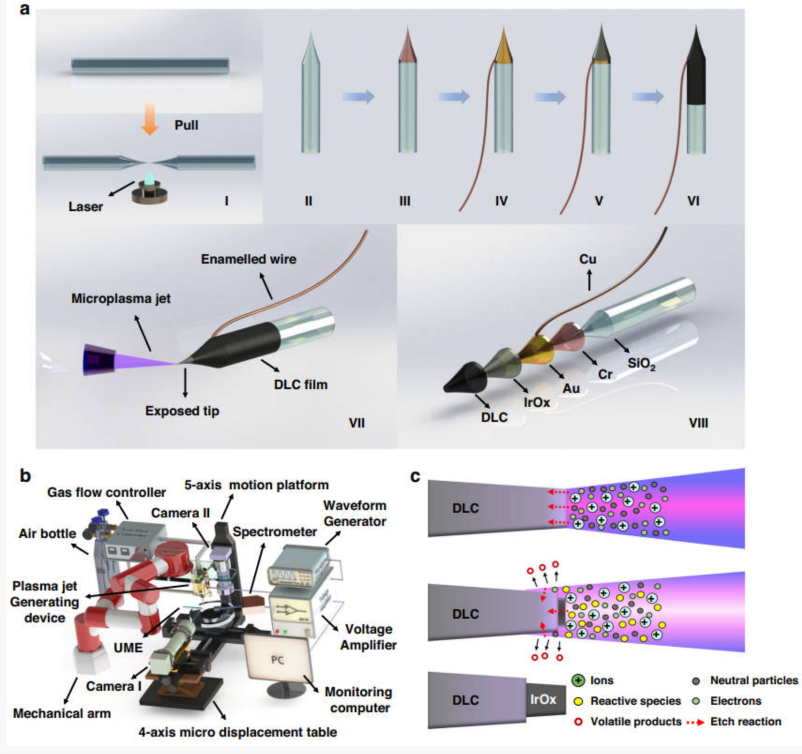
Enhancing neural signal fidelity: controlling ultramicroelectrode tip exposure for single-cell recording

GA, UNITED STATES, March 15, 2025 /EINPresswire.com/ -- Long-term and precise intracellular signal detection is critical for advancing our understanding of brain diseases and developing effective diagnostic tools. A breakthrough method has been introduced to enhance the stability and fidelity of recording signals at the single-cell level using ultrafine electrodes (UME). By controlling the tip exposure of UMEs, researchers have demonstrated a significant improvement in their ability to resist environmental interference, thus improving signal-to-noise ratio and sensitivity, and the collection area has been precisely controlled. This method promises to enhance the performance of implantable neural interfaces for real-time monitoring of intracellular signals.



Fabrication of the DLC-UME and principle of microplasma jet processing for UME tips.

Ultramicroelectrodes (UMEs) have shown great potential for intracellular signal detection due to their small size and high sensitivity. However, achieving stable and reliable signal acquisition from these electrodes has been a significant challenge. Current methods for protecting and controlling UME tip exposure have struggled to provide both the necessary electrical insulation and effective shielding from external noise in areas outside the collection site, compromising signal fidelity. Based on these challenges, there is a need for deeper research into improving the controllability of UME tip protection for long-term, high-fidelity recordings in single-cell applications.

In a recent study (DOI: 10.1038/s41378-024-00819-w) published in Microsystems &

Nanoengineering, researchers from Shanghai Jiao Tong University have developed a novel technique using a cold atmospheric microplasma jet to control the exposure of ultramicroelectrode tips. The approach involves selectively removing protective diamond-like carbon (DLC) coatings from the tips of UMEs, ensuring optimal exposure for enhanced electrochemical stability and signal fidelity. This study, published in February 2025, opens up new possibilities for implantable devices in neurological research.

The key innovation of this study is the use of microplasma jet treatment to precisely expose the tips of UMEs coated with DLC. The team demonstrated that by adjusting the exposure length of the UME tips on the submicron scale, they could significantly reduce signal noise and increase the precision of single-cell recordings. The DLC coating was chosen for its mechanical strength, thermal stability, and biocompatibility, which are critical for long-term use in biological environments. Additionally, the method proved to be highly controllable, with tests showing that the exposure could be precisely managed without damaging the underlying electrode material. The researchers also conducted extensive biocompatibility tests, confirming that the DLC-UME did not adversely affect neuronal cell growth, ensuring its safe application in biological settings. Moreover, electrochemical and intracellular pH detection tests provided further evidence of the enhanced stability and reliability of the DLC-UME, highlighting its potential for continuous, real-time monitoring of intracellular processes.

Prof. Jingquan Liu, lead author of the study, commented, "This breakthrough offers a significant leap forward in the development of neural interfaces. By precisely controlling the electrode tip exposure, we have improved both the performance and longevity of these devices, which will be crucial for the future of brain-computer interfaces and the treatment of neurological diseases."

This technology has the potential to revolutionize single-cell analysis, enabling more accurate and reliable detection of intracellular signals. The ability to control electrode tip exposure precisely opens up new avenues for the development of implantable devices that can provide real-time monitoring of cellular processes, which is essential for advancing research in neuroscience, diagnostics, and personalized medicine. The study’s findings could lead to improvements in the diagnosis and treatment of brain diseases, including neurodegenerative conditions like Alzheimer's and Parkinson's, by enabling more precise monitoring of neuronal activity at the single-cell level.

DOI
10.1038/s41378-024-00819-w

Original Source URL
https://doi.org/10.1038/s41378-024-00819-w

Funding information
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This press release can be viewed online at: https://www.einpresswire.com/article/794149233