexible microneedle for minimally invasive and stable in vivo neural recording

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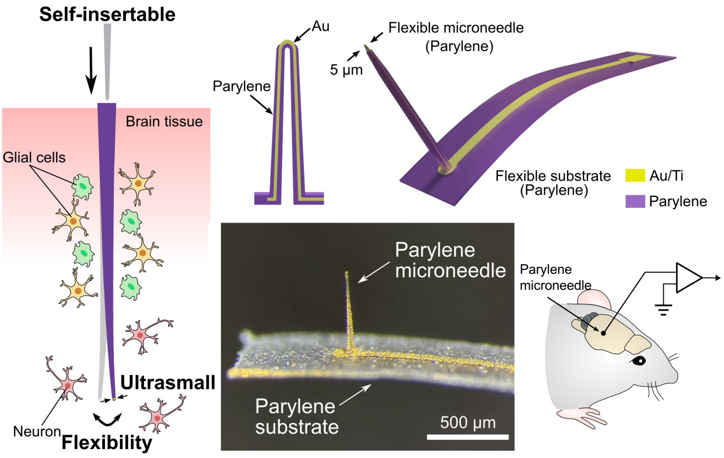
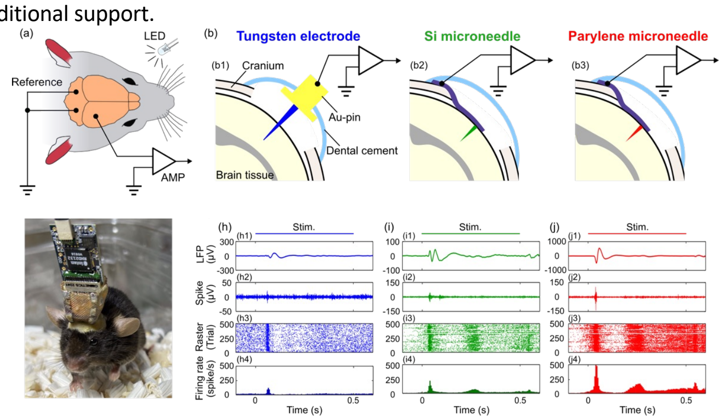
3 すべての人に健康と福祉を

9 産業と技術革新の基盤をつくろう

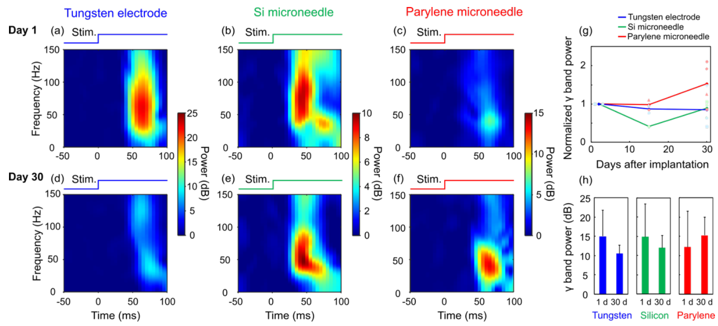
Abstract Implantable intracortical microelectrodes are essential tools for neuroscience research, clinical applications, and brain–computer interfaces. Achieving stable chronic recording of neuronal activity, however, remains challenging due to tissue damage—including neuronal loss, foreign body responses, and disruption of neuronal networks—induced by electrode implantation. Although flexible device strategies can reduce chronic damage, insertion using mechanical supports still creates a large footprint and causes substantial acute tissue damage, leading to neuronal network disruption. Overcoming these electrode issues, here we report a 5-µm-tip-diameter parylene microneedle electrode that offers advantages of ultrasmall size, mechanical flexibility, and insertion capability without additional support.



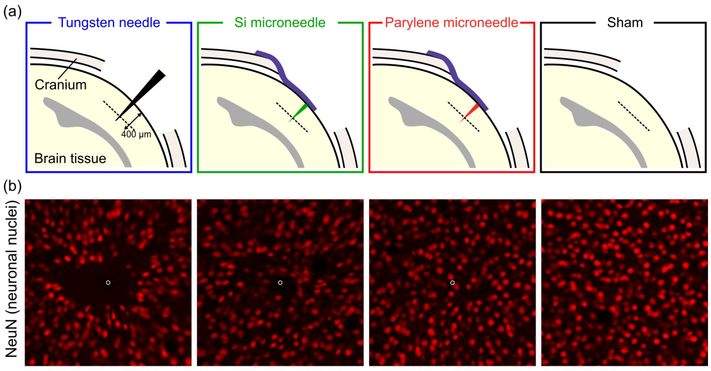
Conceptual diagram of the study, illustrating a fully parylene microneedle electrode device with three key design features: ultrasmall size, mechanical flexibility, and self-insertion capability. The device consists of a coreless microneedle integrated on a flexible substrate, enabling minimally invasive and stable in vivo neural recordings.

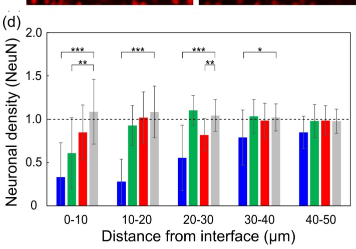


Chronic neural recordings from the mouse visual cortex for 30 days using tungsten electrode, Si microneedle, and parylene microneedle electrodes.

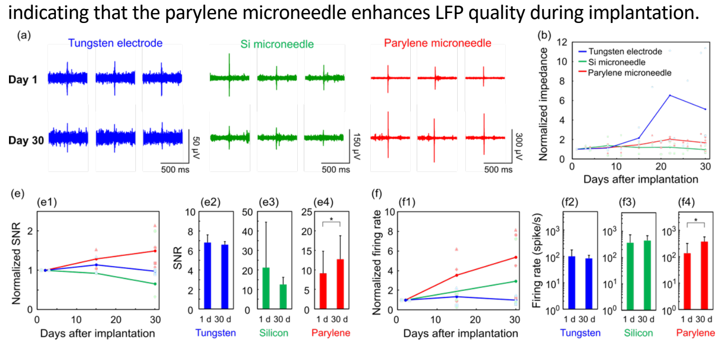


Chronic stability of LFP recording using tungsten, Si, and parylene electrodes, indicating that the parylene microneedle enhances LFP quality during implantation.





Immunohistochemical analysis of mouse cortex 30 days after implantation of three needles: tungsten needle, Si microneedle, and parylene microneedle. These results indicate that flexibility of the microneedle induced minimal neuronal loss and the comparable density to the tissue without needle implantation (craniotomy alone).



Chronic stability of spike recording. These results demonstrate that the flexible parylene microneedle electrode enhances the quality of chronic spike recordings.

Conclusion We developed a fully parylene-based, 5-µm-diameter microneedle electrode device for intracortical electrophysiological recording. The parylene microneedle was fabricated via VLS growth of a Si microneedle, parylene encapsulation, and subsequent Si core removal. The electrode demonstrated self-insertable capability, minimizing acute tissue damage. Chronic neural recordings and immunohistochemical analyses further revealed that its flexibility reduces chronic tissue damage. By combining ultrasmall diameter, self-insertability, and mechanical flexibility, this electrode minimizes both acute and chronic damage compared with conventional microelectrodes, thereby enhancing electrophysiological recording quality. Future challenges include achieving multisite and deep-brain recordings through needle arraying and length extension, enabling high-density brain mapping across regions while preserving the device's advantages. Given its ability to maintain native tissue and neuronal networks, the flexible microneedle electrode device represents a promising platform for future neural interface technologies.

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技術を究め、技術を創る

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